

Intelligent Transportation System (ITS) Implementation Plan for the Tulsa Region

Prepared for:

Oklahoma Department of Transportation
and
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1 Introduction

The Oklahoma Department of Transportation (ODOT) and the Indian Nations Council of Governments (INCOG) have identified a growing need for improved traffic management in the Tulsa region. This need has been substantiated by county transportation agencies, local and state law enforcement, emergency operation center operators, and the traveling public.

An Intelligent Transportation System (ITS) Implementation Plan has therefore been prepared under this project to address operational and other needs within the Tulsa region. This plan provides an introduction to ITS and background on relevant previous work. A concept of operation is included that develops the functional requirements for the region, and addresses the roles and responsibilities of the agencies involved. The plan then develops the infrastructure requirements for the Tulsa region. Finally an implementation strategy is presented including the definition of several projects, procurement method, funding alternatives and a schedule.

2 Purpose and Need

The purpose of this ITS Implementation Plan is to identify and develop improvements to support incident management, specifically in the areas of detection and verification, response, traffic management and interagency coordination. The plan incorporates ITS applications into the transportation planning, design and construction program, providing a “mainstreaming” effect. This mainstreaming of ITS into the traditional ODOT project development cycle can provide early transportation system benefits. These benefits include improved safety and reduced delays and emissions. To develop the ITS and incident management needs, several key factors need to be addressed including:

- Developing functional and operational requirements to support regional ITS implementation
- Defining and formulating the roles and responsibilities of the various agencies involved in operating, maintaining and coordinating the transportation management system
- Defining ITS devices, communications, and Transportation Management Center (TMC) infrastructure requirements, including some trade-off analyses of the various technologies available
- Developing concepts to advance other capital improvements that support improved incident management operations and complement ITS
- Identifying ITS improvements and developing ITS project descriptions
- Preparing work program elements to support phasing and scheduling of ITS improvements to support roadway/capacity improvement programs underway
- Providing recommendations on how to procure ITS infrastructure in a method most likely to result in successful deployment and implementation
- Identifying funding sources for implementation and operation of ITS projects
- Identifying the technologies and portions of the Tulsa ITS Regional Architecture to be implemented in the next seven years

- Satisfying the new FHWA rule on National ITS Architecture (NA) conformance and consistency.

The beginning steps of developing, implementing, operating and maintaining a TMC are included in this study. The TMC is vital to the formation of an advance transportation management system due to its being the focal point of data collection and analysis providing incident detection and verification, inter/intra-agency coordination, traveler information and a service to the public and community by improving safety, congestion, and the regional economy through management of traffic.

3 What is ITS?

Traffic congestion has become one of the greatest problems on today's highways. The majority of congestion is caused by non-recurring incidents. If the number of non-recurring incidents could be reduced or cleared sooner it would help alleviate congestion as well as improve the overall safety of the transportation network. Intelligent Transportation Systems (ITS) is a set of tools that allows technology to improve the efficiency and safety on roadways by providing agencies the ability to "see" the current traffic conditions and manage the roadway system in real time. This is greatly beneficial when dealing with an incident. It allows agencies to visually evaluate the incident and determine the necessary equipment and personnel needed without having to physically be at the site and quickly dispatching the proper response equipment and staff, thus saving time and, more importantly, lives.

In addition, any ITS deployment is able to improve the transportation system's efficiency and effectiveness for both providers and consumers of transportation services. By monitoring what is occurring on the system, making adjustments when needed, responding to unexpected traffic patterns or incidents, and providing real-time information, travelers may adjust their use of the system or adjust their routing to reflect current conditions.

One example of the benefits of ITS and incident management can be found in Calculating Benefits for NAVIGATOR: Georgia's Intelligent Transportation System by Michael Presley, which is a study that was conducted by Georgia DOT to determine the benefits of their ITS system. The NaviGator system consists of Dynamic Message Signs (DMS), Closed Circuit Television (CCTV) cameras, vehicle detectors, signal control system, electronic payment collection, and various other ITS field devices. The benefits achieved that were stated in the study included the following:

1. Reduced response, identification and dispatch time for incidents to two minutes (a 30% reduction).
2. A 23-minute reduction in incident duration during 1997, resulting in cost savings of \$44.6 million due to reduced delay time
3. A 2.3 benefit/cost ratio for 1997 for the freeway and incident management components (Based on a capital investment of \$72 million for these components)

4. Other benefits include air quality impact reductions, fuel consumption improvements, accident reduction, more efficient use of emergency services and more satisfied travelers

4 Concept of Operations

This Concept of Operations outlines the role of the Tulsa region's Transportation Management System, which will be comprised of a number of operating agencies cooperating through several centers. The Concept addresses a Regional Transportation Management Center, local Traffic Operations Centers, Emergency Operations Centers, as well as a Transit Management Center, the centers' operations, and how each of these agencies working together (through operating agreements) will be able to share information vital to a seamless transportation management system. The Tulsa Regional Concept of Operations is based on a stakeholder involvement process, which took place February-March 2002. Summaries of the stakeholder meetings are included in the appendix.

The key concept for the Intelligent Transportation Systems (ITS) program in the Tulsa region is an integrated regional ITS deployment based on institutional cooperation, funding commitments, and establishment of a regional transportation management center (RTMC) with a communications infrastructure for real time traffic information processing, dissemination and display. The vision of the stakeholders in the Tulsa region is to create an integrated transportation management system in the surrounding region that links participating traffic operations, emergency operations and transit agencies by real time communications and disseminates real time travel information to the public. This Concept of Operations envisions a Tulsa RTMC operated under the supervision of a Board consisting of four entities: the Oklahoma Department of Transportation (ODOT), the Indian Nations Council of Governments (INCOG), the Oklahoma Department of Public Safety (DPS) and the City of Tulsa. The RTMC will manage the regional freeway and arterial systems with the capability to share data and video with neighboring agencies as well as the public through a variety of media. Local traffic operations centers, emergency operations centers and a transit management center will share real time data and video through a regional communications network. The following represents the goals that the region is trying to achieve:

- Improve the overall safety and security of the transportation network
- Improve interagency information sharing and increase operating and responding agency efficiency
- Establish and develop regional traffic management strategies and practices
- Establish a regional incident management system
- More effectively disseminate traveler information to the traveling public
- Promote the use of transit and other alternate modes

These goals can be achieved through the effective use and deployment of ITS technologies. The Concept of Operations outlines the role of the Regional Transportation Management Center and its operations, the local Traffic Operations Centers, the Emergency Operations Centers, as well as the Transit Management Center and how each of these agencies working together through operating agreements will be able to share information vital to a seamless transportation management system.

Tulsa Regional Transportation Management Center

The RTMC plays a vital role in the performance of a transportation management system. The RTMC essentially gathers information about the transportation network and other operations centers, processes and fuses this information with other operational and control data, and provides information to partner agencies and travelers. This information is then used to monitor incidents and the operations of the transportation network and implement traveler information and real-time control strategies to improve safety and efficiency. By having multiple agencies present in the RTMC or coordinating through real time communications with the RTMC operators, local traffic, emergency and transit agencies can improve their operations, and form relationships among the participating agencies by sharing resources and information previously unknown to each other. The RTMC can also be a focal point drawing the positive attention of the public, elected officials and the media.

The Tulsa RTMC is envisioned to be supervised by a RTMC Board consisting of four partnering agencies: ODOT, INCOG, DPS (likely represented by the Oklahoma Highway Patrol) and the City of Tulsa. This Board will be responsible for ITS planning activities, implementation of ITS projects, coordination of ITS operations activities and coordination of resources throughout the Tulsa region. The Tulsa RTMA Board will report to the Oklahoma Transportation Commission at the state level and to INCOG at the regional level. The Board should appoint a Technical Committee that will advise the Board on technical and operating issues. A partnering agreement must be developed and adopted by the four participating agencies as well as the Oklahoma Transportation Commission. This agreement will define the roles and responsibilities of each agency and the governance of the RTMC.

The Tulsa RTMC will be the central location for collection and analysis of information and data, dissemination of traveler information, and coordination of incident and emergency management operations. The daily performance of operations on the Interstate and freeway system will be conducted by the RTMC. Operations on the arterial system will be conducted by local traffic operations centers. Emergency operations and incident response will continue to be provided by local emergency response centers throughout the region. The RTMC Board may choose to implement only a few of the RTMC functions listed below and implement remaining functions in later phases. In the future, the RTMC could be expanded to conduct off-peak operations of other centers when they are closed. Initially, ODOT staff may conduct operations of the RTMC during peak hours and pass control of the RTMC functions to the Oklahoma Highway Patrol (OHP) – Troop B through a remote workstation for management of the transportation management system in off-peak hours. OHP has also agreed to provide dispatch for the initial phase of the privately operated service patrol. The RTMC should also maintain communications and coordinate with other future centers including the Oklahoma Transportation Authority, the Oklahoma City Regional TMC and the ODOT Statewide ITS program. A diagram showing how the centers in the Tulsa Transportation Management System are connected with each other is in Figure 1 at the end of this document.

Functions of the Tulsa Regional Transportation Management Center may include:

- Incident detection on freeways
- Collect traffic speed and volume data

- Surveillance on freeways and major arterials (in coordination with local agencies)
- Lane assignment and control signs on freeways
- Real time video display
- Real time video control (based on control hierarchy)
- Development and implementation of freeway control strategies
- Incident management coordination
- Traffic data archive and data management/warehousing capabilities
- Traffic, incident and construction information dissemination capability, including DMS, HAR, Internet web site
- Operations of signs and cameras on freeways under emergency evacuation procedures (i.e. – tornados, floods, hazardous materials incidents, etc.)
- Real time communications to local TOCs and transit centers
- Real time information to EOCs for vehicle routing
- Real time communications to information service providers and media
- Real time communications to interactive traveler information network (kiosks and web site)
- Real time regional data sharing capability
- Road weather detection
- Dispatch for service patrol vehicles
- Incident log for service patrol operators
- Vehicle tracking for service patrol vehicles
- Middleware that enables integration among all participating agencies
- ITS maintenance management and information tools
- Maintenance vehicle tracking (ODOT or maintenance contractor vehicles)
- Winter maintenance
- Roadway maintenance and construction
- Work zone management
- Maintenance and construction activity coordination

The Oklahoma Transportation Authority (OTA) operations should be included in the RTMC. The desired functions for OTA would include all the RTMC functions listed above plus electronic toll collection. An operating agreement between OTA and the RTMC must define agency roles, responsibilities and funding mechanisms.

Operating agreements among the local agencies are required to specifically define agency roles in the management of the RTMC. The operating agreements should include negotiations on capital, operating and maintenance costs, a commitment to provide sufficient staff and maintenance resources, hierarchy of system control and use of traffic and video data and information.

Local Traffic Operations Centers

Local city public works departments will continue to operate and maintain surface street signal control in their jurisdictions. Coordination with the RTMC and other local traffic operations centers (TOCs) will be conducted by use of real time surveillance and detection, data sharing, and sharing information on operating plans. The TOCs may have all management functions available in the transportation management center

except for freeway control. A TOC may choose to implement only a few of the functions listed below and delay the implementation of some functions until later phases.

Functions of the local TOCs may include:

- Traffic signal control
- Signal preemption for emergency vehicles
- Signal preemption for buses
- Highway/rail intersection controls
- Real time communications to the RTMC, other local TOCs, EOCs and transit centers
- Real time regional data sharing capability
- Incident management coordination
- Road weather detection
- Parking management (City of Tulsa and Tulsa International Airport)
- Traffic data archive capability
- Real time video display
- Real time video control (based on control hierarchy)
- Traffic, incident and construction information dissemination capability, including VMS, HAR, Internet web site
- Real time communications to information service providers, media and public facilities
- Operations of signals, signs and cameras under emergency evacuation procedures
- Maintenance and construction activity coordination

The cities of Tulsa and Broken Arrow currently have a traffic engineering staff while the other jurisdictions have cooperative agreements for maintenance of their signals. The following cities operate signals:

- City of Tulsa
- City of Owasso
- City of Claremore
- City of Broken Arrow
- City of Bixby
- City of Sand Springs
- City of Jenks
- City of Sapulpa
- Tulsa County

Operating agreements between the RTMC Board and local agencies are required to specifically define agency roles. An operating agreement should include negotiations on capital, operating and maintenance costs, a commitment to provide sufficient staff and maintenance resources, hierarchy of system control and use of traffic and video data and information. The local TOCs may be co-located with local emergency operations centers (EOCs) or other centers in the future.

Local Emergency Operations Centers

Local emergency operations centers (EOCs) will be operated and maintained by police, sheriffs, fire, 911, and Emergency Medical Services (EMS) departments in the cities in the Tulsa region. These EOCs already exist in most cities in the Tulsa region and they would continue to function as they currently do with the addition of video and data communications with the transportation management system. The Oklahoma Highway Patrol and local public safety agencies should have a center (or central point of contact) in the initial phase in order to coordinate with the RTMC. Real time communications and video will be sent from the RTMC to the dispatch center for each participating agency and incident information is to be sent from the EOCs back to the RTMC. Local agencies will use compatible hardware/software for communications with TMC. The following is a list of jurisdictions that have a local 911 center:

- Tulsa County
- City of Tulsa (including the City of Catoosa)
- City of Tulsa Emergency Medical Services Agency (EMSA)
- City of Skiatook
- City of Collinsville
- City of Owasso
- City of Sapulpa
- City of Glenpool
- City of Jenks
- City of Bixby
- City of Broken Arrow
- City of Coweta
- City of Sand Springs
- City of Claremore

The Oklahoma Highway Patrol – Troop B operates a call taking and dispatch center in the Tulsa region. Through an operating agreement with the RTMC Board, OHP may operate some of the RTMC functions during hours the RTMC is not staffed.

Operating agreements are required to specifically define the role of each state and local agency. The operating agreements will include negotiations on capital, operating and maintenance costs, a commitment to provide sufficient staff and maintenance resources, hierarchy of system control and use of traffic and video data and information. Some local jurisdictions may choose to co-locate the operations centers of several local agencies (i.e. police, fire and 911 dispatch). Some jurisdictions may also elect to co-locate a TOC and EOC. That jurisdiction will determine the participating agencies in any jurisdiction's center. Some EOCs may choose to implement only select functions listed below and delay the implementation of some functions until later phases.

Functions of EOCs may include:

- Real time communications to the RTMC, local TOC, other EOCs and transit centers
- Real time video display
- Real time video camera control (based on control hierarchy)

- Incident management
- Vehicle tracking for emergency vehicles
- Signal preemption for emergency vehicles
- Dispatch for emergency vehicles
- Notification of towing providers
- Dispatch for HAZMAT response and cleanup
- Monitoring for abandoned vehicles on the freeways
- Coordination with other centers under emergency evacuation procedures

Transit Management Centers

Tulsa Transit (MTTA) & Broken Arrow Bus System (BABS) are the only two transit agencies in the Tulsa region. At this time, MTTA has automatic passenger counters (APC) and an existing transit management center. The MTTA has plans to implement an AVL system for their buses as well as demand response transit. In addition there are plans to install kiosks at bus station to inform travelers when the next bus will be arriving. MTTA is also interested in an electronic payment system as well as using buses as probes.

Transit agencies should use compatible hardware/software for communications with the RTMC and TOCs. Transit operating agreements are required to specifically define the role of the freeway management centers, the TOCs and the transit managers.

The Tulsa County school bus system is also interested in implementing an AVL system on all of their school buses as well as having the ability to receive live video to monitor traffic conditions.

Operating agreements are required to specifically define the role of each agency. The operating agreement will include negotiations on capital, operating and maintenance costs, a commitment to provide sufficient staff and maintenance resources, hierarchy of system control and use of traffic and video data and information. The transit agencies may choose to implement only a few of the functions listed below and delay the implementation of some functions until later phases.

Functions may include:

- Transit vehicle tracking
- Fixed route operation and management
- Demand responsive operation and management
- Real time video display
- Real time video camera control (based on control hierarchy)
- Automated transit passenger counting
- Transit fare management, including “smart cards”
- Transit maintenance and fleet management
- Transit security
- Traveler information dissemination
- Real time communications to the RTMC, local TOCs and EOCs

Other Tulsa Regional ITS Stakeholders

Indian Nations Council of Governments

INCOG has expressed an interest in continuing to manage and archive real-time data. In addition, they propose work with the RTMC Board to disseminate traveler information to the public. As the Tulsa Regional ITS and the RTMC Board is established, the role of INCOG and its responsibilities in archiving data and disseminating traveler information will be defined.

Tulsa International Airport

The airport has stated a desire to receive real-time traveler information and incident data as well as have access to the video cameras. The airport should receive a RTMC remote workstation that will allow video display for any camera on the network and current roadway condition status. The airport may also implement a parking management system for the on-airport parking garages and lots. An operating agreement will be required to specifically define the role of the airport and the other participating agencies. The operating agreement will include negotiations on capital, operating and maintenance costs, a commitment to provide sufficient staff and maintenance resources, hierarchy of system control and use of traffic and video data and information.

Information Service Providers

An information service provider (ISP) is an entity that receives data and information from the traffic management, transit management and emergency operations centers and distributes information to the traveling public. The information can be disseminated by wide area broadcast (radio or television) or through interactive services (telephone, pager, personal computer or kiosk). The service provider can be a public agency such as ODOT or a city. Private (for profit) companies can also acquire public data, add value and resell it to the public through subscriptions or by broadcast with advertising. The services to be provided include broadcast and interactive traveler services.

Typically a government agency supplies basic traveler information to a web site, local agencies, the public, the media and private vendors through various communications media, such as DMS, HAR, kiosks and linked data communications. In the Tulsa region the RTMC Board will manage the RTMC operations and disseminate traveler information to the public. The RTMC may provide traffic and traveler information for dissemination directly to the public or to private vendors. In the initial phases of the Tulsa Transportation Management System ODOT Division 8, INCOG and the City of Tulsa may share the task of disseminating basic traveler information through a web site or a telephone system. These roles and responsibilities must be defined in the RTMC partnering agreement. In later phases a private vendor may provide additional services.

Private vendors may receive and add value to traveler information received from the freeway management, traffic management and transit centers. Information dissemination may be by a variety of means such as radio and television broadcast,

telephone/cellular service, Internet and pager. Private vendors will use compatible hardware/software for communications with the RTMC. The local agencies may contract directly with a private ISP by agreement with the RTMC Board in order to disseminate locally specific traveler information to the traveling public.

5 ITS Elements

To further illustrate the concept of operations, the ITS elements are individually described below. The Concept of Operations described *what* functions are desired to be implemented in the Tulsa region. This section describes *how* these will be implemented.

5.1 RTMC Hardware

The purpose of the computer hardware platform is to provide a robust, stable platform from which to operate the traffic management system. The platform should have an acceptable cost of ownership with regard to initial cost, maintenance, operating system software, training, upgrades, and hardware replacement. A typical technical architecture of a computer hardware platform is shown below as Figure 1. In this example, all of the ITS field elements are incorporated into this configuration, including integration of a traffic signal control system.

The platform consists of a Local Area Network (LAN) consisting of three to five personal computer (PC) based servers. The servers perform the functions of running the application and support software, communications management, and database storage in a client-server configuration. The servers are rack-mounted and located in the RTMC equipment room. These servers interface with the communications and field devices that make up the ITS.

Insert Figure 1(MIST Configuration)

5.1.1 RTMC Software

The computer software is an essential component of the ITS because it provides all of the functionality for both the devices and the users of the system. The computer software consists of the following modules.

- Application software
- Device drivers
- Operating system software
- Database
- Other commercial off the shelf packages

Application software provides the code to enable the functionality of the system and provide an interface to exercise this functionality for the operators of the system. These are proprietary software packages provided by systems developers/integrators. Applications that are stated to be in the “public domain” still require the same level of effort to integrate the field devices and TMC hardware and populate the database.

The device driver is the computer code that provides commands from the application software to specific devices, both in the RTMC and the field. Each device type and vendor model of equipment require a specific device driver, much like different printers require specific software when connected to a PC.

The operating system software (OS) is an essential component of any system because it provides the interface between the application software and the computer itself. Microsoft Windows NT™ is currently the most widely used and supported multi-tasking OS used today. Traffic management software based on Windows NT OS is available today. There are other software packages available that are based on other operating systems such UNIX.

Other software components play a support role. The most typical is the database software. These are off-the-shelf packages supplied by commercial developers providing database management. Another is the graphical user interface (GUI) for the operator workstations. These commercially available products can be tailored to provide information in a graphical manner using windows in a map-based context. Internet applications are becoming a popular feature in ITS's, expanding the capabilities of the system to broader contexts such as traveler information. Also security and system backup commercial software are generally included in a traffic management software system.

5.1.2 RTMC Staffing

A variety of personnel from the regional traffic management center (RTMC) manager to the individual technical assistants, play significant roles and perform essential duties in the operation of the RTMC. Regardless of the type of RTMC, effective day-to-day operations require the RTMC team to perform a number of basic tasks and administrative procedures, including:

- Maintain the continuity, integrity, and efficiency of traffic management operations
- Obtain, retain, process, analyze, manipulate, and archive data
- Provide for security, operations, and administration of the RTMC's software, hardware, databases, local area computer networks (LANs), communications systems, servers, etc.
- Perform RTMC functions with authorized, dedicated, and properly trained personnel
- Communicate and coordinate with affected agencies and organizations
- Document or maintain logs of all RTMC tasks and activities

Staffing positions depend on the hours of operation and the functions that are carried out in the RTMC. It will also vary depending on whether the RTMC is operated by the responsible agency or by outside sources. Another variable is the number of full-time and part-time positions that will be available in the RTMC. Typical full-time positions indicated by those agencies responding to a recent NCHRP survey include:

- RTMC manager or director
- Supervisors (for operations, engineering, maintenance, law enforcement, systems, etc.)
- Equipment engineer or maintenance coordinator
- Transportation engineers
- Computer programmers
- Workstation operators and analysts
- System administrators (for computer hardware, software, and networks)
- Construction inspectors (e.g., for field equipment, etc.)
- Inspecting supervisor (if applicable)
- Law enforcement personnel (for RTMC's with joint operation by a transportation agency and a police department/highway patrol)
- Radio dispatchers
- Administrative staff
- Building maintenance staff

The following positions have been described by agencies as part-time, full-time, or as-needed staff based on the needs of individual RTMCs:

- Additional workstation operators and analysts
- Desk operators (operators that monitor the system without control capabilities)
- Radio dispatchers
- HAR broadcasters
- Emergency planners
- Maintenance technicians
- Task-oriented trainees (operators and technicians in training that perform tasks for the RTMC manager or shift supervisor)
- Public information and media relations personnel
- Intern employees

Staffing levels and hours of operation depend on many factors, such as the amount of coverage of the system, functions performed, number of field devices, and desired service level. Staffing coverage should be determined by the responsible agency while

developing the strategic management plan. Such a needs assessment should take into account the overall function of the RTMC, the tasks that will be conducted, and a variety of local conditions that may affect staffing coverage. Even though some agencies operate their TMCs continuously, they may not have dedicated staff in the RTMC for the entire time. During "off hours", the functions of the RTMC may be transferred to a regional or statewide TMC, an outside agency or to the police in a jointly operated center. In other cases, the functions of the system may be performed automatically with notice being given to an on-call operator or supervisor when unexpected events arise.

The major duties of the system operator in a freeway operations center include:

- Monitor system peripherals and analyze traffic flow status
- Detect, confirm and start response to incidents
- Report incidents to police and other emergency services
- Dispatch and coordinate Service Patrol Response
- Disseminate traffic information to the public via DMS, HAR and other wireless means
- Provide traffic information to information providers and to the media
- Keep logs of incidents and system operation
- Report malfunctions to maintenance personnel

5.1.3 RTMC Hours of Operation

Ideally, RTMC staffing coverage should be 24 hours per day, 7 days per week. If, due to workload, staffing or funding issues, this coverage can not be maintained, then the minimum acceptable coverage of AM and PM peak hours on weekdays should be accomplished. This typically means the hours from 6 a.m. to 6 p.m. need to be covered. In order to be sure that the peak periods are covered sixteen hours per day, 5 days per week is more desirable for part time operation. When the RTMC is not operational, the RTMC functions should be transferred to another agency. As suggested earlier, the Oklahoma Highway Patrol could perform the duties in Tulsa. An on-call supervisor could also handle many of the RTMC functions remotely as required. As workload increases, and staffing and funding become available, the center operation should be expanded towards the ideal 24/7 operations.

The initial Tulsa RTMC will be handled as a part time facility. Table 1 contains a typical staffing chart for a part time operation. Employees can be full-time or part-time during the first two shifts. Operator 1 positions provide full coverage 8 hours per day, Monday through Friday, and Operator 2 positions provide full coverage and supervision 8 hours per day, Monday through Friday, to accommodate increased activity during peak hours. Similar staffing tables can be developed for operations of fewer hours. Some agencies provide for overlapping shifts to maintain continuity among operations personnel.

A training program will need to be developed to provide operator training on the functions of the RTMC, operation of a RTMC workstation, the use of any software packages that may be needed in conjunction with the workstation, and incident management training. Operator burnout should be mitigated by adjustment of assignments and use of part-time shifts where multiple task activities occur.

TABLE 1: TYPICAL STAFFING CHART FOR 16 HOUR 5 DAY RTMC OPERATION

Operator Level	Sat	Sun	Mon	Tues	Wed	Thurs	Fri
1	Off	Off	5A-1P	5A-1P	5A-1P	5A-1P	5A-1P
2	Off	Off	5A-1P	5A-1P	5A-1P	5A-1P	5A-1P
1	Off	Off	1P-9P	1P-9P	12-9P	1P-9P	1P-9P
2	Off	Off	1P-9P	1P-9P	1P-9P	1P-9P	1P-9P

Source: Sussman 1997 (modified)

The staffing chart in Table 1 reflects only those personnel needed for the operations of the center. Other personnel must be considered, such as the center manager, computer/software support, communications support, service patrol support and dispatch and systems engineering support. These staff members could also have other part-time responsibilities depending on the needs of the operations center. Proposed staffing levels for an initial 16/5 service level with these personnel are contained in Table 2. Service patrol dispatchers or other agency's (state or local police) staff will be in addition to the staffing levels shown in Table 2.

The staffing chart in Table 2 reflects only those personnel needed for the operations of the center. Other personnel must be considered, such as the center manager, computer/software support, communications support, and systems engineering support. These staff members could also have other part-time responsibilities depending on the needs of the operations center. Proposed staffing levels with these personnel are contained in Table 2. Other agency's (state or local police) staff will be in addition to the staffing levels shown in Table 2.

TABLE 2: PROPOSED STAFFING LEVELS

Position	Coverage
	16 hrs. /day, 5 days/week
RTMC Manager	1
Admin Support	1
Operations Supervisor	2
System Administrator	1/2
Sr. System Operator (full time)	2
System Operator (part time)	3
Systems Technician	1/2
Service patrol dispatch	1
Total	11

Advance planning is necessary when developing staffing schedules. It is most efficient if staff shifts do not change during peak hours. Furthermore, all positions related to the RTMC's operations should be in place before the peak travel periods begin.

With RTMC management and operations staff as a vital component of a successful ITS, agencies must commit the necessary resources. When agency resources or skill levels are insufficient for the operations needs of the system, outsourcing is a common solution. Outsourcing can range from total privatization of the management and operation to supplementing of operations staff to cover specific needs. In a white paper published by ITE, a recommended practice is to utilize private sector outsourcing to round out minimal staff.

5.1.4 Remote Terminal(s)

The remote terminal is a feature that allows the viewing and operation of the system from a remote location. The equipment consists of a computer, desktop or notebook, with the application software from the RTMC loaded along with a remote terminal program such as PC Anywhere™. The terminal can see the system graphical user interface and access the variety of information from the system in real time. Multiple remote terminals are possible.

Communications is handled through a leased telephone, higher bandwidth line, or wireless. The user privileges the system provides can be extended to the remote user, allowing viewing only, partial control or full control of the devices. A limitation of the remote terminal is the video image quality. The quality usually expressed in frames per second is a function of the communications bandwidth. It is recommended that remote terminals should be located at the local traffic operations centers, at the OHP dispatch center, the Tulsa Transit center and the County 911 dispatch center.

5.2 Field Hardware

Field devices are the “eyes and ears” for the advanced traffic management system (ATMS). Devices are placed at strategic locations to allow the ATMS to receive data representative of the segment of highway or arterial. These devices then alert travelers of incidents or congestion through DMSs or HARs. This allows commuters to choose alternate routes and reduce the risk of secondary incidents.

5.2.1 Detection

Detection technologies provide vehicle count, classification, speed, and occupancy data. It also provide a means to detect incidents by applying an incident detection algorithm, although, this is not the primary function of these technologies. The data is accumulated at the device or local controller and uploaded to the RTMC at a regular polling rate, typically every 30 seconds. This data is then processed by an incident detection algorithm to determine if any anomalies are present at specific locations along the corridor. If so, the ATMS interprets the detector data as a possible incident and alerts the operator. The ATMS also associates the potential incident location with the applicable CCTV cameras, sign message sets, diversion routes, and incident response protocols. For these purposes, an incident is defined as any event that reduces the capacity of the roadway.

There are three main types of detectors: intrusive and non-intrusive and vehicle probe. Intrusive detection is installed within the pavement or bridge infrastructure. Non-intrusive detection is installed outside the roadway infrastructure. There are several non-intrusive detection technologies readily available in the marketplace today. These include radar, passive acoustic, microwave and video imaging. Vehicle probes use vehicles as a source of travel information. Vehicle probe systems require that a small percentage of vehicles be equipped with transponders, as for toll systems (in Oklahoma the PikePass has a large market penetration). Each transponder equipped vehicle on the roadway is in essence a moving sensor, constantly receiving and sending information to a central processing facility where the information is received and used in conjunction with other information. This merged data can then be used to accurately depict the travel situation including, link speeds, link travel times, and origin and destination information. Information from vehicle probes may be used in conjunction with information obtained from mobile devices for incident management. Mobile devices such as cell phones, freeway service patrols, and call boxes help detect incidents quickly, providing for a more timely response.

Recommendation – Detection

All these technologies should be considered by ODOT. The most commonly used detection technologies are video-based. Video-based detection offers the added benefit of providing a photo (still) image, and should be placed at locations where this additional type of coverage would be useful. To ensure optimal performance, video detection requires precise location. Vehicle probes using the PikePass are also promising in Tulsa. More information on each of these technologies is included in the appendix of this report.

5.2.2 Surveillance

The Tulsa regional ATMS must also include a surveillance capability for the region to allow detected incidents to be verified and their nature determined, (e.g. an overturned truck with spilled load vs. a stalled vehicle). Surveillance is defined as the visual monitoring of the roadway, vehicles, and other activity for the purpose of managing traffic. It should be noted that this surveillance is not for the purpose of providing routine law enforcement or to monitor the travel of individuals.

This visual surveillance is most often used in conjunction with data that is received. The surveillance system allows operators to see the actual traffic and roadway conditions in the vicinity of a detected incident to verify that an incident truly exists and to assist in identifying the appropriate response. Surveillance should be flexible to allow viewing of most areas of the roadway, including interchange areas and cross-streets where possible. It also is desirable to have magnification capabilities of surveillance monitoring allowing for closer views and additional detail when necessary.

Closed circuit television cameras (CCTV)

Closed circuit television cameras are used to visually monitor the freeway system. With CCTV cameras, a control center can immediately confirm incidents along the roadway. Once the incident is identified, the control center can monitor and report any traffic delays the incident is causing. CCTV is also useful for remote weather and road

flooding confirmation as well as monitoring construction activities. More information on the installation of CCTVs is included in the appendix of this report.

Cell phones

In some regions in the U.S. as much as half of all major incidents are reported via cellular phones. The growth of cell phone use has enabled travelers to quickly report an incident. Local agencies assist this process by posting signs with phone numbers to call in the event of an emergency.

The Congress and FCC have required that cellular phones soon must include technology allowing them to be located. Additionally, new methods to use cellular phones as probes have been under development. A first field implementation of cellular phone tracking was implemented in 2001 in the San Francisco region, and in Maryland. The cellular phone tracking method is planned to provide speeds, travel times and incident detection.

Service patrols

Freeway service patrols are another effective means of not only providing incident management, but detecting incidents. They are dispatched to incidents, and report incidents they encounter as a first responder. The service patrols should become an extension of the RTMC by coordinating their activities with two-way communication.

Recommendation – Surveillance

Tulsa should rely on a mix of CCTV, cellular phone call-in, and service patrols for surveillance on the highways. The primary method should be CCTV due its ability to directly show incident managers the nature of the incident and CCTV's ability to be shared directly with other agencies rather than passing information by word of mouth over radio or telephone.

5.2.3 Environmental Sensors

Environmental sensors, known as road weather information systems (RWIS), measure pavement temperatures, and provide ambient weather conditions near the road surface including relative humidity, air temperature, precipitation, and wind speed. Sensors can also detect water over the roadway. In addition to providing information specific to a corridor, RWIS information can be provided to weather forecasting services. The added information can aid forecasters with corridor-specific forecasts of rain, fog, snow, icing and other important weather conditions. Visibility sensors that use various forms of light beams have been installed at several locations across the US to sense fog, dust or smoke conditions. All environmental sensor installations benefit from being installed adjacent to a camera to provide a means of confirming the environmental information remotely.

Recommendation – Environmental Sensors

It is recommended that RWIS be installed in conjunction with visibility sensors at locations such as bridges where weather information is critical to road operations. The sensors should be installed near a full motion color video camera site.

5.2.4 Traveler Information Services

5.2.4.1 Dynamic Message Signs

Dynamic message signs (DMS) convey information to travelers en-route. The messages are transmitted to large signs supported by structures on the roadside or above the roadway. These messages are typically short and concise, consisting of no more than three lines and two “pages”. The effectiveness of these DMSs is limited by the driver’s ability to read and interpret the information during the time the sign is in view. Display technologies can have different contrast qualities to account for the changes in natural lighting during the course of a day. DMSs represent a significant investment and should be carefully located in advance of decision points for major diversion routes.

There are several different types of DMS, light reflecting, light emitting diode (LED), and hybrid (more information on the types of DMS can be found in the appendix of this report). These signs can disseminate traveler information shortly after an incident occurs. Text information can be used to provide near real-time information to motorists regarding lane closures, crashes, work zones, general guidance or weather conditions.

Recommendation – Dynamic Message Signs

Based on several previous evaluations of various DMS technologies, a full-matrix Hybrid LED type of DMS should be strongly considered for application in the Tulsa region. As mentioned earlier, this type of hybrid technology provides the best possible visibility under all types of environmental conditions

5.2.4.2 Highway Advisory Radio

Highway advisory radio (HAR) communicates information to travelers in the vicinity of a HAR transmitter (typically within a range of three to five miles). This system can convey detailed information to travelers since the motorist is in range for a longer time period. HAR can be used effectively in conjunction with DMS, where the DMS alerts drivers to tune to the HAR station for an important broadcast about travel conditions. Certain types of HAR require FCC licensing while others do not. The messages used with HAR are prerecorded for a playlist and used for predictable conditions. For unique conditions, a special message is recorded at the RTMC and transmitted to the HAR transmitter. HAR transmitters are typically placed at major travel decision points and areas of high incident rates.

Highway Advisory Radio is a method of reporting traveler information through AM radio. Information disseminated over HAR is similar to that displayed on dynamic message signs, however HAR can transmit longer messages, and can include information on alternate routes. If the motorist misses the information, the message is continuously repeated providing an opportunity to hear the message again. Studies of driver use of HAR have shown disappointing results, with less than 10 percent of drivers tuning in to HAR. In addition, the functions of HAR should eventually be replaced by transmissions

to in-vehicle computing devices within the next five to ten years, with at least the same penetration rate. HAR is better received by motorists when it is applied at specific locations where recurrent events require motorists be informed.

Recommendation – Highway Advisory Radio

The implementation of HAR must be carefully considered before implementation. HAR requires constant attention to the messages so that fresh messages are continually used. It has been found in regions where HAR has been implemented that the public will stop tuning in the HAR if the messages are out of date. The RTMC staff must be diligent about providing updated messages several times each day and even more often in peak periods.

5.3 Archived Data

For the purpose of ITS data warehousing, the RTMC provides an archive that houses data collected from the various field devices. This archive includes data covering transportation modes and jurisdictions. The data is collected and archived for future use. It provides the basic data quality, data privacy, and meta data management common to all ITS archives and provides general query and report access to archive data users.

ITS data warehousing includes all the data collection and management capabilities provided by the ITS Data Mart, and adds the functionality and interface definitions that allow collection of data from multiple agencies and data sources spanning across modal and jurisdictional boundaries. It performs the additional transformations and provides the additional meta data management features that are necessary so that all this data can be managed in a single repository with consistent formats. The potential for large volumes of varied data suggests additional on-line analysis and data mining features that are also included in this market package in addition to the basic query and reporting user access features offered by the ITS Data Mart.

In the context of the regional architecture, the RTMC will collect and store ITS related data. The data will be provided upon request or routinely by established procedure to MPOs, local agencies and university research centers. The available data will typically include:

- Traffic volume data
- Traffic speed data
- Traffic incident data
- Weather data

Recommendation – Archived Data

Based comments from local agencies and INCOG there is much interest in using ITS data for planning and analysis purposes. A data warehouse should be set up as part the RTMC.

5.4 Incident Management

An incident management program is essential to the effective operation of an incident management system in the Tulsa region. This program reinforces the coordination, cooperation and communication that must occur in the RTMC to fulfill the roles of the response agencies involved. This is also necessary because of the turnover in personnel that can be anticipated in all of the agencies.

The incident management program has two components: capital improvements and a management and operations element. The incident management program can begin in advance of the deployment of the ITS, but needs to continue to run in parallel with the deployment and operation of the system.

5.4.1 Capital Improvements

Capital expenditures for incident management include the purchase of service patrol vehicles, equipment for roadway operations (arrow boards, cones, etc.) and communications equipment (radios, AVL, mobile data terminals).

5.4.2 Management and Operations

Management and operations to support the deployment and operation of ITS include numerous items. They are listed below, but not included in the funding analysis that follows. These items are important for the success of the program.

- Form and continuously facilitate a regional freeway incident management team
- Provide and maintain radios compatible with the City, County and OHP for use by the service patrols and RTMC.
- Perform incident management and diversion route planning, which requires staffing, vehicle maintenance and management.

While initial input from the incident responder stakeholders is reflected, further work should be done with the freeway incident management teams to refine and coordinate the use of these routes.

Recommendation – Incident Management

All of the incident management activities are recommended to be implemented soon. These improvements will help reinforce the partnership with ODOT, the owner-managing agency for the Tulsa regional highways and OHP, the enforcement-operating agency and the local agencies. These improvements will demonstrate responsiveness by ODOT to public need in advance of the capacity improvements. The improvements will also complement the recommended ITS infrastructure improvements.

6 Communications

Communications systems are discussed in this section as trunk and distribution. Distribution communications connects the field devices to the trunk. The trunk brings the communications to the RTMC.

Both trunk and distribution communications needs can be divided into two types: low bandwidth and high bandwidth requirements. For ITS, low bandwidth devices include voice and data transmissions. HARs, DMS, RWIS, and detection require only small amounts of data (low bandwidth needs). High bandwidth requirements in ITS are needed by full-motion video. Full motion video images from CCTV require very large amounts of continuous data. Because the ITS devices to be installed on the highways include full motion CCTV, high bandwidth requirements control the trunk communications. For communications linkages to the trunk, only those locations with full motion CCTV need to consider high bandwidth requirements.

6.1 Trunk Communications

High bandwidth communications can be served using fiber optic cable and microwave communications. Both systems are reliable and stable. Fiber optic cable is capable of transmitting data, voice and video by converting this information into a series of coded light pulses and sending them through optical fiber. The series of light pulses is then internally reflected, and guided by the optical fiber between source and destination.

Microwave communication networks convey point-to-point signals at ultra high frequencies ((UHF) and beyond)). These signals are emitted in a straight line through the atmosphere to and from antennas. Signals can be transmitted in both directions at the same time, but are limited by local topography and the curvature of earth's surface.

In the area of communications, most emerging technologies relate to the means of compressing and transmitting data and video, which are software elements. These new technologies can reduce bandwidth requirements. There are many other emerging technologies on the horizon in the communications infrastructure in high bandwidth applications. Some of these, such as Dense Wave Division Multiplexing (DWDM) are being considered in Statewide networks and long haul applications utilizing fiber optic cable but would not be necessary in a project of this size.

Recommendation – Communications Trunk

The final determination for the communications trunk should be made after further analysis. A preliminary analysis is provided later in this report. This analysis includes the costs of an evaluatory design and the relative strengths and weakness of a fiber optic backbone versus use of the microwave backbone with an evaluation matrix. The fiber optic backbone is the most likely preferred alternative due to the amount of fiber already in freeway right-of-way in the Tulsa region.

6.2 Device to Trunk Communications

Several options exist for connecting field devices to communications trunks. They include both land line and wireless applications. Land line options include:

- Twisted pair cable
- Coaxial cable
- Fiber optic cable.

Wireless communications include:

- Microwave radio
- Area radio networks
- Spread spectrum radio
- Cellular radio

The land line communications options are discussed first, followed by the wireless options.

6.2.1 Wireline

Commonly used in telephone communications, twisted-pair wire is also the most commonly used communications media used in transportation systems, particularly traffic signal systems. They consist of strands of copper wire twisted around each other in pairs. Twisted pair cable is an ideal medium for carrying audio signal frequencies in the range associated with the human voice. This cable type exhibits high reliability over long distances (>10miles) at low data transmission rates (300 bps to 56k bps). Twisted-wire pairs are capable of transferring data at higher rates up to 1.5 – 2 Mbps at high reliability but at much shorter distances (3 – 4 miles). Transferable information includes; data, voice, and slow scan CCTV as well as video at up to 15 frames per second over shorter distances. New video compression technologies are enabling transmission of full motion video over twisted-pair cable. These methods are currently proprietary. Overall, twisted pair cable is a relatively inexpensive communications medium.

Another land line system that can be installed above or below ground is coaxial cable. This medium can transfer data, voice, and video signals. It has the capability of transferring up to 75 video signals, primarily due to its high bandwidth capabilities. In addition, it can transmit digital data at very high speeds (7.5Mbps) with minimal signal losses and low signal leakage.

Fiber optic cable is capable of transmitting data or video by converting this information into a series of coded light pulses and sending them through optical fiber. The series of light pulses is then internally reflected, and guided by the optical fiber between source and destination. Fiber optic cable has the highest bandwidth capability, by far, of any of the communications media discussed. For this project, its capabilities can be considered virtually limitless.

6.2.2 Wireless

The key advantage of wireless communications is that it does not require trenching or pushing conduit for underground installations. In addition, operations costs are lower for wireless applications than for land line applications, especially because there can be no breaks in wireless systems, as sometimes occurs in land lines (i.e. due to construction, shifting in subsurface, etc.). However, wireless applications require poles, power and antennas be installed. These hardware are typically reasonably small for field device to

trunk communications. In addition, most wireless means of communications (except spread spectrum radio, which is described below) or other digitally encrypted radio, are less secure than land line systems.

Microwave radio is a stable means to transmit signals from field devices to communications trunks. The technology involved was described above in the Trunk Communications section.

Area radio networks transmit signals to an area, in 30MHz to 890 MHz bands. These bands are emitted uniformly in all directions. In some cases, the signal may penetrate buildings or bend around changes in topography. Whenever a signal is interrupted, the strength of the signal may decrease.

Installation of an area radio network is beneficial when right of way is not permitted to install other communication systems. Similarly, the area radio network does not require installation of a medium by which the signal will be transmitted, therefore providing savings on installation.

Spread spectrum radio is a wireless technology that can transmit data and a limited number of full motion video channels. Originally developed for the military, spread spectrum radio is a secure wireless transmission technique. It is considered secure because data is transmitted over a wide range of the signal frequency spectrum. When the receiver detects the transmission, the signal is then reconstituted to its original form.

Cellular radio has a number of transportation applications. First, cellular radio can be an effective means of communicating with individuals or devices on an infrequent basis. Such communication can be made to staff or emergency crews, motorist call boxes and/or to control remote equipment. Use of cellular radio on a more frequent basis can be quite expensive when compared to the majority of other communications media. CDPD, a form of cellular radio that uses otherwise unoccupied cellular channels, can transmit data at rates up to 19.2 kbps, and is useful in certain non-critical applications. The primary drawback to using cellular technology is that in critical times during traffic incident drivers may be using the cell tower capacity and calls from the RTMC may not get through to the field devices.

As noted above, in the area of communications, most emerging technologies relate to the means of compressing and transmitting data and video, which are software elements. These new technologies can reduce bandwidth requirements. All emerging technologies that are on the horizon in communications are proprietary, and not suitable for large-scale projects.

Recommendation – Field Device to Communications Trunk

Field device to communications trunk communications could be wireless, due to the lower installation and maintenance costs anticipated. This recommendation also serves this analysis to create a totally wireless alternative for evaluation against the fiber optic alternative. Wireline connections for field devices are feasible and the most common approach used. The final determination for the communications for the field device to communications trunk should be made after further analysis.

7 Implementation Strategy

7.1 Introduction

Transportation management and operation has become a priority nationwide as jurisdictions look for ways to use ITS technology and infrastructure to improve conditions on roadways. Past experiences with congestion on roadways during major incidents has fueled the interest in the benefits of ITS.

After identifying the concept of operations for the ITS, the ITS elements and the communications infrastructure, specific ITS projects to be implemented should be developed. The concept of operations identified what the system does, broken down by subsystems, and the roles and responsibilities of the agencies involved. Subsequently this report identified the individual components and technologies that make up the ITS. Now in this section, the report considers how and when to deploy the recommended ITS.

To implement ITS, a strategy is required. This section provides the capital costs, funding sources, schedule and phasing of the recommended ITS deployment in the corridor. This implementation strategy also discusses procurement methods.

7.2 Deployment Schedule

The Tulsa Regional ITS Implementation Plan comprises sub-plans covering three time frames:

Short-Term Implementation Plan – Projects/actions, which can be implemented in a time span of one to three years.

Mid-Range Implementation Plan – Projects/actions to be implemented three to seven years in the future.

Long-Range Implementation Plan – Projects/actions, which complete the system and would be implemented more than seven years in the future.

7.2.1 Short Term Implementation Plan

Short-term implementation of ITS projects in Tulsa is focused on the development of a basic Transportation Management Center for the region with communications to incident response agencies.

7.2.1.1 Broadcast Traveler Information

Dynamic Message Signs

ODOT has initiated a project to install seven permanent DMSs at fixed locations on the Tulsa freeway system to provide information to travelers. The DMSs will be located at decision points for the traveler. The cost for each DMS sign is approximately \$150,000.

Internet

ODOT's web site should be enhanced to provide real-time traffic information for commuters based on incidents reports from responder agencies and verification from the CCTV cameras. The web site would include current traffic conditions, visual images of current conditions, and weather conditions on the highways. In the future this website should be updated to provide an overview of the regional system while still having the capability to zoom into a particular region. The estimated cost to create a web site is approximately \$75,000.

7.2.1.2 Network Surveillance

A detailed field device implementation plan that defines the number and location of DMS, CCTV cameras, detection devices, road weather stations and the necessary communications network needs to be developed in the near future. A phasing plan for deployment of the field devices should also be developed. The portions of the freeway system that have the highest rate of incidents should be instrumented first. For example, the downtown freeway loop and the approaches to the loop may warrant deployment in the first phase.

Closed Circuit Television

CCTV cameras should be installed at fixed locations. The extent of surveillance and detection coverage as well as the location of dynamic message signs and other devices in the Tulsa area should be determined through a detailed analysis of needs. The estimated cost for the installation of a CCTV is around \$25,000 (excluding video transmission costs).

Detection

For the current implementation, detection should be a mix of radar and video-based detection. The majority of the detectors should be microwave radar type. Video-based detection offers the added benefit of providing a photo (still) image, and should be placed at locations where this additional type of coverage would be useful. To ensure optimal performance, video detection requires location over the roadway, or on poles at least 50-foot high, making placement more difficult and costly. The estimated cost per detector is approximately \$20,000 (excluding video transmission costs).

Road Weather Information System

Environmental sensors, known as road weather information systems (RWIS), measure pavement temperatures, and provide ambient weather conditions near the road surface including relative humidity, air temperature, precipitation, and wind speed. Sensors can also detect water over the roadway. In addition to providing information specific to a corridor, RWIS information can be provided to weather forecasting services. The added information can aid forecasters with corridor-specific forecasts of rain, fog, icing and other important weather conditions. Visibility sensors that use various forms of light beams have been installed at several locations across the US to sense fog, ice, dust or smoke conditions. All environmental sensor installations would benefit from being installed adjacent to a camera to provide a means of confirming the environmental information remotely. The cost for the installation on an RWIS system can be anywhere from \$35,000 -\$75,000 (excluding video transmission costs).

The average cost per mile of field equipment, such as cameras and detectors and communications transmission using fiber optic cable, is estimated to be \$300,000.

7.2.1.3 Incident Management

Inter/Intra-Agency Communication

Providing a link via a short-wave radio, like those found with Nextel phones or 800 mHz radio systems, would give all the public safety agencies and ODOT an instant connection in order to improve communications when responding to an incident. These phones are readily available and inexpensive. All agencies should also develop a contact list providing phone numbers, fax numbers, physical addresses and email addresses. These lists should be compiled into a master list for the agencies and distributed further improving communication among agencies in the region. In addition, freeway incident management plans should be developed to anticipate major incidents on the freeways that could lead to different scenarios.

The Tulsa region is planning to deploy the Tulsa 911 CAD system terminals at seven locations in the area. The RTMC Board should determine the locations of those terminals. This project should be initiated as soon as possible. The expected cost is \$70,000.

It is also recommended that a permanent link be established between ODOT and the major public safety agency centers such as the OHP dispatch center and the Tulsa 911 PSAP center. This could be established through a fiber-optic link or the co-location of the public safety agencies and the ODOT TMC.

Service Patrols

Service patrols are another effective means of not only providing incident management, but in detecting incidents. They are dispatched to incidents, and report incidents they encounter as a first responder. The Service Patrol should become an extension of the TMC by coordinating their activities with two-way communication. It is recommended that ODOT initiate state managed service patrols or if a private service is initiated that a strict performance contract be signed. This is to ensure that the service patrol provides the functions that typical service patrols perform, including: minor repairs to disabled vehicles, providing fuel, road clearance of disabled vehicles, management of traffic at incident scenes, response to incidents, and direct communications to ODOT and to public safety agencies. The cost of operating and maintaining one service patrol vehicle including driver salary and benefits is approximately \$130,000 per year.

7.2.1.4 Regional Transportation Management Center (RTMC)

The RTMC is a crucial element in the advanced transportation management system. It essentially gathers information about the transportation network, processes and fuses this information with other operational and control data, and provides information to partner agencies and travelers. This information is then used to monitor the operations of the transportation network and implement traveler information, and implement real-time control strategies to improve safety and efficiency.

The proposed RTMC Board must be initiated so that decisions on institutional agreements, location of an interim center, plans for the permanent center and daily operations can be made.

Groundwork for the location of the RTMC should begin immediately. While construction and the functions of the RTMC may not be completed within one-year, the initial framework should be implemented in this time frame. The initial phase of the RTMC may be housed in existing ODOT, OHP or Tulsa 911 space and use vendor supplied equipment control software. The estimated cost for an interim phase of a RTMC is \$500,000.

7.2.2 Mid Range Implementation Plan

After the initial implementation of ITS elements along the highways the focus should shift to expanding the integration of the RTMC and local traffic operations centers to coordinate with other agencies.

As new technologies emerge, the ITS system should be modified to accommodate these new capabilities. For example, the functions of DMS and the web site should eventually be enhanced by transmissions to in-vehicle computing devices within the next five to ten years, with at least the same penetration rate. The ITS system should advance to accommodate this new technology replacing the current method for communication to vehicles.

7.2.2.1 Traffic Operations

Surface Street Control

The RTMC should eventually have a link to the traffic signal systems in Tulsa, Broken Arrow and other cities in the region. This would allow coordination between the RTMC and the traffic operations center in the event of an incident. The local traffic operations center would be able to monitor the conditions on the highways and adjust signal timings in the event traffic is detoured onto the arterials. The system should also include CCTV cameras on major arterial streets for use in verifying incidents and to observe signal timing changes.

7.2.2.2 Expansion of RTMC

The functionality of the full implementation of the permanent RTMC should be assessed prior to determining space and equipment needs of the RTMC. As the system grows and becomes more complex, the need for more space and integrated software will become apparent. The estimated cost for integrated software is \$1 million. The cost of RTMC hardware and new space or a new building will range from \$500,000 to \$5 million.

7.2.2.3 Network Surveillance

Instrumentation of the Tulsa freeway system should be expanded. Phasing of additional detection, surveillance cameras, weather stations and the communications network should be determined by the RTMC Board and the availability of funding.

7.2.2.4 Archived Data

ITS Data Mart

An ITS data mart provides for archiving of data within an agency. Access to stored data will be available to ODOT, INCOG or City of Tulsa staff. Other agencies may develop their own data marts in order to manage internal data.

ITS Virtual Data Warehouse

The virtual data warehouse provides for data sharing of defined sections of individual agency's data marts. A central computer server must be defined to allow access to permitted portions of any participating agency's data. INCOG has expressed an interest in hosting a regional ITS data warehouse.

7.2.2.5 Traveler Information

Interactive Traveler Information

An enhanced web site would allow a traveler to simply punch in origin and destination data and receive a customized traffic report as well as different modes of transportation available. INCOG has offered to manage the region's traveler information web site. The regional status map, camera views, incident information and Tulsa Transit information should be included.

7.2.2.6 Traffic Management

Regional Traffic Control

Regional traffic control provides for real time communications of data and video sharing between ODOT and local traffic engineering and public safety agencies.

Multi-modal Coordination

Multi-modal coordination provides for electronic data sharing of real time data among various traffic control systems and transit management systems. Signal system priority for public safety vehicles and Tulsa Transit buses may also be implemented. Also highway-rail intersection controls may be implemented.

7.2.2.7 Incident Management

Emergency Response

Emergency response provides real time data sharing between public safety CAD systems and ODOT traffic control systems. The Tulsa 911, OHP and other local public safety agency CAD data should be integrated as much as possible into the regional traffic control software.

7.2.3 Long Range Implementation Plan

Long range implementation of ITS in Tulsa would expand to include these technologies along major arterials in the counties. It is not anticipated that ITS instrumentation would be implemented along arterials for the next ten years. Additional planning for future ITS enhancements would include the integration of the network in counties into a statewide

system as it is developed. Other future elements may include a parking management system in downtown Tulsa and at the Tulsa Airport, Automated Vehicle Location (AVL) technology with tracking capabilities on buses, emergency vehicles and maintenance vehicles.

7.3 Procurement Method

One critically important aspect of deploying ITS is the use of the proper procurement method. It is well documented and accepted by the FHWA that the use of low bid methods for the delivery of ITS is not appropriate.

Among all of the candidate procurement methods for ITS as described in the appendix, those considered viable have one common characteristic; the contracted party to ODOT is a single entity. Further, this entity is selected for their capabilities, not on the basis of a low bid. It is recommended that the system manager contact type has been found to perform well for implementing agencies and should be considered for use by ODOT in Tulsa. This firm referred to as the system manager is responsible for the system planning and design, and ultimately responsible for providing the system platform, integrating this with the field hardware and communications and delivering the working system to ODOT. This single point of responsibility reduces the risks associated with successful ITS. The approach specifically provides the following additional benefits.

- Unlike with low bid, where the software is designed to do the absolute minimum required to meet the specifications, the system manager can take advantage of the latest thinking and processes in a rapidly evolving technological market.
- The system manager provides the owner access to the system development and integration process. If the field hardware installation is let with the software the bid will be won by an electrical contractor who does not provide software platforms. The electrical company will subcontract the software to another company.
- The system manager approach provides a product that not only incorporates consistent leading edge technologies; it can also enable integration with any traffic control systems of the adjacent network or elsewhere in the state.
- In the current environment of TEA 21 funding using a system manager allows the State to readily modify the implementation to take advantage of new funding sources, such as demonstration projects and other sources of funds.
- The design of the telecommunications network can be prepared to include future requirements that can be designated later by the owner. Often systems that are low bid have limited expansion capabilities. These limitations are often not discovered until control elements are expanded or modified later.
- As upgrades to the system hardware and software are needed in later years, they can be designed and deployed uniformly and with minimum expense.

Design build is an increasingly popular approach to project delivery in the areas of buildings, roadway and bridge. Its weakness when used for ITS is ODOT's loss of control or choice over the final product. This final product is only defined in terms of

functional requirements with this method, leaving the outcome uncertain, except for the cost. However, ITS at the lowest price is often unsatisfactory. Weighting price with technical submissions mitigates this disadvantage, but technical submittals prepared over a short period of time within a fixed number of pages leaves much to be determined later by the contractor, adding risk to the owner. Perhaps the most important distinction of design build over the other methods above is that an electrical installation contractor is typically the prime contractor, removing ODOT from a direct relationship with the system provider/integrator.

7.4 Funding Alternatives

Funding is a vital element of any transportation program. The purpose of this section is to provide the information necessary for ODOT to consider the funding alternatives (and their requirements) that are available for the ITS projects. Innovative funding sources are included.

7.4.1 Federal Perspective

Federal funding is divided into categories, each with its own characteristics. The following categories of federal highway funding exists today:

- National Highway System (NHS)
- Surface Transportation Program (STP)
- Congestion Mitigation and Air Quality Improvement Program (CMAQ)
- Bridge
- Interstate Maintenance
- Safety
- State Funds
- Specific Programs

The enabling Federal legislation allocating these funds is Title 23 of US Code as most recently modified by the Transportation Equity Act for the 21st Century (TEA-21). For ITS, TEA-21 allocates funding primarily for ITS Integration, ITS Standards, Operational Tests, Research, and ITS Deployment Incentives. Except in specific instances of earmarked funding on high priority projects, ITS funding is mainstreamed for the general funding categories listed above. Oklahoma DOT has been successful in obtaining earmarked funds for deployment of ITS projects in Oklahoma City and Tulsa.

Applications for ITS funds must submit an analysis of the life cycle costs of operations and maintenance, if capital costs exceed \$3 million, and a multi-year financing and operations plan.

Under TEA-21, several changes were made to mainstream the ITS program into the well-funded traditional federal-aid highway categories. As a result, ITS projects are explicitly eligible for NHS, STP, CMAQ funding. Further, ITS “capital and operating costs for traffic monitoring, management, and control facilities and programs” are eligible. The definition of operating costs is defined as: labor costs, administrative costs, costs of utilities and rent, and other costs associated with the continuous operation of traffic control, such as integrated traffic control systems, incident management programs

and traveler information and traffic control centers. Use of CMAQ funds for operations is limited to a three-year period. The other traditional funds do not have a time limit.

More recently, on May 25, 2000, the Federal Highway Administration issued two Notices of Proposed Rulemaking (NPRMs) concerning ITS in response to Congressional intent, regarding architecture consistency and the role of MPOs in the process. Specifically, these are titled National ITS Architecture Consistency Policy for Project Development, and Intelligent Transportation System Architecture and Standards. While presently in the comment stage, should the rules be finalized in their current form the eligibility for funding of ITS projects will be affected in the following ways:

- **Conformance with the ITS National Architecture and applicable standards:** Conformance with the National ITS Architecture is defined under this proposal as development of an ITS regional architecture based on the National ITS Architecture, and the subsequent adherence of ITS projects to the ITS regional architecture. The ITS regional architecture would consist of a concept of operations and a conceptual design, which would draw from the National ITS Architecture, but would be tailored to address the local situation and ITS investment needs. A two-year compliance period is provided.
- **Requirement for an Integration Strategy:** ITS will become part of the transportation planning process through the regionally defined ITS Integration Strategy. This ITS Integration Strategy will guide future investment decisions and foster integration and interoperability. Developing the strategy as part of the overall transportation planning process would ensure that ITS is given appropriate consideration as a solution for future transportation needs and services.

The final outcome of the proposed rule is to be determined by FHWA after the comment period closes, which occurred on September 23, 2000. Several Federal legislators, however, after reviewing these comments, have cited the need for further legislation requiring the proposed rules to be more responsive to the initial congressional mandate.

7.4.2 State Perspective

7.4.2.1 Traditional Funding

Another consideration in funding eligibility is the role of the Metropolitan Planning Organization (MPO). In Transportation Management Areas (TMAs), NHS and Interstate Maintenance projects are selected by the State, in consultation with the MPOs, and consistent with the Transportation Improvement Program (TIP). With all other federally funded projects, the MPOs select the projects in consultation with the State, consistent with the TIP. In reality, ODOT and the MPOs strive for consensus on all of the projects in the TIP, whether or not federally funded.

7.4.2.1.1 Surface Transportation Program (STP)

ITS projects are also eligible for use of Surface Transportation Program funds. STP funds can be used in most places in the state including the Interstate system. There are

however, certain subcategories of STP funds that are restricted to certain kinds of projects. Relevant to ITS, these are summarized in the table below:

STP funded projects are selected by the MPOs within the Transportation Management Areas. When in areas with populations below 200,000, the State selects, again with MPO consultation and concurrence. Any Federal Aid ITS projects in an urbanized area, including interstate projects, must appear in the MPO's TIP.

7.4.2.1.2 Interstate Maintenance (IM)

Interstate maintenance funds are designated for resurfacing, restoring, rehabilitating and reconstruction (4R), including adding travel lanes, on most existing Interstate System routes. This category can be used for ITS projects on the interstate system in ODOT. IM candidate projects are submitted to the FHWA Division office. By State policy, IM funds are used only for the interstate system.

7.4.2.1.3 State Primary Highways and PTO (DS)

DS funds are the primary source of state transportation funds. DS funds may be used for ITS purposes on any state highway, any bus system or rail system without any program restrictions on eligibility.

7.4.2.1.4 District Dedicated Revenues (DDR)

Derived from the State Comprehensive Enhanced Transportation System Tax, these funds must only be used for State transportation projects in the specific counties where the revenues were collected to the maximum extent feasible.

7.4.2.2 Innovative Funding

Innovative funding has been advocated for ITS for some time. This perhaps is due to the unique, relatively new nature of ITS projects. At the same time, mainstreaming of ITS projects is advocated using the traditional funding sources. For the ITS program in Tulsa to be fulfilled, it is appropriate to consider all possible funding sources, as agency and political support for the ITS program is gathered. Each of the funding sources below can be used for ITS.

ITS Deployment (Demonstration) Program

Under this program, eligible projects must demonstrate integration of multi-modal ITS components in metropolitan areas, rural areas, statewide, for multi-state city settings to improve mobility, promote safety, increase traffic flow, etc. including building on existing ITS projects. The Federal share is 50%. The FHWA lead contact person is Toni Wilbur, HOTM-1, Telephone, (202) 366-2199. Proposals are submitted to FHWA Washington Headquarters. Traditionally, however, these funds have been earmarked by Congress. This fact requires sponsors of projects to gain local congressional support for candidate projects.

Soft Match

Soft Match involves credit for the non-Federal share of funding on a project. Toll revenue expenditures are used as a credit toward the non-Federal matching share of all programs authorized, with certain exceptions. A different form of soft match involves use of the value of in-kind services for the soft match, under certain rules.

Public/Private Partnerships

These partnerships can take several forms, but can simply be thought of as a barter arrangement between the public and private sector. Funding, via these partnerships, takes many forms including special taxing districts, land or cash donations, impact fees and other arrangements.

State Infrastructure Bank (SIB)

The SIB is an investment fund that offers loans, credit enhancements and other forms of financial assistance to surface transportation projects that meet federal standards and are eligible for assistance under Title 23 and capital projects defined by Title 49. The loans are capitalized with Federal funds.

Advanced Construction (AC)

This approach involves using state funds for a project eligible for eventual reimbursement with Federal funds. Advanced construction funds can be used in IM, NH, CM programs. This approach is characterized as an excellent tool to ensure that no available Federal funds are lost in a Federal fiscal year.

Appendix 1: Detection

Intrusive Detection

Inductive Loop Detectors

Inductive loop detectors are the most prevalent type of vehicle detector with a large installation base. The two components of a loop vehicle detector are a loop consisting of multiple turns of wire buried in the roadway and a loop detector amplifier to sense the change in inductance of the loop of wire as a vehicle passes over it. The output from the loop detector amplifier changes state to indicate the passage of the vehicle over the loop. This presence indication is then processed to provide measurements of volume, speed and occupancy.

Magnetometers

Magnetometer detectors are cylindrically shaped units commonly used in bridge structures for vehicle detection. Because they require less intrusion in the roadway, magnetometers are somewhat less subject to failure due to subgrade or pavement structure shifting. Magnetometers are as accurate as loop detectors. However, as for loop detectors, they require that lanes be closed for installation or replacement.

Nonintrusive Detection

Microwave Doppler Radar

Microwave Doppler radar detectors use low power microwave energy to measure the speed of vehicles using the Doppler effect, whereby the change in frequency of the portion of the energy reflected back from a passing vehicle is proportional to the speed of the vehicle. The beam width of a microwave detector can be either wide or narrow. Wide-beam detectors provide coverage of up to three lanes of traffic and can be mounted either over the center of the roadway or in a side-fired configuration along the side of the roadway. Narrow-beam detectors are used at locations where lane specific speeds are required. An individual detector is mounted over the center of each lane.

Microwave Presence-Type Detector

EIS (Electronic Integrated Systems) has developed a microwave detector called RTMS (Remote Traffic Management Sensor) that detects presence. The detector provides twelve detection zones of user defined length (in 7-foot increments) along the footprint of the beam within a range of 200 feet. The user defines the zone in the field through a lap top computer. The RTMS functions primarily as a presence detector. The detector can be mounted either side fired along the side of the roadway or overhead above the lane of traffic.

Passive Acoustic

The SmartSonic vehicle detector marketed by International Road Dynamics uses passive acoustic sensing and signal processing technology developed by AT&T to

emulate vehicle loops. Each SmartSonic installation consists of one to four acoustic sensors for detecting the acoustic sound emitted by passing vehicles and a controller card for the processing of the detected sound. The controller card is designed for installation in a Type 170/179 controller input file providing presence data to the controller for processing. Each sensor provides a detection zone approximately six to eight feet in the direction of traffic flow with the width of the detection zone user selectable. Sound from vehicles outside the detection zone are filtered out by the sensor. The sensors are usually mounted between twenty and thirty-five feet over the traffic lane for which data is desired. A single sensor provides presence and volume data and two sensors mounted in series provide data for the calculation of speed and vehicle length.

Active Infrared Vehicle Detection

Active Infrared vehicle detection systems, such as the Autosense I manufactured by Schwartz Electro-Optic Technology, use laser technology to detect the presence of vehicles. By measuring the propagation time for two divergent laser beams emitted from the sensor presence and speed can be determined. A microprocessor within the unit converts the time measurements to vehicle speed and presence. The preferred mounting of the Autosense I is over the center of the lane at height of approximately 20 feet with the center of the beams at an incidence angle of between 0° and 30° to the incoming traffic. One Autosense I unit is required for each vehicle lane monitored.

Video Image Processing

Video image processing (VIP) also known as machine vision technology and video image detection (VID) - extracts real-time traffic flow data (e.g., volume, occupancy, speed, classification) by using microprocessor hardware and software to analyze "video" images of the roadway. Many VID systems use a variety of signal processing algorithms to gather traffic flow data by using user defined "pseudo-detectors" within the camera's vision. Each time a vehicle enters or cross this detection zone, a detection signal (i.e., presence) is generated. The signal can be processed locally to provide volume, speed, classification and vehicle length.

A typical VIDS consists of the following subsystems:

- camera subsystem, which consists of one or more monochrome or color CCTV cameras housed in an environmental enclosure;
- processing subsystem, which contains the hardware and software to convert the video image into the various traffic flow measurements and to provide the interfaces with the user interface and the detector I/O; and
- user-interface subsystem, consisting of the computer through which the user programs the detection zones and views the detector data.

Roadside Barrier Detection

The purpose of the roadside barrier detection system (RBDS) is to detect and identify by milepost/location when a vehicle crashes into a fenced barrier wall. The RBDS will be supervised by sensing devices and provide location-specific alarms to the RTMC, in the

event of an incident that results with a crash with the fenced barrier. The RDBS could also be supplemented and integrated with CCTV cameras for verification and dispatch of emergency services to the scene.

Appendix 2: CCTV Installation

Each CCTV installation consists of the following hardware:

- Camera,
- Pan/tilt unit,
- Camera Enclosure,
- Receiver Driver Unit,
- Communications interface.

Since color cameras provide important information needed to describe vehicles and identify license plates, high performance, high sensitivity color cameras are being used in most traffic applications. The three most important specifications that determine the performance quality of a camera are:

- Sensitivity
- Resolution, and
- Signal-to-noise ratio (SNR)

Other important considerations are the camera's ability to withstand shock and vibration, resistance to corrosion and the ability to handle hot and cold temperature extremes.

The camera signal format must be compatible with all applicable National Television Standards Committee (NTSC) standards. The imaging system must be a 1/3-inch or 1/4-inch solid state high-resolution color camera using an interline transfer charge-coupled device (CCD) image sensor and Digital Signal Processing (DSP).

The minimum number of picture elements should be 768 (H) by 494 (V) pixels. The minimum camera resolution should be 460 (H) by 350 (V) total television lines when measured from the composite video output.

The camera shall be designed for use at low light levels and shall function adequately over a wide dynamic range from low light levels to full sunlight.

The imaging system shall be designed to minimize the effect of blooming and smearing of high intensity light sources under nighttime viewing conditions.

Appendix 3: DMS Technology

The most flexible type of DMS is the matrix sign. The desired legend is displayed by turning on or off individual pixels. Matrix options include:

Character Matrix - An individual module is provided for each character (letter). The letter spacing and maximum letter width is fixed.

Line Matrix - A single matrix is provided for each line. This allows proportional spacing between letters, but limited graphics capability.

Full Matrix - There are no built-in divisions between letters or lines. This configuration allows the greatest flexibility in the size and stroke of letters plus graphic symbols. To illustrate the flexibility of a full matrix DMS, a 28 pixel (V) x 105 pixel (H) full-matrix DMS can display 3 lines of 18-inch letters (with 16-21 characters per line) or 2 lines of 24-inch letters (with 12-18 characters per line), depending on the actual characters used and their respective widths. Although the message is limited to fewer characters, the 2-line message capability of full-matrix DMS—incorporating larger letters and a broader stroke width provides more visual conspicuity or “punch” than the 3-line format. This can be effective during times of the day (e.g., sun directly behind the sign) when the extra punch is needed to enhance the legibility and readability of the message. Another advantage of full-matrix DMS is its ability to display graphics, further enhancing message readability. Graphics should be kept simple, be easily recognized, and be familiar to motorists. The most useful graphics—such as directional arrows, interstate shield, airplane, and HOV lane restriction (based on the international diamond sign) -- do not require an accompanying explanation on the sign.

The full matrix DMS, containing more pixel elements and electronics, is approximately 10%-20% more expensive than a line matrix DMS. A character matrix DMS is 5 to 10 percent less expensive than the line matrix sign. The character matrix DMS is no longer recommended for use. The line matrix DMS is much more flexible in message display and letter presentation.

Several DMS technologies are available as described below.

- Bulb Matrix Bulb matrix signs are composed of incandescent lamps that are turned on and off to produce the desired letter array or graphics. Bulb matrix signs provide excellent visibility at night and in daylight. These signs, which can be easily dimmed, are typically operated at full power during daylight hours and at 60% power at night.

Bulb matrix sign technology is well established and has been used in many applications. Maintenance requirements, however, are high due to the necessity of replacing individual bulbs as they fail. (A sign of 15 characters per line, with 3 lines, and a 5x7 matrix for each character, would consist of 1575 bulbs.) The current standard practice is the periodic replacement of all bulbs (e.g., 1 to 2 years), thus avoiding a growing number of maintenance calls as the bulbs age.

Sign maintenance is relatively straightforward, and replacement materials (bulbs, sockets, electrical wiring) are readily available.

Due to the large number of bulbs—each operating at 25-30 watts—power consumption is very high when compared to the other sign technologies. Because of the heat generated by the bulbs, internal ventilation or open screening is required. Bulb matrix signs are considered obsolete technology and have been abandoned by most agencies.

- Flip Disk This DMS technology consists of a matrix of disks that are reflectorized (typically yellow) on one side, and flat black on the other. The individual disks are magnetically rotated (i.e., “flipped”) and held so that the reflectorized disk sides are displayed in the form of the desired character or pattern. The disk is flipped by applying a brief voltage pulse to a coil, which causes the disk to rotate to its other side.

Since flip disk DMSs do not produce their own illumination, visibility is dependent upon the ambient light conditions. During the daylight hours, this DMS technology provides excellent viewing when the sun shines directly on the disks. Otherwise, these signs do not generate the bright images that light-emitting signs create, making flip-disk signs very difficult to read when light levels are low or during conditions of fog, smog, and rain. Although the signs are illuminated during nighttime hours—by lights directed at the face of the sign the visibility is generally less than optimum daytime viewing. In essence, except for conditions of direct sunlight, flip disk signs have very little “punch” to draw attention or to provide conspicuity.

Power requirements during daylight hours are very low—power is necessary only to rotate the disks, but not to retain the disks’ state. At night, power consumption increases because of the illumination provided by the external lighting. The signs also have excellent environmental tolerance.

Potential maintenance problems associated with these signs include:

Disks in older signs have been reported to stick as a result of wear, coupled with dirt and vehicle particulate emissions accumulating in the pivot points. Newer signs—utilizing circular disks that rotate along a horizontal or diagonal axis on a stainless steel or Teflon pivot—apparently have minimized the sticking problems. Nevertheless, the disks need to be exercised regularly and tested to keep them in good operation. The yellow reflective tape will also eventually be bleached white by the sun, and will need to be replaced.

- Light Emitting Diode (LED) The light emitting diode (LED) dynamic message sign consists of clusters of super bright LEDs mounted in a socket. Each cluster forms one pixel of a character or display. The LED clusters can be manufactured in either a light guide cone or a cylinder to protect the display from sunlight washout and to focus the light for optimum visibility.

LED signs provide good visibility under most lighting and weather conditions. A variety of LED colors are available (e.g., red, green, amber), with red providing

the greatest brightness. Three types of LED signs are available as summarized below:

Red Only - As noted above, red LEDs are brighter (i.e., more punch) than amber or green LEDs. However, few agencies use the red only LED because of the color's connotation for traffic flow (regulatory, emergency, etc.).

Red-Green Hybrid - When LED DMS were first introduced a few years ago; the amber LED technology did not provide sufficient brightness for message visibility. In order to obtain an amber display, a cluster of red and green LEDs (e.g., a ratio of 9 red to 55 green) was used. This arrangement yields a "pseudo-amber" display (with a slight trend towards orange) of sufficient brightness when viewed from a distance. However, when viewed close-up or at an angle greater than 10 degrees from center, the individual red and green components are readily visible.

Amber Only - LED technology has advanced to the point where amber-only LED signs of sufficient brightness have recently been introduced by several DMS manufacturers. Sign manufacturers today indicate LED technology is now the most popular based on new orders. LED technology also offers very long lamp life, in excess of 250,000 hours, thereby reducing maintenance costs in the lamp systems.

- **Fiber Optic** Fiber optic DMS are comprised of bundled fiber optic cables terminated in "dots" on the front face of the display. Each sign pixel—analogue to a disk on the previously discussed DMS—consists of two such dots. The light source typically consists of a 50-watt tungsten bulb for every three characters (i.e., 5 pixel x 7 pixel modules) in the sign. Each of these bulbs is augmented by another 50-watt bulb for an "over bright" mode during bright sun, and to function as a back up should the primary bulb burn out. The fiber dots and pixels are continuously illuminated, with their visibility controlled by magnetic shutters that open and close in front of each pixel.

The visibility or "punch" of fiber-optic DMS is very good under all illumination conditions. Fiber optic DMSs have a narrow cone of vision (i.e., 12 degrees) produced by the focused fibers, possibly restricting off-axis viewing, although proper sign placement eliminates this concern. Power consumption for the fiber optic DMS is greater than the flip disk, but less than an LED sign.

- **Hybrid** The hybrid DMS is a mixture of the flip disk and light emitting source (fiber or LED) technology previously discussed. A hybrid sign consists of standard flip disks with a small hole placed in the center of each disk. Behind each hole is either a fiber optic bundle, or an amber LED. When the disk is in the "on" (reflective) position, the light shines through the hole. When the disk is in the "off" (black) position, the continuously illuminated fiber optic bundles are concealed from view, while the LED source is turned off.

The fiber/LED enhances disk readability, particularly during low light conditions, giving the DMS the "punch" that the reflectors alone lack. Less light is required from the emitter because the signs don't attempt to overcome the direct sun. Because of the light-emitting component of the disk mechanism, external illumination is not required at night.

This DMS marries the best visibility characteristics of light emitting and flip disk technologies. Lamps for fiber optic DMS will require replacement and, as previously discussed, rotating disks may jam occasionally. Vendors of hybrid signs include Mark IV Technologies, American Electronic Signs, LEDStar, ADDCO, and Vultron.

Appendix 4: Procurement Issue Paper

1. INTRODUCTION

Successful ITS implementation, operation and maintenance requires effective procurement processes to acquire the services, hardware and software necessary for these systems. But many conventional procurement processes are not well suited to buying these systems, and new approaches present their own unique challenges. This issue paper presents brief descriptions of various contracting methods. It is important to recognize that this paper is merely intended to serve as an initial survey. It is not a detailed analysis and considerably more effort would be needed to further investigate and implement the alternatives and recommendations described here. The purpose of this issue paper is to summarize the state of the practice for procuring ITS and other advanced technology implementations.

2. TYPES OF CONTRACTS

This section summarizes a wide range of contracting vehicles available for the procurement of ITS.

2.1 ENGINEER / CONTRACTOR

Traditional highway construction projects have been procured using a process in which the project design is developed by a public agency or a consultant (the “Engineer”). A bid solicitation is issued which includes forms and design specifications and an award is made (to the “Contractor”) on the basis of the lowest bid received. While this process is highly competitive, it is not well suited to the development of complex, high-tech information and communications systems which are the core of ITS.

If a consultant is to be used to design the project, the consulting engineer is selected based on qualifications and experience to perform the work. The engineer typically prepares the contract documents (plans and specifications). Construction contractors are invited to submit bids in accordance with the contract documents. Award is based on the lowest responsive bid. Once awarded, the contractor builds the project according to the bid documents. The engineer (or another CE&I consultant) inspects the construction, certifies completion and may interpret the bid documents. Most highway construction and smaller closed-loop type traffic control system projects nationally have been procured successfully utilizing this approach.

Advantages:

- The public agency is the responsible entity.
- This approach has a long history of use, with roles clearly defined.
- Its history provides well-established legal precedent to handle disputes arising from this approach.
- The end product is well defined at an early stage in the project.
- The contractor manages the subcontractors
- This approach is well-suited to highway construction

Disadvantages

- Artificial dividing line between design and construction
- Not well-suited to software development in that software projects are difficult to specify and the buyer may not know his needs
- Software/systems integration is not usually performed by the prime contractor
- The contractor has financial incentive to find deficiencies in the bid documents and “changed” site conditions to seek change orders

2.2 DESIGN/BUILD

This type of contract combines both the design function and the construction/installation function into a single contracting vehicle. Also known as a turnkey or public turnkey, the procurement is for the design prepared by the procuring agency. Design/build contracts are usually most successful when they are structured around a preliminary design completed to the 20 to 60 percent level. The agency’s role is to monitor the design/build work. Partnering is generally involved. This contracting alternative can allow for rapid completion of the project and can provide for streamlined procurement. Engineering and construction work can be done cooperatively with a single entity to resolve problems that are common in traditional contracting, where the engineering and construction functions are handled by separate firms. These contracts may also include warranty or operations management tasks. Under this arrangement, the agency assumes greater responsibility for inspections and approvals, and requires a significant quality control effort on the part of the public agency. Selection is often based on low bid, and bids may be somewhat higher than with a traditional approach because of the increased risks to the contractor.

Advantages:

- The time to deliver the project can be reduced significantly.
- Used extensively in private sector (legal precedent).
- Reduced involvement of agency staff in production and construction inspection stages.
- Single point of responsibility for project design and implementation.
- This approach is well-suited to complex systems procurement and integration.

Disadvantages

- Many agencies lack experience in this approach.
- Reduced level of control over system components and construction methods.
- Final product may not be clearly understood until proposal time.
- Requires contract clauses / incentives to assure quality materials and construction.

2.3 SYSTEM MANAGER

Under this contracting approach, the system manager is selected using conventional consultant procurement processes. The system manager is responsible for the design (plans and specifications), software development, hardware procurement, integration, training, and overall quality control. Equipment and electrical contracting services are usually procured on a low bid

basis. System managers are often used for technology-based projects. Large traffic control and freeway traffic management systems have been procured nationally using this approach.

Advantages:

- Overall system design, software development, and testing are controlled by a single entity
- The software developer is usually the prime contractor
- This approach minimizes the shifting of fault
- Its flexibility allows for more changes than traditional contracting approaches
- It is well suited to ITS projects
- There is relatively strong competition available

Disadvantages:

- Requires careful examination of firm qualifications to assure requisite blend of skills
- This approach is somewhat unfamiliar to local engineers and procurement officials
- This approach relies heavily on the successful performance of the system manager
- The end product tends to be less well defined than under the engineer/contractor approach and it is difficult to manage “expectancies.”
- Low bid services (such as equipment and electrical contracting) are the responsibility of the public agency. This may include inspection and acceptance.

2.4 SYSTEM INTEGRATOR

This approach is virtually the same as the system manager, except that the system integrator can bid on equipment and electrical contracting services. This approach was used in Georgia for the Atlanta area ATMS project. .

Advantages:

- Single point of responsibility
- Contracting is simplified.

Disadvantages:

- This approach is not well known to public agencies
- Allowing contractors to directly bid to the system integrator may violate the public agency’s procurement processes.

2.5 COMMERCIAL OFF THE SHELF (COTS) SOFTWARE ACQUISITION

This approach is new to ITS, but it used for the majority of software acquisitions in both the public and private sectors. The local agency develops a functional specification or needs statement, along with an evaluation procedure. It then evaluates all commercially available systems and selects the system that most closely suits its needs, using a predefined evaluation procedure.

Advantages:

- Essentials of competitive procurement are maintained
- Proven effective throughout the computer industry

- Increases that probability of receiving mature relatively bug-free software
- Costs are reduced
- Implementation problems and schedule slippage are minimized
- Encourages the use of standard communications protocols

Disadvantages:

- Agencies cannot readily tailor software to their specific requirements
- Only a limited number of COTS currently exist
- This approach will not work for new applications
- It is difficult for an agency to assume ownership of compute source code

2.6 BUILD TO BUDGET

This approach is different from Design/Build in that functional requirements are used in place of a detailed design. Proposers, then, develop designs based on their best solutions to meeting the functional requirements identified, using existing elements where practical. This approach has been used frequently in toll projects.

Advantages:

- Similar to design/build
- Allows maximum flexibility to proposers to use their most cost-efficient designs
- Reduces the risk based on previous developments and applications
- May allow added functionality for a given budget

Disadvantages:

- Similar to design/build
- Very unusual practice for public agencies
- Increased risk because of a lack of detailed designs
- Detailed design documents may prove contentious and delay the project
- This is a very expensive approach for proposers

2.7 BUILD-OWN-OPERATE-TRANSFER AND FRANCHISE/LEASE

This approach involves long-term contracts with a consortium to finance, design, build, operate and collect revenue. From the system implementation phase, it is equivalent to either the design/build or build to budget alternatives. The differences occur during the system operations and maintenance phases. These alternatives are typically considered because they do not involve an up-front capital cost for the owner.

The most recent example of this approach is Kentucky DOT's use of a "Tax Exempt Master Lease" to finance the construction and operation of an ITS project in Louisville. The contractor receives construction funds (and later operational funds) through a private leasing arrangement. Once the system is operational, the DOT makes periodic payments to the leaseholder. Because private investors are assuming much of the risk, the return is considered tax-free.

Advantages:

- Contractor financing reduces the up-front capital requirements of agency.

- O&M the responsibility of the contractor.
- Allows maximum flexibility to proposers to use their most cost-efficient designs.
- Reduces the risk by tying payment to delivery of service (i.e., system operations).

Disadvantages:

- Similar to design/build
- Very unusual practice for public agencies
- Requires long-term (10-15 year) commitment to assure contractor's return on investment.
- This is a very expensive approach for proposers

2.8 DESIGN TO COST AND SCHEDULE

Under this approach, the public agency develops a prioritized list of requirements. The contractor then supplies all of the mandatory items and as many of the optional items as is feasible under the given cost and schedule constraints.

Advantages:

- This approach reduces scope creep
- It reduces cost and schedule risks

Disadvantages:

- Bidders, in an effort to win the job, may be unwilling to propose not meeting all the optional features.
- Overly optimistic proposals, therefore, will win.

2.9 SHARED RESOURCES

A shared resource project is any agreement between one or more public sector agencies and one or more private sector organizations with the objective of providing services using the combined resources of both -- often trading a grant of a right to a public resource for the addition of a private entity to achieve a service or facility of mutual benefit to both partners. Its most common form in the ITS context is a partnership for sharing highway rights-of-way in exchange for private telecommunications expertise and capacity to further both public sector and private sector objectives.

A shared resource project in this context has four specific features:

- Public-private partnering
- Private longitudinal access to public roadway right-of-way
- Installation of telecommunications hardware
- Compensation granted to the right-of-way owner over and above administrative costs.

Advantages:

- Contractor financing reduces the up-front capital requirements of agency.
- O&M the responsibility of the contractor.

- Agency receives state of the art equipment, built to industry standards.
- Potential revenue generator for agency for valuable right-of-way access.

Disadvantages:

- Dependant on private market forces to create financial incentives
- Very unusual practice for public agencies
- Requires long-term (15-20 year) commitment to assure contractor's return on investment.
- Agency requirements may not match those of private sector, resulting in few to no bidders or increased costs to agency.

There are a number of examples of shared resource arrangements, discussed below:

Florida Fiber Net: FDOT and DMS are preparing to issue an RFP for a shared resource project to provide the state with a fiber optic network using approximately 2000 miles of limited access right of way throughout the state. In exchange for providing the fiber, the successful proposer will get use of the right-of-way for up to 99 years for the construction of a commercial fiber network. In addition to supporting ITS applications, the network also will be used as the principal backbone communications link for various traffic operations centers, data centers and administration buildings. DMS will also offer the opportunity for the successful proposer to provide it with a SONET-based, point to point backbone bandwidth for the state's SUNCOM network. The successful contractor also will be given the opportunity to compete for other communications contracts to provide other state services.

City of Leesburg, Florida: The City's Communications Utility and two private partners (Knight Enterprises and Alternative Communications Networks (ACN)) developed a fiber optics system to deliver telecommunications services in the city. In exchange for the city's grant of right-of-way access to the above ground utility poles and it's construction funding, ACN has designed and contracted the network and is leasing the capacity to public or private customers under a five-year contract with the city.

The city, in return, owns the dark fiber on its right-of-way. Customers own the fiber from the ROW line to their own facilities, pay ACN a fee for access to the city-owned backbone, and can either use their own equipment or pay ACN for the use of its equipment to light the fiber. A total of about 40 miles of fiber will be installed. Leesburg is receiving cash compensation based on lease payments in addition to the fiber capacity. After capital costs are repaid, the revenues will be split evenly between the city and its telecommunications partner.

Maryland: The state has allowed MCI access to 75 miles of ROW for 40 years, in which MCI may lay as many conduits as feasible and desired, and pull fiber as needed afterward. MCI is providing the state with 24 dark fibers for its use. MCI also will serve as the lead contractor for building and maintaining the system. Another partner, Teleport Communications Group (TCG), entered the agreement as a subcontractor to MCI. TCG is paying MCI to install and maintain fiber in privately held conduits. TCG is giving the state equipment needed to light the fibers, and additional fiber capacity for public sector use. Each party retains ownership of the fiber dedicated to its use. Maryland set up the project strictly as a procurement to purchase telecommunications capacity through ROW access.

Minnesota: Mn/DOT has issued a Communications Infrastructure Request for Proposal offering one time communications access to its freeway ROW in exchange for communications infrastructure, consisting of both fiber optics and wireless towers. In August, 1996, the state selected International Communications Systems (ICS) and Stone and Webster to install 96 fibers on the state's 1000 miles of freeway and on enough trunk highway mileage statewide to connect all of Mn/DOT's district offices and the Department of Administration's 13 Mnet HUB sites. Under the agreement, Mn/DOT will grant ICS and Stone and Webster the right to install the cable in the ROW. In return, the state will receive access to a 1500 mile high speed communications network at no cost. In addition, the private partners agreed to develop the network not only in the metropolitan areas, but also in the less populated areas of the state. The project has received opposition from two groups: long distance and other providers who object to the fact that only one provider will be using freeway ROW, and independent phone companies throughout the state who feel threatened by the competition likely to result from the partnership.

In addition, the state has filed a petition with the Federal Communications Commission for a ruling that the grant of exclusive longitudinal use of freeway rights-of-way do not violate Section 253(a) of the Telecommunications Act. Section 253(a) prohibits state and local governments from enforcing statutes, regulations or other requirements that prohibit or have the effect of prohibiting the ability to provide telecommunications service. Section 253(c) of the Act preserves the authority of state and local governments to manage public ROW and to require fair and reasonable compensation from telecommunications providers on a competitively neutral and nondiscriminatory basis for use of public ROW. Mn/DOT is arguing that the partnership is consistent with section 253(c) of the Telecommunications Act.

Missouri: Missouri selected Digital Teleport Inc. (DTI) to install 1300 miles of fiber optic cable to create a statewide communications backbone system. In return for allowing access to the ROW, Missouri received six lighted fibers for state highway use and DTI's maintenance services for the system. The arrangement provides the state with two strong advantages. First, there is limited competition from ROW alternatives, such as railroads, in the areas of greatest interest to bidders (particularly the St. Louis metropolitan area). Second, it grants exclusivity to one telecommunications firm, although that firm can lease access to other telecommunications firms on its lines and is, in fact, doing so.

Missouri also structured the deal strictly as a procurement, purchasing telecommunications capacity through highway ROW, and DTI's access to the ROW is considered a procurement contract awarded to a single contractor, in a competitive process, rather than a special privilege.

2.10 STATE CONTRACT

Purchases of goods and services that are ongoing and are common to several state agencies generally are consolidated under standard specifications and are developed into state contracts or joint institutional purchases. Under the state contract approach, the state issues a Request for Bids for various (and usually indefinite quantities of) commodities and services. Vendors then provide prices for those products and services based on the terms and conditions of the RFB. The vendor providing the lowest bid is selected. The prices are good for some specified period of time. State agencies can then order the products and services they need from a list of providers. While this approach allows agencies to plan for and procure goods and services more easily (prices are known and fixed, ordering process is relatively quick and easy, etc.), it is

not well-suited to complex procurement, such as ITS systems and equipment. This approach has both advantages and disadvantages.

Advantages:

- Latest technology can be procured through State contract
- Eliminates submittal review process when equipment is known to the Department
- State is in complete control over the schedule of equipment and software delivery
- State contracts directly with equipment and software suppliers, giving State greater leverage to insure products supplied are as promoted
- State can quickly procure alternate products when equipment or technology becomes obsolete or unavailable
- State contract equipment has already been product tested and approved
- Allows State to contract and deal directly with suppliers on all testing, giving State more power over suppliers meeting product schedules and adhering to test requirements
- Time required to negotiate and process supplemental agreements due to vendor equipment reduced or eliminated
- State is able to take greater responsibility and control over the success and outcome of the project
- Cost to operate equipment is reduced when the State procures equipment with known, quantifiable operating requirements

Disadvantages:

- Potential for delays getting new products approved and bid to new State contract list
- Contractors' ability to provide innovative approaches restricted or eliminated
- Introduces fourth party (vendors) as a major player in deciding on what and how system functions will be delivered
- Greatly increases Department involvement and liability in system procurement and acceptance
- Transfers some of the responsibility for ultimate system operation from Systems Manager and contractor to the State

3. METHODS OF AWARD

In addition to considering the type of contract vehicle most appropriate to a particular ITS project, the public agency must also consider which method of awarding the contract is most appropriate to ensure adequate competition for the award. A variety of options are described below.

3.1 SEALED BIDS

This approach is perhaps the most common method of award for both Federal and state contracting. This approach requires that contracts be awarded only on a lowest cost, responsible and responsive bidder basis. This approach tends to maximize the number of private firms competing against each other solely on the basis of price, and gives the procuring agency the "best buy."

The sealed bid process is easy to defend in protests because of its objectivity. However, sealed bidding works best when the agency can develop a complete, adequate, and realistic set of specifications, there are two or more responsible bidders willing to compete, the procurement lends itself to a firm, fixed price contract, and the selection itself can be made on price.

In the ITS context, however, sealed bidding presents some significant disadvantages. Detailed specifications may not be available for emerging technology, sealed bidding inhibits innovation, it precludes the public sector from considering anything but price in its selection, and it limits opportunities for the public and private sector to engage in meaningful dialogue to find the most appropriate solution to the agency's needs.

To mitigate some of these disadvantages, many public agencies have adopted pre-qualification procedures to ensure that low bidders have the requisite skills and competencies to successfully execute the work. This is particularly important in the ITS environment.

Lifecycle contracting is another approach agencies have employed to ensure that they receive both low cost and good value in their procurements. Lifecycle contracting is a competitive procurement process that results in the selection of the bid with the lowest lifecycle costs or that increases the weight given to lifecycle cost considerations.

3.2 2-STEP BID PROCESS

This approach allows the procuring agency to gain the advantages of a sealed bid approach when it lacks adequate specifications for a project. The process starts with a solicitation from the public agency that sets forth its technical needs and requirements. Proposers make technical proposals based on the solicitation, without discussing price. Those firms submitting technically acceptable proposals in step one would be invited to submit sealed fixed price bids based on their proposals.

3.3 COMPETITIVE PROPOSALS

This approach uses Requests for Proposals (RFPs) and Requests for Qualifications (RFQs) to select contractors when price and other considerations must be weighed. In general, the more design and professional services that are bundled into a solicitation, the more appropriate the use of competitive proposals. This approach is usually employed when there is more than one source capable of providing the services. While there is some subjectivity involved in selecting a contractor under this method, the process is sufficiently objective to allow for courts to review decisions, if a proposer issues a protest. Competitive proposals encourage innovation, but if the solicitation is too loosely defined, proposers may submit bids that the public agency does not consider to be responsive. The process also does not allow for bidders to clarify their bids in such circumstances. This approach may also invite political problems if the low bid contractor is not selected.

3.4 COMPETITIVE NEGOTIATIONS

Competitive Negotiation uses an RFP/RFQ process to identify one or more firm with which to conduct negotiations. This allows the agency to negotiate different contract terms than those used as the basis for the bid. Among the criteria to be considered in determining whether

competitive negotiations are appropriate are whether there are significant variations in how the services to be procured can be provided, whether attributes other than price are to be considered, and whether there is a need for bidders to revise their work plans after the initial evaluation of the proposals.

3.5 SOLE SOURCE

Sole source contracting is allowed in only very limited circumstances. This approach involves the selection of a contractor for negotiations based on the firm's reputation or its prior relationship with the owner. It should be used only when the supplies or services to be procured are available from only one source.

3.6 UNSOLICITED PROPOSALS

Unsolicited proposals allow public agencies to obtain innovative or unique methods for meeting agency needs. Contracts can generally only be awarded when the unsolicited proposal does not resemble a pending competitive acquisition

4. LAWS/REGULATIONS GOVERNING FEDERAL PROCUREMENT

ITS deployment occurs largely in the realm of state and local agencies. But Federal law considerations play a role in determining what types of contracting vehicles and award methods can be used. This section describes some of the most significant Federal legal requirements to be considered in procurement.

4.1 FEDERAL LAW CONSIDERATIONS

Common Rule

Under the Common Rule, if a public agency is receiving Federal-aid funds, it is required to use the established state or local procurement procedures, but must also ensure that the contracts issued include relevant clauses required by Federal statute, executive order or regulation.

Title 23 Requirements

Title 23 states that highway construction contracts must use bidding methods that are effective in securing competition. In other words, competitive bidding methods are required, unless the state demonstrates that another method is more cost effective or an emergency requires the use of an alternative method.

The definition of construction includes traffic control systems. Currently, there is little guidance as to whether Title 23 requirements apply to specific ITS projects. But in general, if a contract involves installation, then it is considered construction and competitive bidding applies.

Other sections of Title 23 require that contracts for engineering, architectural, and design services must be awarded in the same manner as architecture and engineering services procured under the qualifications-based selection process prescribed in the Brooks Act (or some equivalent qualifications based requirement). Thus, since construction (or installation) projects require the use of competitive low bid methods for procurement, and architectural/

engineer/ design services require a qualifications-based selection process, a number of ITS projects could result in the need for two separate contracts (one for the engineering services and one for the installation services) and two separate contractors.

SEP-14 Innovative Contracting Methods

Within the context of the Common Rule and Title 23, FHWA has been promoting the evaluation of innovative contracting methods known as Special Experimental Project number 14 (SEP-14) for ITS projects. For eligible projects, SEP-14 allows the use of innovative contracting methods, such as design-build, for procurement of construction related items. ITS projects that receive federal aid funds and that have any elements that may be classified as construction items are required to follow the SEP-14 process if using the design-build contracting method. The SEP-14 process requires prior approval of the concept before proceeding with design-build contract.

There are no required selection criteria for design-build projects under the SEP-14 process, however it is the policy of FHWA that cost must be one of the factors. Other factors usually included in award criteria include quality and construction time considerations. The SEP-14 process has been used in North Carolina to award a design-build contract for construction of the Congestion Avoidance and Reduction for Automobiles and Trucks (CARAT) project near Charlotte. Utah DOT used “best value” award criteria for a design-build procurement for reconstruction of I-15 through Salt Lake City, including an area-wide ATMS, in time for the 2002 Winter Olympics.

The exemption allows the state or political subdivision to effectively and efficiently administer a government program and the administration of the program is significantly impaired without the exemption.

6. PROCUREMENT ALTERNATIVES & RECOMMENDATIONS

While there is still much confusion and consternation relative to ITS procurement, one thing is certain -- there are steps agencies can take to improve the acquisition of the hardware, software and services required. It also is true that there are no silver bullets, no magic solutions. A procurement process which worked successfully for one type of ITS procurement may not be appropriate for another one. This section discusses some general guidelines ODOT should employ in preparing for ITS procurements and provides some recommendations for which contracting vehicles should be considered for specific procurements. It concludes with a few additional recommendations for ODOT to consider in easing current procurement processes.

6.1 STEPS TO SUCCESSFUL ITS PROCUREMENT

There are six basic steps to be considered in preparing to purchase ITS. While these generally apply to system and software acquisitions, many of these steps can and should be applied to acquiring consultant services, as well. Each step is discussed briefly below:

Step 1 --- Build a Team

As many transportation professionals, long accustomed to traditional highway contracting procedures, have discovered, procuring ITS is different. It requires the involvement of a myriad of disciplines and specialties, some of which may be outside the Department of Transportation. The team may serve a number of functions: developing the plan and requirements for the procurement, evaluating the proposals, and ensuring that the goods or services procured are meeting the needs identified in the plan. The team can also serve to cement existing interagency relationships or build new relationships which will be critical not only to procuring the ITS system, but also to deploying and maintaining it.

Who should be on the team? Several people, including:

- Software technical expertise
- End users
- Maintainer and administrators of the system
- Domain experts
- Contracting and purchasing officials
- Software, information systems, and intellectual property legal expertise
- "Translators" who can explain technical jargon, concepts, etc across disciplines.

Step 2 -- Plan the Project

Good procurements are ones that are well-planned. Project plans need not be long and detailed, but should concisely present the goals and objectives of the project and highlight high-level strategic decisions about the procurement. The project plan will help to define the boundaries of the project, identify who needs to be on the project team, and provide a communications tool for all those involved in the project procurement. Importantly, the plan helps to explain "why" the project is being pursued - justifying the purchase and ensuring the procurement is focused on meeting these needs. Some things to include in the plan:

- Description of the project
- Rationale for the project
- Project Schedule
- Roles and responsibilities of team members
- Funding estimates and sources
- Facilities
- How the system will be acquired (the build or buy decision) (note: early in the project, this section may be in the form of alternatives)
- How the project fits in with other "legacy" or planned ITS systems
- Standards
- Risk Management
- Contracting Strategy (the extent to which consultants and outside support will be used for the project)
- Contracting Vehicles
- Contract Management
- System Operation and Use (who will use the system, who will administer and manage the system, etc.)
- Acceptance Strategy (how will the system, once acquired, be accepted?)
- Training Plans (how will users be trained in using the system?)
- Maintenance Plans (who will be responsible for maintaining the system?)

- Reality Check (what constraints and conditions must be considered in relation to the procurement?)

A key thing to remember is that the plan should be a living document and be a tool to guide the procurement. It should not become an overwhelming task that inhibits, rather than facilitates the procurement. Items within the document are likely to (and should) change as the project evolves and team members contribute their various perspectives to the project. In addition, externalities affecting the project (budget, schedule, etc.) may force a reevaluation of certain parts of the plan.

Step 3 -- Develop Requirements (Software and Systems Projects)

A good set of requirements is perhaps one of the most important things you can do in a software or systems acquisition. This is where your project team can play an invaluable role. Requirements should be well documented in a configuration control document. The requirements should focus on the functional and performance requirements the system must meet. It should not get into design and technical requirements. Doing so confuses the issue and unnecessarily limits the options available to the agency.

It is important to thoroughly review and revise the requirements. Do not ask for too much. Unnecessary or superfluous requirements can greatly increase cost and complexity, without adding much in the way of functionality. Also consider quality factors in the requirements analysis. Ensure that the system will be able to accommodate anticipated changes.

Step 4 -- Make the "Build or Buy" Decision

Over the last several years, a variety of software and system applications and field devices have been developed and enhanced. Many of these existing systems and devices provide extensive functionality and can be integrated with other existing systems. Too often, however, public agencies have failed to consider "off-the-shelf" products for their systems. It is when systems are customized that bugs and costs explode. Off-the-shelf products can provide agencies with cost-effective systems that are well integrated and meet most, if not all, of their requirements. One approach to determining whether to build or buy a system is to develop a matrix for evaluating off the shelf products. An example is shown below in Table 1.

Table 1. Example Table for Evaluating and Comparing Product Features

	Product 1	Product 2	Product 3
M			
Requirement A			
Requirement B			
Requirement C			
O			
Security			
Data Rights			
Life Cycle Costs			

Using the matrix, weed out products that do not meet your mandatory criteria. It is important to ensure that your mandatory requirements are, in fact, that. Carefully evaluate the remaining products, either through hands on use, or through a rigorous demonstration under conditions as close to yours as possible. Contact the vendor's other customers to determine the product's quality and reliability, the extent and quality of the vendor's support for the product, maintenance issues, etc. If you chose to use off-the-shelf products, be sure the contract includes provisions to accommodate changes in requirements, functionality, costs, etc. Also be sure that you get a flexible licensing agreement for the system. If you choose to customize off-the-shelf products, recognize that there are intellectual property rights issues to be considered, as the "commercialized" portions of your system will be subject to certain restrictions.

Step 5 -- Select a Contracting Vehicle

The next step in the procurement process is to select an appropriate contracting vehicle. This paper has presented a number of contracting types and issues to consider for each type. In addition, the Table 2 provides more guidance on how to select the right contracting vehicle for specific procurements.

Table 2. Contracting Approaches

¹ Sources: Salwin, *The Road to Successful ITS Software Acquisition* and Tarnoff, *Procurement of Professional Services in a High Tech Era*

Contract Approach	Description of Alternative	Advantages	Disadvantages	Example Applications
Engineer/ Contractor	Engineer is selected using a conventional consultant procurement process that is based on qualifications and experience to perform the work. The engineer typically prepares the contract documents and invites contractors to submit bids in requirements of the contract documents. Once the bid has been awarded, the contractor builds the project per bid documents. The engineer may inspect construction and interpret bid documents. The agency is the responsible entity.	<ul style="list-style-type: none"> Long history of use Well-defined roles Legal precedent for handling disputes End product well-defined at early stage Contractor manages subcontractors Well-suited to highway construction 	<ul style="list-style-type: none"> Artificial dividing line between design and construction Not well-suited to software development work (difficult to specify, buyer may not know needs) Software/systems integration not usually performed by prime contractor Contractor has financial incentive to find deficiencies in bid documents and “changed” site conditions to seek change orders Limits communications between customer and software developer when software is developed by a subcontractor 	<ul style="list-style-type: none"> Several agencies surveyed have used this approach, including: Colorado, the Gary-Chicago-Milwaukee Corridor, Houston, I-95 Corridor, Maryland, Missouri, Virginia, Washington and Wisconsin. Most have used for furnishing and installing field devices One ITS software contractor found itself third tier down on a construction contract, effectively shut off from all contact with the customer. Result was very bad software experience for all involved, because of the lack of communication and interaction with the client.
Systems Manager	The systems manager is selected using conventional consultant procurement process (i.e., qualifications-based followed by competitive negotiation). The systems manager is responsible for design (plans and specifications), software development,	<ul style="list-style-type: none"> Overall system design, software development, system integration, and testing controlled by a single entity. Software developer is usually prime contractor Minimizes shifting of fault More flexibility to allow 	<ul style="list-style-type: none"> Fewer firms in marketplace with requisite blend of skills Somewhat unfamiliar to local engineers/procurement officials Heavy reliance on successful performance of 	<ul style="list-style-type: none"> Used by both the Houston and I-95 Corridors in furnishing and installing field devices and software, ITS operations and ITS maintenance. Dade County, Florida is using this approach for a signal system upgrade. Proposers were requested

Contract Approach	Description of Alternative	Advantages	Disadvantages	Example Applications
	hardware procurement, integration, training, and overall quality control. Equipment and electrical contracting services procured on low bid basis. System managers are often used for technology-based projects.	changes than in traditional approach Well-suited to ITS projects Avoids use of low-bid selection Gives customer access to systems manager	system manager End product less well-defined than engineer/contractor approach; difficult to manage "expectancies." Low bid services (equipment and electrical contracting) responsibility of public agency; may include inspection and acceptance	to propose based on capabilities of existing system and improvements identified at functional level. Allowed proposers to use base package.
System Integrator	Same as system manager, except the system integrator can bid on equipment and electrical contracting services.	Single point of responsibility Simplified contracting	Not well-known by agencies Direct bidding to system integrator may violate agency procurement process	Used by Colorado, GCM corridor, Maryland, Missouri and Washington for furnishing and installing software. Used by GCM, Missouri, Virginia and Wisconsin for ITS Operations.
Design/Build	The agency must commission the concept plans. The concept plan is normally 15 to 30 percent complete at the design level before the contractor is selected. this approach relies on a single entity to be responsible for the design and construction of a project. The agency's role is to monitor the design/build work. The design/build approach is frequently used	Full transfer of responsibility to design/build team Eliminates imperfect transfer of design knowledge from designer to contractor Rapid completion possible; significant time-savings Streamlined procurement possible Engineer and construction work done cooperatively with a single entity to resolve problems.	Agency assumes greater responsibility for inspection and approval process May be indistinguishable from engineer/contractor approach when plans developed by engineer and design/build May increase costs because of contractor risk and high proposal costs (design not complete)	Detroit used this approach for a freeway management system upgrade. Primary objective of the procurement was to provide field infrastructure, but did include TMC remodeling, new central control hardware, and operating software enhancements.

Contract Approach	Description of Alternative	Advantages	Disadvantages	Example Applications
	for federal procurements involving structures. Partnering is generally involved.	Financial incentive to rapidly complete work May include warranty of operations management	May violate statutes (17 states) Significant agency commitment to quality control	
Design to Cost and Schedule	A prioritized requirements list is generated. The contractor supplies all the mandatory items and as many of the optional items within cost and schedule constraints.	Reduces requirements creep Reduces costs and schedule risks	Bidders may be unwilling to propose not meeting all the optional features Overly optimistic proposals will win	Utah used this approach for their initial I-15 freeway management system procurement. Limited response led to selection of design/build approach for ultimate system
Build to Budget	Different from design/build in that functional requirements used in place of detailed design. Proposers develop designs based on their best solution to meeting functional requirements using existing elements where practical..	Similar to design build Allows maximum flexibility to proposers to use their most cost-efficient designs Reduced risk based on previous developments and applications May allow added functionality for given budget	Similar to design/build Very unusual practice for agencies Risk based on lack of detailed designs Detailed design document may prove contentious point and delay project Very expensive for proposers	Sometimes used by commercial builders. For transportation projects, this approach has been used mostly in toll projects and major bridges.
Shared Resource	Any agreement between one or more public sector agencies and one or more private sector organizations with the objective of providing services using the combined resources of both -- often trading a grant of a right to a public resource for the addition of a private entity to achieve a service or	Allows public agency to obtain goods/services with little or no up-front costs	Complex and numerous legal issues (some of which are in limbo, including interpretation of key provisions of Telecommunications Act) Somewhat limited application	Several state and local agencies have used this approach to provide a telecommunications backbone, including Maryland, Ohio Turnpike, Missouri, Bay Area Rapid Transit, City of Leesburg.

Contract Approach	Description of Alternative	Advantages	Disadvantages	Example Applications
	facility of mutual benefit to both partners. sector objectives.			
State Contract	Purchases of goods and services that are ongoing and are common to several state agencies consolidated under standard specifications and developed into state contracts or joint institutional purchases.	Quick and easy method of procuring standard equipment and supplies All state agencies buy the same type of equipment Standard equipment may ease maintenance and operation Easier planning and budgeting	Constrains system to only those products on the state contract, thereby limiting flexibility in system design Long term contracts limit ability to buy latest versions	Caltrans pioneered this method for traffic signal controllers and VMS Utah currently using state contract prices for major components on the I-15 Salt Lake City ATMS. This is good approach for purchase of COTS software.
Build, Own, Operate, Transfer (BOOT) Franchise or Lease	Long-term contracts with a firm or consortium to finance, design, build, operate and collect revenue. Equivalent to design/build or the build-to-budget for implementation, but requires seller financing and adds the own-operate phase. These alternatives are typically considered because they do not involve an up-front capital cost for the owner.	Similar to design build Bidders provide financing, reducing up-front capital costs for the agency. Allows maximum flexibility to prosper to use their most cost-efficient designs Reduced risk of operations and maintenance costs, since this is bidder's responsibility.	New approach - often requires statutory authority Reduces agency control over project Finance requirement may limit competition Interest costs ultimately add to total for the project	Dulles Greenway Toll Road Extension, No. Virginia (BOOT) Calif. SR 91 HOV / Toll Lanes (Franchise/Lease)

In addition to the details presented in Table 2, the following are other general observations about procurement methods:

- There is no "one-size-fits-all" for ITS procurements. Contracting vehicles appropriate for some simple field devices will not likely be appropriate for other more complex acquisitions.
- The engineer/contractor approach is not appropriate for software.
- Consider the full range of options before selecting one. Selecting a contracting vehicle because it is familiar may seem easy and convenient initially, but it is likely that the approach's deficiencies for the procurement will become readily apparent, causing significant problems, creating delay and increasing the costs associated with the procurement.
- The requirements definition stage for system and software applications is critical and will play a key role in determining which contracting vehicle is most appropriate.

Table 3 presents a summary of the types of procurement that are appropriate for each type of ITS project or product. These recommendations are based on past experience, in other states.

Table 3. Recommended Procurement Method by Type of System and/or Product

Work Type	Contract Type						
	Engineer/Contractor “Low-Bid”	System Manager	System Integrator	Design- Build	BOOT	Shared Resources	State Contract
Traffic Signal Installation	X						X
Time-Based Signal System	X						X
Closed Loop Signal System	X			X			X
Traffic Adaptive / Hybrid Signal System		X	X	X	X		
Ramp Metering System	X	X		X			
Communications System			X	X	X	X	
Dynamic Message Signs		X	X	X	X		
Highway Advisory Radio	X			X			X
Motorist Aid System (Call Boxes, etc.)	X						X
CCTV Monitoring System			X	X		X	
Electronic Toll Collection System		X	X	X	X		
Multi-modal Systems (transit, ridesharing, etc.)		X	X	X			
ISP (website, travel planning center, etc.)	X	X		X	X	X	

Note: For complex ITS projects, such as an integrated system combining communications, field equipment and software development, the project may be broken up into multiple procurements, with each using the method most appropriate to the items being specified.

Step 6 -- Understand Intellectual Property and Other Contractual Terms and Conditions

Traditional infrastructure design and construction does not present issues relating to rights in intellectual property. Software and system design can and do. It is important that these issues and other contractual terms and conditions (warranties, royalties, etc.) be fully understood by the project team when embarking on an ITS procurement. The active involvement of legal experts in these areas is critical to ensure the maximum response from the private sector and to fully protect the interests of the public agency.

6.2 STATEWIDE CONSIDERATIONS

This paper is intended to provide an overview of ITS procurement alternatives and issues as they relate to Oklahoma. Time and budget constraints do not allow for a significant and in-depth analysis of this very complex issue. In addition to the comments and recommendations above, Oklahoma DOT should consider the following:

Present hypothetical scenarios to the Attorney General to obtain clearer guidance on issues related to Public Records Laws and ITS procurements. While there are some AGOs available on the application of the public records law and agency rights in agency-produced software, copyrighted software, and trade secrets, there is little in these opinions which illuminates the issues presented by ITS procurements. There are presumably instances in which procurements have not gone forward, or private firms have been reluctant to bid on projects because of the Public Records Law. These scenarios should be presented to the Attorney General to clarify the law's application to these instances.

Develop clear guidelines on the Public Records Law and its application to ITS procurement. Once these AGOs are obtained, the ODOT should develop clear and concise guidelines on how Public Records Laws are applied and how proposers can effectively comply with its mandates.

Consider developing new contracting vehicles for ITS procurements. There has been interest and some effort in some states to develop new contracting vehicles for ITS procurement (or to adopt existing procurement methods from other state agencies to buy ITS). In Virginia, after frustrations with the low-bid contracting approach, DOT officials used a procurement category called "non-professional services" to obtain ATMS software. Originally the state had included software development as a part of a freeway construction project. The construction portion of the project was completed late, leaving very little money left for software development. VDOT terminated the contract and is now procuring the software through an "administrative services" RFP, giving the state greater flexibility in selecting an appropriate vendor. It has developed its requirements and scope of work and has adopted a design and process approach. Under the first phase of the project, a detailed design of the software will be developed and "frozen." The software will be built and additional features and functionality will be added later, as necessary. Other states have toyed with the idea of creating new contracting approaches, building on past procurement successes, and incorporating lessons learned from past failures. Oklahoma should consider (perhaps in conjunction with other states and/or with the Federal government) developing these new vehicles.