

CITY OF MISSOURI CITY

ITS Master Plan

SEPTEMBER 2023



PREPARED FOR



PREPARED BY

Kimley»Horn

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Acknowledgements

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Missouri City Police Department
Missouri City Information Technology Department
Missouri City Public Works Department
Missouri City Parks and Recreation Department
Missouri City Development Services Department
Missouri City Management Office
Fort Bend County
Fort Bend ISD
Houston-Galveston Area Council (H-GAC)
Texas Department of Transportation (TxDOT)

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CITIZENS OF MISSOURI CITY

This plan was made for the community, with the help of the community. The continuous dedication of time and effort by members of the community, not only in the planning process, but in their daily interests, is what made this effort possible.



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Acronyms

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway Transportation Officials
ADA	Americans with Disabilities Act
AI	Artificial Intelligence
API	Application Programming Interface
ATC	Advanced Traffic Controller
ATCC	Advanced Transportation Controller Cabinet
ATMS	Advanced Traffic Management System
ATSPM	Automated Traffic Signal Performance Measure
AV	Automated Vehicle
BBU	Battery Backup Unit
CAD	Computer Aided Emergency Dispatch
CAV	Connected and Automated Vehicles
CCTV	Closed-Circuit Television
CDPD	Cellular Digital Packet Data
CIP	Capital Improvement Program
CISS	Crash Investigation Sampling System
COMC	City of Missouri City
ConOps	Concept of Operations
CPU	Central Processing Unit
CRIS	Crash Record Information System
CRSS	Crash Report Sampling System
CV	Connected Vehicle
DMS	Dynamic Message Sign
DOT	Department of Transportation

EOC	Emergency Operations Center
EV	Electric Vehicle
FARS	Fatality Analysis Reporting System
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FM	Farm to Market
FS5	Fire Station 5
FY	Fiscal Year
GDOT	Georgia Department of Transportation
GIS	Geographic Information System
GPS	Global Positioning System
HD	High Definition
HGAC	Houston-Galveston Area Council
ICT	Information and Communications Technologies
IEEE	Institute of Electrical and Electronics Engineers
IJA	Infrastructure Investment and Jobs Act
IoT	Internet of Things
IP	Internet Protocol
IT	Information Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
KPIs	Key Performance Indicators
LAN	Local Area Network
LED	Light-Emitting Diode
LOS	Level of Service

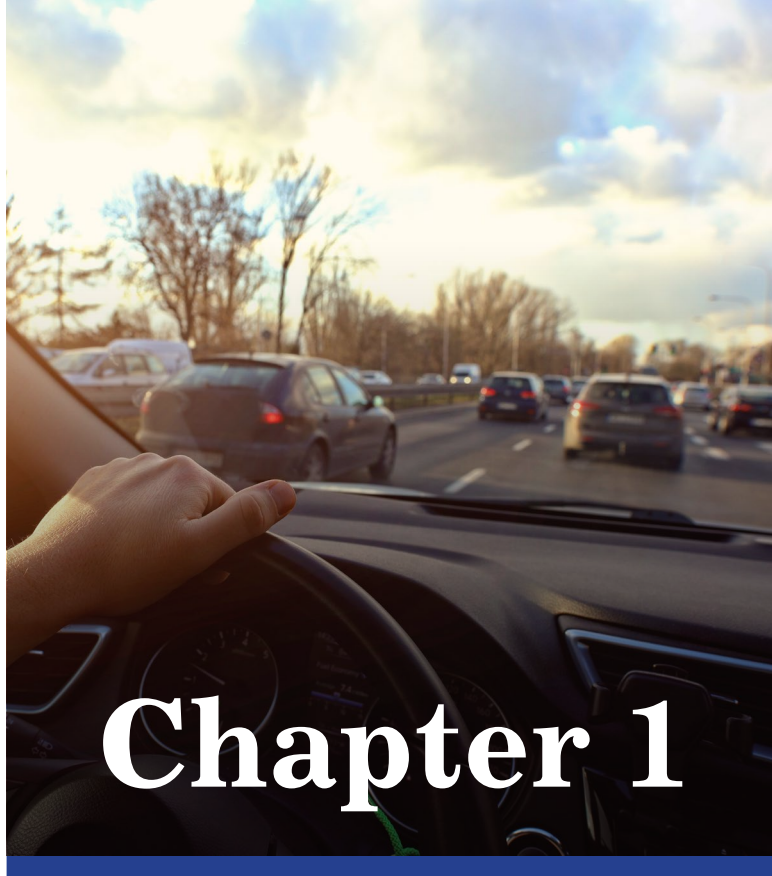
Acronyms

MAN	Metropolitan Area Network
MDPI	Multidisciplinary Digital Publishing Institute
MMS	Maintenance Management System
MMU	Malfunction Management Unit
MOE	Measures of Effectiveness
MTBF	Mean Time Before Failure
MTTR	Mean Time to Repair
NASS	National Automotive Sampling System
NCHRP	National Cooperative Highway Research Program
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NOCoe	National Operations Center of Excellence
NTCIP	National Transportation Communications for ITS Protocol
NTS	Non-Traffic Surveillance
O&M	Operations and Maintenance
O/S	Operating System
PCB	Printed Circuit Board
PD	Police Department
PER	Preliminary Engineering Report
PMC	Preventative Maintenance Compliance
PoE	Power over Ethernet
PS&E	Plans, Specifications & Estimate

PTZ	Pan-Tilt-Zoom
Q	Quarter
RWIS	Road Weather Information System
SCI	Special Crash Investigation
SDI	Smart City Indicator
SH	State Highway
SOP	Standard Operating Procedure
SPaT	Signal Phase and Timing
TIM	Traffic Incident Management
TMC	Traffic Management Center
TRB	Transportation Research Board
TSD	Time Space Diagram
TSMO	Traffic Systems Management and Operations
TWP	Twisted Wire Pair
TxDOT	Texas Department of Transportation
UPRR	Union Pacific Railroad
V/C	Volume-to-Capacity Ratio
VHD	Vehicle Hours of Delay
VMT	Vehicle Miles Traveled
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
WAN	Wide Area Network
WIM	Weigh-In-Motion
WLAN	Wireless Local Area Network
WWTP	Wastewater Treatment Plant



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Chapter 1

Executive Summary



Executive Summary

Intelligent Transportation Systems (ITS) are modern methods by which transportation professionals leverage technology to provide better mobility. An effective ITS benefits all users of the transportation system, including citizens, city traffic engineer and traffic signal technicians, fire department, police, and emergency responders.

This Intelligent Transportation System (ITS) Master Plan evaluates the current ATMS and communications network, determines future needs, and recommends projects to be implemented to improve safety and mobility. The ITS Master Plan guides and prioritizes technology investments in City infrastructure. Creation of the ITS Master Plan was a collaborative effort that engaged City and non-City stakeholders. The ITS Master Plan documents existing conditions, defines stakeholder needs and creates an impactful, cost-conscious, and implementable plan to guide future infrastructure investments. The ITS Master Plan focuses on traffic signals, the traffic management center, field devices (cameras, DMS, etc.), and ITS communications/networks. The plan also addresses City needs related to advanced mobility concepts such as connected and automated vehicles (CAV) and data-driven performance measures.

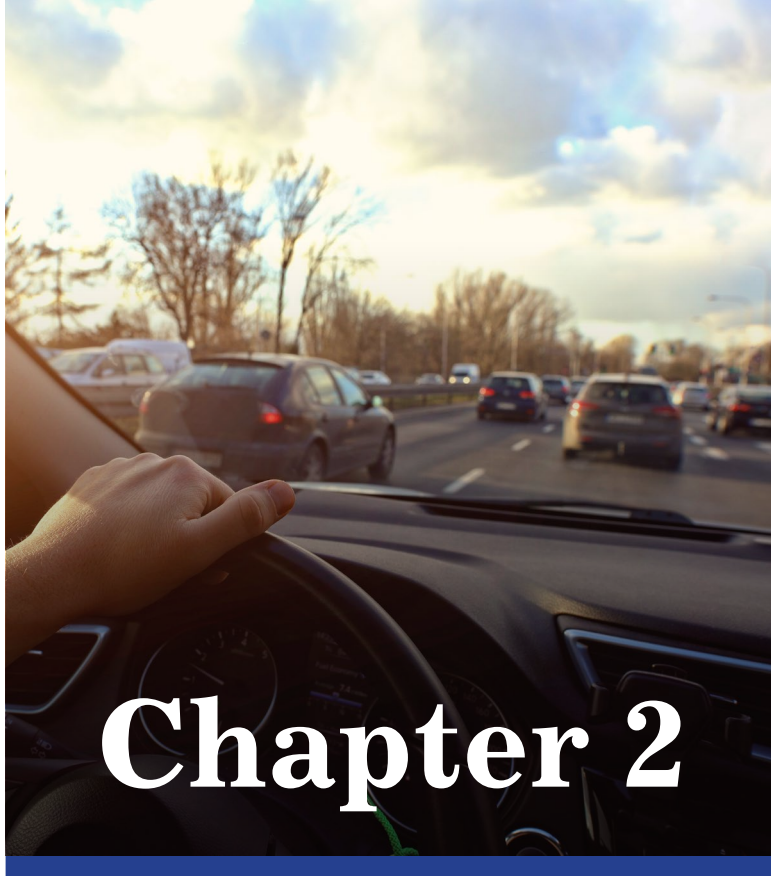
Development of a comprehensive, usable, and sustainable ITS Master Plan involves several steps including data collection and analysis, stakeholder engagement, stakeholder workshops, development and prioritization of needs and requirements, preparation of a Concept of Operations (ConOps), identification of implementable projects, and development of a phased prioritized list of Capital Improvement Plan (CIP) projects. The resulting ITS Master Plan should serve Missouri City well for years to come in terms of improving mobility and safety throughout the City.

The key findings and recommendations of the study include the following:

- ▶ The existing communications network is a combination of fiber optic and wireless technologies, and while functional, is aging, sometimes unreliable, and has bandwidth limitations. There is a need for a reliable, scalable, and secure communications network with higher bandwidth. It is recommended to upgrade the network in two phases. First, upgrade the wireless network by installing and/or upgrading wireless radios and associated equipment at all intersections and radio towers. This first phase is the most critical, high yield ITS improvement the City can make. Second, install a total of 11.4 miles of fiber optic cable on Texas Parkway, Cartwright Road, Murphy Road, including interconnecting the City's Traffic Management Center (TMC), Fire Station 5 radio tower, and the wastewater treatment plant radio tower.
- ▶ The City's TMC serves as the central hub for monitoring traffic operations, adjusting signal timing, responding to incidents, dispatching maintenance personnel, and providing information to the traveling public. Minimal modifications have been made to the TMC since it was constructed. Video surveillance is unstable and often unavailable during times when multiple users access the system, particularly accidents and weather events, the times when the cameras are needed the most. Operator functionality is limited. No website exists to inform the public of traffic conditions, construction, events, or detours. TMC improvements are low-cost, high-yield efforts that positively affect traffic conditions throughout the City. It is recommended the TMC be upgraded including architectural, space utilization, and ergonomic assessments; video wall reconfiguration; video control system replacement; operator capability enhancements; and development of operations and training manuals for knowledge retention and transfer.
- ▶ Traffic signal timing is one of the most cost-effective measures an agency can do to improve traffic flow, sometimes as much as 25% or more. Benefits include improved safety, optimized roadway capacity, increased speed, reduced travel time, reduced delay, and reduced emissions. It is recommended the City develop and implement a sustainable traffic signal timing program that retimes 15-25 signals year such that every signal is retimed every four to five years.

- ▶ Traffic data analytics are becoming more important as cities become more congested. As the City continues to grow, City staff need to understand and analyze traffic flow patterns to make informed mobility planning decisions. Big data providers offer mobility pattern data allowing City planners to make smart decisions regarding planning, infrastructure investment, and mobility optimization, resulting in reduced congestion and improved quality of life. It is recommended that the City use big data analytics to develop safety, operations, and performance dashboard(s).
- ▶ Operations, maintenance, and training documentation is lacking, often resulting in the loss of critical knowledge. Standard Operating Procedures (SOPs) document business processes, preserve critical knowledge, and provide a basis for training. In addition, to become a data-driven, performance-based Smart City, big data needs to be harnessed and managed, and performance metrics established. In addition, It is recommended the City develop ITS-related SOPs; data collection and management plans; and safety, operations and maintenance performance measure plans.
- ▶ Additional recommendations include fiber optic cable installation, development of web site and mobile app, railroad detection and warning system implementation, weigh-in-motion system study, radio tower grounding improvements, center-to-center integration, traffic signal cabinet grounding improvements, upgrading traffic signal backup battery units (BBUs), deploying smart devices, formalize interagency partnerships, and establish a culture of documentation.

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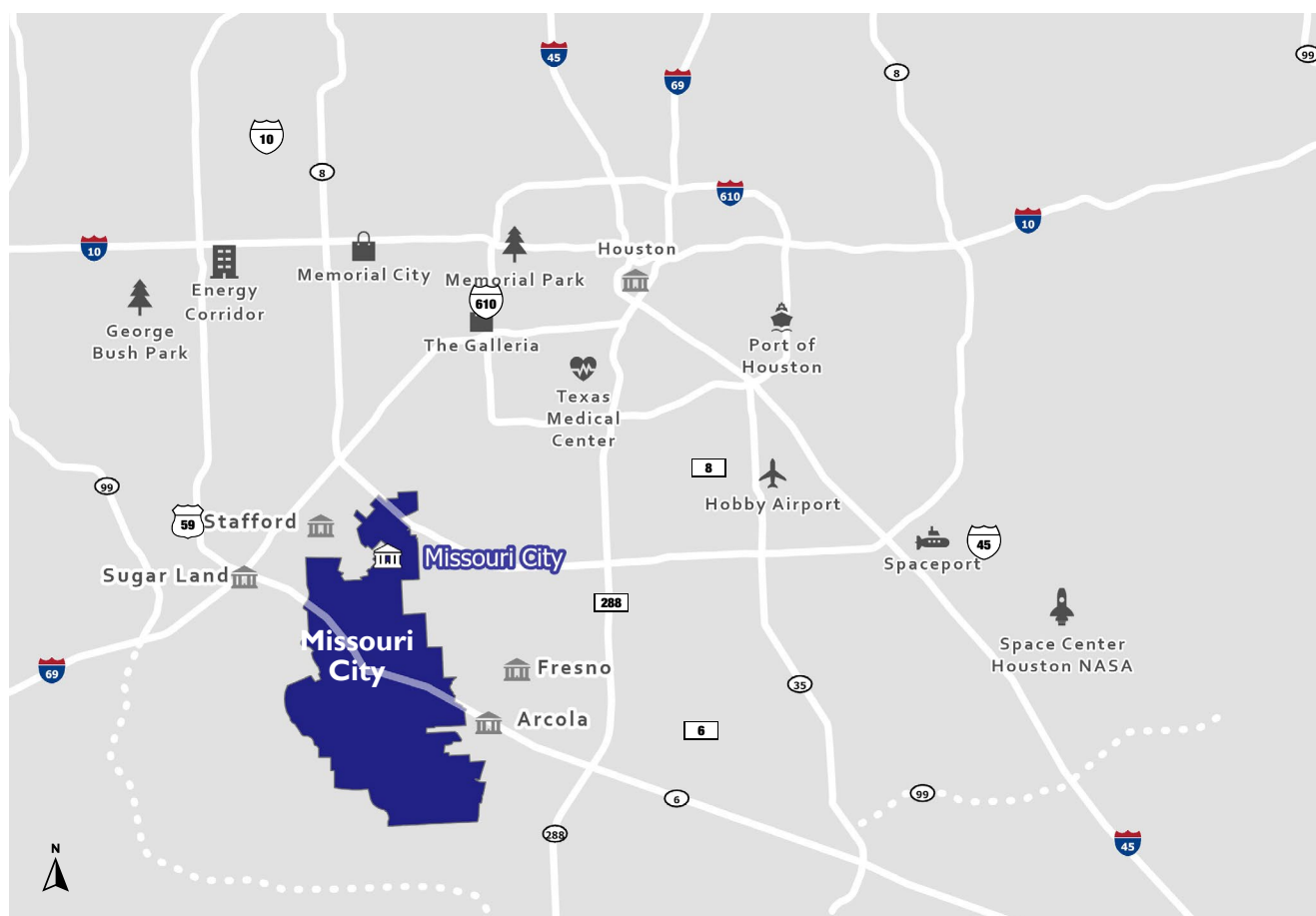
Chapter 2

Introduction



Introduction

Incorporated in 1894, the City of Missouri City is located approximately 17 miles southwest of Houston in both Harris County and Fort Bend County. The City is bordered by Sugar Land to the west, Stafford to the north, Houston to the northeast, and Arcola to the southeast. There are several state highways and toll roads that run through and around Missouri City, including US-90A, Beltway 8 (Sam Houston Tollway), Fort Bend Toll Road, and State Highway 6. These highways provide City access from surrounding communities. Major arterials experiencing continuously increasing traffic include Farm to Market Road (FM) , FM 2234 (Texas Parkway), 1092 (Murphy Road), FM 3345 (Cartwright Road), and Sienna Parkway. Nearby interstate I69/US 59 and Interstate 610 connect the City to regional hubs such as Greater Houston. There are three signalized diamond interchanges and one unsignalized diamond interchange in Missouri City. The three signalized diamond interchanges are located on Fort Bend Toll Road, US-90A, and Sam Houston Tollway. The unsignalized diamond interchange is on Fort Bend Toll Road but is planned for signalization.



Missouri City has seen steady growth in population over the last decade. The City's current population was estimated to be at 74,850 in July 2021 with a land area of 29 square miles. Missouri City is the 54th largest city in Texas and the proximity to the Houston metropolitan area provides residents robust employment opportunities.

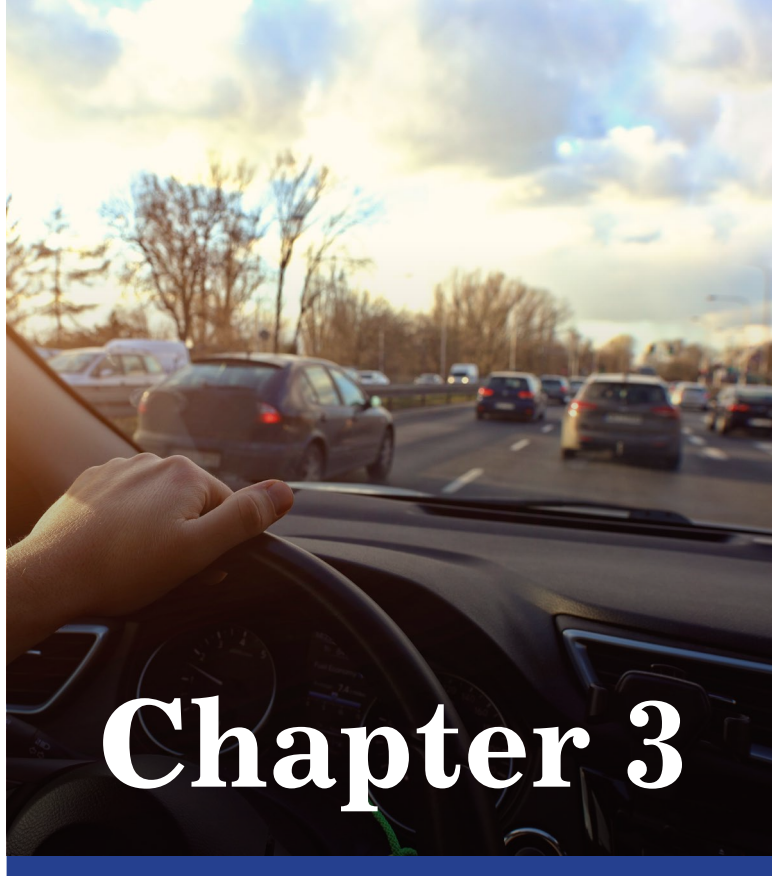
This Intelligent Transportation System (ITS) Master Plan evaluates the current ATMS and communications network, determines future needs, and recommends projects to be implemented to improve safety and mobility. The ITS Master Plan guides and prioritizes technology investments in City infrastructure. Creation of the ITS Master Plan was a collaborative effort that engaged City and non-City stakeholders. The ITS Master Plan documents existing conditions, defines stakeholder needs and creates an impactful, cost-conscious, and implementable plan to guide future infrastructure investments. The ITS Master Plan focuses on traffic signals, the traffic management center, field devices (cameras, DMS, etc.), and ITS communications/networks. The plan also addresses City needs related to advanced mobility concepts such as connected and automated vehicles (CAV) and data-driven performance measures.

Missouri City staff realized that Mobility and ITS are interrelated and took a proactive approach in doing them concurrently so that these two master plans complement each other and provide a unified vision for the City. Several of the stakeholder and public meetings for both master plans were done simultaneously which helped with the overall efficacy of this project and improved accuracy of data gathered and also allowed for a congruent set of recommendations without any discontinuities.

Development of a comprehensive, usable, and sustainable ITS Master Plan involves several steps including data collection and analysis, stakeholder engagement, stakeholder workshops, development and prioritization of needs and requirements, preparation of a Concept of Operations (ConOps), identification of impactful projects, and development of a phased prioritized list of implementable projects. The resulting ITS Master Plan should serve the City of Missouri City well for years to come in terms of improving mobility and safety throughout the City.



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Chapter 3

Project Approach

3.1 PROJECT DEVELOPMENT

3.2 SYSTEMS ENGINEERING PROCESS



Project Approach

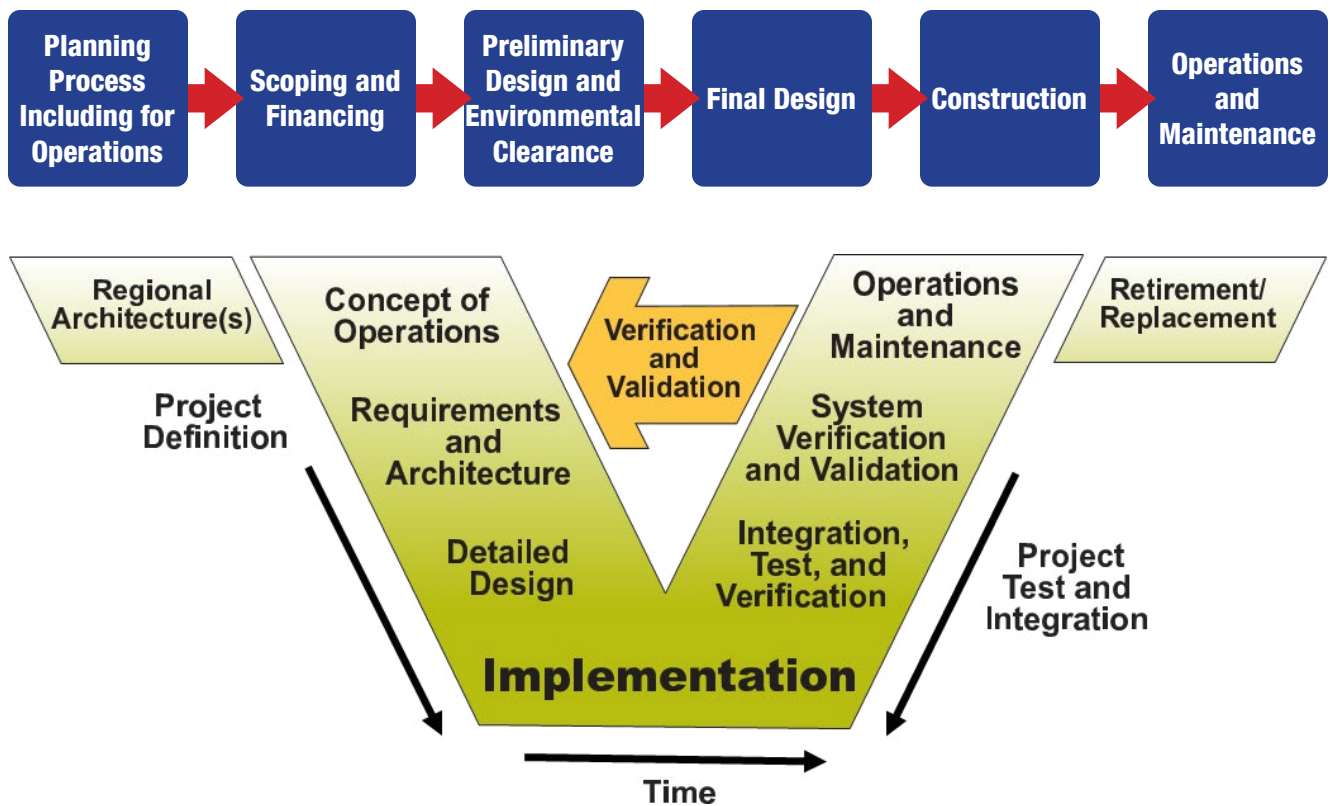
3.1 PROJECT DEVELOPMENT

A comprehensive ITS Master Plan is practical, innovative and a sustainable document that involves several steps including data collection and analysis, stakeholder engagement, stakeholder workshops, development and prioritization of needs and requirements, preparation of a Concept of Operations (ConOps), identification of impactful projects, and development of a phased prioritized list of implementable projects. The resulting ITS Master Plan should serve the City of Missouri City well for years to come in terms of improving mobility and safety throughout the City.

3.2 SYSTEMS ENGINEERING PROCESS

This project was delivered using a methodical process known as the Systems Engineering Process. This proven process has been used extensively on studies such as this because it works through a series of well-defined steps starting with identification of the project goals and objectives. Based on goals and objectives, the project needs, requirements, and overall implementation plan is developed. This process matches technology to the needs of the community.

As shown in Figure 1, the Systems Engineering “V” Diagram suggests an interdisciplinary approach to developing systems and, through checkpoints back to the starting line, ensures that what is ultimately designed and deployed meets the project intent. The Systems Engineering process is tailored to focus on defining stakeholder needs and required functionality early in the development cycle, documenting requirements, then proceeding with design and system validation while considering the “big picture.”



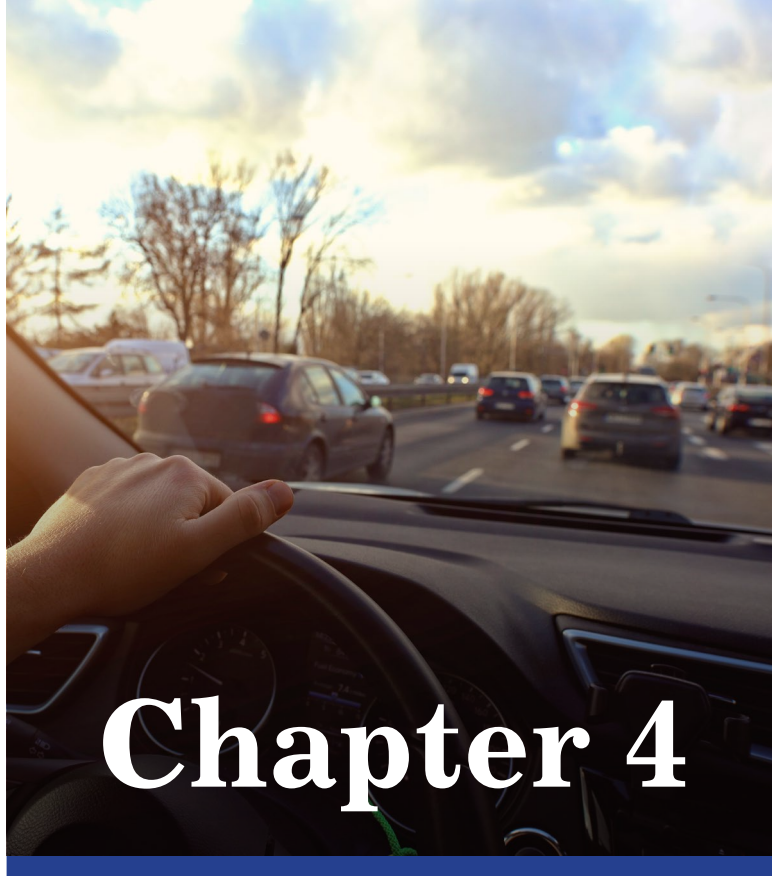
▼ **FIGURE 3.2A - SYSTEMS ENGINEERING "V" DIAGRAM**

Source: *Systems Engineering for Intelligent Transportation Systems*, FHWA, 2007.

It is critical that the planned intelligent transportation system (ITS) reflects a reasonable and comprehensive project which meets the needs of project stakeholders. The needs identified during stakeholder engagement and the workshop were used to identify system requirements that guided development of the implementation plan.



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Chapter 4

Existing Conditions

- 4.1 ADVANCED TRANSPORTATION
MANAGEMENT SYSTEM (ATMS)**
- 4.2 COMMUNICATIONS NETWORK**
- 4.3 TRAFFIC MANAGEMENT
CENTER**



Existing Conditions

This section focuses on three major system components, the ATMS, communications subsystem, and TMC. For detailed information on existing conditions for additional components such as traffic controllers, ITS field devices and school flashers, refer to the City of Missouri City ITS Master Plan Concept of Operations (ConOps) located elsewhere in this document.

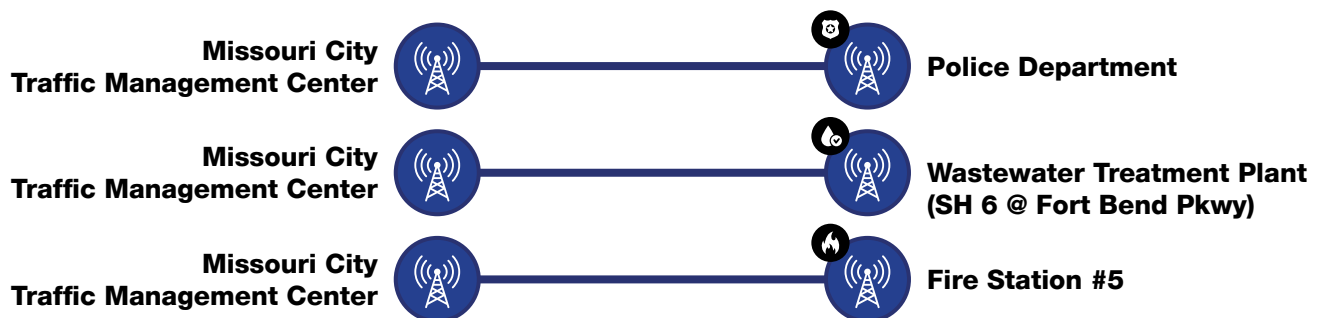
4.1 ADVANCED TRANSPORTATION MANAGEMENT SYSTEM (ATMS)

The central ATMS allows the City to view signal operations in real-time. City staff are provided access credentials and thus anyone with the proper credentials can monitor traffic signal status and adjust signal operations from their City workstation or remote laptop when connected to the City network. The City uses Econolite traffic control products, including Econolite Centracs, the central system software. Centracs is also used by TxDOT Houston District and most of the local municipalities and counties in the greater Houston area. City staff are very satisfied with the operational functionality and control provided by the Centracs system.

4.2 COMMUNICATIONS NETWORK

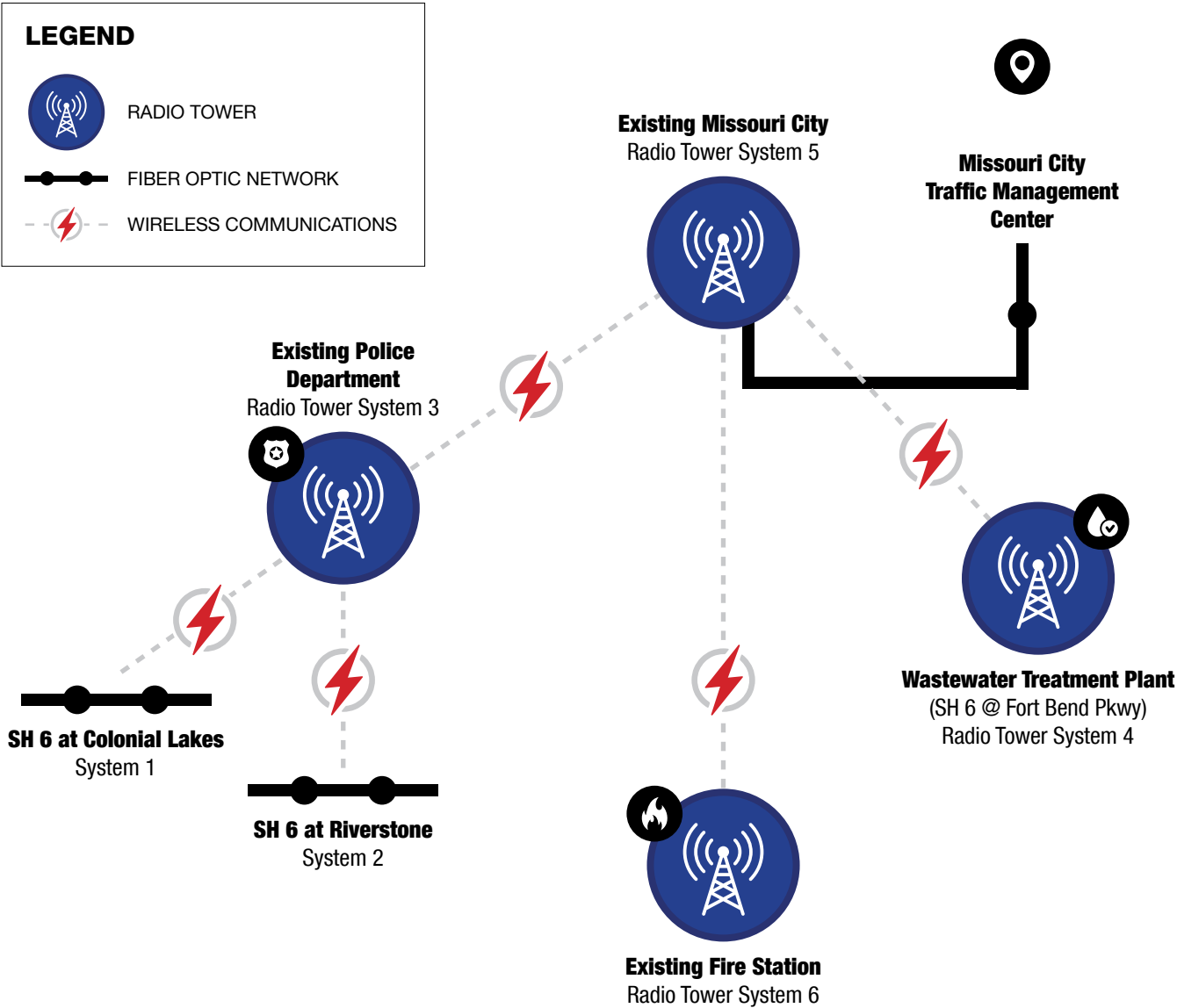
The City operates a hybrid communication system consisting of both wireless (radios) and wireline (fiber optics). Forty-eight (48) signalized intersections (75%) use wireless broadband (5.8 GHz) radios and sixteen (16) intersections (25%) use the fiber systems along SH 6. With exception of the School Zone Flashers that use cellular modems, the remaining field devices predominantly use the 5.8 GHz wireless broadband system that consists of intersection level wireless radios and four radio towers. Existing wireless radios include Alvarion, Ubiquiti, and Encom. The City is currently upgrading the Ubiquiti radios to Cambium radios. AT&T cellular modems are used for artificial intelligence (AI) preemption devices in all traffic signal cabinets. Cellular modems are also used at all 29 School Zone Flashers.

There are four radio towers with no redundant paths, that is, if a link between one of the radio towers is interrupted or lost, the devices associated with that tower lose communications to the TMC. The paths include the following:



The City's fiber optic systems consists of a 144-strand single-mode fiber optic (ring topology) network installed and operated by TxDOT along SH 6 from Colonial Lakes Drive to Sienna Ranch Road and from Riverstone Boulevard to Creekmont Drive. TxDOT also manages allocation of the fiber. Two pair of the 144 strands are currently allocated to the City. Interface points linking the fiber systems with the wireless system are at SH 6 at Colonial Lakes and SH 6 at Riverstone Blvd. The City's ITS communications network utilizes EtherWAN Ethernet switches for the fiber systems along SH 6 and Rugged.com Ethernet switches at all other (wireless) locations.

▼ **FIGURE 4.2A EXISTING COMMUNICATIONS NETWORK**



4.3 TRAFFIC MANAGEMENT CENTER

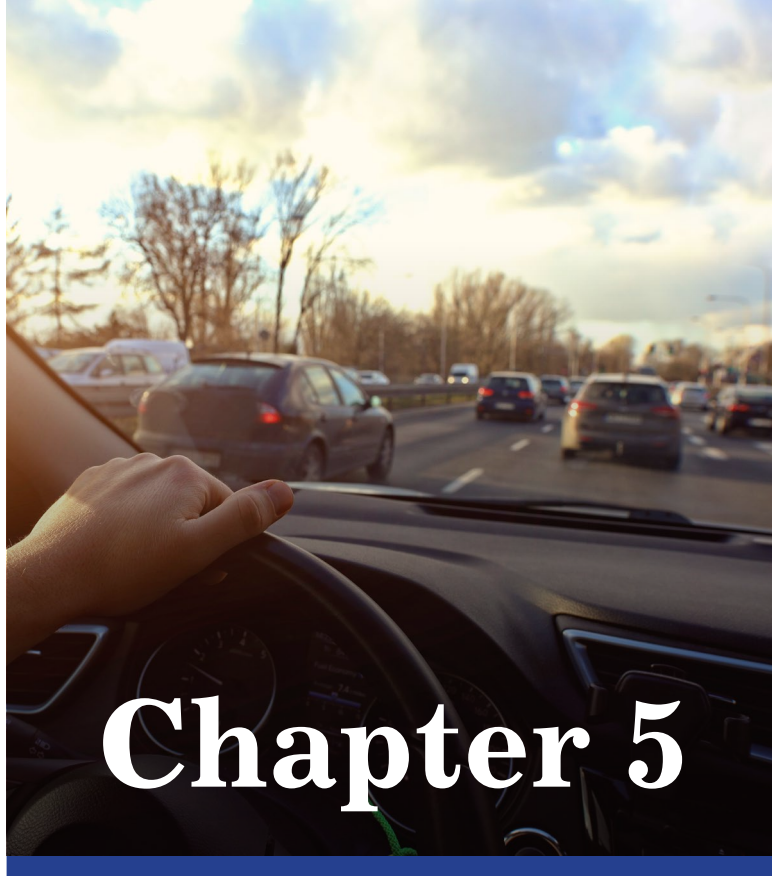
A Traffic Management Center (TMC) serves as a central location for monitoring traffic operations, adjusting signal timing, responding to incidents, and dispatching personnel to fix field problems. The City's TMC is co-located with Streets and Drainage at 1919 Scanlin Road as shown in Figures 8 and 9. The TMC is generally staffed from 7:00 AM to 7:00 PM during the normal weekday. The TMC is staffed during each morning (AM) peak period, and most afternoon peak periods. Engineering staff are working in the field performing maintenance and operations tasks in the afternoon and thus are not always in the TMC. During non-working hours, an answering service is used to route calls to the on-call technician.

The TMC consists of a video wall and two workstations as shown in Figure 4.3a. The video control software is Cameleon ITS provided and supported by Teledyne FLIR. The Cameleon software provides the basic video layout, and also provides control for the CCTV cameras and DMS units.

▼ **FIGURE 4.3A EXISTING TRAFFIC MANAGEMENT CENTER**



The City has grown since the TMC was constructed and, according to the Houston-Galveston Area Council (HGAC) 2021 Regional Growth Forecast, is expected to grow 12% over the next 20 years. The City's traffic management approach needs to keep pace, as does accompanying new generation TMC tools, technologies, and techniques. The existing TMC physical architecture, space allotments, and video wall usage needs upgrading. The existing video control system is aging and operationally suffering in terms of speed, latency, and display capabilities, particularly during heavy usage such as weather or incident events. Operator functionality is limited and not always user-friendly. There is no public website informing motorists of conditions or allowing them to view camera stills. Documentation is lacking in terms of operator/user manual and standard operating procedures (SOPs).



Chapter 5

Concepts of Operations

5.1 DOCUMENT PURPOSE

5.2 CONCEPT OF OPERATIONS DEVELOPMENT



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Concepts of Operations

5.1 DOCUMENT PURPOSE

The purpose of the Concept of Operations (ConOps) is to identify the needs for upgrading the City of Missouri City's existing Advanced Transportation Management System (ATMS) and existing wireless communications network. The ConOps aids the City in identifying specific elements necessary for upgrading the ATMS and all associated elements that traffic engineers, signal operators, and maintenance staff require to perform their day-to-day job functions. ATMS includes central traffic management software, local control software, and intelligent transportation system (ITS) devices used in the field associated with the management of traffic.

The ConOps document identifies the needs of ATMS stakeholders and represents existing and anticipated day-to-day conditions and ATMS operations. The ConOps describes the purpose of the ATMS, the environment in which it operates, how it will be used in terms of the goals it will help accomplish, and the roles and responsibilities of involved parties.

5.2 CONCEPT OF OPERATIONS DEVELOPMENT

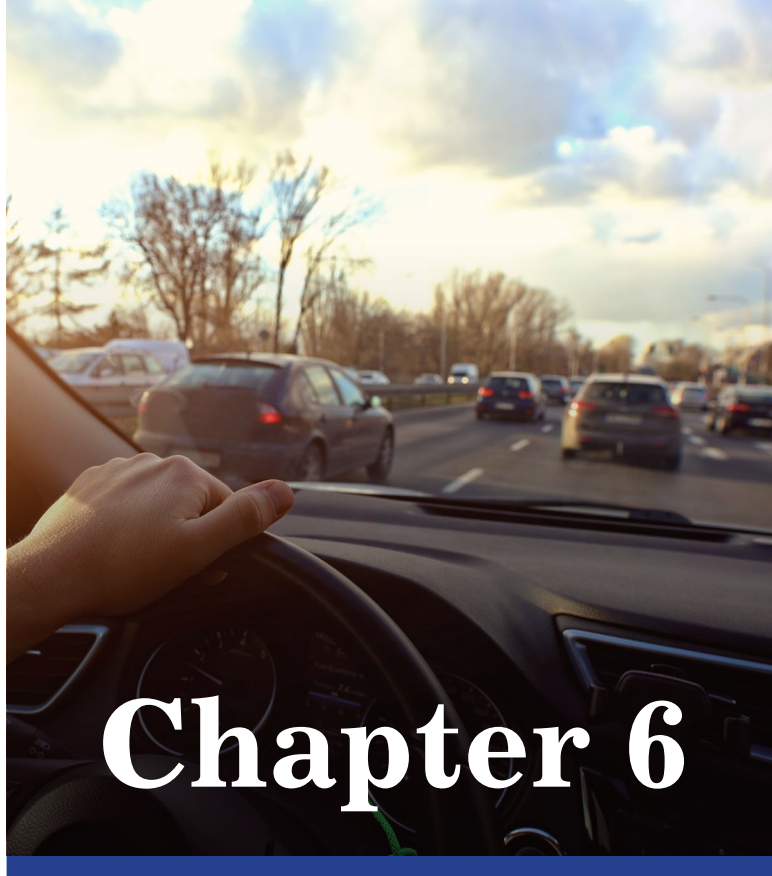
The ConOps is constructed utilizing the Systems Engineering Process and starts by gathering existing system information and data. Some data was collected by performing field reviews. To capture the level of information needed, a workshop was conducted that consisted of senior department staff, traffic technicians, police and fire department staff, and information technology department staff. The needs of the involved City stakeholders were established in the workshop discussion. Collectively, the workshop analyzed how the current system is operating and identified the elements of the existing ATMS that need to be upgraded. This was accomplished by discussing operations in a variety of operational scenarios including a normal traffic day, inclement weather, major incident, and during construction activities.

Based on data collection and analysis, stakeholder interviews, and results of the workshop, the ConOps concludes with a list and description of system needs and recommended changes. It is critical the planned intelligent transportation system (ITS) reflects a reasonable and comprehensive project that meets the needs of project stakeholders. The needs identified during stakeholder engagement and the workshop were used to identify system requirements that ultimately guided development of the implementation plan.

A completed Concept of Operations document was provided as a separate stand-alone report during the ITS Master Planning process.



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Chapter 6

Description of System Needs

6.1 HIGH-LEVEL NEEDS

6.2 LOW-LEVEL NEEDS



Description of System Needs

The Concept of Operations and Advanced Mobility and ITS elements documents identified many system needs. Needs are identified at two levels - high and low. High-level needs reflect the guiding principles of the project's goals and objectives. Low-level needs are specific in nature and reflect functionality required by stakeholders (system users) to perform their respective job functions efficiently and effectively. In general, needs identified in the stakeholder workshop include:

- ▶ **User access control**
- ▶ **High resolution data**
- ▶ **Capability to push out SPaT data**
- ▶ **Adaptive control**
- ▶ **Automated reports**

6.1 HIGH-LEVEL NEEDS

High-Level needs are categorized below based on aspects of the system.

6.1.1 Traffic Operations

- ▶ There is a need to store and manage support documentation in a central location that has hyperlinks to personal workstations.
- ▶ There is a need for the ITS to collect signal status data.
- ▶ There is a need for the ITS to collect turning movement count data.
- ▶ There is a need for the ITS to collect volume data.
- ▶ There is a need for the ITS to collect speed data.
- ▶ There is a need for the ITS to collect video data.
- ▶ There is a need for the ITS to collect occupancy data.
- ▶ There is a need for the ITS to collect detection data (vehicle and preemption).
- ▶ There is a need for the ITS to collect weather data.
- ▶ There is a need for the ITS to collect roadway condition data.
- ▶ There is a need for the ITS to collect communications data.
- ▶ There is a need for the ITS to log all performance measure and communication data.
- ▶ There is a need for the ITS to support adaptive control of traffic signals.
- ▶ There is a need to develop and implement a traffic signal timing program.

6.1.2 Central System Software

- ▶ There is a need for the City's ATMS software to provide useful, current, and accurate information on system health and status of field devices.
- ▶ There is a need for ATMS software to support the development and maintenance of optimized traffic signal timing plans.
- ▶ There is a need for the ATMS software to provide real-time information.
- ▶ There is a need for the ATMS software to provide a robust selection of reports.
- ▶ There is a need for the ATMS software to provide alarms and alerts.
- ▶ There is a need for the ATMS software to be accessible from remote locations.

- ▶ There is a need for the ATMS software to be able to monitor detector state of operation.
- ▶ The ATMS software and local controller software needs to be able to execute and respond respectively to a pre-empt call issued from the TMC.
- ▶ There is a need for the ATMS software to be able to manage time-of-day schedules.
- ▶ There is a need for the ATMS software to manage ATMS devices as groups.
- ▶ There is a need for the ATMS software to support multiple communication media to field devices.
- ▶ There is a need for the ATMS software to provide controlled access and only allow specific rights by individual users.
- ▶ There is a need for the ATMS software to log specific actions by the system and user.
- ▶ There is a need for the ATMS software to incorporate aerial imagery of intersections.
- ▶ There is a need for the ATMS software to display maps of the intersection.
- ▶ There is a need for the ATMS software to display intersection information on a map.
- ▶ There is a need for the ATMS software to share data at varying levels with various stakeholders.
- ▶ There is a need to use performance data to adjust signal timing plans for future incidents.
- ▶ There is a need to use signal performance measures to adjust signal timing plans for future incidents.
- ▶ There is a need for automatically generated alerts for heavy delays and volumes.
- ▶ There is a need for increased alerts for fiber outages through management software.
- ▶ There is a need for asset management software.
- ▶ There is a need for software to diagnose different failure points within the communications system (e.g. ports on switches).
- ▶ There is a need for the ATMS software to employ a distributed client/server interconnection to accommodate current needs and future expansion.
- ▶ There is a need to secure the City's ATMS network from external threats.
- ▶ There is a need for the ATMS software to manage controller firmware upgrades.
- ▶ There is a need for the ATMS software to be module-based, to allow future functionality such as CV/AV technologies.

6.1.3 System Support

- ▶ There is a need for the ATMS software application and database to be backed up automatically.
- ▶ There is a need for the ATMS software to support a modern server platform, such as Windows Server 2022.
- ▶ There is a need for the ATMS software to support a secure desktop operating system, such as Windows 11.
- ▶ There is a need for the ATMS software to support Microsoft SQL Server database either as a stand-alone instance or within a virtualized environment.
- ▶ There is a need for the ATMS software to have internet access.
- ▶ There is a need for the ATMS to support mobile devices, including iOS and Android.



6.1.4 Regional Traffic Management

- ▶ There is a need to support regional transportation operations.
- ▶ There is a need for the ITS to have the capability to support regional data sharing.
- ▶ There is a need for the ITS to support regional video sharing with neighboring cities and agencies for incident management and emergency response coordination.
- ▶ There is a need for the ITS to support major reporting of major construction activities.

6.1.5 Traffic Management Center

- ▶ There is a need to conduct a TMC space allotment and layout assessment.
- ▶ There is a need to conduct a video wall space and technology assessment.
- ▶ There is a need to upgrade the TMC video control system.
- ▶ There is a need for a traffic website with accident, DMS and speed information.
- ▶ There is a need for TMC operator manuals.
- ▶ There is a need to enhance the safety and efficiency of railroad crossings.
- ▶ There is a need develop and accident tracking system.

6.1.6 Devices

- ▶ There is a need to install CCTV cameras with PTZ at select locations.
- ▶ There is a need to incorporate additional CCTV cameras to provide observation and proactive management capabilities.
- ▶ There is a need to upgrade existing Cohu CCTV cameras to HD cameras.
- ▶ There is a need to support CCTV cameras with no noticeable delay in providing full-motion broadcast quality video images.
- ▶ There is a need to support CCTV cameras with no noticeable jitter in providing full-motion broadcast quality video images.
- ▶ There is a need to support CCTV cameras with no noticeable lag in providing full-motion broadcast quality video images.
- ▶ There is a need for better remote management of ITS devices, such as communications diagnostics and remotely managing traffic signals.
- ▶ There is a need for state-of-the-art traffic signal controllers to support the City's current traffic operations and provide future capabilities.
- ▶ There is a need to upgrade existing video detection to cameras at intersections throughout the City.
- ▶ There is a need to bring video feeds from video detection back to the TMC.
- ▶ There is a need to have modern detection for traffic that meets the needs of adaptive signal control.
- ▶ There is a need to upgrade traffic detection equipment to detect all modes of transportation accurately and reliably, including vehicles, bikes, and pedestrians, providing more efficient operations.
- ▶ There is a need for MMUs to support IP communications for remote monitoring.
- ▶ There is a need to upgrade BBUs across the City to a more robust system.
- ▶ There is a need to install stand-alone BBU cabinets.
- ▶ There is a need to integrate BBUs into the ATMS for monitoring.

- ▶ There is a need for BBUs to support IP communications for remote monitoring.
- ▶ There is a need to upgrade and expand the pre-emption system.
- ▶ There is a need to integrate the pre-emption system into the ATMS.
- ▶ There is a need to configure the pre-emption system to prevent the potential for unauthorized use.
- ▶ There is a need to enhance the monitoring of railroad crossings and distribute information collected to stakeholders.
- ▶ There is a need to install additional DMS in the City.
- ▶ There is a need to develop a library of preset messages for the DMS.
- ▶ There is a need to integrate weigh-in-motion systems into the ATMS.
- ▶ There is a need to install air sniffers at select locations throughout the City.
- ▶ There is a need to upgrade wireless radios.
- ▶ There is a need for proper grounding of the radios to prevent radios from going offline during weather events.
- ▶ There is a need to upgrade existing Ethernet switches to a more industrial grade product.
- ▶ There is a need to integrate RWIS sensors into the ATMS.

6.1.7 Communications

- ▶ Overall, there is a need for enhanced communications, higher bandwidth, and increased signal strength for traffic signals, cameras, DMS and RWIS.
- ▶ There is a need to upgrade and expand the existing communications network to achieve a reliable, expandable, scalable, redundant, and secure system.
- ▶ There is a need for the communications network to communicate with remote NTCIP-compliant ITS and ATMS devices.
- ▶ There is a need for the communications network to be Ethernet-based and support IP communications.
- ▶ There is a need for staff in the field to connect and sync to the asset management system, either through cellular coverage or offline syncing.
- ▶ There is a need to extend fiber Citywide.

6.1.8 Communications Network Architecture

- ▶ There is a need for a network architecture that maximizes legacy investment and integrates fiber and wireless subsystems.
- ▶ There is a need for a network architecture that provides redundancy and expandability.
- ▶ There is a need for a network architecture that provides structure and bandwidth to account for anticipated infrastructure growth.
- ▶ There is a need for a network architecture that provides bandwidth and greater signal strength to eliminated video lags.
- ▶ There is a need for a network architecture that includes enhanced EOC/PD connectivity.
- ▶ There is a need for a network architecture that provides for Smart City initiatives and data analytic applications.
- ▶ There is a need for a network architecture that supports connection to TxDOT and the City of Sugar Land for video sharing.
- ▶ There is a need for a network architecture that integrates third-party (lease) communication providers.

6.1.9 Connected/Autonomous Vehicles

- ▶ There is a need to collect data from autonomous vehicles.
- ▶ There is a need to provide data to autonomous vehicles.
- ▶ There is a need to collect data from connected vehicles.
- ▶ There is a need to provide data to connected vehicles.
- ▶ There is a need to broadcast SPaT (Signal Phase and Timing) data to connected vehicles.
- ▶ There is a need to deploy smart devices when possible.

6.1.10 Documentation

- ▶ There is a need to document Standard Operating Procedures for traffic operations and the ATMS in general.
- ▶ There is a need to document Standard Operating Procedures for inclement weather.
- ▶ There is a need for pre-planned response plans for incident corridor management (ICM).
- ▶ There is a need to document Standard Operating Procedures for contacts, response plans, and after-action reviews of large-scale, unanticipated events.
- ▶ There is a need to document Standard Operating Procedures for long-term construction.
- ▶ There is a need to document Standard Operating Procedures for work zones.
- ▶ There is a need to document Standard Operating Procedures for ITS equipment operations such as wireless radios, switch configurations, DMS, and CCTV cameras.
- ▶ There is a need to document Standard Operating Procedures for pedestrian crossings throughout the City.
- ▶ There is a need for Standard Operating Procedures for Centrac's Signal Turn On, Adding New Devices, Signal Timing, Uploads and Downloads, Configuration, and Administrator Functions
- ▶ There is a need for Standard Operating Procedures for system maintenance including preventative, emergency, troubleshooting, and reporting.
- ▶ There is a need for Standard Operating Procedures for Emergency Operations Center (EOC) functions including staffing and tasks, CCTV and DMS operations, emergency management, and hurricane evacuation.

6.1.11 High Resolution Data

- ▶ There is a need to collect high-resolution data.
- ▶ There is a need to analyze high resolution data.
- ▶ There is a need to use high resolution data for proactive management of the ATMS system.

6.1.12 Crowd-Sourced Data

- ▶ There is a need to integrate crowd-sourced data into the City's operations.
- ▶ There is a need to leverage crowd-sourced data to detect incidents in real time.
- ▶ There is a need to leverage crowd-sourced data to assess the performance of arterials and signals
- ▶ There is a need to leverage crowd-sourced data to monitor and respond in real-time to non-recurring congestion.

6.1.13 Public Information

- ▶ There is a need to share information with the public.
- ▶ There is a need to stream video to the public and/or media.
- ▶ There is a need for more communication with the public (i.e. via Twitter or a dedicated web portal).
- ▶ There is a need to share data with school districts.
- ▶ There is a need for public outreach and information, to ensure citizens are aware of special events.
- ▶ There is a need to expand social media outreach.
- ▶ There is a need to enter into the Waze Connected Citizens program.
- ▶ There is a need to use the ATMS map to show lane closures and share that data with Waze (via the Connected Citizens program) automatically.

6.1.14 Training and Staff

- ▶ There is a need for full staffing of signal technicians.
- ▶ There is a need for additional staff in the TMC.
- ▶ There is a need for signal technician training.
- ▶ There is a need to decrease response time for signals on flash, through remote diagnostics and stocking all trucks with spare parts.
- ▶ There is a need for traffic incident management (TIM) training.
- ▶ There is a need for experienced tower climbers.

6.2 LOW-LEVEL NEEDS

The following itemized list of needs is in no particular order and does not represent any priority. These needs are considered fundamental to core operations of the ATMS.

▶ **There is a need for a main display.**

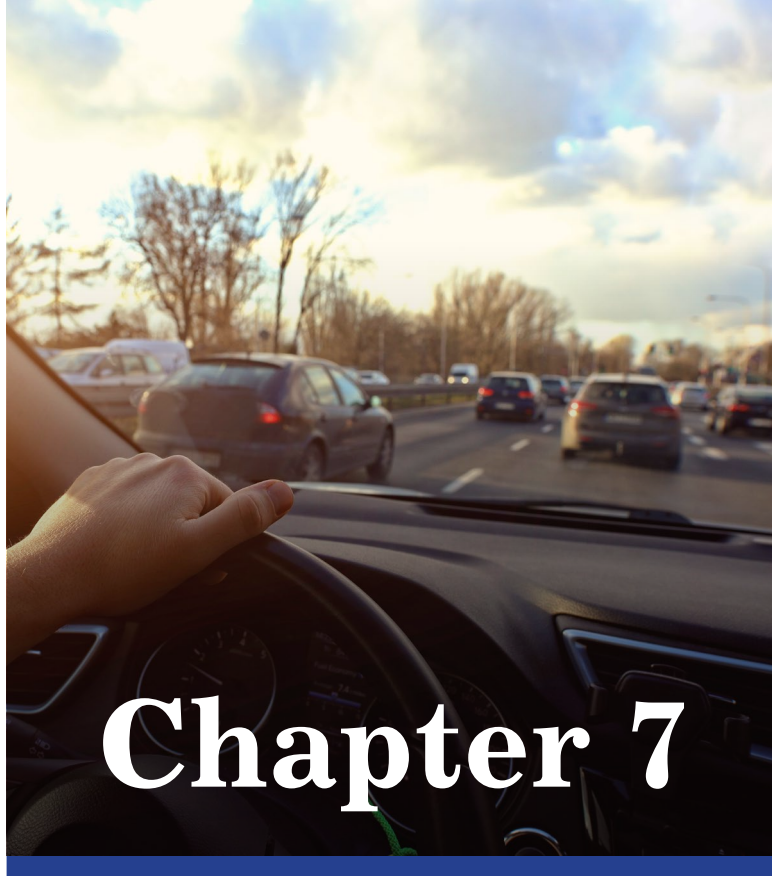
- › Display map that identifies
 - » Controller status (fail state, online, flash, conflict, communication fail)
 - » Controller operation (online, transition, preempt, local manual)
 - » Controller phase (green, yellow, red)
 - » Link data (volume, occupancy, speed)
 - » Cameras (location, status)
 - » MMU alarms
 - » BBU alarms
 - » Preemption status
- › Main display map needs to be generated using existing GIS system graphics

▶ **There is a need for various reports.**

- › Real-time historical
- › Scheduled (time-of-day, frequency, method of delivery (printed, email), distribution list)
- › Intersection status
- › Communication failure
- › Pending signal timing approval



- ▶ **There is a need for an intersection display.**
 - › Real time phase timing data
 - › Identification of signal status
 - › Identification of mode of operation
 - › Identification of faults (bad detectors)
 - › Identification of plan and offset
- ▶ **There is a need for an intersection phase split table.**
 - › Identify minimum, maximum, and average split times by user-defined interval (time of day, plan number)
- ▶ **There is a need for user alerts.**
 - › Major and minor alerts
 - › Minor alerts indication remains in the background
 - › Major alerts (e.g., signal on conflict flash) appear on foreground
- ▶ **There is a need for a time space diagram.**
 - › Used to identify offset values
 - › Save new offset values to database, and operator download to field
 - › TSD based upon average split times
- ▶ **There is a need to create new/updated signal timings.**
 - › Operator identifies changes to be made
 - › System tracks what changes are made; create history
 - › Operator identifies notes in the file on what changes were made
 - › Timings can be downloaded to the intersection
 - › New timing sheets printed for filing and delivery to field controller cabinet by traffic signal shop staff.
 - › Environment to create new timing changes – offline – such that personnel do not download “work in progress.”
- ▶ **There is a need to manage intersection timings.**
 - › Field data automatically uploaded daily during early morning hours
 - » Differences in field and central database values identified by the system
- ▶ **There is a need to define schedules by time of day, day of week, and holiday.**
 - › Calendar-style GUI to schedule TOD plans and other scheduled events.
- ▶ **There is a need for a central database and remote workstation data coordination.**
 - › Easily keep all databases synchronized
- ▶ **There is a need for the central system to support traffic responsive operation.**
- ▶ **There is a need for detector monitoring.**
 - › Monitor detector faults from TMC
 - » System identifies ‘bad’ detectors in a report
 - » Ability to “dismiss all” faults during known environments that create false reports (e.g., weather).
- ▶ **There is a need for improved cabinet and tower grounding systems.**
- ▶ **There is a need for a Conflict Monitor Tester to accurately gauge the performance, functionality and reliability of the traffic signal system.**
- ▶ **There is a need for an Earth Ground Resistance Tester to ensure that electric currents safely pass through the earth during voltage spikes and lightning strikes.**



Chapter 7

Communications Network

7.1 COMMUNICATIONS NETWORK DESIGN

7.2 COMMUNICATIONS MASTER PLAN



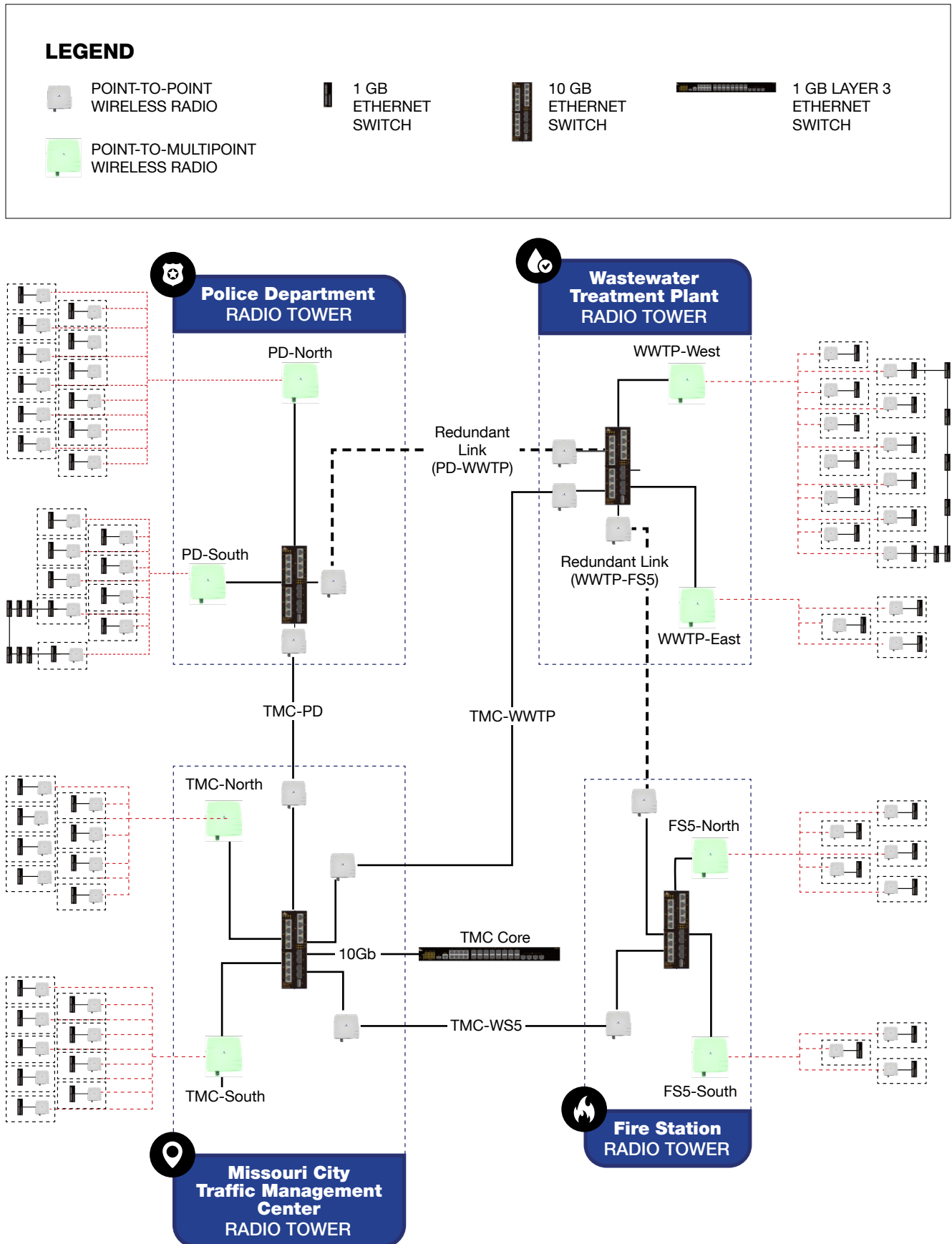
Communications Network

7.1 COMMUNICATIONS NETWORK DESIGN

The City of Missouri City operates numerous field devices including 64 traffic signal controllers, 55 CCTV surveillance cameras, seven DMS, 19 Bluetooth Readers, and 29 School Zone Flashers. With the exception of School Zone Flashers that use cellular communications, the remaining field devices communicate predominantly using a 5.8 GHz wireless broadband system consisting of intersection level wireless radios and four radio towers. Forty-eight (75%) of the traffic signals communicate via wireless and sixteen traffic signals (25%) communicate via the fiber optic systems along SH 6. Refer to the City of Missouri City ITS Master Plan Concept of Operations for existing network architecture and assignments. There is currently limited redundancy in the wireless system, that is, if a link between one of the radios towers is interrupted or lost, the devices associated with that tower lose communications to the TMC.

The single most impactful improvement the City can implement is to upgrade its current communication systems, starting with network architecture design. Reference is made to EtherWan City of Missouri City – Network Design Proposal Ver 1.0. Depicted below is the proposed network architecture presented in the proposal. The proposal consists of a three-tier approach with local switches, mid-tier switches, a core switch and two redundant paths per tower. The lowest tier is the intersection, or local, level tier consisting of a full-duplex, field hardened 1 GB Ethernet switch connected to the local field devices via a state-of-the-practice wireless radio. The devices can also be connected to the local switch using fiber optic cable. The switch is non-ventilated, designed to operate in harsh environments, and provides robust Power Over Ethernet (PoE) functionality and management/security features. The mid-tier layer, referred to the as the “roof switch” in the EtherWan proposal, connects the local switches to a single “core” switch at the TMC. There are a total of four mid-tier switches, one at each radio tower. Similar to the intersection level switch, the mid-tier switch is a full-duplex, field hardened higher bandwidth, i.e., 10 GB, switch with the same PoE and management features. The core switch is a full Layer 3 10 GB switch with 128 Gbps switching capacity.

▼ **FIGURE 7.1A - COMMUNICATIONS NETWORK ARCHITECTURE**



7.2 COMMUNICATIONS MASTER PLAN

7.2.1 Introduction and Background

A critical component of any intelligent transportation system (ITS) is network connectivity between field devices and the central traffic management system at the Traffic Management Center (TMC). The communications network provides the ability to remotely monitor, control, and configure field devices. To effectively operate remote City devices such as traffic signals, CCTV cameras, Bluetooth and DMS, a robust, reliable, maintainable communications system is required. The communications system is expected to support the following operational functions:

- ▶ Signal timing synchronization
- ▶ Upload and download of timing plans between controller and TMC
- ▶ Monitoring field equipment status and reporting malfunctions
- ▶ Transfer of video information to TMC and control of cameras by TMC
- ▶ Displaying travel times on DMS using Bluetooth
- ▶ Support of traffic probe-based incident detection equipment

The existing City communication network is a hybrid, that is, a combination of wireless radios and fiber optics (hardwire). The system has served the City well for years but is in need of upgrades due to:

- ▶ Natural aging of equipment lifecycles,
- ▶ Growing demand on City infrastructure, and
- ▶ Increased emphasis on more efficiently operated transportation systems.

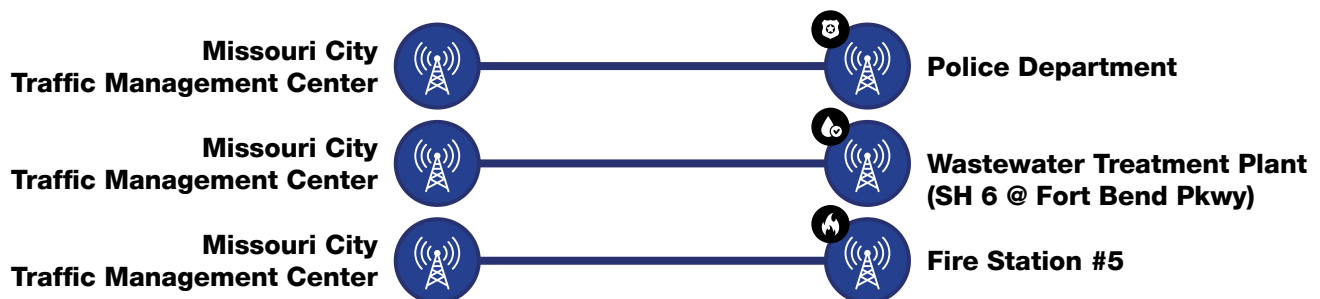
Overall, there is a need for improved communications and increased bandwidth to support existing and planned field devices. As defined in the City of Missouri City ITS Master Plan Operations Concept, “there is need for an expandable and scalable communications network that supports high-bandwidth and communicates with NTCIP-compliant ITS and ATMS devices”. Communications upgrades may include revised network architecture, upgrade or replacement of wireless equipment, expansion of existing fiber systems, and investigating third-party lease opportunities.

7.2.2 Existing Conditions

7.2.2.1 Communications Network

The City operates a hybrid communication system consisting of both wireless (radios) and wireline (fiber optics). Existing wireless radios include Alvarion, Ubiquiti, and Encom. AT&T cellular modems are used for AI preemption devices in all traffic signal cabinets. Cellular modems are also used at all 29 School Zone Flashers.

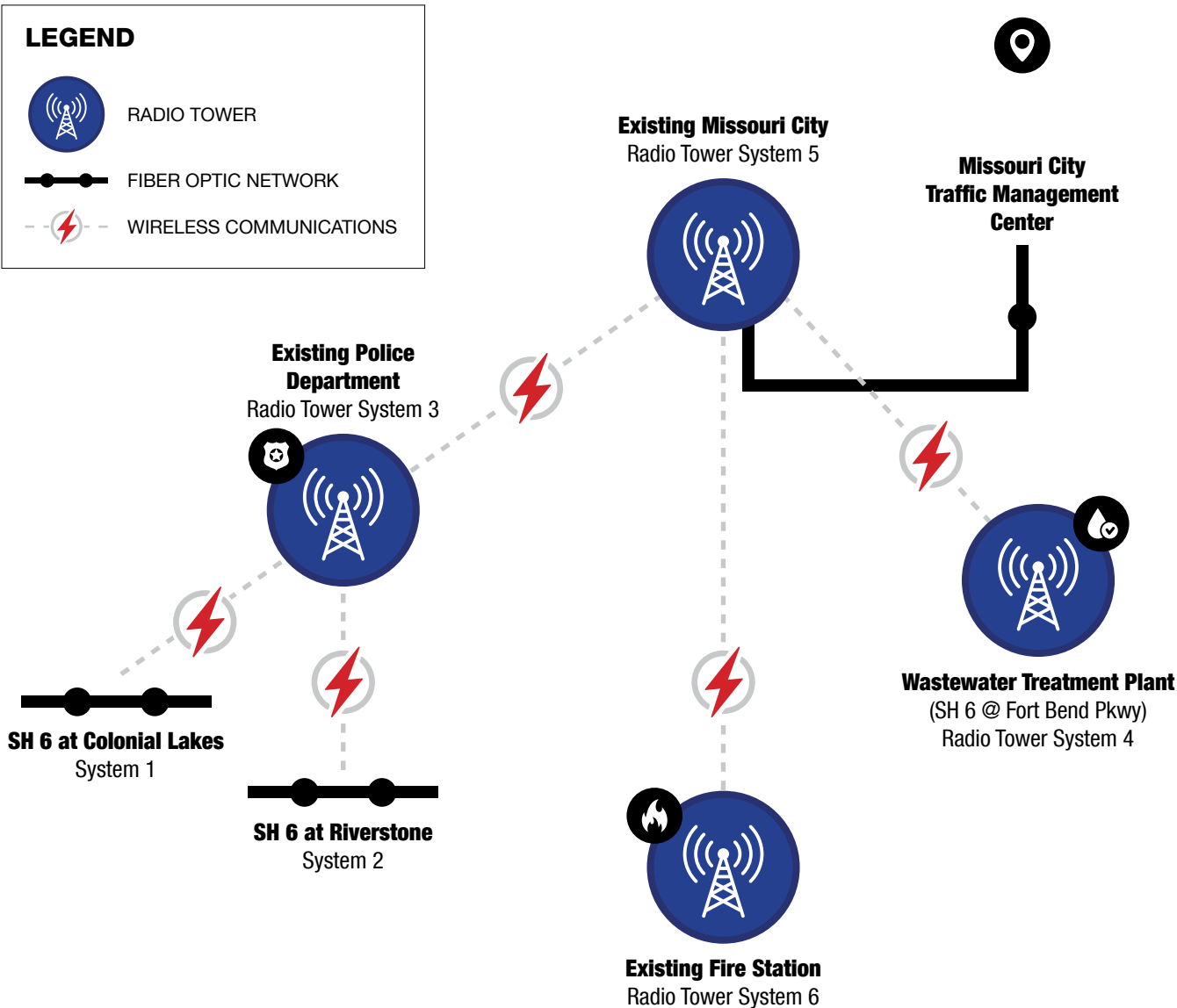
There are four radio towers with no redundant paths, that is, if a link between one of the radio towers is interrupted or lost, the devices associated with that tower lose communications to the TMC. The paths include the following:



7.2.2.1.1 Existing Communications Network

The City's fiber optic systems consists of a 144-strand single-mode fiber optic network installed and operated by TxDOT along SH 6 from Colonial Lakes Drive to Sienna Ranch Road and from Riverstone Boulevard to Creekmont Drive. TxDOT also manages allocation of the fiber. Two pair of the 144 strands are currently allocated to the City. Interface points linking the fiber systems with the wireless system are at SH 6 at Colonial Lakes and SH 6 at Riverstone Blvd. The City's ITS communications network utilizes EtherWAN Ethernet switches for the fiber systems along SH 6 and RUGGEDCOM Ethernet switches at all other (wireless) locations.

▼ **FIGURE 7.2.2.1.1A - EXISTING COMMUNICATIONS NETWORK**



7.2.2.1.2 Planned Communications Network

One of the goals of the ITS Master Plan is “Support City Growth” by providing a scalable and expandable communications network to serve the projected population growth of Missouri City. The City’s topography creates a challenging environment for wireless communication due to the presence of dense trees throughout the City. However, some areas within the City do not have a clear path to install fiber, or such installation would be cost-prohibitive. Therefore, wireless radios or other network communication methods may be needed to reach some ITS devices. The City’s IT Department also leases fiber from third party providers, such as AT&T and Verizon, and has indicated that the Traffic Operations staff may be able to leverage those contracts.

7.2.3 Needs Assessment

Overall, there is a need for a reliable, scalable and maintainable communications network.

7.2.3.1 Network Architecture

As noted in the COMC Concept of Operations, the City experiences severe video delays, lags and outages when more users than normal access video feeds, particularly during inclement weather and heavy traffic events. There is a need for a network architecture that:

- ▶ Maximizes legacy investment,
- ▶ Integrates fiber and wireless subsystems,
- ▶ Provides redundancy and expandability,
- ▶ Provides structure and bandwidth to account for anticipated infrastructure growth,
- ▶ Provides bandwidth and greater signal strength to eliminate video lag issues,
- ▶ Includes enhanced EOC/PD connectivity,
- ▶ Provides for Smart City initiatives and data analytic applications,
- ▶ Supports connection to TxDOT and City of Sugar Land for video sharing, and
- ▶ Allows for third-party lease opportunities such as AT&T and Verizon.

7.2.3.2 Wireless

There is a need for a reliable wireless communication network to support remote ITS and ATMS device locations that do not have access to the fiber. There is a need for the wireless network to support high-bandwidth, continuous live-stream video operations back at the TMC. There is a need to upgrade the existing radios to Cambium (or equal) radios. There is a need for the wireless system to reach planned traffic signal and ITS device installations. There is a need to upgrade signal, radio, and tower grounding systems to prevent disruption and loss during weather events.

7.2.3.3 Fiber Optics

There is a need to extend fiber Citywide. There is a possible need to treat fiber as a Citywide asset to be funded and utilized by multiple City departments. The IT Department currently leases fiber from third-party providers such as AT&T and Verizon as a possible vehicle for fiber expansion.



7.2.4 Requirements

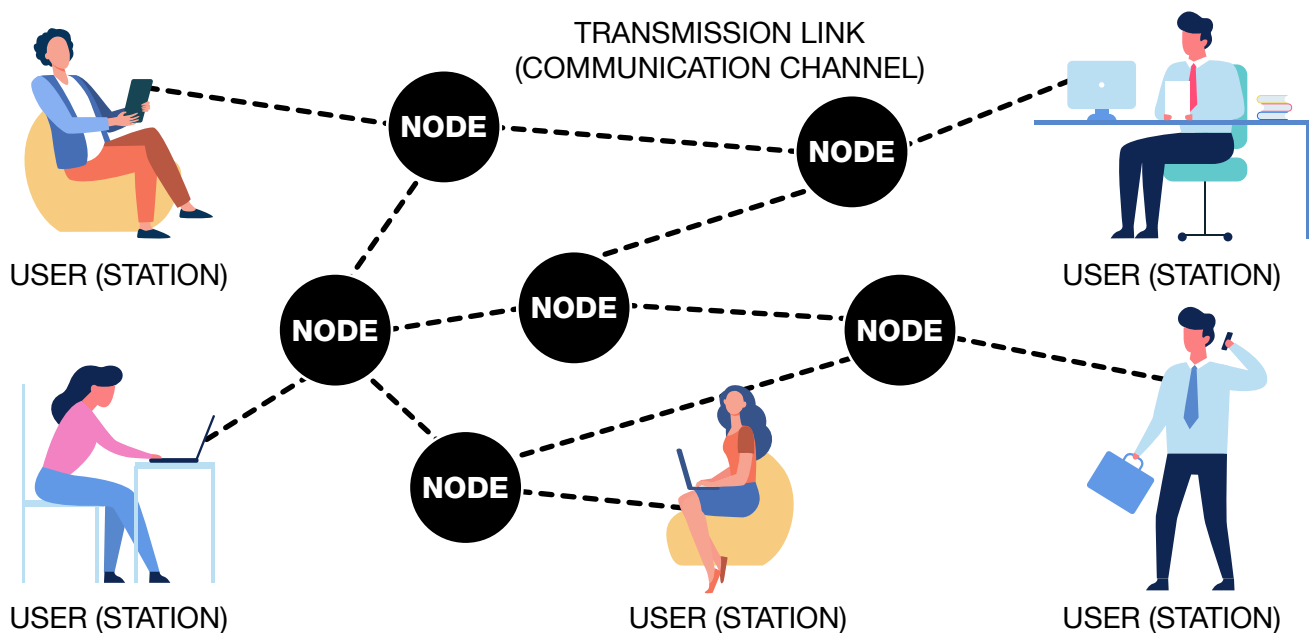
- ▶ Restructure network architecture to accommodate existing and planned ITS fiber and wireless subsystems, City owned fiber and third-party providers.
- ▶ Replace aging or malfunctioning intersection and tower wireless radios and antenna.
- ▶ Replace aging Ethernet switches and peripheral Ethernet equipment.
- ▶ Design and install fiber optic cable and associated Ethernet equipment at the following locations. Integrate new and existing traffic signal and ITS devices into the fiber system and integrate the devices into the TMC:
 - Texas Parkway from Buffalo Run to Cartwright Road including fiber connection to TMC (1.75 miles),
 - Cartwright Road from Dulles Avenue to Texas Parkway (3.3 miles), and
 - Murphy Road from Lexington Boulevard to Glenn Lakes Lane (2.5 miles).
- ▶ Extend SH 6 fiber system to Wastewater Treatment Plant Radio Tower (0.5 miles).
- ▶ Extend SH 6 fiber system to Fire Station 5 Radio Tower (3.6 miles).
- ▶ Prepare Preliminary Engineering Report to study and test weaknesses in the grounding system for all four radio towers, especially for Wastewater Treatment Plant Radio Tower.
- ▶ Deploy smart devices on new and rehabilitation projects when applicable.
- ▶ Aggressively implement big data analytic and dashboard applications.

7.2.5 Overview of Telecommunications Networks

Telecommunications is transmission of information over a distance. Once as simple as phone lines and switchboards, today's telecommunications include complex computer networks, wireless and cellular networks, smart phones, and other similar methods of transmitting information.

Technically, a telecommunications network is a group of terminals with connecting nodes and links that enable communication between terminals. Links connect the nodes using different types of switching to pass the signal through the right links and nodes to reach the destination terminal. Each terminal/user in the network has a unique address, ensuring messages are routed to the intended recipients. Common telecommunications networks include Ethernet, Internet, wireless networks, Local Area Networks (LAN), Wide Area Networks (WAN), radio, telephone, emergency dispatch, ham radios, and broadcast networks.

▼ **FIGURE 7.2.5A - TELECOMMUNICATIONS NETWORKS**



7.2.5.1 Components of a Telecommunications Network

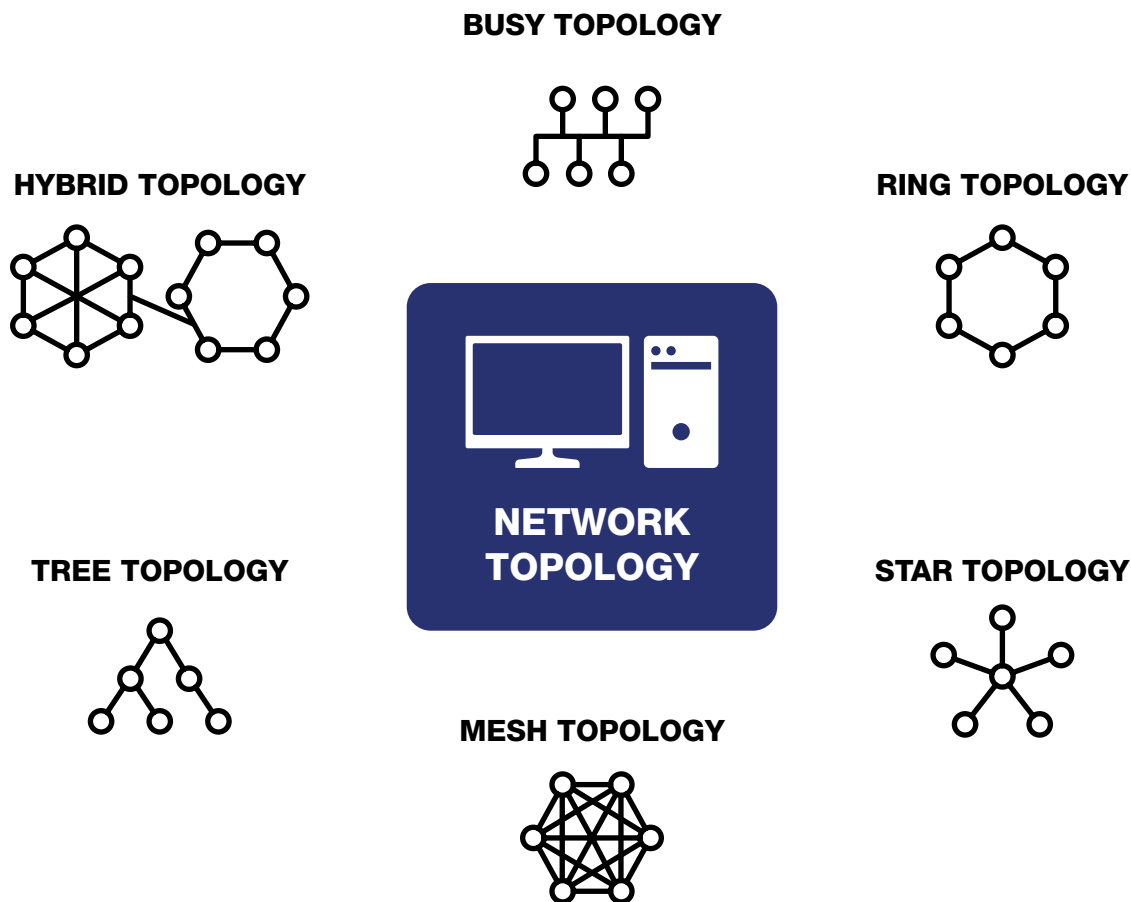
Telecommunication networks transmit voice, video, graphics, images, and text information. Required components include:

- ▶ Input and output devices/terminals to send and receive data,
- ▶ Transmission links/telecommunication channels,
- ▶ Computers and processors to process information,
- ▶ Control software for logic control and protocols, and
- ▶ Messages (transmitted information).

7.2.5.2 Types of Telecommunications Network Topologies

Network topology defines the arrangement/configuration of the various elements (links, nodes, etc.) of a telecommunications network. Common network topologies include ring, star, bus, tree, and mesh, and are briefly discussed below.

▼ **FIGURE 7.2.5.2A - NETWORK TOPOLOGY**



7.2.5.2.1 Ring Topology

Ring topology is a network configuration where device connections create a circular data path with each networked device connected to two others like points on a circle. Data travels around the ring in one direction. When one node sends data to another, the data passes through each intermediate node on the ring until it reaches its destination. The intermediate nodes repeat the data to keep the signal strong. Every node is a peer; there is no hierarchical relationship.

- ▶ Advantages include network servers are not needed, data transfers at high rates of speed, and workstations can be easily added without impacting network performance.
- ▶ Disadvantages include network is impacted if one node goes down, all data passes through each node which can slow down performance, and node hardware is more expensive than Ethernet switches/cards.

7.2.5.2.2 Star Topology

Star Topology is considered the easiest topology to design and implement. Each peripheral node is connected to a central hub, i.e., the hub is the server and peripherals are the clients. All data traffic passes through the central hub.

- ▶ Advantages include centralized management through the hub, the simplicity of adding nodes, and the rest of the network continues to function normally if one computer on the network fails.
- ▶ Disadvantages include the hub represents a single point of failure, and it typically is a higher cost to implement

7.2.5.2.3 Bus Topology

Also known as Line Topology, Bus Topology is a network configuration where each computer and network device is connected to a single cable or backbone.

- ▶ Advantages include works well with small networks, easy to linearly connect computers and peripherals, and requires less cable
- ▶ Disadvantages include difficult troubleshooting, does not work well with large networks, adding devices impacts network performance, and main cable damage may cause full or partial network failure.

7.2.5.2.4 Tree Topology

Network configuration where connected elements are arranged like tree branches of a tree. Tree Topology a combination of Bus and Star topology, is often deployed for corporate networks, and create natural parent and child hierarchy since two nodes can have only one mutual connection.

- ▶ Advantages include high reliability, high scalability, other nodes are not affected if one node fails, easy maintenance and troubleshooting, and supported by several hardware and software vendors.
- ▶ Disadvantages include difficult to configure, segment lengths are dependent on cable type, network performance slows for large number of nodes, required large amount of cabling, backbone is single point of failure, more costly.

7.2.5.2.5 Mesh Topology

Network configuration where each computer and network device interconnects with one another, allowing for most transmissions to be distributed even if one connection fails. Mesh is commonly used for wireless networks. connection.

- ▶ Advantages include manages high amounts of traffic because multiple devices transmit data simultaneously, failure of one device does not impact data transmission, and adding devices does not disrupt data transmission between other devices.
- ▶ Disadvantages include cost is higher than other topologies, building and maintaining is difficult and time-consuming, and the chance of redundant connections is high which adds costs and potential inefficiency.

7.2.5.3 Types of Telecommunications Networks

7.2.5.3.1 Local Area Network (LAN)

LAN is designed for small areas like an office, group of buildings or factory. LANs are widely used because they are easy to design and troubleshoot. PCs and workstations are connected through the LAN using various topologies such as Star, Ring, Bus, and Tree. Features include:

- ▶ Resource, Internet, and software applications sharing
- ▶ Centralized data
- ▶ Easy and cheap communication
- ▶ Data security

7.2.5.3.2 Wide Area Network (WAN)

WAN is used for networks that cover large distances like large cities, metropolitan areas, and states, and can be private or public leased. For example, WANs are used by many multinational companies to transmit their data and receive information among their employees, suppliers, customers, and other organizations across various cities, regions, countries, and the whole world. Features include:

- ▶ Covers large area
- ▶ Shares software and resources with connecting workstations
- ▶ Messages (pictures, sounds, data) are sent quickly
- ▶ Everyone uses the same data

7.2.5.3.3 Metropolitan Area Network (MAN)

MAN is a larger version of LAN designed to extend across a whole city using similar technology as LAN, often connecting several LANs into a larger network or is often one cable. Features include:

- ▶ Extremely efficient
- ▶ Fast communication via high-speed carriers
- ▶ Single backbone provides greater access to WAN

7.2.5.3.4 Internet

Internet is the world's largest network of networks, connecting individual networks using various devices such as routers, bridges, and gateways.

7.2.5.3.5 Intranet

Intranet is a network designed to be open but secured with internal networks whose web browsing software provides easy point-and-click access to multimedia information on internal internet sites.

Extranet is a network that links intranet resources with other organizations and individuals.

7.2.5.3.6 Wireless Network

Wireless Network is a network that uses wireless data connections between nodes, i.e., not connected by cables, thereby avoiding costly cable infrastructure. The basis of wireless systems are radio waves. Examples of wireless networks include cell phone networks, wireless local area networks (WLANs), satellite communication networks, and terrestrial microwave networks. Until recently, the perception was wired networks were faster and more secure than wireless networks. Wired networks still hold the advantage in expandability, but wireless network technology advancement such as the IEEE 802.11ax standard, also known as Wi-Fi 6, has minimized speed and security differences between wired and wireless networks.

- ▶ Advantages include increased efficiency, access and availability, flexibility, cost savings, and new opportunities/products/services.
- ▶ Disadvantages include security, installation, interference, coverage, and transmission speeds.

7.2.6 Communications Options

There are a variety of methods used for ATMS communications between intersections/ITS devices and a central location (TMC). Methods include dial up, copper wire, fiber optic cable, spread spectrum radio, wireless broadband radios, cellular networks, licensed channel radio, and leased lines. The modern traffic signal controllers such as TS 2 supports all the above communication methods. The trend in the industry is towards IP Ethernet communications. The system(s) chosen should support high-resolution traffic signal data, signal phasing and timing data (SPaT), and video streaming back to the TMC. Below is a brief synopsis of the most available and applicable COMC communication alternatives.

7.2.6.1 Fiber Optic Cable

Fiber optics is transmission of light through thin strands of optical fiber bundled together to form a fiber optic cable. Data transmission is in the form of data encoded light rays that transmit data, images, video, and voice over fiber between fiber optic “end” equipment such as transmitter receivers (transceivers) and switches. Fiber optics is popular for telecommunications due to its data transfer capabilities, resistance to electrical interference, expandability, flexibility, and continually improving “end” equipment. A single strand of fiber can transmit more than 100 terabits/second, indicating fiber optics can meet anticipated future bandwidths and speeds. Single-mode fiber optic cable is the preferred medium, and foundation, on which most fiber optic communications networks are built.

Intersection and device bandwidth speeds between 100 megabit per second (Mbps) and 1 gigabit per second (Gbps) is typical. Backbone and network bandwidth speeds of 1 to 10 Gbps is typical. Bandwidth speeds of 40 Gbps up to 100 Gbps is possible but is cost-prohibitive and not needed for the City’s existing or planned applications. Underground fiber installation is preferred but can be expensive, particularly in urban areas. Aerial cable is an alternative, but pole attachment agreements can be time consuming and expensive, and roadscape aesthetics suffers.

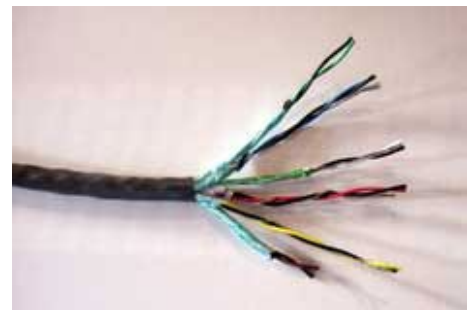
Fiber optics should be considered when:

- ▶ Constructing or rehabilitating roadway and drainage systems where installing conduit and fiber infrastructure is a small percent of the overall project cost.
- ▶ Bandwidth, distance, and reliability requirements exceed other options, i.e., fiber transmits large amounts of data over long distances reliably and securely.
- ▶ Concentration of field devices makes fiber a cost-effective solution.
- ▶ Along corridors where resource and cost sharing opportunities exist.

7.2.6.2 Twisted Wire Pair (Copper) Cable

Electrical properties of copper wire create resistance and interference. The further communication signals travel the more they weaken by resistance and interference. These electrical properties limit communication transmission speed and distance but those same properties along with cost and ease to manufacture make copper a solid choice as a communication medium. Cross-talk happens when strong signals create magnetic fields, or when close to power transmission lines or fluorescent lighting fixtures. Cross-talk is minimized by twisting a pair of wires around a common axis and using metallic shielding, thus, twisted wire pair (TWP). The greater number of twists provides more protection against crosstalk. TWP is still commonly used today.

Twisted wire pair may have applications for traffic signal interconnect along minor arterials and in locations not easily accessed by wireless line-of-sight where fiber is cost-prohibitive. Higher bandwidths are achieved using specialized Ethernet switches capable of transmitting high-speed video over TWP.



Source: FHWA Telecommunications Handbook

This also extends IP communications to signal cabinets not needing the broadband capabilities of fiber. Similar to fiber, underground installation of TWP is preferred where possible.

Two types of TWP commonly used in computers and communication networks are Category 5 (CAT 5) and Category 6 (CAT 6). CAT 5 cable provides bandwidth of 100Mhz and speeds up to 100 Mbps, is suitable for Ethernet and Internet connections, and can also carry video signals albeit limited distances. CAT 6 cable provides bandwidth of 250 MHz and speeds up to 10Gbps for limited distances (350 feet), and meets more rigid “cross-talk” requirements than CAT 5.

7.2.6.3 Wireless Broadband

Broadband refers to various high-capacity transmission technologies that transmit high-quality data, voice, and video across long distances and at high speeds. The City’s existing wireless system uses fixed 5.8 GHz wireless broadband radios in a combination of point-to-point and point-to-multipoint configurations. Broadband applications include traffic signal interconnect, CCTV cameras, dynamic message signs, weather monitoring stations, wrong-way detection systems, school zone flashers, emergency preemption and more.

Wireless broadband is cost-effective (no cabling or trenching costs), scalable (networks are easily expanded), can be deployed almost anywhere (rugged terrain, bodies of water, remote areas), uses IP based communications standards (Ethernet, WiFi, etc.), supports both licensed and unlicensed frequencies, provides high-speed data rates with low latency, and provides Carrier Class security features.

7.2.6.4 Cellular

Cellular data radio using 4G and 5G technology is a viable solution where other technologies are not feasible and rapid deployment is a priority. Cellular data radio may also be used in remote, isolated, and access-limited locations, and as a short-term solution. Cellular is susceptible regional outages and brown-out events so deployment must be carefully considered. Using data radios with dual-redundant functionality provides additional redundancy but may not address brown-outs.

Recent advances in cellular data modem technology provide higher bandwidths at lower costs. For applications such as simple field device monitoring and control, cellular is a very cost-effective solution. Future 5G standard radios are expected to provide even greater bandwidth capabilities. Cellular requires recurring cost to a carrier such as AT&T or Verizon.

7.2.6.5 Licensed Channel Radio

Private leased public safety band 4.9 Ghz radio technology may be a suitable technology where cable is not practical or feasible, or where construction timelines of other solutions is not acceptable. This is a licensed band that supports point-to-multipoint (i.e. master radio to many remote radios) or point-to-point topologies and can be used to interconnect isolated field cabinets or possibly “buckets” of cable connected field cabinets. FCC licensing is required. These radios are capable of 260 Mbps up to 40 miles but often have limitations in terms of latency and data packet per second transmission capacities. Consideration for deployment must account for proposed applications with regards to aggregate data transmissions.

7.2.6.6 Leased Lines

Leased line solutions may be a viable option where other solutions are not practical, feasible, or as cost-effective. These solutions are not as quick to deploy as cellular data modems but are typically quicker than built infrastructure and may also be used to provide redundancy to otherwise non-redundant network segments. Due to typically high recurring monthly service costs, leased lines should be carefully compared to other options. Leased lines are all packet-based services and easily integrated into Ethernet-IP based network architectures.

7.2.6.7 Cost Considerations for Communications Options

Table 1 provides planning-level cost estimates by communication media, which were effective at this time this report was authored.

▼ **TABLE 1. COMMUNICATIONS COSTS**

Source: Kimley-Horn

CABINET	APPROXIMATE COST
Copper Wire	\$50,000/mile
Fiber Optic Cable	\$264,000/mile
Point-to-Multipoint Wireless (low data)	\$3,000 to \$6,000 per intersection/ITS device
Point-to-Point Wireless (high data)	\$12,000 to \$30,000 per link
Licensed Wireless	\$35,000 per link
Cellular Modem	\$50 to \$80 per month

7.2.7 Redundancy, Availability and Resiliency

System redundancy and resiliency is an important factor to consider in the upgrade of the City's communications network. Redundancy is the ability of the communications backbone to function if one or more components fail using alternative equipment and communication paths. Availability is the amount of time the system is up and serving its intended function relative to the total time it could have been up. System availability generally improves with increased system redundancy. Resiliency is the ability to recover from setbacks and difficulties and adapt well to change in a timely manner. This can be achieved by incorporating the following requirements into communication equipment procurements:

- ▶ Provide redundant system communication paths,
- ▶ Provide surge protection and properly ground all equipment,
- ▶ Provide back-up power to each intersection controller and ITS device location,
- ▶ Properly train City maintenance staff,
- ▶ Select industry standard equipment, stock spare equipment and parts, and stay current with equipment and software upgrades, and
- ▶ Select critical network components with excellent market availability, and, if possible, next-generation migration plans.

The communications network must be expandable to accommodate additional controllers, CCTV cameras, DMS, and other ITS devices. Expansion should be accomplished by adding new hardware and software without necessitating upgrades to existing system hardware and/or software. Hardware components of the communications network should be compliant with the applicable standards and implemented using open standards equipment and modularity whenever possible. Communications design should support changes in physical topology to support migration to more advanced future communications technologies.

7.2.8 Recommended Telecommunications Network Expansions

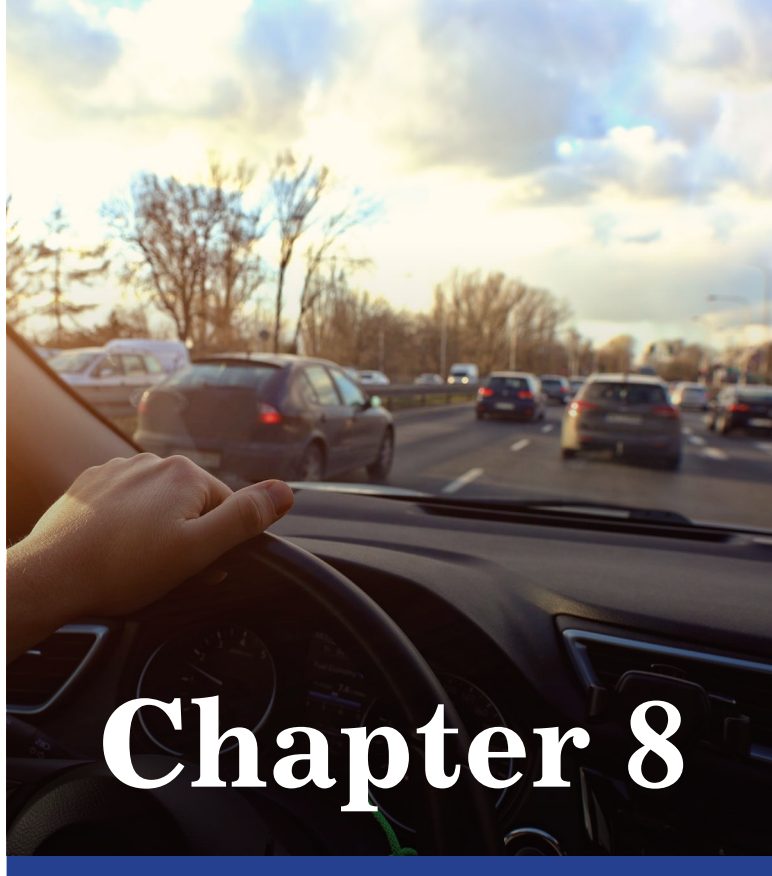
Taking into consideration ownership, network efficiency, network redundancy, and cost, the long-term preferred alternative is a hybrid-type network architecture that consists of both wireless communication technologies and fiber optic cable. This will require additional staff resources and training, additional operations and maintenance costs, and capital costs associated with fiber infrastructure and upgraded wireless components. Expansion is recommended for both the wireless and fiber communication subsystems.

7.2.8.1 Wireless Communications

The City would benefit by continued investment in a comprehensive replacement of the existing wireless communications system including antenna, radios, old or malfunctioning Ethernet switches and other aging networking equipment and infrastructure necessary to operate a reliable and maintainable communications subsystem. The City should continue replacement of older radios to Cambium and upgrade the existing ethernet switches to a more industrial grade product. EtherWAN prepared a proposed design that utilizes a three-tier architecture: intersection switches connected to field devices, hub switches connected to intersection switches, and a core switch connecting hub switches to the TMC. The EtherWAN design also included EtherWAN wireless radios and a user-friendly network management interface. The City may consider developing wireless equipment specifications for planned and future projects or capitalize on regional efforts to date and use wireless ITS and ATMS equipment specifications from TxDOT, Harris County and/or City of Houston.

7.2.8.2 Fiber Optic Communications

Fiber optics offer the most reliable, flexible, and expandable communications solution for the City of Missouri City. When possible, the City should expand fiber deployment via traffic signal projects, roadway projects, drainage projects, utility projects, and dedicated fiber projects. The City should expand fiber to critical locations most impacted by rapid growth and inclement weather such as the Sienna/South Tower. The City should develop a citywide fiber optic plan that incorporates connection of multiuse city facilities not just at traffic and law enforcement facilities, but at schools, libraries, parks and other locations. The fiber plan should provide for collaboration between Public Works and the City IT departments for the purpose of sharing capital and maintenance costs.



Chapter 8

Advanced Mobility and ITS Elements

8.1 MODERN TRAFFIC CONTROL CABINETS

8.2 TRAFFIC CONTROL CABINET GROUNDING

8.3 TRAFFIC SIGNAL OPERATIONS

8.4 PERFORMANCE MEASURES

8.5 DATA ANALYTICS AND BIG DATA

8.6 TMC UPGRADES

8.7 STANDARD OPERATING PROCEDURES

8.8 DETECTION



Advanced Mobility/ITS Elements

8.1 MODERN TRAFFIC CONTROL CABINETS

Modern traffic control cabinets include the National Electrical Manufacturers Association (NEMA) TS-2, and the Advanced Traffic Controller (ATC).

8.1.1 NEMA TS-2

The City of Missouri City currently operates NEMA TS-2 traffic control cabinets. NEMA TS-2 was developed by member companies in the NEMA Transportation Management Systems and Associated Control Devices Product Group. This cabinet architecture was first introduced in 1982 under the technical specification of TS-2 Traffic Control Assemblies with NTCIP Requirements. The NEMA TS-2 standard is the successor to the discontinued NEMA TS-1 standard. The TS-1 standard was based on a basic set of features and standard connectors and was successful for isolated actuated intersection control but lacked advanced features such as coordinated-actuated operation and preemption.

NEMA TS-2 provides coordinated-actuated operation, preemption, and an optional serial bus to simplify wiring. Other advanced features include 1) communication between major equipment within the cabinet over a data channel with almost unlimited capacity, maximizing future expandability, 2) use of a high-speed data channel between the controller unit, malfunction management unit, detectors, and rear panel reducing connections and facilitating diagnostics, and 3) enhanced user interface. Additional advanced functionality includes complex phasing, detector processing, communications, adaptive timing, and full systems operation in a closed-loop, hybrid, or centralized configuration.

NEMA TS-2 meets all current AASHTO and ANSI standards and complies with all current and applicable National Transportation Communications for ITS Protocol (NTCIP) standards. This control cabinet has been the work horse for many cities throughout North America. The following Texas agencies have NEMA TS-2 as their standard:

- ▶ TxDOT
- ▶ City of League City
- ▶ City of Conroe
- ▶ City of Flower Mound
- ▶ City of Galveston
- ▶ City of Pearland
- ▶ City of Baytown
- ▶ City of Sugar Land
- ▶ The Woodlands
- ▶ City of Georgetown

NEMA TS-2 does not specify the physical size, shape, or appearance of cabinet and components except where standardization is necessary for physical interchangeability from different manufacturers. There are no requirements for interchangeability of sub-components or software between controllers from different manufacturers. The NEMA TS-2 standard defines two alternative types of input / output interfaces: binary (on or off) logic wires (analog) and a serial bus (less wiring in cabinet). The standard includes basic specifications for the following:

- ▶ A, B, and C connectors for cabinets using the older TS-1 standard
- ▶ Serial bus for communications with MMU, detectors, and load switches
- ▶ Serial ports for communications with computers and master units (RS 232 and FSK modem)
- ▶ User interface (keypad and display, required but details not specified)
- ▶ Maximum dimensions
- ▶ The NEMA TS-2 cabinet can be configured in a variety of cabinet sizes, with the P cabinet being the most common. Other form factors are manufactured to serve different purposes. For example, the 244 cabinet is typically deployed for the control of Diamond interchanges because it provides additional detector inputs. Below represent the most common types of NEMA TS-2 cabinets.

▼ **FIGURE 8.1.1A - M CABINET**



- ▶ 50"H x 30"W x 17"D (Varies)
- ▶ 68"H x 31"W x 17"D (Stretch Model)
- ▶ Space Efficient

Source: <https://www.mccain-inc.com/>

▼ **FIGURE 8.1.1B - MODIFIED M CABINET**



- ▶ 61"H x 36"W x 18.5" D (Varies)
- ▶ Side-by-Side Front Door
- ▶ GPS Interface Panel

Source: <https://www.mccain-inc.com/>

▼ **FIGURE 8.1.1C - G CABINET**



- ▶ 36"H x 24"W x 18"D (Varies)
- ▶ Compact Size / Two Compartments
- ▶ Pole or Pedestal Mount

Source: <https://www.mccain-inc.com/>

▼ **FIGURE 8.1.1D - P CABINET**



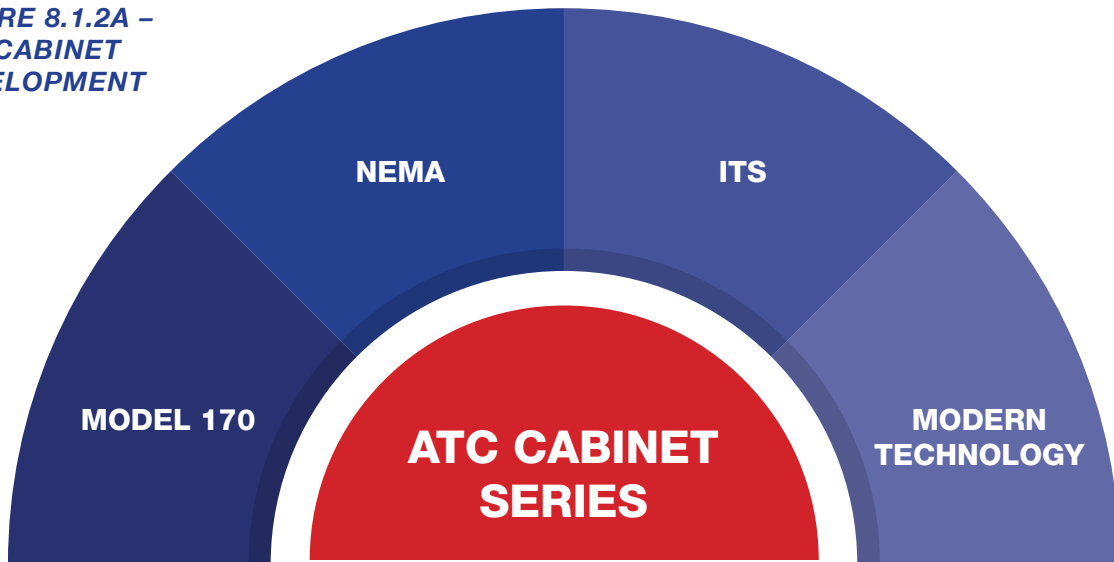
- ▶ 55"H x 44"W x 26" D (Varies)
- ▶ Modular Design/Flexibility
- ▶ Drop Down Technicians Panel

Source: <https://www.mccain-inc.com/>

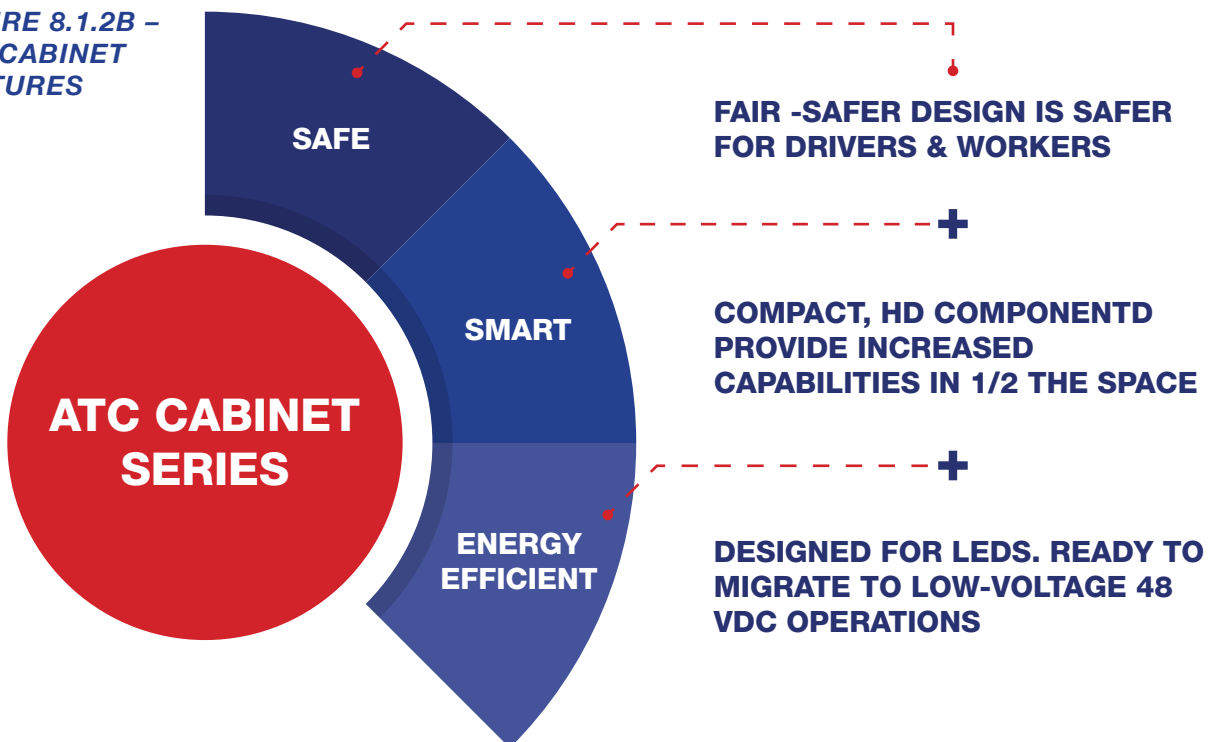
8.1.2 ATCC

The USDOT recently released the Advanced Transportation Controller Cabinet (ATCC) Standard, jointly developed by the American Association of State Highway Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE) and National Electrical Manufacturers Association (NEMA). The ATCC Standard provides an open architecture hardware and software platform that draws from the Caltrans TEES specification for components built around the EIS 19" rack and interchangeable modules, from the NEMA standard for MMU and serial bus architecture, and from ITS cabinets for the latest technological advancements. The standard increases reliability, functionality, ease of maintenance, and supports a wide variety of Intelligent Transportation Systems (ITS) applications including intersection control, traffic management, ramp metering, data collection, safety, security and other applications.

▼ **FIGURE 8.1.2A –
ATC CABINET
DEVELOPMENT**



▼ **FIGURE 8.1.2B –
ATC CABINET
FEATURES**



ATCC uses a transportation controller architecture where computational components reside on a printed circuit board (PCB) called the “Engine Board,” and consists of a central processing unit (CPU), Linux operating system (O/S), memory, external and internal interfaces, and other associated hardware necessary to create an embedded transportation computing platform. The ATCC Standard works closely with the Application Programming Interface (API) Standard to allow applications to share controller system resources. ATCC focus is on low current signal displays (LEDs), high-density load switches, efficient power supplies, interchangeable subassemblies, and some backward compatibility (input cards for example).



▼ **FIGURE 8.1.2C – ATC CABINET**

Source: <https://www.econolite.com>

ATCC offers a variety of cabinet constructs to handle simple intersections to complex roundabouts and diamond interchanges, while allowing ease of maintenance with standardized electrical signals and protocol. The ATCC is available from several vendors.

ATCC key elements include:

- ▶ Purpose-built for light-emitting diode (LED) signals
- ▶ Compact size with modular rack mounted configurable design
- ▶ Advanced operations include adaptive, bicycle detection, count data, Texas Diamond, RWIS
- ▶ Conforms to USDOE ban on incandescent bulb sales
- ▶ Measures load current to identify signal head and wiring failures
- ▶ Power savings allows use of alternate power sources (solar, battery backup)
- ▶ Interchangeable plug-in devices among manufacturers
- ▶ Standard electrical signals and protocols among cabinet types to simplify service training
- ▶ Mechanical size, shape and internal layout adapts to local owner/operator specifications
- ▶ Low voltage option for state legislation and safety of service personnel, pedestrian and drivers
- ▶ Elimination of shock hazard inside electrical cabinets and downed field wiring
- ▶ Elimination of arc flash hazard under NFPA 70E
- ▶ Replacement of internal assemblies while traffic signals remain in FLASH

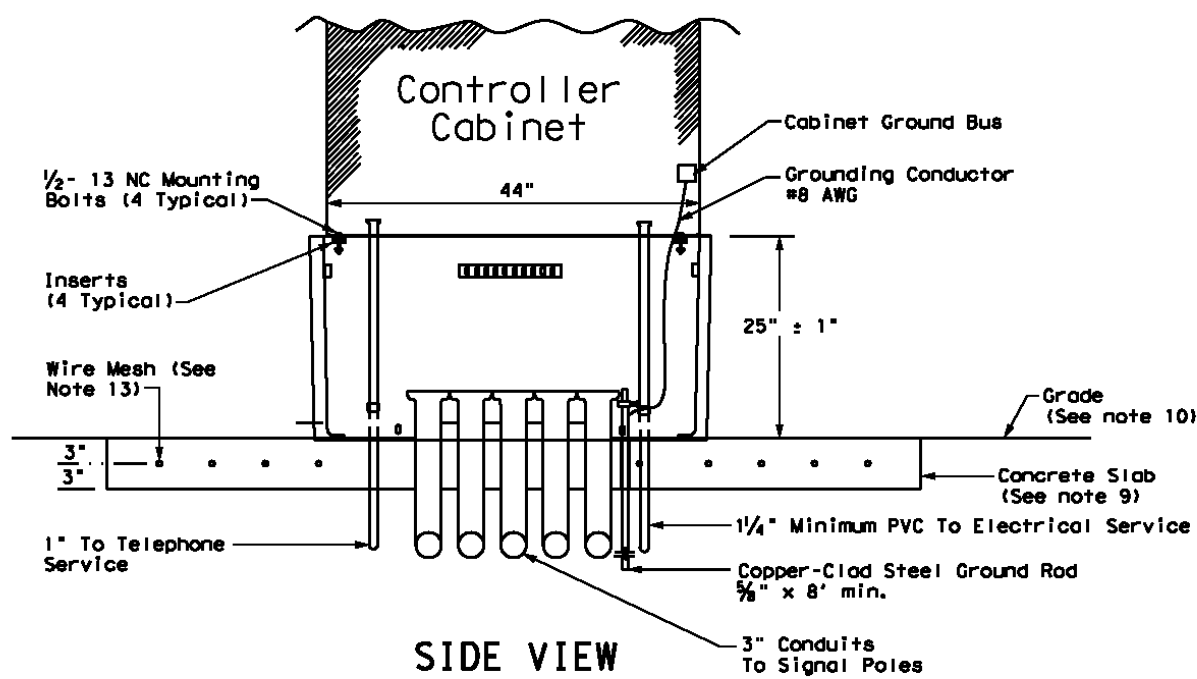
8.1.3 Conclusion and Recommendations

The City of Missouri City has a significant investment in the NEMA TS-2 Cabinet standard which has served them well. Preservation of this legacy investment is a critical factor when considering alternatives. The analysis above did not address the Model 170/2070 Cabinet option due to the unlikelihood of converting to this older platform. The ATCC cabinet offers a powerful, compact roadside computing and integration platform, but is moderately deployed in the U.S., only about 5000 cabinets are currently in operation (1.4% of all U.S. signals) and is still an evolving technology. As the City grows and their needs change, the City should periodically review evolving traffic control technology and next generation ATCCs. Based on the City's investment, and positive TS-2 maintenance and operations experience, it is recommended the City remain with the NEMA TS-2 standard.

8.2 TRAFFIC CONTROL CABINET GROUNDING

The City of Missouri City has experienced impact to normal traffic signal operations due to storms and lightning strikes. As a result, an assessment for possible upgrades to the City's traffic system grounding standard was conducted. The City of Missouri City predominantly uses the below TxDOT Traffic Signal Controller Cabinet Base and Pad Standard, TS-CF-21.

▼ **FIGURE 8.2A – TXDOT TRAFFIC SIGNAL CONTROLLER CABINET BASE STANDARD**



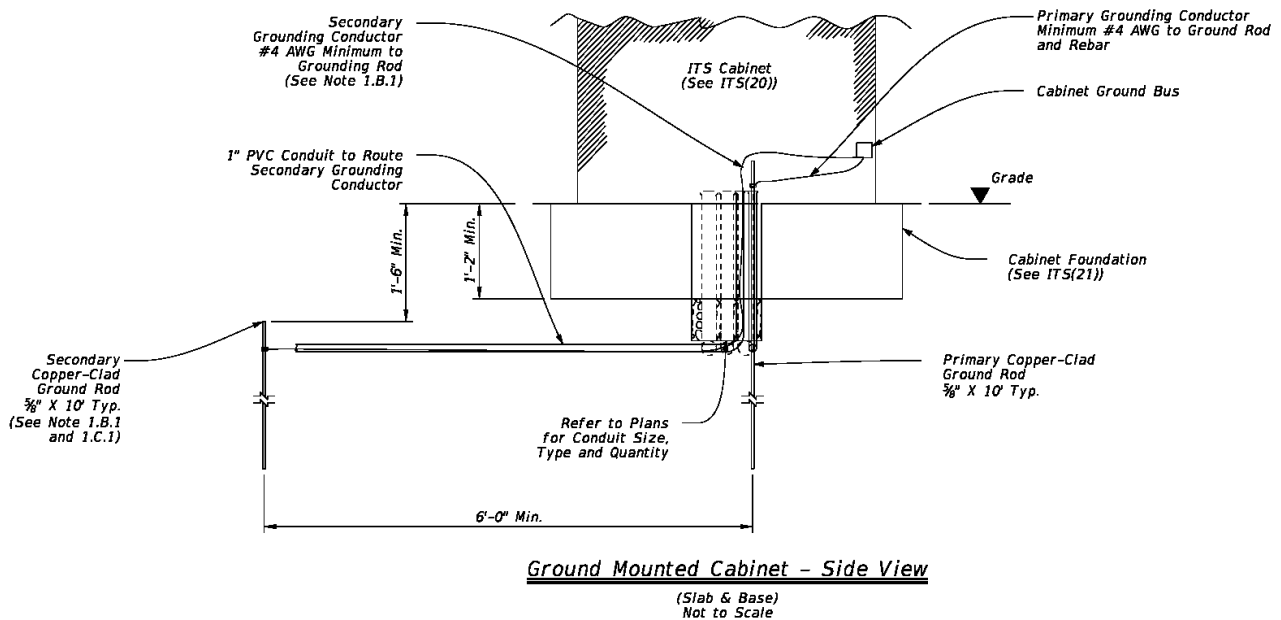
Source: <https://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/traffic/ts-cf-21.pdf>

The above standard consists of a 5/8" x 8' copper-clad steel ground rod connected to the cabinet ground bus using #8 AWG wire. The City of Sugar Land, along with many municipalities across the Houston region, uses this TxDOT standard. For comparison,

- ▶ City of Houston Traffic Cabinet Foundation standard specifies a 5/8" x 10' copper-clad steel ground rod clamped to the RMC system using #8 AWG wire, and
- ▶ Harris County Controller Cabinet Foundation standard specifies a 5/8" x 8' copper-clad ground rod clamped to the RMC system using a ground bushing or PVC and HDPE using bell end fittings.

Another potentially applicable standard is the TxDOT ITS Cabinet Grounding Details standard, ITS (18) – 15. This is a robust and comprehensive standard that includes extensive resistance testing. This standard consists of two 5/8" x 10' copper-clad ground rods, a primary and secondary. The primary rod is located directly below the cabinet and connects to the cabinet ground bus and foundation rebar using #4 AWG conductor. The secondary ground rod is 6' from the primary ground rod and connects to the cabinet ground bus through a 1" PVC using #4 AWG conductor. The top of the secondary ground rod is 18" below grade. The standard requires multiple certifications and compliances as well as phased resistance testing and reporting. This is a hearty standard that should be considered moving forward.

▼ **FIGURE 8.2B – TxDOT ITS CABINET GROUNDING STANDARD**



Source: [https://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/traffic/its\(18\)-15.pdf](https://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/traffic/its(18)-15.pdf)

Another robust grounding system option is to connect traffic signal cabinet grounding to individually grounded traffic signal poles that are collectively connected to each other, offering a combined resistance of multiple grounding systems.

A brief review of other city and state standards revealed very similar solutions to those summarized above, i.e., 5/8" or 3/4" x 8'-10' copper-clad steel ground rods using #6 or #8 AWG to connect to cabinet ground bus, service disconnects, foundation reinforcing steel or metal conduit systems. Mesh and grid type grounding systems are rare and as such, difficult to evaluate. An excellent reference detailing the effectiveness of various grounding systems can be found in the FHWA Traffic Detector Handbook: Third Edition-Volume II 2006, Table N-3. Resistance to ground for various ground system configurations and soils. Table N-3 is included as Appendix A. The Handbook also states:

- ▶ Effect of ground rod diameter is small. Longer not thicker rods yield much better results.
- ▶ Effect of material (copper or steel) has negligible effect.
- ▶ Ground rod spacing should be one rod length away from each other.
- ▶ Effect of size and type of connecting grounding conductor has little effect.
- ▶ Upper 3' of ground rod does not have much effect. Minimum depths must be maintained.
- ▶ Soils contain a wide range of resistance characteristics. Proper grounding considers soil profiles.

8.2.1 Lightning

The Handbook notes damaging effects of lightning on electrical and electronic equipment can be costly and may result from direct strikes, power surges, transient surges, and capacitive voltage spikes. It is not practical to protect against direct strikes so protective systems are designed to prevent or handle surges and transients. Protective systems consist of proper ground, suppression, and shunting. Shunting is providing an electrical current through a conductor joining two points of a circuit, through which more or less of the current may be diverted. Since weather is somewhat unpredictable, protection design is based on the following probabilities:

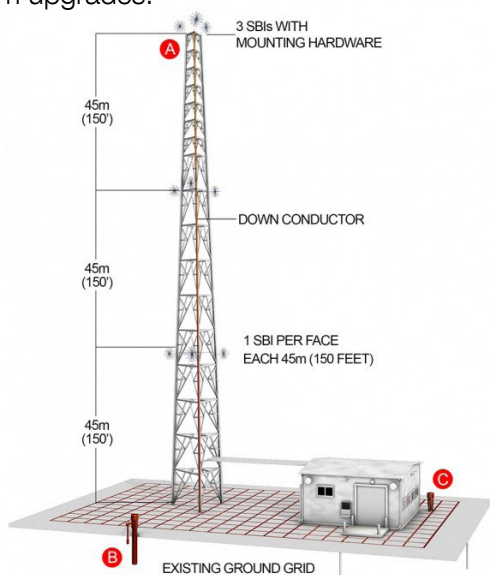
- ▶ Probability of a storm
- ▶ Probability of a strike
- ▶ Probable potential energy and RF energy
- ▶ Probable rise time of voltage (open circuit) wave or current (short circuit) wave
- ▶ Probable duration or repetition of strike.

8.2.2 Conclusion and Recommendations

Based on the assessment performed, it is recommended the City consider using the TxDOT ITS Cabinet grounding standard for all of its traffic signal controllers. The increase in protection is well worth the modest additional cost. It is further recommended the City invest in an Earth Ground Resistance Tester to ensure electric currents pass safely through the earth during voltage spikes and lightning strikes.

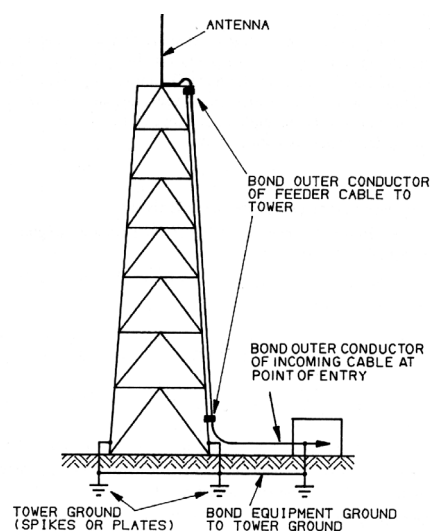
8.2.3 Tower Grounding

The radio tower at the wastewater treatment plant is the State (TxDOT) standard for self-supporting radio towers and hence has a robust grounding system requiring compliance with a multitude of references including the National Electric Code (NEC), National Fire Protection Association (NFPA), UL Standards, Lightning Protection institute Standard of Practice, American National Standards Institute, and Motorola R56 Standards and Guidelines for Communication Sites. Tower grounding consists of multiple ground rods, a top-mounted air terminal lightning protection system, and lightning resistance arrays at variable heights on the tower. The radio components mounted on the tower, the equipment shelter, and its equipment are independently grounded from the tower. If lightning strikes to the tower are impacting operations, additional protection may be needed. Independent, specialized testing can identify inadequacies and will form the basis of meaningful improvement measures. Below are examples of possible mesh and plate grounding system upgrades.



▼ **FIGURE 8.2.3A - TOWER GROUNDING 1**

Source: <https://www.lightningprotection.com/the-tower-kit/>



▼ **FIGURE 8.2.3B - TOWER GROUNDING 2**

Source: <http://www.bscassociates.co.uk/Bibliography/Paper-43.pdf>

8.2.3.1 Conclusion and Recommendations

Tower grounding is important to the reliability of communications during storm events. Additional protection may be needed to reduce the impact to traffic operations. It is recommended specialized testing and study be performed to identify inadequacies and appropriate improvements.

8.3 TRAFFIC SIGNAL OPERATIONS

The communication subsystem is the backbone of successful ITS and integrated signalization operations. The most critical, high-yield improvement the City can make is to upgrade its current communication systems, including network architecture, and both fiber and wireless subsystems. In addition to communications, this section expands on traffic operation components including battery backup units (BBUs), weigh-in-motion (WIM), signal timing program, Smart City, and Connected and Automated Vehicles (CAV).

8.3.1 Communications

To effectively operate remote City devices such as traffic signals, CCTV cameras, Bluetooth and DMS, a robust, reliable, maintainable communications system is required. The communications system is expected to support, among other things, the following operational functions:

- ▶ Signal timing synchronization
- ▶ Upload and download of timing plans between controller and TMC
- ▶ Monitoring field equipment status and reporting malfunctions
- ▶ Transfer of video information to TMC and control of cameras by TMC
- ▶ Displaying travel times on DMS using Bluetooth
- ▶ Support of traffic probe-based incident detection equipment

The City's existing hybrid communications system has served the City well for years but is in need of upgrades due to 1) natural aging of equipment life-cycles, 2) growing demand on City infrastructure, and 3) increased emphasis on efficiently operated transportation system. Overall, there is a need for improved communications and increased bandwidth to support traffic signals, cameras, DMS and Bluetooth. As defined in the City of Missouri ITS Master Plan Operations Concept, there is need for an expandable and scalable communications network that supports high-bandwidth and communicates with NTCIP-compliant ITS and ATMS devices. Implementation of communications upgrades include revisiting network architecture, comprehensive replacement of wireless equipment, expansion of fiber plant, and investigating third-party lease opportunities.

8.3.2 Network Architecture

As noted in the City of Missouri City Concept of Operations, the City experiences severe video delays, lags and outages when more users than normal are accessing the video feeds, particularly during inclement weather and heavy traffic events. The City requires a network architecture that:

- ▶ Maximizes legacy investment,
- ▶ Addresses fiber and wireless subsystems,
- ▶ Provides structure and bandwidth to account for anticipated infrastructure growth,
- ▶ Provides redundancy and expandability,
- ▶ Provides bandwidth and greater signal strength to address video lag issues,
- ▶ Includes enhanced EOC/PD connectivity,
- ▶ Supports connection to TxDOT and City of Sugar Land for video and DMS data share,
- ▶ Provides for Smart City initiatives and data analytic applications, and
- ▶ Investigates third-party lease opportunities such as AT&T and Verizon.



8.3.3 Wireless Communications

The City would benefit by continued investment in a comprehensive replacement of the existing wireless communications system including antenna, radios, old or malfunctioning Ethernet switches and other aging networking equipment and infrastructure necessary to operate a reliable and maintainable communications subsystem. The City should continue replacement of older radios to Cambium and upgrade the existing ethernet switches to a more industrial grade product. EtherWAN prepared a proposed design that utilizes a three-tier architecture: intersection switches connected to field devices, hub switches connected to intersection switches, and a core switch connecting hub switches to the TMC. The EtherWAN design also included EtherWAN wireless radios and a user-friendly network management interface. The City may consider developing wireless equipment specifications for planned and future projects or capitalize on regional efforts to date and use wireless ITS and ATMS equipment specifications from TxDOT, Harris County and/or City of Houston.

8.3.4 Fiber Optic Communications

Fiber optics offer the most reliable, flexible, and expandable communications solution for the City of Missouri City. When possible, the City should expand fiber deployment via traffic signal projects, roadway projects, drainage projects, utility projects, and dedicated fiber projects. The City should expand fiber to critical locations most impacted by rapid growth and inclement weather such as the Sienna/South Tower. The City should develop a citywide fiber optic plan that incorporates connection of multiuse city facilities not just at traffic and law enforcement facilities, but at schools, libraries, parks and other locations. The fiber plan should provide for collaboration between Public Works and the City IT departments for the purpose of sharing capital and maintenance costs.

8.3.5 Battery Backup Units (BBU)

Battery Backup Units (BBU) provide backup power when power is lost, monitor low and failed batteries, and sends alerts on battery status and when cabinets are operating using battery power. All City traffic cabinets have adequate BBUs, most installed in the last 10-15 years. As more technology is installed in roadside cabinets, the impact of power failures become even more critical. Traffic signal operation interruption leads to safety hazards and anxious motorists and demands more robust and systems-centric power protection solutions. New generation BBUs are reliable, powerful, and easy-to-use. Upgrading BBUs will result in improved intersection safety, reduced operating and maintenance costs, and extended battery life.

Advanced features offered in newer BBU models include network friendly features such as comprehensive remote monitoring and control allowing users to configure, receive notifications, review event logs, run diagnostics test, check battery runtime status, and collect and distribute critical alerts and data from anywhere on the network via a web browser. Additional network features include the latest (embedded) network communication protocols for security and integrated temperature compensated charging systems. Estimated runtimes are 7.5 hours at full load and 3.5 hours at half load.

8.3.6 Weigh-In-Motion

Weigh-in-motion (WIM) systems are designed to capture and record truck axle weights and gross vehicle weights as they pass over sensors. Unlike static weigh stations, WIM systems do not require trucks to stop making them more efficient. Gross vehicle and axle weight data is useful for several reasons including pavement and bridge design, monitoring, and research; legislation and regulation; size enforcement; weight enforcement; and, in the City's case, pavement preservation. Data indicates an average 5-axle semi tractor-trailer vehicle weighs approximately 36,000 lbs empty and 80,000 lbs full. Overloaded trucks cause significant damage to street and highway pavements.

8.3.6.1 Advantages of WIM

- ▶ **Processing Rate.** Trucks can be weighed at highway speeds, yielding a greater number of counts in a much shorter time (compared to weigh stations).
- ▶ **Safety.** Decreases vehicle accumulation at highway lanes leading to weigh stations.
- ▶ **Continuous data processing.** Performed continuously rather than static (sample) weighing.
- ▶ **Increased coverage and lower cost.** More sites for the same cost.
- ▶ **Minimized scale avoidance.** WIM monitors truck traffic without alerting truck drivers, resulting in more accurate data as overweight trucks are less likely to avoid weigh stations.
- ▶ **Dynamic loading data.** Unlike weigh stations, WIM records dynamic axle load information, which may be greater than static load information.

8.3.6.2 Disadvantages of WIM

- ▶ **Less accurate.** National Bureau of Standards requires to have an accuracy of ± 1 -2%. The best accuracy obtained with the most expensive WIM system is 6% for 95% of measured trucks.
- ▶ **Reduced information.** Information easily collected at weigh stations such as fuel type, state of registry, year model, loaded / unloaded status, origin, and destination is not collected with WIM.
- ▶ **Susceptibility to damage from electromagnetic transients.** WIM systems are sensitive to electromagnetic disturbances caused by lightning strikes.

8.3.6.3 Contemporary WIM Technology

- ▶ **Piezoelectric Sensor.** Most common WIM sensor is pavement-embedded and produces a charge equivalent to deformation induced by tire loads on the pavement surface. Provides gross vehicle weights within 15% of actual vehicle weight for 95% of the measured trucks.
- ▶ **Piezoelectric Quartz Sensor.** Most accurate WIM sensor is pavement-embedded along with piezoelectric quartz disks produces electrical charge proportional to applied forces and then converted into voltages for processing. Accuracy is not influenced by tire type, quantity or pressure and achieves an accuracy of 2.5 % and features an extremely long high lifetime.
- ▶ **Bending Plate.** Bending scales consists of two steel plates instrumented with strain gages, which measures tire load induced plate strains. Bending plate accuracy is 10% for 95% of measured trucks.
- ▶ **Single Load Cell.** Consists of two platforms adjacent to monitored lane with hydraulic load cell installed at center of each platform to measure load induced forces. Accuracy is 6%.

Source: www.pavementinteractive.com

8.3.6.4 Conclusion and Recommendation

The damaging effects of overloaded trucks on pavement include fatigue, which reduces pavement design life, and rutting which causes maintenance problems, resulting in increased maintenance and rehabilitation costs. According to an Urban Institute report, the annual expenditure on streets and highways in the U.S. was \$181 billion in 2017, three quarters of which comes from states and local governments like the City.

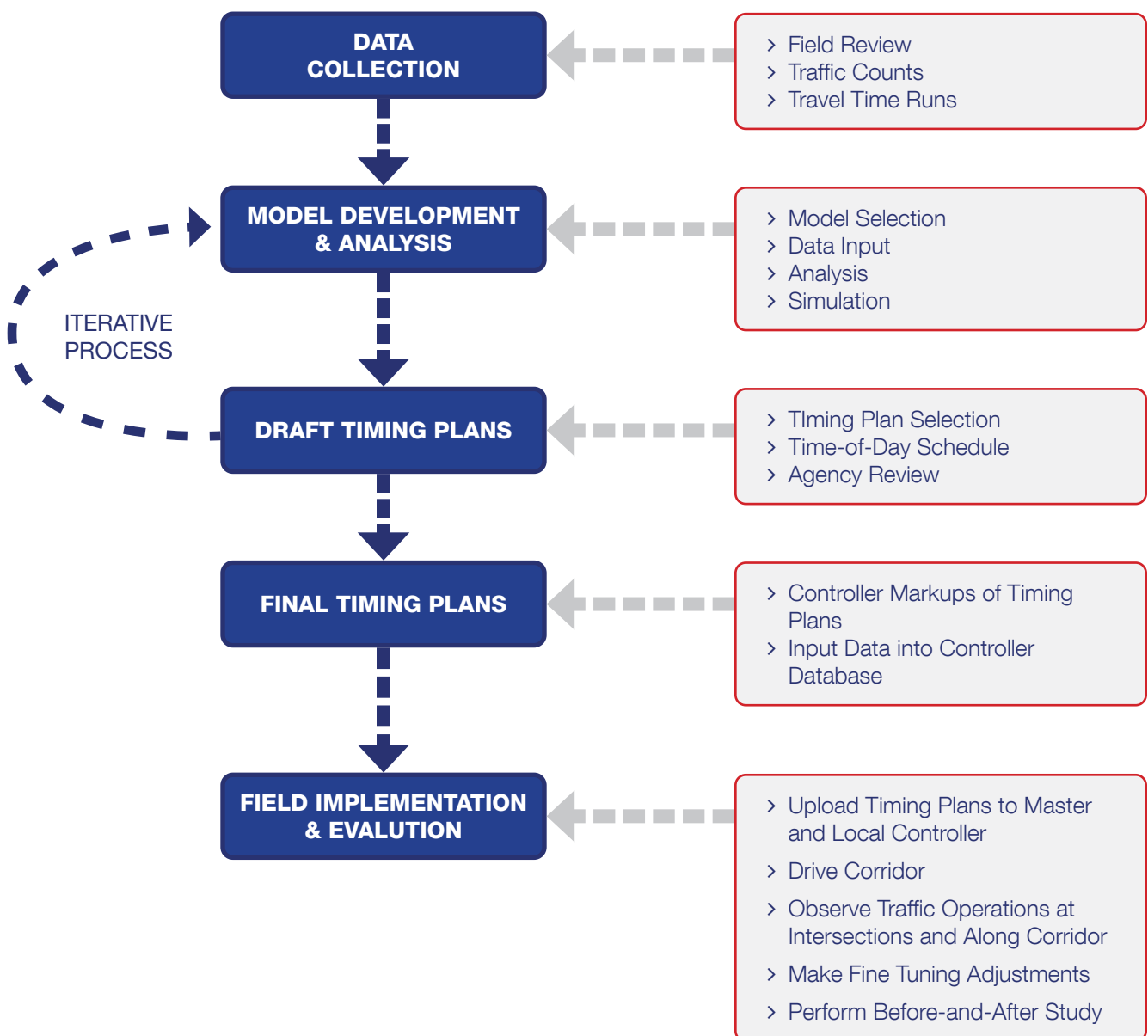
It is recommended the City develop a Preliminary Engineering Report (PER) to more closely study the most appropriate WIM technology, locations, and implementation methodology for the City. The PER should also investigate enforcement strategies and processes that could potentially generate funding sources for pavement repairs. It is further recommended the City use the **FHWA Weigh-In-Motion Pocket Guide** as a resource for developing WIM solutions. The guide provides traffic professionals information on WIM technology selection, data acquisition requirements, procurement, site selection, design, installation, maintenance, and calibration. In addition, the guide has four instructional video supplements showing installation for different types of WIM sensors.

8.3.7 Signal Timing Program

The Traffic Signal Benchmarking and State of the Practice Report, prepared in 2019 by the National Operations Center of Excellence (NOCoe) and Institute of Transportation Engineers (ITE), includes a self-assessment of 144 agencies representing 24% of all traffic signals throughout the U.S. (327,860 total signals). The average “Overall” Grade was C+ and the average “Operations” Grade was a C+. Research and experience show retiming traffic signals is one of the most cost-effective tasks an agency can do to improve traffic flow and can often improve traffic flow by 25% or more. The FHWA Traffic Signal Timing Manual recommends signals be timed every 3-5 years. The TxDOT Statewide TSMO Strategic Plan Update, July 2021, lists as its first Business Processes Strategy No. 1: Develop methodology to allocate ITS/Signals O&M funding to align with TSMO goals. However, despite TSMO emphasis on signal timing and proof of its effectiveness, budget constraints restrict agencies from developing and implementing sustainable signal timing programs using conventional methods (see [Figure 8.3.7A](#)).

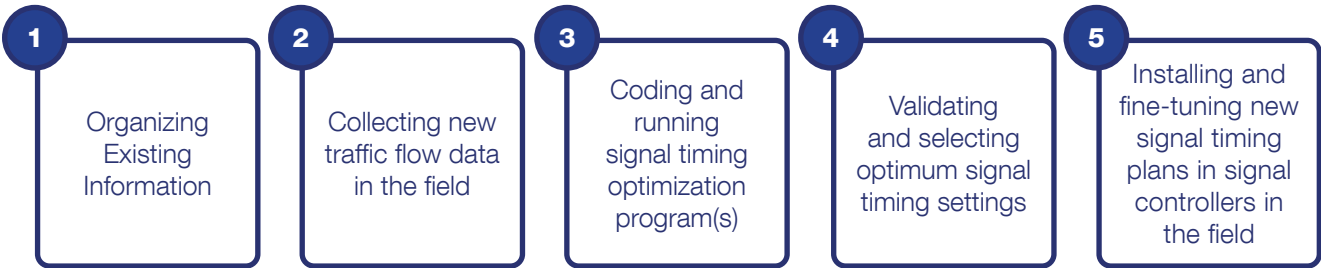
▼ **FIGURE 8.3.7A – CONVENTIONAL SIGNAL TIMING METHODOLOGY**

Source: FHWA Traffic Signal Timing on a Shoestring



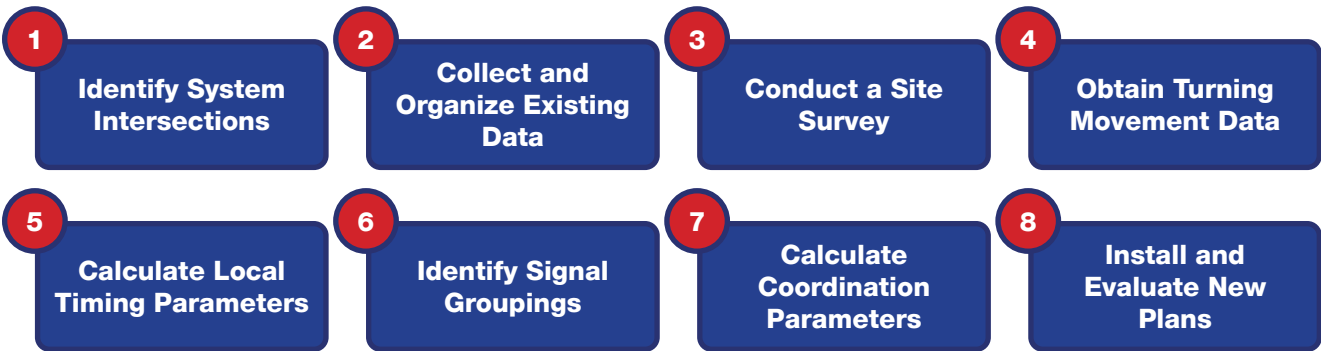
The conventional approach to signal timing optimization and field deployment requires current traffic flow data, experience with optimization models, familiarity with signal controller hardware, and knowledge of field operations including signal timing fine-tuning. This often daunting process is time-consuming and expensive, and involves five distinct steps:

CONVENTIONAL APPROACH TO SIGNAL TIMING OPTIMIZATION



However, practitioners across the country have developed practical and cost-effective timing methods that still generate signal timing plans almost as effective as timing developed using the formal process, commonly referred to as “near-optimum” plans. When faced with a lack of resources, these “shortcut” methods should be considered, rather than not retiming the signals at all. The FHWA Signal Timing on a Shoestring report examines informal traffic signal timing processes and defines methods to minimize cost of generating near-optimum timing plans. In short, the report shows how good signal timing plans can be developed and updated efficiently at the lowest possible cost. The report identifies an eight-step process:

UPDATED APPROACH TO SIGNAL TIMING OPTIMIZATION



The report details each step and identifies procedures to minimize costs in each step. The report also offers a “toolbox” of procedures and examples of how the toolbox can be used with minimal budgets.

8.3.7.1 Conclusion and Recommendations

Funding for ITS and traffic signal operations and maintenance (O&M) significantly lags the need. O&M funding is often discretionary and used for roadway and other maintenance rather than signals. There is a need to develop a dedicated, sustainable funding source to ensure low-cost, high-yield O&M improvements such as regularly scheduled signal retiming is unthreatened. There is a need for a Conflict Monitor Tester to accurately gauge the performance, functionality and reliability of the traffic signal system.

O&M fund allocation should be revisited and a methodology developed that capitalizes on available and eligible federal, state, and local funds created and/or supported by the Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law. Consideration should be afforded to requesting and programming funds to cover lifecycle costs with strong emphasis on O&M costs for a five-year funding program. The methodology should provide for an equitable balance of O&M funds for ITS/Signals as compared to roadways, bridges, and other facilities. To the extent possible, the City should utilize other improvement projects such as roadway rehabilitations and drainage systems installs as a signal retiming vehicle.



8.3.8 Smart City

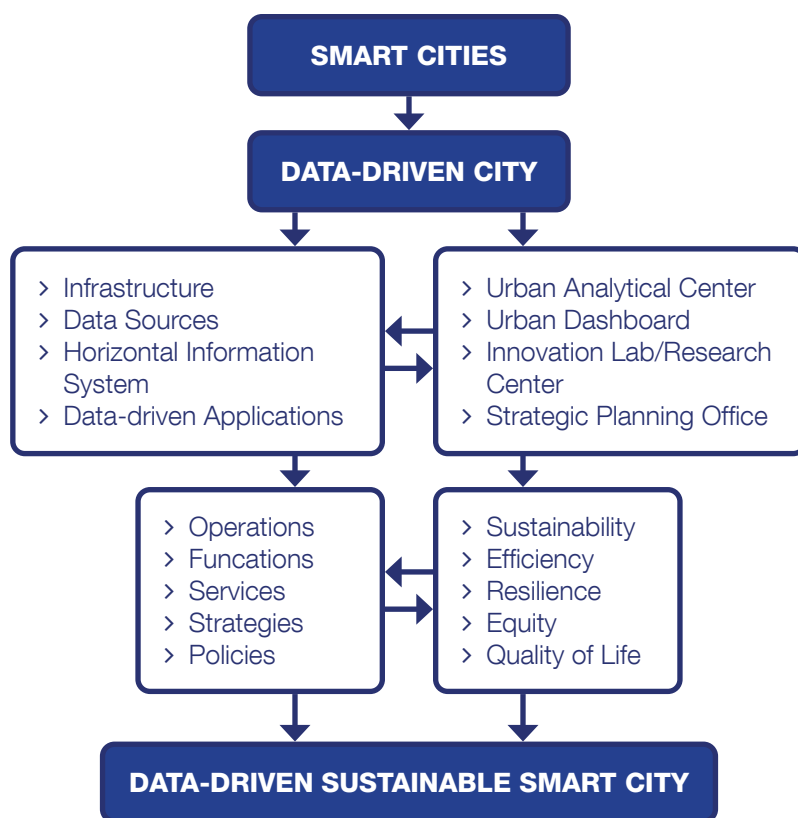
The definition of a Smart City varies extensively depending on the vision and goals of a City. FHWA defines a Smart City as “a system of interconnected systems, including employment, health care, retail/entertainment, public services, residences, energy distribution, and not least, transportation. The system of systems is tied together by information and communications technologies (ICT) that transmit and process data about all sorts of activities within the City.” The City of Missouri City Operations Concept defines a Smart City as “data sharing, a modern ATMS, and other abilities to distribute information.” For perspective, IBM defines a Smart City as “one that makes optimal use of all the interconnected information available today to better understand and control its operations and optimize

the use of limited resources.” Smart cities use information and communications technology (ICT) in conjunction with the Internet of Things (IoT) to optimize efficiency and enhance quality of life.

Cities contain 54% of the world's population and is expected to increase to 66% by 2050. This projected growth has led to investment in infrastructure for transportation, water, electricity, and telecommunications to be estimated at \$53 trillion from 2010 to 2030. (Source: Multidisciplinary Digital Publishing Institute (MDPI) Article Implementing Data-Driven Smart City Applications for Future Cities). Below represents a high-level overview of the data driven decision process.

There are Smart City initiatives in many large and mid-size cities across the U.S at various stages of development, some more sophisticated than others. For example, Austin, Texas is a leading U.S. Smart City with an innovative, technology-centric transportation plan that includes automated and connected vehicles, intelligent sensors, open data, real-time traveler information, and regional partnerships with TxDOT, the University of Texas, and Austin Energy. Boulder, Colorado on the other hand focuses on developing a smart energy grid, the first in the country, in addition to addressing climate change and sustainability through Smart City initiatives. Examples and variants are wide-ranging as the number of Smart Cities in the U.S. and around the world continues to grow and evolve. Accompanying this Smart City growth and development is extensive literature and research offering guidelines on Smart City initiatives designed to drive data driven decisions. This evaluation focuses on those initiatives identified in the Operations Concept Workshop as well as some “low-hanging fruit”, i.e., common, low-cost, low-effort, high-yield initiatives that directly benefit the City's start towards becoming a Smart City.

Data-driven smart technologies generate vast amounts of data. Harnessing and effectively using this data will help the City cost-effectively forecast, respond, and plan for future mobility investments. Data



▼ **FIGURE 8.3.8A - ENERGY INFORMATICS**

Source: *Energy Infomatics.com* (The emerging data-driven Smart City and its innovative applied solutions for sustainability: the cases of London and Barcelona)

driven results have proven to be impactful and may include improved productivity, smarter decision-making processes, cost efficiencies, new opportunities for innovation, new products and services, new and increased revenue streams, and shift towards a data-driven culture.

8.3.8.1 Proposed Initiatives

8.3.8.1.1 Deploy Smart Devices

Transportation infrastructure improvement and rehabilitation projects are ideal opportunities to install or retrofit smart devices such as smart sensors. The difference between smart sensors and standard sensors is intelligence capabilities inherent in new-generation integrated microprocessors with digital processing, analog-to-digital or frequency-to-code conversions, calculations, and interfacing functions which facilitate self-diagnostics, self-identification, and decision-making functions.

8.3.8.1.2 Formalize Partnerships

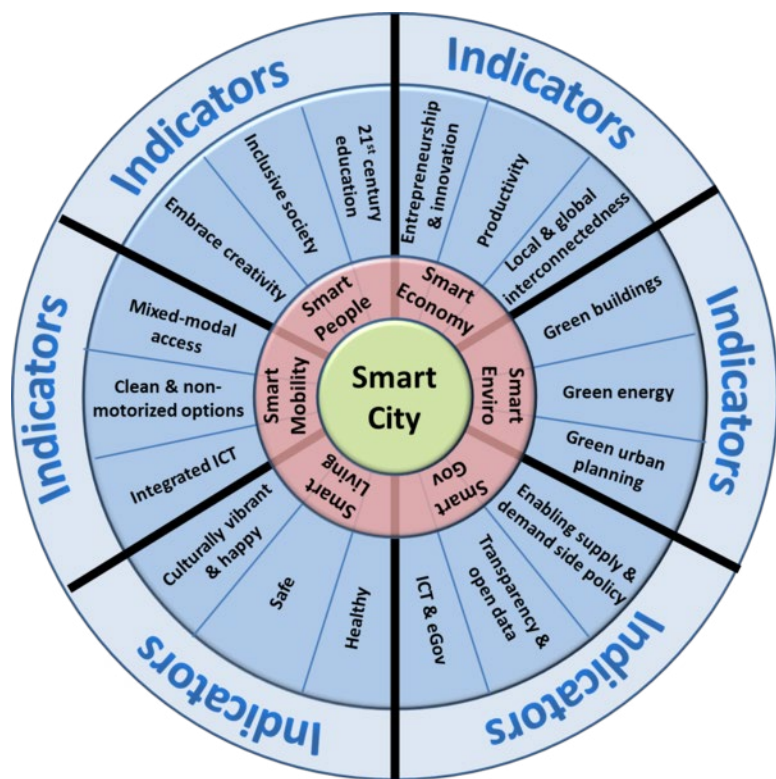
Partnerships with public agencies, local organizations, academia, research groups, and other stakeholders improve the local data ecosystem and can help the City manage the technical complexities as well as funding and analysis needs.

8.3.8.1.3 Develop Data Management Strategy

A data management strategy will provide opportunities to maximize data and collectively co-relate with similar datasets, often from other similar entities or sources. Strategy should include a citywide data collection plan that includes air quality, noise, weather, and traffic information. Data compatibility is an issue that cities have struggled with for years and may be worse when IoT and big data solutions generate extensive new information without a plan. Developing clear standards for data collection, storage, and sharing can prevent fragmentation and encourage collaboration and growth.

8.3.8.1.4 Incorporate Smart City Indicators (SDI)

The Smart Wheel, developed by renowned urban and climate strategist Boyd Cohen, identifies six Smart City Indicators (SDIs). It is universally accepted that an approach covering all six indicators is a holistic strategy towards becoming a Smart City. As depicted in the Smart Wheel, the six SDIs are Smart Government, Smart Economy, Smart Environment, Smart Living, Smart Mobility, and Smart People.



▼ **FIGURE 8.3.8.1.4A - SMART WHEEL BY BOYD COHEN**

8.3.8.2 Smart City Dashboard Case Study: London

Urban Smart City dashboards generate visualizations that help users interpret and analyze information. London is recognized as one of the foremost Smart Cities in the world and uses dashboards to communicate live feeds of real-time data to citizens. As depicted below, the dashboard provides real-time information about the weather, air pollution, public transit schedules and delays, electricity demand, public bike availability, traffic conditions, and more. The dashboard relies on big data to track city performance in numerous areas including, but not limited to, transportation, environment, health, housing, communities, jobs, economy, and crime.

▼ **FIGURE 8.3.8.2 - LONDON DASHBOARD**

Source: Energy Informatics.com

(The emerging data-driven Smart City and its innovative applied solutions for sustainability: the cases of London and Barcelona)



8.3.8.3 Conclusion

Smart Cities leverage ICT and IoT to enhance service levels, citizen well-being, sustainability, and economic development. Given the City's planned and projected growth, Smart City technology will make the City more effective and efficient. Expected benefits include:

- ▶ More effective, data-driven decision-making
- ▶ Enhanced citizen and government engagement and alignment
- ▶ Safer communities
- ▶ Reduced environmental footprint
- ▶ Improved transportation
- ▶ Increased digital equity
- ▶ New economic development opportunities
- ▶ Efficient public utilities
- ▶ Improved infrastructure
- ▶ Increased workforce engagement

8.3.8.4 Recommendations

It is recommended the City consider implementing strategies today to prepare for CAV integration in the future.

8.3.9 Connected and Automated Vehicles (CAV)

In a Smart City environment, a network of sensors connected to the internet will communicate with each other to build a City data map. Sensors will be everywhere including traffic signals (Applied Information), smart traffic devices, streetlights, buildings, and even road surfaces. The center of this information network is projected to be the Connected and Automated Vehicle (CAV). In the next few years, 75% of all cars will be connected to the internet, generating massive amounts of data. Sensors in cars will collect and transmit data about other vehicles, cyclists, pedestrians, and road conditions using vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X) protocols. Cars will be WiFi hotspots, creating a moving network from where data can easily be shared with City staff. City planners will be able to assess travel times, bottlenecks, fuel and charging station availability, trip origins and destinations, and more. Vehicles may also be able to make real-time traffic signal changes to ease congestion.

Suggested strategies include reviewing transportation projects for CAV opportunities, including CAV in the planning process, standardizing traffic control elements such as signing and striping, promoting electric vehicle (EV) infrastructure, and educating the public.

To prepare for, and optimize, connected vehicle integration, the City needs sensors, smart traffic devices, robust communications, and secure IT systems to handle projected data increase.



8.4 PERFORMANCE MEASURES

8.4.1 Automated Traffic Signal Performance Measures (ATSPM)

Agencies across the U.S. are putting more emphasis than ever on performance measures and objective-based decisions. With the development of TSMO Strategic Program Plans, Automated Traffic Signal Performance Measures (ATSPM) are gaining traction and getting more attention by states and local municipalities as a means of cost-consciously assessing the effectiveness and efficiency of traffic signal operations. Even though more agencies are investing in sophisticated traffic signal communications and central software, metrics for evaluating signal performance has lagged. ATSPM are tools available to agencies to manage traffic signal systems and consist of a collection of data analytics tools and approaches that automatically collect and convert high-resolution traffic signal controller data into actionable performance measures. The FHWA Every Day Count 4 Program focuses on ATSPM implementation citing ATSPM help agencies quickly identify issues, proactively respond to issues, efficiently operate traffic signals via improved timing, and easily communicate outcomes to engineers, decision makers, and the traveling public.

Agencies typically retune signals on a three- to five-year cycle at significant effort and cost following a project-based process. For many signals, citizen complaints are the primary measure of performance. Intersection performance is normally simulated based on manual traffic data collection, adding cost and time to the signal retuning process. The resulting timing parameters are then implemented in the field, fine-tuned based on observations, and a comparison of before and after travel-time data is performed to demonstrate the effectiveness of optimization efforts. No ongoing performance measurement capability exists, compromising safety and efficiency and contributing to congestion. An objectives-based traffic signal program follows a more operations-based approach. After establishing traffic signal program objectives based on goals and context, performance measures are identified and continuously used to monitor the effectiveness of strategies and tactics, and corrective actions are more immediate.

Early development of ATSPM concepts evolved from a partnership between the Indiana Department of Transportation (DOT) and Purdue University in 2002 to evaluate vehicle detection devices. Additional early development was also done by Georgia DOT and Utah DOT. Utah DOT has since developed open-source software code for any agency to install and implement free of charge. At least 17 agencies (DOTs, counties, and cities) have deployed ATSPM software developed by UDOT, along with the documentation to help them install and operate it. The UDOT ATSPM dashboard provides a user-friendly way for traffic staff, the public and others to access performance measures at specific signals and during specific days and times. Users can choose from available measures to customize data and reports. However, this is not the only option for ATSPM and may not be best for smaller agencies with limited IT resources.

A typical ATSPM consists of five components: high-resolution signal controller, communications, software, central server for data storage, and detection (optional). Communications can be continuous (such as fiber or wireless), periodic (such as a dial-up connection), or manual (obtained by field technician). Basic ATSPM can be achieved without detection (green time analysis, for example), but detection provides much more advanced capabilities, and advanced and specialized detection such as setback detectors, speed detectors, and turning movement detectors can obtain an even greater number of ATSPMs. A list of performance measures with their descriptions can be found in Appendix D, Automated Traffic Signal Performance Measures. The three methods of ATSPM implementation are:

- ▶ **Open-Source ATSPM Software:** Open-source UDOT ATSPM software freely available on the US DOT's Open-Source Application Development Portal. Agencies provide and maintain data storage are responsible for configuring and hosting local installation.

- ▶ **Integrated ATSPM Solution:** Certain traffic controller vendors offer ATSPM capability in conjunction with their central traffic signal system management software. Some Econolite software has performance measurement functionality. CentraCS Mobility offers signal performance measures, CentraCS SPM offers user-selectable data parameters and user-definable performance metrics, and CentraCS MMS offers maintenance performance measures.
- ▶ **Third-Party ATSPM Solution:** Third-party provider hosts ATSPM data in the cloud. Supplemental data collection equipment is often installed to collect and forward data to the third-party provider. This solution usually involves subscription fees. In today's marketplace, ATSPMs are a mainstream tool for signal operations. In addition to the open-source software, several vendors offer ATSPM software including:
 - ▶ Utah open-source ATSPM software,
 - ▶ GDOT open-source ATSPM software,
 - ▶ Live Traffic Data Corp
 - ▶ Iteris® Signal Performance Measures (SPM)™
 - ▶ Kimley-Horn Traction SPM
 - ▶ TraffOp
 - ▶ Econolite CentraCS® SPM
 - ▶ Intelight MAXVIEW
 - ▶ Trafficware Cloud SPM

Source: FHWA Methodology and Case Study: Evaluating the Benefits and Costs of Implementing Automated Traffic Signal Performance

8.4.2 Benefits and Challenges

Agencies that have implemented ATSPMs report significant benefits. Although some agencies quantify benefits in terms of signal maintenance cost savings and/or travel time savings, the generalized benefit is obtaining invaluable data traffic engineers can use provide efficient and effective traffic control systems to the public. Other benefits include improved public safety, decreased travel times and delays, savings, maintenance efficiency and costs, public information, low-cost implementation, and remote intelligence and monitoring (saving valuable field technician time). However, ATSPM deployment does not come without challenges such as staffing resources, technical support, internal IT policies and procedures, data storage, and establishing an ATSPM culture among traffic engineers and technicians unfamiliar with ATSPM use or benefits.

8.4.3 Conclusion and Recommendation

The City can benefit from implementing ATSPM in terms of improved operations and safety, enhanced public information and minimizing costs. It is recommended the City consider either using the open-source programs or contracting with a third part provider to deploy and report ATSPM for the City.

8.4.4 Operations Performance Measures

Traffic operations performance measures, sometimes called measures of effectiveness (MOEs), are quantitative estimates on the performance of a transportation facility or system with respect to goals and objectives. Some common performance measures include level of service, accidents, travel times, average speeds, incident durations, volume to capacity (v/c) ratio, level of service (LOS), and delay. According to FHWA, a successful performance measurement system:

- ▶ Comprises a balanced set of a limited vital few measures,
- ▶ Produces timely and useful reports at a reasonable cost,
- ▶ Displays and makes readily available information that is shared, understood, and used by an organization, and
- ▶ Supports the organization's values and the relationship the organization has with customers, suppliers, and stakeholders.

8.4.4.1 Major Issues in Operations Performance Measurement

- ▶ Cost of data collection
- ▶ Assuring appropriate comparisons to other operations
- ▶ Data quality
- ▶ Data completeness
- ▶ Extrapolating from partial coverage
- ▶ Matching measures to their purposes
- ▶ Understanding extraneous influences in the data
- ▶ Conflicts with other measuring programs - which is “right”
- ▶ Timeliness of data for measures
- ▶ Use of measures in allocation of funding
- ▶ Liability for action (or lack thereof) based on measurement results
- ▶ Responsibility for measures for which there may be limited control
- ▶ Benchmarking and targets
- ▶ External factors
- ▶ Good multimodal measures

Source: FHWA Performance Measurement Fundamentals

8.4.4.2 Conclusion and Recommendation

Performance measurement uses evidence to determine progress toward specific goals and objectives, including quantitative measurement such as travel times and possibly even qualitative measurement such as customer perception. Dashboards or other visual reports provide easily accessible and understandable vehicles for user consumption. It is recommended the City implement, at a minimum, a mission-critical operations performance measurement program.

8.4.5 Maintenance Performance Measures

Maintenance performance measures, also referred to as key performance indicators (KPIs) are metrics that monitor performance against goals tied to things like equipment failures, downtime, repair times, maintenance backlogs, and costs. Maintenance KPIs include: downtime, mean time to repair (MTTR), mean time before failure (MTBF), preventative maintenance compliance (PMC), maintenance backlog (delays), cost savings, and logged maintenance calls.

The best way to track maintenance KPIs is to use a commercial maintenance management system (software). There are several products in the marketplace including the Econolite Centracs MMS which offers asset management, preventative maintenance features, call ticket support, scheduling features and mobile app support. The City has made recent investment in Cartegraph, a popular public works software program that offers asset management, work order management, and space management. Another similar and popular product is Citiworks, a cloud-based GIS-centric asset management system.

8.4.5.1 Conclusion and Recommendation

Maintenance Performance Measures automate the management of assets, workflow, field workforces, maintenance business processes, reporting and documentation, health and safety, and other components of comprehensive maintenance activities. It is strongly recommended the City take advantage of the Cartegraph tool available to them for automated maintenance management of their traffic control and ITS systems, components, and equipment.

8.4.6 Data Collection Plan

Data collection is an important step in many of the activities outlined in this plan.

A clear and concise data collection plan will help streamline the data collection process and includes:

- ▶ Identify how much data needs to be collected, data sources, and time to collect the data.
- ▶ Identify types of data, frequency of collection, retention, and storage.
- ▶ Identify charts and graphs to be used, charting frequency, and type of comparisons to be made.
- ▶ Identify the characteristics and attributes of data to be collected.
- ▶ If the performance measure is new, identify existing data sources or create new sources. All data sources need to be credible and cost effective.

8.5 DATA ANALYTICS AND BIG DATA

By 2050, more than two-thirds of the world's population will live in urban areas. This unprecedented urbanization requires deeper understanding of travel habits and trends. Traffic data analytics are becoming more important as our cities become more congested. Agencies responsible for urban planning and mobility rely on traffic data and accompanying dashboards to understand how vehicles travel and to analyze traffic data in real time. Big Data providers offer insights to mobility patterns that can help municipalities make smarter decisions in city planning, infrastructure investment and mobility optimization. Traffic data attributes may include traffic count data, traffic speed data, traffic congestion data, traffic incident data, and vehicle classification data. Data is obtained by a variety of methods including traffic sensors, traffic cameras, mobile devices and connected vehicles. Some of the most common traffic data providers are INRIX, Waze, and StreetLight. Others include Teralytics, Here, Wikiroutes, TomTom, mapbox, and Live Traffic Data. Two data analytics start-ups that recently received, along with INRIX, data collection and analytics contracts with the Texas Department of Transportation are Replica and Wejo. The City of Missouri City is eligible to access this TxDOT data as it is available to all state agencies as well as local municipalities. Below is a brief summary of Waze and StreetLight for informational purposes but the focus should be on INRIX, Replica and Wejo since they are available to the City.

8.5.1 Waze

Waze leverages data from millions of drivers in real time to build the world's largest database of road data. Waze partners with municipalities and transit authorities to provide traffic insight and assist cities to better plan the future. Waze features uninterrupted navigation underground where GPS signals reach.

8.5.2 StreetLight Data

StreetLight Data transforms data from millions of mobile devices to on-demand traffic insight for transportation planners, modelers, and engineers. StreetLight products include metrics such as AADT traffic counts, origin-destination data, turning movement counts, VMT, vehicles hours of delay (VHD), demographics data, link analysis, inferred trip purpose, and trip speed, travel time, and length. StreetLight also provides mode information such as origin-destination analytics, routes, and trip attributes for bicycles and pedestrians, personal vehicles, bus and rail, ride hailing and delivery, and truck trips.

Source: <https://www.streetlightdata.com/>



8.5.3 INRIX

INRIX provides real-time, location-based data collection and analytics for traffic conditions, road safety, and parking availability worldwide, utilizing Waze as its turn-by-turn navigation tool. Founded in 2005, INRIX pioneered the practice of managing traffic by analyzing data not just from road sensors, but also from vehicles. INRIX collects anonymized data on congestion, traffic incidents, parking, and weather-related road conditions from millions of data points daily in 145 countries. Data is aggregated from connected cars, mobile devices, roadway cameras and sensors, and major events affecting traffic. INRIX works closely with automated vehicle (AV) stakeholders to establish rules and protocols of AV data extraction and application.

INRIX uses real-time, predictive, and historical traffic data to allow for planning, analysis, and operation of roadways. INRIX tools can effectively optimize signal timing resulting in improved traffic flow and reduced greenhouse gas emissions, digitally manage on-street parking inventory, and provide information regarding travel patterns to aid in corridor analysis and congestion studies. INRIX additionally allows for real-time crash data and road weather information to be communicated thus enhancing emergency response time and road safety. INRIX has been the preferred data supplier of the United States Federal Highway Administration (FHWA) and several State DOTs and MPOs nationwide since 2017. This year, the U.S. FHWA announced they will continue to use INRIX traffic data for assessment of congestion, emissions, and travel reliability.

Application Programming Interface (PI) applications include **INRIX Parking** helps users find available parking and compares prices; **INRIX IQ** compiles and analyzes traffic patterns, congestion, traffic signals, safety and another transportation information used by commuters, businesses, and municipal planners; and **INRIX AI Traffic** which uses anonymized wireless data from drivers' cell phones and automobiles to provide live traffic data to users. INRIX also provides mobile phone and in-car applications, and publishes research reports on traffic congestion, parking, roadway safety, and autonomous vehicles in major cities.

8.5.4 Replica

Replica provides comprehensive, high-fidelity data collected from disparate datasets to present a holistic view of mobility, land use, people, economic activity, and the ways they interact. Replica has over 60 clients across the U.S. including state transportation departments, transit authorities, and a wide range of small and mid-size local government agencies. Replica's mission is "To organize the world's information about the built environment and make it accessible, valuable, and actionable". Replica data supports transportation and city planning and understanding activity in the built environment. In addition to commute patterns, bike and pedestrian traffic, network link volumes, online and in-person spending, week-over-week retail spending, and shopping trip origins, Replica supports numerous analyses including:

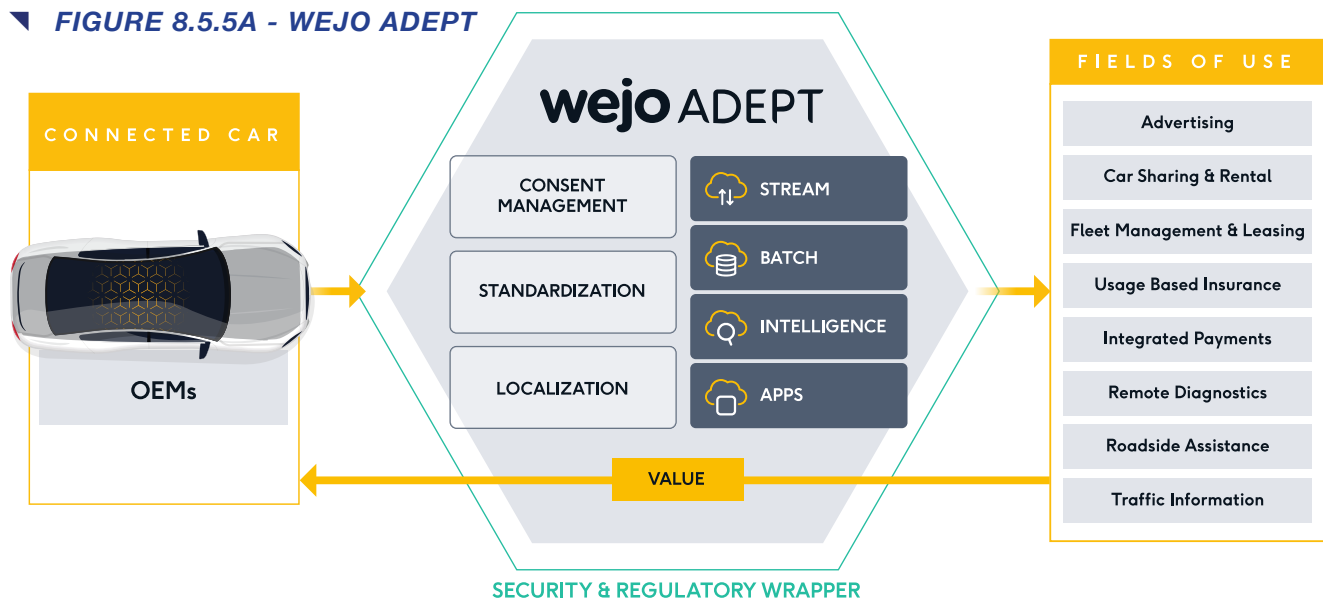
- ▶ Origin-destination flows
- ▶ Pandemic recovery
- ▶ Residential profile conditions
- ▶ Freight studies
- ▶ Corridor studies
- ▶ Workforce profiles
- ▶ Tax forecasting
- ▶ Transit studies
- ▶ Environmental justice
- ▶ Active transportation
- ▶ Economic impact

Replica solutions have been used by 1) El Paso Metropolitan Planning Organization to examine economic segregation in order to take more comprehensive approaches to delivering equitable outcomes, 2) Sacramento Area Council of Governments to implement SB 743 which requires planners to study how a transportation project will affect vehicle miles traveled (VMT) added to the roadway network, and 3) Chicago Regional Transportation Authority to understand how commuting habits are changing over time, and what impact that has on funding streams from sales taxes and rider fares.

8.5.5 Wejo

Data from autonomous, electric, and connected vehicles is becoming increasingly available as more cars become more sophisticated, creating extensive, reliable and accurate data. Wejo collects, organizes, and analyzes data from connected, electric and autonomous vehicles exclusively, i.e., Wejo doesn't use sensor, camera, or mobile device data. Wejo currently streams massive volumes of autonomous, electric, and connected vehicle data from trillions of processed data points from millions of vehicles, covering 95% of roads in the U.S. with location data accuracy within 3-meters captured every 2 seconds. Wejo curates and standardizes raw car data and streams directly to clouds or APIs. Wejo solutions currently deployed include optimizing traffic signals, establishing dynamic pricing, determining timelines for construction closures, enhancing incident detection and response, and using data from connected vehicle journeys to model and predict how new roadways and traffic signals impact traffic patterns. Wejo data products include Road Health, Winter Road Insights, Historic Traffic Patterns, Real-Time Traffic Intelligence, Driving Events, Vehicle Movements, Journey Intelligence, Traffic Intelligence, Historic Traffic Patterns, Intersection Performance, Origin Destination, Waypoints, and Points of Interest.

▼ **FIGURE 8.5.5A - WEJO ADEPT**



A new breed of data analytic providers is emerging including **Flow Labs** and **Urban Logic**. **Flow Labs** integrates data sets from multiple sources and applies proprietary machine learning (AI) algorithms to provide traffic analytics, predictive traffic control, health monitoring, signal optimization, and performance management with a 94.4% accuracy rate with no hardware investment or deployment.

Source: <https://www.flowlabs.ai/>

Urban Logic is a nonprofit organization blending design, finance, technology, systems, and organizational management for the purpose of appropriately focusing funding “to improve urban quality of life, sustainability and resiliency” for businesses and residents through:

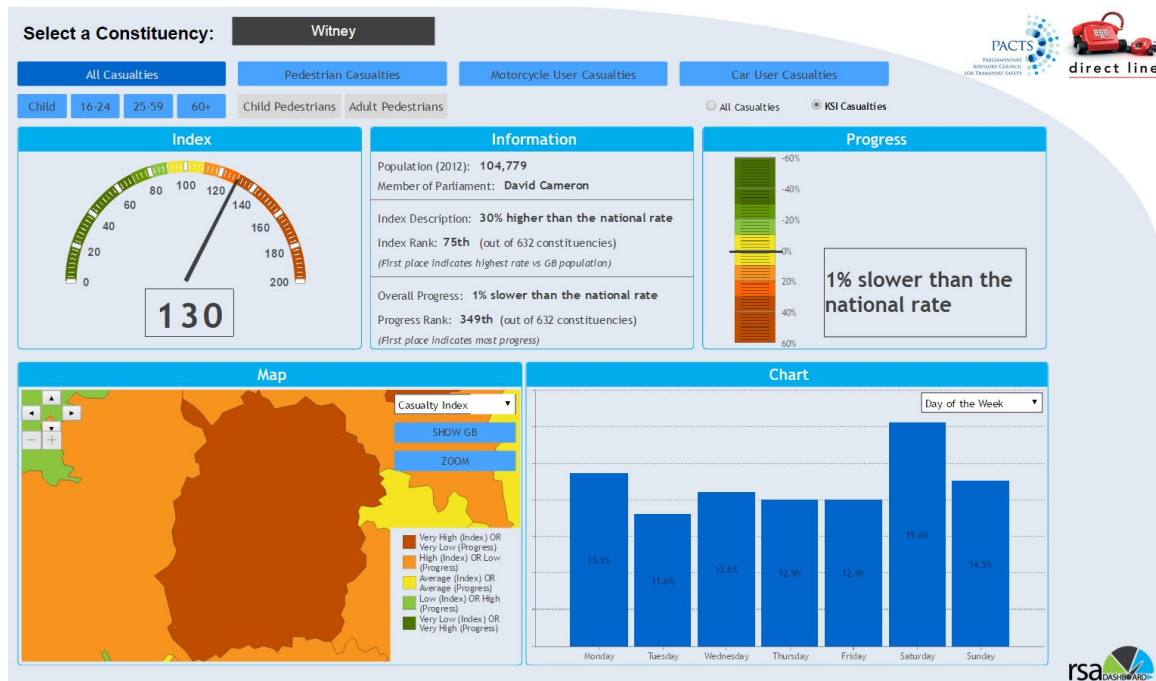
- ▶ understanding urban and regional demographics,
- ▶ improving urban information management and digital government accessibility,
- ▶ improving urban financial management, empowerment and capital availability,
- ▶ improving holistic construction design, project management and finance,
- ▶ exploring financial, insurance and land use incentives for better environmental design and operations of buildings and infrastructure systems for buildings, and
- ▶ redesigning the fundamental risk models for banking, finance and insurance in urban settings.

Source: <https://urbanlogic.org/>

8.5.6 Dashboards

Dashboards provide operators and engineers a holistic overview of systemwide status and performance instantly in a user-friendly manner. Dashboards serve as powerful tools that allow decision makers to identify trends, monitor performance against strategic goals, and communicate critical information. Dashboards present data in real-time or based on historical data and may include data such as crashes, crash history, volumes and volume history, speeds and speed history, safety performance metrics, traffic signal operations status, ITS device status, deployed maintenance units and their location, and/or other useful and relevant information.

▼ **FIGURE 8.5.6A - DASHBOARD**



Source: Road Safety Analysis Dashboard, www.roadsafetyanalysis.com

With the emergence of big data and analytics, dashboards have also become big business. Dashboard development will be based on a number of factors including source data, user needs, presentation preferences, information prioritization, layout and drill down options, and appropriate color schemes. Selection of the best development tool will be based on these factors as well as cost. Google Analytics, Microsoft Power BI, and ClicData are common low-cost dashboard tools well-suited for traffic data processing. A recommended resource for traffic management dashboard use, benefits and development is FHWA Report Transportation Management Center Performance Dashboards, April 0221. The report contains many City and DOT practitioner examples, recommended best practices, and a dashboard development checklist.

It is recommended the City capitalize on TxDOT's data capture contracts described above to develop meaningful dashboards for operators, supervisors, senior staff, council members, and the public.

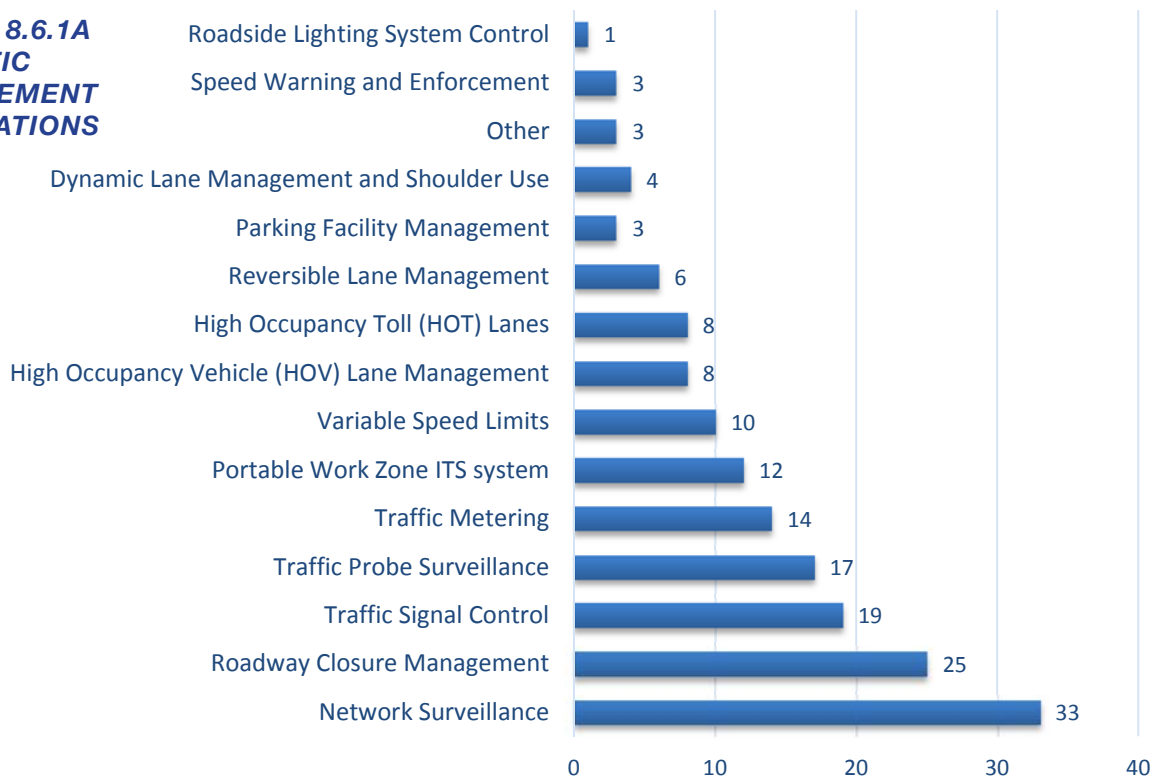
8.6 TMC UPGRADES

8.6.1 General Discussion

The City's Traffic Management Center (TMC) provides an excellent opportunity to implement, deploy and showcase advanced mobility concepts and ITS elements. TMC improvements and upgrades are low-cost, high-yield efforts that greatly affect traffic conditions throughout the transportation network. TMCs 1) are operational hubs for most arterial and freeway management systems, 2) monitor and manage traffic flow on the transportation network, and 3) disseminate information to travelers through various ITS devices, technologies, and strategies. TMCs also serve as technical and institutional hubs that facilitate interagency coordination on relevant traffic operations issues including incident response and recovery, evacuation protocols, sustainable funding sources, staffing and knowledge retention, social media engagement, and resource allocation/sharing.

The figure below depicts the result of a survey sent to over 40 TMCs in 25 states around the country and reflects the traffic management applications being used at TMCs. The survey further indicates that incident management and traveler information are two areas that are fairly-well developed amongst TMCs, but gathering and sharing data, although advocated by operating agencies, is not commonplace or well developed. Although not always practiced, agencies indicated desire to obtain data from other agencies such as arterial traffic conditions, transit information, video feeds, and parking availability information.

▼ **FIGURE 8.6.1A**
- TRAFFIC
MANAGEMENT
APPLICATIONS



Source: *Traffic Management Centers: Challenges, Best Practices, and Future Plans*, National Center for Transportation Systems Productivity and Management, 2014

The survey also indicated **advanced technologies, automation tool applications** and **advanced wireless technologies** are becoming more relevant in TMC operations and future ITS plans. Important factors facilitating application of advanced technologies are aggressive documentation, following system engineering processes, and embracing a one-agency culture. Selfless collaboration provides invaluable information, insight and assistance to policy makers and decision makers on what potential technology applications are and how to best incorporate them into TMC operations.

8.6.2 City of Missouri City TMC

Based on data collected and stakeholder input, improvement and upgrade opportunities for the City of Missouri City TMC have been identified and summarized below.

8.6.2.1 Space and Layout Assessment

The first step towards TMC optimization is to conduct a thorough and comprehensive architectural space and layout assessment. There is a slight separation in the floor structure where the control room floor transitions to the ADA-compliant ramp at the back of the room. The assessment should investigate rehabilitation and reconfiguration of not only the floor-to-ramp alignment, but other elements of the TMC including workstations, video display screens, ergonomics, lighting, A/C functions, overall space utilization, and physical and operational layout. Assessment should identify inadequacies and non-code compliant elements, as well as suggested improvements, adjustments, enhancements, upgrades, and replacements.

8.6.2.2 Video Display Wall

The TMC video wall is valuable “real estate” operators use extensively to monitor and control traffic conditions. Initial assessment of the current video wall layout and technology revealed improvement opportunities in terms of space utilization, equipment placement efficiency, and operator capabilities. Potential improvement opportunities include:

8.6.2.2.1 Smart Board

The Smart Board is underutilized and occupies valuable viewing area in the center of the wall. The device is in good working condition and is a candidate for assignment to another department with a need.

8.6.2.2.2 Overhead Projector

The overhead projector is underutilized but still in good working condition, and therefore a candidate for assignment to another department with a need.

8.6.2.2.3 FHWA Video Wall Guidelines

Video wall adjustments should consider the following TMC video wall design guidelines and recommendations provided in the FHWA Freeway Management and Operations Handbook, 2003:

- ▶ Avoid too much detail on large maps or status boards,
- ▶ Limit number of colors for maps, target symbols, alphanumeric headings, etc.
- ▶ If moving objects are displayed on a map, keep the number at a minimum and display only those that move slowly.
- ▶ If color-coded object information is used on large map displays, use neutral color such as gray for map background; this allows the color targets to have maximum effect (contrast).
- ▶ Determine and provide properly sized alphanumeric characters and symbols on large-screen displays for maximum viewing distances that must be read.
- ▶ Orient maps with north to the top.

Source: FHWA Freeway Management and Operations Handbook, 2003

8.6.3 Video Control System

The existing video control system is aging and operationally suffering in terms of speed, latency, and display deficiencies. Upgrade or replacement of the video control system should be investigated using a methodical, phased approach including:

8.6.3.1 Stakeholder Interviews

In-depth interviews with operators, users, IT technicians, and others familiar with the video control software operations and deficiencies. Interviews will also 1) seek perspective of overall TMC operations, and 2) query stakeholders for feedback on possible improvements, desirable features, and strict requirements.

8.6.3.2 System Test

Understanding system weaknesses and vulnerabilities is key to establishing baseline requirements for desired functionality moving forward. Conduct end-to-end troubleshoot test to comprehensively identify location and severity of failure points which may reside in any of the video system components including, but not limited to, camera/PTZ assembly, communications subsystem, Cameleon/FLIR control software, or some combination thereof.

8.6.3.3 Requirements

Conduct Needs Assessment to determine and prioritize a list of desired state-of-the-art features and functionality that, among other things, addresses monitor assignment functionality and flexibility. Develop Requirements Specification.

8.6.4 Operator Interface

Increased operator ability will enhance not only TMC productivity and efficiency but overall improvement of the transportation network as well including reduced accidents and travel times. In addition to showing travel times on DMS, it is recommended the operator be provided:

8.6.4.1 Interactive (website) map that displays travel times to the operator when the DMS icon on the map is clicked/chosen.

8.6.4.2 Application that allows operator to:

- ▶ Review historical travel times,
- ▶ View and schedule DMS messages,
- ▶ Check Bluetooth reader health,
- ▶ Adjust travel time zones (Bluetooth), and
- ▶ View traffic statistics for each (Bluetooth) zone.

8.6.5 Operations and Training Manuals

Operations manuals are critical tools that support day-to-day TMC operation by defining roles, responsibilities, functional capabilities, services provided, major tasks, and day-to-day activities performed in pursuit of agency goals and objectives. More effective operations yield more effective system performance, and operations manuals are key tools in leveraging effective operations. In particular, the potential benefits resulting from use of a TMC Operations Manual include:

- ▶ Operational procedures lend consistency to day-to-day activities, improve interagency and interjurisdictional working relationships, and ease internal training efforts;
- ▶ System maintenance, monitoring, and security procedures improve resource utilization and enhance system safety; and
- ▶ Data collection, analysis and warehousing procedures support short- to long-term transportation facility performance improvements and planning efforts.

Source: FHWA Handbook for Developing a TMC Operations Manual, 2005

It is recommended the City expend effort to create an Operations Manual to document procedures, assist in maintenance, provide training material, and facilitate knowledge transfer and retention. The manual should focus on day-to-day operations, critical functions, and preventative/routine functions. Extent and content of the manual should be clearly defined to facilitate efficient development of the manual. Amendments can be easily made as devices and systems are added and incorporated into the system. It is further recommended that laminated one-page guidelines, procedures, instructions, and SOPs be developed for routine operations.

8.6.6 Web Site

Traveler information has been identified as a primary focus throughout data collection and analysis. It is strongly suggested the City reinstate the traffic website with color-coded speed map, DMS messages, travel times, camera images, construction locations, accident locations, and public service announcements.

8.6.7 Center-to-Center Integration

Data and video sharing has become standard functionality for most traffic operations centers. Data sharing improves traffic operations, provides additional data for collection and study, facilitates interagency coordination, strengthens interagency relationships, fosters interagency trust, and provides a collaborative platform for traffic operations stakeholders. TRB's National Cooperative Highway Research Program (NCHRP) report *Sharing Operations Data Among Agencies*, 2014, strongly supports agencies share operational data for greater interagency cooperation and examines several successful case studies. It is suggested the City develop a plan to collect, share, store and integrate shared data with other regional TMCs including Houston TranStar and City of Sugar Land TMC. Connectivity and shared operations with the COMC Police Department and Emergency Operations Center should be investigated closer for improvement opportunities. It is further suggested the City enter into interlocal agreements with TxDOT and the City of Sugar Land for the purpose of sharing video functionality, and possibly DMS data share. Simple interlocal agreements can be risk free, mostly commitment free and easily terminated.

8.6.8 Expand CCTV Coverage

The COMC Operations Concept identified a need to view DMS messages remotely. It is suggested CCTV cameras be installed at DMS locations so operators can visually verify DMS displays/messages from the TMC.

8.6.9 Railroad Crossing Operations

Union Pacific Railroad (UPRR) operates a railway that passes through the north side of the City of Missouri City roughly parallel to US 90A. Traffic can be disrupted when trains pass during peak hour, particularly at Gessner/Texas Parkway and US 90A. There is a need to enhance railroad crossing operations through train monitoring and motorist warnings to improve safety and reduce delays.

8.6.9.1 Doppler Radar

The City of Sugar Land operates a train monitoring system for the same UPRR train movements. The system uses Doppler Radar to detect the trains. The system monitors train presence, direction, speed, and length, as well as crossing gate closures via monitoring of traffic signal preemption relays. Installations are located at signalized intersections along US 90A with streets crossing the UPRR tracks. Equipment consists of pole mounted field cabinet with electrical service, Doppler radar, signal preemption connections, local processor, and wireless modem. A Yagi or omni-directional antenna provides wireless cellular digital packet data (CDPD) communications to the City's TMC. The system determines real time train status and projects downstream crossing closing and clearance times. This information is posted on the City's ITS website (<http://its.sugarlandtx.gov/traffic>). The Doppler radar-based system has evolved into a reliable operating system for detecting trains and projecting their movements. City of Sugar Land fire, police, and public works find the system useful, particularly for emergency response and verifying the status of crossing protection equipment.

Factors to consider if implementing a similar system include:

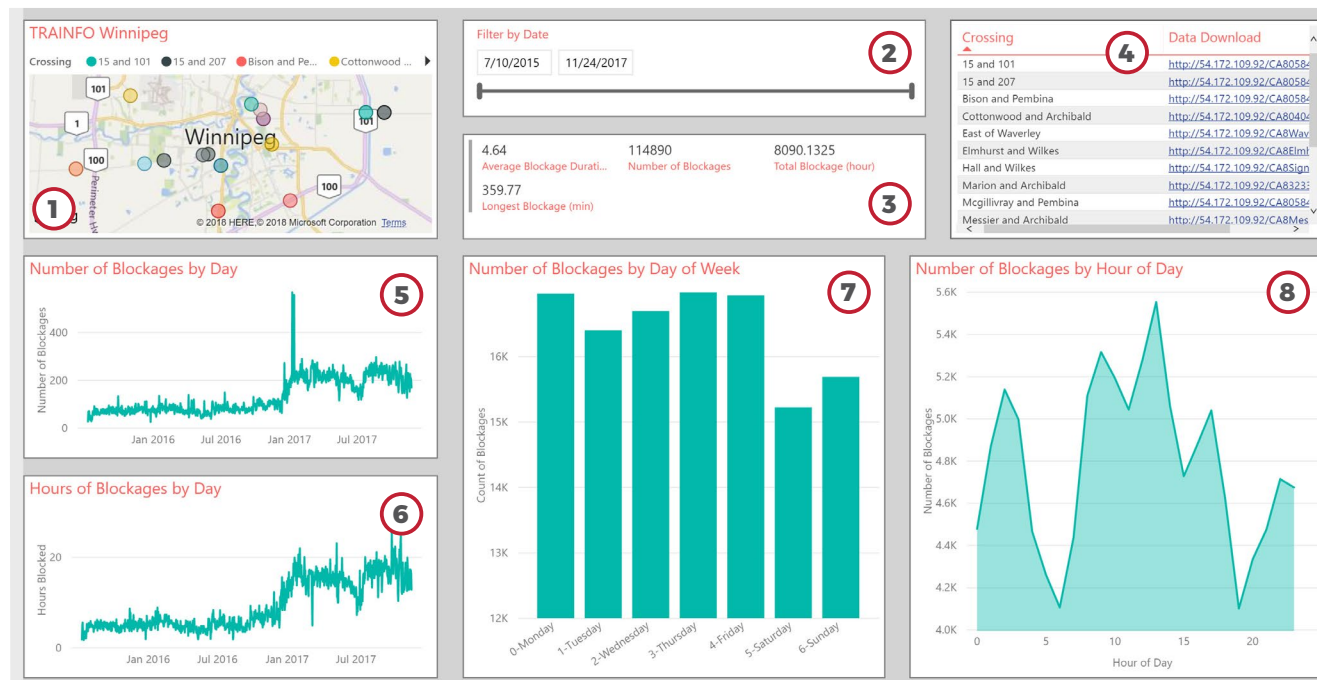
- ▶ Understanding of rail, street, and highway-rail grade crossing characteristics,
- ▶ Traffic demand and operations,
- ▶ Operational characteristics of emergency service / public safety organizations,
- ▶ Review of TxDOT Research Project Non-Vital Advance Rail Preemption of Signalized Intersections Near Highway-Rail Grade Crossings, September 2007,
- ▶ Integration with traffic signal systems to temporarily adjust traffic signal timing to minimize impact of passing trains,
- ▶ Use of in-route traveler information devices to provide information to DMS and HAR,
- ▶ Use of pager and email systems to alert agencies and stakeholders of train activity,
- ▶ Public Internet web site of rail monitoring system, and
- ▶ Link to train monitoring web site on Houston TranStar's traffic web site.

8.6.9.2 TRAINFO

TRAINFO is a train monitoring system platform whose mission is to eliminate traffic delays and accidents at rail crossings. TRAINFO uses machine-learning algorithms, proprietary acoustic sensors, and integration of data from across the rail network to predict rail crossing blockages up to 30 minutes before the train arrives. TRAINFO integrates with ATMS, DMS, and computer aided emergency dispatch (CAD) software. User agencies have access to an online data portal with live map and interactive dashboard. Available blockage statistics include crossing blockages by hour-of-day and day-of-week, and blockage duration. Agencies can also download the raw data. Refer to Figure 4 below for a screenshot of the Blockage dashboard.

▼ **FIGURE 8.6.9.2A – BLOCKAGE DASHBOARD**

Source: trainfo.com



TRAINFO supports the following mobility improvement solutions:

- ▶ **Decrease Traffic Congestion & Emissions at Rail Crossings**
 - Predict crossings up to 30 minutes prior to train arrival
 - Re-route motorists around blocked crossings using DMS
 - Automatically adjust traffic signals before, during and after crossing
- ▶ **Reduce Emergency Responder Delays at Rail Crossings**
 - Receive real-time rail crossing blockage alerts in CAD system
 - Re-route emergency vehicles around blockages
 - Avoid dispatching first responders that will be delayed
- ▶ **Mitigate Collision Risk**
 - Discourage motorists from crossings while warning systems are active
 - Prevent motorists from speeding trying to beat the train
 - Mitigate rear-end collisions at crossings
- ▶ **Quantify Traffic Delays**
 - Understand how blockages impact traffic at network level
 - Strengthen business cases for grant funding applications
 - Respond to public inquiries with reliable and detailed delay statistics

Source: trainfo.ca

8.6.9.3 Alternatives

There are other alternatives and options to the two above referenced systems. One option includes installing video detection cameras to monitor activated railroad flashers and then activate dynamic message signs redirecting traffic around the blocked crossing. Another option is to use the ATMS to track blocked railroad crossings by monitoring the adjacent signals' preemption status. If the railroad blockage is in excess of a set time, then a special timing plan gets activated to direct traffic through bypass routes.

8.6.10 Accident Tracking System

An effective crash monitoring system offers multiple benefits. Tracking accidents allows a city to gain a better understanding of traffic operation issues and problems on a city's roadways. Benefits include identifying hazardous road sections, hot spots, and risk factors; quick and accurate diagnosis of issues; and identifying effective safety improvement measures. Information collected allow a city to develop material to educate the public to reduce crash rates by addressing the underlying causes. Once remedial measures are implemented, the system would allow the city to evaluate effectiveness of implemented measures and road safety programs. Additionally, a crash tracking system benefits those involved in the accident. The system can assist police and insurance companies with filing reports and claims and provide crucial information about the crash and cause. The system can also be used to calculate the cost and years of expected life lost due to crashes resulting in fatalities. A summary of benefits include:

- ▶ Provide valuable information to Police Department and insurance companies
- ▶ Allow city to gain better understanding of traffic operation issues on city roadways
- ▶ Locate hazardous road sections
- ▶ Identifies accident hot spots
- ▶ Identify risk factors
- ▶ Develop accurate diagnosis and remedial measures
- ▶ Educate the public
- ▶ Evaluate the effectiveness of road safety programs and improvement measures

The City of Missouri City would notably benefit by implementing a crash monitoring system because of the information/data produced and utilized, the anticipated improvement in safety, and improvement in the quality of life for City residents. Crash monitoring systems are typically dashboards that pull data from crash databases such as:

- ▶ Crash Record Information System (CRIS)
- ▶ Crash Investigation Sampling System (CISS)
- ▶ Crash Report Sampling System (CRSS)
- ▶ Fatality Analysis Reporting System (FARS)
- ▶ National Automotive Sampling System (NASS)
- ▶ Special Crash Investigations (SCI)
- ▶ State Data Programs
- ▶ Non-Traffic Surveillance (NTS)



Many agencies use PowerBI for their dashboards. PowerBI is an affordable scalable software platform that allows users to connect to and visualize data. The software utilizes AI to prepare data and build models based on real-time analytics. Using PowerBI, the City could create a crash analysis dashboard that provides information on crash rates, crash types, severity of crashes, crash location, and more. PowerBI also provides data on crash parameters such as who, when, where, and why. Two example dashboards are presented below.

FIGURE 8.6.10A – CAMPO DASHBOARD

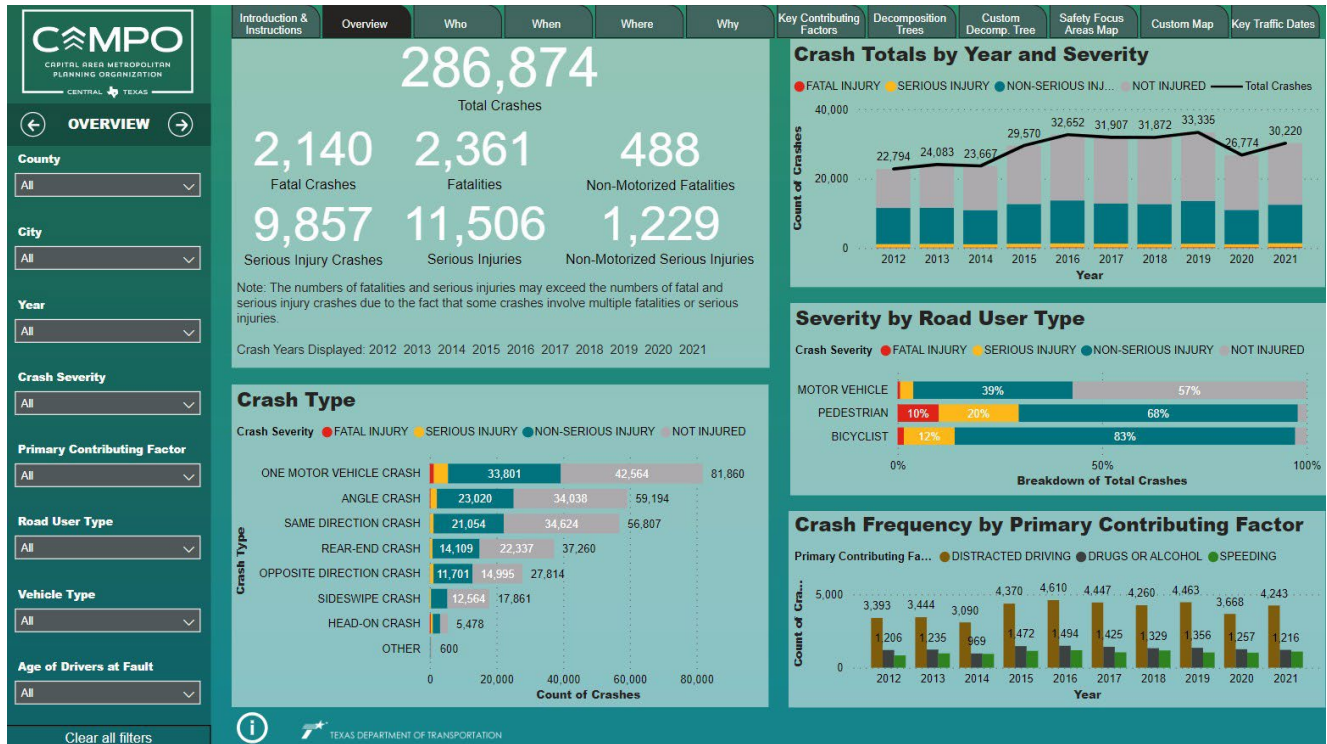
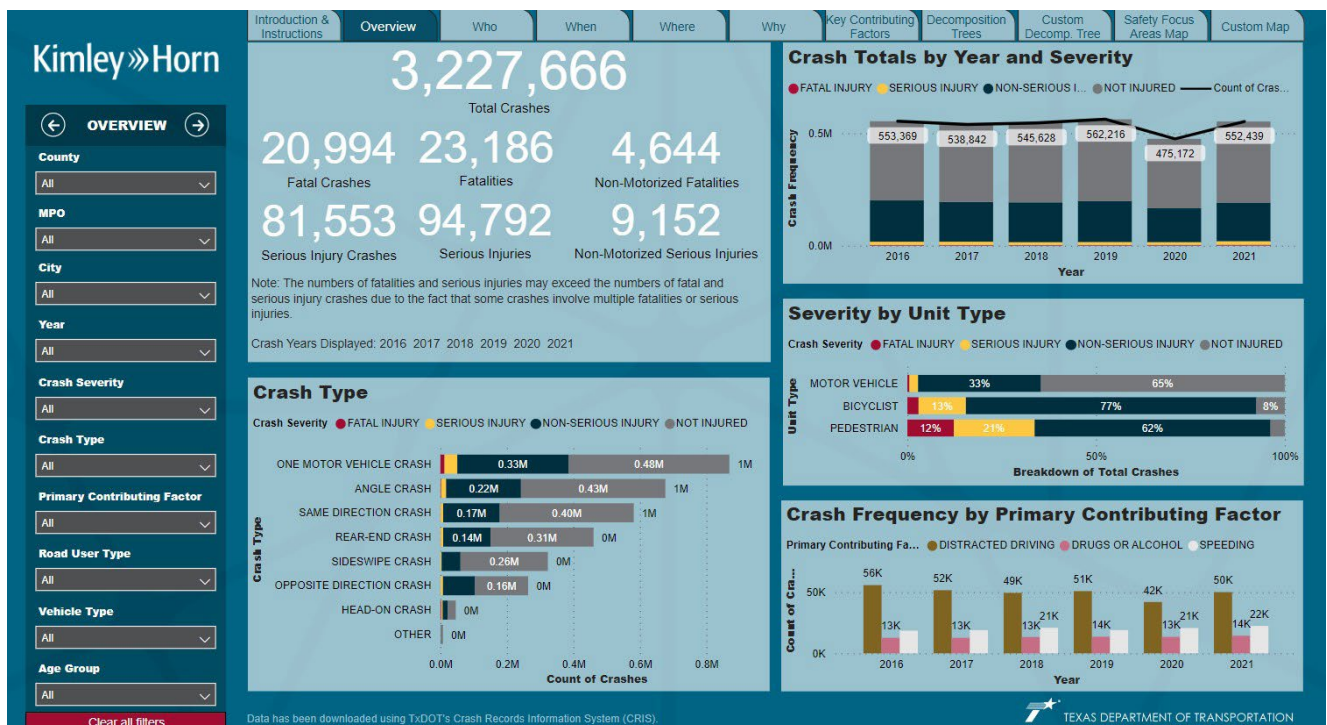


FIGURE 8.6.10B – KIMLEY-HORN DASHBOARD



8.7 STANDARD OPERATING PROCEDURES

There is a need to document processes and procedures not only as references but for knowledge management and retention, i.e., passing it along to new staff. A Standard Operating Procedure (SOP) is a written instruction that describes the step-by-step process that must be taken to properly perform a routine activity. Benefits include staff alignment, clarification, and consistency, improve operational efficiency, and knowledge transfer (training). Development of Standard Operating Procedures (SOPs) will benefit the City in terms of ITS and traffic management. Proposed SOPs based on City business practices and analysis performed to date include:

8.7.1 *Centracs*

- ▶ Signal Turn On
- ▶ Adding New Devices
- ▶ Signal Timing
- ▶ Uploads and Downloads
- ▶ Configuration
- ▶ Administrator Functions

8.7.2 *Maintenance Management*

- ▶ Preventive
- ▶ Emergency
- ▶ Trouble Shooting
- ▶ Reporting

8.7.3 *Emergency Operations Center (EOC) Functions*

- ▶ Staffing and Tasks
- ▶ CCTV and DMS Operations
- ▶ Emergency Management
- ▶ Hurricane Evacuation

8.7.4 *General Operations*

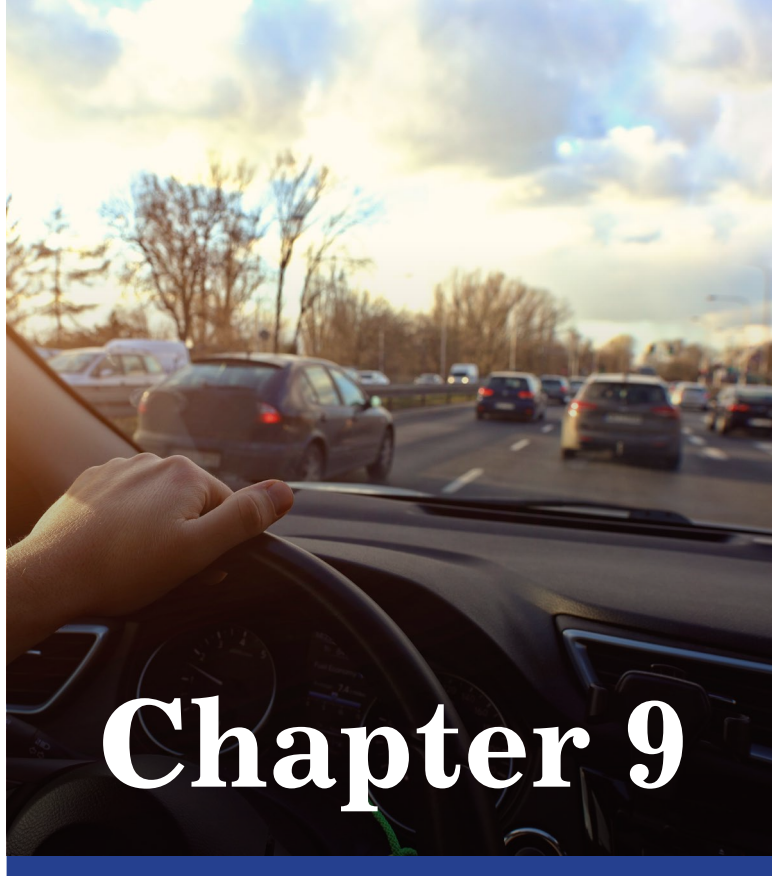
- ▶ Staffing and Tasks
- ▶ CCTV and DMS Operations
- ▶ Special Event Management
- ▶ DMS Library Standard

Appendix B provides a SOP template the City can use for the above mentioned items. Appendix C is a list of relevant SOPs used by other cities. SOP development should be prioritized to focus first on those items that are most critical. Second tier SOPs can be developed over time as relevant programs evolve and funding is secured.



8.8 DETECTION

The City is interested in investigating various detection applications, technologies and methodologies as it relates to traffic signal operations. Detectors can be intrusive (inductive loop, magnetometer, microloop, fiber optic acoustic sensing) or nonintrusive (radar/microwave, video imaging, infrared, ultrasonic, photoelectric). Comprehensive and informative resources have been published in recent years regarding detection for traffic signal applications. Reference documents include Federal Highway Administration, Traffic Signal timing Manual, FHWA-HOP-08-024, June 2008, and National Cooperative Highway Research Program, Signal Timing Manual, Second Edition, 2015.



Chapter 9

CIP Implementation Plan

9.1 INTRODUCTION AND BACKGROUND

9.2 CIP IMPLEMENTATION PLAN

9.3 RECOMMENDED BEST PRACTICES



CIP Implementation Plan

9.1 INTRODUCTION AND BACKGROUND

The Systems Engineering process (largely the Concept of Operations) revealed over 140 needs within the City's ATMS concept. Chapter 9 identifies projects that address the needs deemed most important to the City. Due to the granularity of many of the needs, not all of the 140 needs are directly addressed in the recommend CIP Projects discussed in this Chapter. As with all Master Plans, it is good practice to routinely revisit the needs of the City and elevate appropriate needs to higher priority on a case by case basis. Continued use of the City's ATMS will reveal best where needs remain and should be addressed.

Purpose of this Document

The purpose of this report is to recommend and prioritize projects to achieve the goals of the ITS Master Plan.

Document Organization

The remainder of this document describes the following projects, priority of the project, the basis for recommendation, benefits, and estimated cost:

- ▶ **Project 1:** Wireless Communications
- ▶ **Project 2:** Traffic Management Center
- ▶ **Project 3:** Traffic Signal Timing
- ▶ **Project 4:** Big Data
- ▶ **Project 5:** Documentation
- ▶ **Project 6:** Fiber Expansion
- ▶ **Project 7:** Website and Mobile App
- ▶ **Project 8:** Railroad Detection and Warning System
- ▶ **Project 9:** Weigh-In-Motion
- ▶ **Project 10:** Tower Grounding
- ▶ **Project 11:** Center-to-Center Integration

In addition to the project mentioned above, this document also describes the following recommended best practices:

- ▶ **Item A:** Traffic Signal Cabinet Grounding
- ▶ **Item B:** Battery Backup Units
- ▶ **Item C:** Smart Devices
- ▶ **Item D:** Partnerships
- ▶ **Item E:** Asset Management
- ▶ **Item F:** Knowledge Management

9.2 CIP IMPLEMENTATION PLAN

PROJECT	DESCRIPTION	BASIS FOR RECOMMENDATION	ESTIMATED CONSTRUCTION COST
 PROJECT 1 Wireless Communications HIGH	Plans, Specifications & Estimates (PS&E) for upgrading or replacing network architecture, intersection and tower wireless radios and antenna, Ethernet switches, and other aging and obsolete peripheral equipment associated with replacement or upgrade of the above mentioned items.	The communication subsystem is the backbone of any successful ITS operation. The most critical, high-yield improvement the City can make is to upgrade its current communications system.	\$600,000
 PROJECT 2 TMC Upgrade HIGH	PS&E to reconfigure video wall, replace video control system, perform architectural assessment and architectural upgrades, enhance operator capabilities, and develop operations and training manuals.	The TMC has undergone little modification since inception and will benefit from an assessment and upgrade that optimizes space utilization and operator environment. The TMC provides an excellent opportunity to implement, deploy and showcase advanced mobility concepts. TMC improvements are low-cost, high-yield efforts that greatly affect traffic conditions throughout the City.	\$400,000
 PROJECT 3 Signal Timing HIGH	Develop and implement 4-year citywide signal retiming program such that 1/4 of the City's signals are retimed annually.	Research indicates retiming traffic signals is one of the most cost-effective tasks an agency can do to improve traffic flow and can improve traffic flow by 25% or more. The FHWA "Traffic Signal Timing Manual" recommends signals be timed every 3-5 years. FHWA "Signal Timing on a Shoestring" offers guidance on low-cost methods to retiming traffic signals.	\$200,000 annually
 PROJECT 4 Big Data HIGH	Implement big data (Waze or new TxDOT contract) for data collection, analysis/ analytics, reporting and dashboard development and maintenance.	Traffic data analytics are becoming more important as cities become more congested. City planners rely on data to understand traffic flow and to analyze data in real time. Big Data providers offer mobility pattern data that can help the City make smarter decisions in terms of planning, and infrastructure investment. Using TxDOT's existing contract minimizes costs.	TBD

9.2 CIP IMPLEMENTATION PLAN (CONTINUED)

PROJECT	DESCRIPTION	BASIS FOR RECOMMENDATION	ESTIMATED CONSTRUCTION COST
 PROJECT 5 Documentation HIGH	Develop the following: 1. Data Collection Plan 2. Data Management Strategy 3. Performance Measure Plan 4. Operations Performance Measure Plan 5. Maintenance Performance Measure Plan 6. Standard Operating Procedures (SOPs)	The era of big data is here. The first steps towards becoming a data-driven Smart City is harnessing data and establishing performance metrics. Attrition often results in loss of critical knowledge. It's important the City establish critical SOPs in order to combat attrition, document business processes, preserve critical knowledge, and provide a basis for training.	\$50,000 annually
 PROJECT 6 Fiber Expansion MODERATE	Plans, Specifications & Estimates (PS&E) for design and installation of fiber optic cable, Ethernet communications equipment, and integration of existing (traffic signal) devices for the following: 1. Texas Parkway from Buffalo Run to Cartwright Road including fiber connection to TMC (1.75 miles) 2. Cartwright Road from Dulles Avenue to Texas Parkway (3.3 miles) 3. Murphy Road from Lexington Boulevard to Glenn Lakes Lane (2.5 miles) 4. Connect Fire Station 5 Radio Tower to existing SH 6 fiber system (0.5 miles) 5. Connect Waste Water Treatment Plant Radio Tower to existing SH 6 fiber system (3.6 miles)	Fiber optics offer the most reliable, flexible, and expandable communications solution for the City. Roadway segments were selected based on the concentration of traffic signals along the section and close proximity (ease to connect) to the existing SH 6 fiber. The proposed fiber also runs near some school flashers as well as City facilities. The existing SH 6 fiber runs relatively close to the Fire Station 5 (3.6 miles) and Waste Water Treatment Plant radio towers (0.5 miles). Since lightning strikes on the towers severely affects wireless communications, connecting with fiber lessens the risk of storm impacts.	\$350,000 per mile
 PROJECT 7 Web Site and Mobile App MODERATE	Purchase Order or Existing On-Call Work Order to reinstate/update the City's traffic website with color-coded speed map, DMS messages, travel times, camera images, construction locations, accident locations, and public service announcements.	Traveler information has been identified as a primary focus throughout development of the OpsCon and ITS Master Plan. A City traveler web site and mobile app are powerful, low-cost tools used extensively by an increasingly sophisticated public.	\$160,000

9.2 CIP IMPLEMENTATION PLAN (CONTINUED)

PROJECT	DESCRIPTION	BASIS FOR RECOMMENDATION	ESTIMATED CONSTRUCTION COST
 PROJECT 8 Railroad Detection and Warning System MODERATE	Study, PS&E and Installation of train monitoring and motorist warning system.	UPRR trains pass at Gessner/ Texas Parkway and US 90A causing disruption and backup, particularly at peak hour. This project will enhance railroad crossing operations and safety through train monitoring and motorist warnings. Sugar Land operates a robust and data-driven train monitoring system that automatically closes gates.	\$125,000
 PROJECT 9 Weigh-In-Motion (WIM) LOW	PER and PS&E to 1) study WIM technologies, placement and guidelines/ standards, and 2) develop construction bid package for the selected technology/ approach.	Data indicates an average semi tractor-trailer weighs about 36,000 lbs empty and 80,000 lbs full. Overloaded trucks cause significant damage to street and highway pavements. Weigh-in-motion (WIM) systems capture truck weights as they pass over sensors without stopping. Weight data is useful for several reasons including enforcement and pavement preservation. Other users include pavement and bridge design, monitoring, and research; and size and weight enforcement.	\$20,000 study + PS&E if recommended
 PROJECT 10 Tower Grounding LOW	Preliminary Engineering Report to study and test weaknesses in the grounding system for all four radio towers, especially for the Waste Water Treatment Plant radio tower.	Lightning strikes to the Wastewater Treatment Plant radio tower impacts traffic operations, so additional protection may be needed. Independent, specialized testing will identify inadequacies and form the basis for low-cost, high-impact improvements.	\$60,000 for test & \$35,000 install per tower if needed
 PROJECT 11 Center-to-Center Integration LOW	Development and implement software and integration that allows for reciprocal sharing of video and DMS data with Houston TranStar and the City of Sugar Land TMC.	Data and video sharing is common amongst most traffic management centers/systems. Data sharing improves traffic operations, enhances regional data ecosystem, facilitates interagency coordination, fosters interagency trust, and provides a collaborative platform for regional traffic operations stakeholders.	\$350,000

9.3 RECOMMENDED BEST PRACTICES

BEST PRACTICE	DESCRIPTION	BASIS FOR RECOMMENDATION
 A Traffic Signal Cabinet Grounding	Begin using TxDOT ITS Cabinet Grounding on new projects and rehabs rather than the standard TxDOT signal cabinet grounding.	The TxDOT ITS Cabinet grounding system is robust and provides significant increased protection at modest additional cost.
 B BBUs	Begin using network capable, industrial hardened BBUs on new and rehab projects.	Traffic signal operation interruption leads to safety hazards and anxious motorists, and demands more robust and systems-centric power protection solutions. New generation BBUs are reliable, powerful, easy-to-use, and result in improved intersection safety, reduced operating and maintenance costs, and extended battery life.
 C Smart Devices	Begin deploying smart devices on new projects and rehabs when possible.	City should promote low-cost, low-effort, high-yield initiatives that directly benefit the City's start towards becoming a Smart City, including the deployment of smart devices. These can be installed during construction and rehabilitation projects as a fractional cost of the overall project.
 D Partnerships	Formalize partnerships with TxDOT and City of Sugar Land for data, video and fiber share.	Partnerships improve the local data ecosystem and can help the City manage technical complexities as well as funding and analysis needs.
 E Asset Management	Investigate transportation asset management software that meets the requirements of the Traffic Operations Department. Common products include Citiworks, Centracs MMS and KITS.	Asset Management is key to maintaining the City's ITS infrastructure. It is important the chosen product provides rich information and is easy to use and train on.
 F Knowledge Management	Begin a strict, regimented documentation initiative to capture and record identified business processes and critical knowledge.	The document project listed above does not address all of the processes and guidelines the City possesses. Documentation is an important, on-going activity, not a single project.



PROJECT I

Wireless Communications

PROJECT DESCRIPTION

The Wireless Communications Upgrade project will procure, install, and configure communications equipment at signalized intersections on priority corridors in support of traffic signal operations. The project will include Plans, Specifications & Estimates (PS&E) for upgrading the network architecture, antenna, radios, old or malfunctioning Ethernet switches and other aging networking equipment.

Recommended Deployment Date

Q3 2023.

BASIS FOR RECOMMENDATION

The City would benefit by continued investment in the replacement of the existing wireless communications system to ensure a reliable and maintainable communications subsystem. The communication subsystem is the backbone of a successful ITS operation. The most critical, high-yield improvement the City can make is to upgrade its current communications system.

PROJECT BENEFITS

Robust, reliable, and redundant communications will allow the City to take advantage of full capabilities of traffic controller cabinets, signal controllers, vehicle and pedestrian detection, Advanced Traffic Management System, Closed Circuit Television, Automated Traffic Signal Performance Measures, Traffic Management Center, and adaptive signal control. Reliable communications will increase City staff efficiency when maintaining traffic signal equipment, operating traffic signals, and monitoring traffic flow across the City.

ESTIMATED COST

Communications unit costs vary widely depending on the ultimate solution; however, total cost is estimated to be around \$600,000.00.

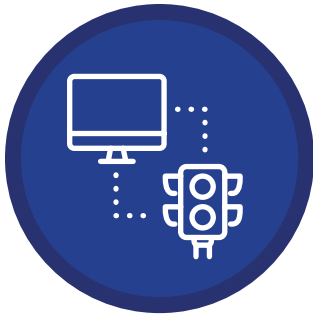
LOCATIONS

Initial rollout of communications will install radios and Ethernet switches at all four tower locations and at select intersections. Then, radios and the Ethernet switches will be installed at the remaining locations.

RELATED PROJECT(S)

Most projects included in this recommended CIP project description list are dependent upon reliable communications; however, this project does not have any dependencies.





PROJECT 2

Traffic Management Center

PROJECT DESCRIPTION

The Traffic Management Center (TMC) project is focused on upgrading the existing TMC including reconfiguring the video wall, replacing the video control system, and enhancing operator capabilities. Performing an architectural assessment and proposing architectural upgrades would additionally be included.

As part of this project, operations and training manuals would be developed to guide the staff on procedures and provide instructions for various tasks.

Recommended Deployment Date

It is recommended to upgrade the TMC after the City has upgraded the wireless communications network.

Approximate FY 2024.

BASIS FOR RECOMMENDATION

Missouri City's TMC has undergone minimal modifications since inception. Focused on optimizing space utilization and operator environment, this project would provide many benefits to the TMC.

PROJECT BENEFITS

Fully operational TMCs serve as the central command center during everyday operations, special events, and severe weather events that threaten travel conditions. On an everyday basis, the TMC staff observes field conditions and dispatches signal technicians to problem locations. The TMC staff typically receives public complaints, investigates the problem, and responds with the appropriate action. The TMC staff utilizes the ATMS software to collect data, generate reports, generate performance measures, and provides appropriate level of reporting to City management. All of these duties benefit the traveling public.

ESTIMATED COST

Upgrades to the TMC are estimated to be approximately \$400,000.00. As mentioned previously, this cost includes updating and reconfiguring the existing TMC as well as developing operations and training manuals.

RELATED PROJECT(S)

Because the TMC is the central command center, most other projects make the TMC more efficient and beneficial. However, only the reliable communication (Project 1) is essential. The following projects are recommended to be deployed, or partially deployed before the TMC is updated:

Project 1 – Wireless Communications

Project 3 – Traffic Signal Timing

Project 4 – Big Data

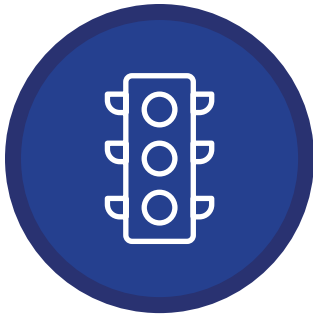
Project 5 – Fiber Expansion

Project 7 – Documentation

Project 8 – Tower Grounding

Project 9 – Railroad Detection and Warning System

Project 10 – Weigh-In-Motion



PROJECT 3

Signal Timing

PROJECT DESCRIPTION

The Traffic Signal Timing project includes developing, implementing, and fine-tuning traffic signal timing. For a City the size of Missouri City, it is healthy to perform routine traffic signal retiming every year, which should be approximately one-fourth of all signals. This way, all traffic signals are retimed every four years. Development can influence the frequency of revisiting traffic operations. Likewise, for areas of the City with little to no traffic pattern change, the frequency of update can be every 5 years.

Recommended Deployment Date

FY 2023-2027 and thereafter.

BASIS FOR RECOMMENDATION

Traffic signal retiming is one of the most cost-effective tasks an agency can do to improve traffic flow. Research indicates traffic flow can improve by 25% or more. The Federal Highway Administration (FHWA) recommends signals be retimed every 3-5 years in their Traffic Signal Timing Manual. FHWA has another manual, Signal Timing on a Shoestring, that offers guidance on low-cost methods to retiming traffic signals.

PROJECT BENEFITS

Benefits of traffic signal timing include improved safety, maximized capacity of existing facilities, reduced delay and fuel costs, increased speed, reduced travel time, reduced delay, increased travel reliability, decreased fuel consumption, reduced emissions, and improved air quality. The Institute of Transportation Engineers (ITE) reports a benefit cost ratio of 15 to 50:1, which represents a significant return on investment.

ESTIMATED COST

It is recommended to allocate approximately \$200,000.00 per year for signal timing; which retimes 15 to 25 traffic signals per year.

LOCATIONS

For the next several fiscal years, the City should retime approximately 15 intersections per year. As the number of intersections increases, the City should increase the number of intersections retimed per year.

RELATED PROJECT(S)

This project can be deployed independently of other projects.





PROJECT 4

Big Data

PROJECT DESCRIPTION

The Big Data project includes implementing big data, such as Waze or the new TxDOT contract, for data collection, analysis, analytics, and reporting to assist in understanding and alleviating congestion. This project includes development and maintenance of a dashboard that displays the previously mentioned items.

Recommended Deployment Date

FY 2023.

BASIS FOR RECOMMENDATION

Traffic data analytics are becoming more important as cities become more congested. As Missouri City continues to grow and develop, the City staff will need to be able to understand and analyze traffic flow patterns to make informed decisions about the future planning and mobility of the City.

PROJECT BENEFITS

Big data allows City staff responsible for planning and mobility to understand traffic flow and analyze data in real time. Providers of big data offer mobility pattern data that can assist the City in making smart decisions regarding planning, infrastructure investment, and mobility optimization. This leads to reduced congestion and improves the quality of life for residents.

ESTIMATED COST

Costs will vary based on the TxDOT joint-use agreement dashboard development costs should not exceed \$50,000.

LOCATIONS

N/A

RELATED PROJECT(S)

This project can be deployed independently of other projects.



PROJECT 5

Documentation

PROJECT DESCRIPTION

The Documentation project will develop the following key documents for the City:

- ▶ Data Collection Plan
- ▶ Data Management Strategy
- ▶ Performance Measure Plan
- ▶ Operations Performance Measure Plan
- ▶ Maintenance Performance Measure Plan
- ▶ Standard Operating Procedures (SOPs).

Recommended Deployment Date

FY 2024.

BASIS FOR RECOMMENDATION

With the arrival of the big data era, the City will need to take steps to become a performance-based and data-driven Smart City. The first steps are harnessing data and establishing performance metrics.

PROJECT BENEFITS

Attrition often results in loss of critical knowledge. It's important the City establish SOPs in order to combat attrition, document business processes, preserve critical knowledge, and provide a basis for training.

ESTIMATED COST

It is recommended the City allocated approximately \$50,000.00 annually to the development and updating of critical documentation.

LOCATIONS

N/A

RELATED PROJECT(S)

This project can be deployed independently of other projects. However, the project should take into account all of the other proposed projects to ensure the most accurate and up-to-date information is documented.





PROJECT 6

Fiber Expansion

PROJECT DESCRIPTION

The Fiber Expansion project includes Plans, Specifications, and Estimates (PS&E) for design and installation of fiber optic cable and Ethernet communications equipment. Existing traffic signal devices will be integrated onto the fiber system and devices will be integrated into the TMC for the following:

- ▶ Texas Pkwy from Buffalo Run to Cartwright Rd (1.75 miles);
- ▶ Cartwright Rd from Dulles Ave to Texas Pkwy (3.3 miles);
- ▶ Murphy Rd from Lexington Blvd to Glenn Lakes Lane (2.5 miles);
- ▶ Connect Fire Station 5 Radio Tower to existing SH 6 fiber system (0.5 miles);
- ▶ Connect Wastewater Treatment Plant Radio Tower to existing SH 6 fiber system (3.6 miles).

Recommended Deployment Date

FY 2024.

BASIS FOR RECOMMENDATION

The City currently has fiber along SH 6 and would benefit from expanding fiber to various corridors throughout the City. The roadway segments listed above were selected based on the concentration of traffic signals and proximity to the existing SH 6 fiber. The proximity to the existing fiber allows for easier connections. Additionally, several of the segments are near school flashers as well as City facilities. Lastly, frequent lighting strikes hinder the wireless communications from the Fire Station 5 Radio Tower and Wastewater Plant Radio Tower.

PROJECT BENEFITS

Fiber optics offer the most reliable, flexible, and expandable communications solution for the City. The speed, connection quality, and security is greatly improved with fiber compared to wireless communication. Fiber optics require less maintenance reducing the overall cost over time. Connecting with fiber additionally lessens the risk of storm impacts as compared to wireless communications. With the issues the City has had with lighting strikes at several of the towers, fiber offers a more dependable solution.

ESTIMATED COST

It is recommended to allocate approximately \$350,000.00 per mile of proposed fiber.

LOCATIONS

- ▶ Texas Pkwy from Buffalo Run to Cartwright Rd (1.75 miles);
- ▶ Cartwright Rd from Dulles Ave to Texas Pkwy (3.3 miles);
- ▶ Murphy Rd from Lexington Blvd to Glenn Lakes Lane (2.5 miles);
- ▶ Connect Fire Station 5 Radio Tower to existing SH 6 fiber system (0.5 miles);
- ▶ Connect Wastewater Treatment Plant Radio Tower to existing SH 6 fiber system (3.6 miles).

RELATED PROJECT(S)

This project can be deployed independently of other projects.



PROJECT 7

Website and Mobile App

PROJECT DESCRIPTION

The Website and Mobile App project will utilize a purchase order or existing on-call work order to reinstate and update the City's traffic website. The upgrades include a color-coded speed map, dynamic message sign (DMS) messages, travel times, camera images, construction and accident locations, and public service announcements.

Recommended Deployment Date

FY 2023.

BASIS FOR RECOMMENDATION

Through the development of the Concept of Operations and ITS Master Plan, traveler information has been identified as a primary focus area. A City traveler website and mobile app are powerful, yet low-cost, tools used extensively by an increasingly sophisticated public.

PROJECT BENEFITS

A website and mobile app will greatly benefit the citizens of Missouri City by providing them valuable information about the conditions of the roadways in the City. Thus, allowing them to make educated and informed travel decisions. Additionally, the website and mobile app would allow the City to easily and quickly disseminate important information to the public.

ESTIMATED COST

The estimated cost to update the website and deploy a mobile app is expected to be around \$160,000.00.

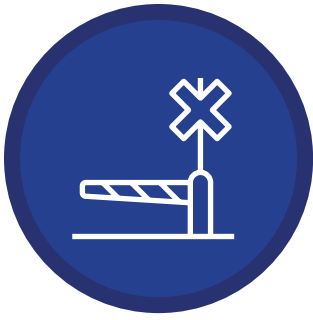
LOCATIONS

N/A

RELATED PROJECT(S)

This project can be deployed independently of other projects.





PROJECT 8

Railroad Detection and Warning System

PROJECT DESCRIPTION

The Railroad Detection and Warning System project will enhance operations near railroad crossings with a train monitoring and motorist warning system. The project will include a study, PS&E, and installation of the system.

Recommended Deployment Date

FY 2024.

BASIS FOR RECOMMENDATION

Union Pacific Railroad trains pass at the intersection of Gessner Rd/Texas Parkway and US 90A causing disruption and backup especially during peak hours. Sugar Land, a nearby city, operates a robust and data-driven train monitoring system that automatically closes gates.

PROJECT BENEFITS

Through the train monitoring and motorist warning system, this project will enhance operations near railroad crossings allowing for reduced congestion and delay and increased safety. The system would provide information to the City of stopped trains which the City could then relay to the public allowing motorists to take alternate routes.

ESTIMATED COST

It is recommended the City allocate \$125,000.00 for the study, PS&E, and installation of the system.

LOCATIONS

The system will be installed at the intersection of Gessner Rd/Texas Pkwy and US 90A.

RELATED PROJECT(S)

This project can be deployed independently of other projects. However, the wireless communication system (Project 1) should be in place before this project is deployed.



PROJECT 9

Weigh-In-Motion (WIM)

PROJECT DESCRIPTION

The Weigh-In-Motion (WIM) project will study WIM technologies, specifically placement and guidelines/standards and then develop a construction bid package for the selected technology or approach. This project will include a preliminary engineering report (PER) and PS&E.

Recommended Deployment Date

FY 2024.

BASIS FOR RECOMMENDATION

Data indicates an average semi tractor-trailer weighs approximately 36,000 pounds empty and 80,000 pounds full. Overloaded trucks cause significant damage to street and highway pavement. WIM systems will capture truck weights as they pass over sensors without stopping the trucks.

PROJECT BENEFITS

Weight data is important for a variety of reasons. Size and weight enforcement as well as pavement preservation are the two most recognized benefits. However, weight data can be used in pavement and bridge design, monitoring, and research.

ESTIMATED COST

It is recommended the City allocate \$20,000.00 for the study. The PS&E will be an additional cost if recommended by the outcome of the study.

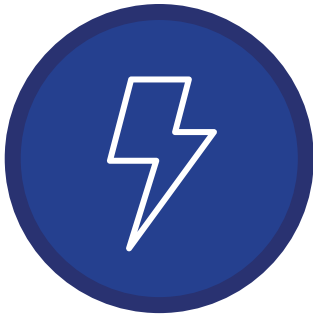
LOCATIONS

The locations will be focused on major corridors and dependent on nearby land use.

RELATED PROJECT(S)

This project can be deployed independently of other projects.





PROJECT 10

Tower Grounding

PROJECT DESCRIPTION

The Tower Grounding project includes a preliminary engineering report to study and test the weaknesses in the grounding system for all four radio towers in the City. From the report, appropriate updates can be determined to reduce the likelihood of severe impacts from lightning strikes.

Recommended Deployment Date

FY 2023.

BASIS FOR RECOMMENDATION

Tower grounding is important to the reliability of the communications during storm events. The Wastewater Treatment Plant radio tower is noted as having several issues with lightning strikes. Additional protection may be needed to reduce the impact to traffic operations. Independent, specialized testing will identify inadequacies and form the basis for low-cost but high-impact solutions.

PROJECT BENEFITS

The study and testing will result in recommended improvements that will reduce the impact to traffic operations from lightning strikes during storm events. The outcomes of the testing will inform the City on the current grounding issue, in turn, allowing the City to make educated updates that will improve the protection of the radio towers now and in the future.

ESTIMATED COST

It is recommended the City allocated approximately \$60,000.00 to perform the study including testing, and \$35,000.00 to install extra protection if needed. Estimated cost will vary depending on the outcome of the study.

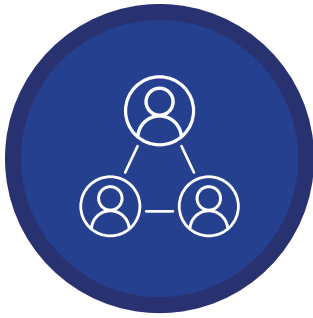
LOCATIONS

The study and testing will need to be performed at all four of the city's radio towers:

- ▶ Wastewater Treatment Plant Tower
- ▶ Fire Station 5 Tower
- ▶ Police Department Tower
- ▶ Traffic Management Center Tower

RELATED PROJECT(S)

This project can be deployed independently of other projects.



PROJECT II

Center-to-Center Integration

PROJECT DESCRIPTION

The Center-to-Center Integration project is focused on developing and implementing software and integration that allows for reciprocal sharing of video and DMS data. The entities that information is to be shared with include Houston TranStar and the City of Sugar Land TMC

Recommended Deployment Date

FY 2024.

BASIS FOR RECOMMENDATION

Data and video sharing is common amongst most traffic management centers or systems. Currently, Missouri City does not have information sharing capability with the specified agencies.

PROJECT BENEFITS

There are several benefits associated with sharing information between agencies. Data sharing improves traffic operations, enhances interagency coordination, fosters interagency trust, and provides a collaborative platform for regional traffic operations stakeholders.

ESTIMATED COST

It is recommended the City allocate \$350,000.00 for the development and implementation of the software.

LOCATIONS

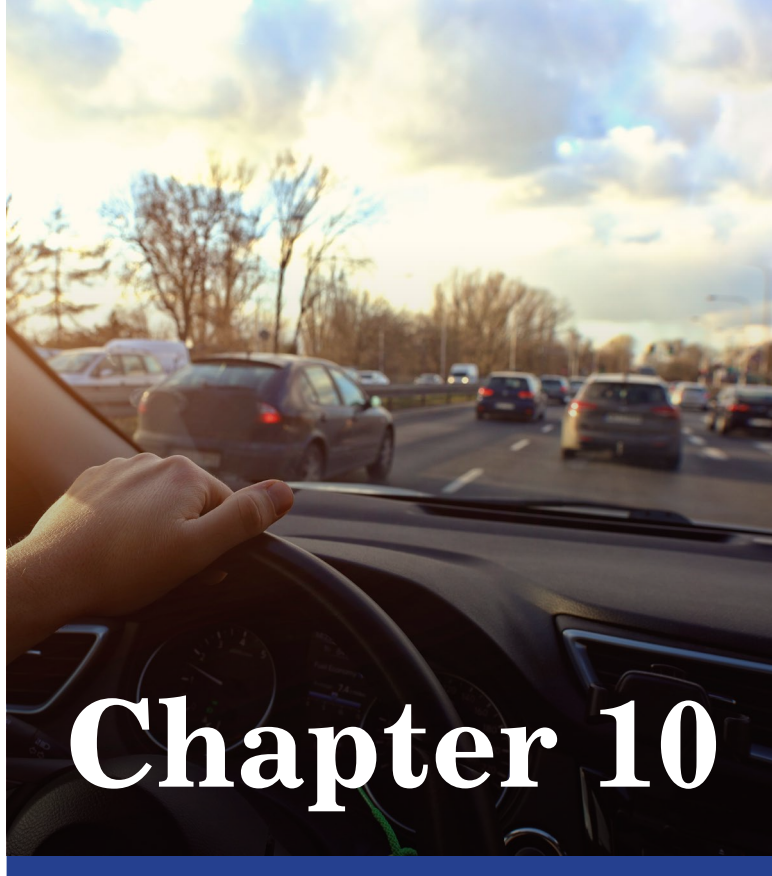
N/A

RELATED PROJECT(S)

This project can be deployed independently of other projects. However, the wireless communication system (Project 1) should be in place before this project is deployed.



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Chapter 10

Appendices

**APPENDIX A – FHWA TRAFFIC
DETECTOR HANDBOOK TABLE N-3,
GROUNDING DESIGN GUIDELINES**

**APPENDIX B – STANDARD
OPERATING PROCEDURE (SOP)
TEMPLATE**

**APPENDIX C – STANDARD
OPERATING PROCEDURES USED BY
OTHER CITIES**

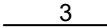
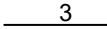
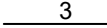
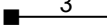
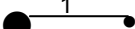
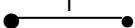
**APPENDIX D – AUTOMATED TRAFFIC
SIGNAL PERFORMANCE MEASURES**



Appendix A

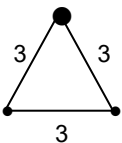
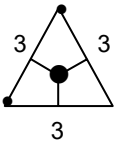
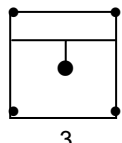
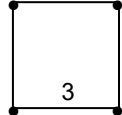
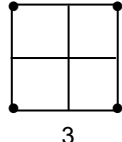
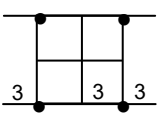
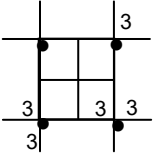
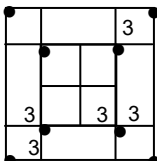
FHWA GROUNDING DESIGN GUIDELINES

Table N-3. Resistance to ground for various ground system configurations and soils.

Ground System Configuration	Description	Normal Use	Resistance to Ground (Ω) in Clay ($\rho=100\Omega\text{m}$)	Resistance to Ground (Ω) in Sandy Clay ($\rho=200\Omega\text{m}$)	Resistance to Ground (Ω) in Clayey Sand ($\rho=500\Omega\text{m}$)	Resistance to Ground (Ω) in Sand ($\rho=1500\Omega\text{m}$)	Resistance to Ground (Ω) in Sand, Gravel ($\rho=5000\Omega\text{m}$)
•	1. Single 20 mm x 3 m rod	Addition to system	32	80	160	480	1610
●	2. Single 220 mm dia. x 2300 mm steel footing	Poles (requires additional system)	28	70	140	420	1400
●	3. Single 85 mm dia. x 1830 mm steel footing	Poles, cabinets (requires additional system)	40	100	200	600	2000
■	4. 610 x 610 x 6 mm plate	Rock overburden 0.6 to 2.0 m	46	115	230	690	2300
	5. Single #6 wire, bare, 3 m long	Addition to system	41	103	205	615	2050
	6. Single #2/0 wire, bare, 3 m long	Addition to system	38	95	190	570	1900
	7. Single #6 wire, 2 rods	Service	19	38	95	290	950
	8. Single #2/0 wire, 2 plates	Service in overburden	27	54	140	410	1400
	9. 220 mm dia. x 2300 mm steel footing, #6 wire, 1 rod	Poles	19	38	95	285	950
	10. 85 mm dia. x 1830 mm steel footing, #6 wire, 1 rod	Poles	16	34	80	240	800

Source: Traffic Detector Handbook-2006

Table N-3. Resistance to ground for various ground system configurations and soils (continued).

Ground System Configuration	Description	Normal Use	Resistance to Ground (Ω) in Clay ($\rho=100\Omega\text{m}$)	Resistance to Ground (Ω) in Sandy Clay ($\rho=200\Omega\text{m}$)	Resistance to Ground (Ω) in Clayey Sand ($\rho=500\Omega\text{m}$)	Resistance to Ground (Ω) in Sand ($\rho=1500\Omega\text{m}$)	Resistance to Ground (Ω) in Sand, Gravel ($\rho=5000\Omega\text{m}$)
	11. 85 mm dia. x 1830 mm steel footing, #2/0 wire, 2 rods	Cabinets	14	28	70	210	700
	12. 85 mm dia. x 1830 mm steel footing, #2/0 wire, 3 rods	Cabinets	13	26	65	195	650
	13. 85 mm dia. x 1830 mm steel footing, #2/0 wire, 4 rods	Cabinets	10	20	50	150	250
	14. #2/0 wire, 4 rods	Service Any for $\rho < 125 \Omega\text{m}$	11	22	55	165	550
	15. #2/0 wire, 4 rods, 2 ties	Any for $\rho < 125 \Omega\text{m}$	11	22	55	165	550
	16. #2/0 wire, 4 rods, 2 ties, 4 tails	Any for $125 < \rho < 150 \Omega\text{m}$	(9)	18	45	135	450
	17. #2/0 wire, 4 rods, 2 ties, 8 tails	Any for $150 < \rho < 200 \Omega\text{m}$	(6)	12	30	90	300
	18. #2/0 wire, 8 rods, 6 ties	Any for $200 < \rho < 350 \Omega\text{m}$	(5)	10	25	75	250

Appendix B

STANDARD OPERATING PROCEDURE TITLE

STANDARD OPERATING PROCEDURE NUMBER

1. PURPOSE

Brief description of SOP purpose and why SOP is required. (How to change signal timings)

2. RELATED TOPICS

List of relevant topics or related SOPs.

3. CONTEXT

Statement outlining areas and context covered under Standard Operating Procedure (SOP). List areas that do not apply.

4. DEFINITIONS

List of definitions used in the SOP.

5. PROCEDURE

Main text of SOP detailing procedure(s) for task to be performed. Sufficient detail, clearly expressed, to enable trained personal to perform procedure(s) without supervision and trained personal to train others to perform the task.

Step 1 – Beginning steps with details.

Step 2 – Next steps with details.

Step 3 – Final steps with details.

6. FORMS, RESOURCES, REFERENCES AND OTHER RELATED DOCUMENTS

List all controlled internal and external references referred to within SOP text only. Information should be sufficient for user to find source document.

Appendix C

STANDARD OPERATING PROCEDURES USED BY OTHER CITIES

Below is a list of Standard Operating Procedures maintained by the City of Austin Mobility Management Center. These represent a subset of sample SOPs implemented around the country.

Overview

- ▶ Introduction
- ▶ TMC Overview
- ▶ Administration

Typical Operation

- ▶ TMC Operations
- ▶ Daily Tasks
- ▶ Backlog Tasks

Events

- ▶ Overview/Coord.
- ▶ Event Management
- ▶ Severe Weather Response
- ▶ SXSW
- ▶ Trail of Lights
- ▶ Austin City Limits
- ▶ UT Football
- ▶ Erwin Center
- ▶ Austin FC
- ▶ Blues on the Green
- ▶ COTA
- ▶ HS Football
- ▶ Other Smaller Events

Incident Management

- ▶ Incident Definition
- ▶ Roles/Responsibilities
- ▶ Devices/Tools
- ▶ Quick Guide: Incident

Software & Tools

- ▶ KITS
- ▶ Cameras
- ▶ CCTV
- ▶ Wisenet CCTV
- ▶ Video Wall
- ▶ VI Monitor Plus
- ▶ DMS
- ▶ PCMS
- ▶ DSDD
- ▶ Twitter
- ▶ D4
- ▶ NextPhase
- ▶ Detection
- ▶ KITS Detection Status
- ▶ ITS+
- ▶ Gridsmart
- ▶ ATSPM
- ▶ Traffic Maps
- ▶ Fire Viewer
- ▶ Lane Closures Map
- ▶ Austin Energy Outage Map
- ▶ Traction
- ▶ School Zone Flashing Beacons
- ▶ Conflict Monitors
- ▶ KorWeb



Appendix D

AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES

METRIC	DESCRIPTION
Approach Delay	The time between approach activation during the red phase and when the phase turns green. Start-up delay, deceleration, and queue length that exceeds the detection zone are not accounted for.
Approach Speed	The speed at which vehicles are approaching the intersection, typically filtered to measure speed 15 seconds after start of green to start of yellow. Includes information on posted speed limit, average speed, and 85 th percentile speed.
Approach Volume	The number of vehicles approaching the intersection for each approach direction using both advance and stop bar detection. Typically includes information such as peak hour, peak hour factor, and peak hour volume in addition to total volume.
Arrivals on Red (AoR)	The quantity of vehicles arriving at an intersection during the red phase. Includes the percentage of vehicles arriving on red compared to vehicles arriving on green or yellow.
Pedestrian Delay	The time between pedestrian detector actuation during the Don't Walk phase and when the Walk phase is activated.
Purdue Phase Termination Chart	A graphic that displays why each phase terminated (trigger event) during a period. Trigger events include force off, gap out, or max out.
Preemption Details	Data from the preemption request through the end of preemption service. Can include data for both rail and emergency preemption. Data includes information regarding service time, dwell time, entry delay, end call, call max out, track clear, and gate down.
Purdue Coordination Diagram (PCD)	A graphic displaying the beginning and end of each phase for a cycle and the arrival of vehicles during each movement of the cycle. Used to evaluate coordinated signals and analyze platoons.
Purdue Split Failure Diagram	A graphic that displays the count, percentages, and classifications of split failure. Includes the average green occupancy ratio (GOR) and red occupancy ratio during the first five second of red (ROR ₅).
Split Monitor	Identifies the factor responsible for terminating a phase. Includes phase duration and trigger event.
Turning Movement Counts	The number of vehicles making all supported turn and through movements for each approach at an intersection. Requires detection for each lane in movement and creates separate charts for each movement direction.
Yellow and Red Actuations	Vehicles approaching on yellow and red whose speed is too high to safely stop. Provides information on if vehicles passed through the intersection on yellow, during the red clearance interval, or when a conflicting phase was active.

Sources:

¹https://traffic.dot.ga.gov/ATSPM/Images/ATSPM_Reporting_Details.pdf

²<https://ops.fhwa.dot.gov/publications/fhwahop20002/index.htm#toc>





Kimley»Horn
Expect More. Experience Better.