Multi-Agency Coordinated Traffic Signal Systems with Central Software Control

Concept of Operations – Version 1.X

Prepared for:

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Anyplace County

CSJ XXX-XX-XXXX

MPO Project ID: XXXXX

Concept of Operations [Template]

## Multi-Agency Coordinated Traffic Signal Systems with Central Software Control

The Concept of Operations (ConOps) document defines the operational mission of the [project name] project and states the operational requirements necessary to achieve that mission. The ConOps defines: 1) the goals, objectives, and capabilities of each system included in the project; and 2) the roles and responsibilities of the city, other agencies, and associated project stakeholders.

# Concept of Operations Scope

This section provides an overview of the ConOps document and the proposed coordinated traffic signal system to which it applies.

* + 1. Identification of System

This project will deploy, operate and maintain a traffic signal control system with central software control with participation and control of multiple agencies on/in [describe roadway segment or area]. This project is referenced as CSJ ###-##-#### on the H-GAC Transportation Improvement Plan (TIP) and referenced by city documents as ITS Project ###.

* + 1. Document Overview

This project is motivated by a central need to coordinate traffic signals along corridors and within networks as an overall system instead of as individual signals or signal systems operated by individual agencies without regard for operations crossing jurisdictional boundaries.

The purpose of this ConOps document is to:

* To ensure that city (and other stakeholder) needs and expectations have been documented early in the project development process;
* To ensure that the project deployment is linked to the agency mission, goals, and objectives;
* To identify and document existing operations, and where gaps may exist;
* To identify where the proposed system could supplement existing operations;
* To define the envisioned operational environment with the [project] in operation;
* To establish a list of operational requirements; and
* To begin the traceability of the systems engineering process.
	+ 1. System Overview

[Blind Note: Briefly state the purpose of the proposed system. Describe the general nature of the system, and identify the project sponsors, user agencies, support agencies, and the operating centers that will run the system. Mention other documents relevant to the present or proposed system. A graphical overview of the system is strongly recommended. This can be any type of diagram that depicts the system and its environment.]

A centralized traffic signal coordination and control system is used to synchronize multiple traffic signals and allow real-time signal timing adjustments in a coordinated manner. When signal systems are not coordinated across jurisdictional boundaries, excessive delays and queues can result, increasing fuel consumption and resulting in higher vehicle emissions.

The project will be sponsored by [agency]. Other users of the data generated by the system will include [other users/agencies]. The centralized traffic signal coordination system will be run through the [local center OR Houston TranStar OR other].

[Blind Note: include high-level system operational graphic here – show representations of physical equipment and connections indicating high-level data elements to be transmitted AND calculations completed – DO NOT show technologies to be used in this graphic as the ConOps should be technology-neutral. Technologies are selected in the market studies/pre-design or design phases]

# Referenced Documents

[Blind Note: List the document number, title, revision, and date of all documents referenced in the ConOps document here. If references are not in the public domain, list the owning agency or source.]

1. U.S. Department of Transportation, California Division. Systems Engineering Guidebook for ITS. [Online] [Cited: Date] <http://www.fhwa.dot.gov/cadiv/segb/>
2. Travel Time Data Collection Handbook, Report No. FHWA-PL-98-035, Office of Highway Information Management, FHWA, March 1998, Page 3-6, Table 3-4.
3. U.S. Department of Transportation, Federal Highway Administration. Traffic Control Systems Handbook, Chapter 8 [Cited: Date] <https://ops.fhwa.dot.gov/publications/fhwahop06006/chapter_8.htm>

Additional Local References:

* Houston-Galveston Area Regional ITS Architecture
* National ITS Architecture
* Houston TranStar IS Requirements
* Houston TranStar Policy and Procedures Manual

# Current System or Situation

[Blind Note: In this section, describe the system or situation as it currently exists. If there is no current system on which to base changes, describe the situation that motivates the proposed system.]

This section describes the current operational situation and summarizes the rationale for deployment of a central traffic signal control system in the First Street.

* + 1. Background, objectives and scope

City 1 and City 2 currently operate a total of 14 traffic signals along First Street (8 in City 1 and 6 in City 2). City 1 and City 2 both coordinate their signals on the corridor, however the two signals on either side of the city limit are not currently operated in a coordinated system. This lack of coordination causes the platoons along First Street to stop, increasing delays, queues and frustrations for drivers. In addition, both city’s traffic signal controllers and communications systems have aged and do not provide the desired level of functionality to operate the corridor optimally. After numerous complaints, both city councils have agreed to take action and have directed the engineering departments of each city to work together towards coordinated signal operations on First Street.

The objective of this system is to connect the 14 signals along First Street to operate in a coordinated manner within a central Software System that is mutually procured, administered and operated. The scope of this system includes installation of communications, upgraded local controllers and software, central control software, and policies and procedures to mutually operate the corridor.

* + 1. Operational policies and constraints

Both city councils have determined that the First Street corridor should operate with a higher level of service and more reliably than currently experienced. In a joint meeting in January 2017, both councils directed staff to work towards a coordinated signal system in the corridor while recognizing city ordinances and to operate the system in a secure manner per each city’s IT and Engineering Department policies. Current city policies (for both cities) do not approve of, nor do they exclude, sharing of resources with other agencies. However, the legal departments of each city has recognized that procurement of a new system will require legal agreements not currently in place. In addition, the engineering departments at both cities have recognized that new policies and procedures not currently in place.

* + 1. Description of current system or situation

[Blind Note: The purpose of this section is to describe the current system and how it operates. This description should be simple enough and clear enough that all intended readers of the document can fully understand it using the users' terminology. Graphics should be used wherever possible. If parts of the descriptions are large or overly complicated, they can be included in an appendix or incorporated by reference. When the proposed system is new, discussion should focus on the current situation.]

The current situation is for both cities to operate the traffic signal systems along First Street without daily regard to operations of the other city. Staff of the two cities occasionally talk about setting offsets and similar cycle lengths, but without communications between the two systems the signals easily get out of sync. This has been problematic as traffic has grown along the corridor and with the older signal control equipment used by both agencies does not provide adequate coordination.

With growth in the corridor, including major retail developments, there is a need to change signal timings in response to holiday shopping patterns and special events, and do so across jurisdictional boundaries. This cannot be achieved with the current equipment, lack of communications between signals, or lack of central control software that can operate and change timings in real-time.

* + 1. Modes of operation for the current system or situation

Each city operates First Street in a time-based coordination manner with no communications to a central control server. The signal systems have the same cycle lengths for AM and PM weekday peak hours, with time-based offset coordination. Coordination for signal timing changes between jurisdictions is via direct staff verbal communication. No process exists for formal assessment for the need of such timing changes, nor is there a process to ensure that the time-based coordination is staying in sync.

* + 1. User classes and other involved staff/personnel for the current system or situation

Traffic signal operation for both cities is housed in their respective Public Works and Engineering Departments under Street Maintenance Sections. These sections have a section manager who reports to the Director of Public Works. The Director of Public Works reports directly to the City Manager.

City 1 has one full-time traffic signal technician who works with one of the staff engineers on signal timing operation. City 2 outsources their signal technician process to two outside contractors: 1) a traffic engineering consultant, and 2) an electrical contractor.

* + 1. Support environment for the current system or situation

Traffic signal support is internal at City 1 and outsourced at City 2 (see Section 1.3.5). Both cities operate the signal systems independently and support for signal operations is independently procured. Both city’s traffic signal operations are run by the Department of Public Works and Engineering Departments under Street Maintenance.

# Justification for and Nature of Changes

In this section, shortcomings of the current situation that causes the need for development of a new system is described. This section provides justification for features of the new signal control central operating system.

* + 1. Justification for changes

Both City 1 and City 2 have realized that, in response to citizen concerns about traffic congestion in the First Street corridor, that coordinated signal operations was needed to address congestion, provide staffs of both cities with the ability to cooperatively manage traffic operations daily and react through traffic signal timing changes. A central software system – one software control component – was desired so that both cities could visualize what changes

* + 1. Description of desired changes

The new coordinated signal system, at a high level, should provide the following capabilities, functions, processes, and interfaces:

* Provide a system graphical user interface
* Provide system functions, including:
	+ communications,
	+ database administration,
	+ controller database management,
	+ download/upload functions, and alert and event notification
* Provide Intersection control functions
* Provide traffic responsive control
* Provide system analysis and engineering tools
	+ Provide for adaptive signal control
	+ Maintenance management system
	+ Data collection and monitoring
	+ Performance reports
		1. Priorities among desired changes and new features

Priorities among the new features are shown in Table 1 below. Each feature is classified as essential, desirable, or optional. Classifying the new features is important to guide the decision-making process during the life cycle of the proposed system. This information is also helpful in cases of budget or schedule cuts or overruns, since it permits determination of which features must be finished, and which ones can be delayed or omitted. Desirable priority does not mean that a requirement should not be met, but may be met at a level lower than stated if schedule or budget constraints preclude reaching stated performance thresholds.

Table . High-Level Requirements and Priority.

|  |  |
| --- | --- |
| High-Level Requirement | Priority (Essential, Desirable, Optional) |
| * Provide a system graphical user interface
 | Essential |
| * Provide database administration
 | Essential |
| * Provide controller database management
 | Essential |
| * Provide download/upload functions
 | Essential |
| * Provide and alert and event notification
 | Essential |
| * Provide Intersection control functions
 | Essential |
| * Provide interconnected control
 | Essential |
| * Provide adjusted signal control
 | Essential |
| * Provide traffic responsive control
 | Desirable |
| * Provide for adaptive signal control
 | Optional |
| * Provide system analysis and engineering tools
 | Desirable |
| * Provide a maintenance management system
 | Desirable |
| * Provide for data collection and monitoring
 | Desirable |
| * Provide for performance reports
 | Essential |

* + 1. Changes considered but not included

There were no changes considered, but not included, in the proposed system. The only limitation was on keeping this initial system focused on the First Street corridor only. Other mutually operated corridors may be considered for future expansion of the system.

* + 1. Assumptions and constraints

The following assumptions were made to enable deployment of the system:

* The cost of central control software will be shared equally;
* The cost of local (controller) software will be paid by each city for their intersections;
* The cost of any ancillary upgrades (detection, cabinet, etc.) will be borne by each city for their intersections;
* The central control software will be installed on a server located at City 1 with a virtual desktop provided to City 2.
* Communications between intersections and central processing host will be via a new fiber optic cable network along the First Street corridor and supplemented with wireless or cellular as needed;
* Ongoing maintenance of the server and central software shall be equally shared by both cities;
* Ongoing maintenance of the field components, including communication, will be borne by each city for intersections in their jurisdiction.

The following constraints will be placed on the system:

* The system must comply with both cities IT department and/or Engineering Department security protocols for shared data elements;
* The system should protect public privacy using encryption and/or truncation and encryption or techniques as necessary.

# Concepts for the Proposed System

In this section, the proposed system is described in a high-level manner, indicating the operational features that are to be provided without specifying design details. This section explains how the proposed central signal monitoring system is envisioned to operate in fulfilling user needs. This discussion does not contain design specifications, but it does have examples of design strategies.

* + 1. Background, objectives, and scope of the new or modified system

Both cities have identified enhanced arterial operations as a priority initiative along the First Street corridor. As both cities have developed, First Street has experienced growing congestion, with the need for enhanced signal operations and data collection along the corridor.

The goals (high-level needs) of the proposed central signal control system are:

* Control and coordination of traffic signals along the First Street corridor (Need 1)
* Surveillance and monitoring of traffic through signal detectors (Need 2)
* Monitor for faults and malfunctions (Need 3)
* Increase travel time reliability through the First Street corridor (Need 4); and
* Provide preemption for emergency vehicles.

The scope of the system is as follows:

* Traffic signals controlling First Street, from Intersection 1 in City 1 to Intersection 14 in City 2.

The objectives of the system are:

* Result in a XX% reduction in route travel times in the corridor;
* Increase travel speeds by XX% in the corridor;
* Decrease vehicles stops by XX% in the corridor;
* Reduce delay by XX% in the corridor;
* Decrease fuel consumption by XX% in the corridor;
* Reduce vehicle emissions by XX% in the corridor; and
* Reduce intersection downtime by XX% through monitoring of faults and malfunctions remotely.
	+ 1. Operational policies and constraints that apply to the proposed system

The Engineering Departments of both cities have been tasked to deliver the central traffic signal control system and has set the goals listed in Section 1.5.1 as minimum for the system. The engineering departments have determined that the system (including field controllers, communications, and the central processing and interface system) should be operational 99.5% of the hours over a year, allowing time for system maintenance as needed. Both city councils have set aside additional operational funds for the system once installed at an annual amount of $XX,XXX, provided through the Engineering Departments. Both City Councils agreed that data from the system may be shared with partner stakeholders (including TxDOT and other cities and counties) through internet connections and in compliance with IT Department policies of both cities.

* + 1. Description of proposed system

This section contains a description of the proposed system.

* + - 1. The operational environment and its characteristics

The central signal control system will operate in three environments: 1) field/roadside, and 2) server located in a city facility with an operator workstation, and 3) secure, remote access via the internet (and how City 2 will take access to the system).

The operational environment for the field controller include requirements typically specified for roadside equipment with respect to minimum and maximum temperatures, humidity rates, and other environmental requirements.

The server and workstation would need to comply with City IT requirements, including physical specifications and cooling functions.

* + - 1. Major system elements and the interconnections among these elements

Figure 1 shows the system elements and connections between elements (with high-level data types noted). The system components can be separated into four primary elements:



Figure 1. System Elements and Connections (3).

* + - 1. Interfaces to external systems or procedures

The primary system data interface to external systems is out via an NTCIP-compliant data stream.

* + - 1. Capabilities or functions of the proposed system

The capabilities and functions of the proposed central traffic signal system include:

* System graphical user interface
	+ General display
	+ Map
	+ Scheduler
* System functions
	+ Center to field communications
	+ Database administration
	+ Controller database manager
	+ Controller database download/upload function
	+ Alert and event notification
	+ System analysis tools
* Intersection control functions
	+ Controller access
	+ Control modes
* Traffic responsive control
* System analysis and engineering tools
	+ Time/space diagrams
	+ Split monitors
	+ System reports
* Maintenance management system.
	+ - 1. Charts/descriptions depicting inputs, outputs, dataflow

See Figure 1 for general high-level system inputs, outputs and data flows between field elements, central server and the interfaces.

* + - 1. Cost of systems operations, including manpower requirements

It is estimated that the cost of the central signal control system operations and maintenance is incremental to existing operations and maintenance costs – meaning that the O&M of the system can be accommodated by existing staff given current workload. If current workload increases, or priorities changed, additional cost to operate and maintaining the signal control system may be required.

The monetary value of central signal control system operations and maintenance cost is estimated to be approximately $30,000 per year ($30/hour x 4 man-hours/day x 250 days/year) for labor and $15,000 per year for communications cost and supplemental equipment for each city.

* + - 1. Operational risk factors

The primary operational risk factor of the central traffic signal control system is the loss of detection and/or communication between field and server. Other operational risk factors include failure of the city staff to understand the operations or limitations of the central server or misinterpret system outputs. Operational factors could also include inadequately trained maintenance staff, operating staff, and inadequate funding for system operation and maintenance.

* + - 1. Performance characteristics

The central traffic signal control system shall be able to control 800 traffic signalized intersections for ultimate build-out of the system.

* + - 1. Quality attributes, including: reliability and availability, others as needed

The central traffic signal control system shall be available 99.5% of the time of the year.

* + - 1. Provisions for safety, security, privacy, integrity, and continuity of operations in emergencies

There are no additional provisions for safety, security, or privacy in emergency operations versus normal operations. The integrity and continuity of system operations is provided by the data sharing agreement between the cities.

* + - 1. Logistics requirements to support system

Other than providing communications to field controllers, standard inventory control of replacement parts (including confirming lead times with suppliers) and regular software updates of server operating system, there are no other significant logistics requirements to support the system.

* + 1. Modes of operation

The central traffic signal system control system will operate in normal and incident modes. See Section 1.6.

* + 1. User classes and other involved staff/personnel

This section discusses the user classes and how they interact with the system

* + - 1. Organizational structure

The organizational structure of user groups and classes at both cities that will be involved with the proposed system are shown in the figure below. This shows the relationship of city administration in relation to the various user classes listed in Section 1.5.5.2.



Figure 3. System/Organizational Structure of User Classes

* + - 1. Profiles of user classes

User classes for the system include:

* System Operator – individuals (likely Engineering Department staff) that manage system configuration and use the signal system for real-time operations. These users require the highest levels of system authentication, are trained in the use of the system, and may make decisions on how to interpret system outputs. This class of user should be trained in the operation and configuration of the system and are responsible for its daily operation and function. The interface with the system will be primarily on the host configuration and data output interfaces.
* System Maintainer – individuals (likely Engineering Department staff) or contractors with primary responsibility to maintain the function of field equipment and communications links between field equipment and central signal system server. A system maintainer could also function as one who maintains the host server with operating system and host software updates. These users should be skilled in electronics installation, troubleshooting and repair, and are likely the same staff that currently deal with traffic signal and telecommunications issues for both agencies.
	+ - 1. Interactions with system among user classes

The various user classes interface with the proposed system as described below. Most of the interface will be through the central software server interface at the primary operator workstation, internet browser-based screens via PC and mobile devices, but some users will have access to field equipment interfaces and will need to connect via laptop computer or over mobile internet connections.

* System Operator – interaction with the system will be primarily on the central server interface. Operators will monitor the signal system, detector outputs, system status pages, and map.
* System Maintainer – interaction with the system will be through the system status page, which shows communications status, last received read, IP/network address, and charts including communications status and reliability. Their interaction will also be in the field where they will interface with the controller and cabinet and communication interfaces.
	+ - 1. Other involved personnel

Agency executives and staff members may not directly interact with the central traffic signal system but will influence it use and operational status. City managers may not directly use the system but will use reports from the system to prioritize initiatives to improve mobility. City Council members may also not directly use the system but will use reports and input from staff derived from the system to make decisions on budgeting and priorities for investment in transportation systems in the community.

* + 1. Support Environment

The central signal control system is envisioned as one that requires moderate amount of resources to maintain and operate. Aside from ensuring power and communications remain in operation, the continuous operation of the central signal control system has maintenance requirements which include daily operations, replacement of field equipment and communications cost. Preventative maintenance is recommended but is mainly limited to checks of the field equipment.

Support for the system can be under the direction of the Engineering or Public Works Department for each city, with additional support by contractors as needed. Typical levels of spare parts should be kept on hand (5-15% replacement in inventory). In some cases, bucket trucks or other heavy equipment may be needed. The software interface should be used to identify signals which malfunction, either to the units themselves or from communications interruptions and identify the current phases of the signal. This interface should identify signals that experience communications uptime below acceptable levels.

# Operational Scenarios

Below are step-by-step descriptions of how the proposed central traffic signal control system should operate and interact with its users and external interfaces under certain circumstances.

## Normal Operations

It is expected that the system will operate under normal conditions for the clear majority of the time. The operation of the system may be monitored remotely from the central control system (or over the internet) via the City 1 traffic management center, but there will be no requirement to intervene in system operations.

## Major Events

For this scenario it is assumed that a special event is taking place requiring special traffic signal timings. In this case the traffic management center staff of City 1 will adjust the timings as needed, in consultation with pre-agreed upon signal modification parameters by City 2. Traffic will be monitored via detector loops in the corridor and traffic data relayed back to the center to confirm the effectiveness of the timings and strategies being applied. If there is heavily directional traffic before or after an event, the system will be set to favor the predominant direction and coordinate accordingly, with appropriate green times and offsets. The corridor may be set by the operator to operate as one or more coordinated groups under this condition.

## Minor Incidents

This scenario assumes that a minor incident has occurred along the First Street corridor. A minor incident is a traffic incident that does not close a lane but does affect traffic conditions. This would be a minor vehicle collision or a stalled vehicle. In this scenario the central control system could manage the signal timings automatically with operations monitored remotely at the center.

## Major Incident

When a major incident occurs on the First Street corridor traffic can unpredictably change and the response by the central system can be varied by time of day, day of week and the current traffic conditions at the time the incident occurs. The central system should detect an increase in traffic volume and take automated, but authorized, action.

The system can modify green splits to accommodate all movements at all intersections in the corridor. The system can increase green times, but only up to the maximum permitted by the operator. If diversion traffic changes the predominate direction of the traffic on the corridor, the progression can be changed to match the traffic flow. A major incident will typically not result in uniform increase in traffic in one direction for the entire corridor thus the system can change by sections of the corridor.

# Summary of Impacts

This section describes the operational impacts of the proposed central traffic signal control system on the users and the operations and maintenance organizations involved and describes how those users can prepare for the changes that will be brought about by the new system.

* + 1. Operational impacts

The anticipated operational impacts of the system on users, support, and operations and maintenance staff during the operations of the central signal control system include:

* Users
	+ System Operator – operators will spend time interacting with the system, particularly in peak periods as they monitor traffic. Operators will monitor the system map and produce tabular and graphical data on system operation. Operators will be the most well versed users at the agency, and may be required to assist others with interpreting data outputs or supplying reports, charts and graphs from system output. The anticipated man-hours per week spent by one operator on this system could be 25-35 hours per week. New procedures may need to be developed to guide operators on their responsibilities with the system and their priorities related to it versus other duties.
	+ System Maintainer – system maintenance may require field work where they will interface with the reader hardware, antennas, and communication interfaces. System maintenance may require less than 4 hours per week per 10 readers. The maintenance staff will need to understand where in the repair priority the signal control system is in relation to other equipment and maintenance responsibilities. Departmental budgets will need adjustment to include the additional manhours and materials needed to maintenance the system.
* Support Staff – there will likely be a need for city IT staff to assist with obtaining network addresses for signal equipment initially, and to assist Engineering Department with ongoing maintenance issues. The level of support could be expected to be about 4 hours per intersection deployed initially, and less than 2 man-hours per week thereafter for normal operations and maintenance. City IT may also need to supply computerized archive space on the city server where the system will be housed. Both cities will have to mitigate any security risks associated with the new system and ensure that security updates are applied to applicable servers.
	+ 1. Organizational impacts

At this point, it is envisioned that this system would require additional staff to monitor and maintain the system. In City 1, it is anticipated that one additional staff member may be needed. Existing operations staff will add monitoring to their normal duties and advise administration if additional resources are ultimately needed. Regarding maintenance, existing staff and/or contracted services can accommodate needs. Both City Councils will have to provide funding to deploy and maintain the system, and incrementally fund expansion as desired.

Where existing communications links are not available at deployment sites, cellular or wireless communications links will need to be provided and paid for using allocated operations funds. Both City Councils and Engineering Department administrators will need to determine if those funds come from existing operations allocations or will need supplemental funds added.

* + 1. Impacts during development

During development of the system, staff members at various level of both agencies may be needed to provide input or be involved in meetings to discuss requirements, high-level design, and detailed design. In addition, key staff may be needed to be involved in verification and validation efforts to document compliance with system requirements once deployment begins. Designated staff members may need to take time from normal duties for training activities and support staff may be required to escort contractors during field installation and work in the right-of-way.

# Analysis of proposed system

*Provide an analysis of the benefits, limitations, disadvantages, and alternatives considered for the proposed system. These benefits can be quantitative (preferred) or qualitative.*

* + 1. Benefits

The benefits of the proposed central traffic signal control system is that it enables lower travel times, reduced delay and queues, lower fuel consumption and emissions and allows for operators to adjust traffic signal timings during special events and incidents across city limit lines and eliminates the current limitations on coordinating across city limits.

* + 1. Disadvantages and limitations

Higher initial cost for both field equipment and traffic management center software. Higher maintenance cost for field components and communications. The central system is a more difficult initial system setup and tuning process.

* + 1. Alternatives considered

No other alternatives were considered.

# Appendices

[Blind note: Some information may be placed in appendices to the document. Each appendix should be referenced in the main body of the document where that information would normally have been provided. This can include proposed system coverage maps, locations of readers, communications links (existing and proposed) and graphics regarding the system.]

# Glossary

[Blind note: A glossary should be maintained and updated during the processes of concept analysis and development of the ConOps document. Include an alphabetical listing of all acronyms and abbreviations, along with their meanings as used in this document, and a list of any terms and definitions needed to understand the document. ]