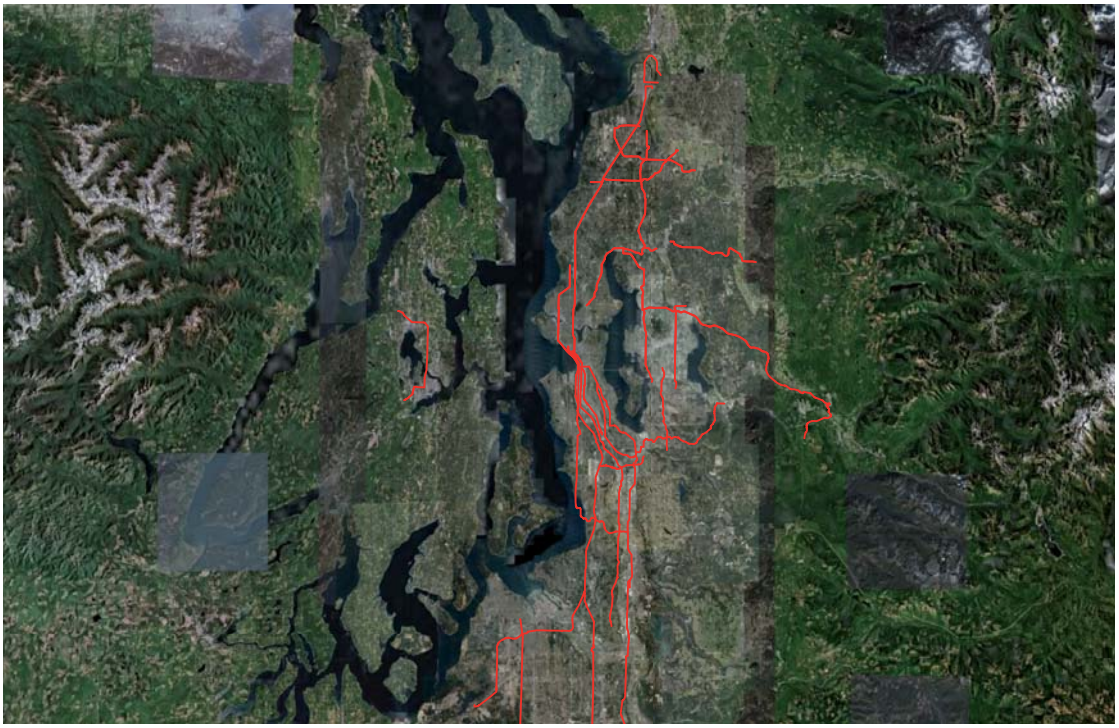
IBI GROUP

Puget Sound Regional Council

Regional Signal Operations Strategy



Submitted to the Regional Traffic Operations Committee

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1. INTRODUCTION

The Regional Traffic Operations Committee (RTOC) is a coalition of central Puget Sound city, county and state agencies that was formed to provide regional traffic operations leadership, in response to a Federal Highways Administration (FHWA) study of our region. The RTOC is leading two projects to implement cross-jurisdictional signal coordination and other Intelligent Transportation Systems (ITS) improvements:

1. **Regional ITS Implementation Plan (RITSIP)**: The RITSIP has identified ITS improvements for 25 key multi-jurisdictional arterial corridors. These 25 corridors were collaboratively selected by the group based upon a number of criteria that assessed the regional significance of over 130 multi-jurisdictional arterials.

2. **Regional Concept of Transportation Operations (RCTO)**: The RCTO will identify the relationships, procedures, and resource arrangements needed to operate these corridors. The successful implementation of the physical improvements recommended by the RITSIP will rely on the adoption of the RCTO strategies by partnering agencies and jurisdictions.

1.1 Background

The major arterial roadways within the central Puget Sound region are, and will continue to be, crucial transportation facilities. Arterials will continue to take on a higher percentage of demand in the future. Currently, approximately 50% of the region's VMT is on the regions' arterials and the central Puget Sound region is growing. By the year 2040, the central Puget Sound region is going to need to accommodate the addition of 1.5 million people and 1.2 million jobs. Ranked 15th among U.S. Metropolitan Areas in 2006 with a population of 3.5 million people, these increases continue several decades of dramatic growth. Forecasts from the Puget Sound Regional Council indicate a 65% increase on in delay on freeways and 144% increase in delay on arterials by 2040. Efficiency improvements are imperative to keep the transportation system moving and improved arterial and freeway management are critical for that to take place.

Unfortunately the traffic signal systems within the central Puget Sound are, in large part, not regionally coordinated. The region has over 80 jurisdictions, many of them operating their own signal systems isolated from neighboring jurisdictions. The Washington State Department of Transportation (WSDOT) operates state routes in unincorporated areas and small cities. However, once a jurisdiction reaches a population of 22,500, they are responsible for the maintenance and operation of their roadways. This has created many traffic signal control systems that do not communicate with each other. Smooth traffic flow can be disrupted when the vehicle moves from one jurisdiction to another if the systems are not coordinated in some way. Traffic flow can also be disrupted at freeway ramp/arterial interchanges where ramp terminal signals do not "talk" with arterial signals or with ramp meter signals.

To focus on issues of system efficiency, a group of city, county and state traffic engineers began to meet and also requested review and opinion from a national expert. This resulted in a study called "An Assessment of Puget Sound Regional Traffic Operations Program[1]".

The regional operators continued to meet and based on the recommendations of this study, the group was formalized into the RTOC in April, 2007. This committee reports to the PSRC

[1] http://www.psrc.org/assets/2953/Puget_Sound_Signal_Review_draft_final_v_3-1b.pdf, prepared by the US Department of Transportation Federal Highway Administration, November 2006

Transportation Policy Board. RTOC's charter is to promote a collaborative and coordinated approach to regional traffic operations investments and practices in the central Puget Sound region with an emphasis on:

1. Traffic signal enhancement and system coordination

2. Regional traffic operations (Active Traffic Management) at the arterial and freeway levels

3. Intelligent Transportation Systems (ITS)

1.2 Purpose

The purpose of this document is to present a strategy for implementing regional signal coordination in central Puget Sound. The strategy will support the diverse requirements of the operating agencies, recognizing that there are many differences, both technical and operational, that impact how agencies manage traffic in their jurisdictions.

Previously, a review of other regional signal coordination efforts was performed, and the results documented in a report of *Best Practices and Concept of Operations* for Puget Sound. The Concept identified high-level roles for a lead agency, partner agencies and contract agencies undertaking a given signal coordination project. The lead agency would typically be the agency with the most signals on the project. The lead agency would develop daily and incident signal timing plans using global parameters that were agreed to by all parties. Partner agencies would provide data collection and performance analysis support. While ideally all of the corridor's signals would be on a single system and operated by the lead agency, a partner agency may still operate its signals along a segment of the corridor and coordinate with the lead agency. The Concept noted there will likely be multiple "lead agencies" across the region depending on the geographic basis of the projects being implemented. The Concept is intended to support eventual Center-to-Center (C2C) system integration between traffic operations agencies.

This document presents a strategy to attain coordination between the region's diverse traffic operators and their respective systems while building from the *Best Practices and Concept of Operations* in the following ways:

- Defining roles and responsibilities for the parties participating in regional signal coordination efforts, as identified in the Concept of Operations.

- Incorporating noted Best Practices, such as identification of performance measures, data collection and analysis.

- Recognizing that some C2C interfaces between "like" systems may offer significant benefit in the near-term, while other more complex interfaces should be considered on a case-by-case basis.

- Supporting incident conditions as well as normal operations.

- Encouraging a flexible approach that allows implementation over time as both local and regional resources allow.

- Acknowledging the natural geography of the Puget Sound region in setting priorities for integrating diverse signal systems.

- Fostering technology independence, allowing participation by any agency as well as other stakeholder groups such as transit, freight and emergency management.

The document is structured as follows:

- **System Strategies** presents the various techniques and options for coordinating signal timing across jurisdictions and discusses their applicability to the Puget Sound region.
- **Multi-Jurisdictional Operations Strategy** describes the proposed approach for implementing signal coordination between partner agencies.
- **Implementation Strategy** describes the actual steps to implement the operational strategy.
- **Agreement** section identifies high-level topics that would need to be addressed in interagency agreements for regional signal coordination. These will be the primary areas covered in the template agreement that will be developed for the next step of the RCTO process.
- **Conclusions** that summarize the findings and recommendations presented in this strategy document.

2. SIGNAL SYSTEM STRATEGIES

Coordinated signal systems range widely in complexity and level of integration. The following subsections provide some background on the various options for timing and coordinating traffic signal systems, increasing in complexity from independently operating isolated signals to coordinating an entire region. This section is provided as a reference to the reader.

2.1 Isolated Signal

An isolated signal is one that has been optimally timed independently of any other signals by only considering the traffic demands for the individual intersection. This option is preferred when the signalized intersection is relatively isolated from any other signalized intersections, has characteristics that are significantly different from any adjacent signalized intersections, or is otherwise not influenced by the operation of adjacent signals. The signal operations can be performed through a local controller. As this operation does not coordinate with other adjacent intersections, a field master controller or central system is not always necessary.

In terms of a strategy for regional signal operations, isolated signals result in individually-optimized intersections as opposed to a coordinated signal network. Isolated signals can, however, be coordinated with each other through the use of time-based coordination. In this case, clocks within the signal controllers are used to determine the local timing based on the time of day or day of week. While this approach could be used sparingly to coordinate geographically remote, isolated signals that happen to be operated by different jurisdictions, it is not a viable approach to coordinating the majority of the region. This timing strategy is included here as a “baseline” as the most basic approach.

2.2 Time-Based Coordination

Time-based coordination uses a common time clock to synchronize individual signals into a coordinated set of signals, and can also smooth traffic flow between jurisdictions through the application of mutually agreed-upon signal timing plans. This strategy is frequently used by agencies wishing to coordinate systems that cannot otherwise “talk” to each other, as it is a relatively inexpensive means of improving traffic flow along a multijurisdictional corridor, especially

compared to the cost of replacing or upgrading equipment and central traffic signal control software. Time-based coordination may be suitable, for example, when a single arterial is shared by two agencies with significantly different signal systems, or where traffic is not heavy enough to warrant investment in more sophisticated system interfaces and communications.

Time-based coordination may be an appropriate approach when a corridor system or C2C interface is not practical.

However, without any communications links between the systems, there is no means of remotely verifying that one's partner agencies are implementing the coordinated timing plans as agreed or react in a coordinated fashion to incidents and events. Agencies must be willing to work proactively with other agencies and be able to reasonably trust that the signals will be timed per the agreement. Among the RTOC agencies, it is generally agreed that time-based coordination as a strategy will not get the region where it needs to be in terms of operational sophistication and responsiveness to changing conditions.

2.3 Corridor System

Beyond time-based coordination, operating a series or grid of signals as a coordinated corridor generally requires communications between the signals and a central traffic signal control system housed at a traffic management center (TMC).

2.3.1 INTERCONNECTED SIGNAL SYSTEM

This approach coordinates the timing of all signals on an interconnected network (may be along a single arterial or multiple arterials). The advantages of interconnecting and coordinating a network of signals include: higher level of service due to smoothed travel speeds and reduced stops; reduced delay and emissions; and safer and more uniform traffic flow.

With this strategy, coordination generally requires that a fixed cycle length be used on all or groups of signals within the interconnected network. The interconnected signals are integrated with a field master controller, which may be one of the local controllers, or a separate controller usually placed alongside one of the interconnected local controllers. The clock in the field master is used to synchronize all interconnected local controllers, assuming coordinated signal timings are deployed. Providing a field master for interconnected signals is also a relatively low cost solution for signal coordination and synchronization.

This strategy can support multi-jurisdictional coordination, but it is very inefficient in terms of the ability to manage signals in real time and making signal timing adjustments. This inefficiency can be attributed to the low bandwidth communications network used in these systems and/or lack of communications to a central system. There are some examples in which an agency has a small number of traffic signals along a corridor, and agrees to put the signals on another agency's interconnected system for coordination purposes. However, the inability to monitor the signals from a central system, and the increased difficulty in changing timing in response to events and incidents makes this option unattractive for multi-jurisdictional coordination. Accessing the master controller remotely via a dial-up connection provides some additional flexibility, but still does not offer real-time monitoring capability.

If two agencies have the same central and field systems and wish to jointly operate a corridor, they can potentially adopt one of two general approaches for shared signal control as shown below:

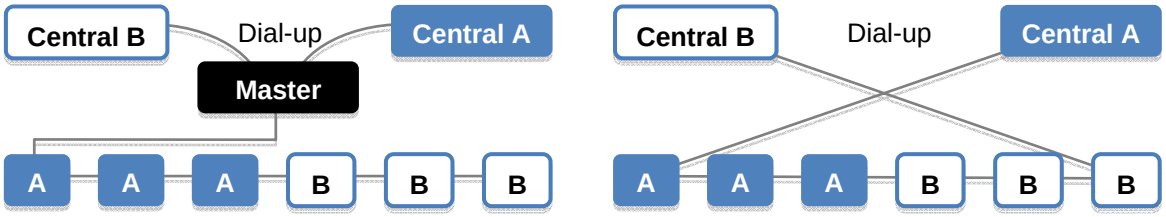


Figure 1: Multi-party control of interconnected signals

On the left side of Figure 1, Agency A and Agency B both share dial-up access to a single field master controller that sets timing for interconnected signals that are owned by both agencies. Either agency can adjust the timing along the entire corridor by dialing into this master controller, depending on the parameters they have agreed to.

On the right side, Agency A and Agency B each control the signals only through their own local field controllers or separate central systems. The trouble with this approach is that there is no shared master controller to mediate timing changes, potentially resulting in conflicts.

2.3.2 CENTRALIZED TRAFFIC SIGNAL CONTROL SYSTEM

This strategy provides a similar arrangement to interconnected signals except the field master is replaced or supported by a central traffic signal control computer system. The central computer system contains software for overall system management and can be located inside a TMC. This permits operations staff to remotely monitor local controller status, and upload/download signal timing data to and from the local controller. This option is more expensive than the field master but provides the remote management capability and can support additional integrated traffic management elements like traffic camera and dynamic message sign (DMS) operations.

Most of the signals in the urban areas of the central Puget Sound region are centrally controlled. The difficulty for multijurisdictional coordination lies with the many different traffic signal control systems that have been deployed over a number of years. The Trans-Valley project in South King County is a notable example of a successful multi-jurisdictional corridor signal system. For this project, King County partnered with multiple agencies to get all of the corridor's signals on the same traffic signal control system and operated by King County. The partner agencies can still control their signals, but have given operational responsibility to King County. This project did require the participating agencies to all use the same central traffic signal control system, in this case, the Siemens ACTRA system.

2.4 Sub-Area System

While the Puget Sound region encompasses a broad four-county urban area, the majority of agencies wishing to coordinate signal timing across jurisdictional boundaries only have a handful of neighboring agencies with which coordination is required. PSRC divides the region into subareas or SMART Corridors for purposes of planning and analysis on a more refined scale than the region at large. These SMART Corridors are shown in Appendix A and potentially provide a convenient and reasonable approach to considering how the region could initiate coordination on a broader scale beyond a corridor-by-corridor approach.

2.4.1 CENTER TO CENTER

Center-to-Center (C2C) is the next step in centralized traffic signal control and information sharing between agencies and involves establishing connectivity between central systems. C2C allows for agencies to maintain their respective system operations (local controllers and central systems), with the added benefit of visibility and potentially control of other connected systems. This connectivity requires communications infrastructure and, if dealing with different system manufacturers or

versions, the development of a customized interface to act as an interpreter between the disparate communications protocols and data structures of the systems. The ideal result is the ability to view and potentially control partner agency systems directly and seamlessly through "your own" system interface without additional log-ins or workstations.

However, developing a robust interface between different vendor systems is a complex undertaking that few jurisdictions have undertaken. While most system vendors state compliance with the National Transportation Communications for ITS Protocol (NTCIP) standard that would theoretically make a C2C interface more straightforward between compliant systems, the proprietary vendor-specific features that make the products most attractive are often not be available in NTCIP format.

Alternatively, a "light" version of C2C could entail each agency working with their system vendor to build an interface to a common web-based Graphical User Interface (GUI). The GUI functionality could range from a basic system status information display, up to remote system access and control, depending on the desires and capabilities of the participating agencies. While this common GUI approach requires a separate login to view the partner agency systems, it offers a "build it and they will come" phased approach to C2C by providing a regional interface standard that others can integrate with as their resources allow.

As noted above, there are many different systems currently operating in the region. A map of the existing signal systems operating on the Regional ITS Plan key arterial corridors is provided in Appendix B. This map clearly illustrates the challenges of establishing C2C communications even between immediate neighboring jurisdictions. As an example, in East King County, Kirkland, Redmond, Bothell, Bellevue and WSDOT are all on different signal control systems. In addition, the City of Bellevue operates an adaptive signal control system, which adds another level of complexity. In Snohomish County, Lynnwood, Everett and Snohomish County all operate different systems, as do agencies in the Pierce County subarea. Ramp meter signals throughout the region are not interconnected with ramp terminal signals, which are not coordinated with arterial signals.

One effort by WSDOT and the City of Seattle is currently developing interfaces between WSDOT's Freeway Management System, WSDOT's Siemens i2TMS signal system, and Seattle's new Siemens TACTICS[2] system. Within the Seattle-Shoreline regional subarea, Seattle and WSDOT share operation of a number of major north-south arterial corridors identified in the Regional ITS Plan where timing differences impact transit, freight and commuters. Additionally, through a shared licensing agreement with Siemens, other agencies currently using ACTRA including King County, Renton and Tukwila, may upgrade to TACTICS. This would provide some level of system continuity between WSDOT, Seattle, and Seattle's immediate neighbors. One of the benefits of the upgrade is expected to be improved transit signal priority functionality, particularly on light rail corridors.

2.4.2 SINGLE SYSTEM

The strategy of deploying a single traffic signal control system as a regional effort provides all of the operational and coordination benefits of centralized control systems and C2C connectivity, and also reduces the complexities of integrating central systems from multiple vendors. As described in the *Best Practices* document, several other regions have chosen a single system for their entire signal network. Under this strategy, the central system resides with a host agency, and each partnering agency has a workstation connected to the host system. This strategy readily enables control sharing and other resource sharing possibilities (i.e., communications, maintenance, operations). Under a single system strategy, each agency's local controllers would have to be compatible with the chosen single central traffic signal control system, likely resulting in some need for new controller procurement, installation and staff training.

[2] Seattle previously ran the Siemens ACTRA system. In addition to Seattle, King County, Renton, Tukwila and Issaquah have also deployed ACTRA.

Significant institutional will, regional resources, and agreements are needed to implement such an approach. Given that substantial investment has been made by many Puget Sound agencies in procuring, implementing and maintaining a chosen system, a single regional system for the four-county area is not a desired or feasible option. Rather, as agencies naturally look towards replacing their systems towards the end of their lifecycle, it would be beneficial to require system compatibility with neighboring systems and/or the most common system within the subarea, and even potentially teaming with other agencies in a joint procurement.

3. MULTIJURISDICTIONAL OPERATIONS STRATEGY

Currently, most signals in the Puget Sound region are interconnected or centrally controlled, with some isolated signals in less developed areas. There is little to no time-based coordination between jurisdictions and no existing C2C interfaces.

Of the existing central traffic signal control systems, each operating agency has procured the system that best met their individual operating and technical requirements. As stated above, implementing a single regional system that would require significant investment to replace software and hardware that is otherwise functioning satisfactorily is not a viable approach. Yet, with at least nine different systems from seven different vendors currently operating in the region[3], developing a complete suite of custom interfaces between these systems would likely be a costly and complicated undertaking.

Therefore, the question remains: how to move forward with an approach that will allow the region to realize the many benefits of cross-jurisdictional operations without requiring undue software and hardware replacement or system development costs. This has been an ongoing topic of discussion with the RTOC throughout the RITSIP and RCTO development process.

The RTOC agencies have indicated that a phased approach would offer the greatest flexibility for the region's operators while still delivering the benefits of multi-jurisdictional coordination. This phasing would implement necessary upgrades to support time-based signal coordination between centrally controlled signals in the near-term, and implement C2C interfaces between same-vendor systems for information sharing, and, possibly control sharing capabilities, as these projects become feasible over the longer term. Custom C2C interfaces could be developed to provide visibility between disparate proprietary systems, if it is felt that the interface would be particularly beneficial to regional or corridor operations. Existing hardware and software would be upgraded if needed to support central control, but the agencies would continue to use their system of choice.

The Concept of Operations document noted that implementation of C2C-based regional signal coordination could follow a stepped process by providing signal coordination at four levels of deployment. The following sections describe the steps involved in this strategy under both normal operating conditions and incidents.

3.1 Level 1: Baseline Relationships and Interagency Communications

Level 1 is essentially the current baseline operating condition of the RTOC agencies: meeting regularly, maintaining established working relationships and jointly identifying key multi-jurisdictional corridors. Staying in touch with traffic operations peers in neighboring jurisdictions entails participating in regular meetings such as the RTOC and maintaining an up-to-date contact list that can be used to notify others of incidents or road closures. Many of the Puget Sound agencies maintain contact through the monthly RTOC meetings and on an as-needed basis with their immediate neighbors.

[3] *Intelligent Transportation Systems (ITS) and Signal Operations Survey Response*; prepared by IBI Group and HDR, Inc. August 7, 2008.

Under normal conditions, interagency communication is on casual as-needed basis. When an incident occurs on a route that impacts traffic flow in a neighboring jurisdiction, agencies generally notify each other using an established call list[4]. This coordination effort should be formalized.

3.2 Level 2: Joint Timing Plans

As resources allow, the agencies plan to move forward with implementing the RITSIP projects and upgrading signal equipment and communications to support coordinated operations and centralized signal control. Level 2 entails establishing the necessary agreements and working together to jointly develop traffic signal timing plans so that the given corridor operates as one system from the public's perspective. The actual system coordination strategy may include time of day operations combined with "shared" system monitoring between agencies, or, if more cost efficient and beneficial to the traffic agencies, the corridor may be operated by a single agency. Communications would be upgraded between the field equipment and the central traffic signal system, and between the traffic agencies, if necessary. Timing plans should be developed for normal operations, incidents, and emergency scenarios.

3.3 Levels 3 and 4: Active Corridor Management with C2C

Active corridor management is a term that is used to indicate a higher level of real-time monitoring and control capability from a traffic operations perspective.

Level 3 would establish mechanisms to share signal timing plans between the various traffic agencies, to provide automatic notification of incidents, and to provide public traveler information. Level 4 would, where desired and feasible, implement center-to-center interfaces between systems for regional traffic and event management.

Functionality that could be established as part of an active corridor management initiative could include:

- **Information Sharing:** Information sharing includes both video and data. The Traffic Busters program will provide some video sharing capability between traffic management centers, but is not scoped for data sharing. Data can be real-time or historical.

- **Control Sharing:** Control sharing allows partner agencies the ability to control each other's signals under pre-set, agreed-upon conditions. This functionality may be desirable, for example, during off-hour periods to respond to an incident when a particular agency may not have the operational resources to respond accordingly. Control sharing capability enhances multi-jurisdictional coordination during unplanned traffic incidents when one or more agencies along the connected network would not have real-time operational resources available. Control sharing can be implemented through a C2C interface, a common GUI, or by providing access via a workstation. The larger effort is on the operations side in the development of procedures, roles and responsibilities, and agreements, as well as potentially additional staff time for operating the shared systems. The workstation approach to control sharing can quickly become cumbersome in terms of staff training, TMC space, and system maintenance needs.

- **Data Warehousing and Archival:** A Data Warehouse can act as a central location where various data is archived for the long-term. Data could be used for regional

[4] Note that during off hours, there may not be anyone available to receive the notification and the "courtesy call" is not necessarily a standard procedure across the region.

transportation studies, inter-jurisdictional signal retiming efforts, and construction planning. The data stored could include:

- Timing plans
- Traffic volume and speed data
- Incident logs
- Signal controller status
- Transit signal priority requests
- Emergency vehicle preemption requests

To remain viable over the long haul, agencies must require their system vendors to integrate, support and maintain the regional C2C interface. Without this commitment, the agencies risk finding themselves with an interface that requires frequent "band-aid" updates (at additional cost) and that loses its usefulness over time.

Agencies must require their system vendors to integrate, support and maintain the regional C2C interface.

4. IMPLEMENTATION STRATEGY

This section describes the technical and operational steps the RTOC agencies may follow to implement the multijurisdictional operations strategy described above.

4.1 Define Program

The operational roles and responsibilities should be determined first: lead agency, partner agencies, etc. For the selected project corridor, the lead agency; the partnering agencies; and other non-signal operating stakeholder agencies (non-operating traffic agencies, transit, police/fire/other emergency responders, and freight operations) must be identified and agreed upon by the collective team. The lead agency selection will most likely be based on the number of traffic signals affected and the available resources an agency possesses, such as:

- TMC functional capabilities and hours of operation
- Engineering and maintenance staff availability and expertise
- Performance assessment/reporting program in place

The goals and desired outcomes of the program should be collectively identified with input from all partners. Examples may include more than general signal timing coordination, such as:

- Enable real-time corridor management
- Improve transit reliability and operations
- Mitigate construction impacts
- Implement multi-agency special event management

- Enable incident mitigation
- Enable freeway/arterial coordination
- Improve traveler information dissemination

The overall scope of work will be based on the determined goals and desired outcomes. The stated goals and outcomes will help determine the needs for local controller equipment and central system equipment. Signal timing plan development will be a major part of the scope. Other capital improvement elements may be necessary, including TSP, CCTV cameras, DMS, and communications between field locations and centers.

The geographical boundaries should be reviewed and defined based on the identified RITSIP corridors. The program partners should review each signalized intersection within the selected corridor, as well as other nearby signalized intersections not specifically on the selected corridor, and determine the geographical boundaries of the program. The need for DMS and CCTV at certain key locations will further define the program boundaries.

Based on the scope of work, the partners may determine that additional resources are required for such activities as:

- Signal timing plan development
- Capital improvement design
- Capital improvement construction
- Construction inspection and testing
- Daily operations, specifically, increased TMC staffing
- Performance monitoring

If additional resources are required, the partners will need to agree upon how the resources will be retained, and who will administer and manage these resources. Whether these resources are internal or external, the development of a scope of work will aid in the development of a program budget and schedule. The process of defining the scope of work should also be helpful towards identifying any inter-agency agreements required for program deployment. If external resources are required, the selection of consultants and contracts would proceed through the normal procurement mechanisms. These resources should be brought to bear at appropriate times over the course of the program.

4.2 Define Performance Measures

All participating agencies must collectively and mutually agree to the performance measures against which the program will be assessed. Then, agreement on the roles and processes for collecting, processing, and monitoring data and how the results will be used to make future changes should be reached. Performance measures may include such metrics as travel time and transit reliability. Ideally, a set of regional performance measures would be developed as a future RTOC initiative. As noted in the *Best Practices* report, performance measures should include measures of value to all users: travelers, operators, and decision makers (elected officials). In addition to determining the performance measures, the partners will need to decide how the measures will be calculated and what data will be collected and how. This process should be considered along with the scope of work.

4.3 Develop and Sign Agreement

In order to initiate a multi-agency action plan, one or several agreements will most likely be found necessary in order to enable agency actions and permit the transfer of funding. The contents of such agreements are discussed more in Section 5. Whether an agreement is based on a regional template model, previous agreements, or written from scratch, one party will need to take the lead on preparing a draft version for review by other partners. The draft agreement should be submitted to each agency, who in turn reviews from a technical point of view first to make sure the scope contents are appropriate. Then each agency will likely require a legal review by their respective attorneys. Any comments will be collected and addressed by the lead agency. If any issue proves difficult to resolve, a meeting with the attorneys involved should follow to find common agreement on appropriate terms. The party within each agency who will sign the agreement on behalf of the agency should be kept apprised of the agreement's terms and status as it develops to reduce the potential for last-minute issues with the final drafted agreement.

4.4 Information Gathering

Once the necessary agreements are in place, the partners can begin the actual work. This preparatory step provides the baseline information necessary to move forward with design and deployment. External resources may be brought to bear at this time. At the outset of the program, the necessary information should include:

- *Inventory*: This step involves compiling existing hardware, software, ITS and communications inventory; roadway geometrics; traffic volumes and other required information.

  While data must be provided for all involved agencies, the partners must determine the roles of who is doing what and the process for compiling. Some information may be readily available, and other information may need to be researched or collected through field investigations.

- *Timing Plans*: This step involves meeting with all participating agencies to review existing timing plans and operations. This meeting will be a discussion of each individual agency's requirements, policies and standards, and how these will be incorporated into the new corridor timing plans.

  Issues to address in these discussions would include:

  – Yellow and all-red clearance times

  – Pedestrian signal timings

  – Phase sequencing, including left-turn lead/lag treatments

  – Local timing parameters

  – Time-of-day schedules

- *Gaps*: This step involves the identification of infrastructure or equipment gaps; compatibility issues; problems with existing timing plans; and other known issues, such as high accident locations, flood zones, etc. This information is based on data collection, inventory analysis, field observation reviews and input from stakeholders.

The identified gaps should be reviewed with all participating agencies, and a process established to achieve consensus on the gaps that are to be addressed through the program.

- *Operational Strategy:* Given the inventory and timing data, and the identified gaps, the partners should identify the operational strategy for their program, namely how the partners will share information, whether control sharing will be enabled and the corresponding conditions, and how the partners will engage active management strategies during incidents.

- *Action Plan*: This step establishes a plan for moving forward and addressing gaps (i.e., equipment needs, signal system incompatibilities, traffic counts and other data collection, time-of-day schedules, corridor sectioning, and software modeling calibration). The Action Plan must determine the process for resolving gaps, and proceeding with any needed capital improvements and timing plan development.

4.5 Implement Program

Implementation would be undertaken in a three-step process as follows:

1. *Design and Deploy Capital Improvements* (if any): This step involves the implementation of capital improvements as identified in gap analysis. It begins with design plan development and follows with the installation process. Elements will include field equipment, communications, and central hardware and software. This can be performed under one single project or broken down into elements and/or agency jurisdictions. Work may be performed by contractors or in-house as resources permit.

2. *Design and Deploy Information Sharing and/or Control Sharing Functionality*: If the partners have determined during the program definition step that an electronic system-to-system interface is desirable and reasonably feasible between the signal control systems on the corridor (assuming that multiple systems are still present after the capital improvements step is complete), the partners will need to undertake the design and deployment of this interface as part of the program. This effort would include: technical and operations requirements definition, procurement, development, testing and installation.

3. *Develop and Deploy Timing Plans*: This step involves the development of new timing plans. While this must be addressed cooperatively by all operating agencies, ideally one entity (either the lead agency, regional body or third party contractor) would be tasked with leading the timing plan development.

   Timing plan development will likely need a modeling effort and also field observations. Agreement will be needed as to which software to use, and the input of traffic data and parameters. Then a review of the model findings is done by each agency to assure conformance of policies and standards. If necessary, and very likely, adjustments are made to the model until satisfaction is achieved by all agencies. Finally, new timing plans are downloaded into the systems.

   As the region moves forward with multi-jurisdictional coordination, it may be beneficial for one partner to serve as the designated timing plan manager or developer for the regional program. Centralizing the timing plan development effort would likely result in streamlined plan development that could incorporate the regional performance measures and be familiar with local standards.

4.6 Evaluate, Adjust and Maintain

The following steps would be performed on an ongoing basis following implementation.

- *Monitor*: Collection of before/after data, field observations, feedback from the public, system operators, and other appropriate stakeholders.

- *Document*: Preparation of a report on outcomes and performance measure attainment is crucial for communicating the positive benefits of the program and helping to secure support and resources for future projects. The contents of such a report should be determined by consensus of the participating agencies.

- *Adjust*: Following initial operational assessment of the deployed signal timings, adjustments are made and repeated again until the demonstrated performance is accepted by all parties.

- *Maintain*: The signal timings and overall systems operations must be regularly maintained. This will be a continuous ongoing effort. Documentation logs of maintenance activities can be useful in assessing system performance, determining required resources, and indicating future improvement needs. The frequency of timing plan reviews should be agreed upon by all parties, and performed at a rate that is supportive by the participating agencies and serves the public's best interests. The roles and responsibilities of this effort should be prearranged. The conditions that may determine the need for review include:

  - Changes in traffic demands and/or changes in turning movement counts
  - Changes in vehicle mix (i.e., percentage of trucks)
  - Impacts from construction activities
  - Changes to roadway geometrics
  - Land use changes
  - Other factors may include: bus service changes, new adjacent signals, etc.

The magnitude of the conditional changes will determine the effort needed for re-timing, which may range from a few simple alterations to full re-modeling and analysis.

4.7 Roles and Responsibilities

The following table lists each of the steps for implementing multi-jurisdictional signal coordination, as described above, and identifies the roles and responsibilities of each Corridor Partner, as follows:

- *Lead Agency*: Primary role in operating corridor and overseeing implementation. Lead agency must be agreed upon by all agencies with traffic signals along corridor.

- *Partner Agencies*: All local agencies that operate traffic signals along corridor.

- *WSDOT*: Operator of select traffic signals on state routes and at intersection freeway ramps. (WSDOT may take the role of either a lead or partner agency)

- *Transit Agencies*: Any transit agency with bus service along any portion of the corridor.
- *Emergency Management*: City, county and state emergency management agencies with tie-ins to emergency responders (fire and police).
- *Freight Operators*: Representatives of freight operator groups who navigate the corridor.
- *Non-Operating Jurisdictions*: Agencies with jurisdiction along the corridor but who do not operate any signals or ITS, either because none is existing or because operations are performed under contract by another party.
- *Contract Administrator*: Any partnering agency that will be procuring contract support for any portion of the program.

Table 1: Regional Signal Coordination Roles and Responsibilities

	Steps	Lead Agency	Partner Agencies	WSDOT	Transit Agencies	Emergency Management	Freight Operators	Non-Operating Jurisdictions	Contract Administrator
1	Scope	Primary leadership role in developing the goals and desired outcomes, confirming geographical boundaries, roles and responsibilities for entire program, and need for contractors.	Contribute to scope by determining what is needed along corridor in their jurisdiction, and how their signals will be operated and maintained.	Contribute to scope by determining what is needed along corridor in their jurisdiction, how their signals will be operated and maintained, and any other needs related to freeway operations and ramp metering.	Provide input from transit perspective (i.e., signal prioritization, bus routing and scheduling).	Provide input from emergency management perspective (i.e., signal preemption, evacuation routes)	Provide input from freight operations perspective (i.e., safety concerns, incident management diversions).	Informed of scope of work and ongoing rogress.	Develop detailed scope of work needed for procurement of required contracts.
2	Performance Measures	Develop plan for the collecting, processing, monitoring data and determining future changes.	Contribute to Performance Measure Plan as it impacts signal and arterial operations.	Contribute to Performance Measure Plan as it impacts signal and arterial operations and the freeway corridor.	Contribute to Performance Measure Plan as it impacts transit operations.	Contribute to Performance Measure Plan as it impacts emergency responder operations.	Contribute to Performance Measure Plan as it impacts freight operations.	Provide "before" data if available, assist with “after” data collection	Oversight and management of contractor support.
3	Inventory	Develop and execute plan for compiling inventory of signal, ITS and communications along corridor.	Contribute to inventory	Contribute to inventory	Contribute to inventory	Contribute to inventory	Not applicable.	Not applicable.	Oversight and management of contractor support.
4	Review Existing	Lead meeting to review signal timing operations along corridor, and each agency's policies and standards for timing plans.	Contribute existing timing plan information for signals along corridor within jurisdiction, and agency policies and standards.	Contribute existing timing plan information for signals along corridor within jurisdiction, and agency policies and standards.	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Oversight and management of contractor support.
5	Identify Gaps	Lead meeting to review Gap Analysis for corridor, and make any necessary revisions.	Review and comment on initial Gap Analysis.	Review and comment on initial Gap Analysis.	Review and comment on initial Gap Analysis as appropriate..	Review and comment on initial Gap Analysis as appropriate.	Not applicable.	Not applicable.	Oversight and management of contractor support.

	Steps	Lead Agency	Partner Agencies	WSDOT	Transit Agencies	Emergency Management	Freight Operators	Non-Operating Jurisdictions	Contract Administrator
6	Action Plan	Coordinate effort to develop Action Plan with input from partners.	Contribute to development of Action Plan.	Contribute to development of Action Plan.	Review and comment on Action Plan as appropriate,	Review and comment on Action Plan as appropriate,	Not applicable.	Not applicable.	Oversight and management of contractor support.
7	Agreements	Lead the draft of any needed agreements for timing plan development and operations, and any capital improvements.	Review the draft agreement both from a technical and legal standpoint, submit comments to Lead Agency, and support execution of final version of agreement.	Review the draft agreement both from a technical and legal standpoint, submit comments to Lead Agency, and support execution of final version of agreement.	Participate in agreement development if applicable for TSP deployment.	Not applicable.	Not applicable.	Not applicable.	Oversight and management of contractor support.
8	Capital Improvements	Oversight and support of all design development, construction and system installation.	Oversight and support of all design development, construction and system installation within jurisdiction.	Oversight and support of all design development, construction and system installation within jurisdiction.	Possible lead of TSP implementations.	Not applicable.	Not applicable.	May provide some capital improvement support for improvements in jurisdiction.	Oversight and management of contractor support.
9	Signal Timing Plans	Lead timing plan development and deployment.	Oversight and support of all timing plan development and deployment within jurisdiction.	Oversight and support of all timing plan development and deployment within jurisdiction.	Review of timing plans and TSP strategy	Not applicable.	Not applicable.	May need to review and approve timing plans depending on agreement with signal operator.	Oversight and management of contractor support.
10	Monitor	Lead overall Monitoring Plan, making sure all data collection is proceeding and directing all responses.	Contribute to Monitoring Plan.	Contribute to Monitoring Plan.	Contribute to Monitoring Plan as applicable.	Offer feedback.	Offer feedback.	Offer feedback.	Oversight and management of contractor support.
11	Report	Lead effort to develop a Draft and Final Report on program outcomes.	Contribute information to and review reports.	Contribute information to and review reports.	Contribute information to and review reports for TSP efforts	Not applicable	Not applicable	Provided copy of final report	Oversight and management of contractor support.

	Steps	Lead Agency	Partner Agencies	WSDOT	Transit Agencies	Emergency Management	Freight Operators	Non-Operating Jurisdictions	Contract Administrator
12	Evaluate, Adjust & Maintain	Determine conditions for and frequency of timing plan updates, and conduct efforts for timing plan adjustments.	Support and implement signal timing adjustments within jurisdiction.	Support and implement signal timing adjustments within jurisdiction.	Notify operators of any adjustment or maintenance needs.	Notify operators of any adjustment or maintenance needs.	Notify operators of any adjustment or maintenance needs.	Notify operators of any adjustment or maintenance needs.	Oversight and management of contractor support.

5. AGREEMENTS

This section describes the agreements that might be required for implementing the above signal coordination strategy and Concept of Operations, with analysis of the special considerations that may need to be incorporated for regional initiatives.

A comprehensive multi-agency agreement is crucial for establishing the terms of the program

The following list identifies, at a high level, the potential key components for inclusion in these agreements. The list is followed by some special considerations that are recommended if appropriate for the program scope.

- *Overall Statements and Mutual Understanding*: The agreement should have an introductory section that describes the overall intent and purpose of the agreement. In addition, a statement of mutual understanding by all parties helps reflect a spirit of cooperation needed for the effort.

- *Corridor Identification*: A detailed description of the corridor(s) comprising the physical project limits is important to be sure all impacts are understood by each party. The corridor identification will include the names of all roadways that are part of the effort and the limits of each section of roadway included in the corridor, preferably by name of intersection.

- *Program Definition:* Each agreement should include a definition and general scope of the program.

- *Participating Agencies' Roles and Responsibilities*: Each participating agency should be identified with each task or activity that agency will be responsible for at each stage of the program, from design through to ongoing operations and maintenance. The more detailed the activity description, the less likely confusion will occur; however, there should be some allowance for contingencies.

- *Administration*: The effort should identify a lead agency with overall administrative responsibility. This includes any reporting requirements, channeling of funds, and general program management. These duties should be detailed in the agreement. If contractors will be retained for some portion of the work, contractor oversight responsibilities should be detailed as well.

- *Indemnification/Hold Harmless*: Clauses that indemnify each agency against each other is required to minimize liability concerns. These are very important for multi-jurisdictional and information-sharing programs that result in a high level of coordination; particularly those that may include control sharing or other resource sharing arrangements.

The following items are recommended for inclusion in the agreement if the activity is considered as part of the program scope.

- *System Acquisition/Upgrade Process*: This section should clearly identify the quantities of each component, the locations for deployment, high-level requirements of each, and the compliance standards to be met for compatibility of each component.

- *Review and Introduction of New Timing Plans*: This section should identify the process steps for the development of new timing plans and specify the times when agency reviews are required, along with the overall goals of the new timing plans.

- *TSP Corridors and Intersections*: The interactions between the transit agencies and traffic signal agencies should be clearly presented, identifying what actions each agency must take related to equipment changes on the buses and the intersection hardware.

- *System Monitoring, Management and Maintenance*: This section should clearly identify the authority, roles and responsibilities of each agency following the deployment of the new system or system upgrade for each of these activities. All known event scenarios (system faults and failures, roadway incidents, agency personnel changes, etc.) should be detailed with acceptable responses to cover unexpected actions.

- *Performance Monitoring*: Once a system is implemented, performance monitoring is very important. A process should be identified in the agreement to enforce this activity so that it is not forgotten.

- *Reporting*: All agency and funding program reporting requirements should be identified with the responsible agency roles. These reporting needs may include: progress tracking, before-after evaluations, etc.

- *Termination*: The terms for which an agency role or an entire program can be terminated should be clearly detailed. While these programs are generally seen as lasting into the foreseeable future, conditions may change, and possible termination should be addressed. Given the investment in both staff time and funds (potentially from a pooled fund or grant) that the program will require, it may be desirable to include a financial penalty clause if an agency "bails out" from the agreement prematurely.

The next step in the RCTO development will be to prepare a Memorandum of Agreement template, expanding on the elements identified above, for use by the agencies as they move forward with a multi-jurisdictional ITS and signal program.

6. CONCLUSIONS

C2C offers the benefits of multijurisdictional coordination without locking the region into a single system vendor.

Given the diverse operational requirements, timing practices, and availability of resources facing central Puget Sound traffic operations agencies, which has led to the deployment of equally diverse traffic signal systems, a one-size-fits-all approach to traffic signal operations will not be found. Instead, the strategy described in this document is a flexible framework for deploying multi-jurisdictional signal coordination, ITS and data sharing projects like those documented in the Puget Sound Regional ITS Implementation Plan. As projects move forward, whether they are two agencies coordinating a handful of signals located on a jurisdictional border, or an entire subarea jointly developing a C2C interface, the strategy is scalable to support this range of complexity.

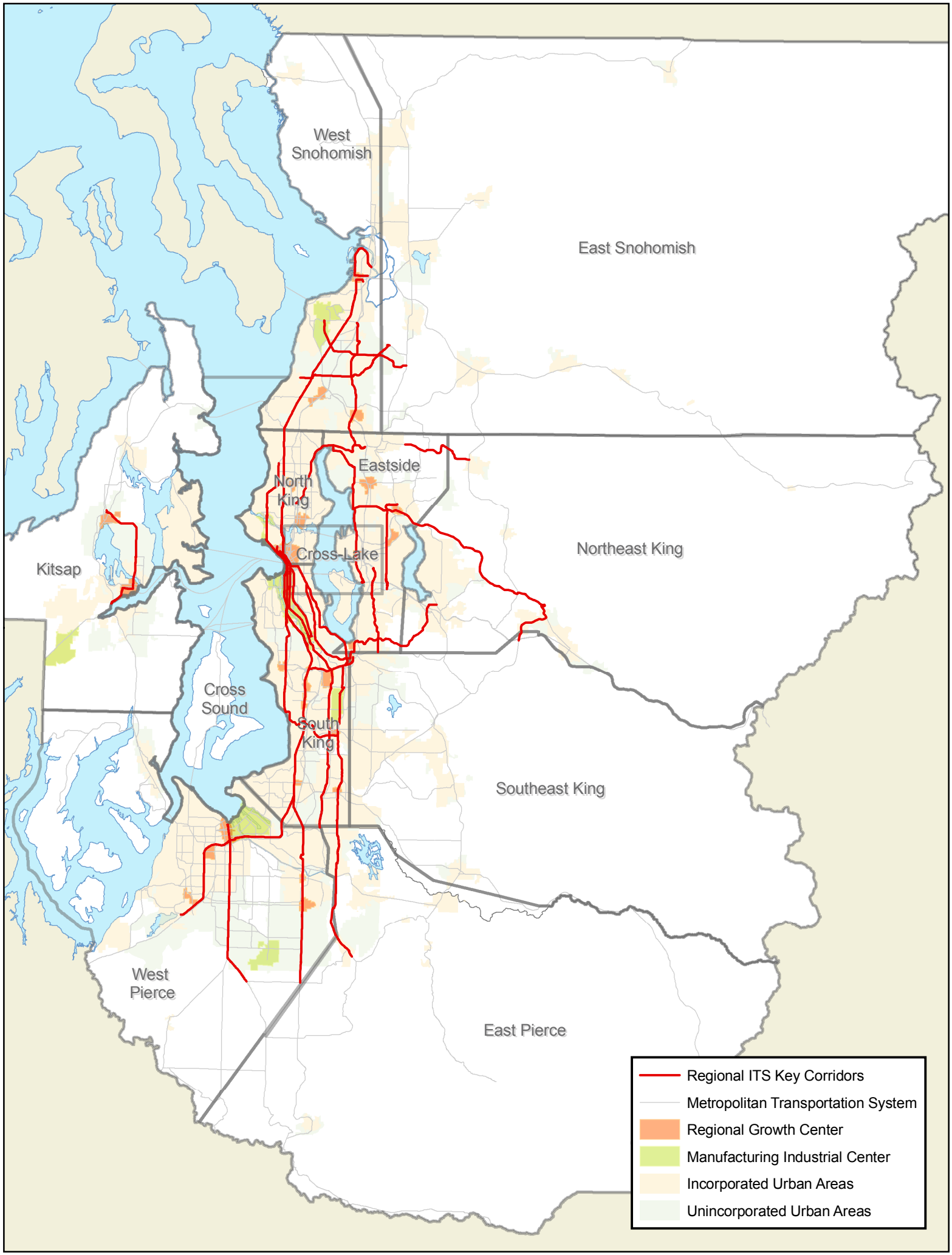
C2C interfaces offer the opportunity for agencies to have unparalleled visibility into others' systems, resulting in significant operational benefit for agencies whose traffic operations are regularly impacted by conditions in neighboring jurisdictions. However, the various disparate systems in the region results in an integration effort that would be far from seamless and, in the case of systems that are operated at a geographic distance, of limited value. Therefore, the strategy supports

utilizing time-based coordination on corridors where C2C would be more cumbersome or of limited value and instead selectively applying C2C to “like” systems that share a manufacturer, and/or have a reasonable level of NTCIP-compliant functionality.

The Freeway Management System-i2TMS-TACTICS interface under joint development between WSDOT and City of Seattle offers an initial C2C venture for the region. Additional C2C connections should be considered on a case-by-case basis as funding and local conditions make them feasible and desirable. Further, as agencies procure new systems, which several wish to do in the next few years, installing systems that are compatible with those in neighboring jurisdictions will reduce the need for complex custom interfaces.

APPENDIX A

REGIONAL SMART CORRIDORS MAP


West Snohomish
East Snohomish
Eastside
North King
Cross-Lake
Northeast King
Kitsap
Cross Sound
South King
Southeast King
West Pierce
East Pierce
Regional ITS Key Corridors
Metropolitan Transportation System
Regional Growth Center
Manufacturing Industrial Center
Incorporated Urban Areas
Unincorporated Urban Areas

APPENDIX B

EXISTING SIGNAL SYSTEMS MAP

Regional Intelligent Transportation Systems Implementation Plan

- S4 Marine View Drive/SR529/ Everett Ave
- S6 SR99
- S9 SR527
- S10 SR526/Airport Rd/128th St SW/ SR96/Cathcart Wy
- S11 168th St SW/44th Ave W/ 164th SW/Seattle Hill Rd
- K1 Woodinville-Duvall Rd
- K5 NE 90th/148th Ave NE/ 150th Ave SE
- K10 Central Way/NE 85th St/ Redmond Way/SR202
- K12 68th Ave NE/NE 170th St/ Simonds Rd NE/100th Ave NE/ 98th Ave NE/Market St/ Central Way/Lake Street S/ Lk Washington Blvd NE/ Bellevue Way NE/SR908
- K14 Richards Rd SE/Factoria Blvd SE/ Coal Creek Pkwy/Duvall Ave NE
- K16 Logan Way/Park Ave N/Sunset Blvd NE/ SR900/17th Ave NW/NW Sammamish Rd/ SE 56th St/Sunset Blvd NW
- K17 SR 99/Aurora Ave
- K20 4th Ave/4th Ave S/E Marginal Way S/ Interurban Ave S/W Valley Hwy/ SR181/68th Ave S/W Valley Hwy
- K22 1st Ave N/1st Ave S/Myers Way S/ 1st Ave S/SR509/S 216th/SR516/ S Kent-Des Moines Rd/W Willis St
- K23 S 154th/Southcenter Blvd/Grady Wy/ I-405/Main Ave S
- K25 S Jackson St/Rainier Ave S
- K27 SR522
- K29 Greenwood Ave N/Holman Rd NW/ 15th Ave NW
- K58 Lind/SW16th/E Valley Hwy/ E Valley Rd/84thAve S/Central Way/ Central Ave/Auburn Way
- K70 Airport Way S
- P1 16th Ave S/SR161/Enchanted Pkwy S/ Meridian St
- P3 Auburn Ave/A St NE/E Valley Hwy/ SR162
- P6 Pacific Ave/SR7
- P8 SR99/E G St/E 26th St/S Tacoma Way/ Pacific Hwy SW/Gravelly Lake Dr SW
- KT1 SR304/SR303

Signal Control System

- BI Tran **QuicNet**
- Computran **MTCS**
- Econolite **ICONS**
- Econolite **Aries**
- McCain **QuicNet 2006**
- Naztec **ATMS.now**
- Quixote **Multisonics VMS-330**
- Siemens **ACTRA***
- Siemens **i2TMS**
- None

Legend

- Traffic Management Center (TMC)
- City Hall

* The City of Seattle will be switching to the Siemens TACTICS system. Several other jurisdictions that are currently running ACTRA may also make this switch.

SNOHOMISH COUNTY

KING COUNTY

KITSAP COUNTY

PIERCE COUNTY

Everett
Marysville
Monroe
Lynnwood
Edmonds
Shoreline
Bothell
Woodinville
Kirkland
Redmond
Seattle
Bellevue
Sammamish
Mercer Island
Newcastle
Issaquah
Renton
Tukwila
Burien
SeaTac
Kent
Maple Valley
Covington
Federal Way
Auburn
Algona
Pacific
Tacoma
Puyallup
Lakewood

PUGET SOUND SIGNAL CONTROL SYSTEMS