TASK 3: ASC CORRIDOR IMPLEMENTATION

NEXT GENERATION ITS

Prepared for:

SDOT

Seattle Department of Transportation

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Executive Summary

Executive Summary

Adaptive signal control technology (ASC) adjusts the timing plan of traffic signals based on prevailing traffic conditions and traffic demand. ASC has been around since the early 1980s with the majority of the use and development taking place throughout Europe, but now growing in popularity in the US. Modern ASC systems cater not only to traffic / personal cars, but also transit, pedestrians, LRT and cyclists.

In their current state, the traffic control systems operated by SDOT do not provide adaptive control, nor system-generated notification of abnormal traffic conditions (manual identification is possible via CCTV observations), and limited functionality to influence traffic automatically when an abnormal event occurs.

The current signal system includes pre-timed "time-of-day" pre-set plans. Pre-set plans are programmed based on historical data, where normal traffic conditions per time of day (peak, inter-peak, and off peak) are determined. The signal system will automatically switch from one plan to another based on the time of day, requiring frequent adjustments by traffic engineers as traffic flows and patterns change. There is partial vehicle actuation and full vehicle actuation in areas such as SODO (around the major event venues), where signal timing plans are triggered based on traffic demand.

There is merit in automating signal operations, since travel patterns and prevailing conditions may change to become outside the "norm" – a scenario where fixed time plans will cease to be effective. This is particularly true for the planned major construction projects in the Seattle area, which will severely disrupt traffic patterns.

The operational benefits of installing ASC to counterbalance some of these system disruptions have been demonstrated in several studies. In many cases, the benefits have been outweighed by the financial burden, the complexity of developing and maintaining the systems, and the benefit to cost ratio. However, there are long-term benefits associated with deploying ASC that go beyond the construction period.

Ahead of the capital expenditure needed to introduce ASC to control the signals, further analysis is required to quantify the true benefits of ASC as it applies to Seattle's transportation network in relation to the current signal timings. This report suggests using microsimulation as an operational tool for further analysis.

Once the benefits that ASC provides have been validated, the FHWA process should be adopted for selecting an appropriate system. This process provides a non-biased selection process specifically tailored to the City's network, needs, and functional requirements.

Section 1:
Existing Conditions

1. Existing Conditions

Existing transportation and communication infrastructure and operational procedures were reviewed as part of the development of the Next Generation ITS Strategy. This included the types of signal infrastructure, back office systems, and operational procedures. Figure 1 shows the location of all traffic signals within the City limits.

Existing Infrastructure

In order to identify what improvements need to be made to the overall system to counter construction activities, it is important to establish a baseline from which to work. The existing infrastructure and operational procedures provide a good baseline to identify any gaps that exist. This is discussed in more detail in Task 1.

In general, the existing signal infrastructure is dated (some signal infrastructure has not been upgraded since 1985), therefore, limitations need to be addressed ahead of any enhancements. They should be addressed prior to introducing ASC, and include upgrading controllers for compatibility with ASC, signal cabinets, and the introduction of detection.

The following describes the existing infrastructure for the traffic signal system within the City.

Existing Traffic Signals

There are approximately 1075 signals within the Seattle area currently operated by the Traffic Management Division. 258 signals are controlled with fixed timing (time of day) and lack any form of detection (especially in the downtown core). Signal timing plans are developed based on historic volume.

There are Six Traffic Responsive Corridors currently in operation (Aurora – Winona to 145th; E Marginal; 15th Ave NW (Market to Holman/85th); 1st Ave S; 4th Ave S; Elliot/15th Ave W).

Existing Controller Types and Central Systems

Historically, four controller types have been installed in the city signals with recent focus on Eagle/Seapac and Peak/LMD controllers:

- Eagle (Siemens - Tactic) – typically installed at major intersections closer to the downtown area (approximately 700 controllers)
- ATC Peek (LMD) – typically installed in the outer regions such as Greenwood, 85th, West Seattle/Route 120 (approximately 370 controllers)

There are two operating systems currently serving the two different controllers:

- Tactics (Siemens)
- IQ Software (Peak)

Existing Cabinet Types

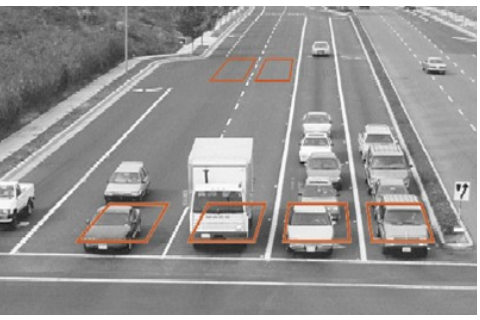
- Type III (P cabinet) - Standard
- Type II (M cabinet) – Smaller version of Type III (TS1 & TS2)
- Type VI (DP Cabinet) – Double door with “freezer” style compartment used for transit communication equipment

Existing Detection

There are various types of detection currently deployed, where each type of detection has been considered on a case by case basis (dependent on road layout, restrictions, operations). These include:

Video Detection

Video detection uses CCTV camera footage and video analytical tools to virtually "detect" the presence of vehicles within a lane. "Virtual Loops" are user defined and calibrated in accordance with the required accuracy.



CCTV Camera Footage

Issues and Drawbacks: Accuracy has been acceptable with few setbacks especially false calls (triggered by roadway utilities, shadows, reflection, etc.). Devices can be fine-tuned to accommodate (image processing).

Induction Loops

Induction loops are physical loops set wihtn the roadway and and electric current running through them allows a certain induction to form around the loops. The loop then has the ability to "detect" vehicles seen as the metal contained within the vehicle changes the level of induction which is sensed by the System.

Induction Loop

Issues and Drawbacks: Currently there is no mechanism to pull real-time traffic data from loop detectors. Tactics (Siemens Central) system does not allow (expensive to configure). System is limited to signal operation and reporting historical occupancy/volume data from signal study sites. Loops system can produce data for travel map (GIS –Red/Amber/Green), but cannot export data to another system (traveler information).

Magnometer Detection

Magnometer Detection (in this instance, Sensys) is slowly being introduced in the market as alternatives to Loops. This is a small detector in a "puck" like shape which is slotted into the roadway and transmits it signals to a nearby wireless detector which, in turns, communicates directly to a controller.

Issues and Drawbacks: The battery life of the Sensys has not yet been tested even though manufacturers preach a 5 to 10 year lifespan. In addition, they do not have the ability to classify vehicles and do not detect cyclists.

Existing Operational Procedures

Existing Signal Timing Efforts

Currently, signal timings are developed based on traditional traffic counting methods. The City has established long-term contracts with firms who specialize in collecting traffic data, namely: turning movement counts for weekday and weekend conditions as well as 24-hour count data to establish weekly trends and traffic patterns. Once this data is collected, an already established simulation modal is calibrated with the new counts where the following is evaluated:

- Signal grouping
- Signal phasing
- Cycle length
- Split
- Offset

Once this evaluation is complete, timing adjustments are made (if necessary) and the new data is entered into this signal system. Fine-tuning includes field review and timing plan adjustments by City staff. Normally, the traffic studies department develops signal timings. On occasion, a consultant may complete the signal timing based on workload and deadlines.

Existing Signal Operations

Figure 2 shows the modes of operation:

- Quick response at the Ferry dock
- Traffic responsive within the SODO
- Corridor coordination within the CBD area
- Time of day plans in all areas not run as vehicle actuation /traffic responsive

Existing Transit Services

The goal of transit priority is to improve transit travel time and reliability, and assist in schedule adherence by providing priority to buses. Typically, priority calls are placed by the transit vehicles using an on-vehicle transmitter that sends a signal to the controller at each intersection. When a call is received at the intersection the transit vehicle can obtain priority by receiving additional green time at the end of the priority phase or early green to the priority phase. This allows the transit vehicle to proceed through the intersection at the end of the signal phase (instead of stopping), or at the beginning of the priority phase (earlier than it would normally be released). The early green or extended green is accomplished by reducing the split time from the non-priority phases and providing that time to the priority phases.

Currently, the signal system and King County Metro's Transit Signal Priority (TSP) system grants priority to all buses regardless of schedule to improve bus speeds on TSP corridors. At some locations, the City has installed DMS that display bus arrival information provided by One Bus Away. One Bus Away is a mobile application providing real-time arrival information based on bus odometer data, instead of AVL data and/or connection to TSP central systems. To date, the application's data has been relatively accurate in providing real-time data except for cases where there is an unplanned re-route.

King County Metro also uses transit improvements such as bus bulbs and queue jumps to improve speed and reliability.

Summary

- The City's signal system consists mainly of intersections coordinated using fixed time "time-of-day" plans
- There is a mixture of old signal equipment with new signal equipment
- Some of the old signal equipment will need upgrades ahead of the introduction of Adaptive Signal Control
- Detection is available in only at a limited number of intersections
- TSP operates by giving priority to transit at all times

Figure 1: Existing Signalized Intersection

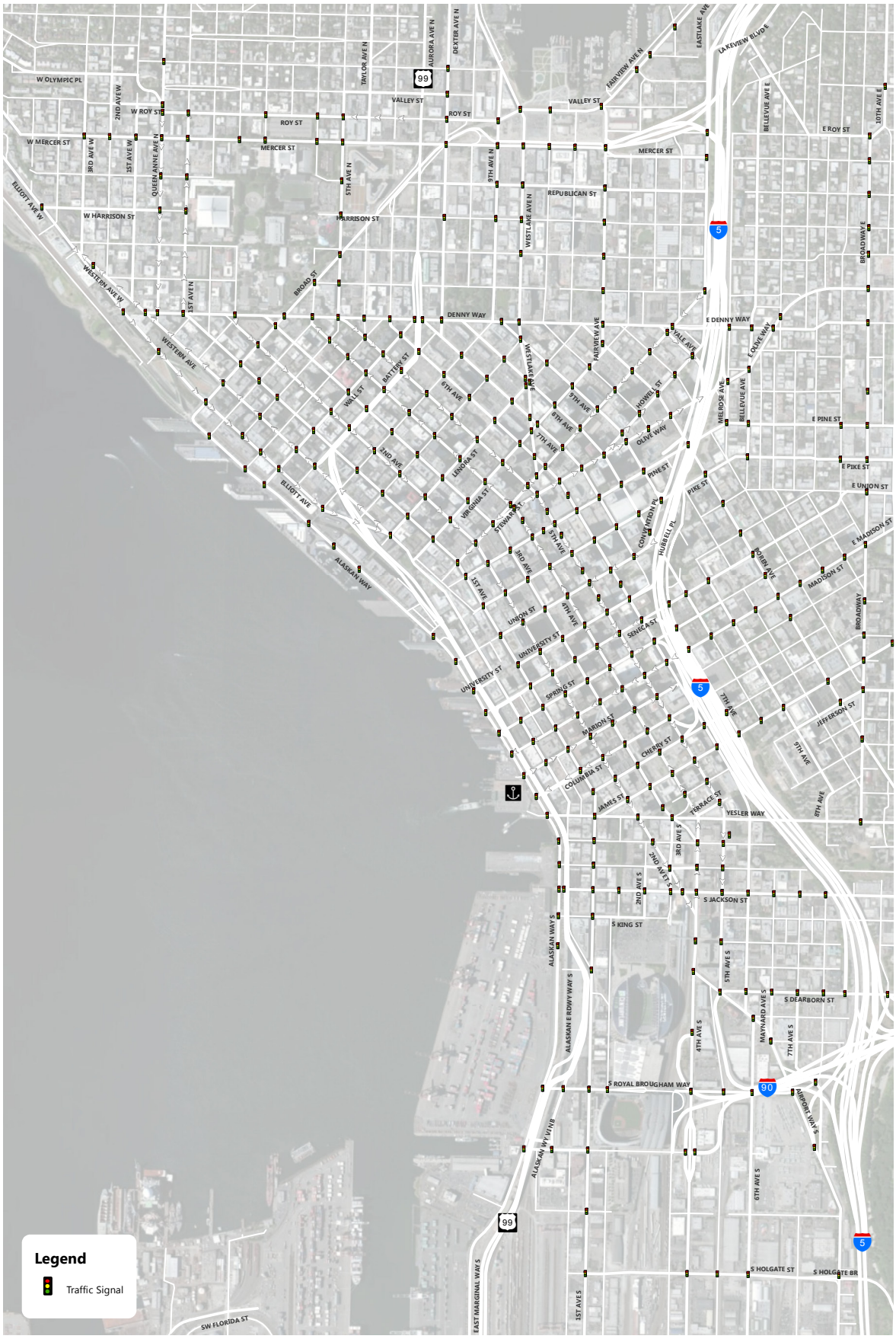
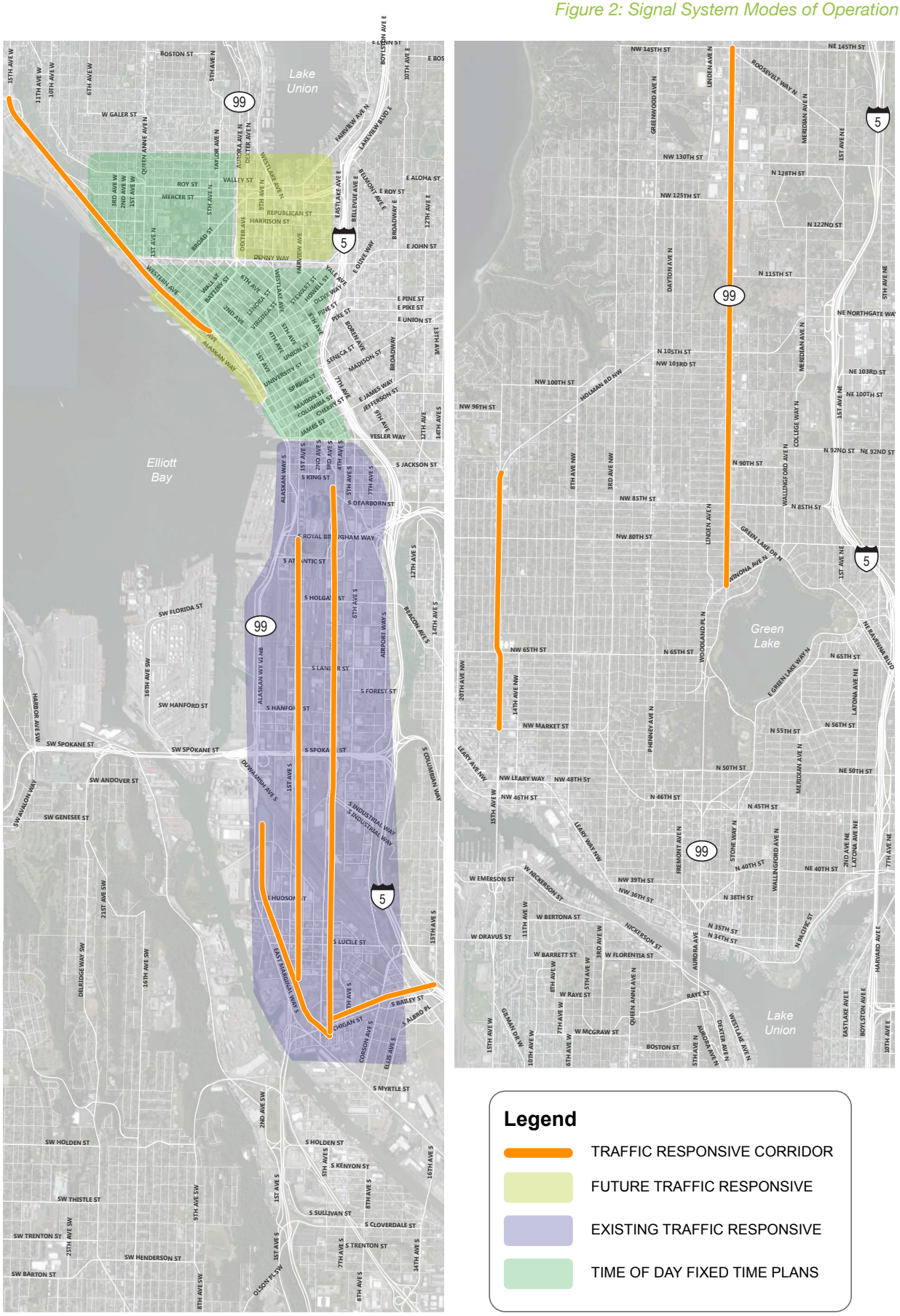


Figure 2: Signal System Modes of Operation



Section 2:
Adaptive Signal Control Processes

2. Adaptive Signal Control Technology

Adaptive signal control technology (ASC) offers the potential benefit of managing the additional traffic along major corridors or in larger areas that will be generated by construction projects. ASC also offers potential longer term benefit to the City after the construction period ends.

What is Adaptive Signal Control Technology?

The Federal Highway Administration (FHWA) defines Adaptive Signal Control as: "A technology that adjusts the timing of red, yellow and green lights to accommodate changing traffic patterns and ease traffic congestion". ASC is able to monitor traffic flow and volumes along corridors or entire areas, and "adapt" the signal timing dynamically dependent on these prevailing conditions. The main benefits of adaptive signal control technology over conventional signal systems are that it can:

- Continuously distribute green light time equitably for all traffic movements
- Improve travel time reliability by progressively moving vehicles through green lights
- Reduce congestion by creating smoother flow
- Minimize traditional timing and re-timing efforts

Components of ASC

ASC has the following physical components:

- Detection (e.g. loop detectors, video detection)
- Compatible Signal Controllers
- Communication Medium (Fiber, WiFi)
- Central Server System
- Front End Operator Station

Detection is used to monitor traffic flow and volumes, feeding that information back to the controller which, in turn, feeds to other controllers / or central server system for processing.

Generally speaking, ASC can be placed into one of two categories, each have their own merits and can be applicable to any city dependent on the level of functionality required within a central system and / or a controller.

Centralized ASC: Here, traffic flow data is fed back to a central server, where all optimization calculations are undertaken, changes to phase timings determined and instructions issued to the individual signal controllers. This permits network-wide optimization which is considered to be the most effective approach overall, from a theoretical standpoint.

Distributed ASC: These systems allow controllers in the network to communicate with each other and compute their own optimal parameters based on information from surrounding nodes. This approach results in a local focus which, to a large extent,

ignores the wider network conditions but does offer a finer 'granularity' in terms of tuning settings to deal with localized flow changes.

Applications of ASC Internationally

Adaptive Signal Control has been adopted by cities around the world since the early 1980s. However, it is difficult to obtain extensive recent data relating to 'before and after' analyses of ASC implementations.

In looking at international applications of ASC, it is fair to conclude that the two most widely used systems (SCOOT and SCATS) each have over 200 installations worldwide. The less common systems (European products such as UTOPIA and MOTION, and USA products such as ACS-Lite and InSync) may account for a collective 200 installations.

Here, the characteristics of the cities/areas where these systems have been installed and operated over long periods (in the case of London, 30 years) include:

- Commercial centers, with 'traditional' peak periods reflecting commuter movements
- Retail centers, where high pedestrian movements compete with road-based traffic
- Center's with high volumes of tourists adding to the pedestrian volume
- Areas where road-running LRT/ trams have to be accommodated and prioritized
- Areas of high volumes of commercial traffic, especially in/around logistics hubs and industrial areas on the urban fringe
- Arterial routes from inner-urban to outer-urban areas and beyond, where precedence of movement traditionally has rested with through movements rather than local trips
- Road networks that are predominantly 'grid-iron' in nature
- Road networks, particularly in older cities, which follow physical contours and/or historical land ownerships, rather than any formal 'planned' layout

It is apparent that there are no real restrictions for deploying ASC, and it can be deployed along any corridor or across any area provided that benefits are realized.

The following cities have, between them, employed SCOOT, SCATS, UTOPIA, ITACA and ACS-Lite:

Table 1. ASC Implementations

Major International Cities		
Auckland	Galway	Mexico City
Bangkok	Hong Kong	Milan
Barcelona	Jakarta	Perth
Beijing	Jeddah	Rome
Beirut	Johannesburg	Sao Paulo
Bucharest	London	Shanghai
Cape Town	Macau	Sydney
Delhi	Madrid	Toronto
Dubai	Manila	Turin
Dublin	Melbourne	Wellington
US States		
Alaska	Kansas	Oregon
Arkansas	Minnesota	Texas
Colorado	Missouri	Virginia
Georgia	New York	Washington
Iowa	Ohio	

In looking at the above areas of installation, there does not appear to be any particular trend in the ACS systems selected for these networks. Indeed, the spread of different systems that have been chosen perhaps indicates that other factors (such as institutional matters or desired reporting facilities) have held sway in the selection process. Therefore, the selection of the right ASC for the City of Seattle should take into account the desired functional requirements rather than specific system attributes. The FHWA have developed model system engineering documents for selecting an adaptive signal control system that is more focused on functional and operational requirements and is non-technology and non-vendor biased. This process for applying the FHWA process is described in detail under section 5.

The FHWA completed a study that reviewed several ASC systems, understandably (for reasons of commercial propriety) did not provide any specific recommendations for one ASC over another. The study did provide some respective strengths and weaknesses and useful feedback from operating agencies, including:

Resource Requirements

ASC are considered more operationally demanding than conventional traffic signal systems, which tend to be maintenance-intensive in respect of the preparation and use of timing plans. ASC require more emphasis on the expertise necessary to operate their sophisticated algorithms to the best effect. This difference is often not recognized by an agency until the ASC is already deployed.

Level of Expectation

Some agencies moved directly to installing an ASC to replace an outdated fixed-time or isolated traffic signal system, believing that the implementation would generate very high gains in network performance. In some cases this did not occur, leading the agencies to wonder if the same operational benefits could have been achieved with simpler vehicle actuated and coordinated traffic control. However, most of these instances could be shown to have occurred where insufficient attention had been given to assessing existing network conditions and the vital pre-planning of the ASC 'starting condition' plans.

Staffing Requirements

In order for the full benefits of an ASC system to be realized, staff should be present who specialize in the operation of an adaptive system. The number of required staff is really dependent on the type of system deployed. Normally, increased resource efforts are required during deployment and a gradual reduction thereafter as the systems becomes more independent.

Typically, for a signal system running a central system, the ratio of 1 operator to 250 intersections would provide the operational efficiency required to successfully operate the network. This does not, however, preclude form the back office staff (e.g. signal engineers).

Performance and Efficiency

Moving from a fixed time plan to a combination of vehicle actuation and partial vehicle actuation may result in increases in network performance of the order of 20 to 25 percent, arising mainly in the off-peak and peak-hour 'shoulder' periods. Moving from vehicle actuation to ASC may only contribute a 5 to 10 percent improvement in network performance, due to its ability to extract additional efficiencies within the peak hours.

This is not to say that ASC does not provide economical benefit but more to highlight that a definite benefit-to-cost analysis is recommended. Specific results vary dependent on location, traffic flows, density, volumes and area / corridor characteristics.

Summary

- Different Adaptive Signal Control systems exist worldwide. Each system has different operating characteristics; however, the ultimate purpose is common across systems
- The functional components of ASC are common between all systems
- There is no established documentation recommending one universal ASC system over another, leading us to rely on functional and operational requirements
- All systems share common characteristics, such as the level of resources required to operate the system and the level of expectation from each system in terms of results
- Increases in efficiency are noted for each ASC; however, a benefit-to-cost analysis should be completed prior to implementing a system

Section 3:
Multi-modal Implementation

3. Multi-Modal Implementation

Urban Traffic Control systems (such as Tactics, which is currently deployed in the TMC) were originally developed to minimize delay to vehicles moving through an urban network. However, in recent years there has been a shift in emphasis away from accommodating the private car and towards more sustainable transport. ASC technology has already been tried and tested to allow priority to Transit, however, it is currently also being developed further to include pedestrians and cyclists.

Benefits of ASC for Transit

Transit priority is one of the tools that have the benefit of increased transit attractiveness among the travelling public. Delays incurred by buses at signalized intersections typically account for 10 - 20 percent of bus travel times; therefore, TSP offers the potential for significant reductions in travel time. One of the other major benefits of TSP is that an effective system may entice motorists to switch modes, resulting in a reduction of the number of vehicles using the network that will ultimately reduces congestion.

The concept of TSP dates back to the 1970s, and there have been many studies carried out demonstrating the benefits to transit. The following results have been documented when looking at applying TSP within an ASC system:

- TSP generally benefits buses along a corridor regardless of the mode of operations (Fixed Time, VA or ASC)
- Benefits are mostly realized when priority is given to Premier Buses (Express Buses) and late buses only, not when offered to all buses running along a single arterial at all times
- There are negative impacts to traffic as a result of TSP; however, these negative impacts are minimized when ASC is implemented due to the nature of ASC being able to adapt and adjust to the prevailing traffic conditions

Benefits of ASC for Pedestrians

When pedestrian crossings are operating under UTC control, or fixed plan (time of day) control, the pedestrian stage is only allowed to occur at specific times during the signal cycle. Some adaptive signal control systems (such as SCOOT) enables priority to be given to pedestrians at sites where the pedestrian demand is high, allowing the “WALK” time to be extended dependent on the numbers of pedestrians waiting to cross.

Adaptive Signal Control can improve pedestrian waiting times by decreasing the delay at intersections. There are certain options that can be used to influence pedestrian movements at signalized intersections such as extended “walk” phases, double cycle, ‘call ahead’, early introduction of pedestrian phases, and pedestrian scramble phases (for areas with a high volume of pedestrians).

In the case of the CBD area (such as at Pike Pace), there is an option to introduce all way pedestrian scramble arrangement where there are a high number of pedestrians relative to the number of vehicles. This is in operation using the current fixed time

signal plans, however, with ASC the ability of the system to recover the from the disruption of traffic is more efficient.

Benefits of ASC for Other Modes

Various ASC systems have included recent updates with specific functionality for cyclists; however, it is best adopted when there are dedicated cycle lanes and facilities. ASC developers are starting work to investigate the impact of cycles on dispersion factors on shared links and on junction saturation flows.

ASC can also facilitate LRT priority, allowing a tram to run on demand and then recovering to normal traffic operations afterwards.

Summary

- Adaptive Signal Control implemented in an area serves not only traffic, but other modes of transport such as Transit, Cyclists, Pedestrians, and Freight
- The benefits of ASC for transit (including the adoption of TSP) has been widely documented
- A policy change for how transit signal priority is implemented is required to fully appreciate the benefits of TSP on ASC

Section 4:
ASC Microsimulation

4. ASC Microsimulation

A traffic operation microsimulation analysis allows the benefits of ASC to be measured prior to committing to costly field deployments. When the City considers investing in an ASC system, it first determine what actual benefits will be gained from implementation. The variables are such that specific economic appraisals should be carried out for each case. This typically accounts for:

1. The existing traffic control and communications infrastructure
2. Whether the move is from purely fixed time operation to ASC or from a mixture of fixed-time and vehicle actuated operation

In our review of the current traffic signal systems, we are confident that the natural next step in the implementation of Adaptive Signal Control is to undertake a microsimulation modeling assessment of the relative performance of three signal control strategies in three areas of Seattle as displayed in Figure 3. The reasons for picking these distinct areas was due to the nature of geometric layout, modes of operation, and their type of urban area.

Microsimulation Modeling Fundamentals

Microsimulation modeling involves simulating the behavior of every vehicle on the road network. This differs from other types of traffic modeling which work at the macro- or mesoscopic levels. Those techniques focus either on overall link flows or, at best, they consider platoons of vehicles.

The main reason for using a microsimulation technique is that small variations in driver behavior can have a large effect on the throughput of the road network, e.g. a bus transit stop can cause a shockwave to form behind the bus. That can break up the platoon of vehicles travelling on that link which, in turn, may form separate smaller platoons that arrive at the next set of signals in a disjointed manner. Taxi drop-off and pick-up can do likewise. Heavy trucks have a slower rate of acceleration than cars, and so the number of these present at any given time has a significant effect on signal throughput.

Guidelines for Microsimulation Modeling

As appropriate, recommendations contained within the Federal Highways Agency (FHWA) document 'Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software (July 2004)' would be adopted for the purposes of any study we are recommending to the City. The Toolbox, albeit dated in certain aspects, remains a good source of general information on conducting a microsimulation modeling project. Additionally, elements of the Oregon Department of Transportation's Protocol for VISSIM Simulation could also be considered.

Seattle Test Areas

The three areas of interest to the City for making an assessment of ASC are South of Yesler Way where SDOT currently has vehicle actuation, the CBD area where no vehicle actuation exists and the signal system works on pre-timed "time of day" set plans, and north of Denny where the upgrades to the Mercer corridor are taking place.

These areas exhibit very different network and road user characteristics. The area south of Yesler Way in the vicinity of the Port of Seattle terminals area has a higher

proportion of heavy vehicles than the commercial and business district, which is predominantly passenger car and transit. The northern part of the City (in particular the South Lake Union area) contains dominant corridors with local roads feeding to and from them. Despite the similarities in network configuration (i.e. predominately grid-like), the different user classes may result in very different performances in terms of the benefits to be achieved through the application of new signal control techniques.

Given the nature of the assessment, this would include utilizing existing traffic data or collecting new data where data isn't available. The data should include:

- Turning movement counts at 15-minute intervals (5 minutes preferred) at each major junction in the study area
- Turning movements by vehicle type, including the separate identification of
    - Car
    - Light Goods Vehicle (LGV)
    - Heavy Goods Vehicles
    - Articulated Trucks
    - Transit
    - Bike / Pedestrian
    - Taxi
- Signal Timing data, preferably taken from the day that the turning movements were recorded
- Observed queue length data, if available
- Observed journey time data, if available

If queue and travel time data are available these can be used to calibrate the models, otherwise the Base model would simply be calibrated using the default settings and the resulting queues assumed to be representative of existing conditions. As part of the next generation strategy, a number of Quick Win solutions are being recommended, which include the gathering of travel time data and average speed data using Bluetooth technology. Information from which can be used to inform the microsimulation model.

There are other details to be considered, for example the modeling of bus and taxi operations. This will need further discussions with each of the stakeholder groups and an agreed criteria needs to be established as inputs to the model.

It is also important to also note that the data sets available may well fall short of the desired coverage listed above. Some parameters may have to be derived from information gathered for other purposes and this would be the approach taken rather than undertaking new surveys unless the new surveys proved critical to the success of the study. It is advisable to keep in mind that the objective is to demonstrate the relative performance of different strategies on a reasonable representation of the network, not to determine absolute values of forecast traffic flows for operational purposes.

Modeling Software and Platforms

There are a number of modeling software and platforms that are capable of being used to carry out this type of microsimulation. Both Paramics and PTV Vissim are widely recognized as being leading platforms for network modeling. Due to the fact that Paramics includes controller emulators for the M52 and xxx controllers that SDOT currently have deployed, it is our recommendation that Paramics is used to conduct this microsimulation model.

Detailed Modeling Methodology

Once the assessment model areas have been confirmed and the traffic data obtained, the model can be developed, calibrated and validated in the normal manner.

The OD matrix for use in the study should be synthesized from the turning counts or through CCTV observation where available. There would be no major advantage to trying to obtain accurate origin and destination data as traffic volume by vehicle type and turning proportions are modeled at each intersection.

Assessments

There will be three assessment scenarios:

1. Fixed Time
2. Vehicle Actuated
3. Fully Adaptive

Fixed Time

Ideally, the signal timings for this model would be those obtained on the day that the turning counts information was gathered, but if that data is not available then it would be based on the best available signal plan data from the City. This model would provide a baseline for comparing the proposed control strategies.

Vehicle Actuated

This model would use the NEMA/2070 and Eagle M5X controller emulators. The intersections would each be coded as operating in vehicle actuated (VA) mode in

accordance with a set of NEMA and Eagle controller configurations. The individual intersections would operate as stand-alone, but in accordance with the controller. The exact configuration, for example the minimum / maximum greens per phase and phase recall should be agreed upon ahead of the model / study inception.

It would be possible within the model to test different actuation strategies, e.g. fully actuated, semi-actuated and semi-actuated coordinated.

Fully Adaptive

The Fully Adaptive model would be configured using the VA Plan (VAP) feature of Paramics. This is a means of writing programming code to alter signal timings depending on individual events within the model. The code is based on the C+ programming language, and uses preset variables to control the model.

It must be understood that the VAP method of modeling Adaptive Control is a simulation of an ASC algorithm not any of the actual algorithms (e.g. SCATS, SCOOT) themselves since these are subject to copyright control. However, both Paramics and Vissim can be configured to use the actual adaptive control algorithms of SCATS, SCOOT and others, but can only be achieved by the purchase of the relevant license. For the purposes of this particular 'proof of concept' study, the financial outlay to purchase these add-on modules (the SCATS license costs approximately $25,000) is not recommended.

Analysis

The key performance indicators in Paramics are similar to those reported by the Highway Capacity Manual (HCM) methodologies. The most appropriate measures of network performance to be reported in this study should be agreed at the start of the study.

Microsimulation models are stochastic, meaning that the driver behavior varies randomly each time the model is run. For that reason they are run a number of times and the results aggregated. This enables the modeler to specify the statistical range of the results that are obtained. This is more robust, and more like the daily variation encountered in the real world, than running deterministic models which produces a single average value without any information regarding variability.

In this way the performance indicators can for each of the three signal strategies be presented as a statistical range around the mean, including 95 percent confidence intervals and standard deviations. This allows the modeler to demonstrate whether there is a statistically significant difference between the strategies and, if so, if the benefit of the capital expenditure is warranted. The differences determined from this analyses would be compared against those defined in the FHWA Toolbox and conclusions would be drawn accordingly.

Potential Corridors Suitable for ASC

Based upon feedback and results from earlier stakeholder meetings and the review of current infrastructure, as well as our understanding of the future infrastructure being deployed (such as that on Mercer West), we have identified the following corridors (depicted in Figure 2) as having the potential to benefit from ASC. These corridors already have the necessary infrastructure to support ASC and are running in a traffic responsive mode, or have plans to install the needed infrastructure.

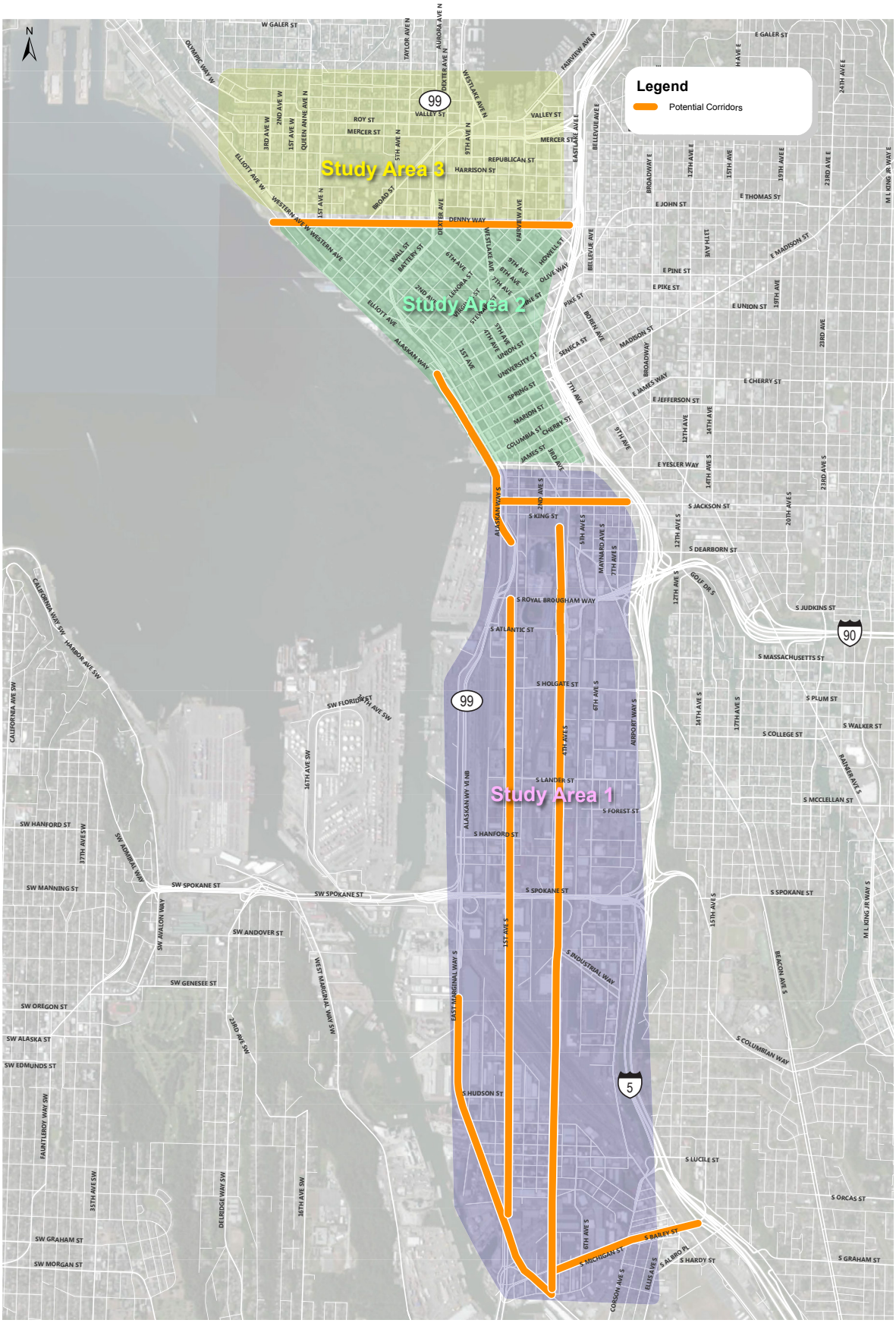
- Denny Way
- Jackson
- 1st Avenue S
- 4th Avenue S
- East Marginal Way S
- S Michigan Street

Even though these corridors have been identified, we recommend further analysis to determine the actual benefits. Once these are quantified, the FHWA model should be used to provide the City with the ideal system to meet corridor needs.

Summary

- For this situation, microsimulation offers greater benefits than macro or meso simulation modeling due to the nature of the results needed (i.e. benefits and measures of efficiencies of deploying ASC)
- Paramics modeling is recommended as the software contains controller emulators that match those deployed within the City and is most consistent with cost constraints
- All three modes of operations should be simulated (fixed, VA and ASC)
- Results will be compared and a benefit to cost ratio established

Figure 3: Adaptive Signal Control



Section 5:
Recommendation

Recommendations

It is clear there are a number of high level recommendations that will allow the City to gain the most benefit from applying Adaptive Signal Control in Seattle.

Institutional Requirements

ASC is operationally more demanding than traditional traffic system operations. To gain the most out of the deployed system, more operational staff are required to within the TMC who understand the complicated and sophisticated algorithms which are part of any system, therefore, an increase in the number of operators who specialize in signal control is recommended ahead of any ASC installation.

System and Technical Requirements

The City's current signal system is a "mixed bag" of equipment and standards. There are multiple types of signal controllers, including legacy equipment that needs to be replaced or upgraded to be compatible with ASC technology. Detection is non-existent in the CBD area and only located within the SODO area, although, during the construction of the Mercer West project and the Alaskan way (temporary road), efforts are being made to install detection compatible with vehicle actuation and ASC.

To enable ASC, we recommend that legacy equipment is upgraded and detection is installed, specifically in the CBD area.

Establishing Benefits

True benefits of ASC deployment should be assessed ahead of any major deployment. A cost effective form of assessment is microsimulation modeling, where current data (which is collected regularly) is fed into a model (such as Paramics), that can measure the level of benefit to the network's overall performance. We believe microsimulation will provide the City with a benchmark for making informed decisions on where capital expenditures are warranted.

FHWA Model Systems Engineering Documents for ASC

We recommend the FHWA Model System Engineering Process is followed ahead of any ASC deployment. This will provide the City with a non-technology/non-vendor biased system to create the operational and functional requirements, and would be tailored to the City's needs.

Section 6:
Cost Estimates

6. Cost Estimates

Costs of deploying Adaptive Signal Control vary depending on the type of system and the type of civil work required at each intersection. Therefore, accurate costs of deploying ASC in the City of Seattle cannot be estimated until further analysis is completed and corridors / areas for ASC technology deployment are selected.

That said, costs are normally quoted "per intersection" and can range from $30,000 for InSync to $80,000 for LA ATCS (assuming civil work is required). Table 2 provides "worst case scenario" per intersection costs for each of the most popular systems.

Table 2. Cost Estimates

System	Cost Per Intersection (including civil work)
ASC Light	$40,000
InSync	$30,000
SCATS	$60,000
SCOOT	$50,000
OPAC	$70,000
LA ATCS	$75,000

In relation to microsimulation, again, a number of different factors should be considered ahead of determining an accurate estimate. For instance, should a microsimulation model be carried out for the CBD area, an estimated cost of $250,000 to $350,000 would not be unreasonable to produce the model and provide the City with the required results. This is obviously dependent on the availability of information and the complexity of the model required.

Appendix A:
FHWA Model for ASC Implementation

Appendix A. FHWA Model for ASC Implementation

This chapter describes how to establish a framework for implementing ASC in the City of Seattle that adheres to Federal Highway Administration (FHWA) protocol for project procurement. The systems engineering process provides context for establishing needs that are identified in the Concept of Operations. The System Requirements, Validation, and Verification Plans are based on the Concept of Operations that ensure the underlying objectives for ASC are met in the RFP for adaptive signal projects. To implement successful adaptive signal control systems, system-wide needs and requirements were established through weekly stakeholder meetings and vendor demonstrations, supported by text contained in the Model Systems Engineering Documents for Adaptive Signal Control Technology (ASC) Systems. With the completion of the corridor-specific Evaluation Form for individual projects, this federally required systems engineering process has been development for ASC in the City of Seattle.

Concept of Operations

The Concept of Operations establishes the "needs statements" for ASC implementation that support the mobility, air quality, and safety objectives for the City of Seattle. This component of the systems engineering process provides the information necessary to define ASC projects and the develop system requirements for procurement. The Concept of Operations was developed out of "Appendix B, Concept of Operations Sample Statements" from the FHWA Model Document to serve as a general document that applies to all projects within the city. This applies to future ASC projects in the City of Seattle with the completion of the ASC System Evaluation Form that applies to specific for ASC corridors, grids, and networks.

The Concept of Operations document was tailored to convey the specific purpose and needs for ASC in the City of Seattle. The existing signal systems are unable to accommodate large fluctuations in travel demands based on planned (i.e. games, ferry arrivals) or unplanned (i.e. incidents, hazards) events, which impacts mobility on roadways. ASC projects have the potential to improve travel for all modes and support congestion policy objectives through mitigation of traffic due to planned major construction projects. ASC is capable of supporting priority for transit while adjusting operations to changing traffic conditions for peak and off-peak operations.

ASC System Evaluation Form (Worksheet)

The Evaluation Form applies project specific Concept of Operations to an Arterial, Grid, Intersection, and Interchange project to provide additional information necessary to complete the systems engineering process. The form incorporates information on signal timing parameters, typical volume flows, and multimodal characteristics into the development structure for a wide range of adaptive signal control projects that could be implemented throughout the city of Seattle. Each section of the Evaluation Form is directly linked to an accompanying section of the Concept of Operations to provide a cohesive set of systems engineering documents for procurement of ASC projects. The goal of the form is to streamline the FHWA application process reducing the need for outside support and increasing the rate at which adaptive signal control can be procured and installed.

System Engineering Requirements

The System Requirements translate the needs statements from the Concept of Operations into a testable requirements statement for the adaptive signal control technology. This component of the systems engineering process provides the requirements necessary by the city for adaptive signal implementation and is the basis for the Verification Plan included in the RFP for ASC vendors. The System Requirements were developed out of "Appendix C, System Requirements Sample Statements" from the FHWA Model Document to serve as a general document that applies to all projects within the city. The document describes what the system is to do, how well it is to perform, under what conditions it will perform, and what other actions are required in order for the system to be fully operational.

The System Requirements document was tailored to list out required functions of the ASC to accommodate the needs of the City of Seattle as detailed in the Concept of Operations. Particular attention was placed on the failure and fall back features, pedestrian activation inclusion into adaptive signal operation, and transit signal priority. Example requirements from the FHWA model document that were found to be vendor specific were removed or modified to allow a range of adaptive signal technologies, but still will ultimately determine what adaptive signal control system will best meet the city's needs.

Validation Plan

The Verification Plan ensures that the system being built satisfies all the requirements set out in the System Requirements. Example verification plans from other jurisdictions and information provided during FHWA ASC Model Document Training were used as references to help provide details on how to construct the Verification Plan. The document establishes a format for testing procedures and how the vendor's adaptive signal control system fulfills the requirements. The Verification Plan will be included with the city's RFP and will be completed by each vendor.

Verification Plan

The Validation Plan ensures the system meets the city's needs and scenarios developed in the Concept of Operations. The Validation Plan was built upon the framework laid out in the FHWA Model Document. In coordination with FHWA, example validation plans from other jurisdictions were consulted to provide further insight into completing the plan. Methods for evaluation and other resources included measures of effectiveness as a reference for how each operational objective can be evaluated as well as potential data sources. Reference numbers from the Concept of Operations document included in the Validation plan were identified and included in the final table. SDOT will be responsible for tailoring this document to the procured ASC once configured and installed.

Procurement / RFPs

These documents will be submitted to FHWA for funding approval and development of the RFP for Adaptive Signal Control Technology. This is the next step in the process and should be fairly simple to complete.