2015

CITY OF LYNNWOOD ADAPTIVE SIGNAL CONTROL TECHNOLOGY

CONCEPT OF OPERATIONS

PREPARED BY DKS ASSOCIATES

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Contents

Chapter 1: Scope 1
1.1 Document Purpose and Scope 1
1.2 Project Purpose and Scope 1
1.3 Procurement 2
Chapter 2: Referenced Documents 2
Chapter 3: User-Oriented Operational Description 2
3.1 The Existing Situation 2
3.1.1 Network Characteristics 2
3.1.2 Traffic Characteristics 4
3.1.3 Signal Grouping 21
3.1.4 Land Use Characteristics 23
3.2 Limitations of the Existing system 29
3.3 Proposed Improvements to the System 29
3.3.1 Proposed Improvements 29
3.3.2 Project ITS Architecture 30
3.4 Vision, Goals and Objectives for the Proposed System 31
3.4.1 Vision 31
3.4.2 Goals 31
3.4.3 User Objectives 31
3.5 Strategies to be Applied by the Improved System 32
3.6 Alternative Non-Adaptive Strategies Considered 33
3.6.1 Traffic Responsive Pattern Selection (TRPS) 33
3.6.2 Complex Coordination Features 33
Chapter 4: Operational Needs 34
4.1 Adaptive Strategies 34
4.2 Network Characteristics 35
4.3 Coordination Across Boundaries 35
4.4 Security 35
4.5 Queuing Interactions 35
4.6 Pedestrians 36

4.7 Non-Adaptive Situations 36
4.8 System Responsiveness 36
4.9 Complex coordination and controller features 36
4.10 Monitoring and Control 37
4.11 Performance Reporting 37
4.12 Failure Notification 38
4.13 Preemption and Priority 38
4.14 Failure and Fallback 38
4.15 Constraints 38
4.16 Training and Support 39
4.17 External Interfaces 39
4.18 Maintenance 39
Chapter 5: Envisioned Adaptive System Overview 39
5.1 Size and Grouping 39
5.2 Operational Objectives 40
5.3 Fallback Operation 41
5.4 Crossing Routes and Adjacent Systems 41
5.5 Operator Access 41
5.6 Complex coordination and controller operation 41
Chapter 6: Adaptive Operational Environment 43
Chapter 7: Adaptive Support Environment 43
7.1 Institutions and Stakeholders 43
7.2 Facilities 44
7.3 System Architecture Constraints 44
7.4 Utilities 44
7.5 Equipment 44
7.6 Software 44
7.7 Personnel 45
7.8 Operating Procedures 45
7.9 Maintenance 45
Chapter 8: Operational Scenarios 45
8.1 Overview 45

8.2 Typical Heavy Congested Conditions 45
8.2.1 Traffic Conditions 45
8.2.2 Operational Objectives 46
8.2.3 Coordination and Signal Timing Strategies 46
8.2.4 Summary of Operation 46
8.3 Typical Heavy Uncongested Conditions 46
8.3.1 Traffic Conditions 46
8.3.2 Operational Objectives 46
8.3.3 Coordination and Signal Timing Strategies 47
8.3.4 Summary of Operation 47
8.4 Typical Light Traffic Conditions 47
8.4.1 Traffic Conditions 47
8.4.2 Operational Objectives 47
8.4.3 Coordination and Signal Timing Strategies 47
8.4.4 Summary of Operation 48
8.5 Typical Holiday Traffic Conditions 48
8.5.1 Traffic Conditions 48
8.5.2 Operational Objectives 50
8.5.3 Coordination and Signal Timing Strategies 50
8.5.4 Summary of Operation 50
8.6 I-5 Incidents 50
8.6.1 Traffic Conditions 50
8.6.2 Operational Objectives 51
8.6.3 Coordination and Signal Timing Strategies 52
8.6.4 Summary of Operation 52
8.7 Transit Signal Priority and Emergency Vehicle Preemption 52
8.7.1 Transit Signal Priority 52
8.7.2 Emergency Vehicle Preemption 52
8.8 Fault Conditions 53
8.8.1 Communications Fault Condition 53
8.8.2 Detection Fault Condition 53

List of Figures

Figure 1: Map of Project Signals 3
Figure 2: Daily Volume on SR 99 5
Figure 3: Daily Volume on 196th St SW 6
Figure 4: Hourly Volume at SR 99 and 164th St SW 7
Figure 5: Hourly Volume at SR 99 and 224th St SW 7
Figure 6: Hourly Volume at 196th St SW and SR 99 8
Figure 7: Hourly Volume at 196th St SW and Alderwood Mall Parkway 9
Figure 8: Hourly Volume at Alderwood Mall Parkway and Alderwood Mall Boulevard 9
Figure 9: Hourly Volume at Alderwood Mall Parkway and 184th St SW 10
Figure 10: Weekend Northbound Hourly Volume on SR 99 at 164th St SW 11
Figure 11: Weekend Southbound Hourly Volume on SR 99 at 164th St SW 12
Figure 12: Weekend Northbound Hourly Volume on SR 99 at 224th St SW 13
Figure 13: Weekend Southbound Hourly Volume on SR 99 at 224th St SW 13
Figure 14: Weekend Eastbound Hourly Volume on 196th St SW at SR 99 14
Figure 15: Weekend Westbound Hourly Volume on 196th St SW at SR 99 15
Figure 16: Weekend Eastbound Hourly Volume on 196th St SW at Alderwood Mall Parkway 16
Figure 17: Weekend Westbound Hourly Volume on 196th St SW at Alderwood Mall Parkway 17
Figure 18: Weekend Southbound Hourly Volume at Alderwood Mall Parkway and Alderwood Mall Blvd 17
Figure 19: Weekend Southbound Hourly Volume at Alderwood Mall Parkway and 184th St SW 18
Figure 20: Existing Traffic Operational Elements 20
Figure 21: Existing Signal Coordination Groups 21
Figure 22: Existing Non-Holiday Weekday Cycle Lengths 23
Figure 23: Lynnwood City Center Development Area 24
Figure 24: City of Lynnwood Land Use Map 25
Figure 25: Typical Video Detection Placement 27
Figure 26: City of Lynnwood TMC 27
Figure 27: Detection Type by Location 28
Figure 28 Lynnwood Subsystem Interaction 30
Figure 29: Alderwood Mall Area Holiday Congestion 49
Figure 30: Detour Routes During an I-5 Blocking Incident 51

CHAPTER 1: SCOPE

1.1 Document Purpose and Scope

The scope of this document covers the consideration of adaptive signal control technology (ASCT) for use within the Cities of Lynnwood and Edmonds on the SR 99 and 196th St SW (SR 524) corridors. The Lynnwood Adaptive project will potentially implement ASCT at up to 29 intersections on these major arterials.

This document describes the expected operations of the proposed adaptive system and provides justification for use of an adaptive system. It documents the outcome of stakeholder discussions and consensus building that has been undertaken to ensure the system that is implemented is operationally feasible and has stakeholder support. It is part of the System Engineering Documents that will be developed and used to select and deploy an ASCT system for the City of Lynnwood. This document illustrates user-oriented operational descriptions, operational needs, and an envisioned adaptive system overview, including clearly defined vision, goals and objectives, adaptive operational environment, support environment, and various operational scenarios.

The intended audience of this document includes: traffic engineers, administrators, decision-makers, elected officials, non-technical readers and other stakeholders who will share the operation of the system and/or be directly affected by it.

This document is part of the overall stakeholder-driven process to evaluate various adaptive signal technologies through a systems engineering process in order to select an ASCT system to deploy in the City of Lynnwood. In addition to the City of Lynnwood, stakeholders include the City of Edmonds, the City of Mountlake Terrace, Community Transit and WSDOT.

1.2 Project Purpose and Scope

The purpose of this project is to identify an upgrade to Lynnwood's existing traffic signal system that would provide reasonable and predictable travel times, improved safety, additional operational functionality, and an improvement in traffic operations over their existing time-of-day signal coordination. The existing coordination works well under normal conditions, but cannot respond to random fluctuations in traffic. The City of Lynnwood would like to improve operations during predicable and unpredictable heavy traffic demand. Such events may include increased traffic detouring onto SR 99 due to an incident on I-5; heavy congestion on 196th St SW and around Alderwood Mall during the holiday season; events at the Lynnwood Convention Center; and other unpredictable incidents.

Lynnwood has gradually upgraded the field components of its signal system to provide the detection and communication infrastructure needed to accommodate advanced traffic signal operations like adaptive signal control. An adaptive traffic signal system responds to changes in traffic conditions by automatically adjusting signal timings, such as cycle lengths, phase splits, and local zero offsets in near real time.

1.3 Procurement

The ASCT system will be procured using a two-step process that includes both a Request for Qualifications (RFQ) and a Request for Proposals (RFP). Statements of Qualifications (SOQ) will be initially reviewed by the City of Lynnwood to determine which proposers can meet the minimum requirements defined in the RFQ. Any Vendor that does not currently meet all these minimum requirements or cannot provide a way to meet all the minimum requirements by completion of the project will not be deemed qualified to submit a proposal to provide the work.

CHAPTER 2: REFERENCED DOCUMENTS

The following documents have been used in the preparation of this Concept of Operations and stakeholder discussions. Some of these documents provide policy guidance for traffic signal operation in this area; some are standards with which the system must comply; while others report the conclusions of discussions, workshops and other research used to define the needs of the project and subsequently identify project requirements.

- *Intelligent Transportation Systems (ITS) Regional Architecture,* Puget Sound Regional Council, http://www.psrc.org/assets/3515/Final_Report_20AUG-06_updated_22DEC-08.pdf
- *Systems Engineering Guidebook for ITS*, California Department of Transportation, Division of Research & Innovation, Version 3.0, http://www.fhwa.dot.gov/cadiv/segb/>
- *Lynnwood Intelligent Transportation Systems (ITS) Plan and Local Architecture,* February 2004

CHAPTER 3: USER-ORIENTED OPERATIONAL DESCRIPTION

This section presents the current conditions (existing situation); the City of Lynnwood's goals and objectives for signal system operations; and describes other non-adaptive strategies considered.

3.1 The Existing Situation

This subsection describes each corridor and their signal operational characteristics. It also describes the signal operational limitation identified for each corridor.

3.1.1 Network Characteristics

This section breaks down the project area into a description of how each portion of the study area operates (i.e., as an arterial, grid network or isolated intersection). There is also a freeway interchange within the project area that must be addressed.

3.1.1.1 Arterial

The ASCT system is proposed on two major arterial corridors in the City of Lynnwood, SR 99 and SR 524 (196th St SW). SR 99 (Pacific Hwy) runs northeast/southwest and is roughly parallel to I-5. 196th St SW runs east/west through the City and crosses through SR 99 and over I-5. A map of the project intersections is shown in Figure 1.

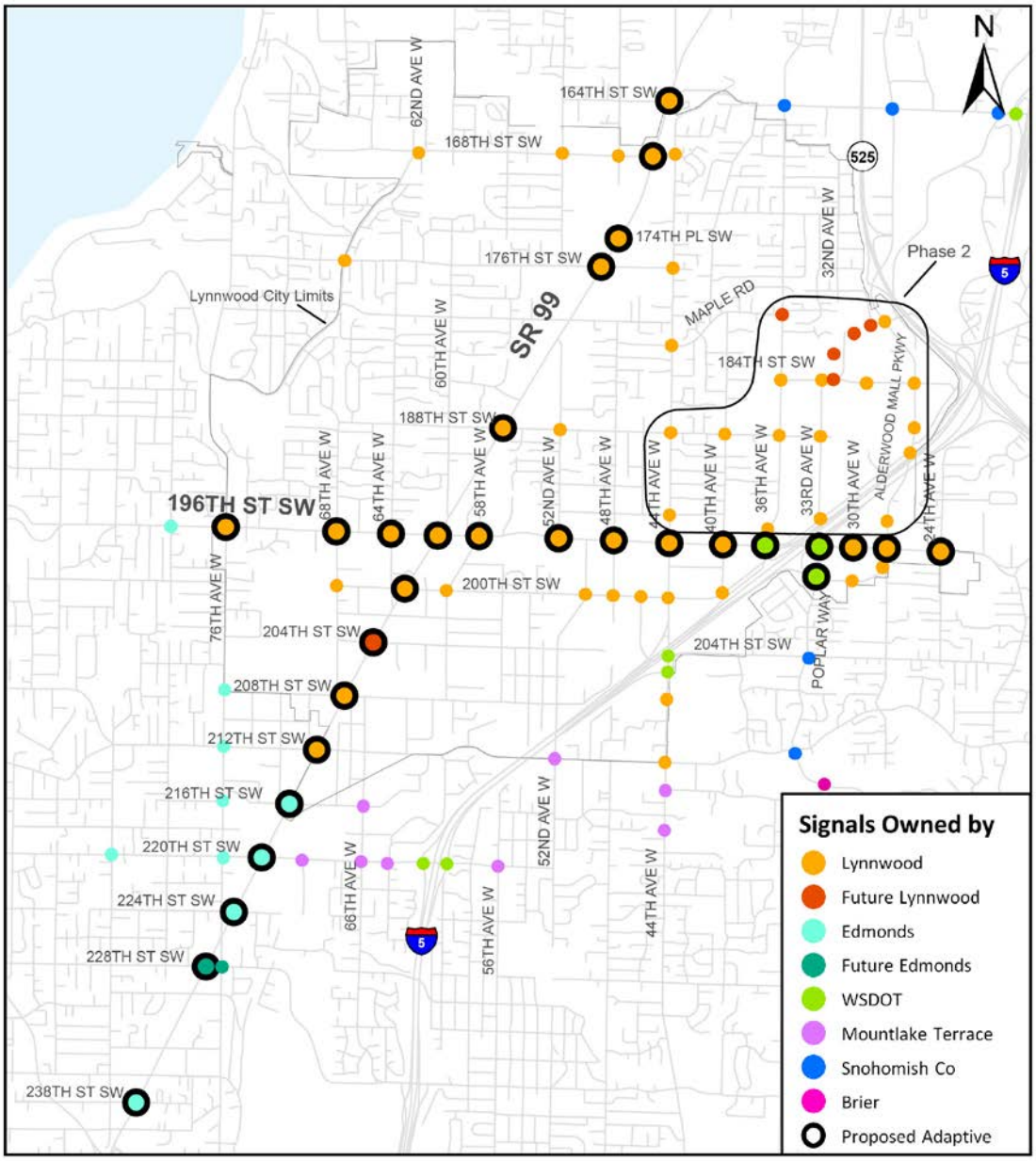

Figure 1: Map of Project Signals

SR 99

The section of SR 99 through the cities of Lynnwood and Edmonds is 5.2 miles long and currently has 13 signalized intersections, with two more that will be built by the time ASCT is implemented. From 196th St SW to the south, the 10 signals are spaced approximately 1,500 feet apart, with the exception of 238th St SW, the southernmost signal. 238th St SW is about 3,700 feet from the adjacent signal at 228th St SW. The signal spacing is much more varied north of 196th St SW, ranging from 800 to 4,500 feet.

The intersections in the north half of the corridor, north of 196th St SW, have similar natural cycle lengths of around 140 seconds. The south end of the corridor has varying natural cycle lengths due to varying cross-street demand.

196th St SW

The section of 196th St SW through the City of Lynnwood is 3.3 miles long and has 14 signalized intersections. The signals are spaced between 1,000 and 1,500 feet apart.

3.1.1.2 Grid

The area around Alderwood Mall is the desired location for a future adaptive system (Phase 2). This area includes intersections north of 196th St SW and between SR 99 and I-5/SR 525 in the City of Lynnwood. The crossing coordination in this area will require consideration of an adaptive system that supports grid coordination.

3.1.1.3 Isolated Intersection or Small Group

SR 99 and 238th St SW at the south end of the project corridor is about 3,700 feet from the closest signal at 228th St SW. The intersection currently operates uncoordinated due to the long distance between intersections. During normal daily operations, it may not make sense to coordinate 238th St SW with the intersections to the north. However, during incident conditions, and assuming an increase in traffic on SR 99, there may be a need to coordinate 238th St SW with the traffic signals to the north.

3.1.1.4 Freeway Interchange

There is an existing interchange at I-5 and 196th St SW that has several closely spaced intersections and major turning movements. The interchange requires careful management of queue lengths to reduce queue spillback onto the interstate and between intersections. There are on ramps from 196th St SW to northbound and southbound I-5 within the proposed ASCT corridor. The southbound on-ramp is at the 36th Ave W signal and the northbound on ramp is accessible from 196th St SW westbound only between 30th Ave W and 33rd Ave W (Poplar Way). Off of I-5, the southbound to westbound ramp merges with 196th St SW just before the 36th Ave W signal and the southbound to eastbound loop ramp merges just before the Poplar Way signal. The northbound I-5 ramp exits to Poplar Way just south of 196th St SW.

3.1.1.5 Jurisdictions

The signals within the proposed ASCT corridors are owned and/or operated by several different agencies. The two I-5 ramp signals on 196th St SW at 36th Ave W and 33rd Ave W and the one on Poplar Way just south of 196th St SW are owned and operated by WSDOT. All other signals on 196th St SW are owned and operated by the City of Lynnwood. On SR 99, all signals from 212th St SW and north to 164th St SW are owned and operated by the City of Lynnwood. The five signals at the south end, from 216th St SW to 238th St SW, are owned by the City of Edmonds and operated by the City of Lynnwood.

3.1.2 Traffic Characteristics

The following subsections describe how the traffic signals in the study area operate during various typical travel periods.

3.1.2.1 Overview

SR 99 serves approximately 50,000 vehicles per day. North-south volumes are heaviest based on traffic volume data collected by the traffic signal system. Traffic is heaviest throughout the summer months and the winter holiday shopping season. Figure 2 shows daily volume throughout the project corridor on an average summer weekday.

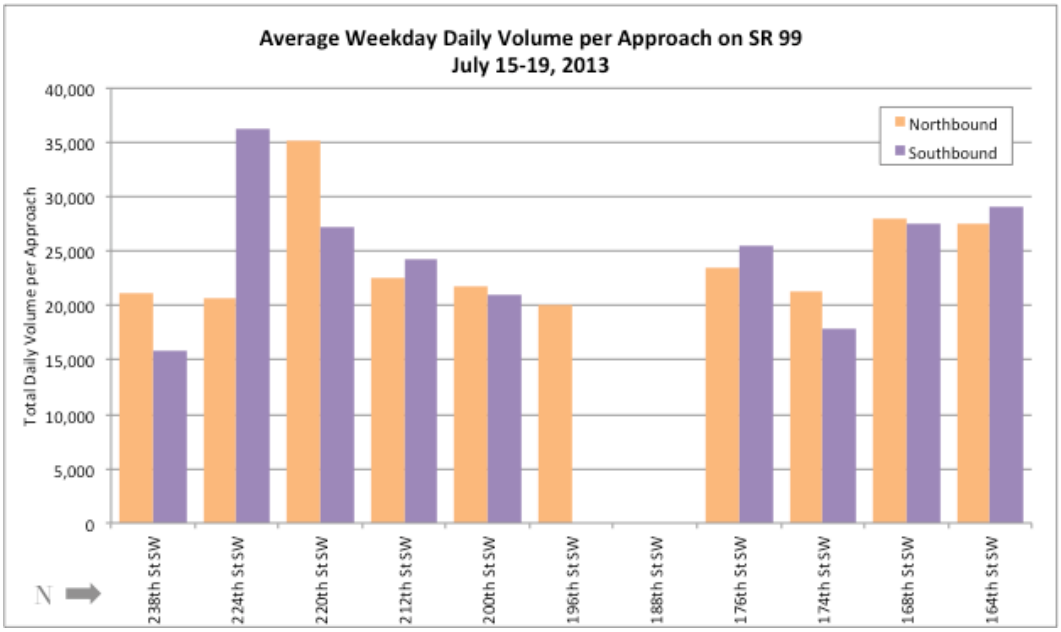

Figure 2: Daily Volume on SR 99

196th St SW serves approximately 40,000 vehicles at an intersection per day. Figure 3 shows daily volumes throughout the project corridor on an average summer weekday.

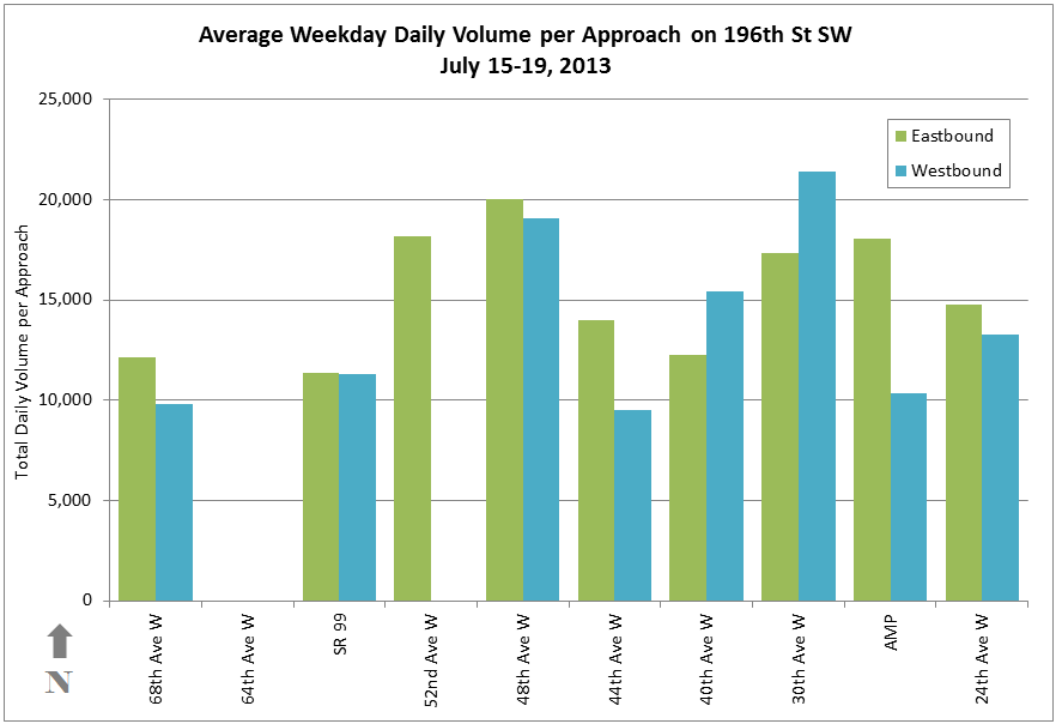

Figure 3: Daily Volume on 196th St SW

3.1.2.2 Peak Periods

On SR 99, weekday traffic peaks southbound in the AM and northbound in the PM. The directional peak is more pronounced towards the northern end of the corridor and is more balanced towards the southern end of the corridor. However, during summer months in the northern end of the corridor, southbound volume is just as high as northbound volume in the PM peak. Figure 4 and Figure 5 show hourly volume at sample intersections (164th St SW and 224th St SW) on SR 99 on a typical summer weekday.

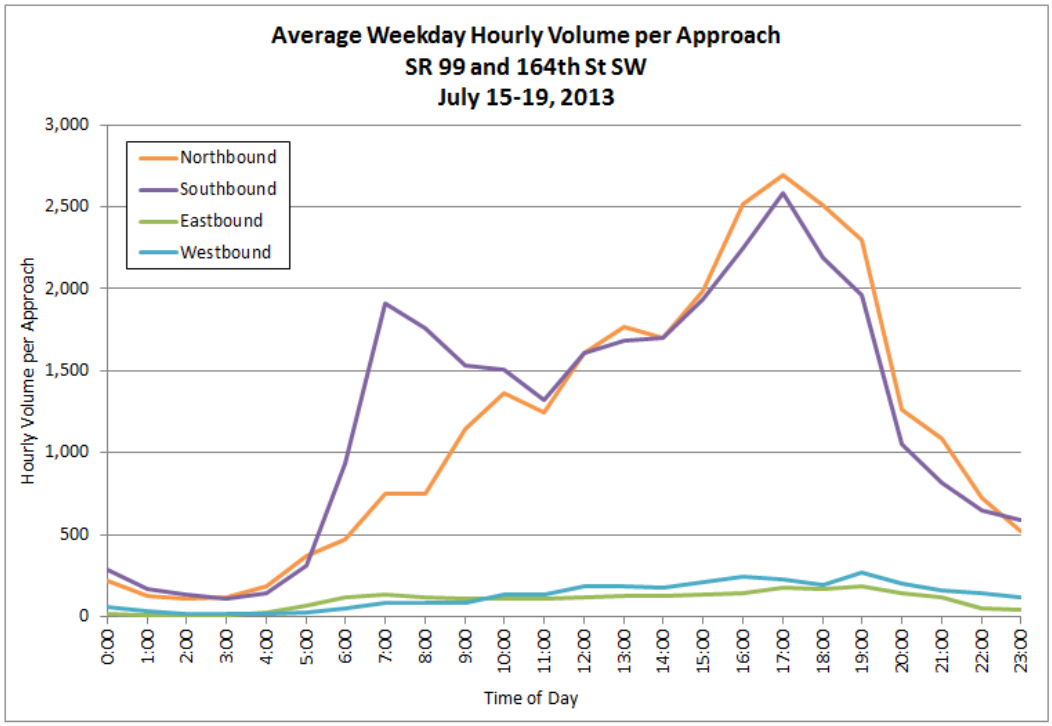

Figure 4: Hourly Volume at SR 99 and 164th St SW

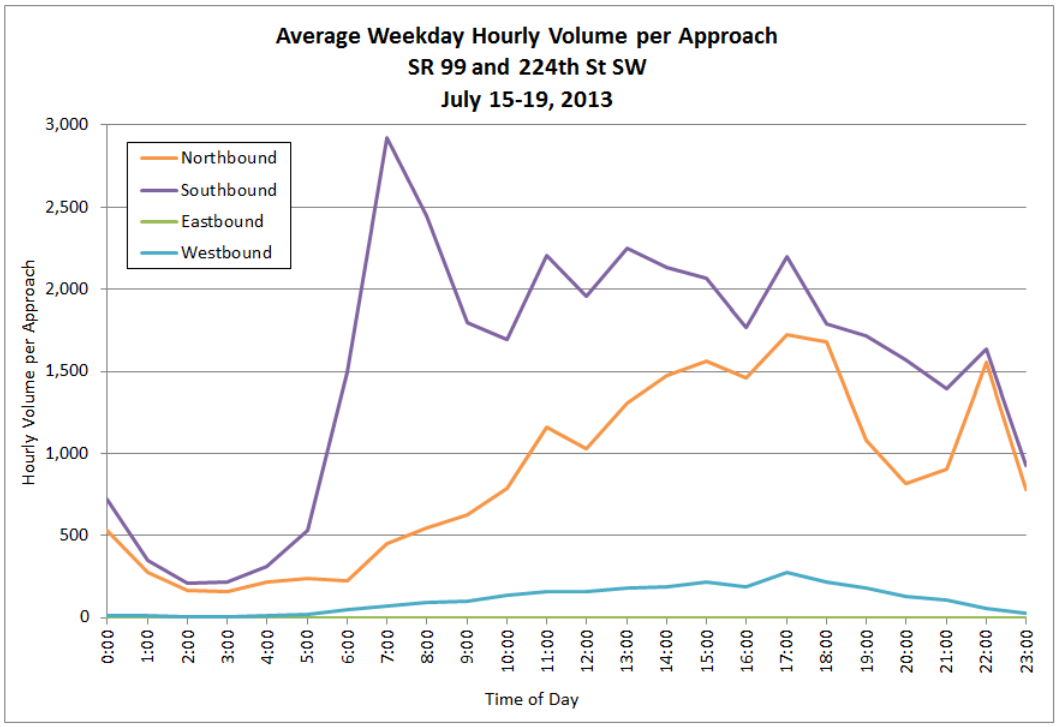

Figure 5: Hourly Volume at SR 99 and 224th St SW

On 196th St SW, traffic is more balanced throughout the day. At SR 99, eastbound and westbound volumes are similar to each other and stay fairly steady throughout a typical weekday between 10 AM

and 6 PM with no defined peaks. At the east end of the corridor just east of I-5, eastbound volume grows throughout the day and peaks in the PM, while westbound volume is much less and stays steadier throughout the day. Figure 6 and Figure 7 show hourly volume on 196th St SW on a typical weekday.

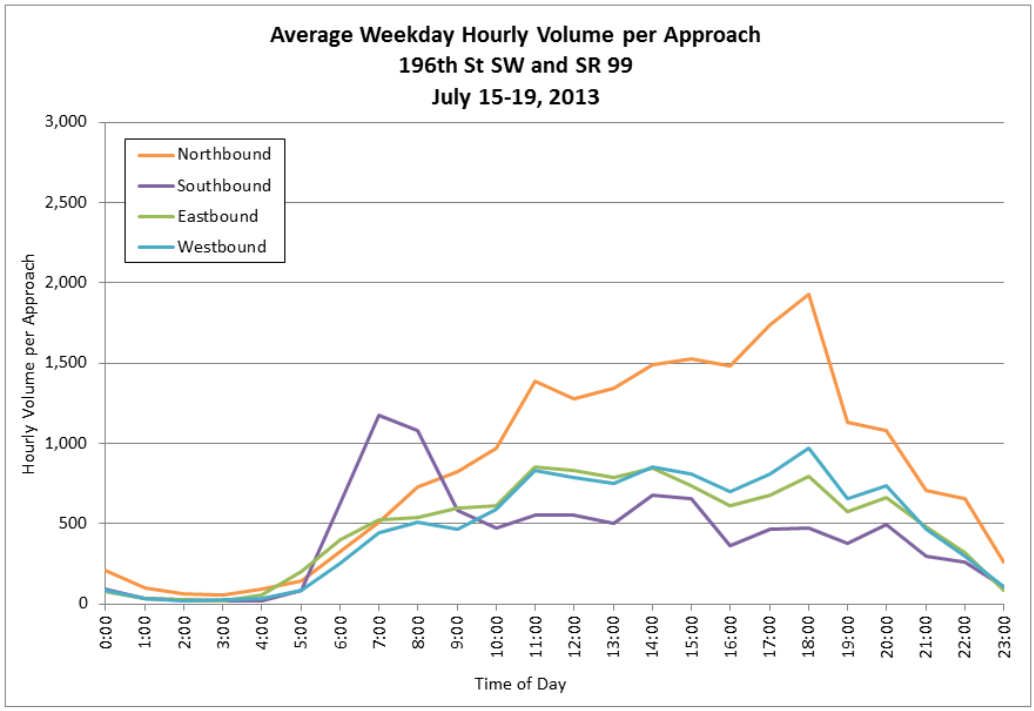

Figure 6: Hourly Volume at 196th St SW and SR 99

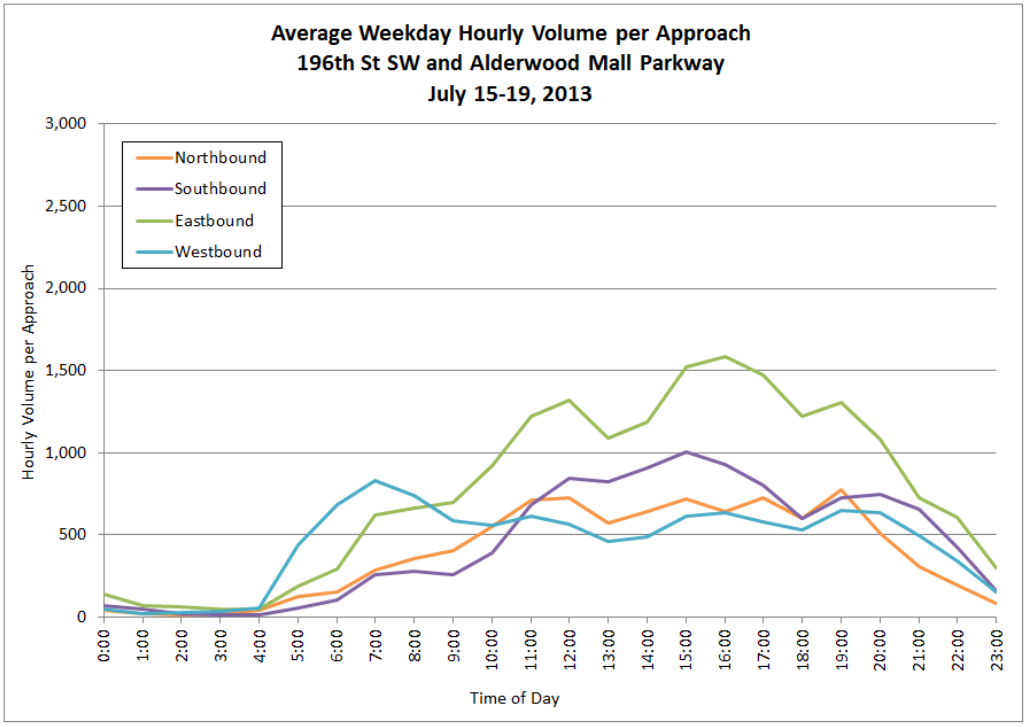

Figure 7: Hourly Volume at 196th St SW and Alderwood Mall Parkway

Near Alderwood Mall, there is generally not a significant morning peak, with traffic increasing gradually in the morning then staying steady throughout the day. Figure 8 and Figure 9 show the summer weekday volume at Alderwood Mall Parkway and Alderwood Mall Bouldevard, and at Alderwood Mall Parkway and 184th St SW.

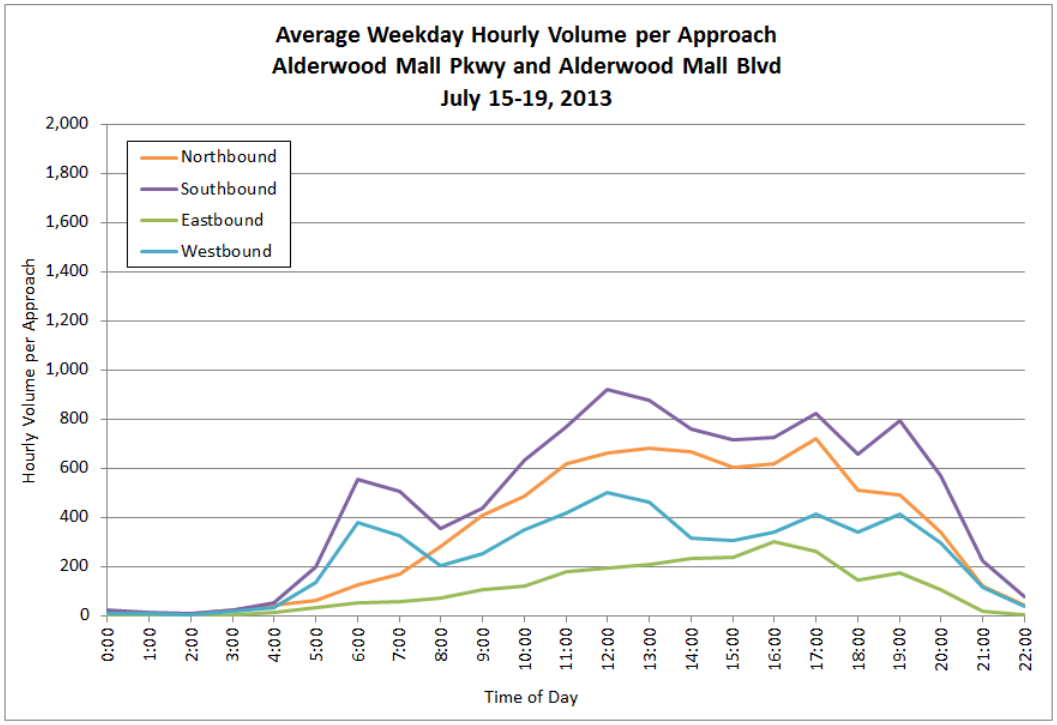

Figure 8: Hourly Volume at Alderwood Mall Parkway and Alderwood Mall Boulevard

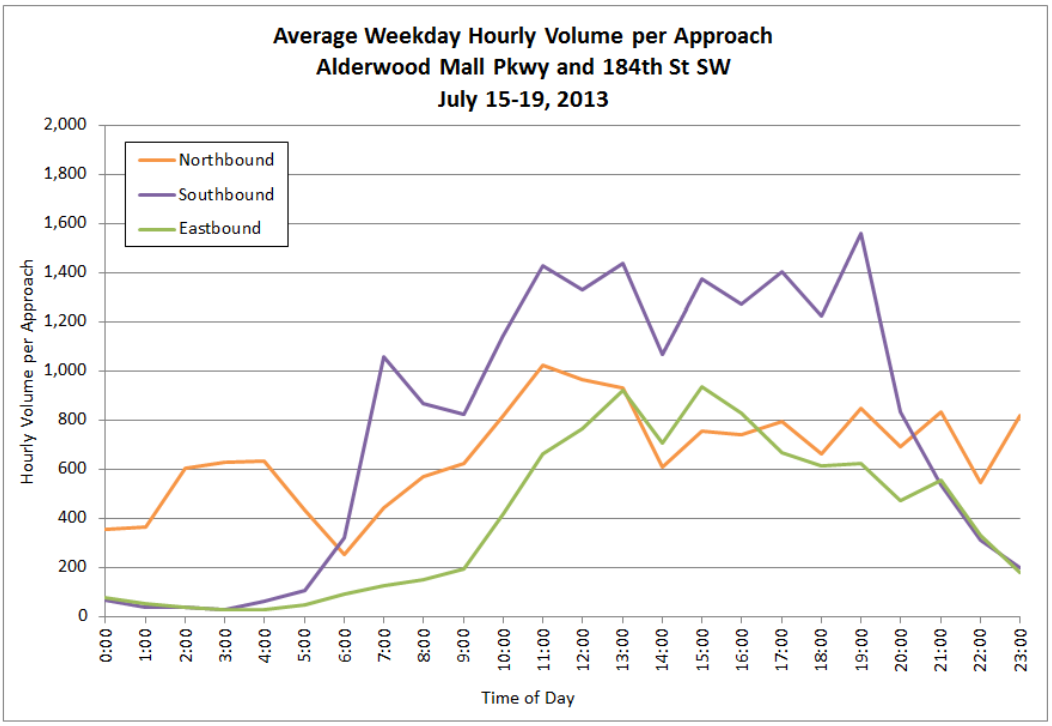

Figure 9: Hourly Volume at Alderwood Mall Parkway and 184th St SW

3.1.2.3 Business Hours

Traffic volume between the AM and PM peaks varies throughout the project corridors. On SR 99, northbound volume increases throughout the day until dropping after the PM peak. Southbound, volume drops after the AM peak and stays mostly steady throughout midday with only a slight increase in the PM peak.

On 196th St SW at SR 99, eastbound and westbound volume stays quite steady throughout the day with no defined peaks. Further east at Alderwood Mall Parkway, eastbound volume increases throughout the day, stays steady from about 2-6 PM, then decreases. Westbound volume drops slightly after the AM peak and stays steady throughout the rest of the day.

Traffic volume stays fairly steady throughout the midday period around Alderwood Mall. Some areas show a slight peak from noon to 1 PM.

3.1.2.4 Evenings

The PM peak generally ends around 8 PM throughout the project corridors. On an average day, volume decreases steadily throughout the evening at all locations. There are no significant unusual trends after the PM peak.

3.1.2.5 Weekends

During the weekends, traffic volume varies widely depending on the location within the project corridors and the time of year. On SR 99 at the north end, volume is similar in the northbound and southbound directions, as shown in Figure 8 and Figure 9 for the intersection at 164th St SW.

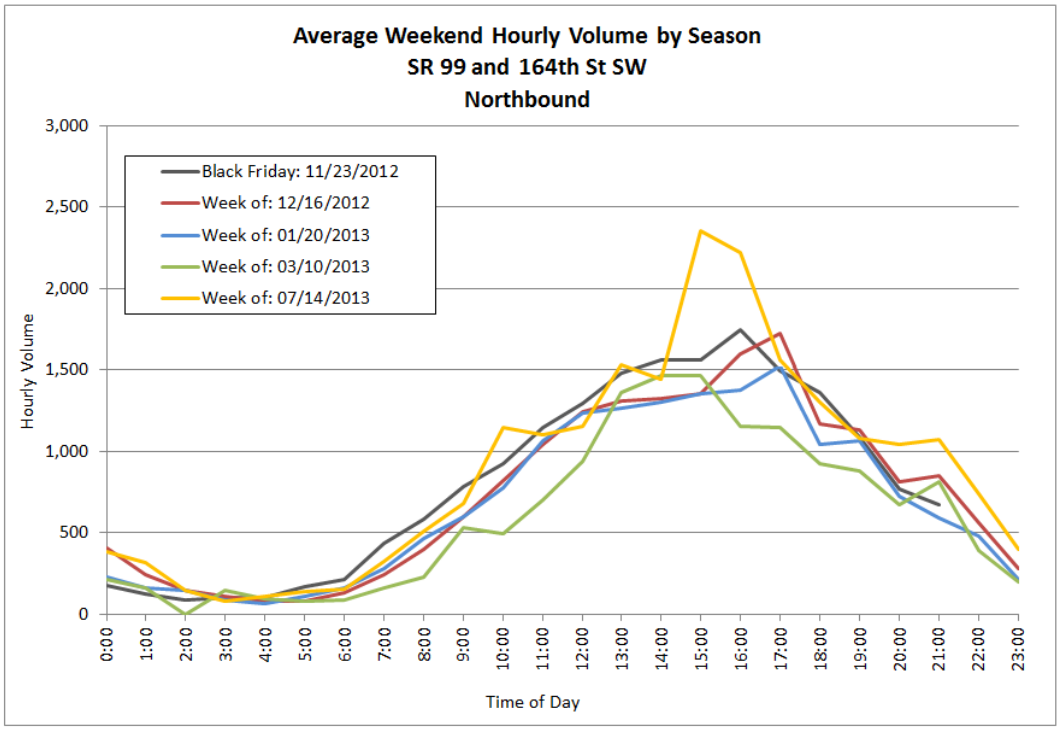

Figure 10: Weekend Northbound Hourly Volume on SR 99 at 164th St SW

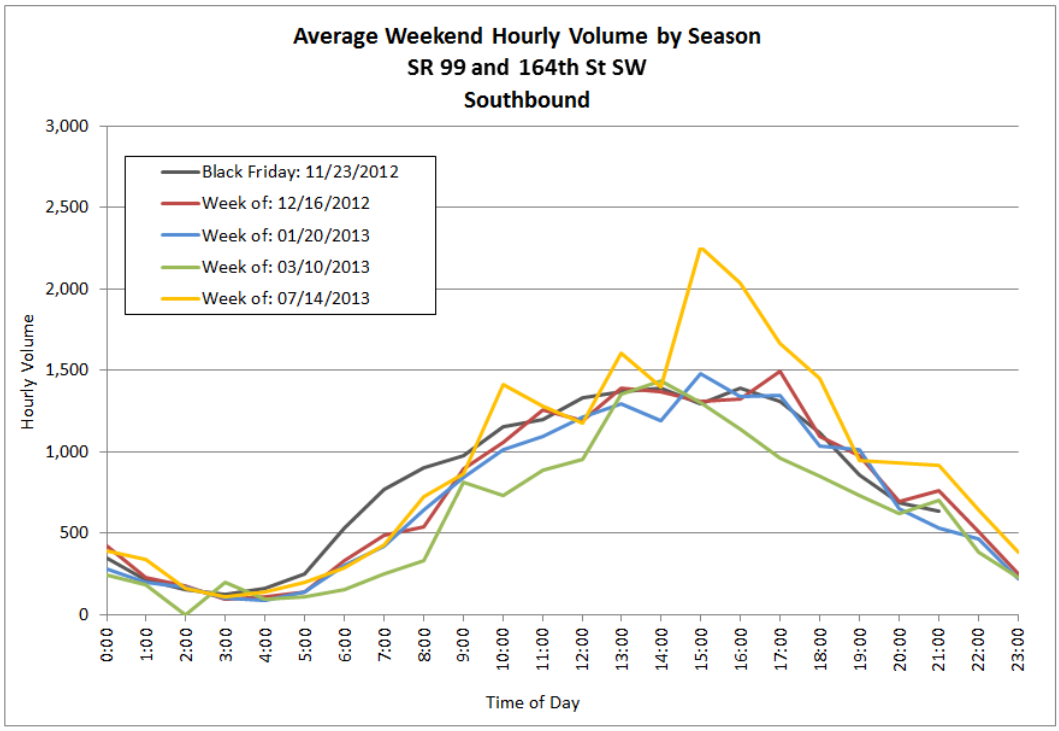

Figure 11: Weekend Southbound Hourly Volume on SR 99 at 164th St SW

In general, volume increases throughout the day and peaks at about 2 PM. During the holiday shopping season, the peak occurs later, around 5 PM. During the summer months, there is a very high peak between 3 and 5 PM that is likely due to recreational traffic.

At the south end of SR 99, southbound volume is much higher than northbound, as shown in Figure 12 and Figure 13 for 224th St SW.

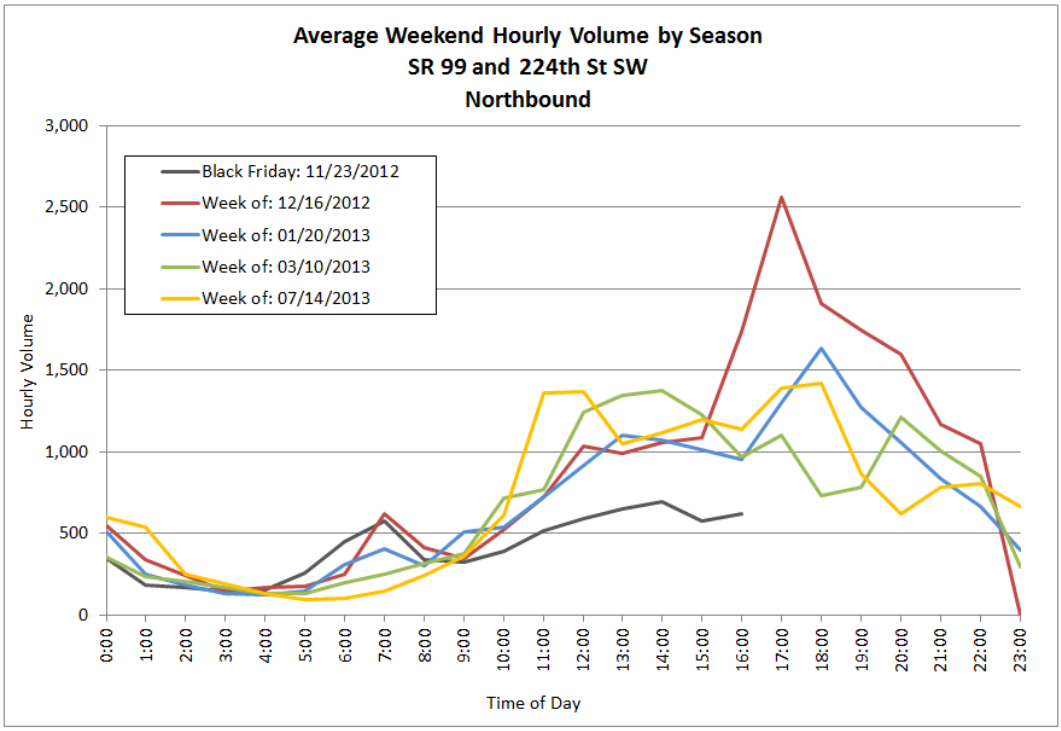

Figure 12: Weekend Northbound Hourly Volume on SR 99 at 224th St SW

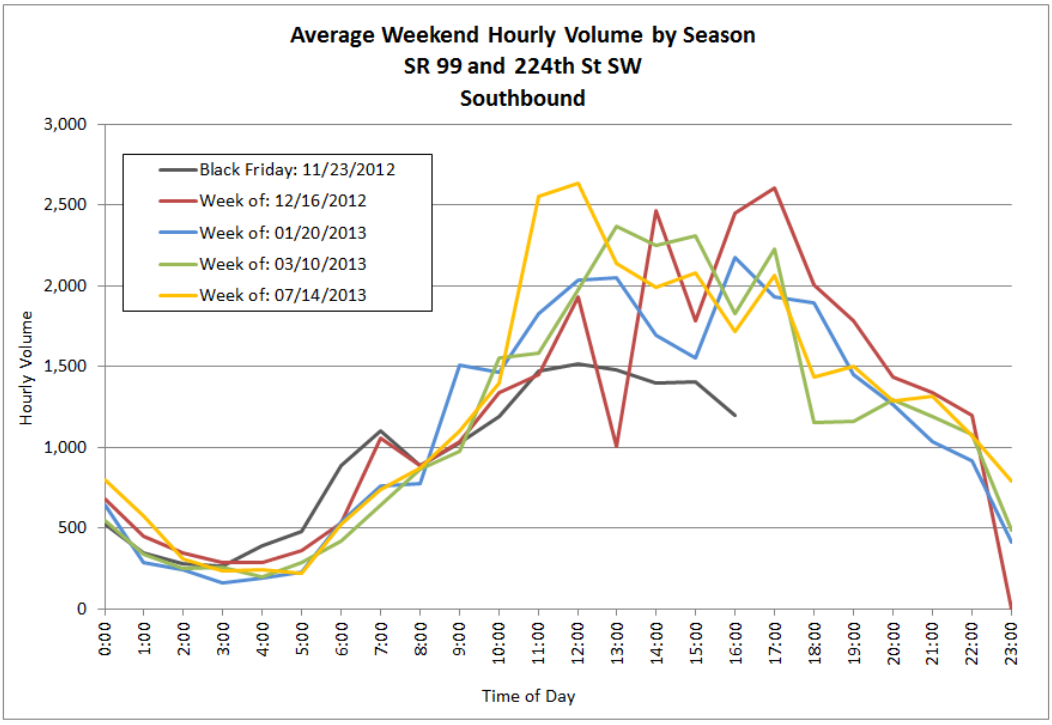

Figure 13: Weekend Southbound Hourly Volume on SR 99 at 224th St SW

Southbound volume increases throughout the morning then stays steady from 12-5 PM before decreasing in the evening. Northbound volume is lower throughout the day and stays fairly steady

between 12 and 8 PM, except during the holiday season when volume increases significantly around 5 PM. In both directions, volume during the summer months is higher in the morning than during the rest of the year.

On 196th St SW at SR 99, eastbound and westbound volume is balanced and stays similar throughout the year, as shown in Figure 14 and Figure 15. Volume increases until about 12 PM then slightly decreases throughout the rest of the day.

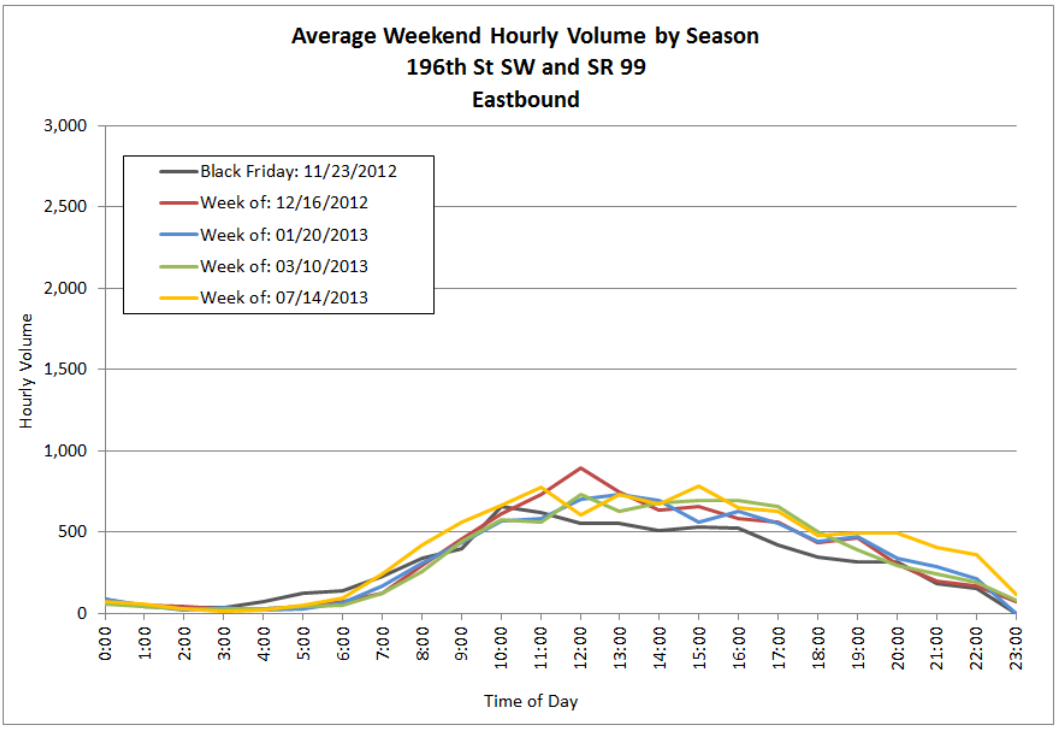

Figure 14: Weekend Eastbound Hourly Volume on 196th St SW at SR 99

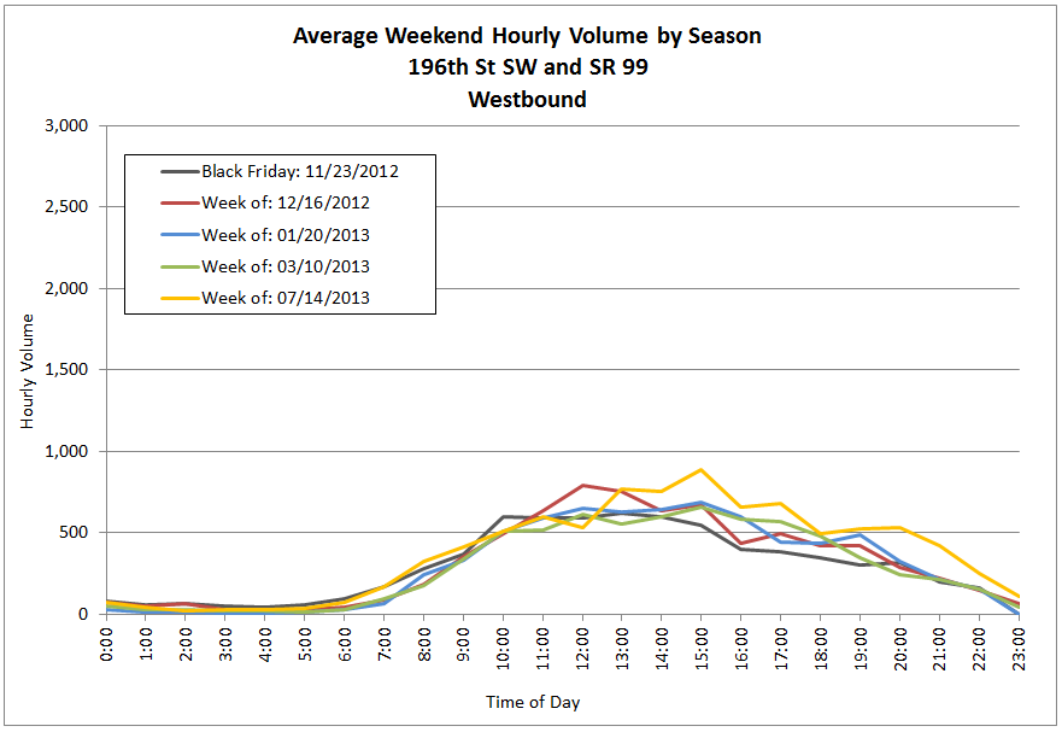

Figure 15: Weekend Westbound Hourly Volume on 196th St SW at SR 99

Figure 16 and Figure 17 show hourly volume at the east end of the corridor at Alderwood Mall Parkway. Westbound volume stays low and fairly steady throughout the day. Eastbound volume is much different, increasing throughout the morning and peaking between 11 AM and 2 PM before decreasing throughout the afternoon. Eastbound volume peaks slightly higher during the holiday shopping season.

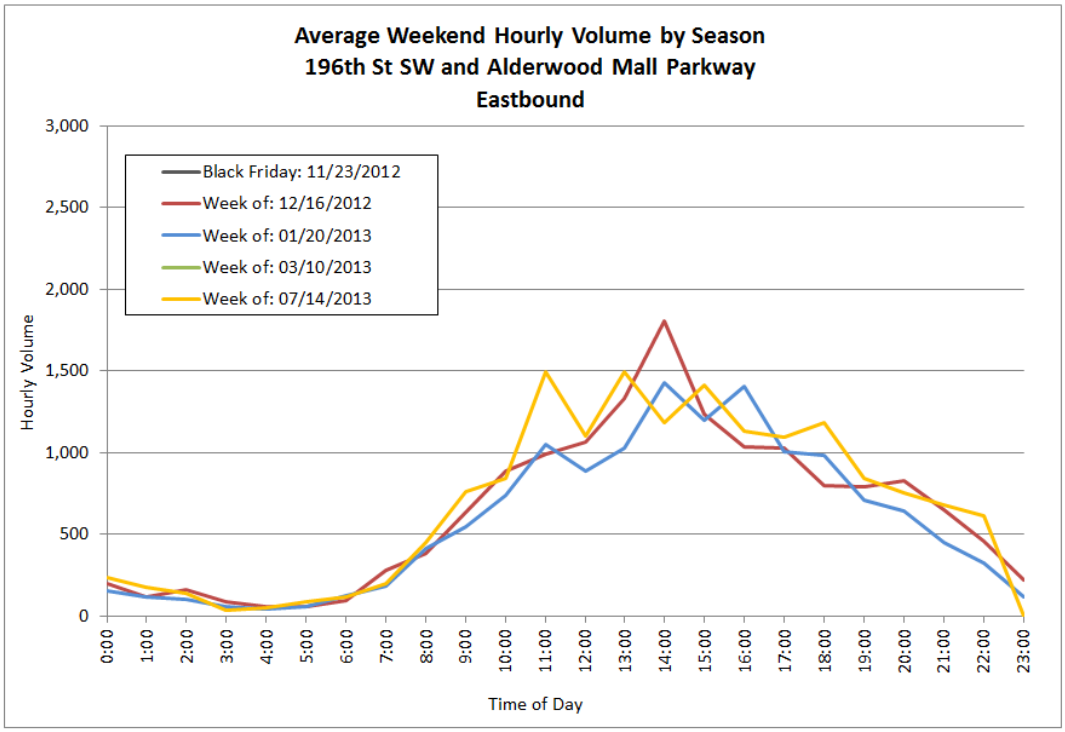

Figure 16: Weekend Eastbound Hourly Volume on 196th St SW at Alderwood Mall Parkway

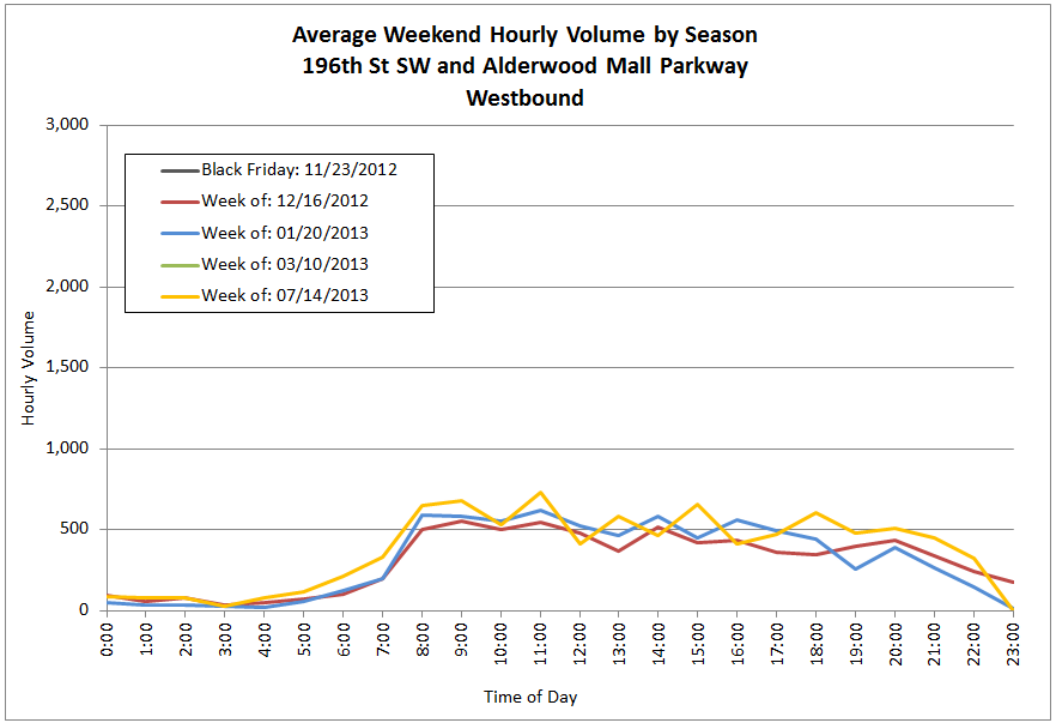

Figure 17: Weekend Westbound Hourly Volume on 196th St SW at Alderwood Mall Parkway

Around the Alderwood Mall area, weekend traffic increases throughout the morning and peaks in the early afternoon. Volume during the early morning hours of Black Friday is significantly higher than normal weekend volumes. During the holiday shopping season in November and December, volume is also generally much higher than normal until it reaches capacity. Figure 18 and Figure 19 show the weekend hourly volume and seasonal variations near the Alderwood Mall at Alderwood Mall Parkway and Alderwood Mall Boulevard and at Alderwood Mall Parkway and 184th St SW.

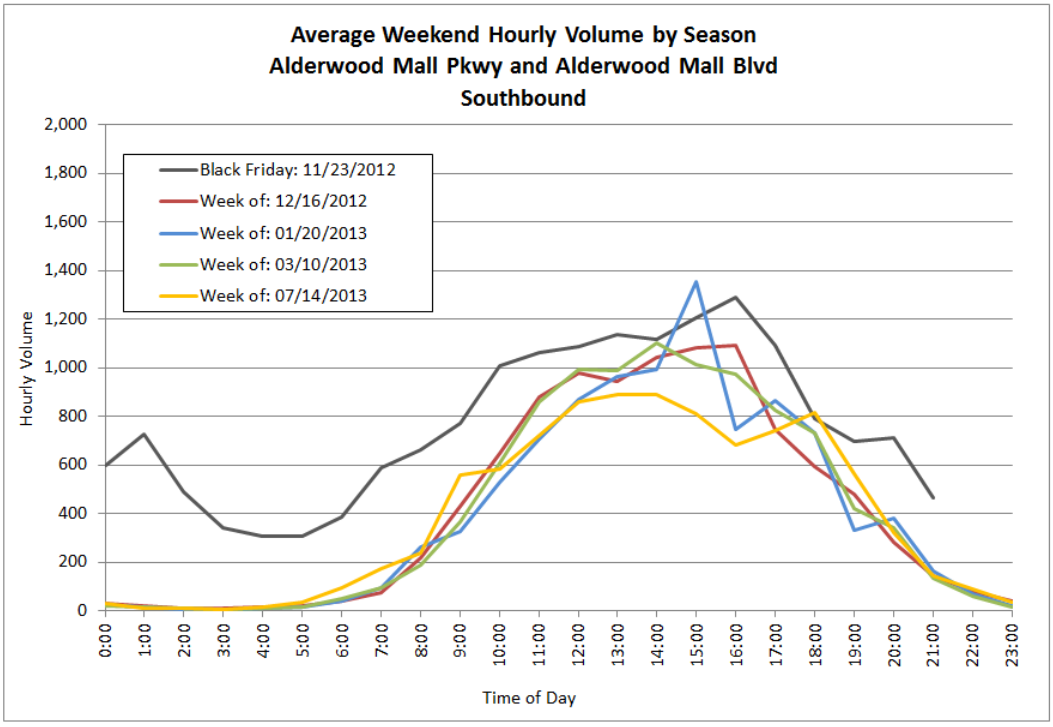

Figure 18: Weekend Southbound Hourly Volume at Alderwood Mall Parkway and Alderwood Mall Blvd

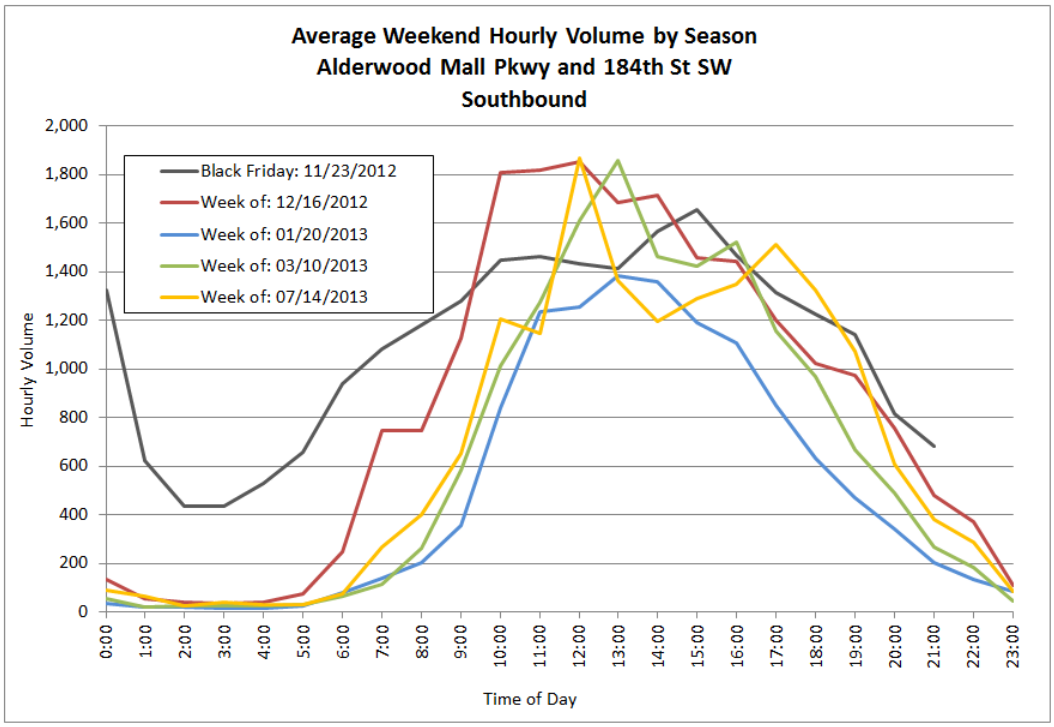

Figure 19: Weekend Southbound Hourly Volume at Alderwood Mall Parkway and 184th St SW

3.1.2.6 Events and Incidents

The largest predictable event that affects traffic within the project corridors is heavy congestion near Alderwood Mall during the holiday shopping season. Currently, there are holiday signal timing plans that are implemented beginning November 1st along 196th St SW east of SR 99 and around the whole mall area, north up to 174th Pl SW and Maple Rd and east to Alderwood Mall Parkway. Cycle lengths are increased up to 150 seconds within the holiday plans.

Unpredictable events, such as a blocking incident on I-5, can cause heavy volume at unexpected times within the project corridors since SR 99 is roughly parallel to I-5 in this area and can act as the main detour during an I-5 incident. 196th St SW may also be used as a detour route between I-5 and SR 99 to exit or re-enter the freeway, depending on the incident location. Detour routes vary widely, depending on the incident location, so signal timing has to be closely monitored and manually adjusted. If a major incident occurs, the City Traffic Engineer can manually adjust the signal timing during the incident. First, green times are increased to the max green time, and then green times on the minor movements are reduced if necessary. Other adjustments are made manually throughout the incident to keep operations moving as efficiently as possible.

3.1.2.7 General

The general traffic characteristics of SR 99 within the project corridor are listed below:

- Traffic movement is predominantly through traffic in the AM peak
- Traffic is heavy southbound in the AM and northbound in the PM

- Long queues build in the northbound direction during the PM peak. Most clear in one cycle. From 196th St SW to the south the queues sometimes reach the upstream intersection at 200th St SW and do not clear in one cycle.
- Traffic conditions can change quickly during an incident on I-5 due to drivers using SR 99 as an alternate route
- Congestion varies significantly with the weather
- High turning volumes occur at 168th St SW, 188th St SW, 196th St SW, 208th St SW, and 200th St SW

The general traffic characteristics of 196th St SW within the project corridor are listed below:

- The west end and east end of the corridor have different traffic patterns
- There is high turning volumes at the I-5 interchange
- Queue spillback occurs eastbound and westbound between 36th Ave W and 48th Ave W in the PM peak
- The corridor can get heavily congested during the holiday shopping season at the east end near Alderwood Mall
- Congestion varies significantly with the weather
- High turning volumes occur at SR 99, 44th Ave W, 36th Ave W, and Alderwood Mall Parkway

The general traffic characteristics around the Alderwood Mall area are listed below:

- There is very high congestion around the mall and surrounding retail areas during the holiday shopping season
- Congestion varies significantly with the weather
- High turning volumes occur at Alderwood Mall Parkway and Alderwood Mall Boulevard, Alderwood Mall Parkway and 184th St SW, 184th St SW and 33rd Ave W, and Alderwood Mall Boulevard and 33rd Ave W.

The map in Figure 20 shows some of the major traffic generators and operational elements in the City of Lynnwood that affect the signal system. Transit Signal Priority (TSP) currently operates on SR 99 and equipment is installed for TSP on 196th St SW. In the future, at least three corridors crossing SR 99 will have TSP, requiring the adaptive system to be compliant with four-way TSP at an intersection. There is also potential in the future for multiple streets crossing SR 99 and 196th St SW to be coordinated, which will directly affect adaptive signal operations.

Figure 20: Existing Traffic Operational Elements

3.1.2.8 Future Traffic Conditions

Lynnwood is constantly evolving to provide denser housing near the core of the City and more commercial and retail facilities to support the demands of the growing population. One example is the redevelopment of the old Lynnwood High School property just north of Alderwood Mall. Construction has begun for a new Costco on the north end of this site and smaller retail and office complex facilities on the south end, across from the mall. This development will create a new roadway connecting 184th St SW with Alderwood Mall Parkway.

Sound Transit will begin construction in 2018 of the Lynnwood Link Light Rail Extension, which includes placing a northern terminus station at 44th Avenue W in Lynnwood. Surface street demand patterns on major corridors are expected to increase when the station begins operating in 2025.

3.1.3 Signal Grouping

The City currently operates time-of-day coordination on SR 99 and 196th St SW. The critical intersection is at the crossing of these two corridors, SR 99 and 196th St SW. The existing coordinated signal operation groups for the project corridors are shown in Figure 21.

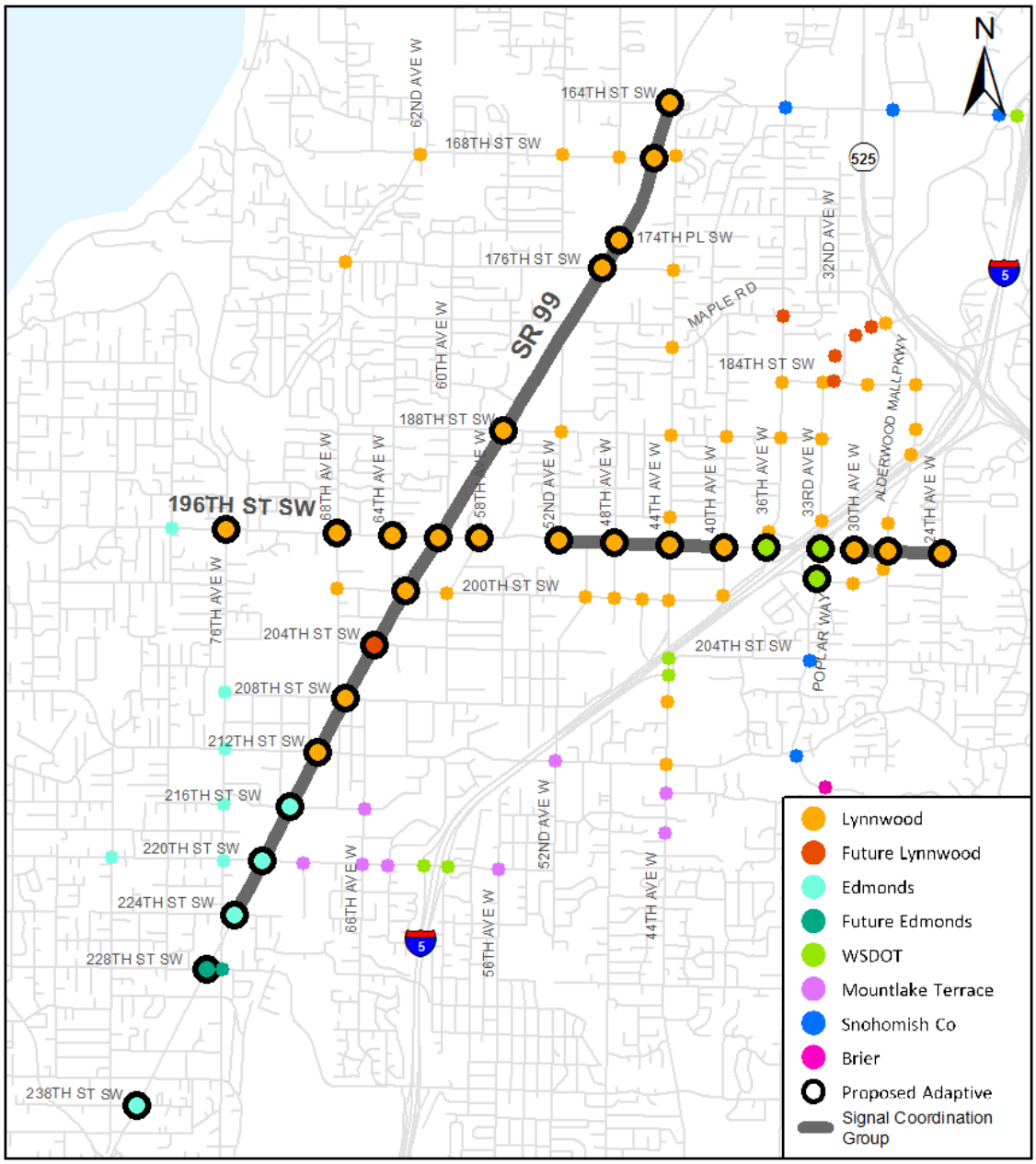

Figure 21: Existing Signal Coordination Groups

Signals on SR 99 within the project corridor are coordinated throughout the day on weekdays. The AM peak hour has a cycle length of 140 seconds while the rest of the AM peak period has a cycle length of 120 seconds. Similarly in the PM peak period, the cycle length is 120 seconds except during the peak hour when it is 150 seconds.

The intersection of SR 99 and 228th St SW is currently unsignalized, but will be signalized before ASCT is implemented. The signal at 238th St SW is over 5,000 feet from 224th St SW and about 3,700 feet from 228th St SW; therefore, it is currently not coordinated with any signals on SR 99 and may possibly be too far to be included in the ASCT implementation. The intersection of SR 99 and 204th St SW is currently unsignalized, but will be signalized before the ASCT implementation.

The signals on 196th St SW operate in three groups: west of SR 99, between SR 99 and I-5, and east of I-5. The WSDOT-owned and operated signals on 196th St SW at 36th Ave W and 33rd Ave W (Poplar Way) are not coordinated with the rest of the 196th St SW corridor. The WSDOT signal on Poplar Way at Alderwood Mall Parkway, just south of 196th St SW, is the entrance and exit ramp to/from northbound I-5 and is coordinated with the signal at 196th St SW and Poplar Way. Preserving this coordination is strongly desired and this traffic signal should be considered as an addition to the ASCT system. The signals west of SR 99 are not coordinated together and operate free throughout each day. The signals on 196th St SW between SR 99 and I-5 operate free during the AM peak and are coordinated during the PM peak with a maximum cycle length of 150 seconds. The signals east of I-5 also operate free during the AM peak and are coordinated during the PM peak with a maximum cycle length of 120 seconds.

The existing cycle lengths on weekdays during non-holiday periods are shown in Figure 22.

SR 99 Intersections: Non-Holiday Weekday Cycle Lengths

	6:00	7:00	8:30	9:30	11:30	13:30	14:30	15:30	18:30	20:00
164th St SW	free	140	120	120	130	120	120	150	120	free
168th St SW	free	140	120	120	130	120	120	150	120	free
174th St SW	free	140	120	120	130	120	120	150	120	free
176th St SW	free	140	120	120	130	120	120	150	120	free
188th St SW	free	140	120	120	130	120	120	150	120	free
196th St SW	free	140	120	120	130	120	120	150	120	free
200th St SW	free	140	120	120	130	120	120	150	120	free
208th St SW	free	140	120	120	130	120	120	150	120	free
212th St SW	free	140	120	120	130	120	120	150	120	free
216th St SW	free	140	120	120	130	120	120	150	120	free
220th St SW	free	140	120	120	130	120	120	150	120	free
224th St SW	free	140	120	120	130	120	120	150	120	free
238th St SW	free	140	120	120	130	120	120	150	120	free

196th St SW Intersections: Non-Holiday Weekday Cycle Lengths

	6:00	7:00	8:30	9:30	11:30	13:30	14:30	15:30	18:30	20:00
76th Ave W	free	free	free	free	110	free	120	120	120	free
68th Ave W	free	free	free	free	free	free	free	free	free	free
64th Ave W	free	free	free	free	free	free	free	free	free	free
SR 99	free	140	120	120	130	120	120	150	120	free
52nd Ave W	free	free	free	free	130	free	120	150	120	free
48th Ave W	free	free	free	free	130	free	120	150	120	free
44th Ave W	free	free	free	free	130	free	120	150	120	free
40th Ave W	free	free	free	free	130	free	120	150	120	free
30th Ave W	free	free	free	free	110	free	120	120	120	free
AMP	free	free	free	free	110	free	120	120	120	free
24th Ave W	free	free	free	free	110	free	120	120	120	free

Figure 22: Existing Non-Holiday Weekday Cycle Lengths

3.1.4 Land Use Characteristics

The following subsections describe the land uses within the project area, the transit operations, and infrastructure that support the traffic signal network.

3.1.4.1 Existing Land Uses

The project corridors serve a mixture of land uses including office, commercial, retail, schools, a community college, and the Lynnwood Convention Center. SR 99 also provides a somewhat parallel route to I-5, and 196th St SW provides access to and from northbound and southbound I-5. The Lynnwood City Center project could potentially impact land use within the study area over the next 20 years. The goal of the project is to create a compact, intense and lively City Center that offers Lynnwood new opportunities for culture, commerce and habitation. The city center development area is shown in Figure 23 below.

Figure 24 shows the land use characteristics surrounding the project corridors.

Figure 23: Lynnwood City Center Development Area

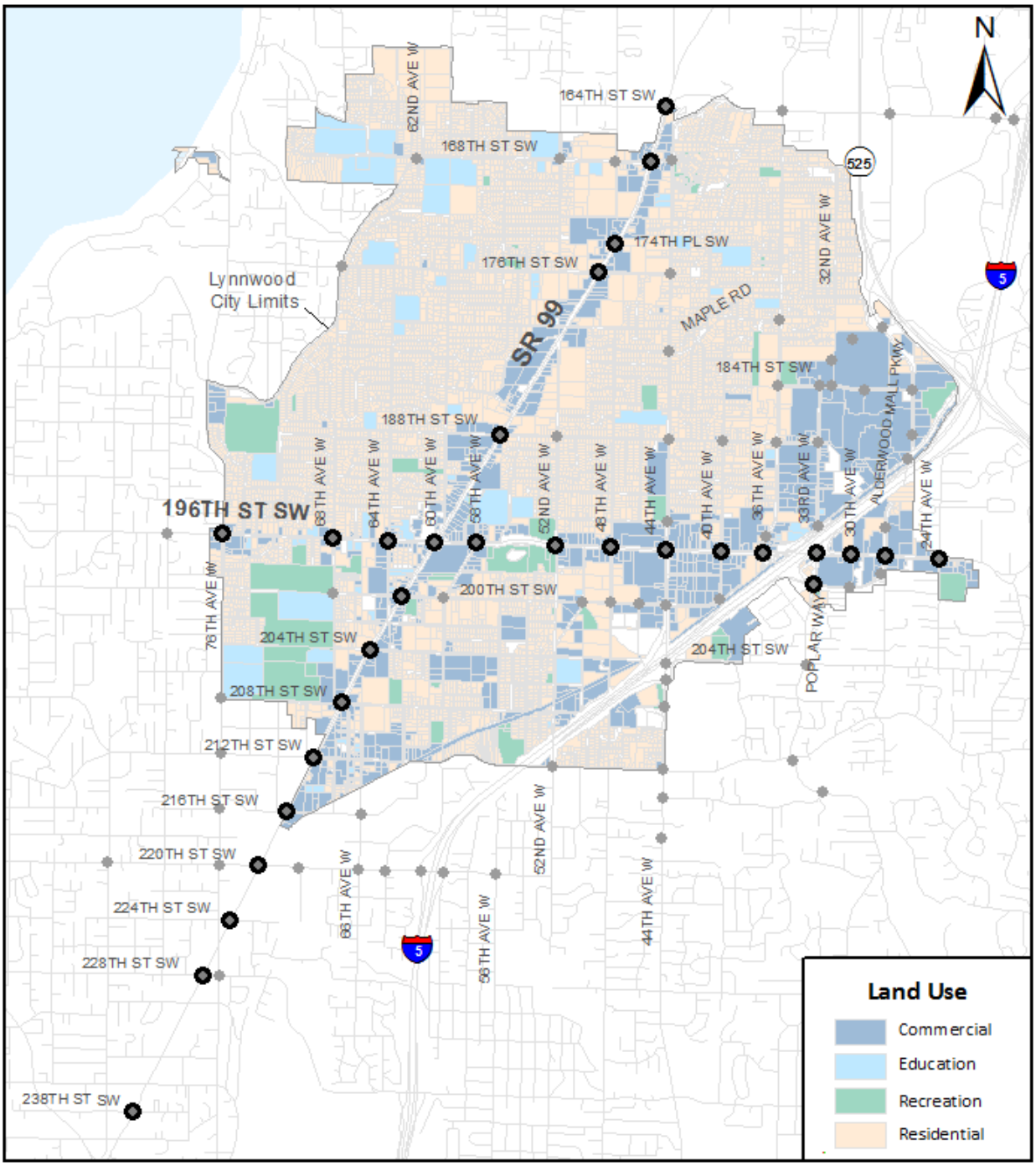

Figure 24: City of Lynnwood Land Use Map

3.1.4.2 Pedestrians and Public Transit

Community Transit's *Swift* bus rapid transit line runs on SR 99 between Everett and Aurora Village, and encompasses the entire SR 99 ASCT project corridor. *Swift* buses run both northbound and southbound every 12 minutes during daytime weekdays and every 20 minutes in the early morning, late evening, and

on Saturdays. TSP is used at every signal along the corridor. TSP would need to be maintained on the *Swift* route after the implementation of ASCT. Community Transit's route 101 also runs along SR 99 through the project corridor with weekday headways of about 30 minutes.

Community Transit's route 196 runs along the length of the 196th St SW project corridor between downtown Edmonds and Alderwood Mall with weekday headways of 30 minutes. Currently, the 196th St SW corridor contains TSP equipment, but it has not been activated. The ASCT system would need to be compatible with the existing TSP systems for future use.

Balancing pedestrian delay and vehicular delay on SR 99 is an important factor in choosing phasing and timing parameters. Due to the large roadway width of SR 99 (up to 115 feet at some intersections), pedestrian phases have a crossing time of up to 27 seconds, which drives the cycle length of the corridor. Other heavy pedestrian areas include intersections close to schools. The system will need to balance the need of pedestrian users and vehicular vehicle progression to provide the best travel environment for all users. Serving the pedestrians at each cycle may result in degradation of vehicular progression through the corridor, and should be considered by the ASCT system when selecting optimal times to serve this demand.

3.1.4.3 Existing Traffic Signal Infrastructure

Lynnwood has one of the most complete traffic signal systems in the region. Over the last 10 years, Lynnwood has gradually upgraded all of the traffic signals in the City to replace old span wire traffic signals and provide uniform detection. Below are some of the key features of Lynnwood's signal system:

- All but two traffic signals have a doublewide 332 cabinet (332D). The cabinet houses all the equipment for operating the traffic signal on one side of the cabinet and the network communication and ITS equipment on the other side.
- Most intersections have stop bar video detection on each approach. Most arterial approaches to an intersection have downstream video detection mounted on the mast arm and advanced video detection that is mounted on a luminaire arm that extends approximately 15' out over the roadway. The advanced camera is usually around 200' upstream of the intersection. See Figure 25 for the typical layout of the video detection. Inductance loops are used in a few locations. A complete list of all detection is provided in Figure 27.
- Every traffic signal controller communicates back to the traffic management center using Ethernet over fiber.
- Almost every traffic signal in the City has a dome CCTV camera located on one of the traffic signal luminaire arms. The CCTV video is brought back to the traffic management center in analog format over a dedicated fiber.
- The traffic signals, video detection system, emergency vehicle preemption, and uninterrupted power supply/battery back-up (UPS) are managed from a traffic management center (TMC) located at City Hall. The TMC has space for two operators plus office space for the City traffic engineer, Assistant City Traffic Engineer, lead signal technician and other signal technicians. Figure 26 shows a view of the TMC video screens and two operator stations.

- Current performance monitoring includes evaluating split times and throughput (volumes) and looking at programmed green versus actual green time.

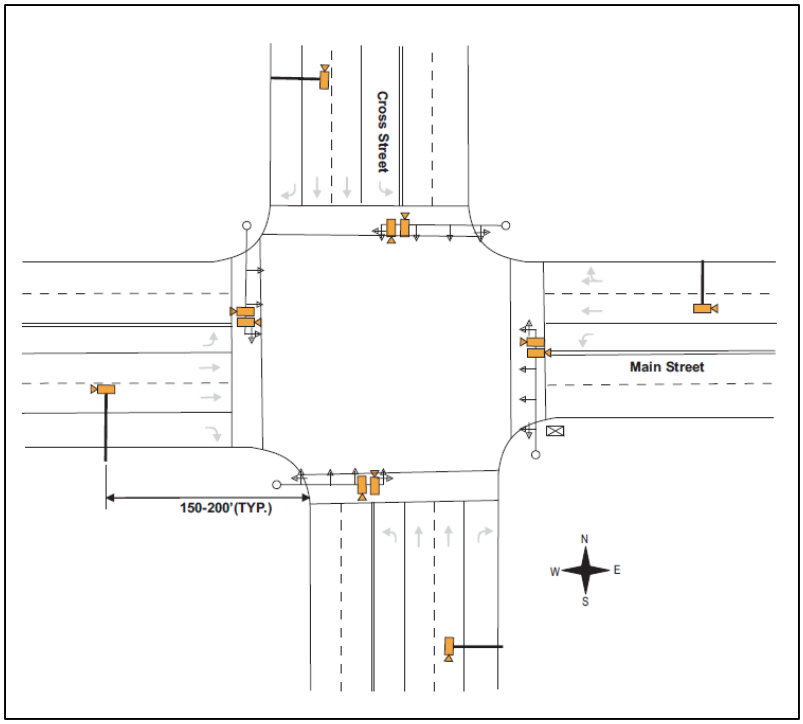

Figure 25: Typical Video Detection Placement

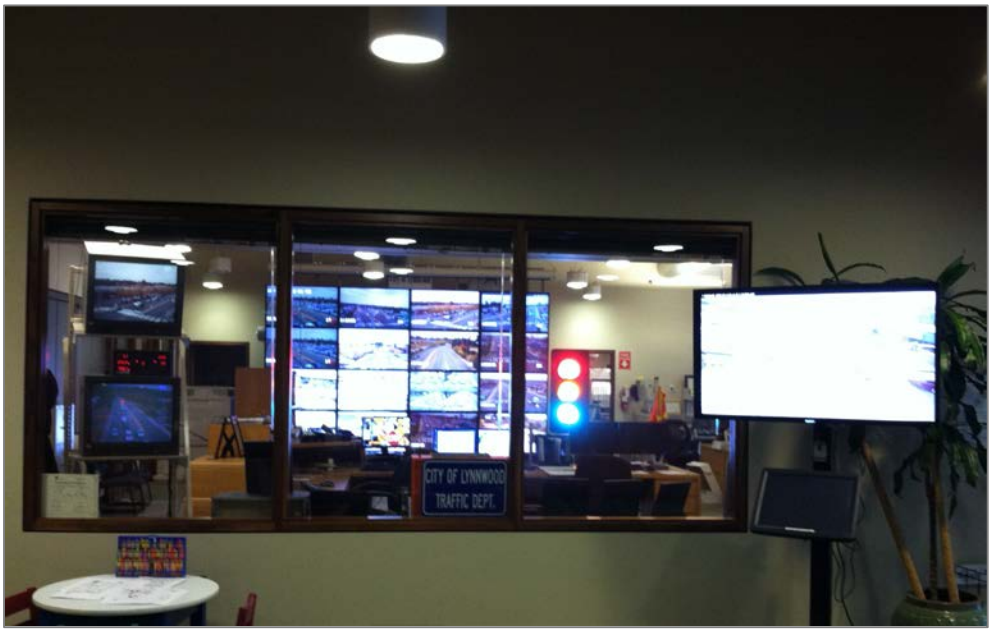

Figure 26: City of Lynnwood TMC

Location	NB			SB			EB			WB		
	Stop Bar	Adv.	Down-stream	Stop Bar	Adv.	Down-stream	Stop Bar	Adv.	Down-stream	Stop Bar	Adv.	Down-stream
SR 99 and 164th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Loops	None
SR 99 and 168th St SW	Video	Video	Video	Video	Video	Video	Video	Video	None	Video	Video	None
SR 99 and 174th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Loops	None
SR 99 and 176th St SW	Video	Video	Video	Video	Video	Video	Video	Video	None	Video	Video	None
SR 99 and 188th St SW	Video	Video	Video	Video	Video	Video	Video	Video	None	Video	Video	None
SR 99 and 196th St SW	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video
SR 99 and 200th St SW	Video	Video	Video	Video	Video	Video	Video	Video	None	Video	Video	None
SR 99 and 204th St SW	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future
SR 99 and 208th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Loops	None
SR 99 and 212th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Loops	None
SR 99 and 216th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Loops	None
SR 99 and 220th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Video	None
SR 99 and 224th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Loops	None
SR 99 and 228th St SW	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future
SR 99 and 238th St SW	Video	Video	Video	Video	Video	Video	Video	Loops	None	Video	Loops	None
196th St SW and 76th Ave W	Video	NA	None	Video	NA	None	Video	Loops	None	Video	Loops	None
196th St SW and 68th Ave W	Video	Loops	None	Video	NA	None	Video	Loops	None	Video	Loops	None
196th St SW and 64th Ave W	Video	NA	None	Video	NA	None	Video	NA	Video	Video	NA	Video
196th St SW and 58th Ave W	Video	None	None	Video	None	None	Video	Video	None	Video	Video	None
196th St SW and 52nd Ave W	-	-	-	Video	Loops	-	Video	Loops	Video	Video	Loops	Video
196th St SW and 48th Ave W	Video	Loops	None	Video	Loops	None	Video	Loops	Video	Video	Loops	Video
196th St SW and 44th Ave W	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video
196th St SW and 40th Ave W	Video	None	None	Video	None	None	Video	Loops	Video	Video	Loops	Video
196th St SW and 36th Ave W	-	-	-	Video	None	None	Video	None	Video	Video	None	Video
196th St SW and Poplar Way	Loops	Loops	None	-	-	-	Loops	Loops	None	Loops	Loops	None
196th St SW and 30th Ave W	Video	None	None	Video	None	None	Video	Loops	Video	Video	Loops	Video
196th St SW and AMP	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video	Video
196th St SW and 24th Ave W	Video	Loops	None	Video	None	None	Video	Loops	Video	Video	Loops	Video
AMP and Poplar Way	Loops	Loops	None	Loops	Loops	None	Loops	Loops	None	Loops	Loops	None

Figure 27: Detection Type by Location

3.2 Limitations of the Existing system

The following are the limitations identified for the existing signal system:

- The existing system cannot be reasonably programmed to address each of the typical changes to traffic volumes on each corridor, especially since conditions can vary greatly from one end of a corridor to the next. The result is that three to five time-of-day plans are prepared for the entire corridor or area of the City in an attempt to find programs that are the best fit for the average condition.
- The existing system cannot detect unexpected changes in traffic demand, such as increased volume in one direction of SR 99 due to a blocking incident on I-5. As a result, the congestion is greater than would be the case if the signal timing could automatically adjust to the unexpected conditions. This would also reduce the need for manual intervention by operators when the incident is brought to their attention.
- The existing system cannot adapt to heavy volumes near the Alderwood Mall during the busy holiday shopping season or fluctuations in traffic caused by weather. The data shown in sections 3.1.2.4 and 3.1.2.5 also showed a significant variation in volumes in different parts of the system between summer months and other times of the year. All of these varying conditions could be better managed through a signal system that could react when changes in volume occur.
- The existing system has no means of dealing with movements that experience excessive queuing without creating new coordinated timing plans and potentially adversely impacting other intersections on the corridor that aren't experiencing the same queuing issue.
- Cycle lengths on the corridor tend to increase as volumes get high, which has an adverse effect on pedestrians by potentially causing them to wait longer. There is little ability to reduce cycle lengths, or overall person delay, when forced to run only a few fixed time-of-day plans throughout the day.

3.3 Proposed Improvements to the System

3.3.1 Proposed Improvements

The following improvements are proposed to address the limitations noted in the previous section:

- Provide the ability to react quickly and automatically to changes in traffic conditions due to incidents, events and general fluctuations in traffic
- Provide the ability to adjust cycle lengths with the intent of keeping the cycle length as low as possible to support pedestrian movements
- Overcome the policy and technological boundaries that currently limit or prevent coordination of traffic signals under control of different jurisdictions
- More efficiently recover coordination of signals from an emergency vehicle preemption and/or transit signal priority event
- Improve the detection and management of queues within the network

- Improve the management of traffic demand on each corridor to allow for changes in signal groupings to address varying conditions in different parts of the City
- Keep signal timing current rather than letting its efficiency deteriorate between periodic signal re-timing efforts

3.3.2 Project ITS Architecture

The ITS Architecture for this project involves different agencies and stakeholders, transportation and communication sub-systems. The ITS Architecture is developed from the Puget Sound Regional Council ITS Architecture Turbo Architecture file. The agencies that are involved in this project are the Federal Highway Administration, WSDOT, Snohomish County, City of Lynnwood, City of Edmonds, City of Mountlake Terrace, Community Transit, University of Washington STAR Lab, road users and City of Lynnwood police and emergency management department. The interaction between the transportation elements and communication methods are illustrated in Figure 28.

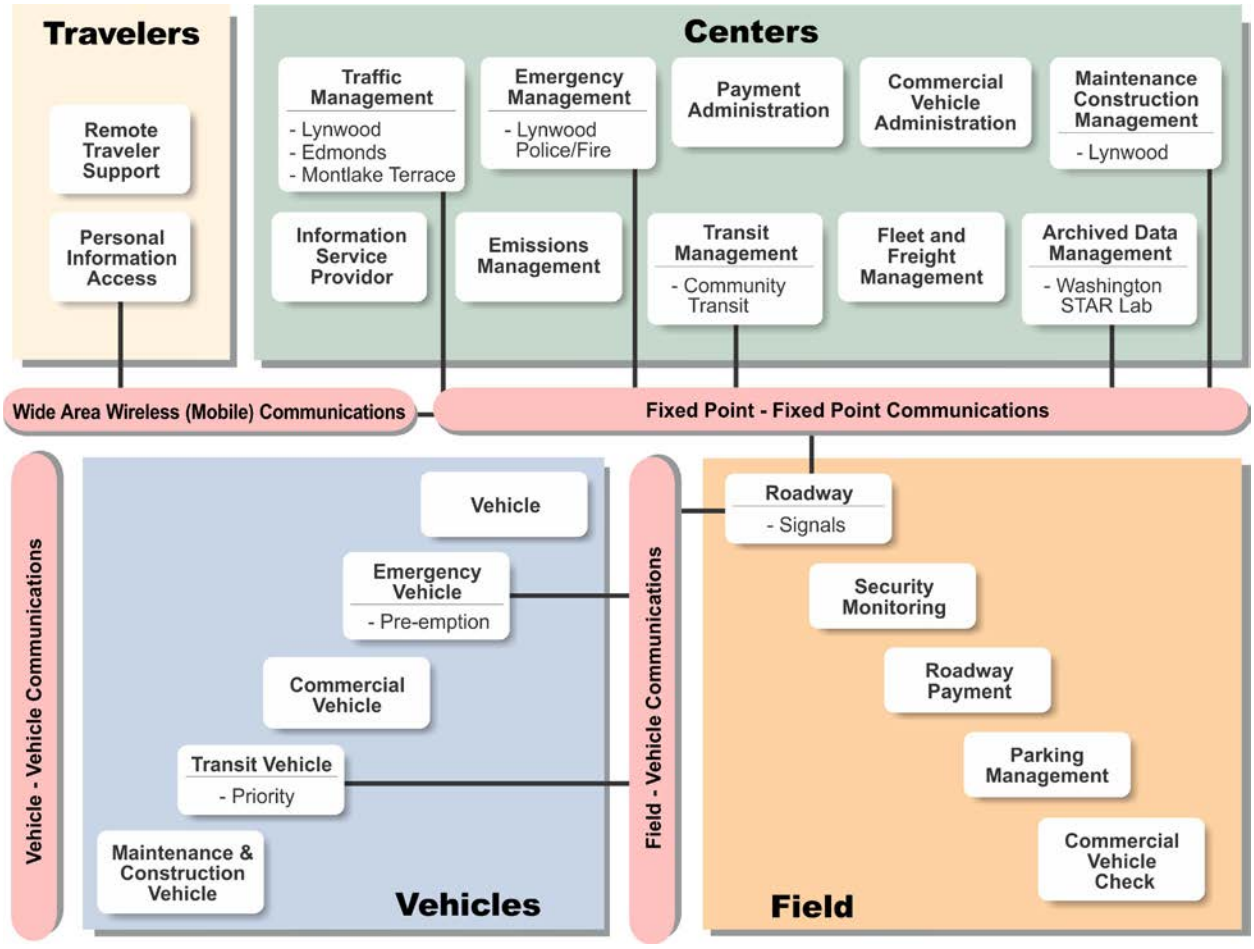

Figure 28 Lynnwood Subsystem Interaction

Changes will be required to the existing Regional ITS Architecture to accommodate this project including:

- Flows to and between additional traffic management centers (TMCs)
- Flows from Community Transit to new field devices (Lynnwood, Edmonds, and Mountlake Terrace signals) for TSP

Security for ITS systems is represented in two forms through the National ITS Architectures, "Securing ITS" and "ITS Security Areas." Securing ITS is defined as the security portion of all subsystems included in the project. ITS Security Areas are additional functions ITS can support to maintain a secure surface transportation system. Deployment of the adaptive system does create the need for addressing an ITS Security Area. Security of the adaptive central control is critical to the safe performance of the signal system. The requirements for security of the central system are discussed further in Section 4.4 of this document.

3.4 Vision, Goals and Objectives for the Proposed System

3.4.1 Vision

The vision of the ASCT system is to provide an advanced traffic control system that supports the efficient movement of motor vehicles, low delay for pedestrians and bicycles, improved safety, and reliable travel times for transit through the ability to actively adjust signal operations in real-time based on changes in traffic flow and volume. This will serve the region by maximizing the capacity of the existing roadway system and reducing the duration of congestion when it exceeds capacity on the system.

3.4.2 Goals

The goals of the ASCT system are:

- Improved safety
- Support vehicle, pedestrian, bicycle, and transit traffic mobility
- Provide effective and efficient pedestrian service near high pedestrian areas and transit corridors
- Support reasonable and reliable travel times for transit and general purpose vehicles through the project corridors
- Maximize efficient use of capacity of the existing and future roadway
- Support interoperability between agencies
- Support data sharing

3.4.3 User Objectives

The following is a summary of the objectives that support each of the defined goals:

Support vehicle, pedestrian, bicycle, and transit traffic mobility:

- Be capable of supporting transit signal priority operations for buses
- Enable the capabilities of the traffic signal controllers to manage varying traffic conditions

Provide effective and efficient pedestrian service near high pedestrian areas and transit corridors:

- Allow for variable cycle lengths to support high pedestrian activity

Support reasonable and reliable travel times for transit and general purpose vehicles through the project corridors:

- Continually adjust traffic signal operations to match changing conditions in real-time in each unique part of the City
- Increase the number of vehicles arriving on green
- Manage spillover queues

Maximize efficient use of capacity of the existing and future roadway:

- Improve progression of traffic through real-time optimization of arterial corridors
- Make more efficient use of green time for all movements at each intersection

Support interoperability between agencies:

- Maintain existing direct access capabilities to signal system from neighboring agencies and provide remote or direct access to any new partners in the system
- Adhere to applicable traffic signal and ITS design standards

Support data sharing:

- Maintain connection to University of Washington STAR Lab for access to signal system data
- Provide access to signal priority data for review by Community Transit

3.5 Strategies to be Applied by the Improved System

Adding ASCT to the existing signal system must result in the ability to accommodate multiple operational strategies to support varying conditions throughout the project area. The two arterial corridors in the project area, SR 99 and 196th St SW, will need the ability to act like a “pipeline” during the AM and PM peak periods that flushes traffic down the corridor as efficiently as possible. This system will need the ability to support the heavy directional traffic in the AM peak and the heavy bi-directional traffic in the PM peak.

Portions of 196th St SW near the major retail core of Lynnwood and the intersections around the mall will also need the improved system to closely monitor distribution of phase time on all approaches because of the grid-like configuration of the roadway network in these and other areas and the potential

for excessive queuing. It will be important to continue to maintain effective progression on the arterial corridors in these areas, but balancing the available green time will be equally as important.

In all areas, the ability to jump into a “pipeline” strategy quickly will be critical for managing traffic during a freeway incident. The system must be able to recognize a major increase of volume in one direction and quickly change the strategy to focus on the movement of the detouring traffic.

3.6 Alternative Non-Adaptive Strategies Considered

3.6.1 Traffic Responsive Pattern Selection (TRPS)

TRPS has been considered, but is not a viable solution to the project needs for three primary reasons:

1. Lack of compatibility with the existing signal system
2. Need for substantial time and effort to develop and test the necessary TRPS patterns (estimated at 10-15 patterns)
3. Need for substantial time to maintain and monitor the system

Although an adaptive system will require traffic engineering support, the level of support is anticipated to be significantly less. The operator will need to observe traffic and provide input to the system, but it won’t require the intense modeling efforts to develop the initial timings and to test potential changes. In addition, an adaptive system can be selected that will be compatible with the existing signal system.

3.6.2 Complex Coordination Features

The following features are currently used in coordination patterns and will need to remain available in fallback operation should the ASCT fail:

- Multiple (repeat) phases or phase reservice
- Variable phase sequence
- Detector switching
- Coordinate different phases at different times
- Coordinate turning movement phases
- Early release of hold
- Late phase introduction
- Stop-in-walk
- Dynamic max
- Transit signal priority
- Floating force-offs
- Offset correction transition features
- Coordination recovery after emergency vehicle preemption, transit signal priority
- Coordination recovery at locations where pedestrian crossing times exceed available vehicle green time

The following features have not been used in the current coordination patterns. While they have been considered, the City did not find them suitable, given the existing traffic conditions.

- Double cycle or half the typical signal cycle length
- Omit phase under some circumstances
- Hold the position of uncoordinated phases

CHAPTER 4: OPERATIONAL NEEDS

This chapter describes the operational needs that should be satisfied by the proposed ASCT system. Each of following sections describes operational needs that must be met by the future system to achieve the goals of this project. Each of these needs will be satisfied by compliance with one or more system requirements. The needs are defined below for adaptive strategies, network characteristics, coordination across boundaries, security, pedestrians, non-adaptive situations, system responsiveness, complex coordination and controller features, monitoring and control, performance reporting, failure notification, preemption and priority, failure and fallback, constraints, training and support, external interfaces, and maintenance.

4.1 Adaptive Strategies

The system operator needs the ability to implement different strategies individually or in combination to suit different prevailing traffic conditions. These strategies include:

- Maximize vehicle throughput on coordinated routes
- Provide smooth flow along coordinated routes
- Distribute phase times in an equitable fashion
- Manage the lengths of vehicle queues at signalized intersections
- Manage the locations of queues within the network
- Manage a preemption event efficiently through one or more signalized intersections
- Optimize operation with a minimum of phase failures at an isolated intersection
- Adjust the grouping of signals to provide the operational scenario that best fits unique areas of the project
- Change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions
- Detect repeated phase failures and control signal timing to prevent phase failures from building queues
- Minimize the chance that a queue forms at a specified location
- Modify the sequence of phases to support the various operational strategies
- Fix the sequence of phases at any specified location (e.g., the operator may need to fix the phase order at locations where a lagging left turn provides unsafe operations)

- Designate the coordinated route based on traffic conditions and the selected operational strategy
- Balance cycle length with pedestrian demand in high pedestrian areas
- Manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
- Set signal timing parameters (such as minimum green, maximum green and extension time) to comply with agency policies.

4.2 Network Characteristics

The ASCT system will consist of an initial deployment at up to 29 signals on SR 99 and 196th St SW. Future expansion to traffic signals around the Alderwood Mall could result in an additional intersections as seen in Figure 1. The system needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.

4.3 Coordination Across Boundaries

The system needs to adaptively control signals that are currently owned and operated by WSDOT, but located in Lynnwood. There are signals within the SR 99 corridor that are owned by Edmonds, but through an existing agreement, the City of Lynnwood operates the Edmonds intersections in the project area as seen in Figure 1. It is assumed this relationship will continue.

Since the SR 99 corridor and 196th St SW corridor bisect, the system will need the ability to maintain adaptive coordination on the two crossing routes simultaneously. Future crossing adaptive corridors will be considered on 220th St SW and 44th Ave W in Mountlake Terrace, and in the area around the Alderwood Mall.

4.4 Security

Based on their roles and responsibilities traffic engineering, maintenance staff and partners from other agencies will be assigned privileges for access to equipment and software. This will allow them to control, view, monitor, and analyze the operation of the system as appropriate.

4.5 Queuing Interactions

The traffic engineer will need to detect queues within the system's boundaries and modify the ASCT operation to accommodate the demand. This could include identifying areas within the system that can support excessive queuing better than others. For example, there are long segments of SR 99 where queues from one signal will not impact another traffic signal or accesses to businesses. There are also locations within the project area where additional effort should be made to minimize queues, such as roadways departing shopping centers where stacking of cars will lead to other problems.

One specific area where queuing needs to be monitored closely is at the I-5 interchange intersections. Queues from the signals shall not extend onto the freeway due to preventable means, such as inappropriate signal timing.

4.6 Pedestrians

Different pedestrian management strategies will be required depending on the area of the project and time-of-day. Minimizing pedestrian wait times, especially within the *Swift* SR 99 corridor, is important for access to transit.

In the early morning before most retail is open, the system needs the ability to accommodate infrequent pedestrian operation and then adaptively recover. From late morning through the evening commute, many of the project intersections need to accommodate frequent pedestrian operation into routine adaptive operation.

4.7 Non-Adaptive Situations

It is anticipated that adaptive control shall operate at all times. The user should have the ability to disable adaptive operations and revert to base time-of-day timings in the event of a malfunction in the adaptive system that impacts more than one or two intersections. The user should also have the ability to override adaptive operations and have manual control when deemed necessary. An example may include during incidents that require one or more approach to be closed.

4.8 System Responsiveness

The responsiveness of the system shall be user programmable. The system operator needs the ability to limit the frequency of cycle changes, if necessary, and also provide limits for the minimum and maximum cycle length. The system should monitor traffic and adjust in real-time to changes in traffic or queuing.

4.9 Complex coordination and controller features

The following advanced controller features shall be maintained by running adaptive operations:

- Service a phase more than once per cycle
- Operate at least four overlap phases
- Operate four rings, 16 phases, and up to four phases per ring (Likely a “desirable” requirement)
- Permit different phase sequences under different traffic conditions
- Prevent one or more phases from being skipped under certain traffic conditions or signal states (the existing video system will automatically put the detector in recall if the detector fails)
- Ability to receive calls from a minimum of 128 detectors.

Accommodate the following custom features used by this agency:

- Allow any phase to be designated as the coordinated phase
- Allow the operator to specify which phase receives unused time from a preceding phase
- Allow the controller to respond independently to individual lanes of an approach. This may be implemented in the signal controller using extension/passage timers, which may be assignable

to each vehicle detector input channel. This may allow the adaptive operation to be based on data from a specific detector or by excluding specific detectors.

- Allow the coordinated phase to terminate early under prescribed traffic conditions
- Allow flexible timing of non-coordinated phases (such as late start of a phase) while maintaining coordination
- Protected/permissive phasing and alternate left turn phase sequences
- Service side streets and pedestrian phases at minor locations more often than at adjacent signals when this can be done without compromising the quality of the coordination (e.g., double-cycle, mid-block pedestrian crossing signals)
- Use negative pedestrian phasing to prevent an overlap conflicting with a pedestrian walk/don't walk
- Adjust offsets based on changes of mid-block entry queuing at downstream intersection
- Allow flashing yellow arrow operation

4.10 Monitoring and Control

The system users need to be able to monitor and control all required features of adaptive operation from the following locations:

- City of Lynnwood TMC: 19100 44th Ave W, Lynnwood, WA 98036
- Lynnwood Operations & Maintenance Center: 20525 60th Ave W, Lynnwood, WA 98036
- City of Edmonds City Hall: 121 5th Ave N, Edmonds, WA 98020
- City of Mountlake Terrace Public Works Office: 6204 215th St SW, Mountlake Terrace, WA 98043
- With a laptop from any controller cabinet or City facility on the fiber optic network
- Through VPN access into City's traffic signal system network

The operator needs access to the database management, monitoring and reporting features, functions of the signal controllers, and any related signal management system from the access points defined for those system components. The University of Washington STAR Lab will need to continue to be able to collect performance data from the existing central traffic signal system.

Communication to each remote building, partner agency and traffic signal controller cabinet is on single mode fiber. The STAR Lab communication is through a VPN connection to the City of Lynnwood signal system server.

4.11 Performance Reporting

The following performance reporting is required for the future system:

- The system needs to interface with the existing ATMS.now software to maintain data flow into existing reporting available in the ATMS.now system
- The system needs to store and report data used to calculate signal timing and have the data available for subsequent analysis

- The system operator needs to store and report data that can be used to measure traffic performance under adaptive control
- The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system and export selected data in Excel or CSV format
- The system operator needs to be able to report the exact state of signal timing and input data for a specified period, to allow historical analysis of the system operation
- The system needs the ability to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions

4.12 Failure Notification

Failure events associated with the adaptive system shall be reported to maintenance and operations staff through texts or e-mail, depending on user-defined parameters. All failures should be logged.

4.13 Preemption and Priority

The system needs to accommodate emergency vehicle preemption. The system shall assess queues following a preempt event and determine the quickest means of recovery and return to management of platooning traffic. The system should be able to actively adjust between long-way or short-way offset correction.

The system needs to support transit signal priority (TSP) operations on at least four transit movements at an intersection. TSP shall interface with the system locally in the traffic signal controller. TSP shall operate without taking the controller out of coordination other than truncation below pedestrian minimum time. TSP will be accommodated by using green time extension for active phases, servicing green time early, or by serving a dedicated transit phase.

4.14 Failure and Fallback

In the event of equipment, communications, and software failure, the system needs to fall back to pre-defined time-of-day plans without causing disruption to traffic flow. Use of alternate detectors or historic data to maintain adaptive operations during a failure is also a desirable feature.

4.15 Constraints

The chosen ASCT system must use the existing controllers and local Apogee software and be able to interface with the ATMS.now central software. Significant investment has been made in these components and all users of the system have become familiar with the software. The system must also use the existing cabinets and communications network.

The City would prefer that the chosen ASCT system be able to use the existing video detection since all equipment is already in place at each intersection. However, the City would be open to replace the detection equipment if an appropriate ASCT system that meets all other operational needs and requirements requires new detection equipment. One constraint of new video detection is that the cameras must be infrared to have the ability to see through fog. Although the City would be open to

replace video detection, the project has a limited budget so the potential procurement of new equipment will need to be closely evaluated.

4.16 Training and Support

The City of Lynnwood needs all staff involved in operation and maintenance to receive appropriate training. The City needs the system to fulfill all requirements for the life of the system. Therefore, the City needs the system vendor to continue support of the system to repair faults that are not defects in materials and workmanship. It is anticipated the City will contract with the vendor to provide support of the system for its estimated life (minimum of 10 years). All requirements of the system shall be maintained for this defined life. The City of Lynnwood may require a source code escrow agreement with the vendor. The City Traffic Engineer and other support staff will be responsible for all maintenance of the signal system hardware in City Hall. If the City Traffic Engineer is not available, the system vendor shall coordinate with the Assistant City Traffic Engineer.

Maintenance of detection equipment required for adaptive operations will be performed by City of Lynnwood signal maintenance staff for City of Lynnwood and WSDOT intersections. City of Edmonds staff would be involved in maintenance of video detection hardware at their intersections.

4.17 External Interfaces

There are no existing external interfaces that will impact adaptive operations. However, the University of Washington STAR Lab uses a clone server of the Naztec ATMS.now central signal system and the Traficon detection and video data, which needs to remain intact.

4.18 Maintenance

The City needs all applicable equipment to be readily accessible. The City needs to have 10% spares (3 units) for any cabinet hardware required and detailed user manuals that describe steps for troubleshooting system malfunctions.

CHAPTER 5: ENVISIONED ADAPTIVE SYSTEM OVERVIEW

This section describes the envisioned adaptive system for the City of Lynnwood. The envisioned adaptive system is defined by the size and grouping of intersections, operational objectives, fallback operation, crossing routes and adjacent systems, operator access, and complex coordination and controller operation.

5.1 Size and Grouping

The City of Lynnwood plans to adaptively control approximately 29 intersections within two corridors for the current project. The system may be expanded in the future to support control of an additional 10 to 20 intersections around Alderwood Mall. The system shall define the grouping of intersections based on the measured conditions on the corridors or around the mall. A group of intersections may be comprised of simply one intersection, or up to the total number of intersections that are sufficiently

close to warrant coordination under the prevailing traffic conditions. During some traffic conditions, there may be separate groups of intersections operating with different characteristics (e.g., different cycle lengths, some coordinated some not, offsets in different directions).

5.2 Operational Objectives

The objective of the coordination will be to provide for smooth flow of traffic along the two project corridors and reduce delay at the intersections around Alderwood Mall. The corridor progression needs will change throughout the day and vary based on event conditions. Typical morning progression will focus on flushing traffic through the corridor in the peak commute direction. Once the many retail centers in Lynnwood are open, the focus will shift to providing the optimal two-way progression on the two study corridors.

During an incident on the freeway, the objective of the coordination will change to maximize throughput on the route that best gets vehicles through town and back to the freeway downstream of the incident. This may involve a tradeoff that increases delay to cross streets and turning movements in order to maximize the green time provided to coordinated traffic flows.

Around the mall and in the retail core of Lynnwood, the objective of the coordination will be to control traffic in a manner that equitably serves the adjacent land uses. The delays experienced by the traffic entering and leaving the coordinated route will be balanced with the delays and stops experienced by other traffic traveling along the route.

A secondary objective of the coordination will be to manage the lengths of queues stored at critical locations within the coordinated group so that long queues do not block upstream intersections or otherwise reduce the capacity available during the green phases. This will involve controlling phase lengths so that the size of platoons entering a downstream block does not exceed the storage length if the platoon will be stopped. It will also involve control of offsets and phase lengths so that queues may be stored in locations where they will not adversely affect capacity of the system.

The system will have the ability to help recognize when different strategies for traffic management are needed. The system operator shall also have the ability to modify how the system makes these decisions.

The operator will have the ability to define groups of intersections to set operational objectives; however, the desire is for the system to do this automatically.

During moderate to light traffic conditions, protected left turns may be omitted. Thresholds for managing protected lefts shall be defined by the system operator.

Within these operational objectives, the ASCT system will change its operation to accommodate the rise and fall of volumes through the peaks and the changing patterns of flow throughout the day and week. However, there is also a stochastic element to traffic in the short term, with the number of arrivals for a phase varying from cycle-to-cycle, and pedestrians not being present on all phases in all cycles. It is

therefore desirable for the system to have some local tactical control. While vehicle-actuated coordination typically allows phases to run longer or shorter from cycle-to-cycle to match the actual number of vehicles using the phase, the system will also allow the operator to decide where the unused time will be used. If a phase is to be skipped, the operator can specify that the spare time will be added to the existing phase, the following phase or the next coordinated phase.

At an isolated intersection with widely varying traffic patterns and a high degree of saturation during peak times, the system will calculate the optimum cycle length, phase sequence and phase times in real-time to match the changing traffic conditions.

5.3 Fallback Operation

The system will have a fallback state that allows coordination using a common cycle length for all signals within a coordinated group and the use of up to eight coordinated plans that are activated by time-of-day.

The system will also have a fallback state that allows individual intersections to operate in a vehicle-actuated, isolated mode in the event of failures of the adaptive processor software or hardware, detectors or communication.

Before falling back to pre-defined timings, the system will attempt to maintain adaptive progression by allowing one or more intersections to be operated from a critical intersection. Failure of a loop will be resolved by using historic detector data to manage operations. There will be a user-defined limit on the number of failed detectors that can be managed by one intersection. After this threshold is met, the controller will revert to a user-defined recall plan.

5.4 Crossing Routes and Adjacent Systems

A coordinated group will be able to include more than one coordinated route, such as two crossing arterials. The system will be able to maintain coordination along both roads. This would include the two project corridors, SR 99 and 196th St SW, as well as future coordinated corridors that cross through the project corridors, and operations in the grid-like area around Alderwood Mall.

5.5 Operator Access

Traffic engineering and maintenance staff from Lynnwood and partner agencies will be assigned different levels of authority and access to equipment for which they are authorized, based on their roles and responsibilities. This will allow them to control, view, monitor, and analyze the operation of the system as appropriate.

5.6 Complex coordination and controller operation

The agency will use the following complex coordination and controller features:

- Allow the operator to specify which phase receives unused time from a preceding phase

- Allow the controller to respond independently to individual lanes of an approach. This may be implemented in the signal controller using extension/passage timers, which may be assignable to each vehicle detector input channel. This may allow the adaptive operation to be based on data from a specific detector, or by excluding specific detectors.
- Allow flexible timing of non-coordinated phases (such as late start of a phase) while maintaining coordination
- Use flashing yellow arrow to control permissive left turns and right turns
    - Ability to hold a flashing yellow arrow until a conflicting pedestrian movement clears
    - Ability to hold a flashing yellow arrow until adequate gaps in traffic are detected
    - Ability to switch to protected only operations based on volume inputs
- The ability to repeat a phase, such as running a left turn phase before and after its opposing through movement
- Provision for the required number of rings, phases, phases per ring, and overlap phases
- The ability to operate different phase sequences based on different traffic conditions or by time-of-day
- The ability to omit a phase under some traffic conditions or based on external input to allow a shorter cycle length to operate, or to provide additional time to other phases
- The ability to use flashing yellow for protected/permissive operations, protected-only and permissive-only based on external inputs or time-of-day
- The ability to maintain coordination with external movements by preventing phases from being skipped, or by omitting phases, based on time-of-day, external input or when certain phase sequences are in operation
- The agency will permit phases or overlaps by time-of-day schedule or external input
- Allow any phase to be designated as the coordinated phase
- Allow the coordinated phase to terminate early under prescribed traffic conditions
- The ability to introduce a non-coordinated phase later than its normal starting point within a cycle, if it can be served with minimum green within the remaining time available
- Protected/permissive phasing and alternate left turn phase sequences
- Support for flashing yellow protected/permissive and permissive only phasing
- The agency may operate external devices using discrete signal outputs from the ASCT including occupancy on a detector, cycle length, and time-of-day (user selects desired features)
- Use negative pedestrian phasing to prevent an overlap conflicting with a pedestrian walk/don't walk

CHAPTER 6: ADAPTIVE OPERATIONAL ENVIRONMENT

The system will primarily be operated and monitored by City of Lynnwood staff from the Lynnwood TMC. Remote access will be available from the maintenance shop, in the field, or through a VPN connection to the system[1].

Partner agencies such as the cities of Edmonds and Mountlake Terrace, WSDOT and Community Transit will have access to the system for their defined needs. Edmonds, Mountlake Terrace and WSDOT should be able to collect data and view timing parameters. Edmonds and Mountlake Terrace need to be able to maintain the control of their respective signals. Community Transit will be provided access to retrieve historic priority operation data for evaluating the functionality of the TSP.

The central server equipment will be housed at the City of Lynnwood City Hall data center. The central server will be a standard platform that meets the minimum requirements of the selected ASCT and able to be replaced independently from the software.

The system will use existing 2070 traffic controllers and Kar-Gor video detection equipment. The video detection equipment will remain in the current configuration although the size and location of the detector zones could be modified to meet the needs of the selected system.

Initial setup of the adaptive system will be performed by the system vendor. The City and partner agencies shall receive training on how to perform this setup so they have the option to add intersections in the future or make changes to timings for intersections in the initial deployment.

All complaints received for intersections on the adaptive system will be directed to the local jurisdiction. Partner agencies will coordinate with the City of Lynnwood on issues specific to the adaptive system.

Maintenance of all field equipment will follow current maintenance and operation agreements with partner agencies. The vendor will not be responsible for maintenance unless the issue requires replacement of failed equipment that is still under warranty.

The agency expects to operate this system using the latest software for a period of 10 years.

CHAPTER 7: ADAPTIVE SUPPORT ENVIRONMENT

7.1 Institutions and Stakeholders

Existing stakeholders of the traffic signal system include:

- City of Lynnwood

[1] The maintenance shop has a client workstation with direct access through fiber. Technicians and engineers can plug into cabinet switches with client laptops to access from field locations. Remote access to a shared client workstation is provided via https and signed certificate to an IP-KVM.

- Federal Highway Administration
- WSDOT
- Community Transit
- City of Edmonds
- City of Mountlake Terrace
- Lynnwood Fire Department
- Lynnwood Police Department

7.2 Facilities

The existing City of Lynnwood TMC is located at Lynnwood City Hall, 19100 44th Ave W, Lynnwood, WA 98036. Any required central applications for adaptive shall be able to run on a server provided by the City. The City traffic engineer and other support staff will be responsible for all maintenance of the signal system hardware in City Hall.

7.3 System Architecture Constraints

The adaptive processor/server will be protected within the City's firewalls. The City's Traffic Engineer will provide resources, equipment and system management so that operators will have appropriate access to the system from within the City's LAN via direct access through fiber, from field locations using direct connections to the cabinet switches, and from remote locations via client workstations as described within this document. The Assistant City Traffic Engineer will cover for the City Traffic Engineer when he/she is unavailable.

The communications media available for use by the system will be the City of Lynnwood's fiber/Ethernet network. The adaptive system will operate within the local ITS Architecture of the City

7.4 Utilities

There is no required coordination with other utility groups within Lynnwood.

7.5 Equipment

Any additional test equipment required to support the adaptive system needs to be identified by the ASCT vendor. The vendor will provide this testing hardware or software as part of their installation contract.

7.6 Software

The City of Lynnwood Traffic Engineer and the Assistant Traffic Engineer will be the administrators for the signal system software. This staff will be responsible for managing the number of users and associated licenses as well as be responsible for processing renewals of software assurance contracts, if needed.

7.7 Personnel

The signal system will be operated by the City of Lynnwood traffic engineers and their two maintenance technicians. This staff will be available during normal business hours, but can respond to alarms outside of business hours, depending on the severity. The system chosen shall be able to be supported by existing staff.

7.8 Operating Procedures

City of Lynnwood signal operation staff will be responsible for backing up databases on a regular basis.

7.9 Maintenance

Maintenance will be performed as described in section 7.8.

CHAPTER 8: OPERATIONAL SCENARIOS

8.1 Overview

The following operational scenarios describe how the system is expected to operate under various conditions. The proposed ASCT system is expected to be able to manage the following operational scenarios and issues envisioned for both the current and future project locations. Scenarios are described for the following operational conditions:

- Typical heavy congested conditions (defined as volume-to-capacity of close to 1.0)
- Typical heavy uncongested conditions (defined as volume-to-capacity between 0.75 and 0.95)
- Typical light traffic conditions (defined as volume-to-capacity of less than 0.50)
- Typical holiday traffic conditions
- I-5 incidents
- Signal preemption
- Transit signal priority and emergency vehicle conditions
- Fault conditions

8.2 Typical Heavy Congested Conditions

8.2.1 Traffic Conditions

During the PM peak, traffic is often congested on some parts of the project corridors. On 196th St SW, congestion typically occurs between 36th Ave W and 48th Ave W. Vehicles turning onto 196th St SW from 44th Ave W are occasionally unable to turn during their green time due to queues backed up from adjacent signals. SR 99 experiences long queues in the northbound direction, especially south of 196th St SW during the PM peak. Queues often stretch back to the upstream intersection, which limits the ability for vehicles to progress between multiple intersections without stopping.

8.2.2 Operational Objectives

The City of Lynnwood's objective during the period of heavy congestion is to try and clear queues in one cycle and create progression between intersections. Distribution of green time will be important at minor intersections that are not driving the overall cycle length for these corridors.

Queuing on freeway-off ramps at the east end of 196th St SW needs to be avoided as a top priority during these heavily congested periods. Achieving this goal will require creating space on the arterials to store the vehicles.

8.2.3 Coordination and Signal Timing Strategies

Coordination during these events will require the system to manage a careful balance of creating the green-band opportunities that promote moving traffic, while managing queues in turn pockets and on side streets. Side street queuing can be tolerated in locations where it doesn't impact adjacent signals, emergency access, transit operations or private property. Queuing in northbound or southbound left turn or right turn pockets that could potentially spill into an adjacent through lane must be avoided.

Queuing on freeway off-ramps shall be monitored based on any detector inputs available and the frequency of force-offs. The system will need to balance time allocated to these movements to ensure traffic is not backing up onto the freeway mainline. In the event that queued vehicles reach a particular detector on the ramp, the system shall be capable of terminating other vehicle phases, serve the ramp phase, and then transition to appropriate adaptive offset. Ramp queue flushing parameters shall allow operators to limit the number of times with a specific period or number of cycles when a ramp queue can be flushed.

8.2.4 Summary of Operation

The signal system will monitor volumes and arrival of platoons on the corridor and actively adjust cycle lengths, splits and offsets to manage the demand and progression of traffic. As traffic reaches saturation in the peak travel direction(s), the system will need to start prioritizing these movements in an attempt to keep traffic moving in the primary direction. Queuing will be monitored on critical movements defined by the user to assure the emphasis on progressing the mainline traffic is not having an unacceptable adverse effect on other movements.

8.3 Typical Heavy Uncongested Conditions

8.3.1 Traffic Conditions

Heavy, uncongested traffic is experienced throughout most of the project area after 12 PM and continuing until 8 PM. The southbound peak traffic on SR 99 can often reach a congested state where queues do not clear every cycle, but most days are in the heavy, but uncongested state.

8.3.2 Operational Objectives

Maintaining progression during these periods is important to reduce stops and maintain reliability for transit. More emphasis can be provided to reduce queuing as well, when the mainline is not

oversaturated. A secondary objective will be to get cycle lengths as low as possible to reduce the wait time for pedestrians.

8.3.3 Coordination and Signal Timing Strategies

The coordination strategy will be very similar to the congested strategy. Moving platoons of traffic is critical, but managing queues will be of equal importance. An attempt shall be made to assure queues at all intersections clear in one cycle. Cycle lengths will be kept low to help manage queuing and promote pedestrian activity.

8.3.4 Summary of Operation

The signal system will monitor volumes and arrival of platoons on the corridor and actively adjust cycle lengths, splits and offsets to manage the demand and progression of traffic. Force-offs will be monitored on all approaches to assure each are receiving adequate time to clear queues. Queue detection may be needed in locations that have recurring problems. Equal emphasis will be given to clearing queued traffic and maintaining progression.

8.4 Typical Light Traffic Conditions

8.4.1 Traffic Conditions

Light conditions are defined as the times during the day where most intersections are operating at level-of-service C or better. There are no queuing issues and some phases are often skipped because of no demand. Light conditions are typically experienced in the off-peak direction during the AM peak, prior to noon on most arterials, and after 8 PM. Weekends before 10 AM and after 6 PM also experience light traffic.

8.4.2 Operational Objectives

The objective during this period is to continue promoting progression along major arterials, but keeping wait times on side streets and protected turn movements low. Protected left turns could be turned off during this period where protected-permissive signals are provided. The operator shall also have the ability to set a volume threshold that would trigger groups of signals to run free.

8.4.3 Coordination and Signal Timing Strategies

The coordination approach for this condition is to provide progression along the arterial, maximizing bandwidth while providing two-way coordination. The timing strategies applied to do this are:

- At each intersection, provide sufficient time to serve all turning and side street traffic without phase failures
- At each intersection, select phase times (or offsets) that provide a smooth flow along the arterial in both directions
- At intersections with protected-permissive left turns, omit protected turning phases to minimize the impact of occasional turning vehicles on other traffic

- At each intersection, select phase times that will accommodate occasional use of pedestrian phases
- Keep cycle lengths low to reduce wait times

8.4.4 Summary of Operation

The adaptive system will continue to promote progression, while working to reduce wait times for pedestrians and side streets and assure that all phases clear in one cycle. Once volumes reduce below a user-defined level, the adaptive system will shut off and the traffic signals will run free.

8.5 Typical Holiday Traffic Conditions

8.5.1 Traffic Conditions

As shown in Figure 29, local streets near the Alderwood Mall area become congested during the holiday shopping season.

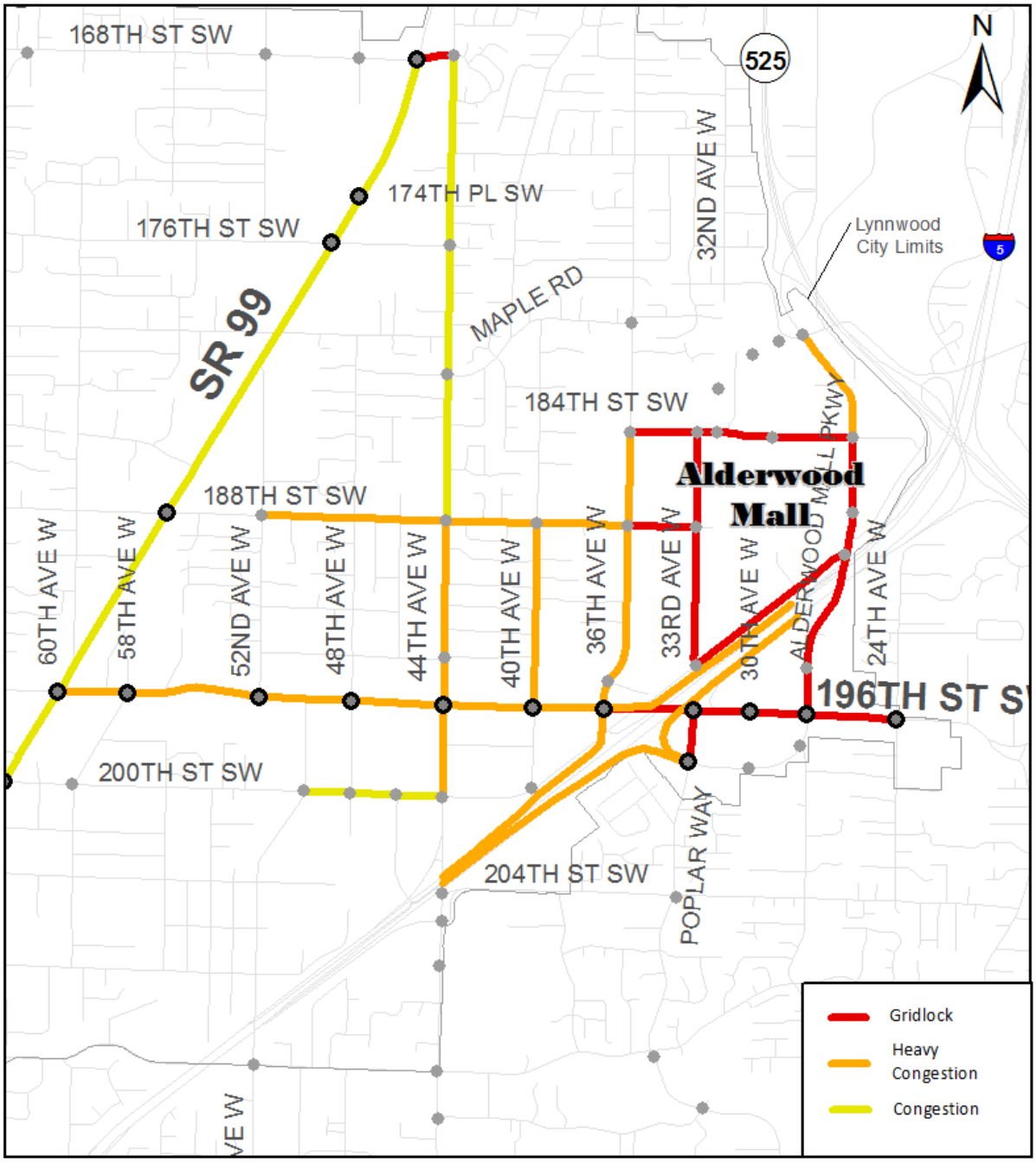

Figure 29: Alderwood Mall Area Holiday Congestion

Holiday congestion begins in November and continues through December. Particularly after Thanksgiving, weekday PM periods typically see heavy congestion or gridlock every day. Weekend congestion is less predictable and often can reach gridlock, as well in the evening after building up throughout the day.

During the worst conditions, local streets adjacent to the Alderwood Mall will become completely gridlocked, with all approaching streets having heavy congestion. Traffic on the I-5 ramps at 196th St SW queues onto the freeway. SR 99 also sees an increase in congestion compared to typical conditions.

8.5.2 Operational Objectives

The objective during the holiday season is to keep traffic moving as efficiently as possible around the Alderwood Mall and to avoid total gridlock. Corridor progression is less important during this time. Ideally, all queues would clear each cycle and intersections would clear to be able to receive vehicles during the next phase.

8.5.3 Coordination and Signal Timing Strategies

The coordination approach for this condition is to use maximum green time to allow as many vehicles through each cycle as possible and to manage queues as efficiently as possible to avoid gridlock.

8.5.4 Summary of Operation

The adaptive system will monitor throughput and queues and actively adjust cycle lengths, splits and offsets to manage the demand and congestion. As traffic reaches saturation, the system will need to start prioritizing these movements in an attempt to keep traffic moving and avoid gridlock.

8.6 I-5 Incidents

8.6.1 Traffic Conditions

During a major I-5 blocking incident in the vicinity of the project corridors, there is the potential for large volumes of traffic to detour onto City streets to avoid the backups on I-5. The interchanges at 220th St SW, 44th Ave W and 196th St SW are often used to enter or exit the freeway during incidents. Traffic will either head to SR 99 to continue north or south or find other local streets that continue through Lynnwood. Conditions will often reach saturation if incidents occur during the AM peak in the southbound direction on I-5 or in the heavy congestion period between noon and 8 PM.

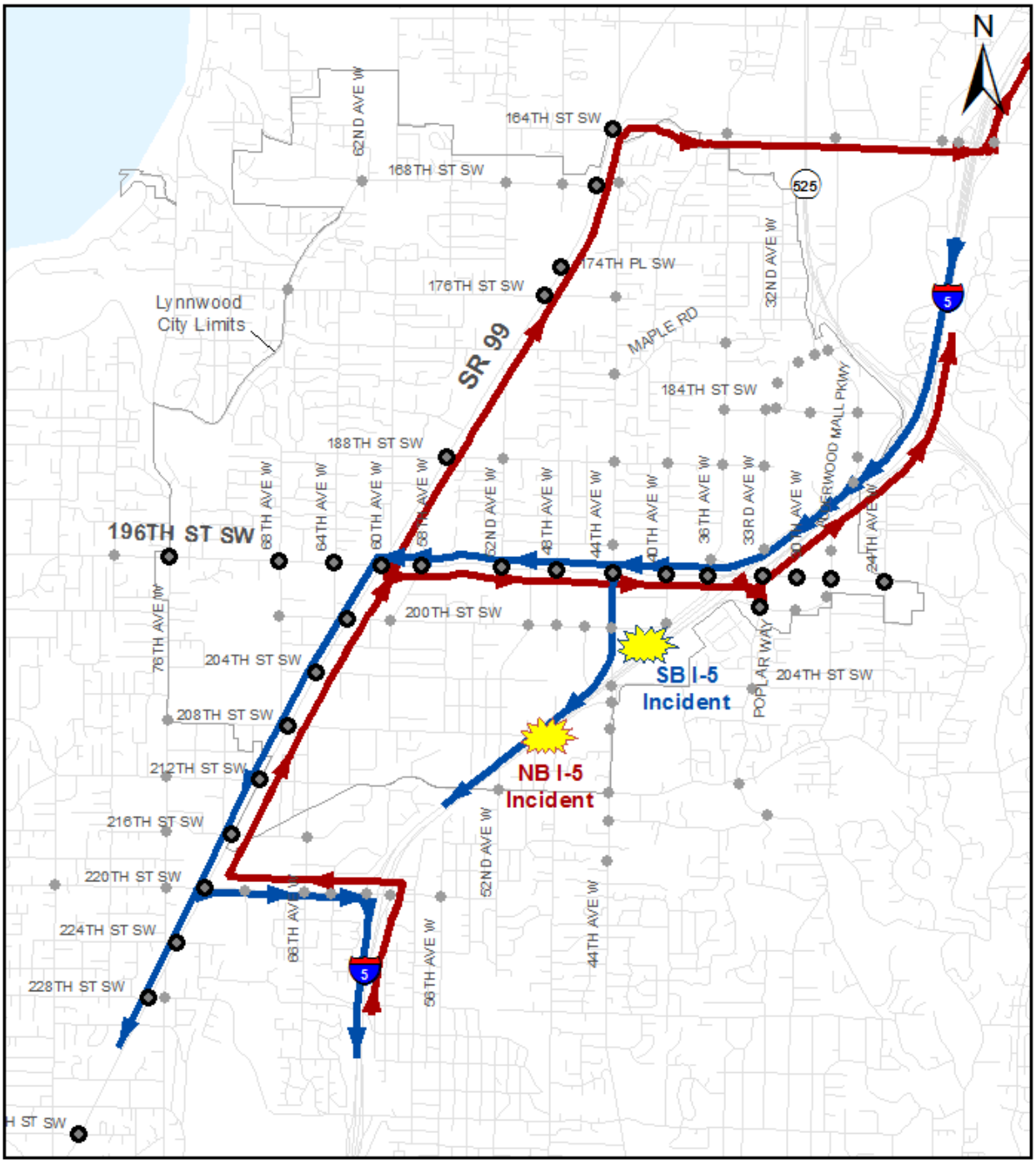

Figure 30: Detour Routes During an I-5 Blocking Incident

8.6.2 Operational Objectives

The top priority during incidents is to keep traffic moving on the local arterials so that diverting freeway traffic does not lead to incidents on local streets and impact transit operations. As with heavy conditions, the peak travel direction will be favored for progression. Queuing on side streets will be

tolerated to promote pushing traffic through the corridor. Monitoring queuing from the freeway may not be as critical in these conditions because traffic on the freeway will likely be stopped. The signals at the freeway can act like meters to the arterials to limit the amount of traffic dumped each cycle.

8.6.3 Coordination and Signal Timing Strategies

Coordination during these events will primarily focus on providing a green band to the diverting traffic. Management of side street queuing will be the secondary emphasis of the system. As with heavy congestion, certain movements may be designated as critical movements where queuing is not tolerated, such as routes that provide emergency access and transit routes. Queuing in northbound or southbound left turn or right turn pockets that could potentially spill into an adjacent through lane must be avoided.

8.6.4 Summary of Operation

The traffic signal system will detect the sudden spike in traffic volumes and start to adjust splits and cycle lengths to manage the increased traffic. Throughput in the diversion direction will be the primary focus for the adaptive system, as will monitoring queuing on designated critical movements.

8.7 Transit Signal Priority and Emergency Vehicle Preemption

8.7.1 Transit Signal Priority

Transit signal priority currently operates on SR 99 for the *Swift* BRT route and is planned for 196th St SW and other future crossing arterials to SR 99 that may eventually have adaptive operations. The signal system will have the capability to extend the existing green if that will serve the bus, introduce an early green by shortening other phases, or run a phase called exclusively by the bus. The decision to provide priority will be determined within the local controller, based on user-definable and settable rules. These rules will include such items as length of time or number of cycles since last priority was provided. The controller shall also have the ability to determine whether there is adequate time to serve a bus arriving on green or if it should serve the normal green time and provide an early green instead.

The controller shall accept both a check-in and check-out call from the TSP system or recognize the end of a steady call from the TSP system as a check-out.

The bus system has its own logic to determine whether a priority request for an approaching bus will be transmitted to the signal controller. This logic will not reside within the adaptive system.

8.7.2 Emergency Vehicle Preemption

When an intersection responds to an emergency vehicle preemption, other signals within the coordinated group continue to operate adaptively. The preempted signal returns to adaptive control once the preemption is released.

8.8 Fault Conditions

8.8.1 Communications Fault Condition

If a communication failure prevents the adaptive system from continuing to control one or more intersections within a defined group, all signals within the group will revert to an appropriate, user-specified fallback mode of operation, either time-of-day operation or free operation. The fallback mode will be specified by the user based on location and time-of-day. All communication failure alarms will be automatically transmitted to maintenance and operations staff for appropriate attention.

8.8.2 Detection Fault Condition

The system will recognize a detector failure and take appropriate action to accommodate the missing data. For a local detector failure, the local controller will place a soft recall or maximum recall (to be user-specified) on the appropriate phase, and issue an alarm. For a detector that influences the adaptive operation (e.g., a system detector), the system will use data from an alternate (user-specified) detector, such as in an adjacent lane or at an appropriate upstream or downstream location. The detector can also use historic data. If the number of detector failures within a specified group exceeds a user-specified threshold, the system will cease adaptive operation and go to a fallback operation specified by the user (such as time-of-day operation or free operation). The fallback operation will be specified by the user based on location and time-of-day. All detector failure alarms will be automatically transmitted to maintenance and operations staff for appropriate attention.