Technical Memorandum

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Subject: Base Year No-Build Conditions Technical Memorandum – Revision 2

1. Introduction

This technical memo documents the Existing and Base Year No-Build traffic conditions based on Level of Service (LOS) and delay outputs from calibrated AM and PM peak hour VISSIM and Synchro models for the seventeen (17) rail-crossing areas included in Phase 2 of the Point Defiance Bypass Traffic Study. This document also discusses the calibration of existing models and provides a comparison of peak hour traffic operations with and without Sound Transit *Sounder* commuter trains.

Thirty-eight study area intersections were modeled for the seventeen (17) rail-crossings included in Phase 2 of the Point Defiance Bypass Traffic Study. Existing Year and Base Year No-Build traffic operations were modeled using either Synchro or VISSIM software and varied by crossing location. All intersections/ramp terminals modeled in the City of Lakewood, WA are shown below in Table 1.

Table 1: Study Area Intersections – Lakewood, WA

Area		No.	Intersection	Control Type	Model
City of Lakewood	A	1	Clover Creek Drive SW/ Hillcrest Drive SW	Sign-controlled	Synchro
		2	Clover Creek Drive SW/ Pacific Highway SW	Sign-controlled	Synchro
	B	3	Bridgeport Way SW/ Pacific Highway SW	Signalized	VISSIM
		4	Bridgeport Way SW/I-5 SB On/Off Ramp	Signalized	VISSIM
		5	Bridgeport Way SW/I-5 NB On/Off Ramp	Signalized	VISSIM
	C	6	108th Street SW/Lakeview Ave SW	Signalized	VISSIM
		7	108th Street SW/Halcyon Rd. SW	Sign-controlled	VISSIM
	D	8	100th Street SW/Lakeview Ave SW	Signalized	VISSIM
	E	9	Steilacoom Blvd. SW/Lakeview Ave SW	Signalized	VISSIM
		10	Steilacoom Blvd. SW/Durango Street SW	Sign-controlled	VISSIM

The applicable traffic control type and model software used has been provided for each study area intersection. All intersections/ramp terminals counted in the City of Tacoma, WA are shown below in Table 2.

Table 2: Study Area Intersections – Tacoma, WA

Area		No.	Intersection	Control Type	Model
City of Tacoma	F	11	South 74th Street/South Tacoma Way	Signalized	VISSIM
	G	12	South 60th Street/South Washington Street	Sign-controlled	Synchro
		13	South 60th Street/South Adams Street	Sign-controlled	Synchro
		14	South 60th Street/South Tacoma Way	Signalized	Synchro
	H	15	South 56th Street/South Washington Street	Signalized	VISSIM
		16	South 56th Street/South Adams Street/South Burlington Way	Sign-controlled	VISSIM
		17	South 56th Street/South Tacoma Way	Signalized	VISSIM
		18	South 56th Street/South Puget Sound Avenue	Signalized	VISSIM
	I	19	South 50th Street/South Adams Street	Sign-controlled	Synchro
		20	South 50th Street/South Burlington Way	Sign-controlled	Synchro
	J	21	South 35th Street/South Tacoma Way	Signalized	Synchro
		22	South 35th Street/South Lawrence Street	Sign-controlled	Synchro
	K	23	South Pine Street/South Tacoma Way	Signalized	VISSIM
		24	South Pine Street/South Center Street	Signalized	VISSIM
	L1	25	South Wilkeson Street/South Tacoma Way	Sign-controlled	Synchro
		26	South Wilkeson Street/South Center Street	Signalized	Synchro
	L2	27	South Alaska Street/South Tacoma Way	Sign-controlled	Synchro
		28	South Alaska Street/South Center Street	Sign-controlled	Synchro
	L3	29	South Chandler Street/South Tacoma Way	Sign-controlled	Synchro
		30	South Chandler Street/South Center Street	Sign-controlled	Synchro
	M	31	South C Street/South Tacoma Way	Sign-controlled	Synchro
		32	South C Street/South 25th Street	Sign-controlled	Synchro
	N1	33	East C Street/East 26th Street	Sign-controlled	Synchro
		37	Parking Lot Entrance between E.25th and E.26th on East C	Sign-controlled	Synchro
		34	East C Street/East 25th Street	Signalized	Synchro
	N2	35	East D Street/East 26th Street	Signalized	Synchro
		38	Parking Lot Entrance between E.25th and E.26th on East D	Sign-controlled	Synchro
		36	East D Street/East 25th Street	Signalized	Synchro

The purpose of this memo is to present and compare Existing and Base Year No-Build traffic operations for each intersection in the study area as well as discuss the calibration of existing condition VISSIM and Synchro models. Existing Year conditions reflect existing (2010) traffic without Sound Transit or Amtrak train operations. The Base Year No-Build condition includes Sound Transit *Sounder* train operations and represents the "No-Build" condition *without* growth for the opening of the Sounder Lakewood Extension.

As well as presenting and comparing the Existing and Base Year No-Build results, the desired outcome is to have WSDOT concur that the VISSIM and Synchro models are accurately calibrated to reflect the existing conditions during the AM and PM peak hours. Throughout the text in this document, **bolded and underlined items** are requests for WSDOT to concur with the actions or assumptions. WSDOT's responses will direct the way in which simulations for the future conditions are developed.

2. Existing VISSIM Simulation Model Development and Calibration Methodology

Existing conditions simulation models were developed for seven (7) rail-crossing areas using VISSIM 5.30, a microscopic traffic flow simulation software, four (4) in the City of Lakewood and three (3) in the City of Tacoma. Existing VISSIM simulation model development included data collection, coding network geometry and signal timing plans, field verification and model calibration. The rail-crossing areas modeled in VISSIM include Bridgeport Way SW, 108th Street SW, 100th Street SW, Steilacoom Boulevard SW, South 74th Street, South 56th Street and South Pine Street. All other rail-crossing areas were modeled using Synchro.

Detailed simulation model development information is presented in Appendix A, including calibration results and detailed intersection operational performance data for each study area intersection. The calibration results provide comparisons between the simulation results and observed field data for hourly traffic volumes and maximum queue lengths. The detailed operational performance data includes average delay, LOS, and average and maximum queue lengths.

Data Collection

Data Collection Units with video cameras were used to collect intersection turning movement counts and the majority of the peak hour queue lengths for the study area. To ensure the traffic counts and queue calibration data were consistent, the traffic counts and queue lengths were collected on the same day for each area/crossing.

Geometry and Signal Timing Plans

Aerial photos obtained from ESRI's GIS base map were used to develop the geometry of the streets, ramps and intersections employed in the VISSIM models. Existing signal timing plans were provided by the City of Lakewood and the City of Tacoma and are provided in Appendix E.

Field Verification

Field verification included verifying roadway geometry and signal operations, measuring effective turn pocket lengths, vehicle behaviors (speed reductions and lane utilization, intersection blocking), and other parameters.

Model Calibration

The calibration process used for the VISSIM models followed Federal Highway Administration (FHWA) guidelines for determining the acceptability of model results as compared to existing operations. The calibration of existing VISSIM simulation models was made by comparing modeled volumes against traffic counts collected in November 2010 (with one set of counts collected in December 2010) and maximum queue length outputs against queue lengths observed in the field. The field videos were collected at the same time as the traffic counts to provide good correlation between the videos of the queue lengths and the number of vehicles counted in a given queue.

Calibration targets were based on FHWA Traffic Analysis Toolbox Volume III, and are summarized below:

(1) Hourly Flows (Model Versus Observed)

- Individual Link Flows
    a. Within 100vph for Flow <700vph
    b. Within 15% for 700vph<Flow<2700vph
    c. Within 400vph for Flow>2700vph
- All Link Flows: within 5% of sum of all link counts

(2) Visual Audits

a. Individual Link Speeds present a visually acceptable speed-flow relationship to the satisfaction of analysts and reviewers.

b. Critical Queue Lengths are visually acceptable to the satisfaction of analysts and reviewers.

When calibrating queue lengths it is important to note that certain real-world factors not accounted for in the VISSIM models may result in larger variations when comparing the simulation results with the data collected in the field. These factors include pedestrians, bus stops and possible platooning from upstream intersections. Given these factors, a queue length of +/- three (3) vehicles was chosen as an acceptable calibration target. The variations in vehicle length should also be considered when evaluating queue lengths.

As shown in Appendix A, the traffic volumes as measured in the VISSIM simulation models correlated well with the volumes collected in the field, with a difference of no more than two (2) percent at the intersection or network level. Some movements with low traffic volumes had more than a ten (10) percent difference but are considered acceptable given the particularly low volume. Therefore, it is concluded that the volumes in the VISSIM models are a good representation of the existing traffic counts that were measured in the field. The maximum queue lengths as measured in the VISSIM simulation models were also within acceptable limits when compared to the number of vehicles collected in the field.

<u>Please confirm if the Existing Year calibration VISSIM results for the study area crossings are acceptable.</u>

3. Existing Synchro Model Development and Calibration Methodology

Existing conditions models were developed for ten (10) rail-crossing areas using Synchro 7, a macroscopic traffic analysis and signal optimization software often used for environmental documentation, one (1) in the City of Lakewood and nine (9) in the City of Tacoma. Existing Synchro model development included data collection, geometrics and signal timing plans, field verification and model calibration. The rail-crossings modeled in Synchro include Clover Creek Drive, South 60th Street, South 50th Street, South 35th Street, South Wilkeson Street, South Alaska Street, South Chandler Street, South C Street, East C Street and East D Street. The crossings on Wilkeson, Alaska and Chandler Streets were combined into a single Synchro model due their close proximity to one another, as was East C and East D Streets.

The Tacoma Link streetcar operates along East 25th Street at approximately ten (10) minute headways during the peak hour, and preempts the traffic signals along East 25th.

Detailed model development information is presented in Appendix B, including calibration results and detailed intersection operational performance data for each study area intersection. The detailed operational performance data includes Highway Capacity Manual (HCM) Unsignalized reports for stop-controlled intersections and HCM Signalized and Synchro Queue reports for signalized intersections.

Data Collection

Data Collection Units with video cameras were used to collect intersection turning movement counts and the majority of the peak hour queue lengths for the study area. To ensure the traffic counts and queue calibration data were consistent, the traffic counts and queue lengths were collected on the same day for each area/crossing.

Geometry and Signal Timing Plans

Aerial photos obtained from ESRI's GIS base map were used to establish intersection locations, lane configurations and turn pocket lengths where applicable. Existing signal timing plans were provided by the City of Lakewood and the City of Tacoma and are provided in Appendix E.

Field Verification

Field verification included verifying geometry and signal operations, measuring effective turn pocket lengths, vehicle behaviors, and other parameters.

Model Calibration

The calibration process used for the Synchro models followed a more qualitative approach when compared to the calibration process in VISSIM. While VISSIM simulates the movements of individual vehicles, Synchro models aggregate movements over the peak hour. The main mechanism used to verify the Synchro models versus field data was a comparison of traffic queue lengths, as traffic flow patterns cannot be observed without simulation.

The calibration of existing Synchro models was performed by comparing the queue length outputs against queue lengths observed on the field. The field videos were collected at the same time as the traffic counts were collected to provide a good correlation between the queue lengths and the number of vehicles counted in a given queue. The queue lengths provided in Synchro are limited to the 50th (average) and 95th percentile queue lengths. For calibration purposes, the 95th percentile queue lengths were compared to the queue lengths observed in the field. Given the qualitative nature of calibrating Synchro, the comparison of these values is considered acceptable.

The majority of calibration in Synchro was focused on the intersections of South 35th Street & South Tacoma Way, East 25th Street & East C Street and East 25th Street & East D Street. Adjustments to model parameters were made at these locations to achieve the approximate queue lengths observed in the field. These parameters included lane utilization factors, left and right-turn factors and minor adjustments to yellow or all-red clearance times. The adjustments made to yellow and all-red clearance times were primarily made along East 25th Street to replicate the Tacoma Link streetcar crossings.

The preemption effects caused by the Tacoma Link streetcar crossings are relatively brief. Synchro does not allow for direct inclusion of the signal preemption, but aggregate preemption effects on queue lengths were incorporated in the calibration process.

As shown in Appendix B, the 95th percentile queue lengths as measured in the Synchro models were within acceptable limits when compared to the queue lengths collected in the field.

Please confirm if the Existing Year calibration Synchro results for the study area crossings are acceptable.

4. Existing Year Intersection Condition Summary

The existing traffic operations at each intersection during the AM and PM peak hours are presented in Table 3 through Table 19. For the study intersections modeled in VISSIM, these tables provide the results of the VISSIM simulations for each intersection (based on a 20 run average of VISSIM model outputs). For the study intersections modeled in Synchro, these tables provide the HCM results for signalized and unsignalized intersections.

Synchro implements methods of the 2000 Highway Capacity Manual (HCM) for signalized and unsignalized intersections to calculate intersection control delay and 95th percentile queue lengths. VISSIM on the other hand, tracks individual vehicle movements and interactions and quantifies movement and individual intersection delays and queue lengths more realistically than typical HCM methods. Intersection performances measured using VISSIM outputs might be different from typical HCM methodology, but for the purposes of this analysis, the Level of Service (LOS) criteria are based on Highway Capacity Manual (HCM) 2000 metrics which are presented in Appendix D.

The existing peak hour traffic operations performance measures include intersection LOS, average delay, worst movement, and the associated maximum approach queue lengths, which represent the queue lengths from the intersection approach downstream of the rail-crossing, if applicable. These values are provided to help identify potential safety issues if traffic is queuing beyond the rail-crossing. If an intersection does not have approach queue lengths that are directed towards the rail-crossing, then this value is omitted because traffic will not queue onto the crossing. The worst movement at the intersection, based on average delay, is provided for both signalized and unsignalized intersections. In the case of unsignalized intersections, the worst movement is used to determine intersection LOS. For more detailed intersection operations information from the VISSIM simulation outputs and Synchro HCM reports, please refer to Appendix A and Appendix B.

Table 3: Clover Creek Drive SW - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
1	Clover Creek Drive SW and Hillcrest Drive SW	A (9.1)	Clover Cr. Dr. Left-Turn to Hillcrest Dr.[1]	N/A[3]	A (9.2)	Clover Cr. Dr. Left-Turn to Hillcrest Dr.[1]	N/A[3]
2	Clover Creek Drive SW and Pacific Highway SW	B (10.2)	Clover Cr. Dr. Left-Turn to Pacific Hwy[1]	25 (Southbound)	B (11.6)	Clover Cr. Dr. Left-Turn to Pacific Hwy[1]	25 (Southbound)

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 4: Bridgeport Way SW - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
3	Bridgeport Way SW and Pacific Highway SW	B (19.1)	Bridgeport Way SB Left-Turn to Pacific Hwy.	250 (Southbound)	C (21.5)	Pacific Hwy EB Left-Turn to Bridgeport Way	350 (Southbound)
4	Bridgeport Way SW and I-5 SB Ramps	B (13.9)	I-5 SB Ramp Left-Turn to Bridgeport Way	N/A[3]	A (9.3)	I-5 SB Ramp Left-Turn to Bridgeport Way	N/A[3]
5	Bridgeport Way SW and I-5 NB Ramps	B (14.0)	I-5 NB Ramp Left-Turn to Bridgeport Way	N/A[3]	B (15.4)	I-5 NB Ramp Left-Turn to Bridgeport Way	N/A[3]

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 5: 108th Street SW - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
6	108th Street SW and Lakeview Avenue SW	A (8.7)	Lakeview Ave. SB Left-Turn to 108th Street	150 (Westbound)	B (11.1)	Lakeview Ave. SB Left-Turn to 108th Street	175 (Westbound)
7	108th Street SW and Halcyon Road SW	A (6.1)	Halcyon Road NB Right-Turn to 108th Street[1]	N/A[3]	A (8.8)	Halcyon Road NB Right-Turn to 108th Street[1]	N/A[3]

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 6: 100th Street SW - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
8	100th Street SW and Lakeview Avenue SW	B (10.5)	100th Street EB Left-Turn to Lakeview Avenue	200 (Westbound)	B (13.1)	100th Street EB Left-Turn to Lakeview Avenue	225 (Westbound)

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 7: Steilacoom Boulevard SW - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
9	Steilacoom Blvd. SW and Lakeview Avenue SW	A (6.6)	Lakeview Ave. NB Left-Turn to Steilacoom	150 (Westbound)	A (9.6)	Lakeview Ave. NB Left-Turn to Steilacoom	150 (Westbound)
10	Steilacoom Blvd. SW and Durango Street SW	C (15.4)	Durango Street SB Left-Turn to Steilacoom[1]	N/A[3]	B (11.8)	Durango Street SB Left-Turn to Steilacoom[1]	N/A[3]

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 8: South 74th Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
11	South 74th Street and South Tacoma Way	C (27.6)	Tacoma Way SB Left-Turn to South 74th Street	350 (Eastbound)	D (36.9)	South 74th Street WB Left-Turn to Tacoma Way	450 (Eastbound)

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.

Table 9: South 60th Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
12	South 60th Street and South Washington Street	A (9.3)	Washington Street NB Left Turn to 60th Street[1]	N/A[3]	A (9.2)	Washington Street NB Left Turn to 60th Street[1]	N/A[3]
13	South 60th Street and South Adams Street	A (9.4)	60th Street Left-Turn to Adams Street[1]	25 (Westbound)	B (10.1)	60th Street Left-Turn to Adams Street[1]	25 (Westbound)
14	South 60th Street and South Tacoma Way	B (14.9)	Westbound 60th Street[1]	25 (Eastbound)	C (23.7)	Eastbound 60th Street[1]	25 (Eastbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 10: South 56th Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
15	South 56th Street and South Washington Street	A (8.2)	Washington Street SB Left-Turn to 56th Street	200 (Eastbound)	B (13.6)	Washington Street SB Left-Turn to 56th Street	175 (Eastbound)
16	South 56th Street and South Burlington Way	A (2.6)	Burlington Way SB Left-Turn to 56th Street	100 (Westbound)	A (3.3)	Burlington Way NB Left-Turn to 56th Street	125 (Westbound)
17	South 56th Street and South Tacoma Way	B (18.7)	South 56th Street EB Left-Turn to Tacoma Way	N/A[3]	C (24.4)	South 56th Street EB Left-Turn to Tacoma Way	N/A[3]
18	South 56th Street and South Puget Sound Ave.	A (4.8)	Puget Sound Ave. NB Left-Turn to 56th Street	N/A[3]	A (8.0)	Puget Sound Ave. SB Left-Turn to 56th Street	N/A[3]

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 11: South 50th Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
19	South 50th Street and South Adams Street	A (8.9)	Adams Street SB Left Turn to 50th Street[1]	N/A[3]	A (9.0)	Adams Street SB Left Turn to 50th Street[1]	N/A[3]
20	South 50th Street and South Burlington Way	N/A[4]			N/A[4]		

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.
[4] Intersection is a traffic circle; LOS, Delay and Queue results not available in Synchro.

Table 12: South 35th Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
21	South 35th Street and South Tacoma Way	A (6.4)	35th Street EB Left-Turn to Tacoma Way	25 (Eastbound)[3]	B (17.1)	Southbound Tacoma Way	50 (Eastbound)
22	South 35th Street and South Lawrence Street	A (9.5)	Southbound Lawrence Street[1]	N/A[4]	A (9.9)	Southbound Lawrence Street[1]	N/A[4]

Notes:
[1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Truck percentage during AM peak hour is 27%, queue length likely longer at times.
[4] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 13: South Pine Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
23	South Pine Street and South Tacoma Way	B (14.5)	Westbound Tacoma Way	200 (Southbound)	C (26.8)	Westbound Tacoma Way	425 (Southbound)
24	South Pine Street and South Center Street	C (21.8)	Westbound Center Street	200 (Northbound)	C (32.3)	Westbound Center Street	450 (Northbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.

Table 14: South Wilkeson Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
25	South Wilkeson Street and South Tacoma Way	B (10.3)	Wilkeson Street SB Left-Turn to Tacoma Way	50 (Southbound)	B (13.3)	Wilkeson Street SB Right-Turn to Tacoma Way	175 (Southbound)
26	South Wilkeson Street and South Center Street	B (12.4)	Northbound Wilkeson Street	150 (Northbound)	C (24.1)	Wilkeson Street NB Left-Turn to Center Street	125 (Northbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.

Table 15: South Alaska Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
27	South Alaska Street and South Tacoma Way	B (11.1)	Alaska St. SB Left Turn to Tacoma Way[1]	25 (Southbound)	B (13.3)	Alaska St. SB Left Turn to Tacoma Way[1]	25 (Southbound)
28	South Alaska Street and Center Street	C (17.8)	Alaska St. NB Left Turn to Center St.[1]	25 (Northbound)	D (30.9)	Alaska St. SB Left Turn to Center St.[1]	25 (Northbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.

Table 16: South Chandler Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
29	South Chandler Street and South Tacoma Way	B (10.7)	Chandler St. SB Left Turn to Tacoma Way[1]	25 (Southbound)	C (15.7)	Chandler St. SB Left Turn to Tacoma Way[1]	25 (Southbound)
30	South Chandler Street and South Center Street	B (13.5)	Chandler St. NB Left Turn to Center St.[1]	25 (Northbound)	C (24.5)	Chandler St. NB Left Turn to Center St.[1]	25 (Northbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.

Table 17: South C Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
31	South C Street and South Tacoma Way	B (10.8)	S. C Street Left Turn to Tacoma Way[1]	25 (Southbound)	B (13.9)	S. C Street Left Turn to Tacoma Way[1]	50 (Southbound)
32	South C Street and South 25th Street	B (13.0)	S. C Street NB Left Turn to 25th Street[1]	25 (Northbound)	C (18.1)	Southbound S. C Street[1]	25 (Northbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.

Table 18: East C Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
33	East C Street and East 26th Street	D (26.2)	Northbound East C Street[1]	25 (Southbound)	C (15.0)	Northbound East C Street[1]	25 (Southbound)
37	Parking Lot Entrance on East C Street	B (10.3)	Westbound Left/Right out of Parking Lot[1]	N/A[3]	A (9.1)	Eastbound Left/Right out of Parking Lot[1]	N/A[3]
34	East C Street and East 25th Street	B (10.8)	Northbound East C Street	100 (Northbound)	A (10.0)	Southbound East C Street	50 (Northbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

Table 19: East D Street - Existing AM and PM Peak Hour Traffic Conditions

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Worst Movement	Approach Queue Length[2] - feet (Direction)
35	East D Street and East 26th Street	A (8.3)	Northbound East D Street	50 (Southbound)	B (10.7)	Southbound East D Street	200 (Southbound)
38	Parking Lot Entrance on East D Street	B (10.3)	Eastbound Left/Right out of Parking Lot[1]	N/A[3]	B (10.3)	Eastbound Left/Right out of Parking Lot[1]	N/A[3]
36	East D Street and East 25th Street	A (9.8)	Eastbound East 25th Street	125 (Northbound)	B (12.8)	Westbound East 25th Street	125 (Northbound)

Notes: [1] The worst-movement at an unsignalized intersection is considered the indicator of LOS because most of the movements at such an intersection flow through the intersection without delay.
[2] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[3] Intersection does not have approach queue lengths from stop-controlled movements that are directed towards the rail-crossing.

As shown in Table 3 through Table 19, Existing Year (2010) intersection operations are LOS D or better. Table 3 through Table 19 also shows that several intersection approach queue lengths come close to or exceed the rail-crossing, creating a potential safety issue if a train is approaching. The intersections summarized in Table 20 have approach queue lengths that may be impacted by the rail-crossing during the AM or PM peak hour or both.

It is important to note that queue lengths may vary substantially depending on vehicle length, composition and daily fluctuations in traffic volumes. Several approach queue lengths listed below do not exceed the

distance to the crossing, but are listed due to the close proximity to the crossing or because the significant queue lengths are worth noting.

Table 20: Approach Queue Length and Rail Crossing Distance Comparison

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Approach Queue Length[1] - feet (Direction) (1)	Distance to Crossing[2]- feet (2)	Difference (1)-(2)	Approach Queue Length[1] - feet (Direction) (1)	Distance to Crossing[2]- feet (2)	Difference (1)-(2)
3	Bridgeport Way SW and Pacific Highway SW	250 (Southbound)	200	50	350 (Southbound)	200	150
6	108th Street SW and Lakeview Avenue SW	150 (Westbound)	210	-60	175 (Westbound)	210	-35
8	100th Street SW and Lakeview Avenue SW	200 (Westbound)	160	40	225 (Westbound)	160	65
9	Steilacoom Blvd. SW and Lakeview Ave. SW	150 (Westbound)	140	10	150 (Westbound)	140	10
11	South 74th Street and South Tacoma Way	350 (Eastbound)	350	0	450 (Eastbound)	350	100
15	South 56th Street and S. Washington Street	200 (Eastbound)	160	40	175 (Eastbound)	160	15
16	South 56th Street and South Burlington Way	100 (Westbound)	130	-30	125 (Westbound)	130	-5
23	South Pine Street and South Tacoma Way	200 (Southbound)	560	-360	425 (Southbound)	560	-135
26	South Wilkeson Street and S. Center Street	150 (Northbound)	200	-50	125 (Northbound)	200	-75
34	East C Street and East 25th Street	100 (Northbound)	100	0	50 (Northbound)	100	-50
35	East D Street and East 26th Street	50 (Southbound)	175	-125	200 (Southbound)	175	25
36	East D Street and East 25th Street	125 (Northbound)	100	25	125 (Northbound)	100	25

Notes: [1] Queue lengths from intersection approach downstream of railroad crossing. Indicates if traffic is queuing onto the crossing. Max queue length output from VISSIM and 95th percentile queue length from Synchro. Queue lengths rounded to nearest 25 feet.
[2] Approximate distances from railroad tracks to edge of intersection.

As shown in Table 20, two intersections have approach queue lengths that exceed the rail-crossing by one-hundred (100) feet or more; Bridgeport Way SW at Pacific Highway SW and South 74th Street at South Tacoma Way. In order to reduce the potential safety issues and keep traffic from stopping on the railroad tracks, pre-signals have been constructed at these locations and have been modeled in the Base Year No-Build condition. Pre-signals are also located at the intersections of South 35th Street and South Tacoma Way and South Pine Street and South Tacoma Way.

Although the existing approach queue lengths on South 35th Street as modeled in Synchro do not indicate traffic queuing onto or beyond the crossing, the heavy vehicle (i.e. truck) percentage at this location is twenty-seven (27) percent. Given the number of large trucks on South 35th Street, and the relatively short distance between South Tacoma Way and the crossing (350 feet), the pre-signal will discourage a truck from queuing on the railroad tracks.

5. Base Year No-Build VISSIM Simulation Model Development Methodology

Base Year No-Build condition VISSIM simulation models were developed for six (6) rail-crossing areas using the calibrated Existing Year models, three (3) in the City of Lakewood and three (3) in the City of Tacoma. The Base Year No-Build condition includes Sound Transit *Sounder* train operations and represents the "No-Build" condition *without* growth for the opening of the Sounder Lakewood Extension. Base Year No-Build VISSIM simulation model development included Sound Transit commuter trains, crossing warning times, signal preemption and applicable pre-signals. The rail-crossings modeled in VISSIM include 108th Street SW, 100th Street SW, Steilacoom Boulevard SW, South 74th Street, South 56th Street and South Pine Street. Sound Transit operations were not modeled at Bridgeport Way SW because the *Sounder* train terminates just south of the 108th Street SW crossing.

Sound Transit *Sounder* Commuter Trains

Based on the proposed Sound Transit *Sounder* schedule, each crossing will experience a southbound commuter revenue train only once during the AM and PM peak hours. In addition, the 100th Street SW and 108th Street SW crossings will encounter a northbound *Sounder* non-revenue train only once during the PM peak hour, approximately 15-20 minutes after the southbound revenue train. The *Sounder* non-revenue trains have no passengers and are traveling at lower speeds as they return to a layover facility north of 100th Street SW.

Average train speeds for the *Sounder* revenue trains are estimated to be sixty (60) miles per hour at South Pine Street, South 74th Street, Steilacoom Boulevard SW and 100th Street SW. Average train speeds for the *Sounder* revenue trains are estimated to be forty-five (45) miles per hour at 108th Street SW and twenty (20) miles per hour at South 56th Street, due to stations located north of each crossing. Average train speeds for the *Sounder* non-revenue trains are estimated to be ten (10) miles per hour at 100th Street SW and thirty-five (35) miles per hour at 108th Street SW.

Detailed simulation model development information is presented in Appendix C, including detailed intersection operational performance data for each study area intersection. The detailed operational performance data includes average delay, LOS, and average and maximum queue lengths.

6. Existing Year and Base Year No-Build VISSIM Simulation Comparison

A comparison of Existing Year and Base Year No-Build traffic operations for each rail-crossing area modeled using VISSIM is presented in Table 21 through Table 26. The Existing and Base Year No-Build peak hour traffic operations performance measures include intersection LOS and average delay. The associated crossing queue length is also provided, which represents the maximum queue length from the rail-crossing while the gate is closed.

As shown in Table 21 through Table 26, AM and PM peak hour intersection operations were relatively unchanged with the addition of Sound Transit *Sounder* trains. In general, average delays per vehicle increased by no more than two (2) seconds and intersection LOS remained the same. In some instances average delays actually decreased, which resulted in an improved LOS in the AM peak hour at 100th Street SW and Lakeview Avenue SW. These improvements in intersection performance were negligible however, with a decrease of two (2) seconds at South 56th Street and South Washington Street during the PM peak hour, and less than a half second in all other cases.

These results indicate that given the assumptions previously mentioned regarding Sound Transit operations, overall AM and PM peak hour intersection performance is not impacted during a *Sounder* revenue or non-revenue train crossing event.

Table 21: 108th Street SW - Existing Year & Base Year No-Build Comparison

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Existing Year	Base Year No-Build[1]		Existing Year	Base Year No-Build[2]	
		Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)
6	108th Street SW and Lakeview Avenue SW	A (8.7)	A (8.8)	125 (Westbound)	B (11.1)	B (11.7)	250 (Westbound)
7	108th Street SW and Halcyon Road SW	A (6.1)	A (6.1)	N/A[4]	A (8.8)	A (9.3)	N/A[4]

Notes:
[1] One southbound *Sounder* commuter train during the AM peak hour.
[2] One southbound *Sounder* commuter train and one northbound *Sounder* non-revenue train during the PM peak hour.
[3] Queue lengths from railroad crossing while gate closed. Max queue length output from VISSIM. Queue lengths rounded to nearest 25 feet.
[4] Cross-street does not experience queuing at the rail-crossing.

Table 22: 100th Street SW - Existing Year & Base Year No-Build Comparison

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Existing Year	Base Year No-Build[1]		Existing Year	Base Year No-Build[2]	
		Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)
8	100th Street SW and Lakeview Avenue SW	B (10.5)	A (9.8)	225 (Westbound)	B (13.1)	B (14.4)	300 (Westbound)

Notes:
[1] One southbound *Sounder* commuter train during the AM peak hour.
[2] One southbound *Sounder* commuter train and one northbound *Sounder* non-revenue train during the PM peak hour.
[3] Queue lengths from railroad crossing while gate closed. Max queue length output from VISSIM. Queue lengths rounded to nearest 25 feet.

Table 23: Steilacoom Boulevard SW - Existing Year & Base Year No-Build Comparison

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Existing Year	Base Year No-Build[1]		Existing Year	Base Year No-Build[2]	
		Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)
9	Steilacoom Blvd. SW and Lakeview Avenue SW	A (6.6)	A (6.2)	200 (Westbound)	A (9.6)	A (9.5)	175 (Westbound)
10	Steilacoom Blvd. SW and Durango Street SW	C (15.4)	C (15.7)	N/A[4]	B (11.8)	B (12.1)	N/A[4]

Notes:
[1] One southbound *Sounder* commuter train during the AM peak hour.
[2] One southbound *Sounder* commuter train during the PM peak hour.
[3] Queue lengths from railroad crossing while gate closed. Max queue length output from VISSIM. Queue lengths rounded to nearest 25 feet.
[4] Cross-street does not experience queuing at the rail-crossing.

Table 24: South 74th Street - Existing Year & Base Year No-Build Comparison

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Existing Year	Base Year No-Build[1]		Existing Year	Base Year No-Build[2]	
		Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)
11	South 74th Street and South Tacoma Way	C (27.6)	C (28.2)	175 (Eastbound)	D (36.9)	D (37.6)	200 (Eastbound)

Notes:
[1] One southbound *Sounder* commuter train during the AM peak hour.
[2] One southbound *Sounder* commuter train during the PM peak hour.
[3] Queue lengths from railroad crossing while gate closed. Max queue length output from VISSIM. Queue lengths rounded to nearest 25 feet.

Table 25: South 56th Street - Existing Year & Base Year No-Build Comparison

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Existing Year	Base Year No-Build[1]		Existing Year	Base Year No-Build[2]	
		Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)
15	South 56th Street and South Washington Street	A (8.2)	A (8.0)	N/A[4]	B (13.6)	B (11.6)	N/A[4]
16	South 56th Street and South Burlington Way	A (2.6)	A (3.4)	N/A[4]	A (3.3)	A (4.1)	N/A[4]
17	South 56th Street and South Tacoma Way	B (18.7)	B (18.7)	N/A[5]	C (24.4)	C (24.8)	N/A[5]
18	South 56th Street and South Puget Sound Avenue	A (4.8)	A (4.7)	N/A[5]	A (8.0)	A (8.0)	N/A[5]

Notes:
[1] One southbound *Sounder* commuter train during the AM peak hour.
[2] One southbound *Sounder* commuter train during the PM peak hour.
[3] Queue lengths from railroad crossing while gate closed. Max queue length output from VISSIM. Queue lengths rounded to nearest 25 feet.
[4] Queue lengths not applicable as crossing is in between intersections. Prohibited upstream movements create negligible queuing.
[5] Intersection not adjacent to rail-crossing.

Table 26: South Pine Street - Existing Year & Base Year No-Build Comparison

No.	Intersection Name	AM Peak Hour			PM Peak Hour		
		Existing Year	Base Year No-Build[1]		Existing Year	Base Year No-Build[2]	
		Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)	Intersection LOS (Avg. Delay-sec/veh)	Intersection LOS (Avg. Delay-sec/veh)	Crossing Queue Length[3] - feet (Direction)
23	South Pine Street and South Tacoma Way	B (14.5)	B (14.7)	50 (Southbound)	C (26.8)	C (27.3)	125 (Southbound)
24	South Pine Street and South Center Street	C (21.8)	C (22.2)	75 (Northbound)	C (32.3)	C (33.4)	125 (Northbound)

Notes:
[1] One southbound *Sounder* commuter train during the AM peak hour.
[2] One southbound *Sounder* commuter train during the PM peak hour.
[3] Queue lengths from railroad crossing while gate closed. Max queue length output from VISSIM. Queue lengths rounded to nearest 25 feet.

Queue Length Comparisons

Although overall intersection performance was not impacted by Sound Transit operations, individual movements may still be affected. Table 27 through Table 32 compares the VISSIM modeled maximum approach queue lengths for Existing Year conditions to modeled maximum approach queue lengths for

Base Year No-Build conditions in terms of feet. Queue lengths are measured by approach, which includes through as well as left-turn movements.

As shown in Table 27 through Table 32, the intersection approaches immediately downstream of the rail-crossing or approaches that are allowed to operate after the track clearance phase during the signal preemption had very little change in maximum queue lengths, if any. Intersection approaches with prohibited movements during the signal preemption experienced increased maximum queue lengths due to Sound Transit crossing operations. In general, the impact to these approaches is short lived, lasting only a cycle or two before returning to normal operations.

The comparison of Existing Year and Base Year No-Build queue lengths also indicates that Sound Transit operations do not significantly impact intersections that are up or downstream of those intersections immediately adjacent to the rail-crossing, as is the case with South Tacoma Way and South Puget Sound Avenue along South 56th Street.

Table 27: 108th Street SW - Existing Year and Base Year No-Build Queue Length Comparison

No.	Intersection	Approach	AM Peak Hour			PM Peak Hour		
			Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)	Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)
6	108th Street SW & Lakeview Avenue SW	Eastbound	67	92	25	179	321	142
		Westbound	134	136	2	174	185	11
		Northbound	96	93	-3	90	100	10
		Southbound	111	112	1	133	152	19
7	108th Street SW & Halcyon Road SW[2]	Eastbound	N/A	N/A	N/A	N/A	N/A	N/A
		Westbound	N/A	N/A	N/A	N/A	N/A	N/A
		Northbound	0	0	0	0	0	0

[1] Average value of 20 VISSIM runs.
[2] Northbound Halcyon Road is Right-Out only, queues are negligible.
[N/A] Intersection approach not stop controlled.

Table 28: 100th Street SW - Existing Year and Base Year No-Build Queue Length Comparison

No.	Intersection	Approach	AM Peak Hour			PM Peak Hour		
			Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)	Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)
8	100th Street SW & Lakeview Avenue SW	Eastbound	108	133	25	233	515	202
		Westbound	196	200	4	205	195	-10
		Northbound	107	111	4	122	125	3
		Southbound	134	155	21	181	288	107

[1] Average value of 20 VISSIM runs.

Table 29: Steilacoom Boulevard SW - Existing Year and Base Year No-Build Queue Length Comparison

No.	Intersection	Approach	AM Peak Hour			PM Peak Hour		
			Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)	Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)
9	Steilacoom Blvd. SW & Lakeview Avenue SW	Eastbound	134	153	19	211	258	47
		Westbound	148	145	-3	140	144	4
		Northbound	142	150	8	197	192	-5
10	Steilacoom Blvd. SW & Durango Street SW	Eastbound	32	34	2	32	31	-1
		Westbound	N/A	N/A	N/A	N/A	N/A	N/A
		Southbound	55	55	0	66	66	0

[1] Average value of 20 VISSIM runs.
[N/A] Intersection approach not stop controlled.

Table 30: South 74th Street - Existing Year and Base Year No-Build Queue Length Comparison

No.	Intersection	Approach	AM Peak Hour			PM Peak Hour		
			Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)	Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)
11	South 74th Street & South Tacoma Way	Eastbound	339	324	-15	435	397	-38
		Westbound	236	252	16	345	364	19
		Northbound	209	227	18	313	299	-14
		Southbound	171	165	-6	433	433	0

[1] Average value of 20 VISSIM runs.

Table 31: South 56th Street - Existing Year and Base Year No-Build Queue Length Comparison

No.	Intersection	Approach	AM Peak Hour			PM Peak Hour		
			Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)	Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)
15	South 56th Street & South Washington Street	Eastbound	201	203	2	180	192	12
		Westbound	273	317	44	118	366	248
		Northbound	56	58	2	56	58	2
		Southbound	56	78	22	521	727	206
16	South 56th Street & South Burlington Way	Eastbound	128	297	169	154	370	216
		Westbound	103	126	23	114	141	27
		Northbound	45	54	9	52	60	8
		Southbound	30	29	-1	42	38	-4
17	South 56th Street & South Tacoma Way	Eastbound	181	179	-2	307	280	-27
		Westbound	157	163	6	317	322	5
		Northbound	140	145	5	240	246	6
		Southbound	123	122	-1	300	309	9
18	South 56th Street & South Puget Sound Avenue	Eastbound	138	144	6	131	160	29
		Westbound	97	97	0	121	117	-4
		Northbound	97	97	0	148	148	0
		Southbound	63	63	0	124	124	0

[1] Average value of 20 VISSIM runs.

Table 32: South Pine Street - Existing Year and Base Year No-Build Queue Length Comparison

No.	Intersection	Approach	AM Peak Hour			PM Peak Hour		
			Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)	Existing Year Queue (feet) (1)[1]	Base No-Build Queue (feet) (2)[1]	Difference (2)-(1)
23	South Pine Street & South Tacoma Way	Eastbound	139	140	1	227	249	22
		Westbound	110	118	18	397	422	25
		Northbound	161	153	-8	439	415	-24
		Southbound	193	198	5	416	392	-24
24	South Pine Street & South Center Street	Eastbound	180	186	6	264	294	30
		Westbound	170	178	8	418	494	76
		Northbound	196	203	7	447	459	12
		Southbound	196	197	1	357	376	19

[1] Average value of 20 VISSIM runs.

The largest increase in maximum approach queue lengths was at the 108th Street SW, 100th Street SW and South 56th Street crossings. At 108th Street SW, *Sounder* revenue and non-revenue trains resulted in an increase of 142 feet in the eastbound direction during the PM peak hour. At 100th Street SW, *Sounder* revenue and non-revenue trains resulted in an increase of 202 feet in the eastbound direction and 107 feet in the southbound direction during the PM peak hour. The increase in queue length in the southbound direction is due to the "no left-turn" blankout sign on Lakeview Avenue SW.

The South 56th Street crossing is between South Burlington Way and South Washington Street, resulting in increased queue lengths at both locations due to *Sounder* revenue train operations. At South Burlington Way there is an increase of 169 feet and 216 feet in the eastbound direction in the AM and PM peak hour, respectively. At South Washington Street, queue lengths increased 244 feet in the westbound direction and 206 feet in the southbound direction during the PM peak hour. The increase in queue length in the southbound direction is due to the "no right-turn" blankout sign on South Washington Street.

Again, the impact to these approaches is short lived, lasting only a cycle or two before returning to normal operations.

7. Base Year No-Build Synchro Delay

As a macroscopic traffic analysis software, Synchro cannot, by its nature, represent the operation of the crossing gates or the changes in traffic signal operations that result from railroad advance preemption sequences. For calibration purposes, Synchro was used to determine Existing Year intersection operations *without* Sound Transit trains. In order to account for the delay introduced by passing trains and the subsequent gate down-time, basic queuing theory equations from Traffic Flow Fundamentals (Adolf D. May, 1990) were used to estimate delays due to Sound Transit *Sounder* commuter trains in the Base Year No-Build scenario.

The parameters that affect traffic delay at at-grade crossings are train frequency, train blockage time, hourly traffic volume and traffic departure capacity. Train blockage time includes the gate warning and closing cycle, the train crossing time and the time for the gates to fully open after the train has passed. A five (5) second "permissive" phase has been subtracted from the train blockage time and represents the initial gate warning and closing sequence where vehicles approaching the gate will continue to cross. It is assumed that all vehicles will be stopped after this "permissive" phase.

Detailed derivation of the delay calculation is included in Appendix F. Total crossing delay is measured in the unit of vehicle-hours per hour (veh-hrs/hr) and quantifies the total delay occurred amongst all vehicles at the rail-crossing during the AM and PM peak hours. The average delay per vehicle is calculated based on the total hourly delay and the expected number of arrival vehicles at the crossing from both the upstream and downstream intersections during the peak hour.

The rail-crossings modeled in Synchro include Clover Creek Drive SW, South 60th Street, South 50th Street, South 35th Street, South Wilkeson Street, South Alaska Street, South Chandler Street, South C Street, East C Street and East D Street. Based on the proposed Sound Transit *Sounder* schedule, each crossing will experience a southbound commuter revenue train only once during the AM and PM peak hours, with the exception of Clover Creek Drive SW. Clover Creek Drive SW was not included in the Base Year No-Build analysis because the *Sounder* train terminates just south of the 108th Street SW crossing. Table 33 summarizes the estimated delays at the rail-crossings modeled in Synchro.

As shown in Table 33, the average delay per vehicle at the rail-crossings during a Sound Transit *Sounder* commuter train event is less than one (1) second per vehicle during the AM and PM peak hours.

Table 33: Base Year No-Build Synchro Delay Summary

Crossing Location	2010 AM Peak Hour[1]				2010 PM Peak Hour[1]			
	Peak Crossing Volume (veh/hr)	Blockage Time (seconds)	Total Crossing Delay[2] (seconds)	Average Delay Per Vehicle (seconds)	Peak Crossing Volume (veh/hr)	Blockage Time (seconds)	Total Crossing Delay[2] (seconds)	Average Delay Per Vehicle (seconds)
East D Street	384	70	313	0.81	523	70	419	0.80
East C Street	223	62	148	0.67	152	62	87	0.57
South C Street	135	51	51	0.38	182	51	71	0.39
South Chandler Street	36	52	14	0.38	46	52	18	0.38
South Alaska Street	25	51	9	0.37	20	51	7	0.36
South Wilkeson Street	446	50	212	0.48	632	50	354	0.56
South 35th Street	263	48	98	0.37	366	48	139	0.38
South 50th Street	69	46	21	0.30	82	46	25	0.31
South 60th Street	54	61	29	0.53	74	61	39	0.53

Notes:
[1]One Southbound *Sounder* commuter train during the peak hour with various blockage times (including gates down & up).
[2]Total crossing delay is for the peak hour volume crossing the tracks from both the upstream and downstream intersections of the crossing.

In order to make a comparison between Existing Year and Base Year No-Build intersection performance for the crossings modeled in Synchro, the crossing delay was applied to the adjacent intersections to estimate the change in intersection LOS and delay as a result of Sound Transit *Sounder* train operations. Given the limitations of Synchro in modeling railroad and traffic signal advanced preemption, the delays that occur at the rail-crossing during the train blockage time were artificially "moved" back to the upstream intersection to estimate the additional intersection delay that would occur while the crossing volumes are prohibited from moving.

The methodology used to estimate intersection delay during a train crossing event was only applied to adjacent signalized intersections. Delay and LOS for an unsignalized intersection is based on the worst movement and the majority of the peak hour crossing volumes from the unsignalized intersections is from movements that are not stop-controlled and therefore have no delay under normal operations. A comparison of Existing Year and Base Year No-Build traffic operations for the adjacent signalized intersections modeled in Synchro is presented in Table 34.

Table 34: Existing Year and Base Year No-Build Comparison for Adjacent Signalized Intersections

No.	Intersection Name	2010 AM Peak Hour[1]				2010 PM Peak Hour[1]			
		Total Intersection Volume (veh/hr)	Crossing Delay[2] - sec (Direction)	Existing Year LOS (Avg. Delay-sec/veh)	Base Year No-Build LOS (Avg. Delay-sec/veh)	Total Intersection Volume (veh/hr)	Crossing Delay[2] - sec (Direction)	Existing Year LOS (Avg. Delay-sec/veh)	Base Year No-Build LOS (Avg. Delay-sec/veh)
21	South 35th Street and South Tacoma Way	875	50 (Westbound)	A (6.4)	A (6.5)	1422	71 (Westbound)	B (17.1)	B (17.1)
25	South Wilkeson Street and South Tacoma Way	1211	141 (Northbound)	B (10.3)	B (10.4)	1949	111 (Northbound)	B (13.3)	B (13.4)
26	South Wilkeson Street and South Center Street	1683	71 (Southbound)	B (12.4)	B (12.4)	2248	243 (Southbound)	C (24.1)	C (24.2)
34	East C Street and East 25th Street	435	11 (Southbound)	B (10.8)	B (10.8)	504	53 (Southbound)	A (10.0)	B (10.1)
35	East D Street and East 26th Street	969	273 (Northbound)	A (8.3)	A (8.6)	1291	155 (Northbound)	B (10.7)	B (10.8)
36	East D Street and East 25th Street	616	39 (Southbound)	A (9.8)	A (9.9)	889	264 (Southbound)	B (12.8)	B (13.1)

Notes:
[1]One Southbound *Sounder* commuter train during the peak hour with various blockage times (including gates down & up).
[2] Directional crossing delay is for the peak hour volume crossing the tracks from the upstream intersection only.

As shown in Table 34, AM and PM peak hour intersection operations were relatively unchanged with the addition of Sound Transit *Sounder* trains. In general, average delays per vehicle increased by no more than three-tenths (0.3) of a second and intersection LOS remained the same in all but one location. The Existing Year average delay for the intersection of East C Street and East 25th Street is 10.0 seconds, which is the maximum threshold for an LOS A using HCM metrics for signalized intersections. The Base Year No-Build average delay is 10.1 seconds, which is an LOS B according to the HCM LOS thresholds.

These results indicate that given the assumptions used to determine crossing and intersection delays, estimated AM and PM peak hour intersection performance is not impacted during a *Sounder* revenue or non-revenue train crossing event.

As well as estimating the delays at each crossing, queue lengths were also calculated based on the estimated number of vehicles stopped during a train event. This average number of vehicles stopped was multiplied by an average vehicle length of twenty-five (25) feet to determine an average queue length by direction. Table 35 summarizes the estimated average queue lengths per direction at the rail-crossings modeled in Synchro.

As shown in Table 35, average queue lengths at the rail-crossings during a Sound Transit *Sounder* commuter train event were one-hundred and seventy-five (175) feet or less based on an average vehicle length of 25 feet. As previously noted in the Existing Year conditions summary, some crossings have a higher percentage of heavy vehicles, such as South 35th Street, and queue lengths may, at times, be longer.

Table 35: Base Year No-Build Synchro Queue Length Summary

Crossing Location	Dir	2010 AM Peak Hour[1]				2010 PM Peak Hour[1]			
		Peak Volume	Blockage Time (seconds)	Average Number of Vehicles Stopped	Average Queue Length (feet)[2]	Peak Volume	Blockage Time (seconds)	Average Number of Vehicles Stopped	Average Queue Length (feet)[2]
East D Street	NB	328	70	7	175	202	70	4	100
	SB	56	70	2	50	321	70	7	175
East C Street	NB	202	62	4	100	59	62	2	50
	SB	21	62	1	25	93	62	2	50
South C Street	NB	61	51	1	25	53	51	1	25
	SB	74	51	2	50	129	51	2	50
South Chandler Street	NB	21	52	1	25	21	52	1	25
	SB	15	52	1	25	25	52	1	25
South Alaska Street	NB	13	51	1	25	8	51	1	25
	SB	12	51	1	25	12	51	1	25
South Wilkeson Street	NB	280	50	4	100	238	50	4	100
	SB	166	50	3	75	394	50	6	150
South 35th Street	EB	124	48	2	50	173	48	3	75
	WB	139	48	2	50	193	48	3	75
South 50th Street	EB	30	46	1	25	63	46	1	25
	WB	39	46	1	25	19	46	1	25
South 60th Street	EB	34	61	1	25	32	61	1	25
	WB	20	61	1	25	42	61	1	25

Notes:
[1]One southbound *Sounder* commuter train during the peak hour with various blockage times (including gates down & up).
[2] Assumes average vehicle length is 25 feet.