Portland Multimodal Arterial Performance Management

Implementation Guidance Document

APPENDIX

APPENDIX Contents

Appendix A - Additional Resources

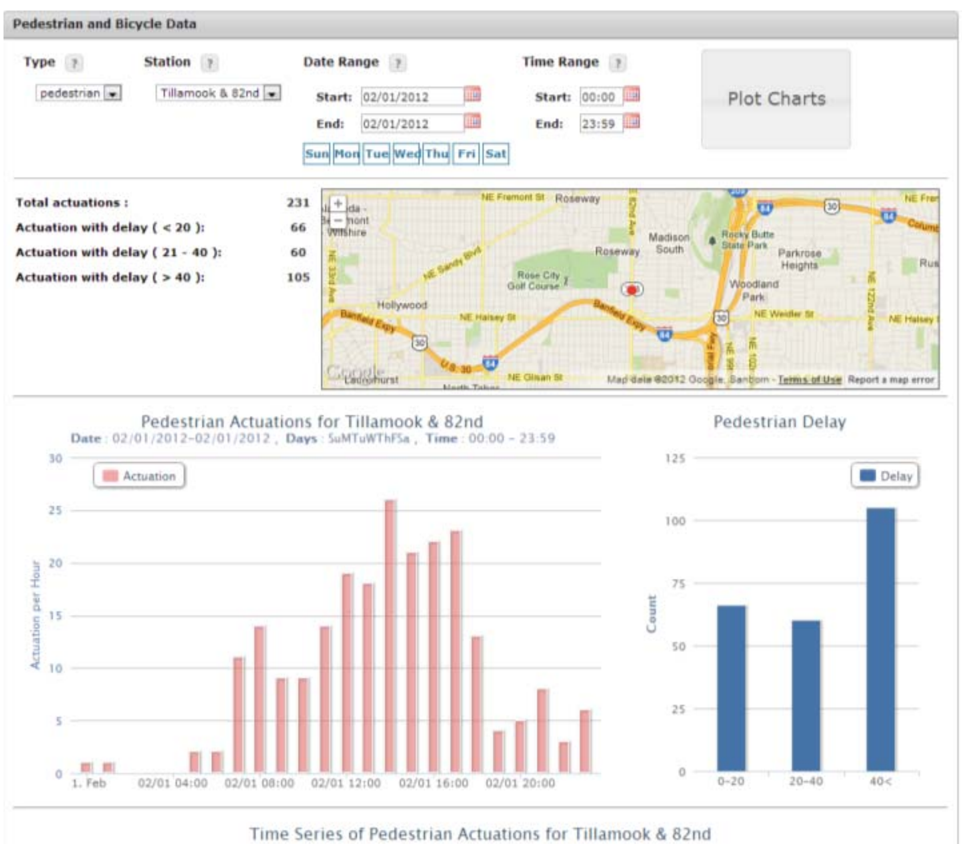
Table 1: Additional Resources

Resource	Relevant Performance Measures		
	Ped/Bike	**Vehicle**	**Other**
Oregon Bicycle and Pedestrian Design Guide (Oregon Highway Design Manual, Appendix N) – ODOT 2011	x		
NACTO Urban Bikeway Design Guide, see "Signal Detection and Actuation" section	x		
ODOT Traffic Signal Loop Layout Examples, Version 01-06	x	x	
ODOT Traffic Signal Design Manual, 2007	x	x	
ODOT Traffic Signal Policy and Guidelines – 2006	x	x	
NWS Voyage Users Guide	x	x	x
"Preliminary Development of Methods to Automatically Gather Bicycle Counts and Pedestrian Delay at Signalized Intersections". Kothuri, S., Reynolds, T., Monsere, C., Koonce, P., Paper 12-2107, *Submitted for presentation at the 91th Annual Meeting of the Transportation Research Board*, Washington, D.C., 2012.	x		
FHWA – Performance Management website http://www.ops.fhwa.dot.gov/perf_measurement/fundamentals/index.htm		x	
FHWA Traffic Monitoring Guide http://www.fhwa.dot.gov/ohim/tmguide/		x	
PeMS website (http://pems.dot.ca.gov/)		x	x
EPA website (http://www.epa.gov/air/emissions/index.htm)			x

Appendix B - PORTAL Status

PORTAL currently collects extensive freeway data and some arterial data. The arterial data includes:

- Bicycle Volumes – hourly bicycle volumes by direction are collected at approximately a dozen intersections.
- Pedestrian Actuations – hourly pedestrian actuations by intersection are collected at six locations (the data is not available by crossing leg).
- Pedestrian Delay – delay is reported at six locations using bins (0-20 seconds, 20-40 seconds, and greater than 40 seconds). The data is for the entire intersection and not by crossing leg.
- Vehicle Volumes and Classifications – hourly volumes are reported at a few dozen arterial intersections. The hourly volumes are reported for all lanes (the volumes are not broken down by lane). No vehicle classifications are currently reported.
- Vehicle Travel Time and Speed – MAC address data is collected and used to calculate travel times and speeds on three arterials via permanent collection stations.
- Transit Measures – TriMet and C-TRAN are both linked to PORTAL. Several transit measures are currently available including: average load, percent on-time, average boardings (TriMet only), total boardings, total alightings (C-Tran only)



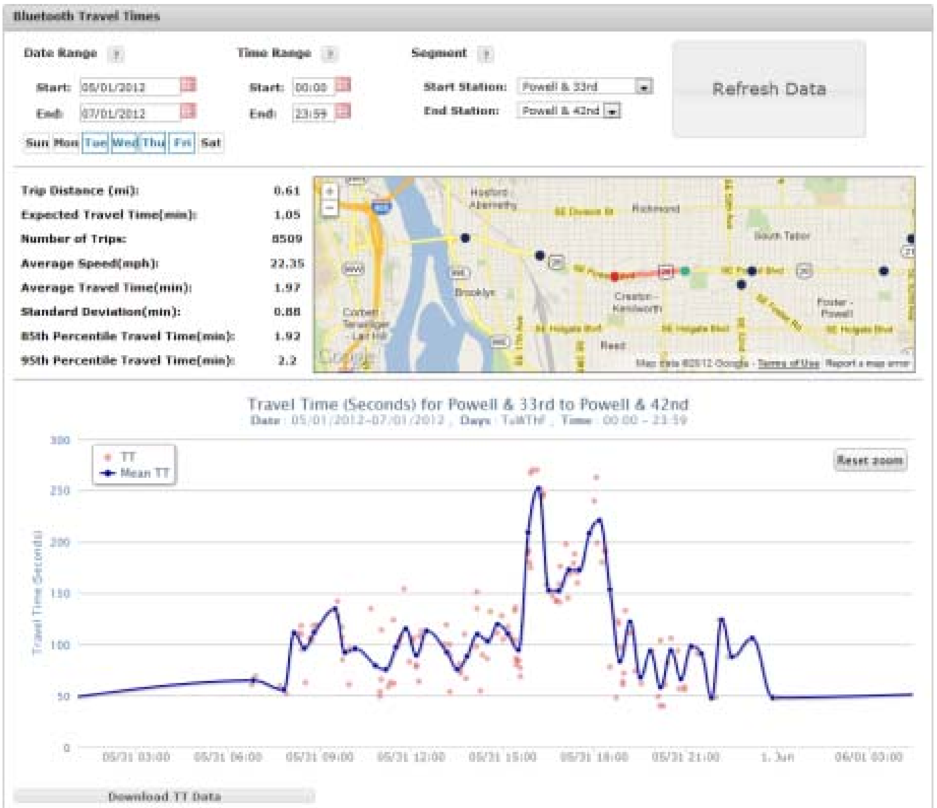


Figure 1: Examples of PORTAL data visualizations

No arterial data is currently collected by PORTAL for the following performance measures:

- Bicycle Delay (disaggregated by approach)
- Vehicle Delay (disaggregated by approach)
- Pedestrian Delay (disaggregated by crossing leg)
- Intersection Operations
- Air Emissions
- Detector Health (although detector health for freeway detectors is currently reported)
- Freight data (classifications)
- Transit data – transit signal priority, AVL travel time and speed data
- Safety data – red light extensions, crash data

Appendix C - Database Fields

Bicycle Volumes (Intersection):

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Date and Time of detection	Date and Time	Timestamp
Aggregated Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	Aggregated count value	Count	Integer
Static Data	Location Description: Street Name A & Street Name B	Location	Text
	Numerical Intersection Number	Intersection ID	SmallInt
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Phase Number	Approach phase	Integer
	Cardinal Direction of Approach (NB,SB,EB,WB)	Approach Direction	Text
	Lane Description (CENTER 1, RIGHT 2 etc.)	Lane	Text
	Last date validated	Date	Timestamp

Bicycle Volumes (Midblock):

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Date and Time of Detection	Date and Time	Timestamp
Aggregated Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt

	Aggregated count value	Count	Integer
Static Data	Numerical Detector Number	Detector ID	Numeric
	Numerical Station Number	Station ID	SmallInt
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Cardinal Direction of Approach (NB,SB,EB,WB)	Approach Direction	Text
	Lane Description (CENTER 1, RIGHT 2 etc.)	Lane	Text
	Last date validated	Date	Timestamp

Pedestrian Actuations:

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Push Button Number	Push Button ID Number	Integer
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Number of pedestrian actuations in the Collection Interval	Number of Actuations	Integer
Static Data	Numerical Push Button Number	Push Button ID Number	Integer
	Numerical Intersection Number	Intersection ID	SmallInt
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Cardinal direction of the crossing leg of the intersection. (N, E, S, W)	Crossing leg	Text
	Phase Number	Crossing phase	Integer
	Data Collection Interval in Seconds	Collection Interval	SmallInt

Pedestrian Delay:

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Push Button Number	Push Button ID Number	Integer
	Time of actuation of push button	Time of Actuation	Timestamp
Aggregated Data	Numerical Push Button Number	Push Button ID Number	Integer
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	Delay in Seconds	Aggregated Delay	SmallInt
Static Data	Numerical Push Button Number	Push Button ID Number	Integer
	Numerical Intersection Number	Intersection ID	SmallInt
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Cardinal direction of the crossing leg of the intersection. (N, E, S, W)	Crossing leg	Text
	Phase Number	Crossing phase	Integer
	Time of walk indication by phase	Walk Time	Timestamp

Bicycle Delay:

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Date and Time of detection	Date and Time	Timestamp
	Time of first vehicle detection	First Detection Time	Timestamp
	Time at start of green phase (for bicycles)	Green Phase Start	Timestamp
Aggregated Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp

Data Type	Description	Attribute Alias	Attribute Type
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	Delay in Seconds	Aggregated Delay	SmallInt
Static Data	Numerical Detector Number	Detector ID	Numeric
	Numerical Intersection Number	Intersection ID	SmallInt
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Phase Number	Phase	Integer
	Cardinal Direction of Approach (NB,SB,EB,WB)	Approach Direction	Text

Vehicle Volumes and Classification (Intersection):

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Date and Time of detection	Date and Time	Timestamp
	Number of axles	Number of axle	Integer
	Length of vehicle in feet	Vehicle Length	Integer
	Speed of vehicle in miles per hour	Vehicle Speed	Numeric
	Length based vehicle class definition	Vehicle classification	Text
Aggregated Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	FHWA vehicle class definition	Vehicle Classification	Text
	Delay in Seconds	Total Count	SmallInt
Static data	Numerical Detector Number	Detector ID	Numeric

Data Type	Description	Attribute Alias	Attribute Type
	Numerical Intersection Number	Intersection ID	SmallInt
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Cardinal Direction of Approach (NB,SB,EB,WB)	Approach Direction	Text
	Phase Number	Phase	Integer
	Number of lanes by phase	Number of Lanes	Integer

Vehicle Volumes and Classification (Midblock):

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Date and Time of detection	Date and Time	Timestamp
	Number of axles	number of axles on vehicle	Integer
	Length of vehicle in feet	Vehicle Length	Integer
	Speed of vehicle in miles per hour	Vehicle Speed	Numeric
	Length based vehicle class definition	Vehicle classification	Text
Aggregated Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	FHWA vehicle class definition	Vehicle Classification	Text
	Delay in Seconds	Total Count	SmallInt
Static Data	Numerical Detector Number	Detector ID	Numeric
	Numerical Station ID	Station ID	SmallInt
	Last date validated	Date	Timestamp

Data Type	Description	Attribute Alias	Attribute Type
	Lane Description (CENTER 1, RIGHT 2 etc.)	Lane	Text
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Cardinal Direction of Approach (NB,SB,EB,WB)	Approach Direction	Text

Vehicle Travel Time and Speed (per vehicle):

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Date and Time of detection	Date and Time	Timestamp
	Vehicle speed over Point detectors (raw data) mph	Vehicle Speed	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	Vehicle Speed Class	Vehicle Speed Class	Text
	Total Count	Total Count	SmallInt
Aggregated Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	Vehicle Speed Class	Vehicle Speed Class	Text
	Total Count	Total Count	SmallInt
Static data	Numerical Detector Number	Detector ID	Numeric
	Numerical Station Number	Station ID	SmallInt
	Last date validated	Date	Timestamp
	Lane Description (CENTER 1, RIGHT 2 etc.)	Lane	Text

Data Type	Description	Attribute Alias	Attribute Type
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Cardinal Direction of Approach (NB,SB,EB,WB)	Approach Direction	Text

Vehicle Travel Time and Speed (Travel Time):

Data Type	Description	Attribute Alias	Attribute Type
Raw	Numerical Segment Number	Segment ID	SmallInt
	Time as vehicle passes beginning of segment	Time as vehicle passes Point 1	time
	Time as vehicle passes end of segment	Time as vehicle passes Point 2	time
Aggregated Data	Numerical Segment Number	Segment ID	SmallInt
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Average Travel Time in Seconds	Travel Time	Integer
Static data	Numerical Segment Number	Segment ID	SmallInt
	Last date validated	Date	Timestamp
	Location Description: Street Name A & Street Name B	From Location	Text
	Location Description: Street Name A & Street Name B	To Location	Text
	Main Street Name (from Street A to Street B)	Segment Name	Text
	Latitude of the end of segment	From Latitude and Longitude	Float
	Longitude of the end of segment	To Latitude and Longitude	Float
	Longitude of the end of segment	Segment Length	Float

Vehicle Delay:

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Date and Time of detection	Date and Time	Timestamp
	Time of first vehicle detection	First Detection Time	time
	Time at start of green phase (for bicycles)	Green Phase Start	time
Aggregated Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Data Collection Interval in Seconds	Collection Interval	SmallInt
	Delay in Seconds	Aggregated Delay	SmallInt
Static Data	Numerical Detector Number	Detector ID	Numeric
	Numerical Intersection Number	Intersection ID	SmallInt
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Phase Number	Phase	Integer
	Cardinal Direction of Approach (NB,SB,EB,WB)	Approach Direction	Text

Intersection Operations:

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Intersection Number	Intersection ID	SmallInt
	Calendar Date and time of data collection.	Date and Time	Timestamp
	Phase Number	Phase Number	Integer
	Green time in Seconds	Green Time	Integer
	Number of gap outs	Gap Out	Integer
	Number of max outs	Max Out	Integer
	Number of force offs	Force Off	Integer
	Vehicles entering intersection in last half of yellow or red clearance	Vehicles on Red	Integer
	Percent arrival on green by cycle	Percent Arrival on Green	Float
Static Data	Numerical Intersection Number	Intersection ID	SmallInt
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text
	Cardinal Direction of Approach by Phase Number (NB,SB,EB,WB)	Approach Direction	Text

Air Emissions (AQI Components and AQI Index):

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Station Number	Station ID	Integer
	Particulate Pollution µg/m3	Particulate	Float
	Ground Level Ozone (O_3) PPM	Ozone	Float
	Carbon Monoxide (CO) PPM	Cargo Monoxide	Float
	Sulfur Dioxide (SO_2) ppm	Sulfur Dioxide	Float

Data Type	Description	Attribute Alias	Attribute Type
Aggregated Data	Numerical Station Number	Station ID	Integer
	Calendar Date and time of data collection.	Date and Time	Timestamp
	AQI is an index for degree of pollution and takes a value from 0 to 500	Air Quality Index (AQI)	Integer

Air Emissions (Greenhouse gases):

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Station Number	Station ID	Integer
	CO_2 Mixing Ratio	Mixing Ratio	Float
	Methane (CH_4) PPM	Methane	Float
	Hydrofluorocarbon (HFC) PPM	Hydrofluorocarbon	Float

Detector Health:

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Detector Number	Detector ID	Numeric
	Calendar Date and time of data collection.	Date and Time	Timestamp
	“active” or “inactive”	Detector Health	Text
	Error options: no data, high value, low value, constant, line down, controller down, etc.	Suspected Error if Inactive	Text
Static Data	Numerical Detector Number	Detector ID	Numeric
	Numerical Intersection Number	Intersection ID	SmallInt
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g: (45.520714, -122.679626)	Latitude and Longitude	Point
	Location Description: Street Name A & Street Name B	Location	Text

Data Type	Description	Attribute Alias	Attribute Type
	Street Name A/Street Name B	Intersection name	Text
	Numerical Intersection Number	Intersection ID	SmallInt

Transit Measures:

Data Type	Description	Attribute Alias	Attribute Type
Raw Data	Numerical Stop ID	Location/Stop ID	Integer
	Route Number	Route Number	Integer
	Route Direction (inbound, outbound etc.)	Route Direction	Text
	Vehicle Number	Vehicle Number	Integer
	Time of arrival at bus stop	Time of arrival	Timestamp
	Time of departure at bus stop	Time of departure	Timestamp
	Number of passengers boarding at bus stop	Passengers boarding	Integer
	Number of passengers alighting at bus stop	Passengers alighting	Integer
	Maximum speed since previous stop	Maximum Speed Since Previous Stop	Numeric
Static Data	Numerical Stop ID	Location/Stop ID	Integer
	Last date validated	Date	Timestamp
	Latitude and Longitude of the intersection. e.g.: (45.520714, -122.679626)	Latitude and Longitude	Point
	Name of the Stop	Stop Name	Text

Appendix D – Performance Measure Objectives and Criteria Memorandum

Final Memorandum

DATE: April 18, 2012

TO: Amy Mastraccio-Lopez, ODOT
Deena Platman, Metro

FROM: Jim Peters, PE, PTOE, DKS Associates
Jennifer Bachman, DKS Associates

SUBJECT: **Objectives and Criteria Memorandum** P06287-017

This memorandum presents potential multimodal arterial performance measures that can be used to:

- Facilitate the transportation choices of travelers
- Improve operations of the system by transportation managers (especially for considering the multimodal environment)
- Enhance emergency response by public safety officials
- Inform transportation modeling tools
- Support investment decisions

The project seeks to identify transportation-related performance measures that can be automated using technology to collect the information. The list of performance measures identified in this memorandum is intended to be a comprehensive list that can be used to define how well an arterial is performing; therefore, some of the measures identified in Tables 1 through 4 may require manual data collection. Future tasks in this project will group the measures based on our ability to automatically collect data to generate the performance measure.

PERFORMANCE MEASURES

Tables 1 through 4 list the draft performance measures organized by mode. Within each table the performance measures are grouped by category. Based on stakeholder input the priority of each category is indicated.

Table 1: Pedestrian and Bicycle Performance Measures

	Category	Performance Measures	Importance
Pedestrian and Bicycle	Volumes	Bicycle volumes	High
		Pedestrian crossing volumes at intersections	
		Pedestrian crossing volumes at mid-block locations	
	Mode split	Percent trips by bicycle	High
		Percent trips by walking	
		Combined percent of trips by walking and bicycling	
	Safety	Number/severity of incidents involving pedestrians or bicyclists	High
		Number of fatalities involving pedestrians or bicyclists	
		Posted speed of adjacent roadway	
	Perceived safety/comfort	Posted speed of adjacent roadway	High
		Separation distance between vehicles and sidewalk for bicycle facility	
		Vehicle classifications adjacent to sidewalk or bicycle facility	
		Conflicting vehicle turning movements	
	Delay	Bicycle delay	Medium
		Pedestrian delay	
	Level of service	Multimodal LOS (MMLOS)	Low
	Intersection Operations	Percent of pedestrians able to cross within the allotted FDW time	Low
	Facility	Miles of multi-use path	Low
		Miles of bikeways (bike lanes or bike boulevards)	
		Miles of sidewalks	

Table 2: Transit Performance Measures

	Category	Performance Measures	Importance
Transit	Travel time and speed	Average travel time	High
		Average segment speed between stops for transit	
		Comparison of auto to transit travel time	
	Travel time reliability	Percent on-time arrival	High
		Travel time reliability	
		Actual to scheduled headway adherence	
	Delay	Transit delay	Medium
		Average duration of transit signal priority time	
		Number of transit signal priority (TSP) requests to number of TSP requests served	
		Bus dwell time	
	Volumes	Passenger throughput	Medium
		Passenger miles	
		Number of boardings and alightings	
		Transit occupancy	
	Mode split	Percent of trips by transit	Medium
	Safety/Incident response	Number/rate/severity of collisions involving transit vehicles	Medium
		Duration of transit incidents	
		Time to clear transit related incidents	
	Accessibility	Walking distance to transit stop	Medium

Table 3: Auto and Freight Performance Measures

	Category	Performance Measures	Importance
Auto and Freight	Travel time and speed	Average travel time for autos	High
		Average segment speed for autos	
		Average travel time for freight	
		Average segment speed for freight	
		Origin and destination data	
	Travel time reliability	Freight travel time reliability	High
		Travel time index (actual/free flow speed)	
		Buffer time index (95%-avg)/avg	
		Planning time index (95%/FFS)	
		Travel time index 80th percentile	
	Delay	Vehicle delay	High
		Person delay	
		Freight delay	
		Auto number of stops on a segment	
		Freight number of stops on a segment	
		Delay due to railroads crossing arterials	
		Delay cost to freight (time value of cargo)	
	Safety/Incident response	Incident number/rate	High
		Incident duration	
		Incident clearance time	
		Incident response time	
		Rate/number of primary collisions	
		Rate/number of secondary collisions	
		Rate/number of fatalities	
		Rate/number of injuries	
		Rate/number of PDO	

	Intersection operations	Vehicle queue lengths	High
		Percent arrival on green	
		Percent of cycle failures	
		Green time effectiveness (gap out vs max out or force off)	
		Movement delay	
		Volume to capacity ratio (v/c)	
		Level of service	
		Real-time arterial capacity	
		Density	
		Turn movement counts	
	Volumes	Vehicle throughput	High
		Freight throughput	
	Environment/Air emissions	Vehicle miles traveled (VMT)	Medium
		Vehicle hours traveled (VHT)	
		Percent of drive alone trips	
		Greenhouse gas emissions	
		Particulate emissions	
		Fuel consumption	
	Extent of congestion	Congested Travel (congested miles x vehicle volume)	Medium
		Congested Roadway (miles)	
	On-Street parking	Parking utilization	Low

Table 4: Agency Performance Measures

	Category	Performance Measures	Importance
Agency Performance	Detector health	Percent of working vehicle detection	High
		Percent of working bicycle detection	
		Average time to fix non-working detection	
	Traffic signals	Average time to fix an intersection in flash mode	High
		Percent of working transit signal priority intersections	
		Percent of traffic signals retimed within the past 10 years	
	Other equipment	Percent of working communications	Medium
		Average time to repair equipment failures	
	Staff	Ratio of staff to equipment needs	Medium
	Customer satisfaction	Percent of population highly satisfied or satisfied with travel conditions	Low
		Number/type of calls to 511 or transit advisory phone	
		Number/types of hits on traveler information website	

Appendix E - Technical Overview Memorandum

Final Memorandum

DATE: April 18, 2012

TO: Amy Mastraccio-Lopez, ODOT
Deena Platman, Metro

FROM: Jim Peters, PE, PTOE, DKS Associates
Jennifer Bachman, DKS Associates

SUBJECT: **DRAFT Technology Overview Memorandum** P06287-017

This memorandum presents technology options that may be used to collect data for arterial performance measures. While there are several performance measures that can be obtained through manual data collection, this project seeks to automate data collection for performance measures where possible. Therefore, the technologies listed in this memorandum focus on the performance measures that can be automated.

TECHNOLOGY OPTIONS

Table 2 lists the draft technologies organized by transportation mode (auto/freight, bicycle/pedestrian, and transit), and includes the data it is capable of obtaining, a brief explanation of how the technology works, where the technology is applicable (e.g. intersection, mid-block or area wide), and the approximate capital and annual operations and maintenance cost. The capital cost estimates assume communications infrastructure already exists.

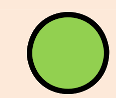
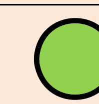
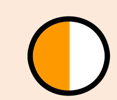
Each technology is ranked according to how widely used it currently is on arterials in the Portland region, and the level of effort it would take to install the technology if the technology is not widely used. The key is provided below in Table 1.

Table 1: Key

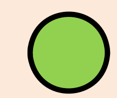
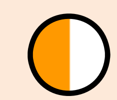
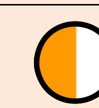
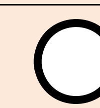
How widely used is the technology on arterial roadways in the Portland Region?	If not widely used, what is the level of effort required to add the technology?[1]
Widely installed across the region	Easy to install (minimal labor and/or disruption to roadway system)
Some installation across the region	Medium (increased labor effort and/or more disruption to the roadway system)
No installation across the region	Hard (high level of labor and/or prolonged disruption to the roadway system)

[1] The level of effort assumes that the corridor already has communication infrastructure, such as Ethernet, to transport the data back to a center. The level of effort estimate focuses on factors including construction complexity, the ability for the technology to work with existing systems, and the complexity of software required to convert the data into useful information.

Table 2: DRAFT Technology Overview

Technology	Data Capabilities	Explanation	Where is it applicable? Inter-Sections	Mid-Block	Area Wide	How widely used is the technology on arterial roadways in the Portland Region?	If not widely used, how easy is it to add the technology?[2]	Feasibility Cost (capital/ annual O&M)[3]
				Auto/Freight				
Inductive Loops	• Volume • Speed • Occupancy • Arrival on green • Phase extensions • Vehicle classification • Queue length • Headway • Density • Turning volume • Signal cycle failure • Incident detection	Electromagnetic loops embedded in pavement detect the presence of vehicles as they pass over the loops.	X	X			n/a	$7,500 to $13,300 per intersection with 4 approaches About $1,000 annual O&M
Video	• same as inductive loops	Video cameras (when installed) are typically mounted to traffic signal mast arms.	X	X				$5,000 to $10,000 per camera plus $10,000 for installation About $1,000 to $2,000 annual O&M
Radar	• same as inductive loops, excluding queue length	Radar detectors are typically installed near intersections, but far enough away to collect accurate speed measurements.	X	X				$5,000 per device plus $10,000 per installation About $1,000 annual O&M per intersection
Tube Detectors	• Volume • Speed • Vehicle classification	Tubes are manually placed across traffic lanes and record as vehicles pass over.		X				$1,000 to $2,000 per location[4]

[2] Assumptions include that the corridor is equipped with full Ethernet communication infrastructure
[3] Costs (unless otherwise noted) are from the US DOT Research and Innovative Technology Administration (RITA)
[4] Source: recent Portland area projects

Technology	Data Capabilities	Explanation	Where is it applicable? Inter-Sections	Mid-Block	Area Wide	How widely used is the technology on arterial roadways in the Portland Region?	If not widely used, how easy is it to add the technology?[2]	Feasibility Cost (capital/ annual O&M)[3]
Traffic Signal Software	• Arrival on green • Green splits • Cycle lengths • Intersection LOS • Turn movement counts • Queue detection • Movement delay • Signal phase max out	Traffic signals collect a substantial amount of data at intersections. The local software and central software can turn this data into useful information.	X		X		n/a	$2,000 to $5,000 per new traffic signal installation Additional cost to enhance software for added data capabilities ($5,000 to $10,000)
Opticom Logs	• Preemption data	Opticom detectors are located on traffic signal mast arms. Emergency vehicles signal Opticom detectors to enable signal preemption. Transit vehicles use Opticom to request priority.	X				n/a	$4,000 to $5,000 for the discriminator or $15,000 for complete installation $500 to $2,000 per vehicle
Bluetooth Sensors	• Travel times • Origin-Destination (O-D) patterns	Devices record unique identifiers and software converts this data to travel times or O-D information.	X	X				$5,000 per location[5]
SMART-SIGNAL System in Minnesota	• Queue lengths • LOS • Delay • Travel times	Algorithm uses real time traffic signal information and models current arterial conditions.			X			Cost data to come
GPS Technology	• Speed • Travel time • O-D • Tracking mileage	Tracks individual device locations.			X			Varies Contract with a private vendor would likely be required.
Vehicle Tags	• Mileage tracking • Volumes • O-D patterns	Similar to toll collection, a roadside device reads a vehicle tag as it passes.	X	X				$40,000 to $80,000 for software $2,000 to $4,000 per tag reader

[5] Per Portland area projects

Technology	Data Capabilities	Explanation	Where is it applicable? Inter-Sections	Mid-Block	Area Wide	How widely used is the technology on arterial roadways in the Portland Region?	If not widely used, how easy is it to add the technology?[2]	Feasibility Cost (capital/ annual O&M)[3]
License Plate Matching	• O-D patterns • Travel time • Average speed	Video is used to match license plates traveling along roadways. Cameras could be placed at intersections or mid-block	X	X		▭	○	$5,000 to $10,000 for the software $6,000 to $8,000 per high speed camera
In-Vehicle Communication Devices	• Incident reporting	In-vehicle devices that automatically communicate to a central hub (such as OnStar)			X	▭	◐	Private sector investment
Magnetometer Detection System	• Travel times • Volume • Occupancy • Speed	Magnetic sensors in the roadway detect vehicles and relay the data via wireless communications.	X	X		▭	◐	$20,000 per intersection assuming 2 lanes per approach
Piezoelectric Sensors	• Classification • Speed • Volumes	Pressure sensors in the pavement detect vehicles.	X	X		▭	◐	$10,000 per intersection assuming 2 lanes per approach [6] About $1,000 annual O&M assuming a 10 year lifespan for the devices
Connected Vehicle (FHWA)	• Travel time • Environmental conditions (roadway and weather) • Incident information • Vehicle presence • Speed	Supports communication between vehicles and infrastructure or hand held devices.			X	▭	○	Cost not yet available
Private sector data collection and processing company	• Real-time traffic information • Delay • Incident/Construction information	The private sector is collecting a range of roadway condition information. This information is available to purchase in many locations.			X	▭	◐	Varies depending on level of data requested Annual contracts could range from $10,000 to $500,000

[6] A Summary of Vehicle Detection and Surveillance Technologies Used in Intelligent Transportation Systems. Funded by the Federal Highway Administration's Intelligent Transportation Systems Joint Program Office. Fall 2000.

Technology	Data Capabilities	Explanation	Where is it applicable? Inter-Sections	Mid-Block	Area Wide	How widely used is the technology on arterial roadways in the Portland Region?	If not widely used, how easy is it to add the technology?[2]	Feasibility Cost (capital/ annual O&M)[3]
Environmental Sensors	• Air quality • Emissions	Sensors collect air quality information	X	X				$25,000 to $42,000 per device About $2,000 to $3,000 O&M
Weather Station	• Pavement temperature • Moisture content in roadway • Precipitation sensor • Wind sensor • Visibility sensor	Measures environmental conditions at a specific site.	X	X				$25,000 to $42,000 per device About $2,000 to $3,000 O&M
Emergency Call Center (911) Data	• Incident statistics	Includes information on crash location, duration of incident, severity, time to respond, and time to clear. In Deschutes County a project is underway to connect the Computer Aided Dispatch system of 911 call centers and ODOT State Dispatch Centers, which will enhance the capabilities to share information and add other partners to the system.			X			$50,000 to $100,000 to integrate call center data to an automated database
Parking Entrance and Exit Ramp Detection	• Parking lot occupancy	Detects vehicles entering and exiting a parking facility so that real-time parking occupancy is known.			X			$2,000 per installation $300 annual O&M
Parking Stall Detection	• Parking stall occupancy	Detects whether a parking stall is occupied.			X			Varies on the size of the parking facility. Cost to be determined.
				Bike/Pedestrian				
Pedestrian push button	• Pedestrian delay • Number of pedestrian actuations	Existing pedestrian pushbuttons can be used to measure pedestrian delay, and evaluate frequency of pedestrians at a crossing.	X				n/a	$500 to $1,000 per device if installed with a traffic signal $5,000 if installed later on a separate pole

Technology	Data Capabilities	Explanation	Where is it applicable? Inter-Sections	Mid-Block	Area Wide	How widely used is the technology on arterial roadways in the Portland Region?	If not widely used, how easy is it to add the technology?[2]	Feasibility Cost (capital/ annual O&M)[3]
Inductive Loops	• Bicycle volumes • Bicycle speeds • Bicycle delay	Electromagnetic loops embedded in pavement detect the presence of bicycles as they pass over the loops.	X					$1,000 per loop (material and installation)
Video	• Bicycle volumes • Pedestrian volumes	Video cameras (when installed) are typically mounted to traffic signal mast arms.	X	X				$8,000 to $16,000 per camera About $1,000 to $2,000 O&M
Infrared Detectors	• Bicycle volumes • Pedestrian volumes	Infrared sensors detect each time a pedestrian or bicyclist passes.	X					$400 per device
Pressure sensor	• Pedestrian volume	An underground sensor detects micro-variations in pressure.	X					$1,000 to $5,000 per location About $500 annual O&M
Magnetometer detection system	• Bicycle volumes • Bicycle detection	Wireless detectors used to detect bicycles in the roadway.	X					$20,000 per intersection
				Transit				
Transit priority logs	• Transit delay	Traffic signal controllers can measure transit delay where transit priority capability exists.			X		n/a	$200 to $400 per preemption processor $10,000 for annual software fees.
Automatic Vehicle Location (AVL)	• Dwell times • Max speeds • Average speed • On-time arrivals • Transit travel times • Run time variability • Headway adherence	Automatically relays a transit vehicle's location.			X		n/a	$400 to $2,000 per device $10,000 for annual software fees.
Automatic Passenger Counter	• Passenger volumes (boarding and aligning per stop) • Passenger miles • Load to capacity	Automatically counts passengers as they board and alight.			X		n/a	$800 to $8,000 (depending whether it is an add on to an existing system or a standalone installation)

Technology	**Data Capabilities**	**Explanation**	**Where is it applicable?**			**How widely used is the technology on arterial roadways in the Portland Region?**	**If not widely used, how easy is it to add the technology?[2]**	**Feasibility Cost (capital/ annual O&M)[3]**
			Inter-Sections	**Mid-Block**	**Area Wide**			
Electronic Fare Collection	• Passenger volume • Passenger miles	Enables passengers to use electronic means (smart card, phone, or other device) to pay transit fare.			X			$500 to $1,000 per installation

Appendix F – Annotated Bibliography Memorandum

Final Memorandum

DATE: April 18, 2012

TO: Amy Mastraccio-Lopez, ODOT
Deena Platman, Metro

FROM: Jim Peters, PE, PTOE, DKS Associates
Jennifer Bachman, DKS Associates

SUBJECT: **DRAFT Annotated Bibliography Memorandum** P06287-017

This memorandum presents resources related to arterial multimodal performance measurement. The first section summarizes documents that identify general arterial performance measure resources and applications, the second section summarizes experiences from other agencies using technologies for arterial performance measurement, and the third section summarizes FHWA's Connected Vehicle program.

Table of Contents

GENERAL ARTERIAL PERFORMANCE MEASURE RESOURCES AND APPLICATIONS

The following resources provide general information and guidance about potential multimodal arterial performance measures and applications to automatically collect these measures.

"A Framework for Multimodal Arterial Data Archiving". Olson C., Kothuri, S., Monsere, C., Koonce, P., Tufte, K., Paper 12-1750, *Submitted for presentation at 91st Annual Meeting of the Transportation Research Board*, Washington, D.C., 2012.
This paper discusses the importance and complexity of collecting performance measures along arterials. It describes how PORTAL is the main data archive for freeway data in the Portland region, and how they plan to mirror the framework of PORTAL for arterial data.

Existing Portland data sources:

- Vehicle detectors – installed along major arterials, information is stored in 1 minute increments (counts, speeds, and occupancies)
- Bluetooth detector – installed along segments of some major arterials (travel times, speeds, origin-destination patterns)
- Intersection phase timing
- Transit stop-level data –Automatic Vehicle Location and Automatic Passenger Counters installed on TriMet buses. Data collected includes arrival and departure times, dwell times, max speeds, number of boardings and alightings.
- Bicycle count detector – installed on some bike facilities (count, and phase extensions)
- Pedestrian delay detector – uses transit priority logging to determine average time differentials between push button actuations and the walk phase.

NCHRP Report 664 Measuring Transportation Network Performance. Transportation Research Board. July 2010
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_664.pdf
This resource is a guidebook that provides methods for jurisdictions to monitor multimodal transportation networks. Chapters 2 and 3 provide general guidelines for establishing regional multimodal performance measures and how performance measures can be used to help MPOs address broader considerations in the planning processes. Table 3.1 lists core performance measures used by the MPO for the Albany, New York region and includes both qualitative and quantitative measures:

Transportation Service

- **Access:** What travel alternatives exist? (% of person trips within a defined non-auto (walk, bike, transit) to auto time difference; % of person trips with a travel time advantage for non-drive-alone modes (including carpools); # or % of major freight movements with modal alternatives)
- **Accessibility:** How much time does travel take? (travel time between representative locations, including major intermodal facilities; peak vs. non-peak, by quickest mode)
- **Congestion:** What is the level of exposure to traffic congestion? (excess delay: recurring, non-recurring by mode [auto, transit, freight, bike, pedestrian])

- **Flexibility:** Can the system respond to unexpected conditions? (reserve capacity on system; percent of person trips that could be accommodated by modes other than auto in an emergency; # of corridors with reasonable alternatives during closure or disruption; amount of risk associated with fixed capacity investment7)

Resource Requirements

- **Safety:** What are the safety costs associated with transportation? (estimated societal cost of transportation accidents)
- **Energy:** How much energy is consumed in providing, maintaining and using the transportation system? (equivalent gallons of fuel/day for transportation capital, maintenance, operation and use)
- **Economic Cost:** How much does the transportation system and its use cost, in addition to safety and energy costs? (Annualized capital, maintenance, operating and [monetary] user costs for transportation system; value of commercial time in travel)

External Effects

- **Air Quality:** What is the effect of the transportation system on air quality? (Daily emission levels (HC and NOx); air quality attainment status)
- **Land Use:** How does the transportation system affect land use? (Amount of open space; dislocation of existing residences and businesses; land use - transportation compatibility index; community quality of life measure)
- **Environmental:** How does the transportation system affect important environmental features? (Impacts on sensitive areas [wetlands, parklands, historic areas, archaeological sites); noise exposure index])
- **Economic:** How does the transportation system support the economic health of the region? (Narrative discussion of economic-activity supporting or constraining features of transportation system)

This guidebook emphasizes cooperation (partnerships) between agencies and how agreement between agencies in a region needs to be reached before effective performance measures can be collected.

This resource also discusses other regions that use multimodal performance measures. That information is discussed in the following section.

NCHRP Report 618 Cost Effective Performance Measures for Travel Time Delay, Variation, and Reliability

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_618.pdf

This report emphasizes the importance of collecting performance measures in order to direct transportation investments. The authors indicate that most agencies face challenges in collecting accurate and system wide performance measurement data. This report highlights three key performance measurement areas: **travel time, delay/mobility, and reliability**. Within each category there are multiple performance measurements to choose from depending on the specific corridor and agency needs.

Chapters 2 and 3 of this report focus on the array of performance measures and methods for data collection and processing. The guidebook lists several **things to consider before selecting the appropriate performance measures** such as: goals and objectives, audience, travel modes, accuracy of data, applicable to existing and future conditions, applicable to different geographic areas and levels, and cost effective means of collecting data.

Congestion is summarized using four components: duration, extent, intensity, and variation. Mobility is summarized using time, location, level, and reliability. Combining those components, exhibit 2.4 lists several quantitative measures to consider:

- Delay per traveler
- Travel time
- Travel time index
- Buffer index
- Planning time index
- Total delay
- Congested travel
- Percent of congested travel
- Congested roadway
- Accessibility.

Exhibit 2.5 lists each of the performance measures (as well as percent on-time arrival, and misery index) and shows which congestion component and geographic level are addressed by each. Exhibits 2.6 and 2.7 show a matrix of the performance measures that are desirable for different analysis areas (individual locations to regional networks) and for uses of mobility and reliability measures (for example land development impact or prioritization of improvements).

"Preliminary Development of Methods to Automatically Gather Bicycle Counts and Pedestrian Delay at Signalized Intersections". Kothuri, S., Reynolds, T., Monsere, C., Koonce, P., *Paper 12-46 2107, Submitted for presentation at the 91th Annual Meeting of the Transportation Research Board*, 47 Washington, D.C., 2012.

This paper reviews methods of collecting **bicycle counts and pedestrian counts and delay**. Three locations with either 170 or 2070 controllers in Portland were chosen as test sites for bicycle counts. The counts were manually downloaded from controllers, but in the future the software will link directly to PORTAL. In general the counts from inductive loops were slightly lower than manual counts.

Two methods are investigated to determine pedestrian delay; both methods rely on the pedestrian push button actuations. One method is transit priority logging which logs the pedestrian actuation as a transit priority call and then measures the time between the call and the relevant pedestrian phase (some internal logic is reassigned to orchestrate this method). The other method discussed is volume bin logging.

US DOT Integrated Corridor Management (ICM) Initiative: ICM Surveillance and Detection Needs Analysis for the Arterial Data Gap. US DOT, Federal Highway Administration, Federal Transit Administration, and Research and Innovative Technology Administration. FHWA-JPO-09-067 EDL 14499. November 2008.

This document examines how to effectively implement an Integrated Corridor Management System (ICMS) on arterials, and what data is required to support and manage such a system. Four key strategy areas include:

1. Demand management: addresses the patterns of usage of the transportation networks
2. Load balancing: addresses operating each network to its maximum effectiveness
3. Event response: addresses the response to events based on their duration
4. Capital improvement: addresses the need for improvements to corridor facilities

The document indicates that there is not a strong consensus about what data is needed from arterials to produce an effective ICM strategy. The data needs and performance measures vary considerably based on the individual strategies, infrastructure, participating agencies, types of analysis, modeling, and decision support tools. Typical surveillance currently available includes:

- Transit Monitoring
  - Volume
  - Fare collected
  - Schedule adherence
- Parking Management Monitoring
  - Volume
  - Parking spaces remaining
- Arterial Monitoring
  - Call (vehicle/pedestrian presence)
  - Volume
  - Road segment occupancy and speed
  - Queue length
  - Headway (time difference between beginning of successive vehicle detections)

Traffic signals are a large source of arterial data. This document lists speeds, headway, volume, and road occupancy as a standard arterial data collected by traffic signals. However, difficulties arise when the data is aggregated in large time segments (for example, 15 or 60 minute averages) that destroy the detail required to effectively monitor the system.

By modifying existing signal systems (mostly by adding detection), additional data can be collected. That data includes: speed, volume, and occupancy data, which can be used to calculate headway, density, turning time, queue clearance failure, arrivals on red, segment travel times, and segment functional capacity.

Emerging technologies to gather arterial data include: toll-tag monitoring or vehicle license plate recognition to determine travel times; automatic vehicle location (AVL) devices on transit vehicles to determine travel times; phone probe data to calculate speeds and travel times on arterials; Vehicle Infrastructure Integration (VII)[1]; GPS, and electronic distance-measuring instruments (DMI). The last three technologies listed (VII, GPS, and electronic DMI) all require devices to be placed in passenger vehicles. VII probe data captures information from individual vehicles and broadcasts it to roadside devices. This technology can capture a wide range of information beyond just speed and volume (such as braking, ambient temperature, etc). GPS systems capture detailed arterial information; and electronic DMI could pinpoint areas of delay and include data for fuel consumption and emissions analysis.

[1] Note: The name of the program for *Vehicle Infrastructure Integration (VII)* has been changed and is now called *Connected Vehicle*.

Table 1 – Data Available from Data Collection Approaches

Device	Data Directly Measured	Data Calculated from Measured Values
Inductive Loop Detectors	Vehicle Presence	Speed Volume Occupancy Headway Density Incident detection Vehicle volume arriving on red Turning time Signal cycle failure
Video Imaging	Vehicle Presence Speed Volume	Occupancy Headway Density Incident detection Vehicle volume arriving on red Turning time Signal cycle failure
RADAR/LIDAR	Vehicle Presence Speed Volume Occupancy	Headway Density Incident detection Vehicle volume arriving on red Turning time Signal cycle failure
Automatic License Plate Recognition	Travel Time	Average speed
Cellular Phone tracking	Average speed/segment	Estimated Volume/segment Incident Detection Travel Time
Transit Vehicle AVL	Speed Average speed/segment Travel Time	Schedule adherence
Automatic Vehicle Identification	Vehicle presence Travel time Average speed/segment	Trip origin/destination
Passenger Vehicle Global Positioning System	Speed Average speed/segment Travel Time	Trip origin/destination
Electronic Distance-Measuring Instruments	Average speed/segment	
VII Probe Data	Presence Speed Roadway conditions Weather conditions	Average speed/segment Travel Time

The following table lists devices that can capture arterial information, what the device can directly measure and data that can be calculated from the measures.

Specific performance measures identified by test sites include corridor specific measures:

- Travel time – mean, maximum, buffer, and range
- Vehicle speed
- Travel time delay and predictability
- Incident duration and frequency
- Fuel consumption and savings
- Pollutant emissions and savings

Arterial specific performance measures:

- Arterial speed based on AVL
- Arterial volume and occupancy
- Arterial capacity
- Arterial segment specific measures:
    - Traffic volume
    - Travel speeds
    - Level of service
    - Vehicle miles and vehicles hours traveled
    - Person miles and person hours traveled
    - Number of incidents and incident rate
    - Number of fatalities and fatality rate
    - Number of injuries and injury rate
    - Incident response and incident clearance times

This document also addresses that not all vehicles should be treated equally. High occupancy vehicles and freight should be given a different weighting factor since they represent a more efficient movement of people and goods than a signal occupancy vehicle.

The following Table is from Appendix E and lists arterial data that can be measured, calculated, extrapolated, or desired but not collected.

Table 3 - Analysis, Modeling, and Decision Support Data Needs

	Beginning		End		Intersection		Mid Block		Source		Sink	
	Typical	**ICM**	**Typical**	**ICM**	**Typical**	**ICM**	**Typical**	**ICM**	**Typical**	**ICM**	**Typical**	**ICM**
Volume	M	M	M	M	M	M	E	E	M	M	M	M
Density	C	C	C	C	C	C	C	C	C	C	C	C
Speed	C	C	C	C	C	C	C	C	C	C	C	C
Classification	D	D	D	D	D	D	D	D	D	D	D	D
heading	E	E	E	E	E	E	E	E	E	E	E	E
Queue Length	C	C	C	C	C	C	C	C	D	D	D	D
O-D	E	E	E	E	E	E	E	E	E	E	E	E
Turns	N	N	N	N	M	M	N	N	M	M	M	M
Block Cap	C	C	C	C	C	C	C	C	C	C	C	C
Trip O-D	N	N	N	N	N	N	N	D/E	N	N	N	N
Tolling/Pricing	M	M	M	M	M	M	M	M	M	M	M	M
HC	E	E	E	E	E	E	E	E	E	E	E	E
Nox	E	E	E	E	E	E	E	E	E	E	E	E
PM	E	E	E	E	E	E	E	E	E	E	E	E
O3	E	E	E	E	E	E	E	E	E	E	E	E
Transit Route	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E
Transit Schedule	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E
Priority	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E	M/C/E
Transit Occupancy	M	M	M	M	M	M	M	M	M	M	M	M

D - Desirable Not Collected
M - Measured
C - Calculated
N - None
E - Extrapolated

Measuring the Performance of Automobile Traffic on Urban Streets. Project No. 3-79A. Prepared for National Cooperative Highway Research Program Transportation Research Board of The National Academies. Prepared by Texas Transportation Institute, Texas A&M University in Association with Kittelson & Associates and Purdue University. January 2008.

This research paper addresses techniques to monitor arterial performance measures. The three key criteria they used were:

1) The technique needs to have real-time traffic signal control, traveler information, and incident management applications.
2) The technique should be based on existing sensor or surveillance technology and should use existing infrastructure as much as possible.
3) It should support the measurement of delay, queue length, or running time. From these measurements, other performance measures can be calculated.

This paper concludes that the "signal-based measurement" approach provides the greatest potential to accurately reflect performance measures on arterial streets. This approach measures the delay at a signal and running time of a segment separately, and then uses those values to calculate other measures. Other approaches addressed include "area-wide measurement" and "segment-based measurement".

The four most promising techniques developed (using the "signal-based measurement" approach) include:

- Input-output analysis for delay and queue length measurement (inductive loops for advance detection) – measures vehicle arrivals with signal phase status to estimate through movement queue lengths.
- Hybrid input-output analysis technique for delay and queue length measurement (inductive loops for advance and stop line detection) – measures vehicle arrivals, vehicle departures, and signal phase status to estimate through movement queue lengths
- Non-intrusive detection for delay and queue length measurement (video detection)
- Traffic flow characteristics for running time measurement – measures vehicle occupancy at a mid-segment location which is used to estimate running speed.

This document summarizes several performance measures desirable for urban streets and whether the measure is applicable to traffic signal control, traveler information, or incident management:

TABLE 2 Urban street performance measures

Common Measures	Description	Applications[1]		
		TC	TI	IM
Density	Number of vehicles in a traffic lane for a given length of roadway	✔		
Bandwidth efficiency	Ratio of green time window for unstopped through movement along a segment or facility to the cycle length.	✔		
Cycle failure rate	Percent of signal cycles where all vehicles in queue at the start of green do not clear the intersection before the end of the same green.	✔		
Stop rate	Number of stops experienced by a vehicle traversing an intersection approach, a segment, or facility; relative to the count of vehicles.	✔		
Queue length	Average number of vehicles stopped in a lane. At intersections, queue length is expressed as an average per signal cycle.	✔		✔
Volume-to-capacity ratio	Ratio of flow rate to capacity for a point or segment.	✔		✔
Control delay	The delay that results when a traffic control device causes a driver to reduce speed or to stop.	✔		
Travel speed	Segment or facility length divided by travel time (includes control delay, if incurred).	✔	✔	
Total delay	The difference between the travel time experienced by motorists and the travel time that would have been incurred if they traveled at the free-flow speed.	✔	✔	✔
Travel time	Time required to traverse a segment or facility (includes control delay, if incurred).		✔	✔
Travel time reliability	The percent of trips along a highway segment that take no longer than the average travel time plus a certain acceptable additional time.		✔	✔
Incident duration	Time between occurrence of incident and its clearance from the traffic lanes.		✔	✔
Fuel consumption	Gallons of fuel consumed by vehicles while traversing the point, segment, or facility.			✔

Note:
1 - Applications: TC-traffic signal control; TI - traveler information system; IM - incident management.

Several measurement techniques are discussed and listed in Table 3 including queue length, through delay, through lane group delay, incident identification, running time, and travel speed.

AGENCIES USING TECHNOLOGIES FOR PERFORMANCE MEASUREMENT

The following resources summarize performance measures used by specific agencies across the United States.

San Diego Associates of Governments (SANDAG).

http://www.sandag.org/

Recent advances:

- *Regional Arterial Management System (RAMS)* - The San Diego area launched an effort to link local and regional agencies to a common traffic signal system. The goal of this effort is to enhance inter-jurisdictional coordination of traffic signals. RAMS will leverage the existing QuicNet 4+ traffic signal system.
- Inter-modal Transportation Management System (IMTMS) – Eventually RAMS will be merged into the IMTMS. The Regional IMTMS Network will serve as the cornerstone data collection and formatting system for the region. The key roles include: coordinating transportation operations, providing safety agencies access to critical transportation systems, and supplying transportation data to San Diego Region's 511 advanced traveler information system (ATIS).
- *Southern California Intelligent Transportation System Priority Corridor Program* – The San Diego area was designated by Congress as a national ITS demonstration corridor. SANDAG is working to connect communications for the 22 agencies in the San Diego region so that they can work together to improve the efficiency and performance of the transportation system.
- *Regional Traveler Information System* – The first phase involves the region cooperating with private industry partners to provide real-time traveler information for freeways, arterials, transit, and commercial vehicles using traditional media sources. The second phase involves dissemination of real-time information by emerging technologies such as cell phones, cellular Internet, hand held computers, and in-vehicle navigation devices.
- SANDAG publishes an annual performance monitoring report *"State of the Commute"* that includes:
  - **annual hours of traffic delay per traveler (freeway)**
  - **transit ridership – passenger miles, total boardings**
  - **mode splits**
  - **travel times (mostly freeways)**
- The hours of delay information in this report comes from the Performance Measurement System (PeMS Version 10.3) which collects real-time traffic data from detectors in the roadway. At this point most of the data is freeway based. SANDAG plans to expand to arterials, but the expansion is in the very early stages. The transit data comes from the San Diego Metropolitan Transit System.

Per phone conversation with Ellison Alegre, Associate Transportation Planner at SANDAG

- SANDAG uses real-time information to build and calibrate arterial and transit models
- The Performance Measurement System (PeMS) is in the infancy stages of expanding to arterials (APeMS). PeMS is similar to PORTAL for the Portland Region.
- Currently arterial data is collected along six facilities and two methods are used to create the performance measures: Highway Capacity Manual and Vehicle Re-identification (Re-ID). Available metrics include speed, flow (vehicles per hour), and occupancy.

Berkley Transportation Systems, Inc. Arterial Performance Measurement in the Transportation Performance Measurement System (PeMS). Karl Petty and Tiffany Barkley. May 10, 2011
http://www.mtc.ca.gov/services/arterial_operations/downloads/pems_arterials_2011_05_10_v3.pdf

This document presents on overview of PeMS and describes how three cities in California (Los Angeles, Carson, and Chula Vista) are adding arterial information to the database. PeMS is a software system that collects transportation data, computes performance measures, and provides visual representations of the data.

The three key inputs necessary for arterial performance monitoring:

- Topology – what are the streets and where are they. There is not a good single GIS database with all this data yet.
- Sensor information – agencies use different configurations and technologies for detectors. It is up to each agency to get the data to PeMS. Sensors may include inductive loops, video detection, Bluetooth tags reads, Sensys dots, or re-id detectors, just to name a few examples.
- Signal timing information

In Los Angeles the PeMS system can access the following information on select arterials

- Turn movement counts by time of day
- Detector health
- Traffic volumes

In Carson a 1.8 mile arterial with eight signalized intersections was added to PeMS. The existing detection was hard to convert to the data collection needs, so Sensys wireless detectors were installed at each intersection and approaches. Along this arterial, arrival on green and control delay were two performance measures the system was capable of collecting after the detector installation. See reference below for more information.

White Paper - Measuring Arterial Performance for Corridor Management in Carson, CA. Barkley, Tiffany.

This paper describes how Carson used sensors on an arterial roadway to produce real-time performance measures through A-PeMS. The project installed in-road detection (Sensys wireless detectors) along the corridor. A total of 125 were installed and each could collect data with a precision of 1 second. The sensors were places just downstream of the stopbar at every intersection for each lane. This way, the detectors did not register stopped vehicles. In a four locations detectors were also placed midblock to report speeds.

Using data that is continuously collected, A-PeMS calculates performance measures for every 5-minute period throughout the day. Performance measures include volumes, speeds, and travel times, as well as measures calculated using standard HCM methodology and real-time data collection.

The key conclusions of this paper are:

1) Accurate real-time arterial performance measurements can be obtained using only in-road vehicle detection that does not need to interface with the traffic signal system.
2) A-PeMS was used to evaluate before and after comparison of traffic management changes. The performance measures evaluated included intersection and approach control delay, corridor level travel times, and the percentage of arrivals on green.

NCHRP Report 664 Measuring Transportation Network Performance. Transportation Research Board. July 2010

Other regions with arterial performance measurements and multilevel agency coordination:

- Capital District Transportation Committee (CDTC) in Albany NY – includes system reliability, land use compatibility, and a wide range of environmental impacts in its planning process. Measures used by CDTC are listed above in the NCHRP Report 664 description.
- San Diego Association of Governments (SANDAG) – see section above for more information
- Sacramento Area Council of Governments (SACOG)
    - Bicycle and pedestrian funding is awarded using performance measures such as **change in miles of bikeways and sidewalks** and **impact of bicycle and pedestrian investments on air quality and public health**.
- Minnesota Department of Transportation (MnDOT)
    - Using measures to help reduce variations in travel time and improve reliability (**buffer index, max travel times, range of travel times, and percent of late bus routes**). The group includes MnDOT, several municipal governments, and Metro Transit. A data hub for the Integrated Corridor Management System (ICMS) is being developed.[2] The data hub will gather, store and share data and event messages from other ICMS systems. Enhancements to the system will include

[2] Additional information from: Minnesota I-394 Integrated Corridor Management System – System Requirement Specification. March 31, 2008.

acquiring data from arterial and transit systems (speeds, volumes, travel times, signal controller information, parking availability, and other measures) and also provide data about incidents, freeway and arterial travel times to the transit computer aided dispatch (CAD) system

- San Francisco Bay Area Metropolitan Transportation Commission (MTC) participates in a multimodal and multistrategy investment prioritization process (case study 2 in this report).
  - MTC created a performance-based planning process to achieve the long range goals defined in the 2035 Transportation Plan. The planning process provides feedback on how individual investments would impact the regions vision, goals, and objectives.
  - MTC's 2035 Transportation Plan focuses on the three E's: economy, environment, and equity. For each focus, MTC created goals and specific performance objectives (Table 4.1):

E's	Goals	Performance Objectives
Economy	Maintenance and Safety	Improve maintenance • Local streets and roads: Maintain pavement condition index of • 75 or better. • State highways: Distressed land-miles no more than 10% of • system. • Transit: Average asset age no more than 50% of useful life and • average distance between service calls of 8,000 miles. *Sources: State and local strategic plans*
		Reduce injuries and fatalities • Motor - vehicle fatalities: 15% from today. • Bike and pedestrian injuries and fatalities: 25% each from 2000 levels *Source: California State Strategic Highway Safety Plan*
	Reliability Freight	Reduce delays • 20% per capita from today. *Source: California ' s Strategic Growth Plan*
Environment	Clean Air	Reduce vehicle miles traveled and emissions • Vehicle miles traveled: 10% per capita from today. • Fine particulate matter (PM2.5): 10% from today. • Course particulate matter (PM10): 455 from today. • Carbon dioxide (C02): 40% below 1990

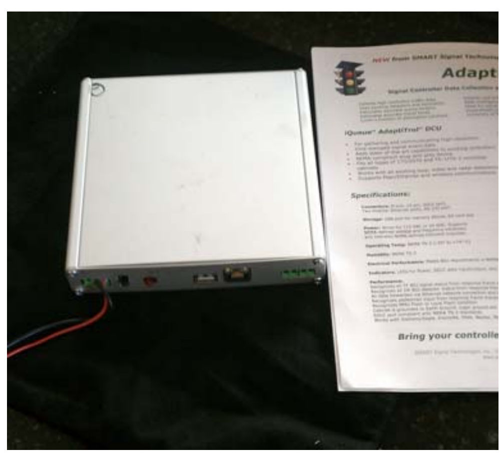
		levels. *Sources: State regulations and laws*
Equity	Access	Improve affordability • 10% reduction from today in share of earnings spent on housing and transportation costs by low and moderately low income households. *Source: Adapted from the Center for Housing Policy*

- The following performance objectives and corresponding performance measures were established by the MTC in the Transportation 2035 Plan (Table 4.2):

Performance Objective	Performance Measures
Reduce congestion Reduce emissions Reduce collisions and fatalities	Benefit-Cost Ratio, reflecting: • Recurrent delay • Nonrecurring delay • Transit travel time • Particulate matter emissions • Carbon dioxide emissions • Fatal and injury collisions • Direct user costs • Public and private cost savings
Reduce vehicle miles driven	Reduction in VMT and cost per VMT reduced
Reduce emissions	Reduction in carbon dioxide emissions and cost per ton reduced
Improve affordability	Cost per low income household served by transit (trial measure)

- MTC created a performance-based planning process to achieve the long range goals defined in the 2035 Transportation Plan. The planning process provides feedback on how individual investments would impact the regions vision, goals, and objectives.

"Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems." Liu, H., Ma, W., Wu, X., Hu, H., Department of Civil Engineering University of Minnesota, Minnesota Department of Transportation, Report No. MN/RC 2009-01, December 2008.



Photos of the SMART signal hardware

Hennepin County, MN uses the SMART-SIGNAL (Systematic Monitoring of Arterial Road Traffic Signals) system at 11 intersections along an arterial. The system collects real time data from traffic signals (all signal events are archived and stored). Then the data is loaded into mathematical models (algorithms) that calculate intersection and arterial performance. Performance measures are generated for both intersections and arterials including:

- Queue lengths
- Travel times
- Number of stops
- Delay
- Level of Service
- Turning movement proportion

No mention of total cost to implement, but case studies found the algorithm to be about 90% accurate, depending on the type of measurement.

Denver Regional Council of Governments (DRCOG). Traffic Signal System Improvement Program 2010 Update.

http://www.drcog.org/index.cfm?page=trafficsignalprogram
The DRCOG administers a federally-funded project to improve traffic signal timing that will reduce travel time and harmful vehicle emissions. Benefits measured include

- Travel times
- Delay time
- Fuel consumption
- Air pollution (pollutants and greenhouse gas emissions)
- User monetary savings.

Estimated benefits are based on simulation analysis. Based on previous projects, DRCOG expects travel times on individual corridors to be reduced by five to fifteen percent for each corridor signal retiming project.

Washington State Department of Transportation. The Gray Notebook

http://www.wsdot.wa.gov/accountability/
This quarterly report monitors performance measures for each of the state's policy goals: **safety, preservation, environment, mobility, stewardship, and economic vitality**. The following are just some performance measures WSDOT uses for each of its goals.

- **Safety**: number of traffic fatalities, rate of fatalities, before and after comparison of collisions following highway improvements.
- **Preservation**: percent of highway pavement in fair or better condition, percent of targets achieved for state highway maintenance activities
- **Environment**: number of vehicle miles traveled, transportation related greenhouse gas emissions

- **Mobility**: travel times, travel delay, percent of drive alone trips, average length of time to clear incidents lasting 90 minutes or more
- **Stewardship**: capital project delivery on time and on budget
- **Economic Vitality**: performance measures are being developed

"Guidelines and Performance Measures to Incorporate Transit and Other Multimodal Considerations into the FDOT DRI Review Process." Seggerman, K., Hendricks, S., Joslin, A, National Center for Transit Research, Center for Urban Transportation Research, University of South Florida, FDOT Contract Number: BD549, RPWO #31, August 2008.
This report supplements how to review a development of regional impact (DRI) to include transit and other multimodal strategies. Previously the focus was heavily vehicle oriented. Multimodal performance measures mentioned in this document include:

- Modal split
- Level of Service for non-vehicular modes
- Access to transit (walking distance)
- Bus stop access every ¼ mile
- Miles of multiuse path/sidewalk/bike facilities
- Traffic signals with pedestrian phase/transit priority
- Increase in ridesharing/bicycling/walking/transit passenger miles

FEDERAL HIGHWAY ADMINISTRATION CONNECTED VEHICLE PROGRAM

http://www.ops.fhwa.dot.gov/travelinfo/infostructure/aboutinfo.htm

The Federal Highway Administration's Connected Vehicle program aims to develop and deploy a fully connected transportation system using a combination of technologies and interfaces. Using leading edge technologies, the connected vehicle research program will enable vehicles to communicate with roadside devices and infrastructure to identify hazards and improve traveler safety. Along with the ability to communicate roadway hazards, this technology would enable vehicles to communicate traffic conditions across the entire system back to a central hub that could process the data and create real-time performance measures. Potential benefits of the Connected Vehicle research include: improved traffic signal control, universal traveler information, improved transportation planning data, and reduced cost of collecting transportation data.

The Connected Vehicle program has the potential to deliver a wealth of real-time multimodal transportation condition information from vehicles communicating to roadside devices. The Connected Vehicle program may ultimately deliver information including roadway weather conditions, travel times, delays, congestion, volumes, and more.

Appendix G - Proof of Concept Memorandum

Final Memorandum

DATE: July 24, 2012

TO: Amy Mastraccio-Lopez, ODOT
Deena Platman, Metro
Peter Koonce, PBOT
Jim Peters, DKS

FROM: Shaun Quayle, PE, Kittelson & Associates, Inc.
Alex Kiheri, Kittelson & Associates, Inc.
Tom Urbanik, PE, Kittelson & Associates, Inc.

SUBJECT: **Final Proof of Concept & Implementation Memorandum** P06287-017

This memorandum presents the proof of concept & implementation for the multi-modal arterial performance measures demonstration including the proposed data to be collected and the necessary procurement efforts for the SE 82nd Avenue arterial corridor. The primary purpose of this memorandum is to define the data sources and performance measures to enable a variety of measures supporting dynamic arterial evaluations from a data-driven perspective.

DEMONSTRATION PROJECT SCOPE

The demonstration project scope is the outcome of the previous *Alternatives Evaluation Memorandums* which defined criterion for prioritizing technologies and treatments on the demonstration corridor, 82nd Avenue. Table 1 summarizes the scope of the demonstration project for this project.

In summary the demonstration scope is based upon the following criteria:

- Ability to produce high importance performance metrics (as identified in stakeholder workshop)
- Ability to demonstration a variety of technologies across modes along and adjacent to 82nd Avenue
- Ease of implementation (i.e. maturity and reliability of the technology & data collection interface)
- Cost Estimate

The expected outcomes of this demonstration project are to determine the feasibility, ease and challenges with collecting, cleaning, and summarizing arterial data to support data-driven key performance measures. The goal of this demonstration project is to in an ***on-going*** fashion:

- Count or approximate **multi-modal demand** (transit, ped, bike, freight, auto). This performance measure data can be used to inform mode split/shift, and safety related items such as conflicts/crash exposure.
- Measurement of **pedestrian delay** experienced at signalized intersections. This can inform our signal timing to balance vehicular and pedestrian demands.
- Measurement of **traffic signal timing performance** to approximate effectiveness, such as % arrival on green and movement gap out vs. max out/force-off. This can inform opportunities to adjust signal timing to meet objectives, such as reducing stops or split failures.
- Monitoring of **vehicular operations** (travel times, speeds). This can inform our understanding of locations, extent and duration of vehicular congestion and incidents.

BEFORE/AFTER EVALUATION

Before/After evaluation is proposed at a capability level; identifying the performance measures available in an automated fashion prior to and after the demonstration project. To the extent project scope/budget allows, the evaluation will review the general quality of the data as well. Lessons learned from the before/after evaluation of this demonstration project will support the Concept of Operations documentation and ultimately future arterial investments. Before/After Evaluation will be summarized in Task 6, Demonstration Memorandum.

IMPLEMENTATION CHALLENGES & PROPOSED APPROACH

Table 1 identifies some key challenges, which were discussed among the project management team and technical advisory committee. For each performance metric category with an implementation challenge, a proposed approach is outlined below. It should be noted that TriMet has agreed to aggregate and provide summarized data for AVL and APC systems along 82nd Avenue.

INRIX TRAVEL TIME / SPEED

The consultant team should coordinate with ODOT and PSU to use parallel efforts to capture a recent Inrix sample data of travel time/speeds along 82nd Avenue. Historical profile data is sufficient for the purposes of demonstrating the arterial performance data. An automated data reduction system will be necessary to allow the consultant team efficient processing and aggregation.

Reduction & summary of Inrix data, as well as a comparison of general trends between other travel time data sources (Bluetooth^{TM} and AVL) may require additional resources.

BLUETOOTH^{TM} TRAVEL TIME / SPEED

The preferred option is to connect BluetoothTM data streaming from PBOT to PSU PORTAL BluetoothTM interface for data reduction & summary. This will require coordination with PBOT and PSU to automate the process or rely on manual downloads of the data sets. A secondary option is to utilize BlueMAC data reduction software to reduce and summarize the data from the 82nd Avenue stations.

Reduction & summary of Bluetooth^{TM} data, as well as a comparison of general trends between other travel time data sources (Inrix and AVL) will require additional resources.

SYSTEM DETECTION (AUTO & FREIGHT TRIPS)

All system detection locations are planned to be dual inductive loops. This will add the ability to collect point speed, occupancy, and classification, in addition to the existing volume detection. For the purposes of this demonstration project, classification logging will occur at a single location, through the use of PLC external hardware programmed by the PBOT. New system detectors should interface with NWS Voyage controller software, TransSuite central software, and/or PORTAL for the purposes of reducing collected volumes, occupancy, point speed, and length-based classification.

Reduction & summary of system detector data, for count, speed, classification (i.e. number of buses/trucks), and occupancy may require additional resources.

NWS VOYAGE LOGS (PED/BIKE COUNTS & SIGNAL TIMING EFFECTIVENESS)

To the extent that ready-made logs, such as MOE, volume, or TSP logs are made available, the consultant team will summarize performance metrics.

For specialized treatments requiring internal logic, such as ped delay logs, and arrival on green for non-coordinated movements or transit vehicles, additional resources may be necessary.

Opportunities & cost estimates for enhanced logging capabilities in NWS Voyage (and/or NWS Central):

- % Arrival on Green for both coord and free operations: next release of Voyage to contain (version 05.01)
- Delay log (call to service) by input = ~$30k; can be done using internal logic for demonstration purposes
- Classification log (vehicle length): not able to do with internal logic. Cost estimate = ~$12k
- Enhancements to Transit Signal Priority logging & visualization (i.e. % Arrival on Green for Transit Signal Priority): ~ $18,700
- All-red extension log: track frequency and course duration (constrained to whole seconds) for occurrences. Cost estimate = ~ $10k

GREEN DRIVER LOGS

This data source is above and beyond the scope of this demonstration project due to the lacking ability to aggregate and summarize the high fidelity data from this source. This data source will be documented in the Regional Concept of Operations.

CORRIDOR SAFETY (ALL-RED EXTENSION)

Discussions with PSU, PBOT and consultant team members indicate this feature is difficult to log and summarize. **The consultant team recommends utilizing previously summarized PSU research data at a single location** to represent the performance metrics that could be gathered from this treatment. The other alternatives are likely above and beyond the scope of this demonstration project and of limited value.

Due to the automated focus of this arterial performance measures project, crash history will not be a part of this demonstration project. Crash exposure metrics rely on accurate traffic volumes across modes, for which this demonstration project will collect count, speed, and other related, useful metrics for safety evaluations, such as those presented in the Highway Safety Manual.

ENVIRONMENTAL CONDITIONS

This performance metric will follow the parallel PSU/PBOT air quality measurement project on Powell Boulevard. If available, performance measures from the Powell Boulevard air quality stations will be documented for this demonstration.

DEMONSTRATION IMPLEMENTATION PLAN

The following list defines the installation scope of the 82^{nd} Avenue equipment, for which PBOT will be responsible for:

- Install Dual Loop System Detectors
  - 82^{nd}/Burnside ($8,000)
  - 82^{nd}/Flavel ($8,000)
  - 82^{nd}/Fremont ($8,000)
- Install Advanced bike detection (loops) along Springwater Trail for both approaches to 82^{nd} Avenue ($6,000)

Total Capital Cost Estimate ~$30,000

Consultant team will work with PBOT to develop sketch (red-line) plans describing the installation of the above equipment identified. Consultant team will assist in device configuration to make sure technology installed provides data identified in Table 1 of this memorandum. Consultant team will identify any additional needs to complete the demonstration evaluation once implementation is complete. Outside contractor(s) will be required for capital improvements identified above as part of this demonstration project. As-built plans, if necessary will be prepared by ODOT staff.

PBOT other support:

- Program and install PLC for vehicle classification logging at 82nd/Burnside system loop location.
- Set-up, enable logging of new system detectors in TransSuite
- Set-up, enable logging at 82^{nd}/Powell
  - Volumes
  - MOE
  - Coordination (version 05.01)
  - TSP
  - Preemption
- Set-up, enable logging at 82^{nd}/Springwater
  - Volumes (bike loops)
- Set-up, enable logging at 87^{th}/Division
  - Volumes (bike loops)
- If available, provide performance measures from Powell Boulevard Air Quality Monitoring

Demonstration Schedule:

Delivery of redline plans for system detectors & bike detectors – **by July 17th, 2012**

Contractor implementation & validation of system detectors & bike detectors – **by October 24th, 2012**

Order of implementation:

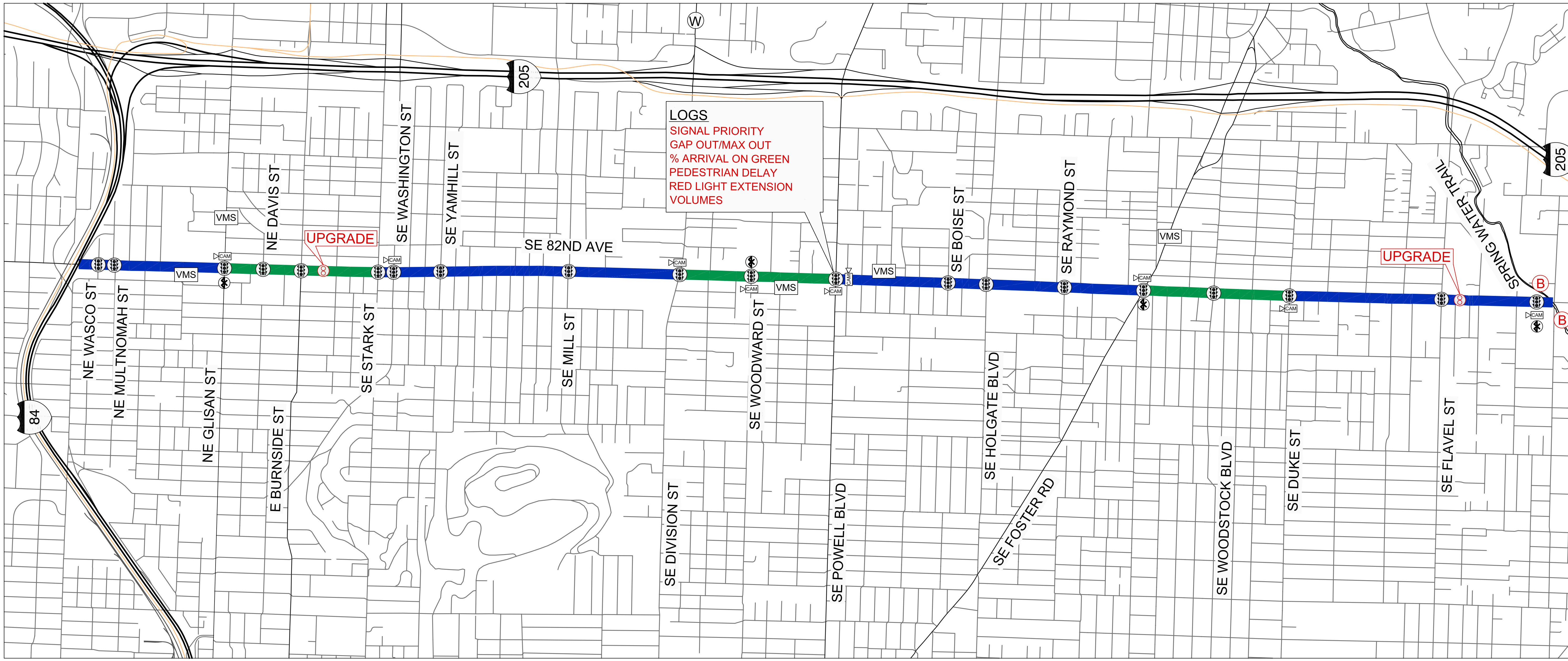
1. Springwater Trail bike loops
2. 82nd/Burnside System Detector (& PLC length-class logger)
3. 82nd/Flavel System Detector
4. 82nd/Fremont System Detector

Table 1 – Summary of Demonstration Scope

Performance Metric Category	Priority	Demonstration Technology	Demonstration Location(s)	Example Metrics	Implementation Challenges	Estimated Capital Costs[1]
Travel Time / Running Speed / Reliability	High	• INRIX (Fleet GPS) • Bluetooth™ (MAC Readers) • TriMet AVL	Along corridor (NE Glisan to Springwater Trail)	• Average Travel Time • Percentile Travel Times • Segment Speeds • Planning Time Index • Buffer Index	• Time-consuming to reduce INRIX • Bluetooth analytics tool • Comparison of Technologies	• INRIX – 3 Options ○ ODOT Purchase – Aggregated Data (TBD) ○ PSU Demonstration – 1 minute Data (TBD) ○ PBOT Purchase ($10,000)
Auto / Freight / Transit Trips	High	• Dual inductive loops • TriMet AVL & APC • NWS Voyage Logs (TransSuite)	• Loops: 82nd/Burnside; 82nd/Flavel; 82nd/Fremont • AVL/APC: Full Study Corridor • Voyage Logs: 82nd/Powell • Classification: 82nd/Flavel	• Number of autos • Number of trucks, • Number of buses • Person trips by mode	• Loop software lacking for classification (freight)	• Convert count stations to double loops stations ($4,000 per station - $8,000 total • New Count Station ($10,000)
Pedestrian/Bicycle Trips	High	• NWS Voyage Logs (TransSuite) • TriMet APC	• Ped Actuation Logs: Full Study Corridor • Ped Activity: Each TriMet Stop (APC) • Bike Actuation Logs: 87th/Division, Springwater Trail/82nd	• Number of pedestrians • Number of bicycles, • Number of pedestrian actuations	• Voyage logs limited by pedestrian detection (# ped actuations)	• Add advanced loop bike detection on Springwater Trail at 82nd Avenue ($6,000).
Signal Timing Effectiveness	High	• NWS Voyage Logs (TransSuite)	• 82nd/Powell	• Pedestrian delay • % arrival on green • Gap out vs. max out • Signal priority frequency / duration	• Set-up for % arrival on green with free operations • Set-up for pedestrian delay logs (available logs)	• Existing Equipment, no capital costs expected.
Corridor Safety	High	• NWS Voyage Logs (TransSuite)	• 82nd/Powell	• Frequency of all-red extension	• Manual log download	• Existing Equipment, no capital costs expected.
Environmental Conditions	Medium	• PSU/PBOT Air Quality Monitoring	• Powell/26th	• CO, CO_2, Particulate Matter, NO, NO_2, NO_x	• Timing on implementation	• Equipment waiting to be installed, no capital costs expected.

1 Capital costs only, doesn't reflect on-going costs or cost to aggregate, summarize and present data.

(NO SCALE)



LEGEND

EXISTING

- SIGNAL
- VMS - VARIABLE MESSAGE SIGN
- CAM - PAN TILT ZOOM CAMERA
- BLUETOOTH COLLECTOR
- W - WEATHER STATION

PROPOSED

- 8 - PROPOSED UPGRADE/NEW DUAL LOOP SYSTEM DETECTOR
- B - PROPOSED BIKE DETECTION (WITH LOGS)

INRIX TRAFFIC MANAGEMENT CENTERS (TMC SEGMENTS)

TMC #1 TMC #2 TMC #3

NOTES

1 - PEDESTRIAN ACTUATION LOGS AVAILABLE AT ALL SIGNALS FOR PEDESTRIANS CROSSING SE 82ND

2 - TRIMET AVL/APC DATA IS AVAILABLE FOR ENTIRE CORRIDOR

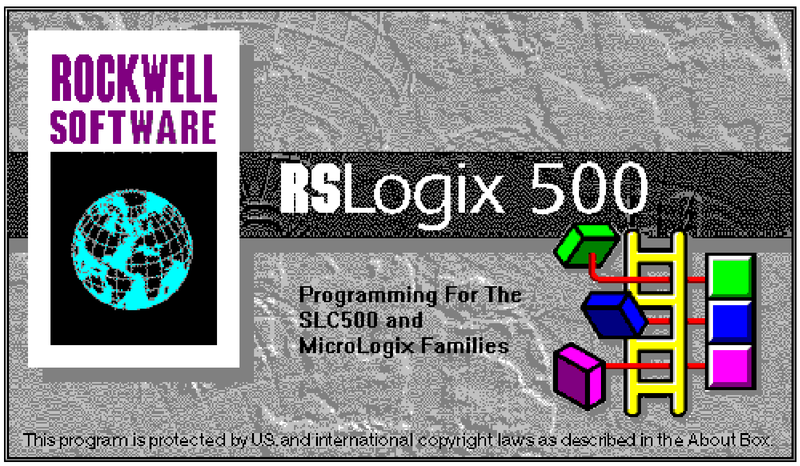
EXISTING AND PROPOSED DATA COLLECTION TECHNOLOGIES
PORTLAND, OR

FIGURE 1

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING / PLANNING

Appendix H – Programmable Logic Controller – Logic Used for Vehicle Classification

RSLogix500 Project Report



Processor Information

Processor Type: Bul.1764   Micrologix 1500 LRP Series B

Processor Name: FLAVEL

Total Memory Used: 637 Instruction Words Used - 156 Data Table Words Used

Total Memory Left: 10691 Instruction Words Left

Program Files: 3

Data Files: 11

Program ID: feb1

I/O Configuration

0	Bul.1764	Micrologix 1500 LRP Series B
1		
2		
3		
4		
5		
6		
7		
8		

Channel Configuration

CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex
CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex Edit Resource/Owner Timeout: 60
CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex Passthru Link ID: 1
CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex Write Protected: No
CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex Comms Servicing Selection: Yes
CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex Message Servicing Selection: Yes
CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex 1st AWA Append Character: \d
CHANNEL 0 (SYSTEM) - Driver: DF1 Full Duplex 2nd AWA Append Character: \a

Source ID: 1 (decimal)
Baud: 19200
Parity: NONE
Control Line : No Handshaking
Error Detection: CRC
Embedded Responses: Auto Detect
Duplicate Packet Detect: Yes
ACK Timeout: 50
NAK Retries: 3
ENQ Retries: 3

CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex
CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex Edit Resource/Owner Timeout: 60
CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex Passthru Link ID: 1
CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex Write Protected: No
CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex Comms Servicing Selection: Yes
CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex Message Servicing Selection: Yes
CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex 1st AWA Append Character: \d
CHANNEL 1 (SYSTEM) - Driver: DF1 Full Duplex 2nd AWA Append Character: \a

Source ID: 1 (decimal)
Baud: 19200
Parity: NONE
Control Line : No Handshaking
Error Detection: CRC
Embedded Responses: Auto Detect
Duplicate Packet Detect: Yes
ACK Timeout: 50
NAK Retries: 3
ENQ Retries: 3

Program File List

Name	Number	Type	Rungs	Debug	Bytes
[SYSTEM]	0	SYS	0	No	0
	1	SYS	0	No	0
MAIN_PROG	2	LADDER	89	No	2939

Data File List

Name	Number	Type	Scope	Debug	Words	Elements	Last
OUTPUT	0	O	Global	No	12	4	O:3
INPUT	1	I	Global	No	12	4	I:3
STATUS	2	S	Global	No	0	66	S:65
BINARY	3	B	Global	No	1	1	B3:0
TIMER	4	T	Global	No	57	19	T4:18
COUNTER	5	C	Global	No	15	5	C5:4
CONTROL	6	R	Global	No	3	1	R6:0
INTEGER	7	N	Global	No	52	52	N7:51
RESERVED	8	r	Global	No	0	0	
	9	B	Global	No	3	3	B9:2
	10	N	Global	No	1	1	N10:0

Lanes 1 and 2

Start the speed timer on the rising edge of the first loop, and set a latch for timing the travel time from the entrance loop to the exit loop for lane 1

Entrance loop lane 1
LOOP_A1
I:0

0000

OSR
One Shot Rising
Storage Bit B9:0/0
Output Bit B9:0/1

0
Bul.1764

T4:10

TT

Entrance loop on lane 2
LOOP_A2
I:0

0001

OSR
One Shot Rising
Storage Bit B9:0/10
Output Bit B9:0/11

2
Bul.1764

T4:10

TT

Entrance loop on lane 3
LOOP_A3
I:0

0002

OSR
One Shot Rising
Storage Bit B9:1/4
Output Bit B9:1/5

4
Bul.1764

T4:10

TT

Entrance loop on lane 4
LOOP_A4
I:0

0003

OSR
One Shot Rising
Storage Bit B9:1/14
Output Bit B9:1/15

6
Bul.1764

T4:10

TT

Stop the speed timer in the rising edge of the second loop

Latched on leading edge of first loop,unlatched by second loop.

LOOP_A1_OSR
B9:0

SPEED_LATCH1
B3:0

0004

L

1

1

Stop the speed timer in the rising edge of the second loop

Latched on leading edge of first loop, unlatched by second loop.

LOOP_A2_OSR
B9:0

SPEED_LATCH2
B3:0

0005

L

11

2

Stop the speed timer in the rising edge of the second loop

0006
LOOP_A3_OSR
B9:1
5

Latched on leadiing edge offirst loop, unlatched by second loop.
SPEED_LATCH3
B3:0
L
3

Stop the speed timer in the rising edge of the second loop

0007
LOOP_A4_OSR
B9:1
15

Latched on leadiing edge offirst loop, unlatched by second loop.
SPEED_LATCH4
B3:0
L
4

Reset speed timer after vehicle leaves exit loop

0008
Latched on leading edge of first loop,unlatched by second loop.
SPEED_LATCH1
B3:0
1

SPEED_TIMER_1
RTO
Retentive Timer On
Timer T4:0
Time Base 0.01
Preset 4000<
Accum 0<
EN
DN

0009
Latched on leading edge of first loop, unlatched by second loop.
SPEED_LATCH2
B3:0
2

SPEED_TIMER_2
RTO
Retentive Timer On
Timer T4:2
Time Base 0.01
Preset 4000<
Accum 0<
EN
DN

0010
Latched on leadiing edge offirst loop, unlatched by second loop.
SPEED_LATCH3
B3:0
3

SPEED_TIMER_3
RTO
Retentive Timer On
Timer T4:4
Time Base 0.01
Preset 4000<
Accum 0<
EN
DN

0011

Latched on leadiing edge offirst loop, unlatched by second loop.
SPEED_LATCH4
B3:0
4

SPEED_TIMER_4
RTO
Retentive Timer On
Timer T4:6
Time Base 0.01
Preset 4000<
Accum 0<
EN
DN

Stop the speed timer on the rising edge of the second loop

0012

Exit loop lane 1
LOOP_B1
I:0
1
Bul.1764

T4:11
TT

Latched on leading edge of first loop,unlatched by second loop.
SPEED_LATCH1
B3:0
U
1

0013

Exit loop on lane 2
LOOP_B2
I:0
3
Bul.1764

T4:11
TT

Latched on leading edge of first loop, unlatched by second loop.
SPEED_LATCH2
B3:0
U
2

0014

Exit loop on lane 3
LOOP_B3
I:0
5
Bul.1764

T4:11
TT

Latched on leadiing edge offirst loop, unlatched by second loop.
SPEED_LATCH3
B3:0
U
3

0015
Exit loop on lane 4
LOOP_B4
I:0
7
Bul.1764
T4:11
TT

Latched on leadiing edge offirst loop, unlatched by second loop.
SPEED_LATCH4
B3:0
U
4

Get ready to do the speed calculation math

0016
Travel time between loops a and b
TIME_BETWEEN_LOOPS1
MOV
Move
Source T4:0.ACC
0<
Dest N7:0
0<

0017
Travel time between loops a and b
TIME_BETWEEN_LOOPS2
MOV
Move
Source T4:2.ACC
0<
Dest N7:4
0<

0018
Travel time between loops a and b
TIME_BETWEEN_LOOPS3
MOV
Move
Source T4:4.ACC
0<
Dest N7:9
0<

0019
Travel time between loops a and b
TIME_BETWEEN_LOOPS4
MOV
Move
Source T4:6.ACC
0<
Dest N7:13
0<

0020
Exit loop lane 1
LOOP_B1
I:0
1
Bul.1764
T4:11
TT
OSR
One Shot Rising
Storage Bit B9:0/2
Output Bit B9:0/3

0021
Exit loop on lane 2
LOOP_B2
I:0
3
Bul.1764
T4:11
TT
OSR
One Shot Rising
Storage Bit B9:0/12
Output Bit B9:0/13

0022
Exit loop on lane 3
LOOP_B3
I:0
5
Bul.1764
T4:11
TT
OSR
One Shot Rising
Storage Bit B9:1/6
Output Bit B9:1/7

0023
Exit loop on lane 4
LOOP_B4
I:0
7
Bul.1764
T4:11
TT
OSR
One Shot Rising
Storage Bit B9:2/0
Output Bit B9:2/1

Calculate the speed in feet per second for lane 1. the compare statement prevents a divide by zero error

0024
LOOP_B1_OSR
B9:0
3
Travel time between loops a and b
TIME_BETWEEN_LOOPS1
NEQ
Not Equal
Source A N7:0
0<
Source B 0
0<
Feet/Second Lane 1
FEET_PER_SEC_1
DIV
Divide
Source A N7:44
2200<
Source B N7:0
0<
Dest N7:1
46<

0025

LOOP_B2_OSR — B9:0 / 13

Travel time between loops a and b
TIME_BETWEEN_LOOPS2
NEQ — Not Equal
Source A N7:4 0<
Source B 0 0<

Feet/Second Lane 2
FEET_PER_SEC_2
DIV — Divide
Source A N7:45 2200<
Source B N7:4 0<
Dest N7:5 52<

0026

LOOP_B3_OSR — B9:1 / 7

Travel time between loops a and b
TIME_BETWEEN_LOOPS3
NEQ — Not Equal
Source A N7:9 0<
Source B 0 0<

Feet/Second Lane 3
FEET_PER_SEC_3
DIV — Divide
Source A N7:46 2200<
Source B N7:9 0<
Dest N7:10 46<

0027

LOOP_B4_OSR — B9:2 / 1

Travel time between loops a and b
TIME_BETWEEN_LOOPS4
NEQ — Not Equal
Source A N7:13 0<
Source B 0 0<

Feet/Second Lane 4
FEET_PER_SEC_4
DIV — Divide
Source A N7:47 2200<
Source B N7:13 0<
Dest N7:14 42<

Convert to miles per hour x10 choose the closest integer to (3600/5280) x 10 (use the scaling factor at n7:11 68 for MPH) The compare prevents a math overflow if the speed is too high (about 320 mph)

0028

Feet/Second Lane 1
FEET_PER_SEC_1
LES — Less Than (A<B)
Source A N7:1 46<
Source B 400 400<

Mph*10 Lane 1
MPH_1
MUL — Multiply
Source A N7:1 46<
Source B 68 68<
Dest N7:3 3128<

0029

Feet/Second Lane 2
FEET_PER_SEC_2
LES — Less Than (A<B)
Source A N7:5 52<
Source B 400 400<

Mph*10 lane 2
MPH_2
MUL — Multiply
Source A N7:5 52<
Source B 68 68<
Dest N7:7 3536<

0030

Feet/Second Lane 3
FEET_PER_SEC_3
LES
Less Than (A<B)
Source A N7:10
46<
Source B 400
400<

Mph*10 Lane 3
MPH_3
MUL
Multiply
Source A N7:10
46<
Source B 68
68<
Dest N7:12
3128<

0031

Feet/Second Lane 4
FEET_PER_SEC_4
LES
Less Than (A<B)
Source A N7:14
42<
Source B 400
400<

Mph*10 Lane 4
MPH_4
MUL
Multiply
Source A N7:14
42<
Source B 68
68<
Dest N7:16
2856<

Track time that vehicle is over loop A. No vehicle is allowed to occupy the loop for more thatn 3 secondsto prevent a math error

0032

Entrance loop lane 1
LOOP_A1
I:0
0
Bul.1764

T4:10
TT

Occupancy of entrance loop.
LENGTH_TIMER_1
TON
Timer On Delay
Timer T4:1
Time Base 0.01
Preset 300<
Accum 0<
(EN)
(DN)

0033

Entrance loop on lane 2
LOOP_A2
I:0
2
Bul.1764

T4:10
TT

Occupance of entrance loop
LENGTH_TIMER_2
TON
Timer On Delay
Timer T4:3
Time Base 0.01
Preset 300<
Accum 0<
(EN)
(DN)

0034

Entrance loop on lane 3
LOOP_A3
I:0
4
Bul.1764

T4:10
TT

Occupancy of entrance loop.
LENGTH_TIMER_3
TON
Timer On Delay
Timer T4:5
Time Base 0.01
Preset 300<
Accum 0<
(EN)
(DN)

0035

Entrance loop on lane 4
LOOP_A4
I:0
6
Bul.1764

T4:10
TT

Occupancy of entrance loop.
LENGTH_TIMER_4
TON
Timer On Delay
Timer T4:7
Time Base 0.01
Preset 300<
Accum 0<
EN
DN

Move the occupancy time on the entrance loop to N7:14

0036

Entrance loop lane 1
LOOP_A1
I:0
0
Bul.1764

T4:10
TT

Occupancy time on loop for lane 1
OCC_TIME_LANE_1
MOV
Move
Source T4:1.ACC
0<
Dest N7:20
45<

0037

Entrance loop on lane 2
LOOP_A2
I:0
2
Bul.1764

T4:10
TT

Occupancy time on loop for lane 2
OCC_TIME_LANE_2
MOV
Move
Source T4:3.ACC
0<
Dest N7:21
34<

0038

Entrance loop on lane 3
LOOP_A3
I:0
4
Bul.1764

T4:10
TT

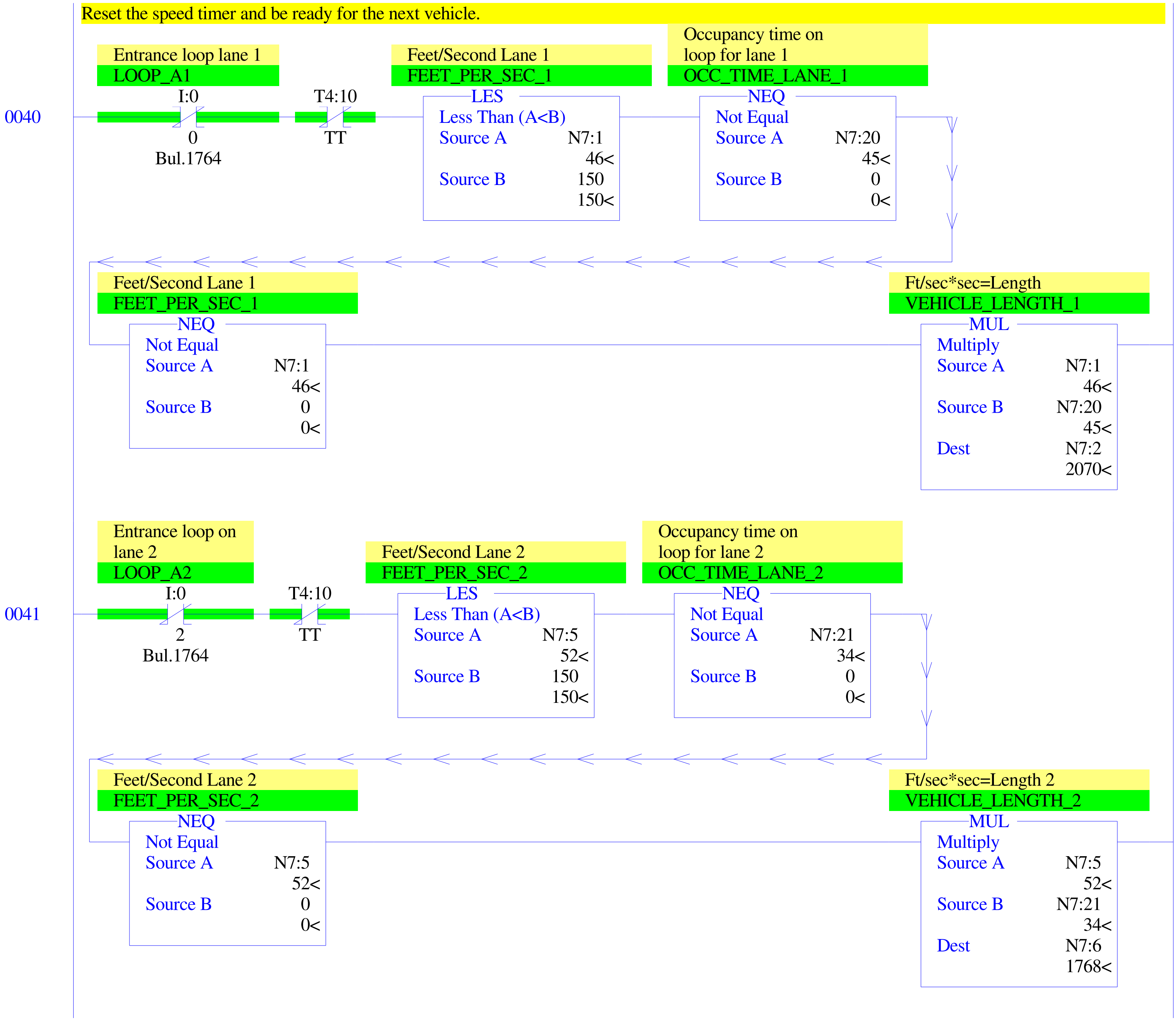
Occupancy time on loop for lane 3
OCC_TIME_LANE_3
MOV
Move
Source T4:5.ACC
0<
Dest N7:22
40<

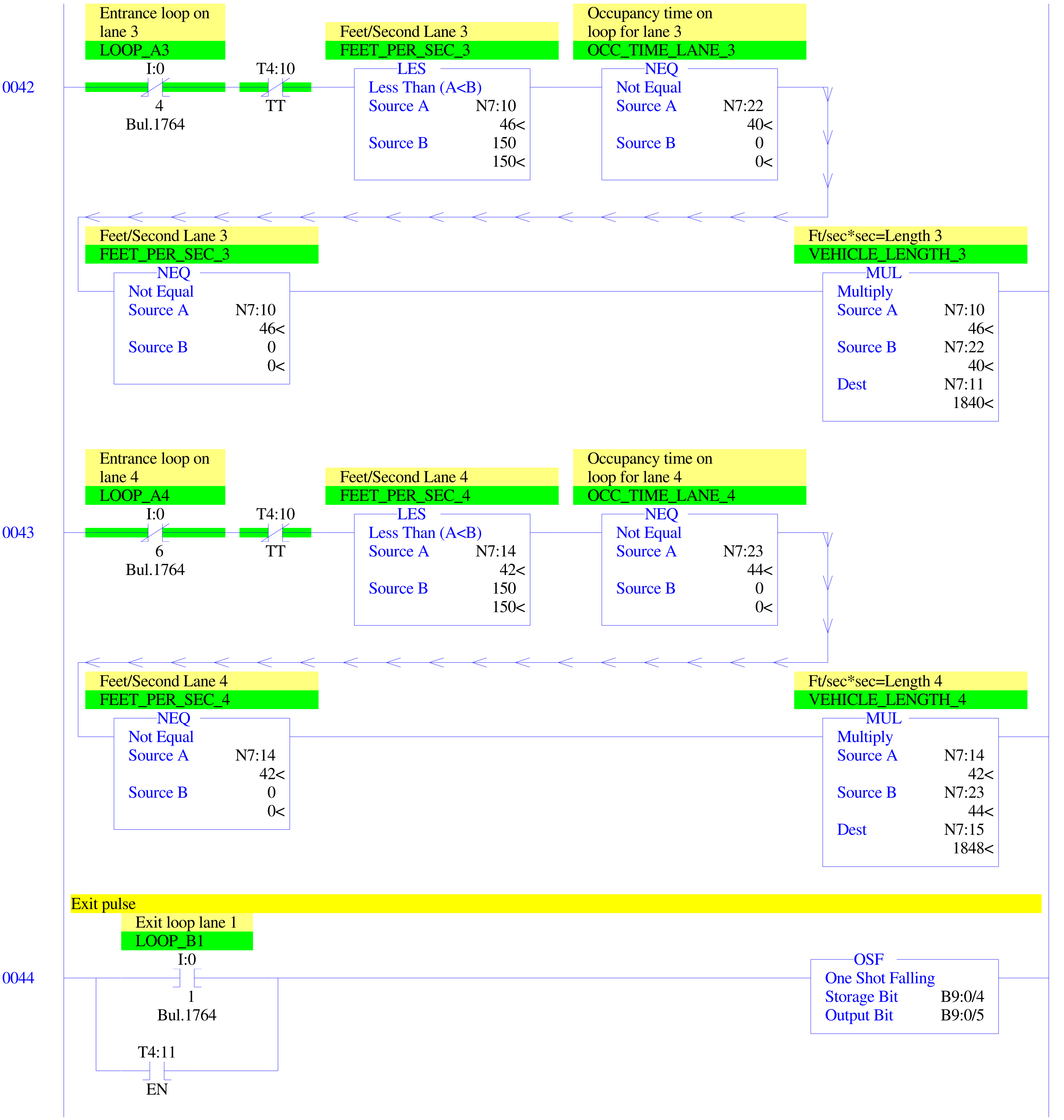
0039

Entrance loop on lane 4
LOOP_A4
I:0
6
Bul.1764

T4:10
TT

Occupancy time on loop for lane 4
OCC_TIME_LANE_4
MOV
Move
Source T4:7.ACC
0<
Dest N7:23
44<


Reset the speed timer and be ready for the next vehicle.
0040
Entrance loop lane 1
LOOP_A1
I:0
0
Bul.1764
T4:10
TT
Feet/Second Lane 1
FEET_PER_SEC_1
LES
Less Than (A<B)
Source A N7:1
46<
Source B 150
150<
Occupancy time on loop for lane 1
OCC_TIME_LANE_1
NEQ
Not Equal
Source A N7:20
45<
Source B 0
0<
Feet/Second Lane 1
FEET_PER_SEC_1
NEQ
Not Equal
Source A N7:1
46<
Source B 0
0<
Ft/sec*sec=Length
VEHICLE_LENGTH_1
MUL
Multiply
Source A N7:1
46<
Source B N7:20
45<
Dest N7:2
2070<
0041
Entrance loop on lane 2
LOOP_A2
I:0
2
Bul.1764
T4:10
TT
Feet/Second Lane 2
FEET_PER_SEC_2
LES
Less Than (A<B)
Source A N7:5
52<
Source B 150
150<
Occupancy time on loop for lane 2
OCC_TIME_LANE_2
NEQ
Not Equal
Source A N7:21
34<
Source B 0
0<
Feet/Second Lane 2
FEET_PER_SEC_2
NEQ
Not Equal
Source A N7:5
52<
Source B 0
0<
Ft/sec*sec=Length 2
VEHICLE_LENGTH_2
MUL
Multiply
Source A N7:5
52<
Source B N7:21
34<
Dest N7:6
1768<


0042
Entrance loop on lane 3
LOOP_A3
I:0
4
Bul.1764
T4:10
TT
Feet/Second Lane 3
FEET_PER_SEC_3
LES
Less Than (A<B)
Source A N7:10
46<
Source B 150
150<
Occupancy time on loop for lane 3
OCC_TIME_LANE_3
NEQ
Not Equal
Source A N7:22
40<
Source B 0
0<
Feet/Second Lane 3
FEET_PER_SEC_3
NEQ
Not Equal
Source A N7:10
46<
Source B 0
0<
Ft/sec*sec=Length 3
VEHICLE_LENGTH_3
MUL
Multiply
Source A N7:10
46<
Source B N7:22
40<
Dest N7:11
1840<
0043
Entrance loop on lane 4
LOOP_A4
I:0
6
Bul.1764
T4:10
TT
Feet/Second Lane 4
FEET_PER_SEC_4
LES
Less Than (A<B)
Source A N7:14
42<
Source B 150
150<
Occupancy time on loop for lane 4
OCC_TIME_LANE_4
NEQ
Not Equal
Source A N7:23
44<
Source B 0
0<
Feet/Second Lane 4
FEET_PER_SEC_4
NEQ
Not Equal
Source A N7:14
42<
Source B 0
0<
Ft/sec*sec=Length 4
VEHICLE_LENGTH_4
MUL
Multiply
Source A N7:14
42<
Source B N7:23
44<
Dest N7:15
1848<
Exit pulse
Exit loop lane 1
LOOP_B1
0044
I:0
1
Bul.1764
T4:11
EN
OSF
One Shot Falling
Storage Bit B9:0/4
Output Bit B9:0/5

Exit loop on lane 2
LOOP_B2
I:0
3
Bul.1764

0045

T4:11
EN

OSF
One Shot Falling
Storage Bit B9:0/14
Output Bit B9:0/15

Exit loop on lane 3
LOOP_B3
I:0
5
Bul.1764

0046

T4:11
EN

OSF
One Shot Falling
Storage Bit B9:1/8
Output Bit B9:1/9

Exit loop on lane 4
LOOP_B4
I:0
7
Bul.1764

0047

T4:11
EN

OSF
One Shot Falling
Storage Bit B9:2/2
Output Bit B9:2/3

Time the output pulse

0048

B9:0
5

OUTPUT_TIMER_LANE_1/TT
T4:12
TT

OUTPUT_TIMER_LANE_1
TON
Timer On Delay
Timer T4:12
Time Base 0.01
Preset 50<
Accum 0<
EN
DN

0049

B9:0
15

OUTPUT_TIMER_LANE_2/TT
T4:13
TT

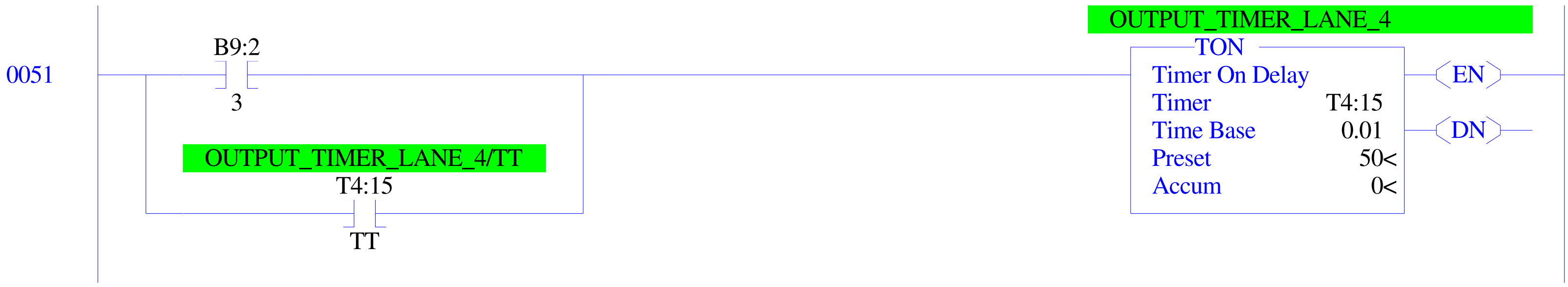
OUTPUT_TIMER_LANE_2
TON
Timer On Delay
Timer T4:13
Time Base 0.01
Preset 50<
Accum 0<
EN
DN

0050

B9:1
9

OUTPUT_TIMER_LANE_3/TT
T4:14
TT

OUTPUT_TIMER_LANE_3
TON
Timer On Delay
Timer T4:14
Time Base 0.01
Preset 50<
Accum 0<
EN
DN


0051
B9:2
3
OUTPUT_TIMER_LANE_4/TT
T4:15
TT
OUTPUT_TIMER_LANE_4
TON
Timer On Delay
Timer T4:15
Time Base 0.01
Preset 50<
Accum 0<
EN
DN

Output for lanes 1 through 4

Turn on the proper output for class 1 lane 1

0052

Ft/sec*sec=Length
VEHICLE_LENGTH_1
LIM
Limit Test
Low Lim N7:30 1000<
Test N7:2 2070<
High Lim N7:31 1900<

OUTPUT_TIMER_LANE_1/TT
T4:12 TT

O:0 1 Bul.1764

Ft/sec*sec=Length 2
VEHICLE_LENGTH_2
LIM
Limit Test
Low Lim N7:30 1000<
Test N7:6 1768<
High Lim N7:31 1900<

OUTPUT_TIMER_LANE_2/TT
T4:13 TT

0053

Ft/sec*sec=Length 3
VEHICLE_LENGTH_3
LIM
Limit Test
Low Lim N7:30 1000<
Test N7:11 1840<
High Lim N7:31 1900<

OUTPUT_TIMER_LANE_3/TT
T4:14 TT

O:0 5 Bul.1764

Ft/sec*sec=Length 4
VEHICLE_LENGTH_4
LIM
Limit Test
Low Lim N7:30 1000<
Test N7:15 1848<
High Lim N7:31 1900<

OUTPUT_TIMER_LANE_4/TT
T4:15 TT

Turn on the proper output for class 2 lane 1

0054

Ft/sec*sec=Length
VEHICLE_LENGTH_1
LIM
Limit Test
Low Lim N7:32
1901<
Test N7:2
2070<
High Lim N7:33
4100<

OUTPUT_TIMER_LANE_1/TT
T4:12
TT

O:0
2
Bul.1764

Ft/sec*sec=Length 2
VEHICLE_LENGTH_2
LIM
Limit Test
Low Lim N7:32
1901<
Test N7:6
1768<
High Lim N7:33
4100<

OUTPUT_TIMER_LANE_2/TT
T4:13
TT

Turn on the proper output for class 2 lane 1

0055

Ft/sec*sec=Length 3
VEHICLE_LENGTH_3
LIM
Limit Test
Low Lim N7:32
1901<
Test N7:11
1840<
High Lim N7:33
4100<

OUTPUT_TIMER_LANE_3/TT
T4:14
TT

O:0
6
Bul.1764

Ft/sec*sec=Length 4
VEHICLE_LENGTH_4
LIM
Limit Test
Low Lim N7:32
1901<
Test N7:15
1848<
High Lim N7:33
4100<

OUTPUT_TIMER_LANE_4/TT
T4:15
TT

Turn on the proper output for class 3 lane 1

0056

Ft/sec*sec=Length
VEHICLE_LENGTH_1
LIM
Limit Test
Low Lim N7:34
4101<
Test N7:2
2070<
High Lim N7:35
6600<

OUTPUT_TIMER_LANE_1/TT
T4:12
TT

O:0
3
Bul.1764

Ft/sec*sec=Length 2
VEHICLE_LENGTH_2
LIM
Limit Test
Low Lim N7:34
4101<
Test N7:6
1768<
High Lim N7:35
6600<

OUTPUT_TIMER_LANE_2/TT
T4:13
TT

Turn on the proper output for class 3 lane 1

0057

Ft/sec*sec=Length 3
VEHICLE_LENGTH_3
LIM
Limit Test
Low Lim N7:34
4101<
Test N7:11
1840<
High Lim N7:35
6600<

OUTPUT_TIMER_LANE_3/TT
T4:14
TT

O:0
7
Bul.1764

Ft/sec*sec=Length 4
VEHICLE_LENGTH_4
LIM
Limit Test
Low Lim N7:34
4101<
Test N7:15
1848<
High Lim N7:35
6600<

OUTPUT_TIMER_LANE_4/TT
T4:15
TT

Turn on the proper output for class 4 lane 1

0058

Ft/sec*sec=Length
VEHICLE_LENGTH_1
LIM
Limit Test
Low Lim N7:36 6601<
Test N7:2 2070<
High Lim N7:37 12600<

OUTPUT_TIMER_LANE_1/TT
T4:12
TT

Ft/sec*sec=Length 2
VEHICLE_LENGTH_2
LIM
Limit Test
Low Lim N7:36 6601<
Test N7:6 1768<
High Lim N7:37 12600<

OUTPUT_TIMER_LANE_2/TT
T4:13
TT

O:0
4
Bul.1764

Turn on the proper output for class 4 lane 1

0059

Ft/sec*sec=Length 3
VEHICLE_LENGTH_3
LIM
Limit Test
Low Lim N7:36 6601<
Test N7:11 1840<
High Lim N7:37 12600<

OUTPUT_TIMER_LANE_3/TT
T4:14
TT

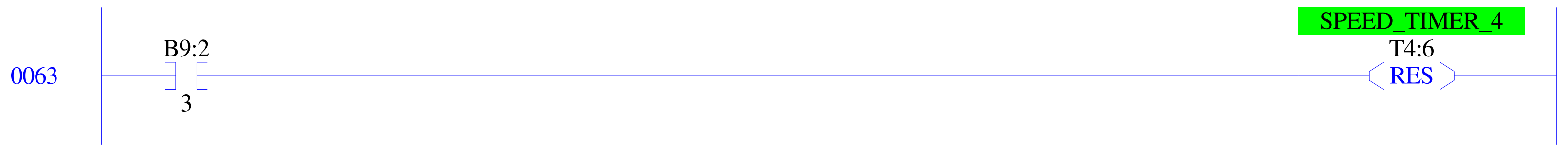
Ft/sec*sec=Length 4
VEHICLE_LENGTH_4
LIM
Limit Test
Low Lim N7:36 6601<
Test N7:15 1848<
High Lim N7:37 12600<

OUTPUT_TIMER_LANE_4/TT
T4:15
TT

O:0
8
Bul.1764

Reset speed timer after vehicle leaves exit loop

0060	B9:0 / 5	SPEED_TIMER_1 T4:0 RES
0061	B9:0 / 15	SPEED_TIMER_2 T4:2 RES
0062	B9:1 / 9	SPEED_TIMER_3 T4:4 RES


0063
B9:2
3
SPEED_TIMER_4
T4:6
RES

This is a new section that records average speed

Set the speed bin period in seconds

0064

MOV
Move
Source N7:41
500<
Dest T4:17.PRE
500<

Time the speed bin interval

0065

T4:17
DN

TON
Timer On Delay
Timer T4:17
Time Base 1.0
Preset 500<
Accum 394<
EN
DN

Reset pulse for speed bin stuff

0066

T4:17
DN

T4:18
TT

TON
Timer On Delay
Timer T4:18
Time Base 1.0
Preset 1<
Accum 1<
EN
DN

Clear Average speed and Volumes at start of bin

0067

T4:18
TT

AVG_SP_1_2
CLR
Clear
Dest N7:8
0<

0068

T4:18
TT

AVG_SP_3_4
CLR
Clear
Dest N7:17
0<

Clear Average speed and Volumes at start of bin

0069

T4:18
TT

VOL_1_2
CLR
Clear
Dest N7:18
91<

Clear Average speed and Volumes at start of bin

0070

T4:18
TT

VOL_3_4
CLR
Clear
Dest N7:19
67<

Clear Average speed and Volumes at start of bin

0071

T4:18
TT

SUM_OF_FTSEC_L1
CLR
Clear
Dest N7:50
4095<

Clear Average speed and Volumes at start of bin

0072 T4:18 TT — SUM_OF_FTSEC_L2 CLR Clear Dest N7:51 2602<

Track volume for lanes 1 & 2

0073 LOOP_B1_OSR B9:0 3 / LOOP_B2_OSR B9:0 13 — VOL_1_2 ADD Add Source A 1 1< Source B N7:18 91< Dest N7:18 91<

Track sum of ft/sec lane 1

0074 LOOP_B1_OSR B9:0 3 — SUM_OF_FTSEC_L1 ADD Add Source A N7:1 46< Source B N7:50 4095< Dest N7:50 4095<

Track sum of ft/sec lane 1

0075 LOOP_B2_OSR B9:0 13 — SUM_OF_FTSEC_L1 ADD Add Source A N7:5 52< Source B N7:50 4095< Dest N7:50 4095<

Track volumes for lanes 3 & 4

0076 LOOP_B3_OSR B9:1 7 / LOOP_B4_OSR B9:2 1 — VOL_3_4 ADD Add Source A 1 1< Source B N7:19 67< Dest N7:19 67<

Track sum of ft/sec lane 1

0077 LOOP_B1_OSR B9:0 3 — SUM_OF_FTSEC_L2 ADD Add Source A N7:10 46< Source B N7:51 2602< Dest N7:51 2602<

Track sum of ft/sec lane 1

0078

LOOP_B1_OSR
B9:0
3

SUM_OF_FTSEC_L2
ADD
Add
Source A N7:14
42<
Source B N7:51
2602<
Dest N7:51
2602<

Log Average speed on the hour for lanes 1 & 2

0079

EQU
Equal
Source A T4:17.ACC
394<
Source B N7:42
499<

VOL_1_2
NEQ
Not Equal
Source A N7:18
91<
Source B 0
0<

AVG_SP_1_2
DIV
Divide
Source A N7:50
4095<
Source B N7:18
91<
Dest N7:8
0<

Log Average speed on the hour for lanes 3 & 4

0080

EQU
Equal
Source A T4:17.ACC
394<
Source B N7:42
499<

VOL_3_4
NEQ
Not Equal
Source A N7:19
67<
Source B 0
0<

AVG_SP_3_4
DIV
Divide
Source A N7:51
2602<
Source B N7:19
67<
Dest N7:17
0<

Log average speed on the hour for both directions if there are any vehicles

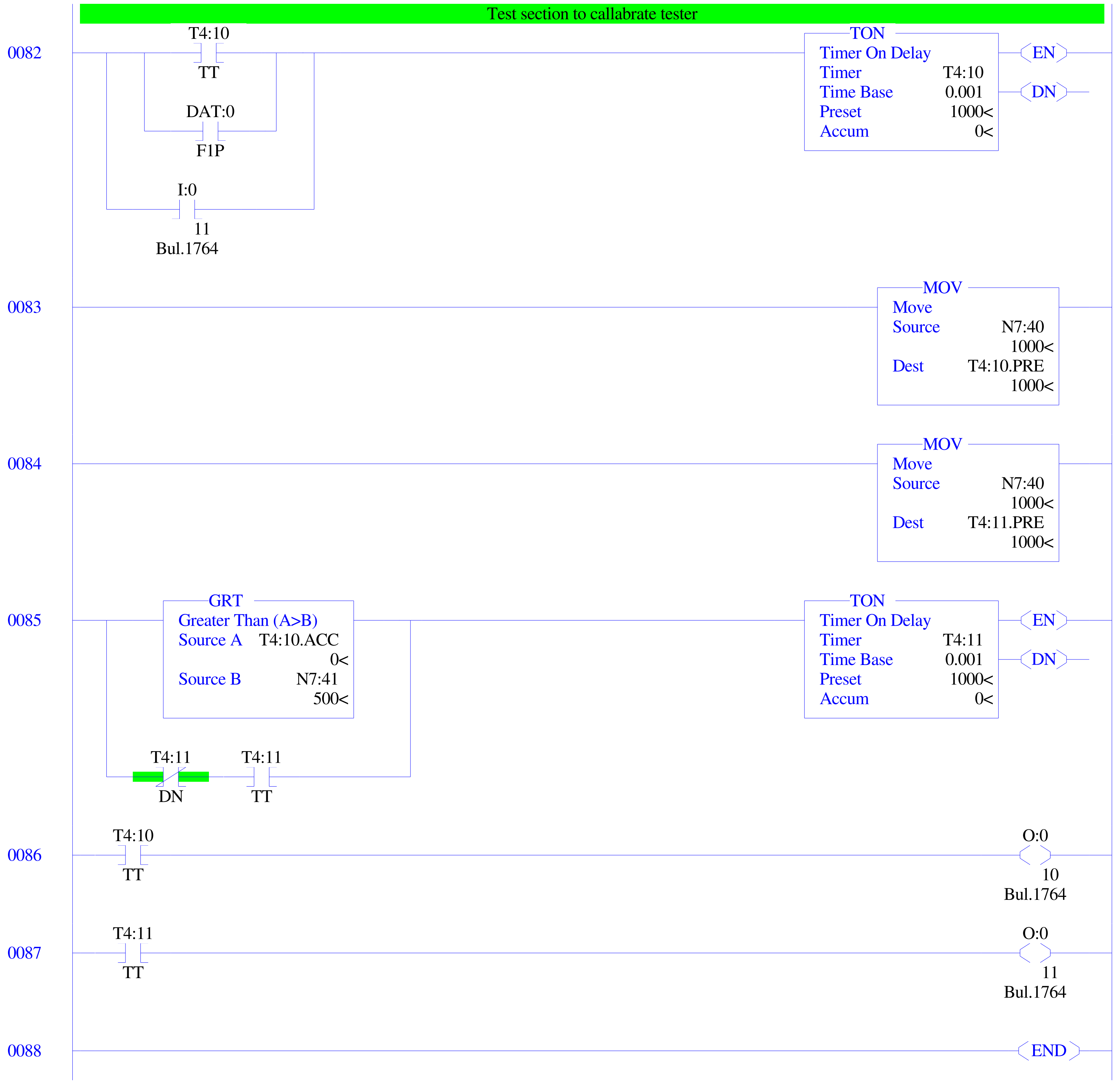
0081

EQU
Equal
Source A T4:17.ACC
394<
Source B N7:42
499<

AVG_SP_1_2
GRT
Greater Than (A>B)
Source A N7:8
0<
Source B 0
0<

AVG_SP_3_4
GRT
Greater Than (A>B)
Source A N7:17
0<
Source B 0
0<

DLG
Data Log
queue number 0


Test section to callabrate tester
0082
T4:10
TT
DAT:0
F1P
I:0
11
Bul.1764
TON
Timer On Delay
Timer T4:10
Time Base 0.001
Preset 1000<
Accum 0<
EN
DN
0083
MOV
Move
Source N7:40
1000<
Dest T4:10.PRE
1000<
0084
MOV
Move
Source N7:40
1000<
Dest T4:11.PRE
1000<
0085
GRT
Greater Than (A>B)
Source A T4:10.ACC
0<
Source B N7:41
500<
T4:11
DN
T4:11
TT
TON
Timer On Delay
Timer T4:11
Time Base 0.001
Preset 1000<
Accum 0<
EN
DN
0086
T4:10
TT
O:0
10
Bul.1764
0087
T4:11
TT
O:0
11
Bul.1764
0088
END

Data File O0 (bin) -- OUTPUT

Offset	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
O:0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	Bul.1764	Micrologix 1500 LRP Series B
O:0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Bul.1764	Micrologix 1500 LRP Series B
O:0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Bul.1764	Micrologix 1500 LRP Series B
O:0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Bul.1764	Micrologix 1500 LRP Series B

Data File I1 (bin) -- INPUT

Offset	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
I:0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Bul.1764	Micrologix 1500 LRP Series B
I:0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Bul.1764	Micrologix 1500 LRP Series B
I:0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Bul.1764	Micrologix 1500 LRP Series B
I:0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Bul.1764	Micrologix 1500 LRP Series B

Data File S2 (hex) -- STATUS

Main

Processor Mode S:1/0 - S:1/4 = Remote Run
On Power up Go To Run (Mode Behavior) S:1/12 = 0
First Pass S:1/15 = No
Free Running Clock S:4 = 0011-0010-0001-1000

Proc

OS Catalog Number S:57 = 1510
OS Series S:58 = B
OS FRS S:59 =
Processor Catalog Number S:60 =
Processor Series S:61 = A
Processor FRN S:62 =

User Program Type S:63 = 801h
Compiler Revision Number S:64 =

Scan Times

Maximum (x10 ms) S:22 = 28
Watchdog (x10 ms) S:3 (high byte) = 10
Last 100 uSec Scan Time S:35 = 10
Scan Toggle Bit S:33/9 = 0

Math

Math Overflow Selected S:2/14 = 0
Overflow Trap S:5/0 = 0
Carry S:0/0 = 0
Overflow S:0/1 = 0
Zero Bit S:0/2 = 0
Sign Bit S:0/3 = 0

Math Register (lo word) S:13 = 0
Math Register (high word) S:14-S:13 = 0
Math Register (32 Bit) S:14-S:13 = 0

Chan 0

Processor Mode S:1/0- S:1/4 = Remote Run
Node Address S:15 (low byte) = 0
Baud Rate S:15 (high byte) = ?
Channel Mode S:33/3 = 0
Comms Active S:33/4 = 0
Incoming Cmd Pending S:33/0 = 0
Msg Reply Pending S:33/1 = 0

Outgoing Msg Cmd Pending S:33/2 = 0

Debug

Suspend Code S:7 = 0
Suspend File S:8 = 0

Errors

Fault Override At Power Up S:1/8 = 0
Startup Protection Fault S:1/9 = 0
Major Error Halt S:1/13 = 0
Overflow Trap S:5/0 = 0
Control Register Error S:5/2 = 0
Major Error Executing User
Fault Rtn. S:5/3 = 0
Battery Low S:5/11 = 0
Input Filter Selection Modified S:5/13 = 0
ASCII String Manipulation error S:5/15 = 0

Fault Routine S:29 = 0
Major Error S:6 = 0h
Error Description:

Protection

Deny Future Access S:1/14 = No
Data File Overwrite Protection Lost S:36/10 = False

Mem Module

Memory Module Loaded On Boot S:5/8 = 0
Password Mismatch S:5/9 = 0
Load Memory Module On Memory Error S:1/10 = 0
Load Memory Module Always S:1/11 = 0
On Power up Go To Run (Mode Behavior) S:1/12 = 0
Program Compare S:2/9 = 0
Data File Overwrite Protection Lost S:36/10 = 0

Forces

Forces Enabled S:1/5 = Yes
Forces Installed S:1/6 = No

Data File B3 (bin) -- BINARY

Offset	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	(Symbol) Description
B3:0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	

Data File T4 -- TIMER

Offset	EN	TT	DN	BASE	PRE	ACC	(Symbol) Description
T4:0	0	0	0	.01 sec	4000	0	(SPEED_TIMER_1)
T4:1	0	0	0	.01 sec	300	0	(LENGTH_TIMER_1) Occupancy of entrance loop.
T4:2	0	0	0	.01 sec	4000	0	(SPEED_TIMER_2)
T4:3	0	0	0	.01 sec	300	0	(LENGTH_TIMER_2) Occupance of entrance loop
T4:4	0	0	0	.01 sec	4000	0	(SPEED_TIMER_3)
T4:5	0	0	0	.01 sec	300	0	(LENGTH_TIMER_3) Occupancy of entrance loop.
T4:6	0	0	0	.01 sec	4000	0	(SPEED_TIMER_4)
T4:7	0	0	0	.01 sec	300	0	(LENGTH_TIMER_4) Occupancy of entrance loop.
T4:8	0	0	0	.01 sec	0	0	(CLASS_1_OUT_TIMER_1)
T4:9	0	0	0	1.0 sec	2	0	
T4:10	0	0	0	.001 sec	1000	0	
T4:11	0	0	0	.001 sec	1000	0	
T4:12	0	0	0	.01 sec	50	0	(OUTPUT_TIMER_LANE_1)
T4:13	0	0	0	.01 sec	50	0	(OUTPUT_TIMER_LANE_2)
T4:14	0	0	0	.01 sec	50	0	(OUTPUT_TIMER_LANE_3)
T4:15	0	0	0	.01 sec	50	0	(OUTPUT_TIMER_LANE_4)
T4:16	0	0	0	.01 sec	0	0	
T4:17	1	1	0	1.0 sec	500	394	
T4:18	1	0	1	1.0 sec	1	1	

Data File C5 -- COUNTER

Offset	CU	CD	DN	OV	UN	UA	PRE	ACC	(Symbol) Description
C5:0	0	0	0	0	0	0	6	5	
C5:1	0	0	1	0	0	0	0	7	
C5:2	0	0	1	0	0	0	0	2	
C5:3	0	0	1	0	0	0	0	0	
C5:4	0	0	1	0	0	0	0	0	

Data File R6 -- CONTROL

Offset	EN	EU	DN	EM	ER	UL	IN	FD	LEN	POS	(Symbol) Description
R6:0	0	0	0	0	0	0	0	0	0	0	

Data File N7 (dec) -- INTEGER

Offset	0	1	2	3	4	5	6	7	8	9
N7:0	0	46	2070	3128	0	52	1768	3536	0	0
N7:10	46	1840	3128	0	42	1848	2856	0	91	67
N7:20	45	34	40	44	0	0	0	0	0	0
N7:30	1000	1900	1901	4100	4101	6600	6601	12600	0	0
N7:40	1000	500	499	0	2200	2200	2200	2200	0	0
N7:50	4095	2602								

Data File B9 (bin)

Offset	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	(Symbol) Description
B9:0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
B9:1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
B9:2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Data File N10 (dec)

Offset	0	1	2	3	4	5	6	7	8	9
N10:0	0									

Address (Symbol) = Value [Description]

Address/Symbol Database

Address	Symbol	Scope	Description	Sym Group
B3:0/1	SPEED_LATCH1	Global	Latched on leading edge of first loop,unlatched by second loop.	
B3:0/2	SPEED_LATCH2	Global	Latched on leading edge of first loop, unlatched by second loop.	
B3:0/3	SPEED_LATCH3	Global	Latched on leadiing edge offirst loop, unlatched by second loop.	
B3:0/4	SPEED_LATCH4	Global	Latched on leadiing edge offirst loop, unlatched by second loop.	
B9:0/1	LOOP_A1_OSR	Global		
B9:0/3	LOOP_B1_OSR	Global		
B9:0/7	LOOP_B1_OSF	Global		
B9:0/11	LOOP_A2_OSR	Global		
B9:0/13	LOOP_B2_OSR	Global		
B9:0/15				
B9:1/5	LOOP_A3_OSR	Global		
B9:1/6				
B9:1/7	LOOP_B3_OSR	Global		
B9:1/8				
B9:1/9				
B9:1/15	LOOP_A4_OSR	Global		
B9:2/0				
B9:2/1	LOOP_B4_OSR	Global		
B9:2/3				
B9:14				
DAT:0/F1P				
DAT:0/F2P				
I:0/0	LOOP_A1	Global	Entrance loop lane 1	
I:0/1	LOOP_B1	Global	Exit loop lane 1	
I:0/2	LOOP_A2	Global	Entrance loop on lane 2	
I:0/3	LOOP_B2	Global	Exit loop on lane 2	
I:0/4	LOOP_A3	Global	Entrance loop on lane 3	
I:0/5	LOOP_B3	Global	Exit loop on lane 3	
I:0/6	LOOP_A4	Global	Entrance loop on lane 4	
I:0/7	LOOP_B4	Global	Exit loop on lane 4	
I:0/11				
N7:0	TIME_BETWEEN_LOOPS1	Global	Travel time between loops a and b	
N7:1	FEET_PER_SEC_1	Global	Feet/Second Lane 1	
N7:2	VEHICLE_LENGTH_1	Global	Ft/sec*sec=Length	
N7:3	MPH_1	Global	Mph*10 Lane 1	
N7:4	TIME_BETWEEN_LOOPS2	Global	Travel time between loops a and b	
N7:5	FEET_PER_SEC_2	Global	Feet/Second Lane 2	
N7:6	VEHICLE_LENGTH_2	Global	Ft/sec*sec=Length 2	
N7:7	MPH_2	Global	Mph*10 lane 2	
N7:8	AVG_SP_1_2	Global		
N7:9	TIME_BETWEEN_LOOPS3	Global	Travel time between loops a and b	
N7:10	FEET_PER_SEC_3	Global	Feet/Second Lane 3	
N7:11	VEHICLE_LENGTH_3	Global	Ft/sec*sec=Length 3	
N7:12	MPH_3	Global	Mph*10 Lane 3	
N7:13	TIME_BETWEEN_LOOPS4	Global	Travel time between loops a and b	
N7:14	FEET_PER_SEC_4	Global	Feet/Second Lane 4	
N7:15	VEHICLE_LENGTH_4	Global	Ft/sec*sec=Length 4	
N7:16	MPH_4	Global	Mph*10 Lane 4	
N7:17	AVG_SP_3_4	Global		
N7:18	VOL_1_2	Global		
N7:19	VOL_3_4	Global		
N7:20	OCC_TIME_LANE_1	Global	Occupancy time on loop for lane 1	
N7:21	OCC_TIME_LANE_2	Global	Occupancy time on loop for lane 2	
N7:22	OCC_TIME_LANE_3	Global	Occupancy time on loop for lane 3	
N7:23	OCC_TIME_LANE_4	Global	Occupancy time on loop for lane 4	
N7:30	LOW_LIM_1	Global		
N7:31	HIGH_LIM_1	Global		
N7:32	LOW_LIM_2	Global		
N7:33	HIGH_LIM_2	Global		
N7:34	LOW_LIM_3	Global		
N7:35	HIGH_LIM_3	Global		
N7:36	LOW_LIM_4	Global		
N7:37	HIGH_LIM_4	Global		
N7:41				
N7:42				
N7:44	LOOP_CTR_TO_CTR_1	Global	Center to center distance between loops lane 1	
N7:45	LOOP_CTR_TO_CTR_2	Global	Center to center distance between loops lane 2	
N7:46	LOOP_CTR_TO_CTR_3	Global	Center to center distance between loops lane 3	
N7:47	LOOP_CTR_TO_CTR_4	Global	Center to center distance between loops lane 4	
N7:50	SUM_OF_FTSEC_L1	Global		
N7:51	SUM_OF_FTSEC_L2	Global		
O:0/5				
O:0/10				
O:0/11				
S:0			Arithmetic Flags	
S:0/0			Processor Arithmetic Carry Flag	
S:0/1			Processor Arithmetic Underflow/ Overflow Flag	
S:0/2			Processor Arithmetic Zero Flag	
S:0/3			Processor Arithmetic Sign Flag	
S:1			Processor Mode Status/ Control	
S:1/0			Processor Mode Bit 0	
S:1/1			Processor Mode Bit 1	
S:1/2			Processor Mode Bit 2	
S:1/3			Processor Mode Bit 3	

Address	Symbol	Scope	Description	Sym Group
S:1/4			Processor Mode Bit 4	
S:1/5			Forces Enabled	
S:1/6			Forces Present	
S:1/7			Comms Active	
S:1/8			Fault Override at Powerup	
S:1/9			Startup Protection Fault	
S:1/10			Load Memory Module on Memory Error	
S:1/11			Load Memory Module Always	
S:1/12			Load Memory Module and RUN	
S:1/13			Major Error Halted	
S:1/14			Access Denied	
S:1/15			First Pass	
S:2/0			STI Pending	
S:2/1			STI Enabled	
S:2/2			STI Executing	
S:2/3			Index Addressing File Range	
S:2/4			Saved with Debug Single Step	
S:2/5			DH-485 Incoming Command Pending	
S:2/6			DH-485 Message Reply Pending	
S:2/7			DH-485 Outgoing Message Command Pending	
S:2/15			Comms Servicing Selection	
S:3			Current Scan Time/ Watchdog Scan Time	
S:4			Time Base	
S:5/0			Overflow Trap	
S:5/2			Control Register Error	
S:5/3			Major Err Detected Executing UserFault Routine	
S:5/4			M0-M1 Referenced on Disabled Slot	
S:5/8			Memory Module Boot	
S:5/9			Memory Module Password Mismatch	
S:5/10			STI Overflow	
S:5/11			Battery Low	
S:6			Major Error Fault Code	
S:7			Suspend Code	
S:8			Suspend File	
S:9			Active Nodes	
S:10			Active Nodes	
S:11			I/O Slot Enables	
S:12			I/O Slot Enables	
S:13			Math Register	
S:14			Math Register	
S:15			Node Address/ Baud Rate	
S:16			Debug Single Step Rung	
S:17			Debug Single Step File	
S:18			Debug Single Step Breakpoint Rung	
S:19			Debug Single Step Breakpoint File	
S:20			Debug Fault/ Powerdown Rung	
S:21			Debug Fault/ Powerdown File	
S:22			Maximum Observed Scan Time	
S:23			Average Scan Time	
S:24			Index Register	
S:25			I/O Interrupt Pending	
S:26			I/O Interrupt Pending	
S:27			I/O Interrupt Enabled	
S:28			I/O Interrupt Enabled	
S:29			User Fault Routine File Number	
S:30			STI Setpoint	
S:31			STI File Number	
S:32			I/O Interrupt Executing	
S:33			Extended Proc Status Control Word	
S:33/0			Incoming Command Pending	
S:33/1			Message Reply Pending	
S:33/2			Outgoing Message Command Pending	
S:33/3			Selection Status User/DF1	
S:33/4			Communicat Active	
S:33/5			Communicat Servicing Selection	
S:33/6			Message Servicing Selection Channel 0	
S:33/7			Message Servicing Selection Channel 1	
S:33/8			Interrupt Latency Control Flag	
S:33/9			Scan Toggle Flag	
S:33/10			Discrete Input Interrupt Reconfigur Flag	
S:33/11			Online Edit Status	
S:33/12			Online Edit Status	
S:33/13			Scan Time Timebase Selection	
S:33/14			DTR Control Bit	
S:33/15			DTR Force Bit	
S:34			Pass-thru Disabled	
S:34/0			Pass-Thru Disabled Flag	
S:34/1			DH+ Active Node Table Enable Flag	
S:34/2			Floating Point Math Flag Disable	
S:35			Last 1 ms Scan Time	
S:36			Extended Minor Error Bits	
S:36/8			Dll Lost	
S:36/9			STI Lost	
S:36/10			Memory Module Data File Overwrite Protection	

Address	Symbol	Scope	Description	Sym Group
S:37			Clock Calendar Year	
S:38			Clock Calendar Month	
S:39			Clock Calendar Day	
S:40			Clock Calendar Hours	
S:41			Clock Calendar Minutes	
S:42			Clock Calendar Seconds	
S:43			STI Interrupt Time	
S:44			I/O Event Interrupt Time	
S:45			Dll Interrupt Time	
S:46			Discrete Input Interrupt- File Number	
S:47			Discrete Input Interrupt- Slot Number	
S:48			Discrete Input Interrupt- Bit Mask	
S:49			Discrete Input Interrupt- Compare Value	
S:50			Processor Catalog Number	
S:51			Discrete Input Interrupt- Return Number	
S:52			Discrete Input Interrupt- Accumulat	
S:53			Discrete Input Interrupt- Timer	
S:54			Discrete Input Interrupt- Timer	
S:55			Last Dll Scan Time	
S:56			Maximum Observed Dll Scan Time	
S:57			Operating System Catalog Number	
S:58			Operating System Series	
S:59			Operating System FRN	
S:61			Processor Series	
S:62			Processor Revision	
S:63			User Program Type	
S:64			User Program Functional Index	
S:65			User RAM Size	
S:66			Flash EEPROM Size	
S:67			Channel 0 Active Nodes	
S:68			Channel 0 Active Nodes	
S:69			Channel 0 Active Nodes	
S:70			Channel 0 Active Nodes	
S:71			Channel 0 Active Nodes	
S:72			Channel 0 Active Nodes	
S:73			Channel 0 Active Nodes	
S:74			Channel 0 Active Nodes	
S:75			Channel 0 Active Nodes	
S:76			Channel 0 Active Nodes	
S:77			Channel 0 Active Nodes	
S:78			Channel 0 Active Nodes	
S:79			Channel 0 Active Nodes	
S:80			Channel 0 Active Nodes	
S:81			Channel 0 Active Nodes	
S:82			Channel 0 Active Nodes	
S:83			DH+ Active Nodes	
S:84			DH+ Active Nodes	
S:85			DH+ Active Nodes	
S:86			DH+ Active Nodes	
T4:0	SPEED_TIMER_1	Global		
T4:1	LENGTH_TIMER_1	Global	Occupancy of entrance loop.	
T4:2	SPEED_TIMER_2	Global		
T4:3	LENGTH_TIMER_2	Global	Occupance of entrance loop	
T4:3.ACC				
T4:3/TT				
T4:4	SPEED_TIMER_3	Global		
T4:4.ACC				
T4:5	LENGTH_TIMER_3	Global	Occupancy of entrance loop.	
T4:5.ACC				
T4:6	SPEED_TIMER_4	Global		
T4:6.ACC				
T4:7	LENGTH_TIMER_4	Global	Occupancy of entrance loop.	
T4:7.ACC				
T4:8	CLASS_1_OUT_TIMER_1	Global		
T4:10/TT				
T4:11/TT				
T4:12	OUTPUT_TIMER_LANE_1	Global		
T4:12/TT				
T4:13	OUTPUT_TIMER_LANE_2	Global		
T4:13/TT				
T4:14	OUTPUT_TIMER_LANE_3	Global		
T4:14/TT				
T4:15	OUTPUT_TIMER_LANE_4	Global		
T4:15/TT				
T4:17/DN				
T4:18/TT				

Instruction Comment Database

Address	Instruction	Description

Symbol Group Database

Group_Name	Description

Appendix I – Sample Dashboards

EXAMPLE of annual report/database to be generated for motor vehicle performance measures

Ability to compare to previous year's

Select time period to compare and days of

Performance measures and rankings for selected time period and days.

	Start	End
Select Time Period	4:00 PM	5:00 PM
Select Days of the week to compare	☒Mon ☒Tues ☒Wed ☒Thurs ☒Fri ☒Sat ☒Sun	

Overall Rank (current year)	Previous year's ranking	Corridor	From	To	Distance	Average Travel Time	Rank	Travel Time Index	Rank	Corridor Delay	Rank	Average Speed	Rank	Average Rank
4	4	82nd Ave (NB)	x	y		0:08:50	5	1.5	7	0:02:50	1	18	4	4.25
10	9	82nd Ave (SB)				0:10:50	8	1.4	6	0:08:50	2	15	7	5.75
6	5	Powell Blvd (EB)				0:05:50	1	1.6	9	0:08:50	2	15	7	4.75
1	1	Powell Blvd (WB)				0:06:20	2	1.1	1	0:08:50	2	20	3	2
3	3	Sunnyside (EB)				0:08:50	5	1.3	4	0:08:50	2	18	4	3.75
1	2	Sunnyside (WB)				0:08:15	3	1.1	1	0:08:50	2	22	2	2
7	6	Barbur (NB)				0:15:15	10	1.6	9	0:08:50	2	25	1	5.5
7	7	Barbur (SB)				0:12:30	9	1.5	7	0:08:50	2	18	4	5.5
7	8	BH Hwy (EB)				0:10:25	7	1.3	4	0:08:50	2	11	9	5.5
5	10	BH Hwy (WB)				0:08:15	3	1.2	3	0:08:50	2	8	10	4.5

Choose the start and end points of the corridor. Default would be the full corridor.

Based on chosen corridor extents, the distance would automatically populate.

Note: This is mock data. It is only meant to demonstrate the potential capabilities of the Dashboard

EXAMPLE of annual report/database to be generated for bicycle and pedestrian performance measures

	Start	End
Select Time Period	4:00 PM	5:00 PM
Select Days of the week to compare	☒Mon ☒Tues ☒Wed ☒Thurs ☒Fri ☒Sat ☒Sun	

Select time period to compare and days of

Ability to analyze data by approach

All intersections with bicycle and pedestrian data could be shown.

Bicycle

Intersection	Total Bicycle Volume	Rank	Bicycle Delay	Rank
Powell/82nd	55	2	01:22	3
Sunnyside/122nd	45	3	01:00	2
Powell/Sandy	70	1	00:39	1
185th/Walker	30	4	01:34	4

Bicycle Volume by Approach				Bicycle Delay by Approach			
NB	SB	EB	WB	NB	SB	EB	WB
11	17	19	8	00:45	01:05	02:20	00:30
5	14	11	16	00:20	00:55	01:45	00:45
14	21	25	11	00:15	00:35	00:45	01:05
3	9	8	11	00:25	01:45	00:45	02:20

Pedestrians

Intersection	Total Ped Actuations	Rank	Intersection Pedestrian Delay	Rank
Powell/82nd	30	1	00:45	2
Sunnyside/122nd	10	4	01:15	3
Powell/Sandy	15	3	00:29	1
185th/Walker	20	2	01:33	4

Pedestrian Actuations by Crossing Leg				Pedestrian Delay by Crossing Leg			
North	South	East	West	North	South	East	West
12	8	4	6	00:45	00:45	00:45	00:45
0	2	5	3	00:00	00:55	00:45	02:20
0	7	3	5	00:00	00:25	00:45	00:25
5	2	6	7	01:45	00:45	00:45	02:20

Note: This is mock data. It is only meant to demonstrate the potential capabilities of the Dashboard

Appendix J - Demonstration Project

Final Memorandum

DATE: January 14th, 2013

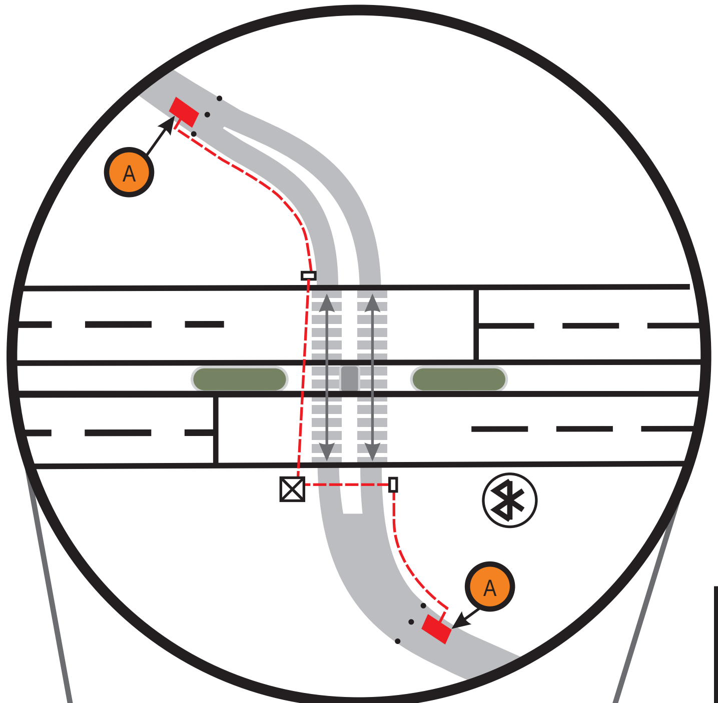
TO: Amy Mastraccio-Lopez, ODOT
Deena Platman, Metro
Peter Koonce, PBOT
Jim Peters, DKS

FROM: Shaun Quayle, PE, Kittelson & Associates, Inc.
Alex Kiheri, Kittelson & Associates, Inc.
Tom Urbanik, PE, Kittelson & Associates, Inc.

SUBJECT: **Final – Arterial Performance Demonstration – 82nd Avenue** P06287-017

This memorandum presents an overview of the arterial performance demonstration project along 82nd Avenue, conducted in cooperation with the City of Portland Bureau of Transportation. This memorandum will summarize the implemented automated data collection features along the arterial, lessons learned with the implementation, and potential future enhancements. The scope and features of the demonstration project are summarized in the Proof of Concept Implementation Memorandum, dated August 7th, 2012.

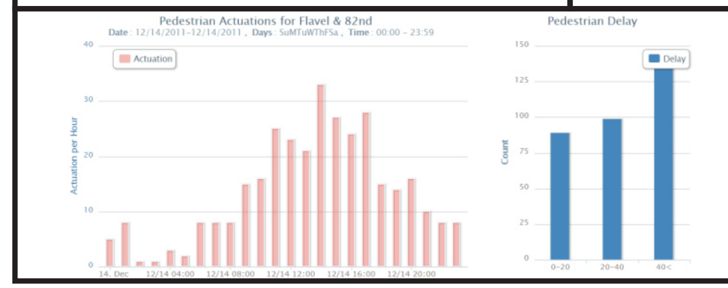
Figures 1, 2, and 3 summarize the various components of the 82nd Avenue demonstration project, along with some sample data. Figure 1 summarizes the multi-modal performance measures collected as part of the demonstration project. Figure 2 summarizes the segment level performance measures. Figure 3 summarizes the intersection level performance measures at 82nd Avenue / Powell Boulevard. An overview of the demonstration elements is summarized in the sections following the summary figures.

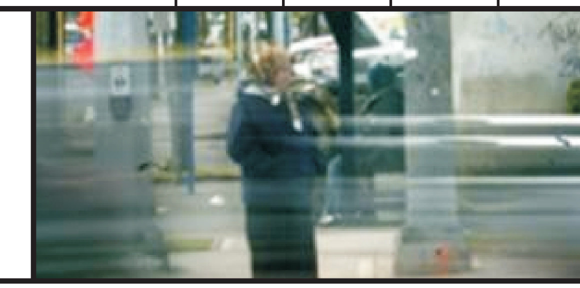


B PEDESTRIAN DETECTION

With pedestrian detection, delay and call request information can be collected and logged by a 2070 traffic controller

AM/PM Peak Period Pedestrian Performance				
Cross Walk Phase	2	4	6	8
Button Calls Per Hour	-	16 / 58	-	16 / 58
Delay to Serve Call (sec)	-	30 / 35	-	30 / 35





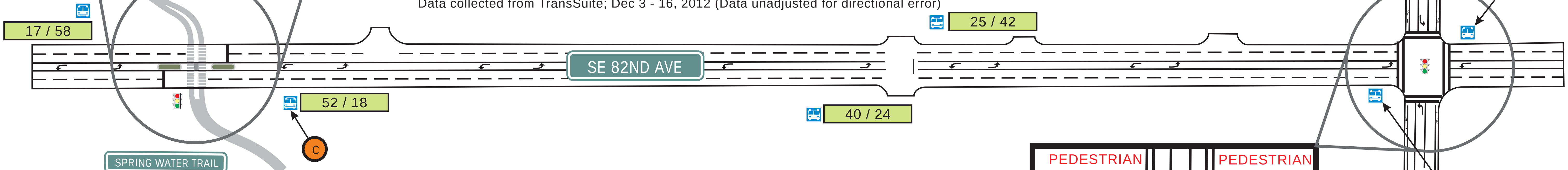
Data collected from Portal; April 2 - 6, 2012 (7 - 8 AM & 5 - 6 PM)

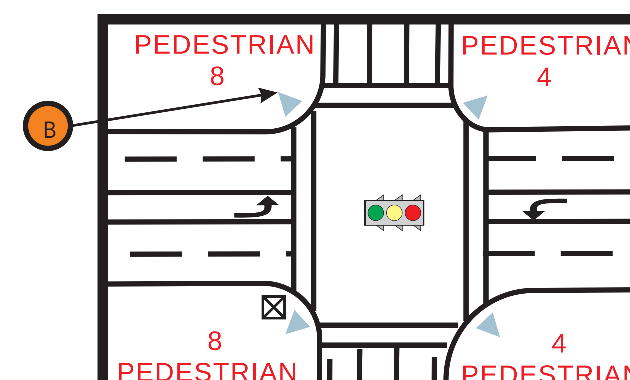
A BIKE DETECTION (NEW)

Installed parallelogram inductive bike loop to count bike traffic.

Performance Metrics	
Name	NB/SB
Weekday PM Peak Hour Bike Volume	13 / 7
Weekday Bike ADT	160 / 100
Weekend Bike ADT	130 / 85

Data collected from TransSuite; Dec 3 - 16, 2012 (Data unadjusted for directional error)





Ped phases 2+6 on recall

C BUS PASSENGER DATA

TriMet buses are equipped with automatic passenger counters which collect boarding and alighting data.

Performance Metrics
Average Daily Passenger Data
XX / YY
Boarding/Alighting

Data collected from TriMet; Fall 2012

(NO SCALE)

82ND AVENUE ARTERIAL PERFORMANCE DEMONSTRATION SUMMARY
MULTI-MODAL PERFORMANCE MEASURES (SPRINGWATER TRAIL TO FLAVEL STREET)

FIGURE 1

H:\projfile\11670 - Metro Arterial Performance Measure RCTO\dwgs\figs\cdrfiles-11670_figure.cdr

D BLUETOOTH MAC ADDRESS READER

A Bluetooth MAC address reader is used to measure segment travel time, speed and origin-destination data.

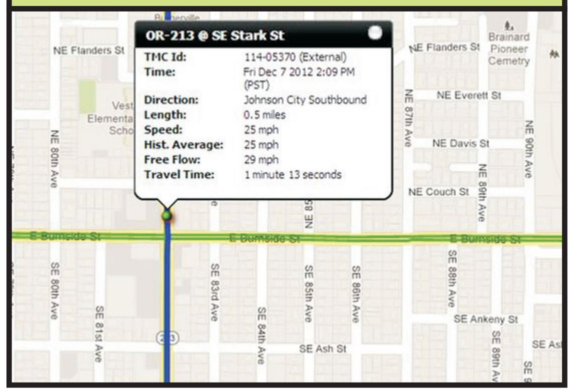
Performance Metrics
Travel Time From Foster Road (NB)
→ 10:40 mins
Travel Time To Foster Road (SB)
← 10:41 mins

Data collected Portal; from Feb 10 - Oct 12, 2012 (4 - 6 PM)

E INRIX DATA SEGMENT

Inrix data is used to measure travel time and average speed data for a segment. (Inrix segment highlighted below)

Performance Metrics
Travel Time SE Foster to NE Glisan (NB)
→ 8:10 mins
Travel Time NE Foster to SE Stark (SB)
← 7:58 mins



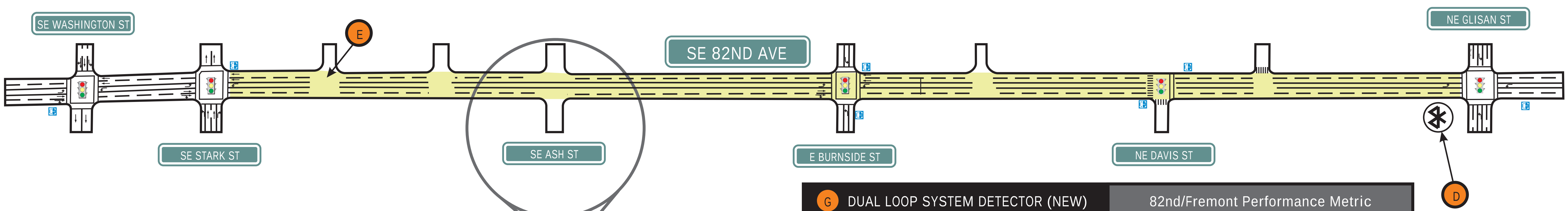
Data based on Inrix 2010 average weekday (4 - 6 pm)

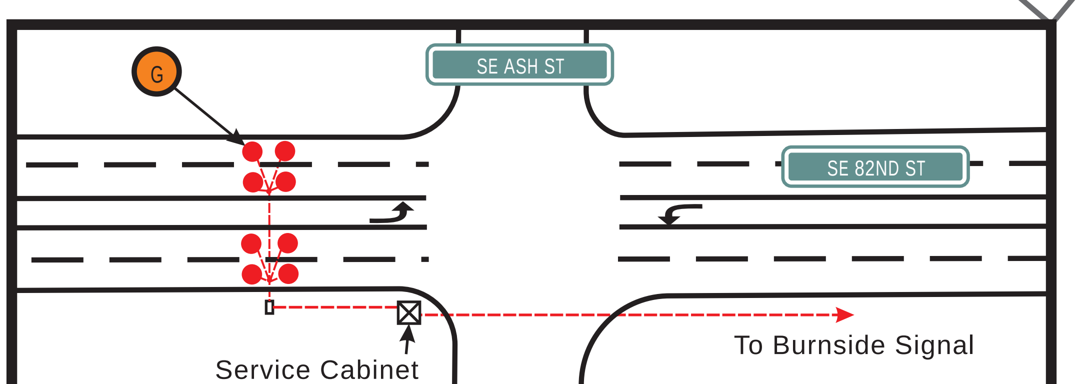
F TRIMET CAD/AVL DATA

TriMet AVL data provides real time vehicle tracking and can be aggregated to determine on-time performance for bus routes.

Bus On-time Performance	
PM Peak hour	
NB Route 72	84%
SB Route 72	78%

Data from TriMet; Fall 2012 (3:30 - 5:30 PM)





G DUAL LOOP SYSTEM DETECTOR (NEW)

Dual inductive loop system detectors can capture volume, length based classification and point speed.

82nd/Fremont Performance Metric	
Name	NB/SB
Weekday Peak Hour Volume	975 / 890
% by Vehicle Classification	
Passenger	97% / 94%
Single Unit Truck	2% / 3%
Combination Truck	1% / 3%
Multi-trailer Truck	0% / 0%

Data collected from TransSuite & PLC at 82nd/Fremont; January 4, 2013 (4:52 - 5:52 PM)

N (NO SCALE)

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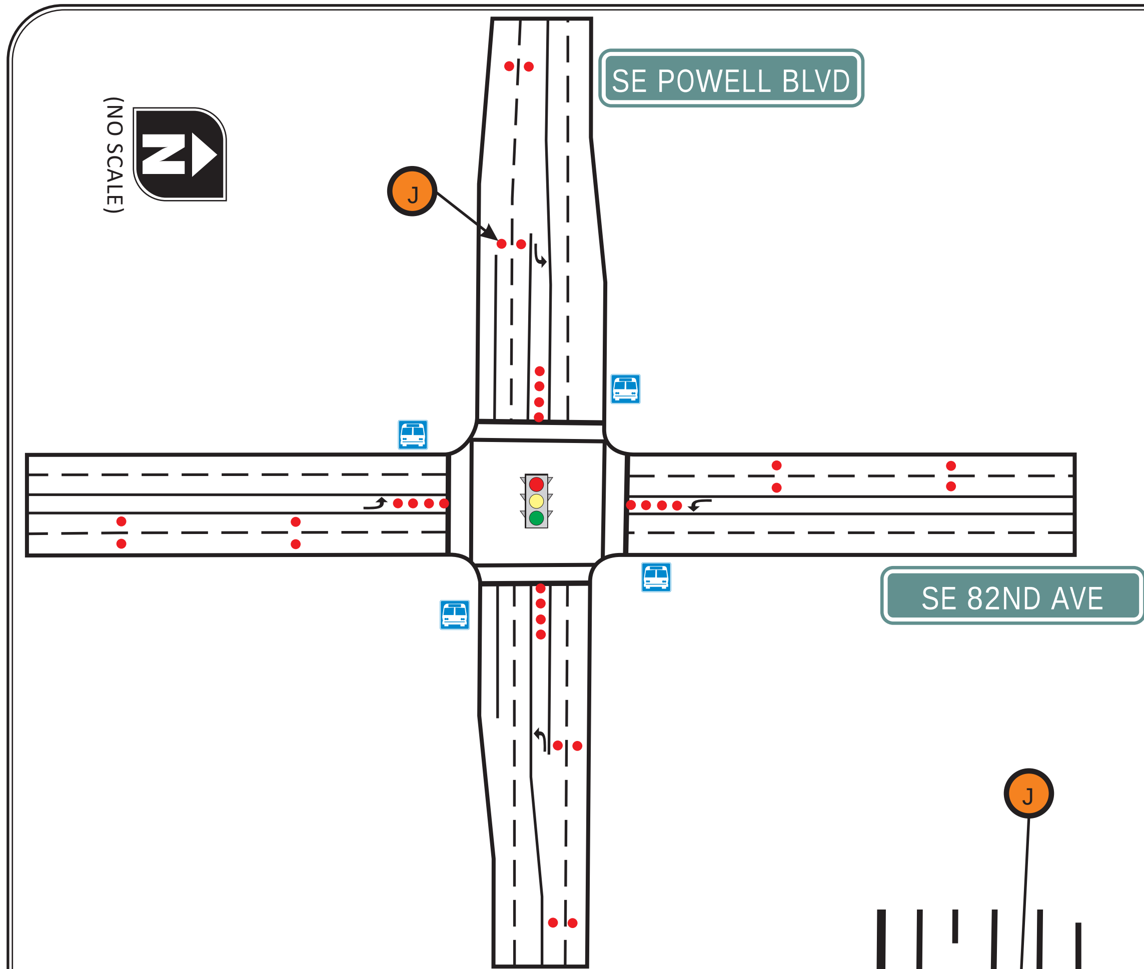
82ND AVENUE ARTERIAL PERFORMANCE DEMONSTRATION SUMMARY
SEGMENT PERFORMANCE MEASURES (FOSTER ROAD TO GLISAN STREET)

FIGURE 2

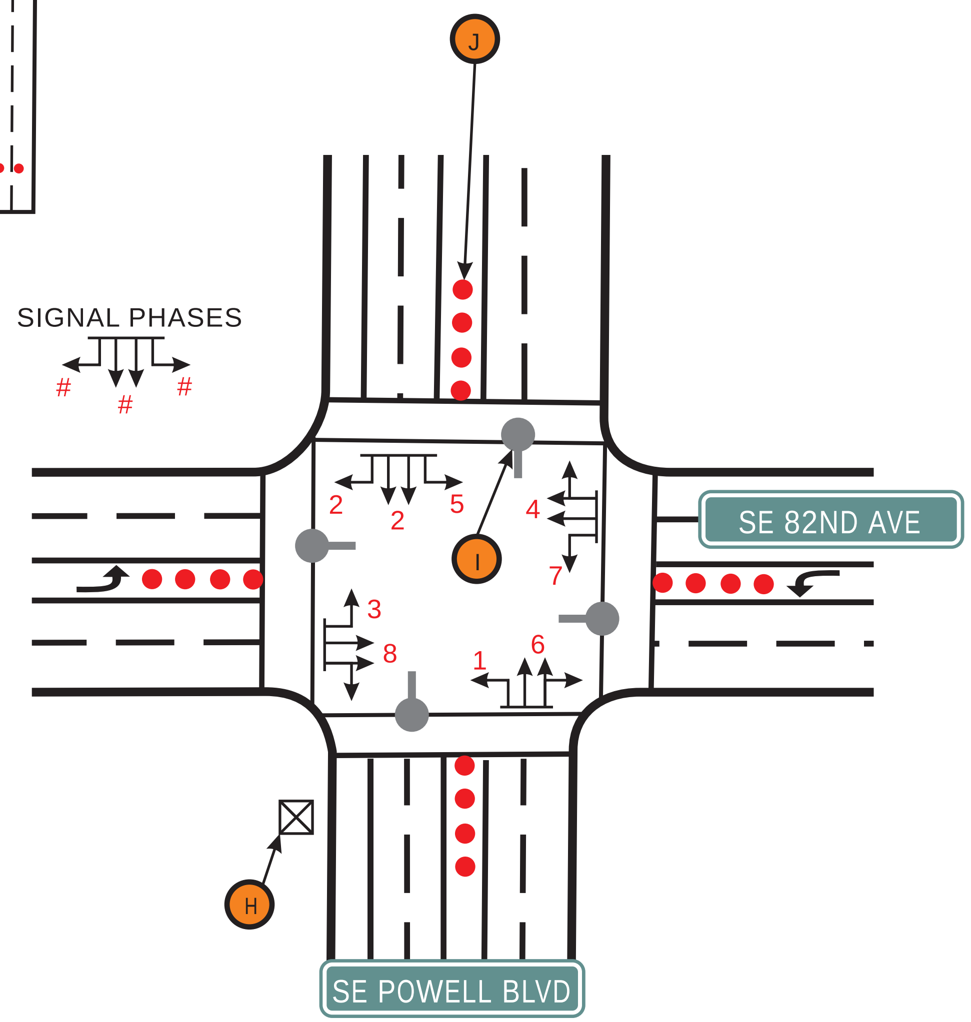


H 2070 TRAFFIC CONTROLLER

2070 traffic controller with NWS Voyage software allows for logging of arterial performance data. (volume, delay, arrival on green, split logs)

Average PM Peak Hour Signal Timing Performance								
Signal Phase	WBLT 1	EB 2	NBLT 3	SB 4	EBLT 5	WB 6	SBLT 7	NB 8
Phase Service	21	21	21	22	21	21	21	22
Average Green (sec)	21	55	16	60	22	54	16	59
Max Outs	9	15	10	18	11	10	12	16
Gap Out	12	6	11	4	10	11	9	6
% Arrival on Green	-	26	-	41	-	28	-	31
Intersection Volume (Vehicle Loops By Movement)								
Volume Per Movement	58	700	31	704	63	587	37	696

Data collected from TransSuite; Dec 5, 2012 (4:52 - 5:52 PM)



J VEHICLE DETECTION

Vehicle Detection allows for count and future delay measures. (see item B)

I TRANSIT SIGNAL PRIORITY (TSP)

Transit signal priority (TSP) operates by transmitting location and vehicle information to traffic signals which prioritize transit vehicles at signals

Transit Signal Priority Performance 82nd/Woodward				
Direction	NB	EB	SB	WB
Calls Per Hour	0	-	8.8	-
Avg. Extension (sec)	0	-	11	-

Data collected from TransSuite; Oct 15 - 19, 2012

MULTIMODAL PERFORMANCE ELEMENTS

Figure 1 summarized the variety of multi-modal performance elements captured along 82nd Avenue for this demonstration project.

BIKE DETECTION

Permanent bicycle detection was implemented along both approaches to 82nd Avenue along the Springwater Trail to collect on-going **bicycle volume counts**. The City selected parallelogram shaped inductive loop detection with dimensions of approximately 0.9 meter width (~3 feet) by 1.1 meter length (~3.6 feet), as shown below. This detection is connected to the signal cabinet and controller at 82nd and Springwater Trail. Bike actuations are recorded to the NWS Voyage volume log in the local signal controller; which is accessible through the region central signal software, TransSuite. Exhibit 1 illustrates the westbound approach bike detector, along with streaming count data into Portland's TransSuite central system. *Redline construction drawings are included in Appendix A.*

PBOT conducted a limited validation test from 7-9 am on December 6th, 2012 using video surveillance at the nearby intersection for the westbound approach only (eastbound view was obscured). All 9 bicycles travelling over the loop were detected; but 3 of the 9 were travelling eastbound over this westbound loop. This indicates that the parallelogram inductive loop is effective counting bikes; but there is a challenge to determining directionality of travel, particularly on facilities such as the Springwater Trail, where side by side bike travel is occurring. Alternate location of detection or directionally sensitive detection technologies could be ways to address this limitation.

Date/Time	Count	Gap		Date/Time	Count	Gap
12/01/2012 09:00:00	4	0		12/02/2012 05:05:00	2	0
12/01/2012 10:00:00	15	0		12/02/2012 06:05:00	1	0
12/01/2012 11:00:00	19	0		12/02/2012 07:05:00	2	0
12/01/2012 12:00:00	29	0		12/02/2012 08:05:00	4	0
12/01/2012 13:00:00	36	0		12/02/2012 09:05:00	9	0
12/01/2012 14:00:00	31	0		12/02/2012 10:05:00	10	0
12/01/2012 15:00:00	14	0		12/02/2012 11:05:00	14	0
12/01/2012 16:00:00	16	0		12/02/2012 12:05:00	29	0
12/01/2012 17:00:00	16	0		12/02/2012 13:05:00	29	0
12/01/2012 18:00:00	5	0		12/02/2012 14:05:00	9	0
12/01/2012 19:00:00	8	0		12/02/2012 15:05:00	7	0
12/01/2012 20:05:00	1	0		12/02/2012 16:05:00	7	0
12/01/2012 21:05:00	0	0		12/02/2012 17:05:00	12	0
12/01/2012 22:05:00	5	0		12/02/2012 18:05:00	3	0
12/01/2012 23:05:00	5	0		12/02/2012 19:05:00	7	0
12/02/2012 00:05:00	0	0		12/02/2012 20:05:00	4	0
12/02/2012 01:05:00	1	0		12/02/2012 21:05:00	2	0
12/02/2012 02:05:00	0	0		12/02/2012 22:05:00	2	0
12/02/2012 03:05:00	0	0		12/02/2012 23:05:00	1	0
12/02/2012 04:05:00	0	0		12/03/2012 00:05:00	1	0

Exhibit 1 – Westbound Springwater Trail at 82nd Avenue Permanent Bike Loop & Data

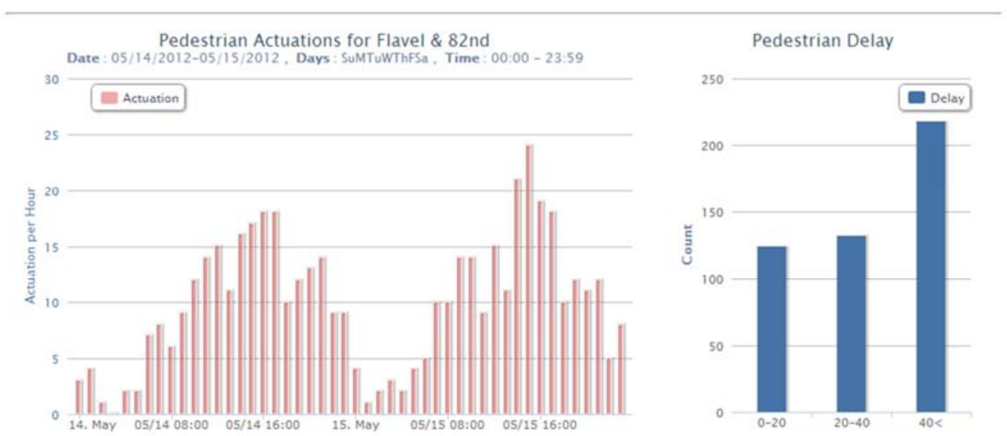
Future Activities:
(1) Further validation of the bike loop data; and development of an adjustment factor for directionality.
(2) Send bike loop to PORTAL data warehouse to enhance regional access to automated data source.

PEDESTRIAN DETECTION

For demonstration purposes, bringing awareness to the existing performance metrics for pedestrian use through existing pedestrian push button detection and controller logging was a priority. Existing pedestrian push buttons can track the **number of pedestrian actuations** occurring over a period of time, which is an approximation of pedestrian volumes. It should be noted that adjustment factors may be necessary to account for (1) multiple pedestrians and a single actuation, and (2) when pedestrians push multiple buttons to request crossing for both directions from a street corner, but only cross in one direction.

Notably, many locations along 82nd Avenue do not have pedestrian detection (push buttons) parallel to 82nd Avenue, since these movements rest in walk and are recalled. The lack of pedestrian detection prevents this form of approximating pedestrian volumes for these movements, as shown in Figure 1 for pedestrian phases 2 and 6 at 82nd and Flavel. Pedestrian detection for all approaches and the removal of pedestrian recall will result in the most accurate pedestrian actuations for approximating pedestrian volumes (pedestrian reservice would likely be effective as well); but removal of pedestrian recall will increase pedestrian delays as a trade-off. Considering the operating environment, users and modal priorities is critical to balancing automated performance measures with effective traffic operations.

Pedestrian delay is measured through the time elapsed between the first pedestrian actuation in a direction and when the walk indication is first displayed using the methods developed and implemented by the City of Portland, along with Portland State University[1]. This feature is currently implemented through custom internal logic coding within the 2070 controllers, with NWS Voyage. A sample of the results is shown below in Exhibit 2.



		Phase	1	2	3	4
Record 624						
Date	Monday, September 24,2012	SERVED	8	10	7	11
Time	12:07	PEDS	0	10	0	2
Period	15	AVG GRN	6	38	7	24
		Force_Offs	0	0	0	0
		Gap_Outs	8	10	7	11

Exhibit 2 – 82nd & Flavel, Number of Pedestrian Actuations in PORTAL and TransSuite

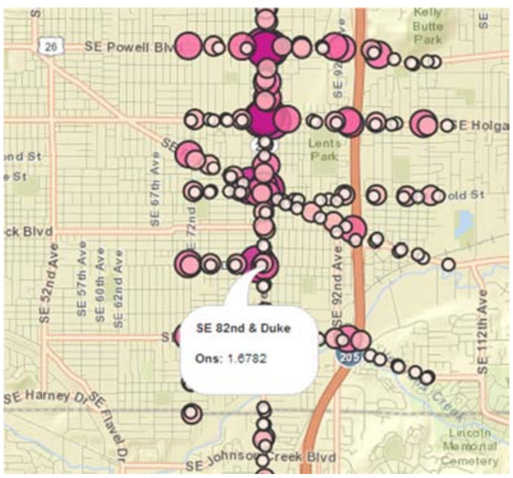
[1] Kothuri, S., Reynolds, T., Monsere, C., and Koonce, P., "Preliminary Development of Methods to Automatically Gather Bicycle Counts and Pedestrian Delay at Signalized Intersections." 91st Annual Meeting of the Transportation Research Board, Washington D.C., January 2012.

Future Activities:
(1) Enhance PORTAL displays to allow for viewing pedestrian volumes and delay by crossing or pedestrian phase (currently all grouped together).
(2) Enhance NWS Voyage and TransSuite to measure, log, and display automated delay for pedestrians (and other detection inputs) tracking time elapsed from call to service by input.

Bus Passenger Data

TriMet buses for nearly the entire fleet are equipped with automatic passenger counters (APC) which collect person-level boarding and alighting data at each stop. This represents another automated data source for gauging the **level of pedestrian activity along an arterial**, given that bus stops are a major origin-destination for pedestrian traffic.

TriMet currently maintains databases with passenger boarding/alighting data and can provide this data upon request, but is not widely broadcast or easily accessible to transportation agencies or professionals and thus maybe under-utilized. TriMet is currently working with Portland State University to bring in transit APC data into the PORTAL data warehouse.



E	F	G	H	I	J	K	L	M
LOCATION_ID	PUBLIC_LOCATION_DESCRIPTION	_NAME_	_05	_06	_07	_08	_09	_10
7964	SE 82nd & Foster	ONS	2.5	5.5	8.5	21.1	21.4	21.6
8029	SE 82nd & Raymond Ct	ONS	0.4	2.0	3.0	6.5	3.8	6.5
8040	SE 82nd & Schiller	ONS	0.1	0.0	0.1	1.1	1.4	1.4
7984	SE 82nd & Holgate	ONS	0.3	3.2	8.3	21.1	14.1	15.3
7935	SE 82nd & Boise	ONS	-	1.1	1.4	2.0	3.2	4.6
7943	SE 82nd & Francis	ONS	0.8	0.1	2.8	3.8	3.4	5.0
8031	SE 82nd & Rhone	ONS	-	0.0	0.7	2.6	1.3	0.9
8023	SE 82nd & Powell	ONS	3.6	13.0	19.9	39.5	28.9	27.4
8052	SE 82nd & Tibbetts	ONS	1.2	0.4	2.6	9.3	3.2	1.6
8061	SE 82nd & Woodward	ONS	-	0.2	0.6	3.0	2.1	3.0
7947	SE 82nd & Clinton	ONS	.	0.1	0.1	2.6	0.8	0.8
7957	SE 82nd & Division	ONS	.	7.2	12.1	31.0	21.1	19.1
12755	SE 82nd & Harrison	ONS	.	0.7	1.0	2.6	2.7	3.0
8007	SE 82nd & Mill	ONS	.	2.1	2.3	7.7	7.1	3.6
7979	SE 82nd & Hawthorne	ONS	.	0.6	1.2	6.6	3.5	3.9
8037	SE 82nd & Salmon	ONS	.	0.7	0.7	2.4	0.4	0.6
8065	SE 82nd & Yamhill	ONS	.	0.5	1.4	4.2	2.0	2.4
7928	SE 82nd & Washington	ONS	.	1.2	1.6	5.4	1.9	2.6
8047	SE 82nd & Stark	ONS	.	2.0	4.6	9.0	6.5	7.4
7930	SE 82nd & Ash	ONS	.	0.2	1.1	1.6	1.3	0.5
7936	SE 82nd & E Burnside	ONS	.	4.0	4.8	13.8	12.7	12.5

Exhibit 3 – Bus Automatic Passenger Count Data

Future Activities:
(1) Create linkage between TriMet APC database and PORTAL.
(2) Enhance PORTAL displays to allow for queries and viewing intuitively of passenger boardings and alighting by stop.

SEGMENT PERFORMANCE ELEMENTS

Figure 2 captures the segment-level performance measures for the different modes. These components are summarized in the following section.

BLUETOOTH™ MAC ADDRESS READERS

A Bluetooth™ MAC address reader is one automated technology to sample and measure travel times, speeds and origin-destinations between fixed points in a network. Prior to this RCTO project, the City of Portland installed 11 permanent Bluetooth MAC readers in and around this demonstration corridor. Readers along 82nd Avenue between Glisan Street and Foster Road were used as a pair to compare to other segment level data sources to do a cursory comparison of travel time between Bluetooth and Inrix data sources (shown in Figure 2).

Bluetooth™ travel time measurements for 2012 weekday PM peak period were calculated to be longer (+30-35%) than Inrix™ probe data from 2010 weekday PM peak period (4-6 pm) for the segment between Glisan Street and Foster Road. This difference is larger than expected, and could be the result of different time periods, or methodologies related to outlier filtering. Either way, the difference warrants further exploration and comparison. Bluetooth™ MAC address captures have shown to remain consistent or slightly increase, as illustrated in Table 1, which contrasts the earliest and latest time periods of data available in PORTAL at this time.

Table 1 – Bluetooth™ Trending of Data Samples

	3/4/12 – 3/10/12	9/9/12 – 9/15/12	Delta
82nd: Glisan - Springwater	454	497	+ 9.5%
82nd: Springwater - Glisan	421	451	+ 7.1%
Powell: 8th - 42nd	3064	3159	+ 3.1%
Powell: 42nd – 8th	3566	3689	+ 3.5%

Future Activities:
(1) Create automated linkage between PBOT Bluetooth server and PORTAL.
(2) Expand comparison of Inrix™ and Bluetooth™ data in PORTAL to identify difference & increase confidence in data sources.
(3) Continue to refine and enhance PORTAL displays for travel times and speeds via Bluetooth™ data.

INRIX™ PROBE DATA

Inrix™ is one of a few commercial data providers for probe data (travel time, speeds). ODOT has purchased historical trend profile data from Inrix™ for 2008 through 2010. The 2010 aggregrated weekday data was used in this RCTO demonstration project, with a sample result shown in Figure 2.

Inrix™ travel time measurements averaged over 2010 weekday PM peak hours (4-6 PM) were measured to be about 30-35% lower than the same time period for Bluetooth™ probe data during 2012. Previous research has illustrated the relative closeness of Bluetooth™ and Inrix™ data, implying close correlation to field measurements[2]. Additional Inrix™ time periods and segments should be compared to Bluetooth™ measurements to understand their resulting travel times and any differences.

A notable limitation for arterials is that Inrix™ data is tied to the national standard definitions for traffic management center (TMC) coding, which pre-defines segments. While the segment ends are often at major intersections, the TMC segments can be too long or lack the ability to specify end points to make a one to one comparison. In addition, certain minor arterials, collectors or local streets may have limited or no data coverage; although third party data providers, like Inrix™ have ever growing data sources and thus larger sample sizes which should increase confidence in data as well as coverage.

	A	B	C	D	
1	TMC	Min_0	Min_15	Min_30	M
2	114+04361	61.33333	60.66667	60	
3	114+04362	57.66667	58.33333	58.33333	
4	114+04363	61	61	61	
5	114+04364	56.66667	57	57.66667	5
6	114+04365	58.33333	60	59.66667	5
7	114+04366	57.33333	58	58.33333	5
8	114+04367	54.33333	57	56	
9	114+04369	49	51.33333	49.33333	4
10	114+04370	39	39.33333	39	3
11	114+04371	45.33333	45	45	

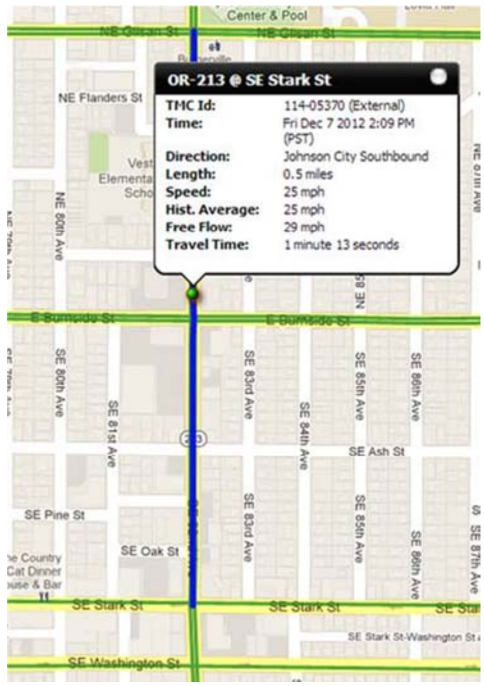


Exhibit 4 – Inrix™ Speed Data & Mapping

Future Activities:

(1) Continue to explore enhanced ways to spatially view and make accessible, Inrix™ and other third party data sources. This may include a linkage to PORTAL and/or purchasing vendor-specific visualization software.

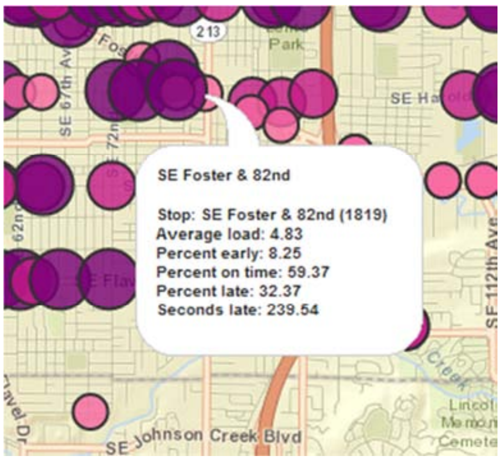
(2) Expand comparison of Inrix™ and Bluetooth™ data in PORTAL to identify difference & increase confidence in data sources.

[2] Lomax, T., Turner, S., Eisele, B., Schrank, D., Geng, L., and Shollar, B., "Refining the Real-Timed Urban Mobility Report." Texas Transportation Institute, March, 2012.

BUS AUTOMATIC VEHICLE LOCATION (PROBE) DATA

TriMet bus fleet has GPS-based automatic vehicle location (AVL) equipment as part of the system to track vehicle locations, adherence to route, and compare to schedule for on-time adherence. Buses can also be used as probes to measure segment travel times. The new AVL system TriMet has is able to produce much higher resolution data and opens up expanded performance measure opportunities.

Bus AVL data was obtained from TriMet for the 82nd Avenue corridor and then compared to Bluetooth and Inrix travel times. As shown in Figure 2, travel times from bus AVL data are longer; which is attributed to the frequent stops made along the route. Exhibit 5 illustrates the current AVL based (percent on-time) performance measures in PORTAL.



Weekday Time Point On Time Performance - Fall 2012

Route: 72-Killingsworth/82nd Ave
Direction: To Clackamas Town Center

Time Point Location	Percent On Time	Percent Early	Percent Late	Avg. Min. Late	Number of Trips
N Anchor & Channel	96%	2%	3%	1.1	90
NE Alberta & M L King	89%	3%	8%	1.7	90
NE Killingsworth & Cully	90%	6%	4%	1.2	19
NE Killingsworth & Cully	81%	5%	15%	2.3	90
NE 82nd & Sandy	93%	7%	0%	0.3	1
NE 82nd & 82nd Ave MAX Stn/I-84	82%	2%	16%	2.4	110
SE 82nd & Powell	76%	3%	21%	2.8	110
SE 82nd & Flavel	69%	8%	24%	2.9	110
Clackamas Town Center Mall	56%	16%	28%	3.2	110

Exhibit 5 – Bus Stop Level Data in PORTAL & From TriMet

Future Activities:
(1) Create linkage between TriMet AVL database and PORTAL.
(2) Enhance PORTAL displays to allow for queries and viewing intuitively of AVL-based performance metrics, including on-time performance and travel time.

DUAL LOOP SYSTEM DETECTION

The ability to measure vehicle length as an approximation for distinguishing freight use along arterials was identified as a priority. Three existing single loop "system count or detector" stations existed in our 82nd Avenue demonstration corridor, as follows:

- 82nd Avenue / Fremont (Midblock ~500' south of Fremont)
- 82nd Avenue / Burnside (Midblock ~620' south of Burnside)
- 82nd Avenue / Flavel (Downstream ~100' of Flavel)

Each of these locations were modified with two new loops per lane to capture length-based classification, as well as point speed data. Loop spacing used is 22' from center to center. Exhibit 6 illustrates the new dual-loop count, speed and classification station at 82nd and Burnside. *Redline construction drawings are included in Appendix A.*

Exhibit 6 – Dual Loop Detection on 82nd Avenue, south of Burnside

Locating dual-loop system detectors away from locations with congestion is important to produce meaningful data. Speeds below 15 miles per hour can result in skewed or unreliable results; thus a mid-block location beyond typical queue lengths is important to optimize data quality. System detectors are wired to the nearest traffic cabinet, with logging occurring within traffic controller volume logs. In the case of 82nd Avenue, this controller data is accessible through the TransSuite unified controller manager (UCM) but requires manual intervention to understand which detectors represent which movements and to combine over multiple time periods, as shown in Exhibit 7.

cord 1		Detector #	1	2	3	4
Date	Friday, August 31,2012	Volume	56	164	42	145
Time	16:30		9	10	11	12
Period	60		625	724	0	307
			17	18	19	20
			71	0	513	566
			25	26	27	28
			608	0	371	0

Exhibit 7 – Volume Logging for Length-Based Classification in TransSuite UCM

There is a need to bring dual-loop or other technologies (radar, video, etc.) data back to TransSuite in TCS for ease of tracking this data in the same format to other system detectors and/or sending the data to PORTAL for data query and visualization. This will require software modification(s) in TransSuite to support this endeavor.

For this demonstration project programmable logic controllers (PLC) were used to capture and sort, and bin measured lengths of vehicles to appropriate bins within the controller volume log, since NWS Voyage controller software has yet to implement a length-based classification log, as shown in Exhibit 8.

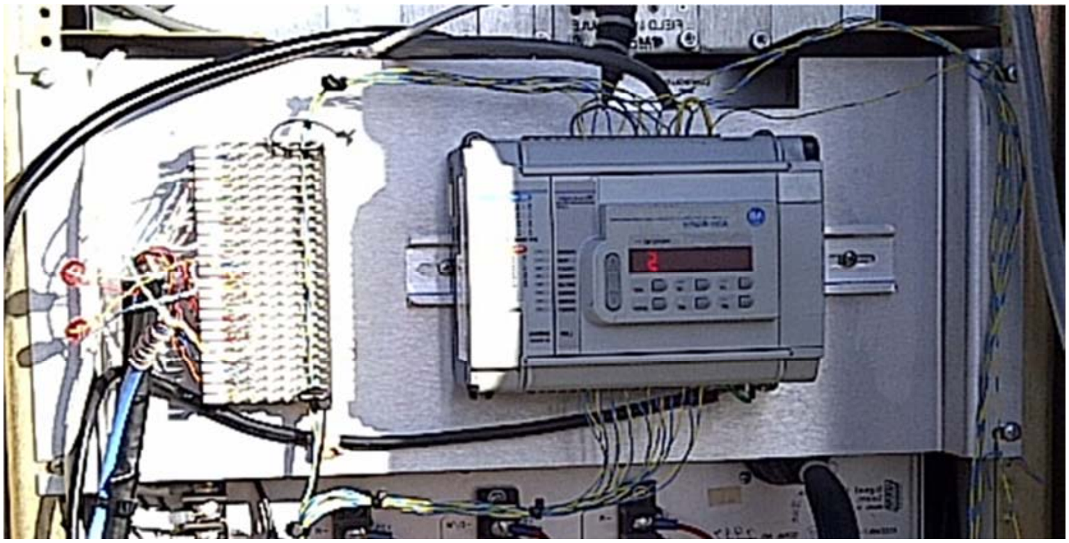


Exhibit 8 – PLC Implementation at 82nd/Burnside

ODOT length thresholds, as shown in the following table were used for this demonstration project, but could be revisited with future research.

Table 1: Length Based Classification Boundaries

Vehicles Classification	Range of Length (in ft)		
	FHWA	ODOT	WSDOT
Passenger vehicles (PV)	Less than 13	Less than 20	Less than 26
Single unit trucks (SU)	From 13 to 35	From 20 to 35	From 26 to 39
Combination trucks (CU)	From 36 to 61	From 36 to 60	From 40 to 65
Multi-trailer trucks (MU)	From 62 to 120	From 61 to 150	Longer than 65

Source: TMG, ODOT and WSDOT

Future Activities:

(1) Enhance TransSuite to pull in length-based classifications, point speeds, and counts into TCS
(2) Create linkage between TransSuite database and PORTAL.
(3) Create length-based classification log within NWS Voyage controller software.
(4) Create visualization and queries for length-based classification data in PORTAL.

INTERSECTION PERFORMANCE ELEMENTS

Figure 3 illustrates the intersection level performance measures collected for this demonstration. The following sections highlight the performance measure components.

2070 CONTROLLER LOGGING

As noted in NCHRP 3-79, Measuring and Predicting the Performance of Automobile Traffic on Urban Street, leveraging necessary infrastructure at every signalized intersection in the form of signal controller to collect and log performance measures in an automated fashion is an efficient and effective objective. To this end, the corridor of 82nd Avenue was selected for this demonstration to highlight the available logging capabilities within the 2070 controllers with NWS Voyage controller software. The following logs are available in the NWS Voyage software and lessons learned related to them:

- **Volume logs** – Requires knowledge of detector numbering and inputs to match logged volumes to the appropriate location (movement). Accuracy is conditional on detection technology and quality of implementation/maintenance.

Record 1		Detector #	1	2	3	4
Date	Friday, August 31,2012	Volume	56	164	42	145
Time	16:30		9	10	11	12
Period	60		625	724	0	307
			17	18	19	20
			71	0	513	566
			25	26	27	28
			608	0	371	0

- **MOE logs**, which are listed by phase:
  - Phase Service – the frequency with which a phase was served during a period of time.
  - Average Green – the average green time allocated to a signal phase during a period of time.
  - Max Out / Force Off – the number of occurrences where the full allocation of green time for a movement was used during a period of time. This is an approximation for movements experiencing cycle or split failures and may benefit from additional green time. Note, it appears in TransSuite UCM, that only force-offs are displayed; if splits are used, then "max outs" maybe the only item indicative of using all available green time. In this case:

    # of Max Out = # of Phase Service – # of Gap Out
  - Gap Out – the number of occurrences where less than the full allocation of green time for a movement was used during a period of time, assuming appropriate detector settings, for a period of time.

		Phase	1	2	3	4
Record 1						
Date	Thursday, October 18,2012	SERVED	10	11	7	11
Time	20:37	PEDS	0	11	0	11
Period	15	AVG GRN	8	26	8	28
		Force_Offs	0	0	0	0
		Gap_Outs	9	7	7	7

- **Coordination Logs** – Measures the percent of vehicle arrivals on green and red and the derived platoon ratio to approximate quality of progression or arrivals for any approach. Note the detection zone used for this measure should be located beyond a standing queue to produce accurate results. Recently in the latest version of NWS Voyage, percent arrival on green or red can be captured during free or coordinated operations. During free operations, there is no set cycle timer, so arrival on green data is logged on 60 second intervals which limit the ease of interpreting actual arrivals on green.

		Phase	1	2	3	4
Record 1						
Date	Wednesday, November 21, 2012	TERM	Green	Not served	Gapout	Gapout
Time	00:58:00	END T	0	0	6	41
Coord Plan	1	% GRN	50	0	0	80
ycle Length	60	P RAT	230	0	0	184

- **TransSuite TCS Split Logger** – This logs by phase and by cycle the allocated maximum green, served green time, number of pedestrian calls, desired and actual offset, desired and actual cycle length, number of communication failures, and detector occupancy

Cycle #	End	Plan	Timing	Ph 1	Ph 2	Ph 3	Ph 4	Ph 5	Ph 6	Ph 7	Ph 8	CF	OF	DL	AL	DO	AO	D 1/33
844712	12/06/2012 15:05:44	255	free	015/017/000	---/049/136	015/014/000	025/046/136	015/013/000	---/053/136	015/012/000	000/048/136	0	0	0	143	0	20	96
-	-	-	-									-	-	-	-	-	-	-
844713	12/06/2012 15:08:25	255	free	015/020/000	---/052/154	015/011/000	025/061/154	015/016/000	---/056/154	015/019/000	000/053/154	0	0	0	161	0	13	90
-	-	-	-									-	-	-	-	-	-	-
844714	12/06/2012 15:10:54	255	free	015/021/000	---/041/142	015/019/000	025/050/142	015/019/000	---/043/142	015/009/000	000/060/142	0	0	0	149	0	24	98
-	-	-	-									-	-	-	-	-	-	-
844715	12/06/2012 15:13:24	255	free	015/023/000	---/044/143	015/014/000	025/053/143	015/015/000	---/052/143	015/013/000	000/054/143	0	0	0	150	0	23	68
-	-	-	-									-	-	-	-	-	-	-
844716	12/06/2012 15:15:58	255	free	015/017/000	---/052/147	015/013/000	025/055/147	015/015/000	---/054/147	015/015/000	000/053/147	0	0	0	154	0	23	71
-	-	-	-									-	-	-	-	-	-	-
844717	12/06/2012 15:18:42	255	free	015/025/000	---/049/157	015/017/000	025/057/157	015/015/000	---/059/157	015/014/000	000/060/157	0	0	0	164	0	27	92
-	-	-	-									-	-	-	-	-	-	-
844718	12/06/2012 15:21:24	255	free	015/021/000	---/049/155	015/010/000	025/065/155	015/017/000	---/053/155	015/015/000	000/060/155	0	0	0	162	0	11	67
-	-	-	-									-	-	-	-	-	-	-
844719	12/06/2012 15:24:11	255	free	015/021/000	---/053/160	015/017/000	025/058/160	015/019/000	---/055/160	015/015/000	000/060/160	0	0	0	167	0	23	96
-	-	-	-									-	-	-	-	-	-	-

- **Transit Priority Logs** –Logs by event the controller inputs received and actions related to transit signal priority requests and service. These logs lack the ability to aggregate data and produce the desired performance measures of type of priority service (green extension or early green), length of priority service, and number of calls.

Record 1			
Date	4/28/11	Transit	3
Time	00:50:28	Code	TP Went Away During Bus Extend
		Phases	34
		Coord Plan	4
		CPlan On	67
		CPlan Grn	67
		CPlan Off	11
Record 2			
Date	4/28/11	Transit	1
Time	00:58:04	Code	TP Phases Achieved
		Phases	34
		Coord Plan	4
		CPlan On	47
		CPlan Grn	47
		CPlan Off	0
Record 3			
Date	4/28/11	Transit	1
Time	00:58:16	Code	TP Input Went Inactive In TP Green
		Phases	34
		Coord Plan	4
		CPlan On	47
		CPlan Grn	47
		CPlan Off	59
Record 4			
Date	4/28/11	Transit	3
Time	05:22:02	Code	TP Phases Achieved
		Phases	34
		Coord Plan	4
		CPlan On	65
		CPlan Grn	65
		CPlan Off	0

Future Activities:

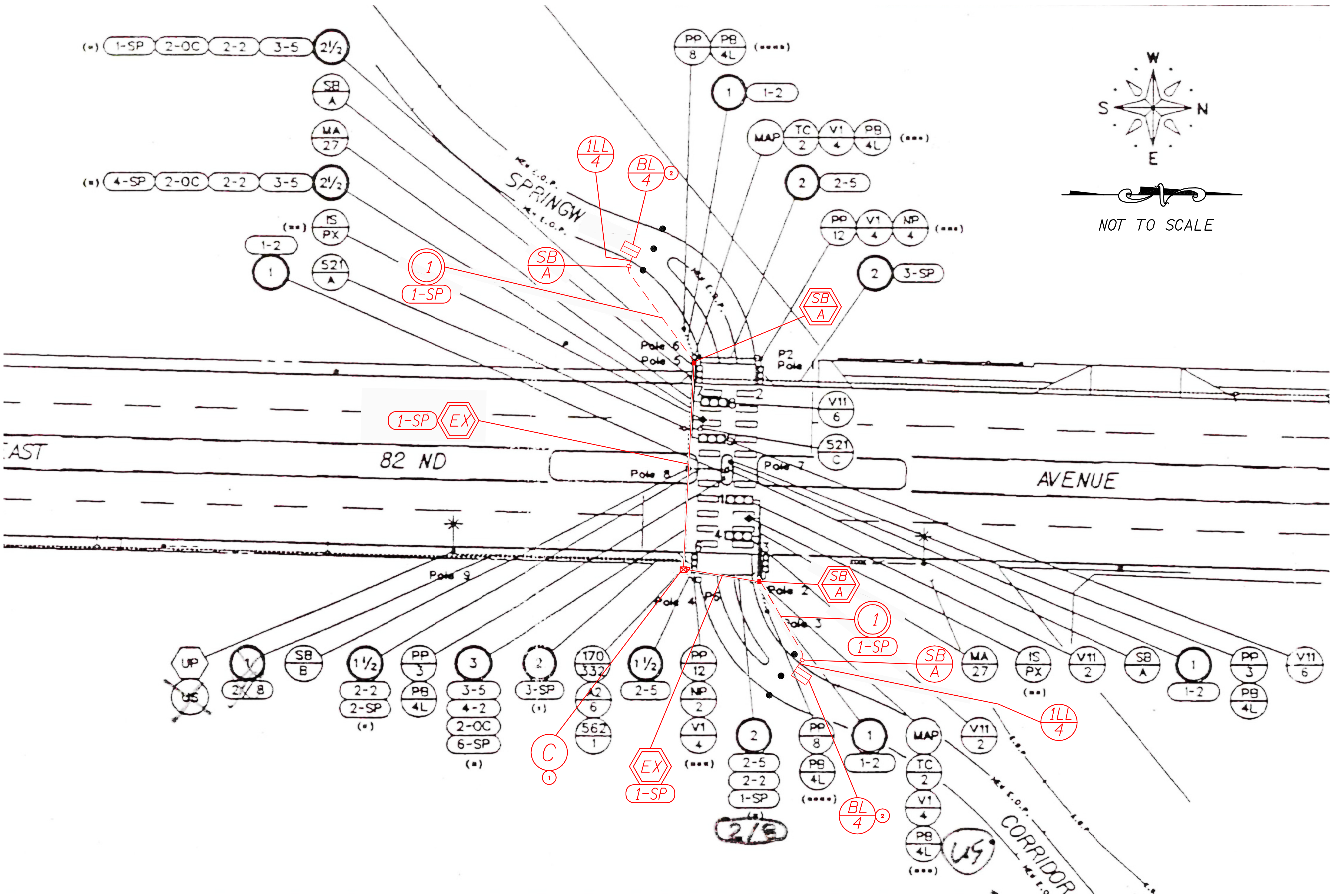
(1) Write Volume, MOE and Transit Logging into TransSuite TCS, rather than UCM to simplify queries and ability to interpret performance measures.

(2) Enhance or expand logging with NWS Voyage controller software to:

   a. Call to service duration log or "delay" log by input. By input allows for isolating different modes and points within the intersection.
   b. Add an element of aggregation to transit logging to more easily understand if the TSP call is for extension or truncation or no change necessary, the length of extension or truncation, and if TSP request still active at TSP timing max/force-off point.
   c. Vehicle length classification log
   d. Red extension log

APPENDIX A – 82ND AVENUE REDLINE CONSTRUCTION DRAWINGS

REDLINE SKETCH
SPRINGWATER TRAIL AT SE 82ND AVENUE



CONSTRUCTION NOTE:

1. INSTALL 2 ADDITIONAL LOOP DETECTOR CARD IN CABINET
2. INSTALL 3'X6' QUADRIPOLE BIKE LOOP

NOTE:
Field Verify Measurements Before Construction

"UTILITIES NOT SHOWN"
Contractor to contact utility companies for field locations.

PROJECT NUMBER
11670.0

	BY	DATE
DRWN	AFK	7/12
DSGN		
CHKD		

SPRINGWATER TRAIL/ SE 82ND AVENUE
INTERSECTION MODIFICATIONS
CITY OF PORTLAND

REDLINE SKETCH

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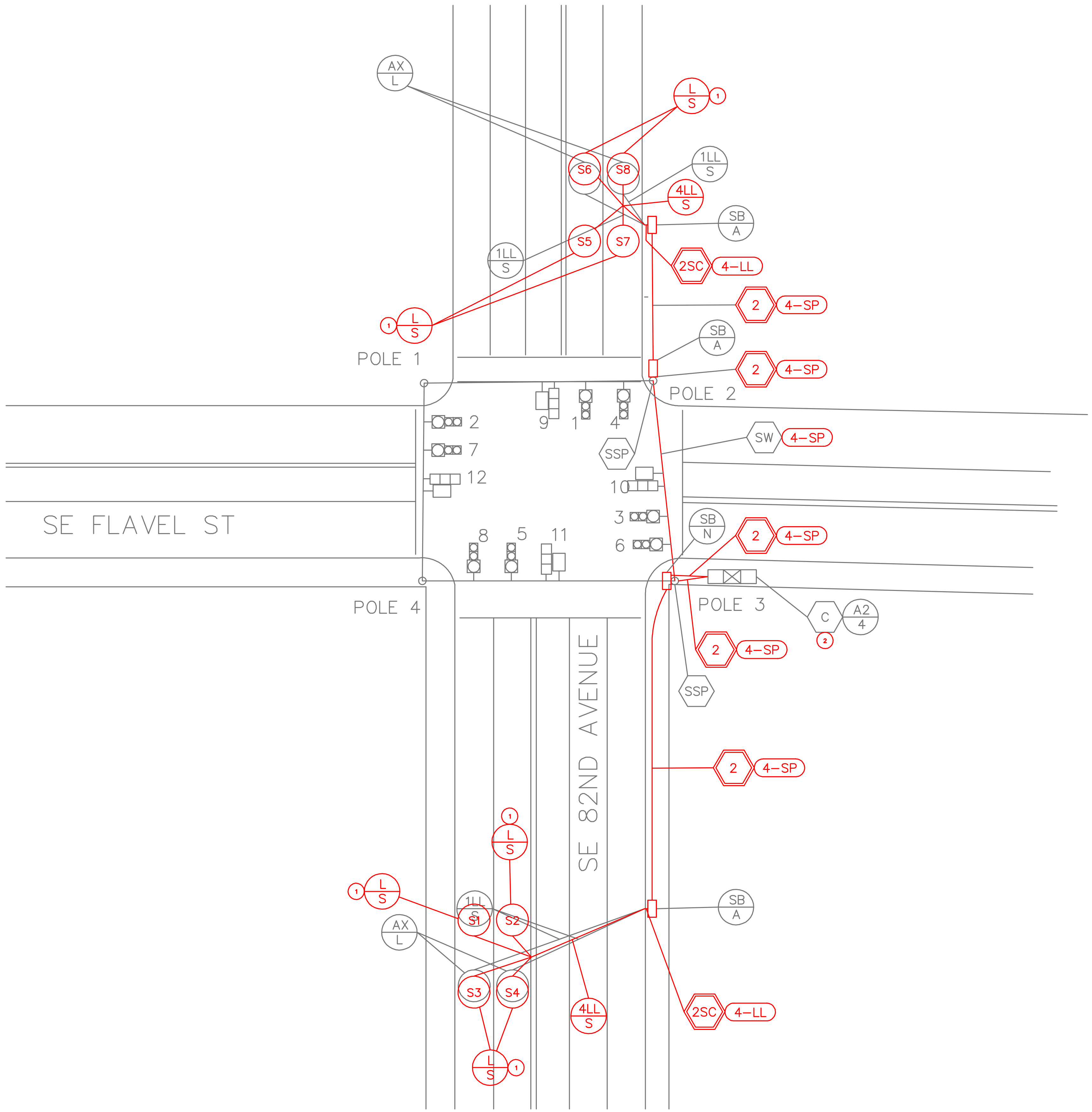
REDLINE SKETCH
SE FLAVEL STREET AT SE 82ND AVENUE



NOT TO SCALE

LEGEND:

- SW — EXISTING SPAN WIRE
- SSP — EXISTING STEEL STRAIN POLE
- C — EXISTING CONTROLLER
- (S) — EXISTING (S) IN. CONDUIT
- SB (T) — INSTALL TYPE (T) SIDEWALK PULL BOX
- (N)LL S — INSTALL (N) PAIRS OF TWISTED LOOP LEAD WIRES IN SAWSLOT
- 2SC — INSTALL 2 IN. DIAMETER CONDUIT STUB 6 INCH PAST CURB
- L S — INSTALL 6 FT. DIAMETER CIRCULAR LOOP FOR TRAFFIC DATA COLLECTION
- (S) — INSTALL (S)IN. DIAMETER RIGID STEEL ELECTRICAL CONDUIT
- (N)–LL — INSTALL (N) PAIRS OF TWISTED LOOP LEADER WIRES
- (N)–SP — INSTALL (N)–2/C NO. 14 AWG SHIELDED TWISTED PAIR CABLE
- A2 (N) — INSTALL (N) TWO CHANNEL SCANNING DETECTOR AMPLIFIERS

N E S W

GENERAL NOTES:

1. CONTRACTOR SHALL INSTALL A PULL LINE AND NO. 12 YELLOW TRACER WIRE IN ALL CONDUITS WHERE NEW WIRE IS INSTALLED.
2. ALL NEW EQUIPMENT LOCATIONS ARE APPROXIMATE. ACTUAL PLACEMENTS TO BE LOCATED IN THE FIELD BY THE CITY OF PORTLAND PROJECT ENGINEER.
3. EXISTING CONTROLLER CABINET TO BE UPGRADED BY CITY OF PORTLAND.

NOTES:

1. INSTALL SB SYSTEM LOOPS APPROXIMATELY 150FT SOUTH OF INTERSECTION. INSTALL NB SYSTEM LOOPS APPROXIMATELY 100FT NORTH OF INTERSECTION.

CONSTRUCTION NOTE:
① *LOOP SPACING IS TO BE 22 FT CENTER TO CENTER*
② *INSTALL 2 ADDITIONAL LOOP DETECTOR CARDS IN CABINET*

NOTE:
Field Verify Measurements Before Construction

"UTILITIES NOT SHOWN"
Contractor to contact utility companies for field locations.

PROJECT NUMBER
11670.0

#	DATE	DESCRIPTION	BY

	BY	DATE
DRWN	AFK	7/12
DSGN		
CHKD		

SE FLAVEL STREET/ SE 82ND AVENUE INTERSECTION MODIFICATIONS
CITY OF PORTLAND

REDLINE SKETCH

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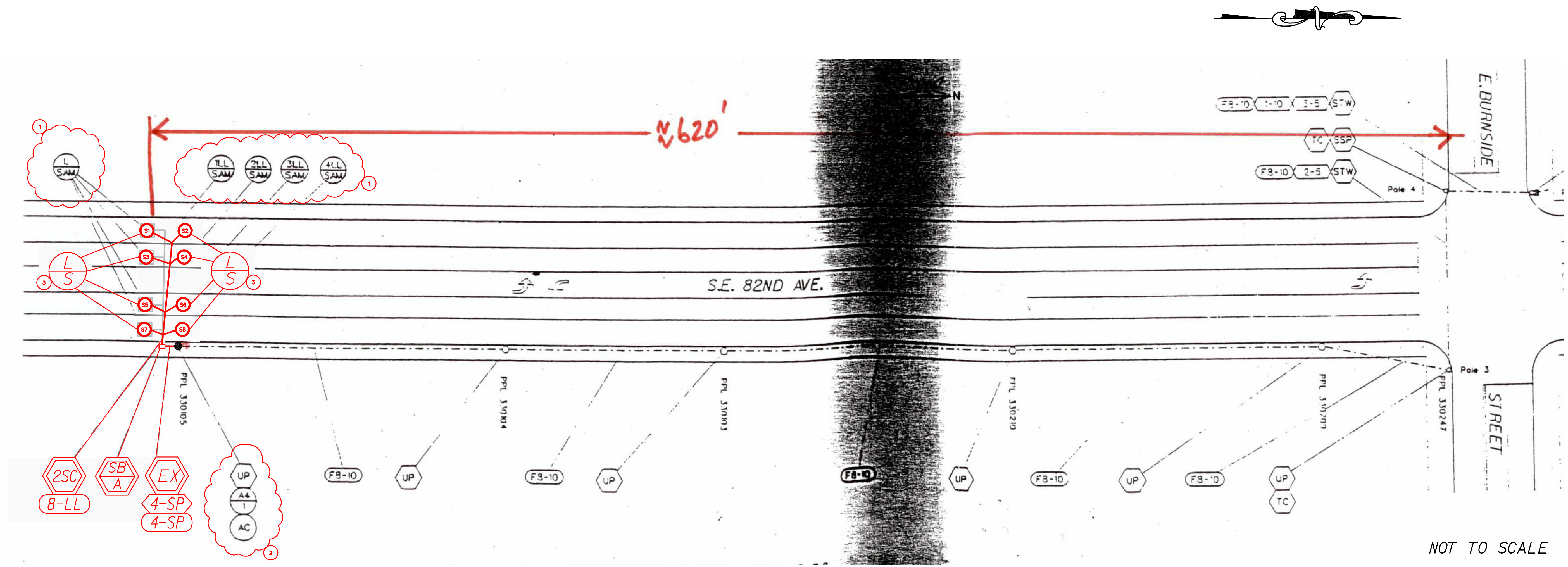
REDLINE SKETCH
E BURNSIDE STREET AT SE 82ND AVENUE



NOT TO SCALE

CONSTRUCTION NOTE:

1. ABANDON EXISTING SYSTEM LOOPS. IF SAWCUT TO 2" STUB-OUT IS IN GOOD CONDITION RE-USE FOR NEW LOOP INSTALLATION. OTHERWISE USE NEW SAWCUT.
2. TERMINATE NEW LOOP FEEDER CABLES INTO EXISTING AUXILIARY CABINET ON POLE.
3. LOOP SPACING IS TO BE 22 FT CENTER TO CENTER

NOTE:
Field Verify Measurements Before Construction

"UTILITIES NOT SHOWN"
Contractor to contact utility companies for field locations.

PROJECT NUMBER
11670.0

#	DATE	DESCRIPTION	BY

	BY	DATE
DRWN	AFK	7/12
DSGN		
CHKD		

E BURNSIDE STREET/ SE 82ND AVENUE
INTERSECTION MODIFICATIONS
CITY OF PORTLAND

REDLINE SKETCH

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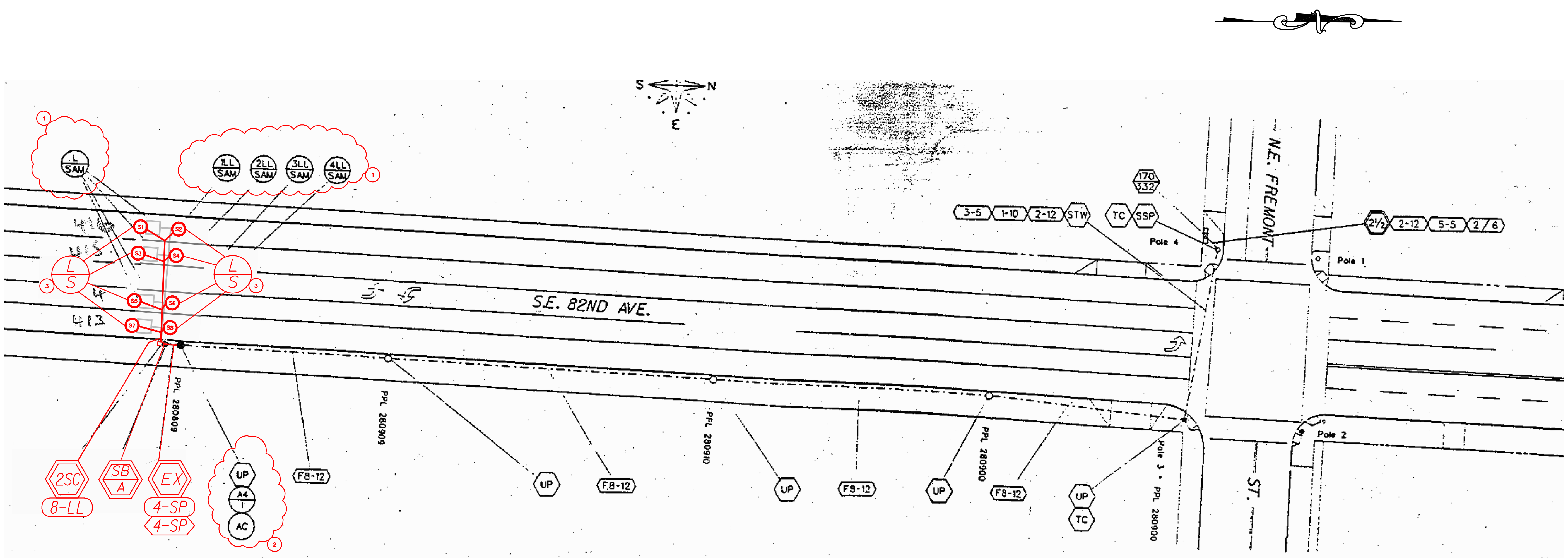
REDLINE SKETCH
NE FREMONT STREET AT SE 82ND AVENUE



NOT TO SCALE

CONSTRUCTION NOTE:

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NOTE:
Field Verify Measurements Before Construction

"UTILITIES NOT SHOWN"
Contractor to contact utility companies for field locations.

PROJECT NUMBER
11670.0

#	DATE	DESCRIPTION	BY

	BY	DATE
DRWN	AFK	7/12
DSGN		
CHKD		

NE FREMONT STREET/ SE 82ND AVENUE
INTERSECTION MODIFICATIONS
CITY OF PORTLAND

REDLINE SKETCH

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