Portland Multimodal Arterial Performance Management
implementation guidance document

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ODOT

METRO

Prepared by

DKS

In cooperation with

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INTRODUCTION AND EXECUTIVE SUMMARY

Using performance measures to guide transportation investment decisions produces an efficient, transparent, and safer transportation system. In the Portland region freeways currently have extensive coverage of automated performance measures accessible through PORTAL[1] (the regional transportation database operated by Portland State University). However, automated data and performance measures on arterial roadways in the Portland region are limited. The Portland Multimodal Arterial Performance Management Regional Concept of Transportation Operations (RCTO) provides regional guidance for collecting automated multimodal performance measures on arterial roadways.

Relying on performance measures to guide transportation investment decisions is gaining momentum on a national scale. In July 2012 the Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into action. MAP-21 creates a performance based multimodal program that requires performance monitoring on a national scale in seven categories: safety, current infrastructure, traffic congestion, efficiency, environment, transportation delays, and project delivery delays. Additionally, in the Portland region the City of Portland is in the process of revamping its operational standards to include multimodal performance.

This RCTO is the critical precursor to continued investment in the ability to measure performance on the region's arterial roadways. This guidance document focuses on the "how to" for implementing automated multimodal performance measures on arterial roadways in the Portland region. Even on corridors that are "ready" for automated performance measurement today, there are disconnected parts of the system. This document provides a foundation for design and implementation of technologies to support a fully integrated, easy to use performance management system. It provides the bridge between the desired performance measures, and the field and system needs to deliver the supporting data. The document also describes a common regional approach to multimodal arterial performance measurement using automated data collection systems.

[1] http://portal.its.pdx.edu/home/

GETTING STARTED: USING THE IMPLEMENTATION GUIDANCE DOCUMENT

The implementation guidance document is organized into nine main sections.

Section I - Operations Objectives

This section outlines the desired outcomes of the multimodal performance measurement project.

Section II - Geographic Scope of the Project

This section highlights the Portland Metro region arterial roadways that are the focus of this project.

Section III - Steps to Automate Multimodal Arterial Performance Measures

This section outlines the steps required to automate multimodal arterial performance measures from installing the field equipment to delivering the data to PORTAL and finally turning the data into useful information using PORTAL reports.

Section IV - Common Questions and Answers

Common questions and answers regarding performance measure automation are addressed in this section. The questions addressed include: what measures are we collecting, where are we collecting them, where is the data stored, how will the data be used, what are the technology options, how accurate does the data need to be, how will the data be validated, and who is responsible for installing maintaining and operating the equipment?

Section V - Corridor Readiness

A map is used in this section to show the level of effort required to begin collecting performance measures on specific arterial roadways in the Portland region.

Section VI - Data Transfer

This section outlines the data types and what data values are collected, processed, and archived. Detailed database fields are included in Appendix C.

Section VII – Performance Measures

This section describes the performance measures selected by the stakeholders. These one-page summaries identify technologies and recommended equipment placement necessary to measure multimodal performance and provide agencies with the information necessary to design and install the data collection equipment.

Section VIII - Action Plan

The section provides an automated multimodal performance measurement implementation strategy. It also includes a specific list of actions for PORTAL and TransPort.

Section IX - Other Related Projects

Other projects related to this multimodal performance measurement RCTO are summarized in this section.

I. OPERATIONS OBJECTIVES

The desired outcomes of the multimodal arterial performance management system include:

- Improve operations of the system by transportation managers (especially for considering the multimodal environment)
- Learn from implementation of applications like transit or freight priority, adaptive or responsive control, and other system management solutions
- Inform transportation modeling tools
- Support investment decisions
- Facilitate the transportation choices of travelers

II. GEOGRAPHIC SCOPE OF THE PROJECT

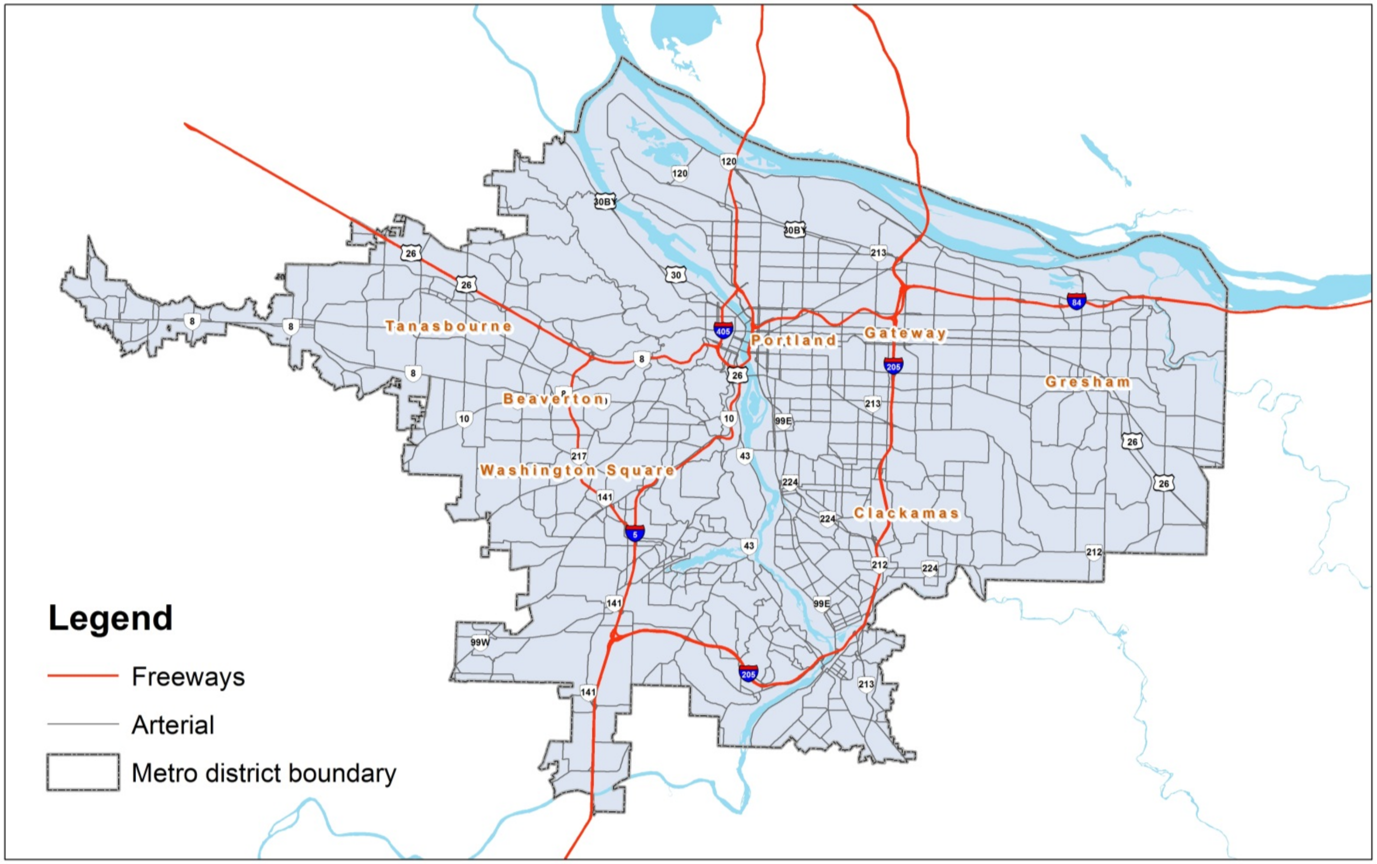


Figure 1: Study Area

The main focus of this project is arterial roadways across the Portland Metro region. Arterial roadways support a variety of users: pedestrians, bicyclists, and transit passengers, in addition to vehicles and freight. This multimodal aspect is one element that makes collecting performance measures on arterial roadways unique from collecting performance measures on freeways.

Figure 1 shows the arterial roadway network (in red) in the Portland metro region. Over 300 miles of arterial roadways crisscross the region, making it important to prioritize and be cognizant of costs and the performance measurement system develops.

III. STEPS TO AUTOMATE MULTIMODAL ARTERIAL PERFORMANCE MEASURES

The five primary steps necessary to automate multimodal arterial performance measures are shown below. These steps should be used in conjunction with the recommendations for each performance measure. Although specific hardware or software may be referenced in this document, the general principles of automating the data collection apply if another version were in place.

Design

- Determine performance measures and data needs
- Determine most appropriate technology to collect the required data
- Procure data source and install field devices/communications as necessary
- Upgrade local traffic signal controllers. Minimum requirement is 2070 with NWS Voyage.
- Upgrade NWSVoyage to support performance measures, if necessary

Collect Data

- Collect field data to a central location, which may be different depending on the agency and type of field equipment. Most traffic signals will use TransSuite
- Connect signals to existing central signal system, if not already connected
- Upgrade existing central signal system data acquisition and storage capabilities

Validate

- Verify the accuracy of the data collected
- Correct mechanical data errors (such as failed detection)
- Smooth the data to adjust for gaps in data
- Create methods to automatically flag data anomalies and failed detectors

Archive and Transform

- Transform the data into a usable database
- Archive the data at the highest precision available
- Geocode the data so that it can be mapped easily
- Upload and save the databases to PORTAL

Analyze and Report

- Create standardized reports and visuals for performance measures
- Allow users to pull raw data where applicable
- Allow users to query the data by location, time period, and data resolution
- Allow data to be cross referenced (linking speeds, weather conditions, collisions, or other factors to traffic conditions)

IV. COMMON QUESTIONS AND ANSWERS FOR MULTIMODAL ARTERIAL PERFORMANCE MANAGEMENT

Collecting and reporting multimodal arterial performance measures is a relatively new effort nationally. The focus of this RCTO for multimodal arterial performance management is on data that can be automatically collected and reported. Achieving the desired level of automation and reporting requires effort from every local agency in the region and Portland State University, but where do we begin? This section answers eight key questions about implementing an automated multimodal arterial performance management system including:

- What do we want to measure?
- Will this data be used for real-time or archived purposes?
- How will the data be stored, and how will the data reach the central data warehouse?
- Where should I implement the data collection equipment?
- What technology and equipment should be used to measure multimodal performance?
- How accurate does the performance measure need to be?
- Does the performance measure need to be validated?
- Who is responsible to install, operate, and maintain the equipment?

What do we want to measure?

At the onset of this project, transportation system operators, planners, modelers, and researchers from the Portland region participated in a workshop designed to gather input on desired performance measures and data collection in four categories: bicycle and pedestrian, transit, autos and freight, and agency performance. Based on participant feedback, the project management team sorted the identified performance measures by priority (high, medium, and low). Then the project team determined whether each performance measure could be collected using fully automated techniques, or if a manual component was necessary.

This RCTO performance measure project focuses on performance measures that can be fully automated. Other important measures, such as safety were identified; however, the majority of safety measures identified requires some manual interaction and cannot be fully automated. These measures are still important to the region, but not the main focus of this effort. Tables 1 thru 4 summarize all the performance measures identified by workshop participants. The **bold** performance measures in the tables are the focus of this RCTO plan.

Table 1: Bicycles and Pedestrians

	Fully Automated	Manual Component
High Priority	• **Volumes**	• Safety, perceived safety & comfort • Mode split
Medium Priority	• **Delay**	
Low Priority	• Intersection operations	• Multimodal level of service

Table 2: Transit

	Fully Automated	Manual Component
High Priority	• **Travel time and speed** • **Travel time reliability** • **Passenger Volumes**	
Medium Priority	• **Signal Delay**	• Mode split • Accessibility • Safety/Incident response
Low Priority		

Table 3: Autos and Freight

	Fully Automated	Manual Component
High Priority	• **Travel time and speed** • **Travel time reliability** • **Delay** • **Intersection operations** • **Volumes**	• Safety/Incident response
Medium Priority	• **Air emissions** • Extent of congestion	
Low Priority	• Parking	

Table 4: Agency Performance

	Fully Automated	Manual Component
High Priority	• **Detector health** • Traffic signal activity	
Medium Priority	• Other equipment health	• Staff ratios
Low Priority		• Customer satisfaction

Will this data be used for real-time or archived purposes?

The focus of this project is to produce data for both real-time and archived purposes, depending on the performance measure and system capabilities. Performance measures such as detector health and intersection operations may be best suited for real-time data, where as other performance measures such as volumes, travel times, and vehicle classifications are well suited for archived purposes (as well as real-time) and can be used for a wide variety of transportation system analysis and planning projects. Eventually system capabilities may advance to enable real-time data for all performance measures.

How will the data be stored, and how will the data reach the central data warehouse?

PORTAL[2] will be the final destination for all of the performance measure data for the Portland region. Figure 2 shows conceptually how information reaches PORTAL from the field equipment. TransSuite and other Server Systems will need to automatically transfer data to PORTAL[3].

The data should be transferred to PORTAL at the highest precision available, using disaggregated or individual data records whenever possible. PORTAL will provide the ability to aggregate and query the data sets (by location, time period, and data resolution). PORTAL will also develop data reports and visualizations (similar to the freeway data and arterial demo site).

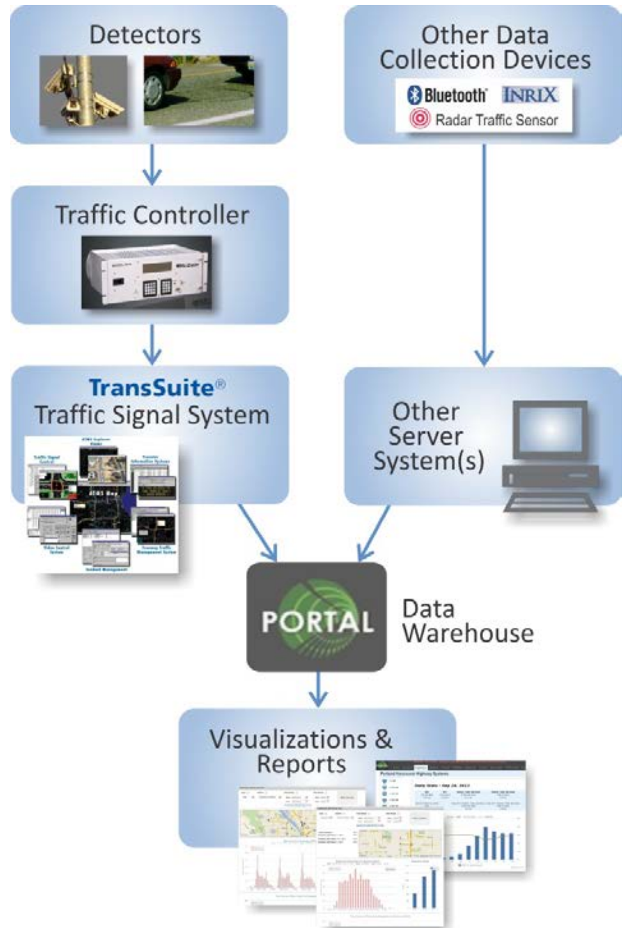


Figure 2: Data Warehouse Access

[2] http://portal.its.pdx.edu/Portal/index.php/home/

[3] Transfer data to PORTAL using RESTful (Representational State Transfer compliant) web service interfaces and a simple, plain text, easily parsable, and extendable format such as JSON (JavaScript Object Notation, CSV (comma-separated values), or XML (Extensible Markup Language), with JSON being the preferred data format

Where should I implement the data collection equipment?

As an example of where to implement detection equipment, Figure 3 depicts a main arterial roadway with three types of intersections: another arterial, a collector or local street, and a trail crossing.

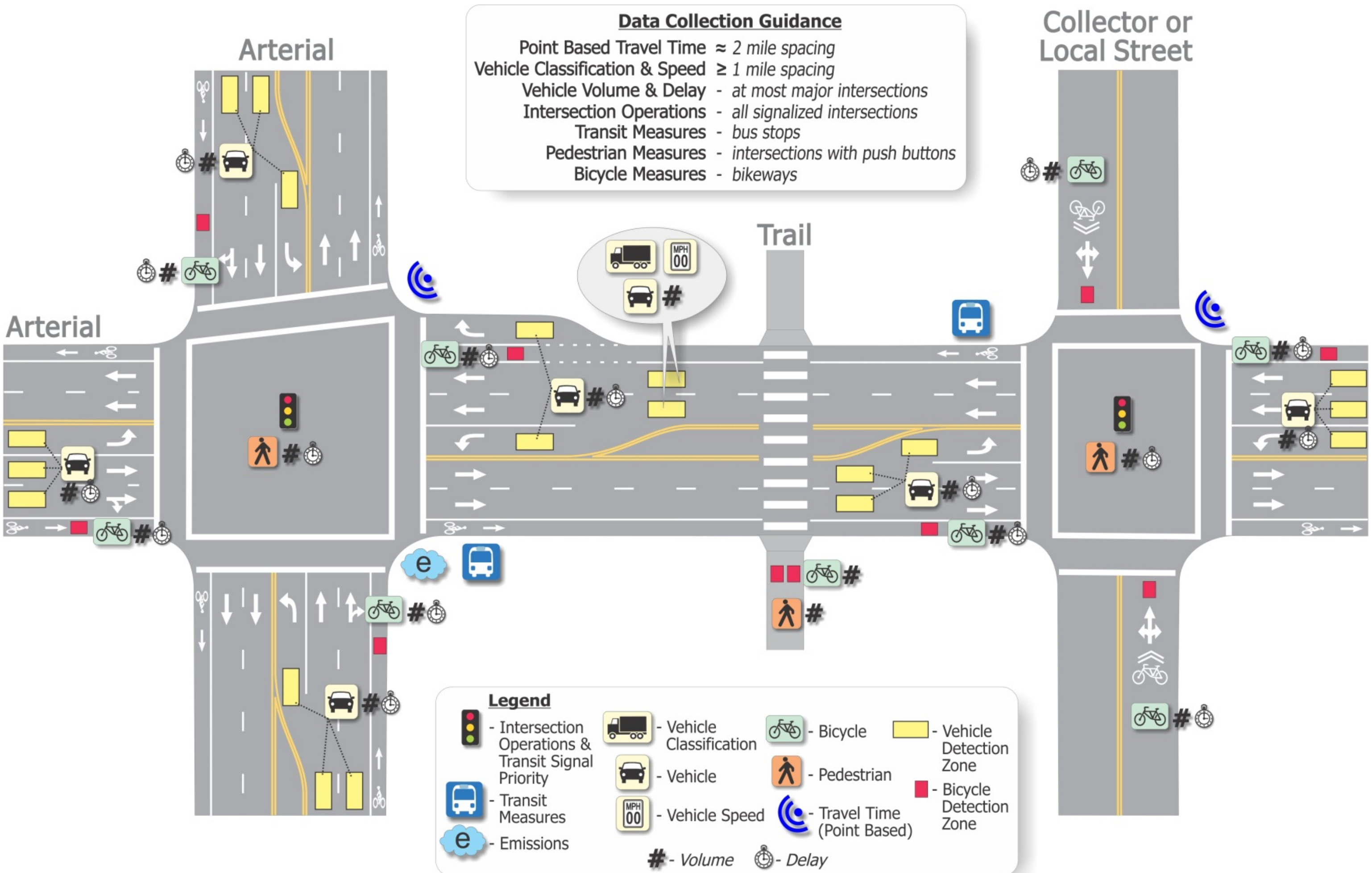


Figure 3: Recommended locations for collecting multimodal arterial performance measures

What technology and equipment should be used to measure multimodal performance?

There are a multitude of technology options for collecting transportation related multimodal performance measure data. Several factors go into deciding which technology choice best suits the user's needs. Those factors include:

- Cost
- Accuracy needs
- Installation location and considerations
- Data Needs

This document presents technology options, but does not specify technology requirements for each performance measure. Depending on the user's needs, the desired data, and the specific location, and costs associated with installation and maintenance of the equipment the correct technology choice will vary.

Another consideration for agencies is whether to use private data or install and operate agency-owned equipment. If private data is used, the cost typically involves an annual fee based on the amount of data requested. If agencies invest in the equipment themselves, lifecycle costs need to be considered including costs for capital, maintenance, operations, and replacement.

Table 5 summarizes the considerations for selecting the most appropriate technology to measure a multimodal arterial performance. Table 6 presents some of the most common technology options to collect performance measures discussed in this document and their pros and cons. For more detailed information including approximate costs, the Technology Overview Memorandum (included in Appendix E) should be referenced.[4]

Table 5: Considerations for selecting technologies to collect performance measures

Cost

- Capital
- Maintenance
- Operation
- Replacement

Accuracy

- What degree of accuracy is necessary?
- Are you more interested in trends or detailed analysis?

Installation location and considerations

- Location (intersection, midblock, trail, etc)
- Does installation cause traffic interruptions?
- What standard equipment is the agency is already using?
- Does the technology require a power source? Conduit? Trenching?

Data

- Are you interested in collecting a single performance measure? (Ex: travel time)
- Do you want the capability to collect multiple performance measures with one technology? (Ex: travel time, volume, classification)

[4] *Technology Overview Memorandum*. April 18, 2012. Prepared for ODOT and Metro by DKS Associates.

Table 6: Technology Options

Technology	PROS	CONS
Bicycle Volumes (and Bicycle Delay)		
Inductive Loops (parallelogram shaped)	• Currently the most accurate technology (with careful placement and installation)	• Installation (and maintenance) interrupts traffic • Detector repairs are often completed in bulk, which can lead to significant down time. • Detector may incorrectly count an automobile as a bicycle (new technology may mitigate this issue).
Video	• Easy to install • Flexibility to modify detection zones after installation	• Occlusions reduce accuracy (such as rain, fog, glare, etc)
Infrared (for trails)	• Easy to install	• Occlusions reduce accuracy • Difficult to collect accurate data at an intersection
Radar	• Easy to install (on existing poles)	• Occlusions reduce accuracy • Difficult to isolate bicycle data
Microwave (in ground)	• Easy to install • Wireless and battery operated	• Installation (and maintenance) interrupts traffic briefly • Battery replacement needed every 7 to 10 years
Pedestrian Actuations[5] (and Pedestrian Delay)		
Push Buttons	• Accurate actuation data • Already installed at many intersections	• Actual pedestrian volumes are not provided • Dependent on pedestrian activation
Vehicle Volumes and Classifications		
Inductive Loops	• Currently the most accurate technology (with careful placement and installation) • Capable of collecting multiple performance measures[6]	• Installation (and maintenance) interrupts traffic • Detector repairs are often completed in bulk, which can lead to significant down time. • Collects length-based classification not axle-based classification (FHWA method)
Video	• Easy to install • Flexibility to modify detection zones after installation • Capable of collecting multiple performance measures[6]	• Occlusions reduce accuracy (such as rain, fog, glare, etc) • Collects length-based classification not axle-based classification (FHWA method)

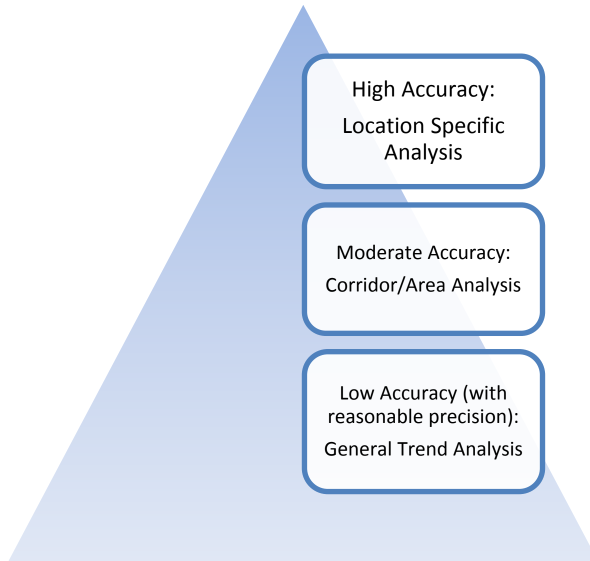
[5] For additional technology options that are capable of detecting pedestrian volume (not just actuations) refer to: *Technology Overview Memorandum*. April 18, 2012. Prepared for ODOT and Metro by DKS Associates.
[6] USDOT FHWA Integrated Corridor Management (ICM) Initiative, ICM Surveillance and Detection Needs Analysis for the Arterial Data Gap. November 2008.

Technology	PROS	CONS
Tubes	• Easy to install • Proven to be accurate • Provides axle-based classification (FHWA method)	• Typically used for approach volumes not turn movement volumes • Not the most durable long term solution
Radar	• Easy to install • Proven to be accurate • Provides axle-based classification (FHWA method) • Capable of collecting multiple performance measures[6]	• Occlusions reduce accuracy
Magnetometer	• Easy to install • Wireless (no trenching or conduit necessary) • Installed between vehicle wheel base so pavement wear does not degrade equipment	• Installation (and maintenance) interrupts traffic briefly • Battery replacement needed every 7 to 10 years
Vehicle Travel Time and Speed		
Dual Inductive Loops	• Highly accurate technology for spot speed (with careful placement and installation)	• Installation (and maintenance) interrupts traffic • Detector repairs are often completed in bulk, which can lead to significant down time.
Bluetooth (MAC Address Reading)	• Proven to be accurate for travel time (speed can be calculated) • Can archive data and provide real-time data with a large sample set	• Potential for diminishing sample size
Private Sector Data (e.g. Inrix, NAVTEQ)	• Provides historical and real-time data with a large sample set • No capital, installation, maintenance, or replacement costs	• Agencies do not have ownership of equipment
Magnetometers	• Easy to install • Wireless (no trenching or conduit necessary) • Installed between vehicle wheel base so pavement wear does not degrade equipment	• Installation (and maintenance) interrupts traffic briefly • Battery replacement needed every 7 to 10 years • If vehicles change lanes between magnetometer installations travel time is not captured
Vehicle Delay		
Inductive Loops (advance)	• Currently the most accurate technology (with careful placement and installation) • Capable of collecting multiple performance measures[6]	• Installation (and maintenance) interrupts traffic • Detector repairs are often completed in bulk, which can lead to significant down time.
Inductive Loops (advance and stop bar)	• Improved accuracy over just advance loops	• Same as above
Video	• Easy to install • Flexibility to modify detection zones after installation • Capable of collecting multiple performance measures[6]	• Occlusions reduce accuracy (such as rain, fog, glare, etc) • Collects length-based classification not axle-based classification (FHWA method) •

Technology	PROS	CONS
Radar	• Easy to install and • Proven to be accurate • Capable of collecting multiple performance measures[6]	• Occlusions reduce accuracy
Intersection Operations		
Traffic Signal Software	• Capable of collecting detailed data	• Software or controller updates may be necessary to capture additional information
Vehicle detection	• See detector options in *vehicle volumes and classifications*	• See detector options in *vehicle volumes and classifications*
Air Emissions		
Environmental Sensor	• Capable of collecting numerous emissions	• Sensitive to placement location
Transit Measures		
Automatic Vehicle Location (AVL)	• Proven to be accurate • Capable of collecting transit speed and travel time information	• Requires installation on individual transit vehicles
Automatic Passenger Counter (APC)	• Proven to be accurate	• Requires installation on individual transit vehicles
Traffic Signal Controller	• Able to provide transit signal priority usage information	• Transit signal priority information is difficult to access
Opticom	• Proven to be accurate and useful	• Limited transit data
GPS	• Capable of accurately depicting vehicle location	• Requires installation on individual transit vehicles
Radio Communications	• Enables verbal communications between transit operators	• Requires installation on individual transit vehicles
Detector Health		
Traffic signal software	• Capable of collecting detailed data	• Software or controller updates may be necessary to capture additional information
Other Server Systems	• Varies depending on the system	• Varies depending on the system

How accurate does the data need to be?

Data has to be accurate or it won't be used. However, given real world technology and budgets, data that is 100 percent accurate is typically not feasible. So, how accurate does the data need to be? What affects the accuracy of the data? What are the benefits of automated data? These questions consider the importance of accurate data and provide some guidance for the level of accuracy required.



How accurate does the data need to be?

It appears that the need for accurate data may be at least partially dependent on the specific use of the measure being calculated from the data and the use of that measure. Consider the difference between a vehicle count and pedestrian actuations. The major difference between these two measures is how they would be used. A vehicle count may be used for detailed intersection analysis and affect decisions that may result in approval or denial of a new development. The pedestrian actuation measure could only be used for more spatial analysis because it is a measure of the relative pedestrian activity, not the actual pedestrian volume at an intersection.

Users of the multimodal arterial performance data described within this document include researchers, planners, engineers, and operators. Each of these users needs these performance measures to make informed decisions. For example, a planner may use the performance measures to refine a model or compare adjacent corridors; an engineer or operator may use the data to evaluate the effectiveness of a project implementation; and a researcher uses the data intensely for detailed evaluation. If these end users cannot trust that the data is accurate, then automatically collecting the data becomes meaningless. As each user of the data has different applications for the data, the level of accuracy needed for each application varies.

The basic rule of thumb for determining how important the accuracy of collected data must be is:

While the planning, engineering, and operations disciplines all require transportation data for their analytical procedures and applications, their spatial and temporal requirements differ considerably, with planning applications generally associated with the least stringent requirements and operations applications associated with the most stringent.[7]

What affects accuracy of the data?

Several things can affect the accuracy of a performance measure:

- Technology choice

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[7] *Guidelines for Data Quality Measurement*, U.S. Department of Transportation – Federal Highway Administration, 2004, http://ntl.bts.gov/lib/jpodocs/repts_te/14058_files/chap4.htm#4.3

- Quality of each field installation
- Detector sensitivity
- Location of the detector relative to the item being detected

The majority of factors affecting accuracy of a performance measure are field based and therefore dependent upon effective design and maintenance of the field equipment. As a result, the need to validate the data collected at each intersection becomes extremely important to assure data produced is accurate and will be used.

What are the advantages of automated data?

Automated data has a distinct advantage over manually counted data. Manually counted data is typically collected over a relatively small window of time such as one peak period, or one day, or maybe over a week or two. But, automated data can be collected 24 hours per day 7 days per week 365 days per year, which provides a much better view of varying conditions on a corridor, at an intersection, on a transit route, or on a bike route then we can achieve with manual counts. It's simply too expensive to manually count for that much time.

Studying a general trend, such as traffic volumes at different times of the year, may not require 100 percent accurate data. However, if you are trying to obtain an average traffic volume to base operations analysis to potentially recommend major improvements, having a more accurate data set is much more important. Figure 4 shows the variation of day to day traffic volumes collected at one location in California as reported from their PEMS system. If data is collected on a day that represents one of the highest 95th percentile volumes than a project may be overdesigned, if data is collected on a day that represents one of the lowest 5th percentile volumes than a project may be under-designed. By having automated data the user can easily pull the average traffic volume, the highest 30th traffic volume, and/or average speeds.

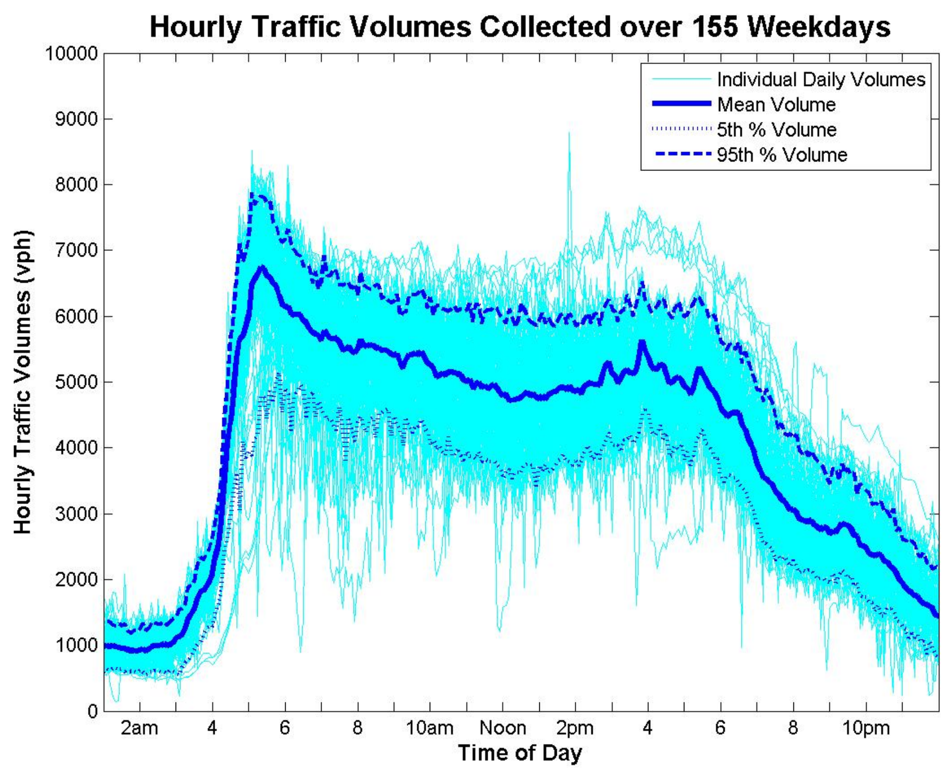


Figure 4: Automated data collected 24/7 enables data users to accurately portray the system, instead of relaying on a single day's worth of data

Does the performance measure need to be validated?

Yes!

Validating the data collected by field equipment is critical to producing effective performance measures. Ideally the accuracy of field devices should be verified within two months of installation and before using any of the automated data from PORTAL. There are a few ways the data validation could be accomplished:

- The validation could be incorporated into a planning study, requiring the study to validate the data before use.
- The validation could be combined with the construction aspect of the project, either requiring the agency, or contractor to validate the data before finalizing a project.
- Or, the validation could be incorporated into an agency's maintenance program.

All equipment capable of collecting performance measures should relay the "last date validated" as one of the static data fields (see Appendix C).

Because detectors require periodic maintenance, detector data should be validated on an annual basis for a few locations of concern by manual counts. Locations of concern should be determined based on a review of historical trends and comparison of typical volumes at neighboring intersections. Typically, a minimum of ten locations should be selected annually to validate.

Additionally, data streams should be monitored on a real-time basis and data should be smoothed and adjusted for gaps in the data (such as null values from failed detection). The monitoring should be automated to flag data anomalies and failed detectors. PORTAL's reporting of freeway detector health should serve as an example.

The following are some guidelines to check for properly functioning detection:

- At low demand times, such as 3 a.m., search the system for detection on minor approaches and phases that max out
- Compare volumes at upstream and downstream detectors to identify irregularities
- Flag detectors with a constant call for more than 3 hours
- Flag detectors with no call for a predetermined timeframe (such as 5 hours)
- Compare against historical data

Some data is generally assumed to be valid based on previous applications that have been verified. This type of data does not have to be validated on an annual basis:

- Transit Data
- Pedestrian Actuation
- Private Sector Travel Time and Speed Data
- Bluetooth Travel Time, Speed, and Origin Data
- Air Emissions Data

Who is responsible to install, operate, and maintain the equipment?

Table 7 lays the basic groundwork for roles and responsibilities involving the collection and processing of performance measure data, as well as the installation and maintenance of field equipment.

Table 7: Roles and Responsibilities

Agency	Role and Responsibility
Portland State University	• Manage PORTAL • Download data from Data Collection Server/System such as TransSuite • Provide raw and aggregated data for download • Generate data summaries and visualizations • Create annual state of the region performance measure reports
City of Portland	• Manage Data Collection Server/Systems such as TransSuite • Install, operate, and maintain field equipment on agency owned facilities • Implement arterial performance measure demonstration project
Other Local Agencies and ODOT	• Install, operate, and maintain field equipment on agency owned facilities • Manage local controllers and servers • Send information to data collection server/system
TransPort	• Oversee the annual state of the region report created by PORTAL

V. CORRIDOR READINESS MAP

The corridor readiness map, shown in Figure 5, is meant to indicate the level of effort necessary to begin collecting performance measures along specific arterials in the Portland region. Arterials marked in green are mostly ready, while those marked in red need significant improvements to be ready. The criteria considered for ranking each arterial includes:

- Does the corridor have existing communications infrastructure?
- Are there 2070 traffic signal controllers on the corridor?
- Is the detection split out by lane?
- Are there other existing data collection devices such as Bluetooth?

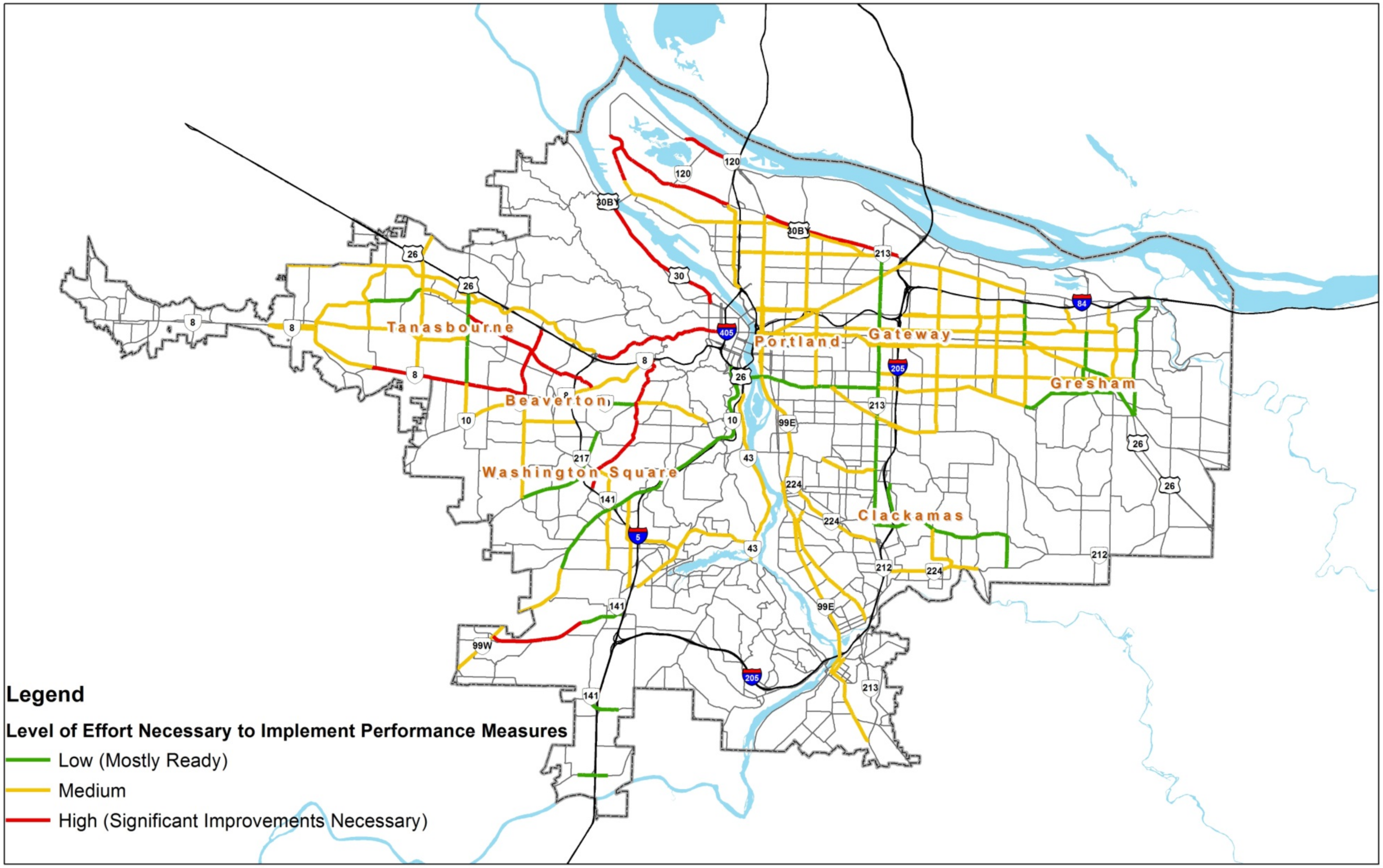


Figure 5: Corridor Readiness Map

VI. DATA TRANSFER

Collecting and analyzing performance measures is easier and faster with standardized data units, formats, and database structures. Data sets from multiple jurisdictions can be quickly combined and used for apples-to-apples evaluations. Raw data collected from individual field sensors are commonly grouped by location, sorted into data bins, and combined over large time intervals for statistical analysis.

Detailed database fields with data type, data descriptions, attribute aliases, and attribute types for each performance measure are included in Appendix C.

Static Data Tables

Static data tables have information and descriptions about site and sensor installations. Static data only needs to be provided once. Examples of static data:

- Assigned unique identification number of site or sensor
- Descriptive text of installation and location
- Location: latitude/longitude, main/cross street, etc.
- Installation details: sensor type, lane position, travel direction, associated traffic signal ID number, etc.

Raw Data Tables

Raw data tables contain the data collected directly from the sensors in the field. Raw data can be event-based or time-based, depending on sensor type and configuration. Event-based data is generated due to an action, such as a transit vehicle opening its doors. Time-based data is recorded on a fixed schedule, such as volume of vehicles crossing a sensor every 60 seconds. Examples of raw data:

- Unique identification number of site or sensor
- Time and date
- Collected data values specific to sensor or installation:
  - Vehicle speed, length, classification, travel time, etc.
  - Transit vehicle ID, number boarding/alighting, etc.
  - Signal actuations per period, volume per interval, etc.
  - Emissions concentrations, mixing ratios, etc.

Aggregate Data Tables

Aggregate data tables contain data that has been grouped together for statistical analysis. Event-based data is often aggregated into time-based data. A common aggregation is combining vehicle counts from many small time periods to a larger time periods, for example volume by lane into 5, 15, and 60 minute intervals. Archiving common aggregations dramatically improves data warehouse performance. In some cases, raw data might be archived offline and with only aggregated data readily available online. Examples of aggregated data:

- Unique identification number of site, sensor, signal, etc.
- Time intervals of 5, 15, 60 minutes, per day, per month
- Volume by direction, intersection, classification, etc.
- Average speed, delay, travel time, etc.
- Emissions air quality index (AQI)

VII. PERFORMANCE MEASURES

Through this project the region will "drill down" on the multimodal arterial performance measures identified in the Regional TSMO plan and define specifically the performance measures for the region. Although many other performance measures were identified, this Implementation Guide focuses on the performance measures that can be automated, and delivered to PORTAL without human intervention.

The performance measure section goes in to detailed recommendations and guidance for each performance measure. The key components discussed for each performance measure include: description, technology options, potential uses, applications, design considerations, data fields to collect, and a graphic showing recommendations for field equipment placement Ten performance measures are discussed in this document.

Figure 6 depicts where to place detection equipment at a typical arterial/arterial intersection.

Performance Measures:

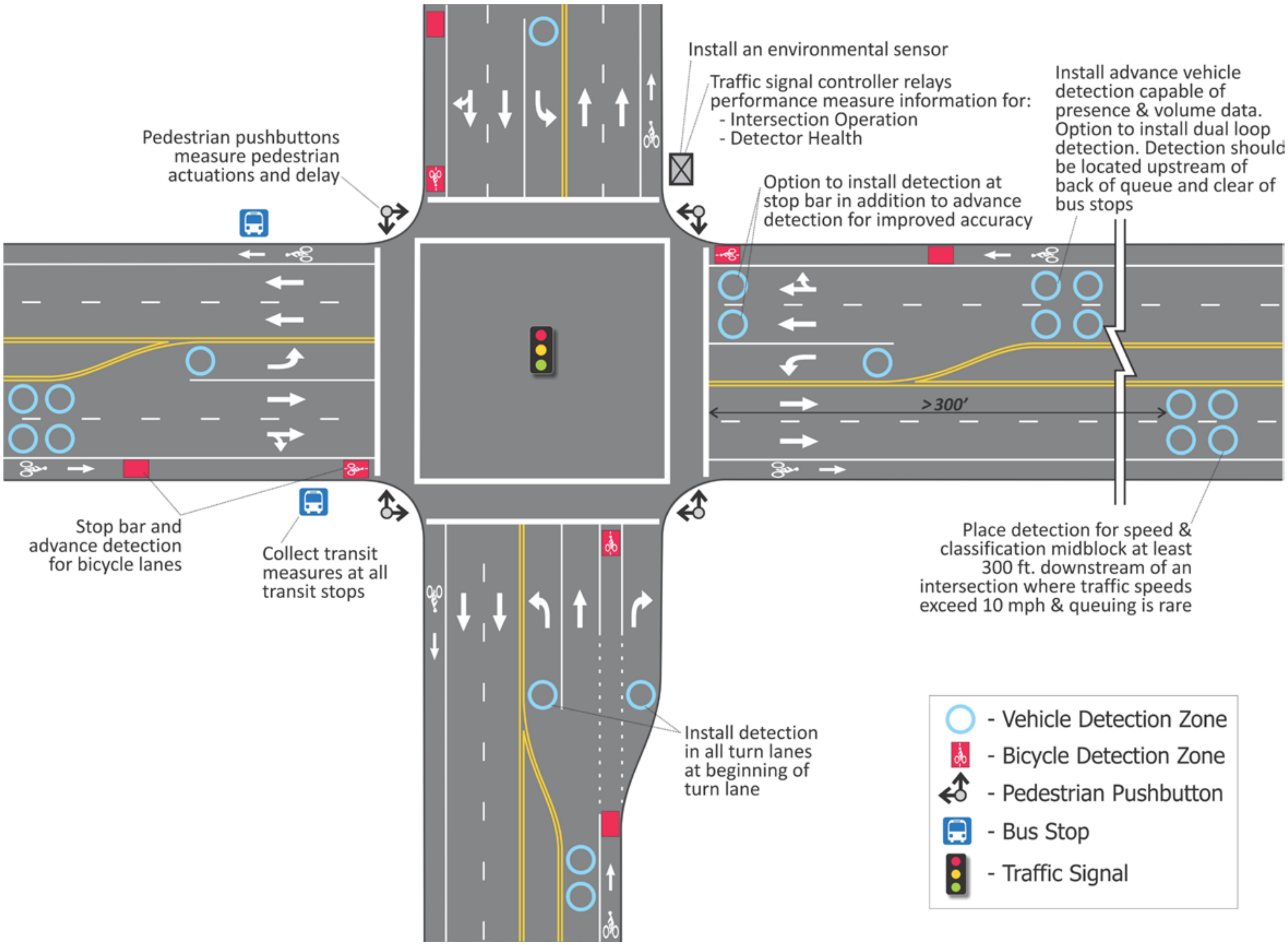


Figure 6: Typical field equipment layout at an arterial/arterial intersection

bicycle volumes

Description

Collect bicycle volumes by approach and direction at signalized intersections and trails.

Detector Technology

- Inductive loops: if this technology is chosen, use parallelogram shaped loops (see ODOT standard detail 4433)
- Video
- Infrared
- Radar
- Microwave (in ground)

Potential Uses

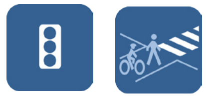
This data would be used to replace manual bicycle counts where direction of movement is not needed, to help with planning projects and signal timing operations, and as input for intersection operations analysis.

Design Considerations

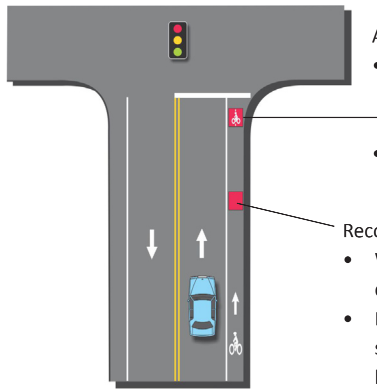
Detecting bicyclists accurately is challenging due to detector sensitivity, bicyclists not riding through the detector zone, and false actuations by vehicles.

Data Fields	
Description	**Format**
Detector ID	Integer
Timestamp	hr:min:sec

Application



Signals Trails

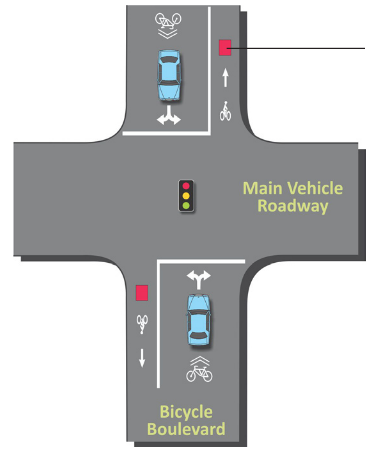


At stop bar:

- Place bicycle detection to minimize false detections by right-turning vehicles
- Paint stencils to indicate sensitive loop area

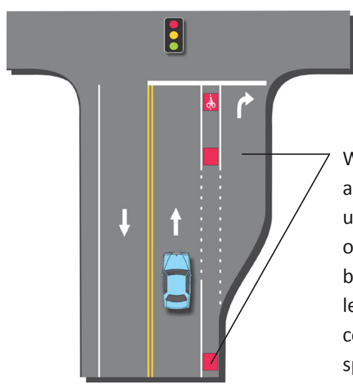
Recommend advance detection:

- Wire separately from stop-bar detection
- Place detection 3 to 5 seconds upstream of the stop bar based on typical bicycle approach speed
- Bicycle counts from advance detection sites are preferable (higher accuracy due to fewer false vehicle detections)

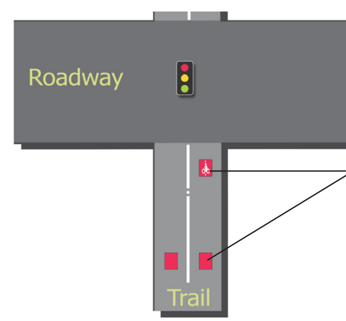


Neighborhood greenway or bicycle boulevard crossing—place bicycle detection zone on the far side of the intersection where bicycles are channeled

*If the facility does not have a channelized bicycle area, bicycle detection should be placed across the full lane on the nearside approach. In this situation, the detection needs to be capable of distinguishing bicycles from vehicles



With right-turn lane—place advance detection either upstream of the right-turn lane or downstream of the dashed bike lane line, depending on the length of the turn pocket, field conditions and typical approach speeds



* Directional bicycle volumes should be collected at trail crossings

Trail crossing—Install stop bar and advance bicycle detection if signalized. At unsignalized trail crossings, placing the detectors on one side of the intersection is sufficient as long as bicycle volumes can be collected directionally

pedestrian actuations

Description

Use pedestrian pushbutton actuations to measure pedestrian activity at crossings. Counting pedestrian actuations can be very accurate; however, this measurement does not reflect actual pedestrians crossing due to a variety of real-world conditions (e.g. pedestrians may cross intersections without activating the pedestrian phase or multiple pedestrians may cross an intersection during one activation phase).

Detector Technology

- Pushbuttons
- As more accurate pedestrian detection technology is available at a reasonable cost, pushbutton detection may be replaced

Potential Uses

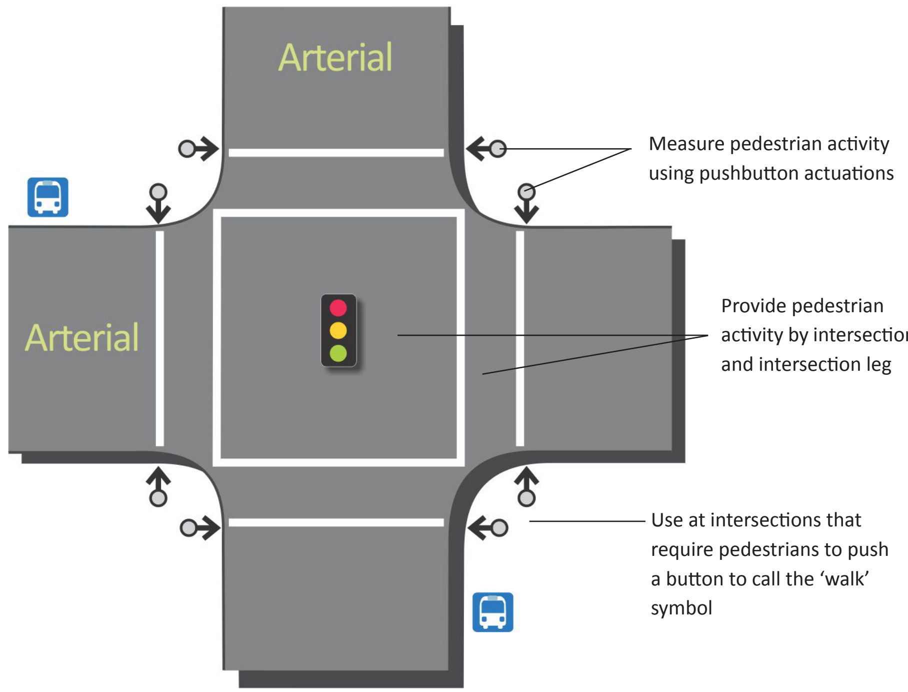
This data would be helpful in making signal timing improvements and would potentially be used to identify high pedestrian areas for planning studies. This data should not be used to replace manual pedestrian counts.

Design Considerations

Measure pedestrian actuations only at intersections with pedestrian pushbuttons. For locations where pedestrian data information is important, install pedestrian pushbuttons.

Data Fields	
Description	**Format**
Pushbutton ID number	Integer
Time periods	hr:min:sec to hr:min:sec
Number of actuations	Integer

Application



bicycle and pedestrian actuation delay

Description
Measure bicycle delay by approach at signalized intersections with bicycle facilities and automated detection or signalized trail crossings that use automated detection. Measure pedestrian actuation delay by crossing at signalized intersections with pushbutton actuation.

Detector Technology
- Pedestrian pushbutton
- Stop-bar bicycle detection (see bicycle volume section)

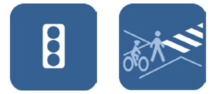
Potential Uses
This data would primarily be used for signal timing projects to determine the impacts of different signal timing improvements. The data may also be used to identify locations where bicycle and pedestrian improvements are needed.

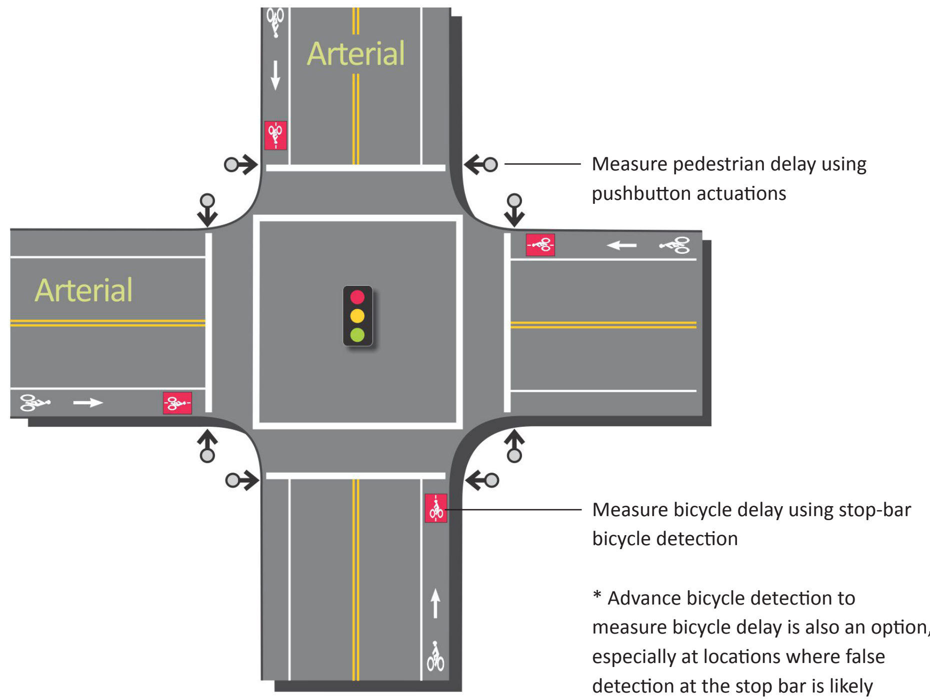
Design Considerations
Pedestrian delay can only be measured at intersections with pushbuttons. Bicycle delay can only be measured at intersections with automated detection.

Data Fields: Pedestrian Delay	
Description	**Format**
Pushbutton ID number	Integer
Time of actuation	hr:min:sec
Time of walk phase	hr:min:sec

Data Fields: Bicycle Delay	
Description	**Format**
Detector ID	Integer
Time of 1st bicycle detection	hr:min:sec
Time at start of green	hr:min:sec

Application





vehicle volume and classification

Description

Use vehicle detection to collect volumes and classifications in advance of signalized arterial intersections by lane and phase.

Detector Technology

- Inductive Loops
- Radar
- Video
- Tubes
- Magnetometers

Potential Uses

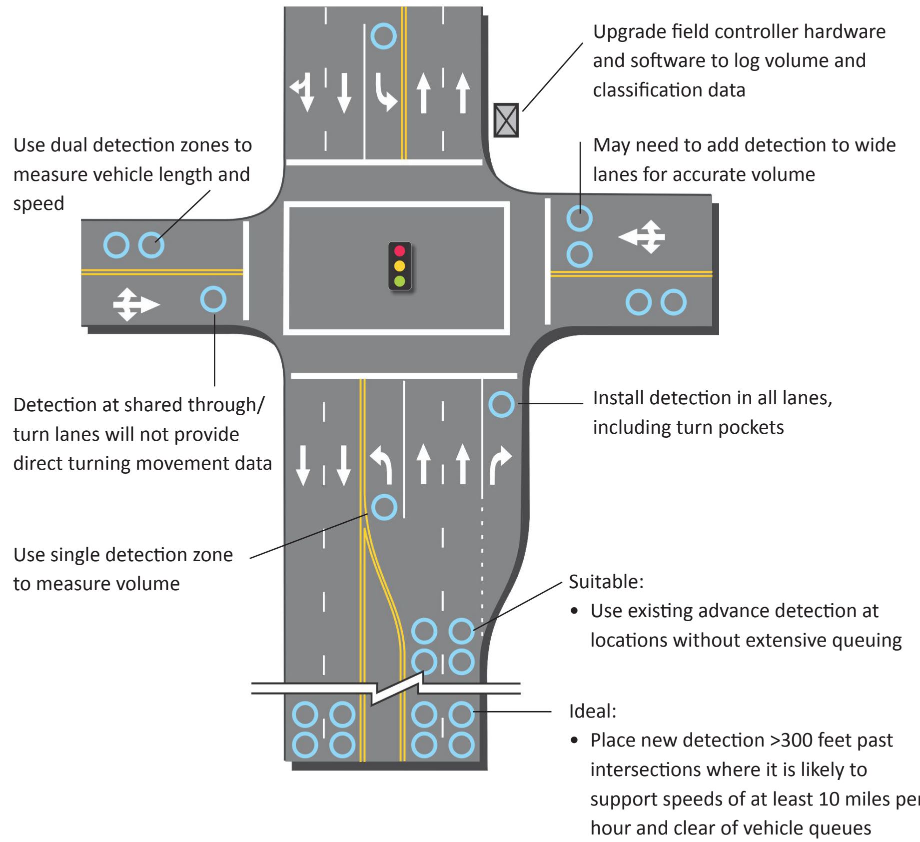
This data could be used for all types of projects if detection is adequate and separated by movement. It could replace turn movement counts used in planning and design projects.

Design Considerations

Speed data can be collected if detector location and technology allows. Detectors at mid-block locations could be connected to different controllers and sent to PORTAL, which can report and aggregate the data. Collecting classification and speed information with inductive loops requires dual loops. Vehicle classification will be length based. Video may be less accurate for volume counts due to occlusion and to times of low visibility

Data Fields	
Description	**Format**
Detector ID number	Integer
Time and date	DateTime
Vehicle length	Integer
Vehicle speed	Integer

Application



Note: Dual loops should not be placed near bus stops as the locations can introduce data errors

vehicle travel time and speed

Description

Use automated technology to collect vehicle speeds and travel times along arterial roadway segments. This performance measure should have the capability of selecting multiple arterial segments for cumulative travel times and calculating different percentiles for speed and travel times.

Recommended Detector Technology

- Dual inductive loops (see Vehicle Volume and Classification)
- Bluetooth
- Private sector data
- Magnetometers

Potential Uses

This automated data would be used for all types of projects. It will replace floating car and spot speed data. Travel time and speed data is commonly used for before and after studies, model calibration, and to identify areas where projects are needed. Travel time reliability is another performance measure that could be calculated from travel time data.

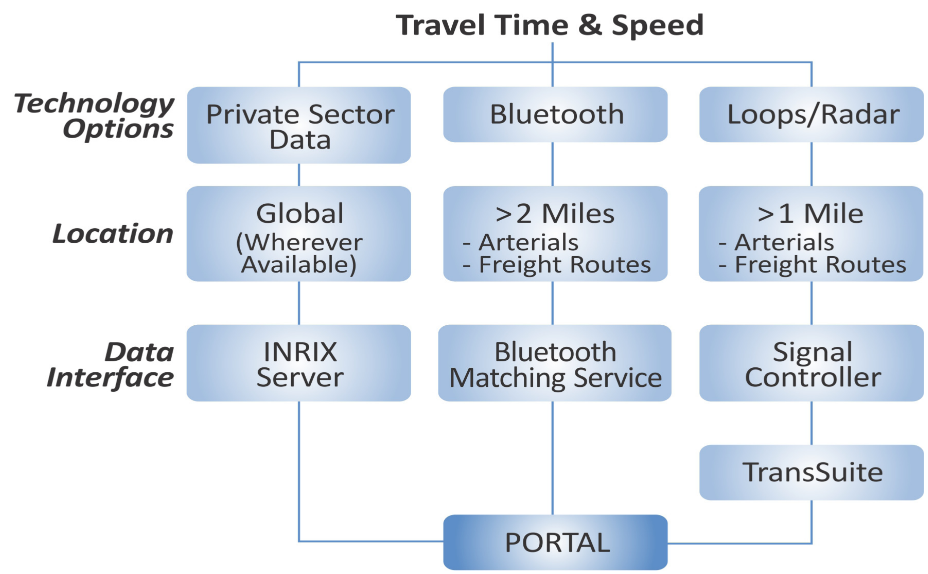
Design Considerations

Technologies that measure travel time between points on an arterial corridor will be more accurate because they account for traffic signal delay. Point detection systems that measure speed are not suitable for measuring arterial travel times because they do not account for traffic delay.

Data Collected		
	Description	**Format**
Speed (Point)	Detector ID number	Integer
	Time and date	DateTime
	Vehicle speed	Integer
Travel Time (Segment)	Segment ID number	Integer
	Time and date	DateTime
	Travel time	Integer

Application

Corridor



vehicle delay

Description

Automatically collect vehicle delay by phase at signalized intersections. Vehicle delay data is collected based on the first vehicle's actuation of the detector. This method does not account for a weighted vehicle delay based on varied arrival in a vehicle queue. However, updates to NWS Voyage may provide opportunities to adjust this calculation.

Recommended Technology

- Traffic signal software with detection (inductive loops)
- Intermediate advance inductive loop detectors must be wired individually by lane
- Radar
- Video

Potential Uses

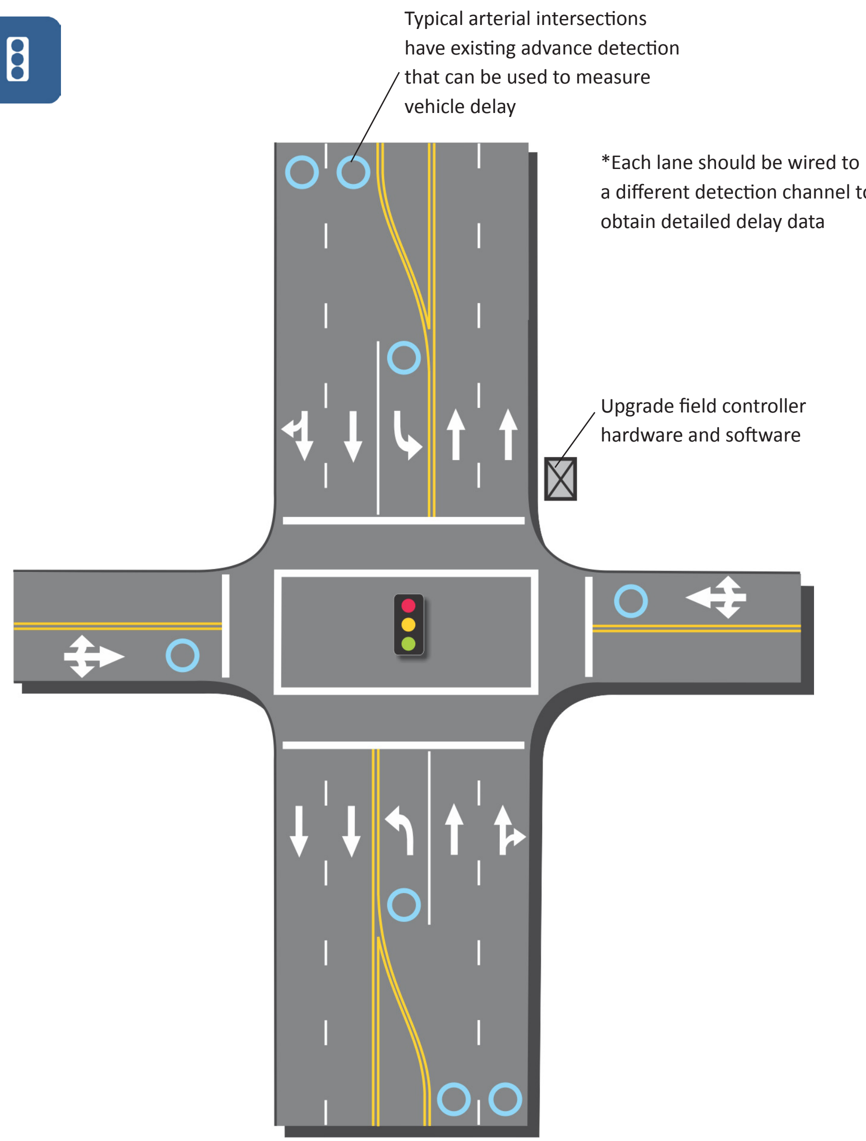
This data is primarily used for signal timing improvement projects. It can be used to identify if signal timing changes are obtaining the expected improvements. This data should not be used to replace detailed intersection operations analysis, but can be used to support it.

Design Considerations

Install volume and presence detection on all approaches to measure vehicle delay. Minimum requirements to collect data are stop-bar or advance vehicle detection. For improved vehicle delay data, consider installing both types of detection at intersections.

Data Fields	
Description	**Format**
Intersection ID Number	Integer
Time and Date at beginning of cycle of coordinated phase	DateTime
Phase Number	Integer
Time between first vehicle detection and when the phase is served	Integer

Application



intersection operations

Description

Monitor intersection operations at signalized intersections along arterial roadways. Intersection operations include performance information for signal timing effectiveness. Intersection operations data may include percent arrival on green by vehicle phase, force offs by vehicle phase, green times by phase, vehicles entering the intersection on red, and red extensions.

Detector Technology

- Traffic signal software
- Vehicle detection at traffic signal: inductive loops, video, radar, magnetometers

Potential Uses

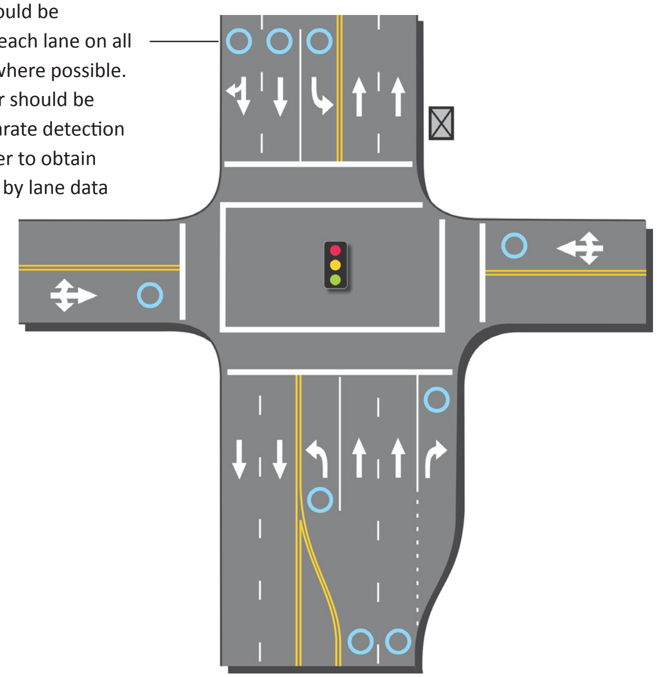
This data would be most commonly used for signal timing improvement and before and after studies. This data may be useful to support some planning and design projects, but should not be used to replace detailed intersection operations analysis.

Design Considerations

Field detection should be capable of supporting measures by approach and lane. Detection is required to obtain percent arrival on a green phase and the number of vehicles entering an intersection on a red phase. Detection on all approaches is recommended where possible.

Data Fields	
Description	**Format**
Intersection ID	Integer
Green times by phase	Time and phase #
Gap outs by phase	Occurrence and phase #
Percent arrival on green by phase	Percent and phase #
Vehicles entering intersection on red by phase	1 and phase #
Red extension activation	1 and phase #

Application



air emissions

Description

Record air emissions near major signalized intersections to understand trends and maximum and minimum emission values.

Detector Technology

- Environmental sensors

Potential Uses

Typically, this data would be used for research and to test the before and after impacts of signal timing.

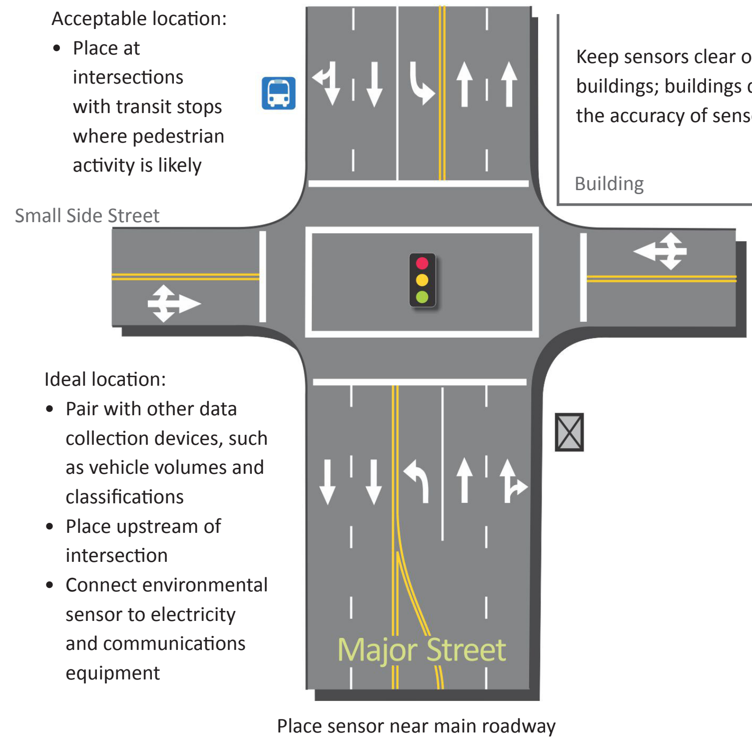
Design Considerations

Emission levels can vary at an intersection depending on the sensor location. For example, placing a sensor at an intersection's near side adjacent to an arterial will likely record higher emissions than a sensor placed at an intersection's far side adjacent to a minor approach. For convenience and constructability, a sensor may be placed in a signal controller cabinet, limiting accuracy. When reviewing emission level accuracy, consider the senor location.

Data Fields: depending on the sensor installed, data on some or all of the pollutants below may be collected. Prior to installing a sensor, approve the data format with PORTAL.

Description
• Particulate matter – PM 2.5 • Particulate matter – PM 10 • NOX • Carbon Monoxide (CO) • Carbon Dioxide (CO_2) • Wind • Temperature • Ozone • Sulfur Dioxide (SO_2) • Methane (CH_4) • Hydro Fluorocarbon (HFC)

Application



Note: Emission detection needs more research before implementing across the Portland region. Emission sensors are expensive, temperamental, and often custom designed for specific locations. This technology is not ready for implementation. Additional research and cooperation within DEQ is necessary

transit measures

Description

Track transit performance using automated technology on-board transit vehicles. Performance data includes transit travel time speed, delay and boarding and alighting passengers. Track transit signal priority (TSP) performance through the traffic signal controller. TSP data includes frequency, duration, and if the call was served.

Detector Technology

- Automatic vehicle location (AVL)
- Automatic passenger counter (APC)
- Traffic signal controller
- Opticom
- GPS
- Radio communications

Potential Uses

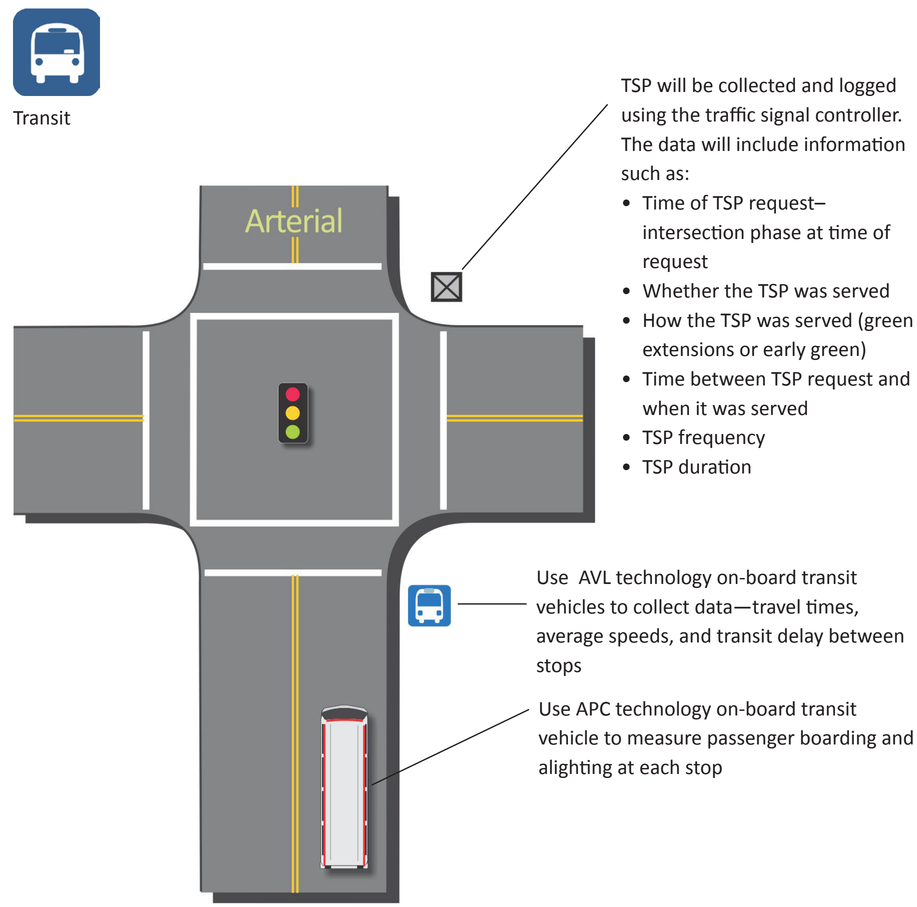
This data can be used for all types of projects. Common uses would include signal timing improvement and transit planning. This data can be used as input for multimodal operational analysis modeling. It may be helpful in identifying locations where transit improvements are needed. Transit occupancy data can also be used to determine person movement through a corridor when integrated with vehicle occupancy, bicycle volumes, and pedestrian volumes.

Design Considerations

In the Portland Metro region, TriMet collects and processes extensive transit data using automated technology.

Data Fields	
Description	**Format**
Transit vehicle ID	Integer
Location/stop ID	Integer
Transit stop arrival time	hr:min:sec
Transit stop departure time	hr:min:sec
Passengers boarding	Integer
Passengers alighting	Integer
TSP log	TBD

Application



detector health

Description

Automate reports from traffic signal controllers or other server systems that indicate whether detectors collecting performance measures are functioning properly.

Detector Technology

- Traffic signal software
- Other server systems (e.g. a Bluetooth device does not interface with the traffic signal controller. Because of this, the Bluetooth server would need to communicate detector health to PORTAL)

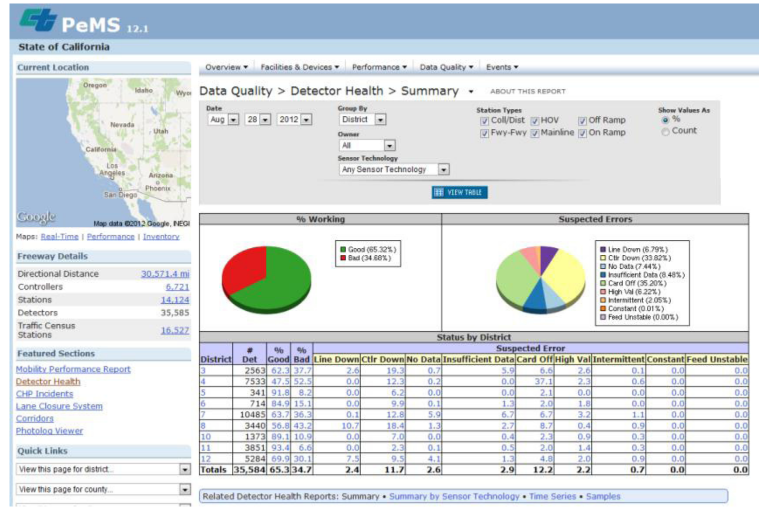
Potential Uses

Detector health reports will be used to determine whether the detectors are functioning property. Knowing if the detector is healthy is key to ensuring accurate system data.

Design Considerations

Detector health reports should be enabled for all detection devices collecting performance measures.

Data Fields	
Description	**Format**
Detector ID	Integer
Detector health	Text: “active” or “inactive”
If inactive, suspected error	text



Source: PeMS

Damaged Detectors

detectorid	stationid	highwayname	locationtext	ATMS lane number	field lane number	startdate	enddate	description
1002	1001	I-5 NORTH	Stafford Rd EB to NB	2	2	2009-10-16		construction-related
1256	5028	I-5 SOUTH	Columbia Blvd SB	1	3	2009-05-11		construction interruption
1027	1004	I-5 NORTH	Nyberg WB to NB	3	1	2009-10-13		construction-related
1035	1040	I-5 SOUTH	Nyberg SB	3	1	2009-10-15		construction-related
1019	1003	I-5 NORTH	Nyberg EB to NB	3	1	2009-10-14		construction-related
1884	1130	I-5 NORTH	Wilsonville to I-5 NB	1	3	2009-08-04		construction-related
1030	5004	I-5 NORTH	Nyberg WB to NB	1	3	2009-10-13		construction-related
1673	1089	US 26 EAST	Parkway EB	3	1	2009-10-22		construction interruption
1022	5003	I-5 NORTH	Nyberg EB to NB	1	3			Temporary off until repaired by E.C(was damaged by an auto accident)
1033	1040	I-5 SOUTH	Nyberg SB	1	3	2009-10-15		construction-related
1238	1026	I-5 SOUTH	Jantzen Beach SB	3	1	2009-06-25		The loops were either ground out or paved over due to repairs to the road surface from winter damage. The contractor will be installing new loops.
1025	1004	I-5 NORTH	Nyberg WB to NB	1	3	2009-10-13		construction-related
1253	1028	I-5 SOUTH	Columbia Blvd SB	2	2	2009-05-11		construction interruption
1026	1004	I-5 NORTH	Nyberg WB to NB	2	2	2009-10-13		construction-related

Source: PORTAL

X. SECTION 4 – ACTION PLAN

Near Term, Mid Term, and Long Term Actions

Time Frame	Actions	Responsible Party
Near Term	Upgrade NWSVoyage capabilities	ODOT
	Modify ODOT traffic signal cabinet standard to enable additional inputs available with C11 connector (see Figure 7) or with a serial cabinet.	ODOT
	Automate data collection (see Steps to Automate Performance Measures).	Agencies
	Update design standards based on RCTO recommendations (see individual performance measures).	Agencies
	Continue to connect field to center communication links	Agencies
	Implement demonstration projects and validate data from demonstration projects. Follow up on the "Future Activities" discussed in the Demonstration Project Report.[8]	PBOT
	Upgrade TransSuite capabilities to automate data transfer to PORTAL	PBOT
	Implement software updates to SCATS (or other adaptive systems) to allow PORTAL to access performance measures.	PBOT/Agencies
	Validate the data (ongoing).	PORTAL and Agencies
	PORTAL upgrades (see section on following page).	PORTAL
	Oversee the creation of an annual State of the Region Report (including freeways, arterials and transit).	TransPort
	Update standard plans and specifications to comply with RCTO arterial performance measures (see individual performance measures).	PMT
Mid Term	As new projects arise, install necessary field equipment and communications to collect all eligible performance measures at the given location.	Agencies
	Improve collection techniques as an ongoing process with the data validation.	Agencies
Long Term	Continue seeking technology advancements that improve the accuracy and ease of implementation to collect performance measures.	Agencies
	Continue to update standard drawings and specifications as needed.	Agencies
	Develop a replacement or retirement strategy	Agencies

[8] *Arterial Performance Demonstration – 82nd Avenue Memorandum*. January 14, 2013. Prepared by Kittelson & Associates.

PORTAL Action Items

Each year PORTAL receives funding from TransPort. As part of that funding, TransPort should provide a priority action item list to PORTAL. The list will need to be prioritized and discussion may be necessary regarding the feasibility of addressing actions within the current PORTAL budget.

The following PORTAL web site upgrades are suggested:

- Make the demo site live (which includes preliminary data for transit, vehicle speeds and traval time via Bluetooth, ped/bike volumes and pedestrian delay, and vehicle volumes and speeds on arterials)
- Integrate INRIX data with PORTAL

The following PORTAL report capabilities are suggested:

- Create detector health reports for arterials
- Update pedestrian actuations to show actuations by crossing leg, in addition to the full intersection
- Create new reports for vehicle, bicycle, and pedestrian delay
- Refine the transit data reporting
- Create a transit priority performance report
- Create a *State of the Region* report
- Create a turn movement count report at intersections
- Create vehicle classification report for arterials
- Create emissions reports
- Create performance measure dashboards (see Appendix I for an example)

Recommended Updates to Design Standards

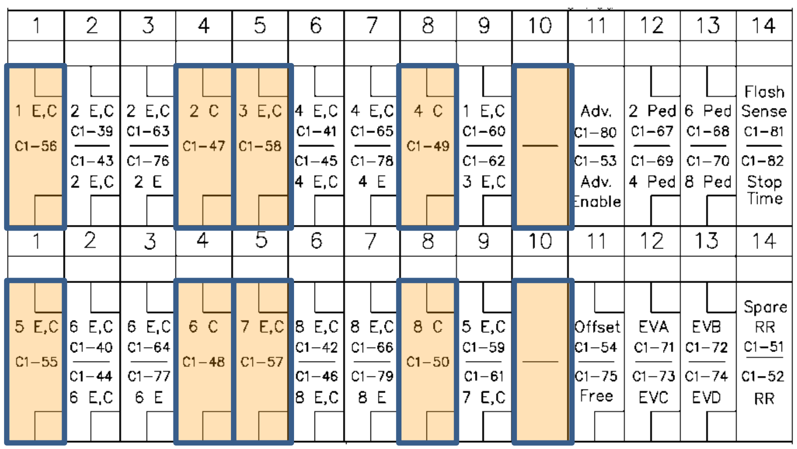
The following are suggested updates to ODOT and other agency design standards:

Update the ODOT Traffic Signal Policy and Guidelines (2006)

- Install advance and stop bar bicycle detection in bike lanes. Advance detection improves count accuracy and doubles as extension detectors. Advance detection should be wired separately from stop bar detection.
- Change the standard controller to the Model 2070 with NWS Voyage firmware. Consider Advanced Transportation Controller (ATC) for future installations.
- Install pedestrian pushbuttons at signalized arterial intersections with crosswalks, and locations where trails cross an arterial at a traffic signal.
- Collect vehicle volumes and classification by lane on arterials where appropriate.
- Install dual loops where collecting speed data via inductive loops.
- Consider modifying the traffic signal guidelines to include the ability for multiple technologies (radar, loops, Bluetooth, etc.) to work with existing controllers and upload data to TransSuite.
- Controllers should be equipped with the capability of reporting an intersection operation report and detector health reports.

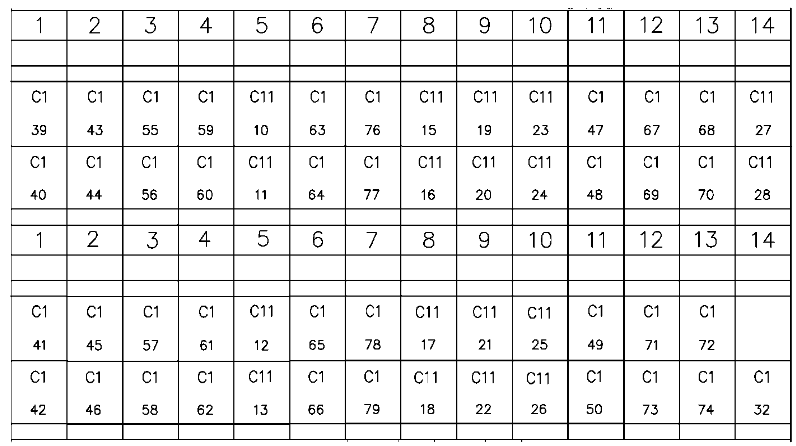
Update standard drawings and specs:

- Modify ODOT traffic signal cabinet standard to enable additional inputs available with C11 connector (see Figure 7)
- Consider installing serial cabinets to expand detection capabilities
- Define bicycle detection requirements at intersections (see bicycle volume and delay performance measures for recommended detector locations).
- Show dual loop vehicle detection (in cases where speed or classification are collected via inductive loops)
- Consider adding a standard drawing to show Wavetronix™ connecting to the controller.
- Create a standard drawing for installing Bluetooth devices to collect travel time.
- Create standard drawings detailing the installation of environmental sensor equipment.



Example of a standard ODOT cabinet

Indicates an input that is unused or under-utilized



Example of a modified cabinet utilizing all available inputs

Figure 7: Recommended modifications to the ODOT traffic signal cabinet to enable additional inputs with the C11 connector.

XI. OTHER RELATED EFFORTS

Multimodal performance measures are appearing in other recent projects in addition to this plan. On the national scale is MAP-21, and on a local scale the City of Portland just embarked on a project to update operational standards to include multimodal performance measures.

MAP – 21 (Moving Ahead for Progress in the 21st Century)

This act, signed into law in July 2012, funds surface transportation programs for the next two years (fiscal years 2013 and 2014). One of the key elements of this act is that it establishes a performance-based program.

> "*Under MAP-21, performance management will transform Federal highway programs and provide a means to more efficient investment of Federal transportation funds by focusing on national transportation goals, increasing the accountability and transparency of the Federal highway programs, and improving transportation investment decision making through performance-based planning and programming.*"[9]

MAP-21 identifies seven areas of national performance goals:

- Safety
- Infrastructure condition
- Congestion reduction
- System reliability
- Freight movement and economic vitality
- Environmental sustainability
- Reduced project delivery delays

The US DOT is currently working with stakeholders to set the performance measures. Then States and MPOs will set performance targets in support of the measures and describe how programs and projects will help achieve the targets. This RCTO plan sets the stage for collecting arterial performance measures related to four of the seven national performance goals (congestion reduction, system reliability, freight movement and economic vitality, and environmental sustainability).

City of Portland Performance Measure Project

The City of Portland is beginning the process of modifying their existing roadway and intersection performance standards. Current standards are based on motor vehicle performance including level of service (LOS) and volume to capacity (v/c) ratios. The City's current practice emphasizes and promotes multimodal transportation, and the performance measure policy will be updated to reflect the multimodal element.

[9] US Department of Transportation, FHWA website. Accessed October 17, 2012. http://www.fhwa.dot.gov/map21/summaryinfo.cfm