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SHRP2 PM Software

Implementing the Routine Computation and Use of Roadway Performance Measures within WSDOT

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16. ABSTRACT

The Washington State Department of Transportation (WSDOT) is one of the nation's leaders in calculating and using reliability statistics for urban freeways. The Department currently uses reliability measures for decision making for urban freeways—where it has applicable data—and as input to analyses that are part of major investment studies and other project identification and prioritization studies.

The project documented in this report is intended to provide WSDOT with an online data analytics system that is capable of producing a variety of roadway performance measures specifically oriented toward identifying bottlenecks, and of determining the size, timing, and scope of delays those bottlenecks impose on travelers and freight shipments. The data used to determine the size of delays are also to be accessible as inputs to tools designed to evaluate alternative strategies for improving roadway performance.

The system, Digital Roadway Interactive Visualization and Evaluation Network (DRIVE Net), which continues to be developed at the STAR Lab, is designed to integrate data from multiple, siloed data sets. It is intended to create key inputs for WSDOT's planning and project selection process, as well as supply inputs to other analytical tools used in the planning and programming processes.

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INTRODUCTION

INTRODUCTION

The Washington State Department of Transportation (WSDOT) is one of the nation's leaders in calculating and using reliability statistics for urban freeways, having been using reliability measures to help manage its urban freeway system since the late 1990s. It is actively working to extend its capabilities to the rest of the National Highway System (NHS) and regional street systems within the state by conflating (combining databases based on common time and geographic references) USDOT's vehicle probe data (the National Performance Management Research Data Set—NPMRDS) with available volume, crash, incident, weather, and construction data and roadway geometry information currently stored in various databases and geographic information system (GIS) digital networks.

The Department currently uses reliability measures for decision making for urban freeways—where it has applicable data—and as input to analyses that are part of major investment studies and other project identification and prioritization studies. The Department needs to expand its ability to perform those types of analyses to other locations in the state. Travel reliability is especially important for key freight routes and for rural areas affected by event and recreational traffic.

The Department also needs to decrease the time and effort required to perform reliability analyses. This project was intended to build the initial deployment of the system needed to incorporate the reliability of roadways into the planning, project identification, and prioritization processes that WSDOT uses. The resulting system was designed to be integrated into the revised planning business process that the Department is currently developing as it works to fully adopt Practical Design concepts.

This project was directly coordinated with the Department's efforts to more fully integrate Traffic Systems Management and Operations (TSM&O) strategies into the planning, project selection, and programming functions of the Department.

PROJECT OBJECTIVES

The outcome of this project was intended to provide WSDOT with overall roadway performance measures, and performance measures specifically oriented towards identifying bottlenecks, and determining the size, timing, and scope of delays those bottlenecks impose on travelers and freight shipments. The data used to determine the size of delays are also to be accessible as inputs to tools designed to evaluate alternative strategies for improving roadway performance.

The system, Digital Roadway Interactive Visualization and Evaluation Network (DRIVE Net), which continues to be developed at the Smart Transportation Applications and Research Laboratory (STAR Lab) of the University of Washington (UW), is designed to integrate data from multiple, siloed data sets. The data system is intended to create key inputs for WSDOT's planning and project selection process, as well as supply inputs to other analytical tools used in the planning and programming processes.

This project was coordinated with WSDOT's internal efforts to refine its planning process and change how WSDOT uses the available information to inform its decision making process.

REPORT ORGANIZATION

This report is organized as follows:

- Chapter 1 provides an introduction to the project
- Chapter 2 introduces the DRIVE Net software platform
- Chapter 3 presents the original project plan for this project, describes changes that needed to be made in that plan and the reasons for those changes as a result of software development and deployment issues
- Chapter 4 describes the current status of the DRIVE Net system
- Chapter 5 discusses the project team's review of the SHRP2 L05 documentation
- Chapter 6 presents the conclusions and recommendations for the project.

Appendix A presents describes the architecture of the system, and is submitted as a separate document.

CHAPTER 2
DRIVE NET SOFTWARE PLATFORM

This chapter introduces[1] the DRIVE Net system, an on-line platform aimed at transportation data sharing, integration, visualization, and analysis. The system provides users with the capability to store, access, query, and manipulate data from anywhere with an internet connection.

The goals of the DRIVE Net project are to remove the barriers existing in current data sets archived by WSDOT and to achieve the integration and visualization of information needed for decision support. The project is aimed to provide data fusion and database design while delivering a functioning DRIVE Net archive service capable of collecting loop detector data from all WSDOT Regions and incorporating third party data from entities such as the National Performance Monitoring Research Data Set (NPMRDS), private companies (such as HERE and INRIX), and weather services.

Roadway geometric data are obtained from WSDOT's GIS workbench, and are stored in an open-sourced geospatial database. This database is connected to traditional transportation system performance databases regardless of the source of those databases (e.g., loop detector data from multiple regions, NPMRDS and INRIX vehicle probe data, incident data from WSDOT's Washington Incident Tracking System (WITS), multi-modal data such as transit vehicle location data, and pedestrian and bike counts, and various geospatial data sets) that can be used to explain variations in travel behavior and transportation system performance such as weather data.

DATA AVAILABILITY

DRIVE Net builds upon existing databases accessible to the UW STAR Lab. A variety of data sources can currently be digested, stored, integrated, and made accessible through DRIVE Net. The system currently houses the following types of data:

- Northwest and Olympic Region freeway loop data
- INRIX vehicle probe data for Washington State Routes
- NPMRDS vehicle probe data supplied by HERE
- Roadway elevation data for the National Highway System
- Current King County Metro transit routes
- Park and ride lot location and size data
- Bike count data at ten permanent bike counter locations
- The current location of Car2Go vehicles in the general Seattle metropolitan region
- Crash data for ten state routes (SR 2, I-5, SR 16, I-90, SR 99, SR 167, I-405, SR 509, SR 518, and SR 520)
- Arterial travel time data for a subset of City of Seattle arterials.

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[1] Much of this chapter has been taken directly from the WSDOT Research Report, WA.RD 854.1, DRIVE Net Phase II: Online Moving Washington Platform for Network-wide System Operations, Monitoring, and Analysis, by Wang, Yinhai, et. al., December 2016.

These data sets are typically available for limited time periods. The time periods vary based on the original data sets' availability as well as when specific data sets were accessed and downloaded to DRIVE Net servers.

Data are currently input into DRIVE Net through four different mechanisms:

- Direct upload
- Periodic upload via web services
- Active data acquisition, and
- Direct data archiving

Direct upload is used to perform batch imports of data sets from data services that do not provide direct access to primary databases. For example, WSDOT purchased several years of roadway performance data from INRIX. INRIX produced a large batch file for WSDOT, and a copy of that file was made available to STAR Lab for upload to DRIVE Net.

Periodic upload via web services is used for obtaining data from on-line services designed to routinely supply data to external users. A scheduled fetch job is run by DRIVE Net to download data at predefined intervals using one of several file transfer protocols, including; File Transfer Protocol (FTP), Hypertext Transfer Protocol (HTTP), Simple Object Access Protocol (SOAP), or through a Representational State Transfer Principles (RESTful) interface. This later method is used to download WSDOT's freeway data for the NW and Olympic regions.

Active data acquisition is a technique used by STAR Lab for those agencies and data sets which restrict access to sensitive data sets. In this case, an "information appliance" that bundles hardware, software, and data processing services into a single provisionable platform that sits inside the agency firewall. The appliance is then configured to provide access to STAR Lab using specialized code and through specific ports, to a restricted list of computers. This allows multi-agency, shared access to the data the agencies wish to share. This method is currently used to retrieve roadway geometric data and WITS data from WSDOT.

Direct data archiving is used to collect data directly from devices in the field. These can be fixed sensors that report directly to DRIVE Net servers, or mobile device applications that report data to DRIVE Net when active.

USER ACCESS

Primary access to DRIVE Net functionality is available through this URL: **http://uwdrive.net/STARLab.** Figure 1 below shows the initial (landing) page users sees upon accessing DRIVE Net. Across the top of the page are ten tabs, each of which provides access to specific DRIVE Net functionality.

The key functionality for this project is found under the Travel Time Analysis and WSDOT tabs. The Travel Time Analysis tab provides access to all of the desired WSDOT travel time computations, including the original Grey Notebook pre-defined urban reporting corridors and the user defined corridor travel time functionality for travel times based on the NW and Olympic Region fixed data collection system. This tab also provides access to statewide travel time computations based on the available INRIX and NPMRDS data. (INRIX data are available from 2009 to 2013. NPMRDS data are available from September 2013 to December 2015.) WSDOT loop data are currently available from January 2011 through December 2016.

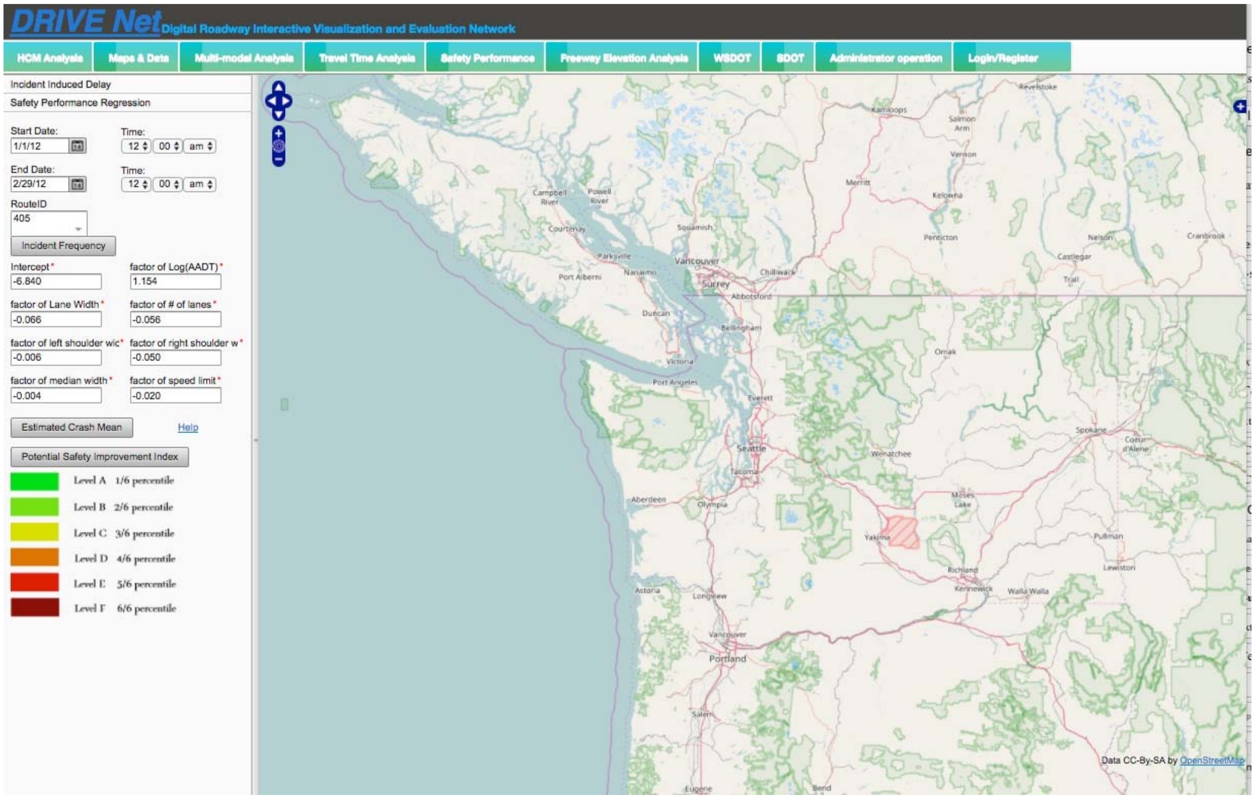

Figure 1: DRIVE Net Landing Page

The WSDOT tab provides access to the actual loop data. DRIVE Net allows downloading volume, speed, and roadway productivity statistics from 1) specific loops, 2) all loops at a specific cabinet location and direction of travel, and 3) summary (mainline and reversible) corridor statistics.

Taken together the Travel Time Analysis and WSDOT tabs provide the basic functionality provided by the TRACFLOW software currently used to produce the urban freeway performance statistics reported in WSDOT's Grey Notebook and Corridor Capacity Reports.

The remaining tabs have been built as part of various STAR Lab research projects. For example, the HCM Analysis tab provides network-wide computation and visualization of roadway level of service using the Highway Capacity Manual procedures. The Maps & Data tab list all vehicle traffic data sets available on DRIVE Net and provide functional buttons for downloading data from some of those data sets. The Multi-modal Analysis tab shows the types of transit, pedestrian, and bicycle data sets available and provides some analytical functions based on mobile sensor data. The Safety Performance tab lists some safety analysis functions, provides visualization of those analyses, and provides a tool for estimating potential safety improvements via a safety index. The Freeway Elevation Analysis tab visualizes the elevation data for all interstate freeways at 10 foot intervals. Finally, the SDOT tab shows the arterial performance analysis functions on the DRIVE Net system.

DRIVE NET FUNCTIONALITY BEFORE THIS PROJECT

DRIVE Net supplies the following database functionality:

- Data entry/update (either in real time or via batch updates) for all data sets that are part of DRIVE Net. This includes a process for updating data stored in the system, whether those data sets are obtained in real time from WSDOT systems (e.g., 20-second freeway data), computed from those data (e.g., 5-minute freeway data), or obtained in batch files from WSDOT (e.g., GIS base files, WITS, INRIX, HERE, and crash records).
- Data quality control for each data set. This includes performing data quality control on each data set and maintaining a record of the quality control outcomes.
- Data retrieval. This includes the ability to extract all base data stored in DRIVE Net. The data need to be available by date or date range, and either by specific location, corridor, or partial corridor.

The analytical functionality being built, or currently contained, in DRIVE Net is intended to meet the basic performance monitoring needs of transportation agencies. The intent of the system is to provide these capabilities state-wide. Many of the analytical capabilities are only currently functional as prototype systems. In most cases, the primary limitations in the statewide deployment of DRIVE Net are 1) lack of data in many parts of the state, and 2) an inability to handle change management activities for the data sets that do exist, given changing roadway alignments and geometry.

The current analytical functionality includes:

- <u>Travel delay quantification and congestion analysis</u>. This includes a universally accessible congestion diagnosis module to analyze congestion onset and evolution and a series of visualization modules for reporting and analytical requirements.
- <u>Travel time analysis</u>. This module calculates travel times, throughput productivity measurements, etc. that are based on different data sources such as freeway loop, INRIX, and HERE.
- <u>Safety analysis</u>. Models are available to estimate expected crash frequencies and identify key associated factors and a universally accessible regional map module to visualize both accident hotspots and safety improvements.
- <u>Multi-modal analysis</u>. Several different modules compute and analyze a variety of performance metrics associated with bicycles, walking, park and rides, and transit.

In support of these analytical functions, DRIVE Net supports a range of visualizations. These include visualization of:

- multiple roadway performance measures computed from both loop and vehicle probe (INRIX and NPMRDS) data, including the location, duration, intensity, and frequency of congestion, and the amount of roadway productivity lost during those periods of congestion
- travel time analysis/HOV analyses
- multi-modal analyses
- safety analyses
- transit routes, transit stops, and park and ride locations
- pedestrian walking paths, given input data
- freeway level of service for selected hours
- the location of Car2Go vehicles that are available for use

New visualizations are periodically being added to this list based on work funded by WSDOT and other sources.

SYSTEM DESIGN

DRIVE Net uses "thin-client and fat server" architecture with three basic tiers of Web application: the presentation tier, logic tier, and data tier. The presentation tier includes the user interface terminal through which users interact with the application. The logic tier, which is also called the computational tier, is the core component of the DRIVE Net system. It performs computations to assist in customized analysis and decision making based on users' interactive input. The data tier organizes and supports data requested for analysis.

The data communication flows in the DRIVE Net system can be summarized as follows:

1. The end-user sends an HTTP(S) request to the web server.
2. The web server looks into the request and retrieves the related data information from the data warehouse.
3. The warehouse sends back the requested data, and the web server performs the computational tasks by using either the built-in analytical tools or external statistical modules provided by R Server.
4. If geospatial analysis is involved, the web server connects to the OpenStreetMap Server and requests the map.
5. Analysis results as well as the map are then returned to the client. The web browser displays the results or visualizes the returned objects on the map.

Database Design

Transportation data and geospatial data are stored separately in DRIVE Net. The transportation data are managed by Microsoft SQL Server 2010, and all the databases are indexed and optimized on the basis of projected needs. Non-spatial relational databases are used to store traffic-related information such as loop detector data and INRIX vehicle probe data. PostgreSQL with the code extensions PostGIS and pgRouting were adopted to maintain geographic data and to perform spatial modeling.

DRIVE Net uses OpenStreetMap (OSM) as the basis for its primary roadway mapping and visualization platform. To operationalize the use of OSM, DRIVE Net generates a request to an OSM Web server which receives that request for a map, and transmits the request to the OSM mapping server to retrieve the desired map contents. The OSM mapping server renders the map with specified geospatial information and sends it back to the Web server. The Web server then passes the map contents to clients. On the client side, OpenLayers software is used to provide the service to obtain map images and display the map tiles on the screen. OpenLayers is an open-source JavaScript library running on the client side that helps users interact with dynamic maps from disparate services.

Transportation network details are currently maintained separately for four different versions of the roadway network: 1) WSDOT's route and milepost system 2) WSDOT's GIS spatial representation of that network, 3) INRIX's TMC code based roadway network, and 4) the NPMRDS TMC code based roadway network supplied by HERE. Conflation tables exist which link these systems to the WSDOT network. Currently the conflation tables are static. That is, they do not account for changes in roadway geometry reported for any of the transportation networks over time. (While roadway alignments are mostly static, they do change slowly over time. Thus, at some point in the future, DRIVE Net will need to be able to identify not only where I-90 currently is located, but where the I-90 alignment was five years ago, as that alignment may have changed, and when it changed, the milepost at which a specific exit ramp starts downstream of that change may also have changed, even though the physical road segment which contains that ramp has not moved.)

DRIVE Net also makes considerable use of the "R" statistical software package. DRIVE Net accesses R code via Rserve, a TCP/IP server. This service integrates R into the DRIVE Net system so that it takes full advantages of R's statistical computation capability. Several modules in DRIVE Net use the combination of Rserve and R as the major tool for statistical analysis and data visualization.

Access Control

Because DRIVE Net contains come data sources that have restricted uses (e.g., NPMRDS can only be used for state DOT or metropolitan planning organization (MPO) analyses), DRIVE Net is designed to incorporate **role based access controls** (RBAC). RBAC is an approach to restricting system access to authorized users and is also a policy-neutral access control mechanism defined around roles and privileges.

DRIVE Net has six basic roles; administrator, normal, database administrator, manager, chief technical officer, and programmer. These roles define the level of access allowed to each user. In order to download and access data, users must log in to the system. Without a Username and Login password, secure data cannot be accessed. This is the primary mechanisms for limiting access to data that cannot be shared outside of WSDOT or the state's MPOs.

CHAPTER 3
PROJECT PLAN AND REVISIONS

This chapter describes the initial project task plan, discusses the events which occurred in the conduct of that plan, discusses the changes to the initial plan that resulted from decisions made in response to those events, and presents the revised project plan and expectations.

INITIAL PROJECT TASK PLAN

The initial project work plan consists of 17 tasks. These 17 tasks are as follows:

Task 1: Obtain GIS and other files
Task 2: Complete conflation of the NPMRDS for the NHS
Task 3: Develop, test, and refine missing data and "geographic and temporal extension" algorithms
Task 4: Determine the system's output needs
Task 5: Develop data storage and data update designs
Task 6: Develop the system interface
Task 7: Construct, test, and refine the user interface
Task 8: Load data and test update functionality
Task 9: Code the desired multi-parameter reliability reports
Task 10: Test and refine the reporting tools
Task 11: Develop enhanced L07 analytical capabilities
Task 12: Test and refine the L07 tools
Task 13: Work with state and MPO staff on implementation
Task 14: Develop training materials
Task 15: Provide training to WSDOT and MPO staff
Task 16: Evaluate the effectiveness of the software tools and their implementation
Task 17: Write the final report

Work that was expected to be performed in each of these tasks is described below.

Task 1: Obtain GIS and Other Files

This initial task was designed to obtain the GIS files for those portions of the NHS that are not already part of the WSDOT GeoData catalog. These files were to be obtained from the MPOs in the state. In addition to the GIS files, the project team looked to obtain current versions of WSDOT's crash files, Washington Incident Tracking System (WITS) files, files describing the times and locations of WSDOT construction events, and WSDOT GIS tables indicating the presence of specific infrastructure features that affect freight performance, including low-height bridges; routes with Spring load restrictions; and the locations of truck climbing lanes. As part of obtaining these files, the project team worked with WSDOT to develop a protocol for routinely obtaining updates to these files. The availability of those data, and the best ways for WSDOT to update those files to the performance monitoring system was an input to Task 5.

Task 2: Complete Conflation of the NPMRDS for the NHS

Task 2 was designed to complete the conflation of the NPMRDS with the geo-referencing systems used to store traffic volume data collected by WSDOT. This task was necessary in order to report delay statistics on a statewide level using the NPMRDS data set.

Task 3: Develop, Test, and Refine Missing Data and "Geographic and Temporal Extension" Algorithms

Previous work done with both the vehicle probe and urban freeway loop data sets showed that none of these data sets are "clean." They all have a significant amount of both missing and invalid data. Task 3 was therefore designed to determine, code, test, and refine the algorithms needed to identify and account for these invalid and missing data. This was particularly important in that WSDOT wished to move away from its current freeway analysis software (TRACFLOW) to DRIVE Net, and TRACFLOW performs a considerable amount of data cleaning and replacement. Adopting DRIVE Net requires that the data cleaning and replacement process incorporated in DRIVE Net be sufficient to meet WSDOT's routine roadway performance reporting needs.

The majority of the work in this task was intended to involve determining how to 1) identify and handle erroneous and missing data in the NPMRDS and 2) use point data (such as traffic volume or weather data) that WSDOT has collected and "extend" those data to locations or road sections other than where the data were collected. Work in this task was to be coordinated with the work being performed as part of the WSDOT Freight Performance Measures project, which was examining the use of the NPMRDS for reporting freight performance measures.

Task 4: Determine the System's Output Needs

In this task the project team will work with WSDOT staff to identify the analytical outputs the system should produce. This task will also be coordinated with the WSDOT Freight Performance Measures project. A good starting point for this task will be the material the project team is developing for the NCHRP 08-98 project, which is determining how to identify freight bottlenecks. In addition, the project team will use the preliminary reports produced under NCHRP project #20-24 (37), which have recommended a series of performance measures for consideration by the USDOT as it develops the MAP-21 roadway performance reporting requirements.

Of particular importance in this task will be obtaining "buy in" from WSDOT staff regarding how each of the measures selected will be computed. These computational steps will be coordinated with the NCHRP study and with other researchers working with this topic nationally. This will ensure both that WSDOT agrees with the use of the adopted measures and that national consensus is obtained on exactly how those measures are calculated.

Task 5: Refine Data Storage and Data Update Design

Task 5 was used to refine and test the core software system, refining, as necessary, how the data were stored, updated, accessed and used within the analytical functions that produce the performance data. Data updates were expected to occur in two ways.

1) New data will be obtained. For example, each month, the next month of NPMRDS data will need to be uploaded to the database.
2) Updates will be made to existing data. For example, a WSDOT bridge replacement project changes the bridge height stored in the database. This fact, and the date when that change occurred, will need to be included in the database. At the same time, the historical bridge height will also likely need to be retained.

Given budget restrictions imposed on the project team, some WSDOT data files may not be included in the initial version of the software. For example, only a limited subset of WSDOT GIS layers will be made available through this system.

Task 6: Develop the System Interface

In this task an interface that allows users to access and request the types of information they require was to be designed. It was anticipated that users will need to be able to request data (either access to specific data items uploaded to the system or performance measures computed by combining two or more data items uploaded to the system) for the following:

- specific points (locations)
- specific corridors (either an entire roadway or continuous segments of a specific state route or other NHS road), and
- trips that use more than one road (where "a trip" is defined as a series of contiguous road segments from a selected origin to a selected destination which may include more than one state route or roadway on the NHS).

For each of these three types of geographic selections (location, corridor, trip), a large number of performance metrics were to be made available, and users must be able to easily select them. Users will need to be able to select specific time periods for the data (e.g., an entire year, a specific day, all Mondays during specific months), as well as the type of outputs desired (graphics on screen, electronic files, or both).

Task 7: Test, Refine, and Construct the User Interface

This task involved testing the screens developed in Task 6. Revisions to the interface design were to be made on the basis of the feedback received. Once the initial screen designs have been finalized, they will be coded.

Task 8: Load Data, Code and Test Database, Update Functionality

In Task 8, the project team developed the code to load data into the system. Of particular importance will be the ability to routinely add new data for existing databases (e.g., adding a new month of NPMRDS data), as well as upload revisions to previously loaded data (e.g., corrections to previously input vehicle crash records). The system should also allow the addition of new data sets (e.g., new types of weather data may soon be available via connected vehicles).

All available data will then be loaded into the system. This will allow coding of the performance measures (in Task 9), and testing of the interface developed in tasks 6 and 7.

The data structure and administrative procedures required to maintain the database will be revised as needed on the basis of the outcome of the data loading and update tests.

Task 9: Code the Desired Multi-Parameter Reliability Reports

In this task, the desired analytics and reporting capabilities identified in Task 4 were to be coded by using input from the interface developed in Task 6.

Task 10: Test and Refine the Reporting Tools

In this task, WSDOT and Puget Sound Regional Council (PSRC) staff were to test the system. The project team also performed quality assurance tests on the analytical outputs produced with the code written in Task 9.

Task 11: Develop Enhanced L07 Analytical Capabilities

In this task, a specific output functionality was to be written that used the data stored in the system to produce the inputs required by the SHRP2 L07 analytical procedures.

Task 12: Test and Refine the L07 Tools

In this task, the project team was to test and refine the tool built in Task 11.

Task 13: Work with State and MPO Staff on Implementation

Task 13 was designed to work with MPO and WSDOT staff to deploy the reporting capabilities of this system within the existing MPO planning process and within the revised planning process that WSDOT continues to develop and deploy.

Task 14: Develop Training Materials

This task was designed to develop training materials. The primary materials will be used to train WSDOT and MPO staff in the use of the performance monitoring website. This will include what data are included in the site and the details of producing the various output reports.

A separate set of training materials describe how to operate and maintain the data system. This set of materials will be used by the agency that is given the job of operating the data system.

Task 15: Provide Training to WSDOT and MPO Staff

In this task, the project team will offer training classes based on the training materials written in Task 14 to WSDOT and MPO staff so that the data system can be used as intended.

Task 16: Evaluate the Effectiveness of the Software Tools and Their Implementation

This task was intended to allow the project team to work with WSDOT and the MPOs to evaluate the use of the new performance measurement and reporting system.

Task 17: Write Final Report

This task simply set aside time to write this report.

EVENTS AND RESULTING PROJECT TASK PLAN REVISIONS

As this project got underway, we encountered some data quality issues. Also, two major events took place which caused major changes in the original work plan.

The first event was the realization within WSDOT that the agency needed to significantly reduce the cost and improve the speed with which roadway performance reporting was performed by WSDOT.

It is good that WSDOT's reporting and use of roadway performance metrics has expanded significantly over the past decade. Unfortunately, the effort required to perform that work has also expanded. Shifting funding priorities at WSDOT have resulted in a need to lower the cost of producing the existing roadway performance measures, while at the same time allowing those measures to be reported in a timelier fashion.

Since DRIVE Net has the potential to both reduce the time required to produce performance measures, and reduce the staff time required to develop those measures, emphasis on this project shifted away from adding multiple new performance reporting functions, to making sure that DRIVE Net could at a minimum replace the current WSDOT software system (TRACFLOW) used to produce the urban freeway performance reports in the Department's renowned Corridor Capacity Report. This required not only being able to produce the existing performance measures, but to be able to meet future reporting needs, while also being to explain to the State Legislature why metrics produced by DRIVE Net can differ from those produced by the current procedures. (Note that this concern is not unique to the shift to DRIVE Net, but a concern whenever changes in WSDOT's reporting systems results in the need to update previously reported performance statistics.)

In response to the need to place more emphasis on the use of DRIVE Net for producing the existing performance reports, a more detailed review of the sustainability of DRIVE Net's urban freeway reporting process was undertaken at the beginning of this project, with specific emphasis on moving the research database into production oriented operations.

The second event which affected this project's scope of work was that this detailed review determined that a number of decisions made during the development of DRIVE Net allowed the system to operate effectively as a research tool to demonstrate the idea, further efforts are needed to make the tool reliable for easy and robust operations over an extended period of time. Most of the issues discovered can be categorized as limitations in "change management" capabilities of the system as mentioned earlier in Chapter 2. That is, changes in the underlying roadway network data that serve as the basis for many of DRIVE Net's computations could be difficult and time consuming to account for using the current computational procedures.

For example, the approach used in DRIVE Net for storing the loops required for producing travel times used by the WSDOT's Grey Notebook was to use a fixed list of loop locations. The same loops were used for each new year of data. The internal DRIVE Net approaches to handling variable data quality and missing values were then used to account for year-to-year differences in data quality and availability at these loop locations.

Unfortunately, this fixed location approach becomes problematic as a long term solution, in that loop detectors periodically are replaced with new loops at slightly different locations over time. For example, when freeway geometry changes (e.g., new lanes are added), the location of lane lines change. This means that new loops must be installed, and those loops tend to be installed at slightly different locations. These new loops are also given different names. The overall result is that the list of loops used for computing a travel time from a given starting point to a given ending point, changes over time, depending on which loops are present, and which of those loops is actually functioning correctly.

A somewhat different version of this change management problem occurs with the TMC code based networks used for the NPMRDS and INRIX vehicle probe networks. For NPMRDS, new roadway geometry files are transmitted every six months. Most changes are modest in scope, but these changes mean that each query of the NPMRDS performance metrics database must be able to select the network file description for that specific time period in order to identify the names and locations of road segments for which data need to be extracted. If the wrong set of roadway geometrics are used to determine the set of roadway sections for which data are required, the data query will miss data that should be part of the desired analysis. Again, at the start of this project DRIVE Net did not contain this change management capability and the research team considered it important to fix it to produce good results for this project.

A good example of why speed of analytical response, combined with a need to account for changing sensor locations, and a high profile need to be able to defend the accuracy of their results occurred early in this project. In late Summer of 2015, WSDOT implemented a major High Occupancy Toll (HOT) project on I-405, between downtown Bellevue and the northern I-5 & I-405 interchange at Swamp Creek. The I-405 Express Toll lanes project converted an existing single lane HOV facility in the corridor into an HOT lane, but also added a second HOT lane in the southern half of the corridor. (See Figure 2.)

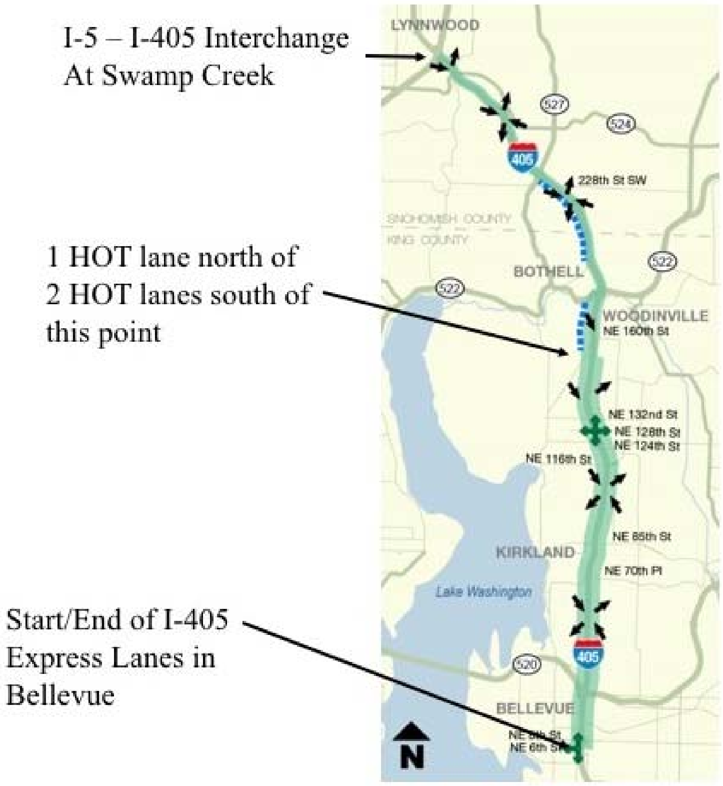

Figure 2: I-405 Express Toll Lane Map

Not surprisingly, this project had a very high public profile. As a result, WSDOT reported early and often on the performance of the corridor after opening the new HOT lane. The reporting used the available tools and the travel time trips that WSDOT has traditionally used for reporting roadway performance on this corridor.

WSDOT reported before and after travel times, travel time reliability measures between I-405 in downtown Bellevue and the I-5/I-405 interchange in Lynnwood for both general purpose (GP) and HOV/HOT lanes for both directions of travel, along with traffic volumes at multiple locations in the corridor.

However, to produce the "after" period reports, it was necessary to account for the changes in induction loop locations in the corridor. The addition of an extra lane in the southern half of the corridor, plus the changes in roadway geometry and lane lines needed to incorporate the weave areas which were required to allow access into and out of the HOT facility, required the replacement of a number of old loops with new loops that matched the new lane lines. This required manual revision of the trip definitions. This was a slow manual task, but a function routinely performed in the past.

While WSDOT was confident in their before and after performance reporting, controversy ensued when the WSDOT performance reports – which showed improvements in HOT lane performance and little or no change in general purpose lane performance - were hotly contested in the press by individuals that routinely used the corridor. Citizens in the anti-HOT lane group, claimed that WSDOT statistics were not accurate, and that congestion in the general purpose lanes had grown considerably with the implementation of the HOT lanes. Support for the citizen protests came from the CEO of a local traffic data provider who published selected data from his company's system showing significant degradation in roadway performance.

In response to these questions about the accuracy of their performance reporting, WSDOT had to respond by providing all new, more detailed, performance reports. Those more detailed reports showed that general purpose lane roadway performance in the corridor varied considerably by location; with some segments of the corridor showing improvements, and others showing degradation. When averaged together, trips that traveled the length of the corridor did not experience major changes in performance. However, trips being made over only portions of the corridor often experienced considerably worse roadway performance after the HOT lanes were opened. These results resulted in the Legislature requiring WSDOT to define and report on new "partial corridor trips" so that the reliability of the facility could be examined for different groups of constituents.

Additional reports were also provided to various public citizen's groups in order to allow those groups to double check the accuracy of WSDOT's travel time reports by comparing the reported WSDOT travel times with those observed in floating car runs made by those individuals.

The ultimate result of these two major events and the very public questioning of the veracity of WSDOT's reporting system was a shift in priorities within this project. Emphasis was changed from adding additional data sets and new reporting capabilities to ensuring that DRIVE Net could be relied on to produce the current reports, could supply accurate data, and could respond to the sometime unpredictable requirements being placed on the reporting system.

FINAL PROJECT TASK PLAN AND OUTCOMES

As a result of the above project inputs, changes were made to the scope of work. These changes are described by task below. These outcomes are summaries in Table X.

Task 1: Obtain GIS and Other Files

Task 1 was directly impacted by both major events discussed above. In order to meet the needs of WSDOT's routine roadway performance measure reporting, it was necessary to perform travel time computations for multiple years. However, roadway networks change over time. This is true whether it is the WSDOT linear referencing system, or the networks used by the vehicle problem data sets that are being used to compute travel times.

The detailed review of DRIVE Net performed at the beginning of the project determined that the version of DRIVE Net that was running at the start of this project was not capable of accessing different roadway geometry data files. This meant that significant programming changes were required to 1) store multiple versions of roadway networks, 2) track which roadway network version or versions was needed for any given request for travel time data, and 3) change the travel time code itself to look for and use different roadway networks.

To improve DRIVE Net for change management, it was determined that the best option was to create a single, routable network based on WSDOT's linear referencing system, and then conflate all other road networks to that routable system. This means that whenever a new network is added, a new conflation table must be created. When changes to an existing network are uploaded, the conflation table associated with that roadway network must also be updated, with time stamps associated with each of those changes. (That is, "roadway network configuration A is applicable from January 1, 2012 to December 31, 2013.")

DRIVE Net must then keep all of these historical networks and network conflations. As requests for historical travel time computations in the future will need to reference these networks and conflation tables. For example, a request in June 2017 looking to compare travel time reliability from Vancouver, WA to Seattle, WA for 2010 versus 2016 would need to use the correct roadway geometry for 2010 for the first computation, but a roadway network for 2016 for the second travel time computation.

In Task 1, a number of meetings were held with WSDOT staff. WSDOT updates their GIS files agency-wide once a week. It was determined that such an update cycle was too often for DRIVE Net to handle. Thus a joint decision was reached where DRIVE Net would store and use a single GIS file for each year. That file would be obtained by the operators of DRIVE Net in January of each year for the previous year's roadway geometry. This network includes the updated WSDOT linear referencing system. That linear referencing system would then be used as the base network against which all other roadway networks, such as the TMC network, would be conflated. (Note that each conflation table is specific to a given annual WSDOT network file.)

In the case of the NPMRDS, the federal contract which obtains the vehicle probe data states that a revised TMC network is to be provided every six months. Thus, minor conflation updates will need to be performed twice a year for the TMC network. Travel time calculations will need to be sensitive to these changes, selecting from the correct TMC geometric file and WSDOT conflation table the road segment numbers and definitions for the correct six months of each year. (Note that the recommendation is that while two TMC network files are stored for each year, they are conflated to a single WSDOT linear referencing system file.

One limitation with this approach of storing only a single definition of WSDOT's road geometry for each year is that when those geometric changes occur, that – if changes have occurred to a road – the "annual" network will only be "correct" for those trips occurring at the end of the year. Trips made prior to the end of the year will be using incorrect road geometry if geometric changes have been made to that roadway that year. While this outcome is not ideal, it was determined that more frequent updates were not practical either from the operational perspective of either WSDOT or DRIVE Net's operators.

As noted above, to account for the fact that there was no longer going to be a single network upon which to base travel tie computations, the programming which produces the travel times was also changed. The basic change that was needed was to include the year for which travel times were required, and use that year to look up the "correct" roadway network for that year. This means that – if a travel time reliability data request spans years (e.g., "Tell me mean and 80th percentile travel times from Point A to Point B from October 1, to March 31"), the road network file used for the first three months could be different than that used for the last three months.

While this is simple in concept, this capability required extensive changes to the DRIVE Net code. These changes were completed, implemented and tested under this task.

Because of other implementation issues, the project team did not upload more than one additional year of WSDOT's linear referencing system.

Task 2: Complete Conflation of the NPMRDS for the NHS

Task 2 was removed from the project as a result of the project team's need to reduce the scope of work in order to address the issues raised by the major events discussed above.

Our pilot analysis and the review of the NPMRDS data provided by USDOT prior to 2016 as part of the WSDOT project showed that considerable effort was going to be needed to clean the NPMRDS data.[2] When this effort was added to the need to update the travel time computation algorithm to account for multiple different network files, and the need to prioritize freeway performance reporting for the Congestion Capacity Report, it was determined to suspend this task from further work.

Task 3: Develop, Test, and Refine Missing Data and "Geographic and Temporal Extension" Algorithms

This Task identified a significant number of issues in the output initially produced by DRIVE Net. Of most concern was that the definitions of HOV and HOT lane travel times reported for the Congestion Capacity Report were not always correct. The start and ending points were not always correctly identified. These were fixed with a significant investment of our research efforts.

A second major issue noted in the initial review of the DRIVE Net output was that the system had difficulties correctly handling changes in loops. That is, when some loops were removed from active use, and were replaced by new loop locations, DRIVE Net did not successfully handle the transition from one set of loops to the other.

In a case such as the new I-405 Express Toll Lanes, this is a particularly difficult problem, as the database supplied by WSDOT's data system includes both sets of loops (the old loops being de-commissioned and the new loops which describe traffic conditions in the revised lane conditions.) Both sets of loops are active for a portion of time. One provides correct information. The other provides invalid data, as the loops are not correctly positioned relative to the actual lane lines. When the new loops initially start to report data, the data are typically invalid. Once the lane lines are moved, these loops report accurate data, and the old loops suddenly report invalid data.

Both the travel time computation and the corridor performance summaries need to account for these changes in performance. This is partly a function of knowing that these conditions exist, partly a function of how well the data quality algorithms can detect the change in loop performance, and partly a function of having computational algorithms that can handle these cases.

For example, assume that the new loops become active on September 1, but that the lane lines are not actually moved until September 15th. While the before/after comparison of corridor performance will be performed as two separate queries (prior to September 15th, when the lane lines move, and after September 15th, when the HOT lanes become active), the annual travel time reliability computation needs to include travel times throughout the month of September when these changes are taking place. In September, the data query for determining annual conditions will see both sets of loops, since they are both active in the data set. That is, a different set of loops will be present in the database for September than was present in August (when the new loops did not exist in the database). However, travel time computations for September 1 through September 14 must exclude those new loops, because the data are not reliable. Travel times for September 15th onward must include those loops, and disregard the old loops as the new loops are now reliable and the old loops are not, but remain in the data set.

Handling shifting loop availability is also important in the computation of corridor reliability graphics, such as the location and timing of congestion on the corridor, or the

[2] Developing a System for Computing and Reporting MAP-21 and Other Freight Performance Measures, by Hallenbeck, M., E. McCormack, and S. Sankarakumaraswmy, WA.RD 844.1, 2015.

computation of corridor delay which requires both location specific speed and volume data. That is, the delay for an entire corridor is a key output of the performance metrics software system, and that value is computed by having volumes and speeds for all segments of a corridor. Performing this function requires that the software be able to determine which loops are valid, which are invalid, and be able to handle the invalid data, either by removing them, or interpolating the missing data. In the case of new loops replacing previously used loops, the software needs to be able to detect this condition, and select the correctly functioning loops for each daily computation.

For the I-405 Express Toll Lanes analysis, all of these metrics were important, and being able to differentiate performance before and after the switch from HOV lane to HOT lane performance was vital. In the older TRACFLOW system, the data analyst was able to manually add or remove loops from the data summaries. This was both a strength and a weakness of the system. It was a strength in that the analyst could obtain external knowledge of the loop system (i.e., call WSDOT's traffic management center to learn which new loops were functioning for any given time period) and apply the correct loops for the specific analyses.

However, this approach takes a highly knowledgeable system operator. It is also slow, in that it requires that operator to perform a large number of manual tasks before requesting data summaries.

Since the primary goals for the project included increasing the speed with which performance results could be produced, while increasing the ability of all WSDOT and MPO staff to use the system, this manual approach needed to be removed. The desire was to have DRIVE Net handle these data issues seamlessly. The alternative required both a much higher level of user knowledge and more staff resources being required to make manual adjustments.

Unfortunately, the initial version of DRIVE Net was not capable of handling these change management issues. The code used to produce the required summary statistics required considerable revision to identify and handle data associated with new and replacement loops. The need to retrofit these capabilities required significant effort which impacted the delivery schedule.

Task 4: Determine the System's Output Needs

In this task, documentation was written which described the basic user needs for the system. This document was written after the scope of work changes made in response to the shift in WSDOT emphasis towards migrating the TRACFLOW functions into DRIVE Net which could be used by a larger set of individuals and within a much faster response time.

Six major tasks were identified that needed to function in order for DRIVE Net to replace TRACFLOW. These tasks were:

- Retrieve individual loop, station and loop group performance summaries
- Retrieve summaries of speed, volume, and frequency of congestion for defined corridors
- Compute travel time and reliability statistics for trips with origins and destinations defined by users (within the urban freeway network)
- Compute lost-productivity statistics for individual locations
- Compute vehicle-hours of delay for both individual locations and corridors
- Be able to perform the above function for both general purpose and HOV/HOT lanes

This same functionality is desired for all roads in the state for which WSDOT reports performance.

For all of these reports, users need to be able to select start and end dates for the analysis, and to select specific days of the week for which data were to be provided. That is, "I need all Tuesdays – Thursdays for the months of January and February 2016, so that I can compare those results against them against the performance from the same time period in 2015.

These results are exactly what is needed to respond to the detailed analyses required by projects such as the I-405 Express Lanes implementation. The ability to observe results along the entire corridor, allow analysts to quickly identify specific problem areas, and then extract detailed data for just those locations. New trips (origin/destination points in the corridor) can then be defined which allow the computation of the travel time reliability measures needed to talk to the public.

Task 5: Refine Data Storage and Data Update Design

No changes were made to this task under the revised scope of work. Based on the completed architecture document, data storage requirements were defined. In the middle of the project, a major hardware failure occurred. This further pushed the project behind schedule.

New disk storage was purchased both to replace the failed hardware and to meet the storage needs identified as part of the finalized system architecture.

Task 6: Develop the System Interface

Task 6 focused on the development of the user interface needed to meet the needs identified in Task 4. The results of this task are shown in the following section.

Task 7: Test, Refine, and Construct the User Interface

Figure 3 shows the main page for DRIVE Net. The green tabs across the top of the page give access to the multiple capabilities of the system. The system currently provides access to all DRIVE Net functionality, even though many of these functions are still in the research phase. The two tabs which contain the interface work either built or refined under this project are the Travel Time Analysis tab and the WSDOT tab.

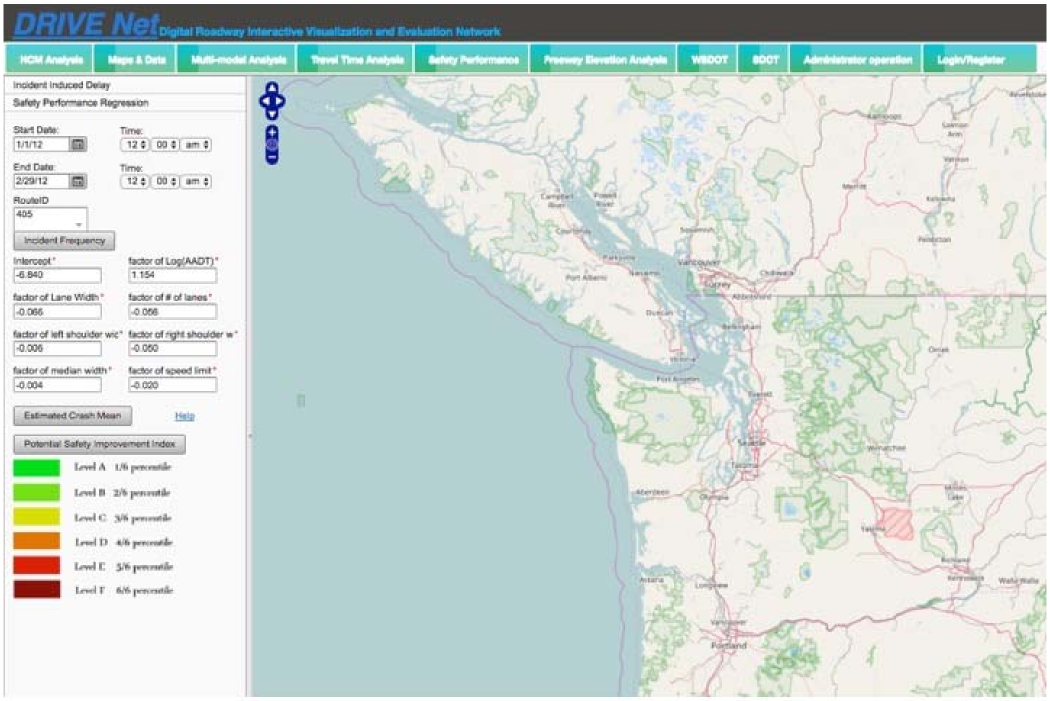

Figure 3: DRIVE Net Start Page

When selecting the WSDOT Tab, users are shown the interface options seen in Figure 4. Once a specific freeway corridor is selected, the system shows the cabinet locations where data are available. Users can then select specific minimum and maximum mileposts for which data are desired. This lets users access only the length of corridor needed for their specific analysis. Start date and end date are then selected along with the direction of travel and the lane type (HOV or GP). Finally, users select the type of output desired; speed, frequency of congestion, total volume, or all three of these options.

The Download Data button is then selected and Excel files are prepared and downloaded to the user's browser. The output produced consists of matrices that consist of the data present for each cabinet in that corridor. Summary data are provided by 5-minute interval.

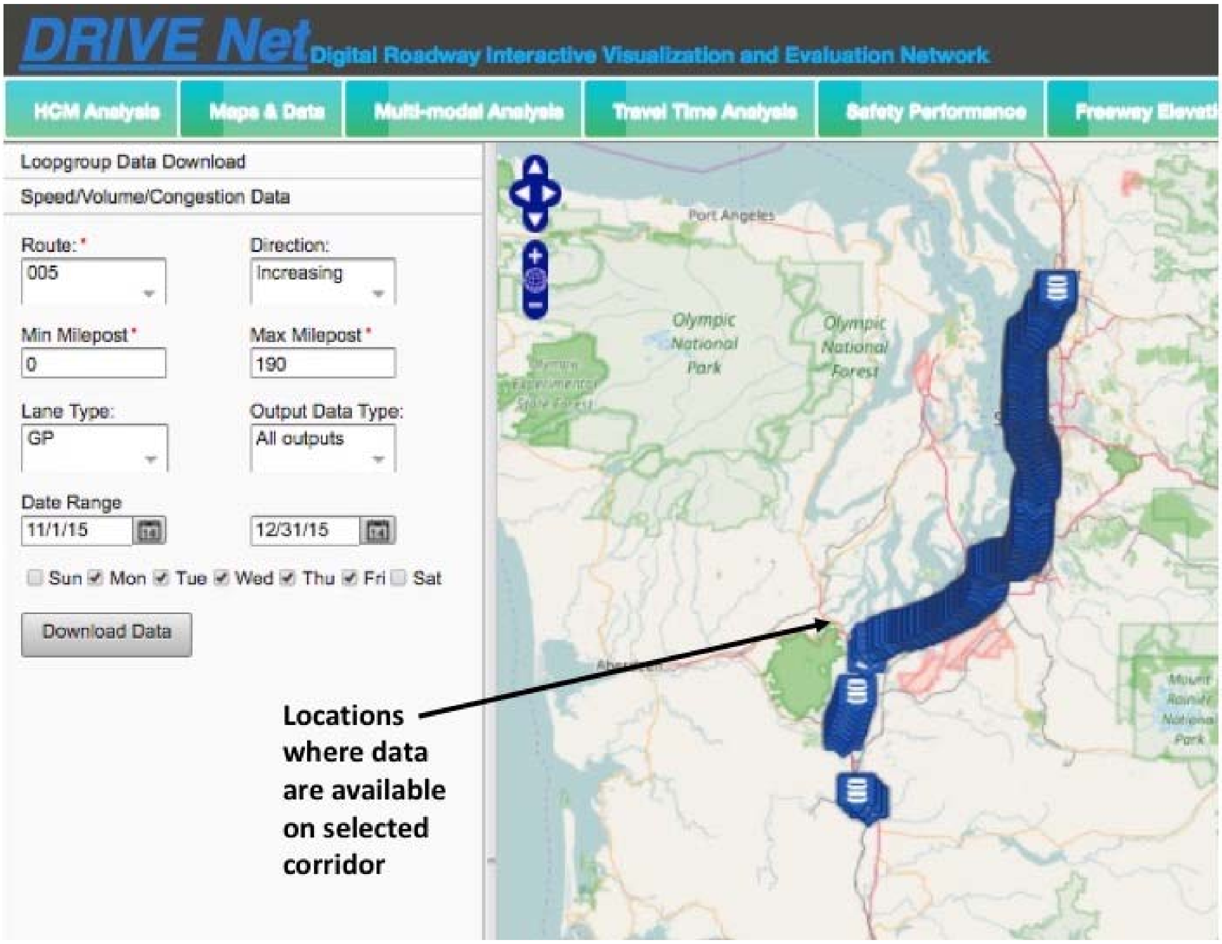

Figure 4: Corridor Data Selection Options

At the top of the menu shown in Figure 5, the option "Loopgroup Data Download" can be seen. If that option is selected, users have the ability to obtain data for either specific loops, specific sets of loops (loop groups) at a location (e.g., all mainline northbound loops), or all loops which make up a WSDOT station. The user interface for selecting data from specific loops is shown in Figure 4.

When the "Show Cabinets" button is selected on this interface page, all cabinets for which data are available are shown on the screen as blue boxes. When users select one of those boxes, a pop-up box appears (see "Loop Selection Box" in Figure 4) describing which loop location was selected. Under the Show Cabinets box on the left side of the screen, the individual loops at that location are then shown. Users then select from the list of loops or loopgroups, shown as highlighted in blue in Figure 5.

Once a loop or loopgroup and a date range of interest have been selected, clicking on the Check Data Quality button brings up the monthly data quality scores for this location. The data quality score varies from 0 to 1 and indicates the fraction of good data present at that location for the time period selected. Values close to 1 mean that the user should have confidence in the available data. Values below 0.7 should be used only with great caution.

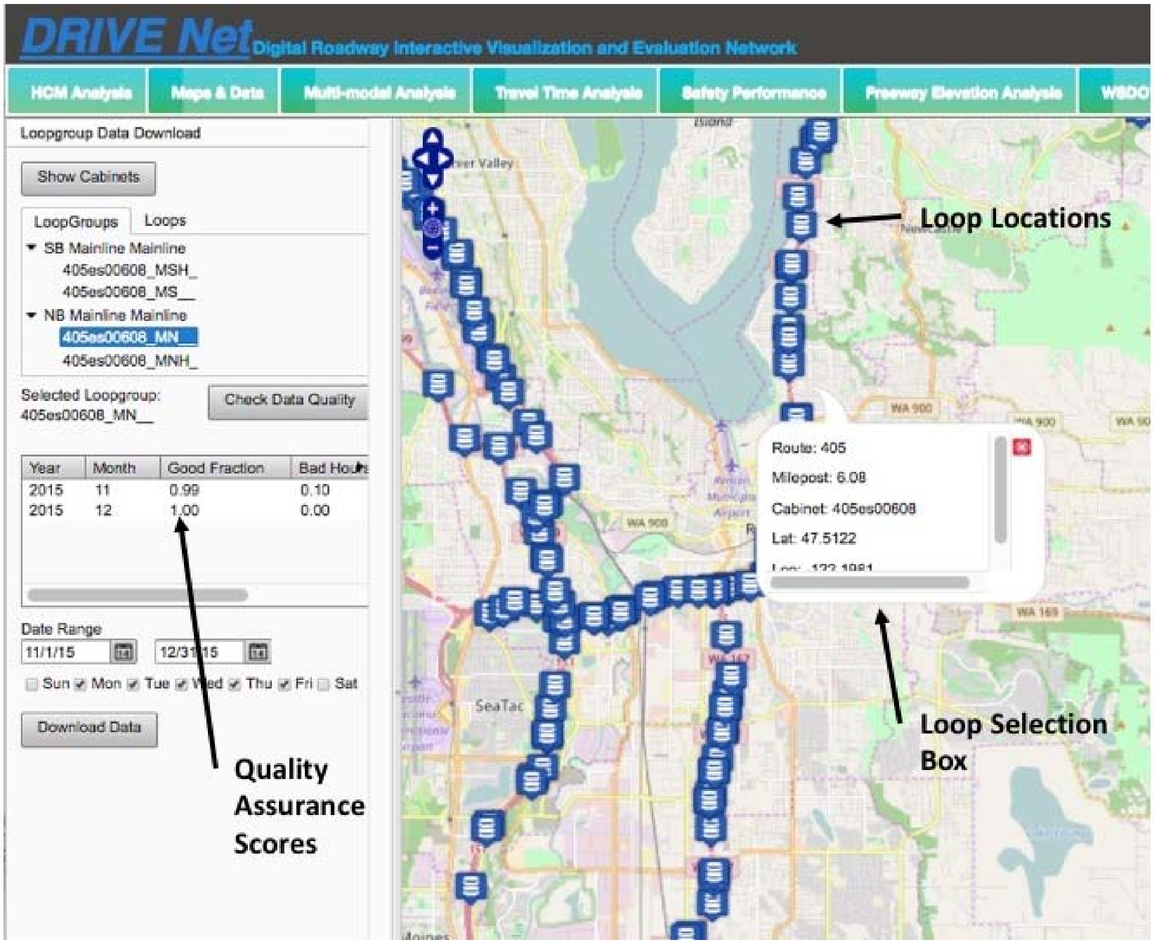

Figure 5: Individual Loop Data Selection Options

Selecting the Download Data button at the bottom of the menu results in data being downloaded to the user's browser. The data come as a zipped Excel file, with the data presented in 5-minute increments for all days requested.

The remaining functionality that was incorporated in this project was the revision of the travel time computations. This functionality is found under the main Travel Time Analysis tab. Figure 6 shows the user interface that appears when this tab is first selected. The default selection is for the pre-defined travel time corridors reported in the WSDOT Grey Notebook. Both general purpose lane corridors and HOV lane corridors are present.

Users have the option of selecting individual corridors or selecting all corridors. A number of data selections are available to them. The Travel Time Statistics button produces the output table used by the Grey Notebook. The Stamp Graphs button produces the lost productivity graphics reported in the Grey Notebook. Users can refine the stamp graphs by selecting different speeds as the threshold below which speed must drop before delay—and therefore productivity loss—occurs. The Output TTS button produces the travel time summary statistics (mean and percentile travel time statistics by 5-minute increment) in Excel file format that is the primary output of the TRACFLOW travel time software. The Output TTM button produces travel time statistics by 5-minute increment for each day in the selected year.

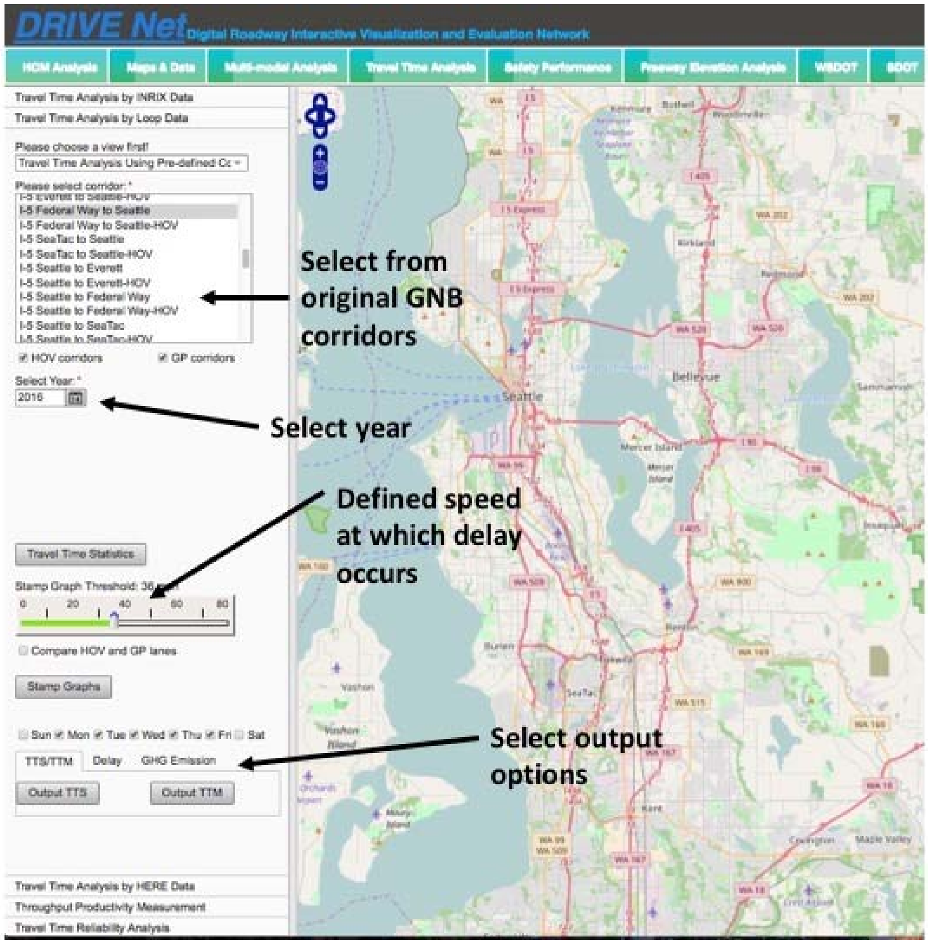

Figure 6: Pre-Defined Travel Time Corridor Options

In addition to the pre-defined trips, users can create their own trips for producing travel times. To access this function, users select the User Defined option near the top of the menu box. This results in a change to the menu, which is shown in Figure 7.

From this menu, users can simply enter the starting and ending point of their desired trip. When entering these values, users need to enter the route number as a three-digit value, so I-5 is entered as “005.” Users must also enter whether the trip starts and end in the increasing milepost direction (north- or eastbound) or the decreasing direction (south- or westbound.)

To make this interface work, users must select the “Confirm Selection” button after entering the start point, then enter the end point for the trip, and then select the “Confirm Selection” button for the end point.

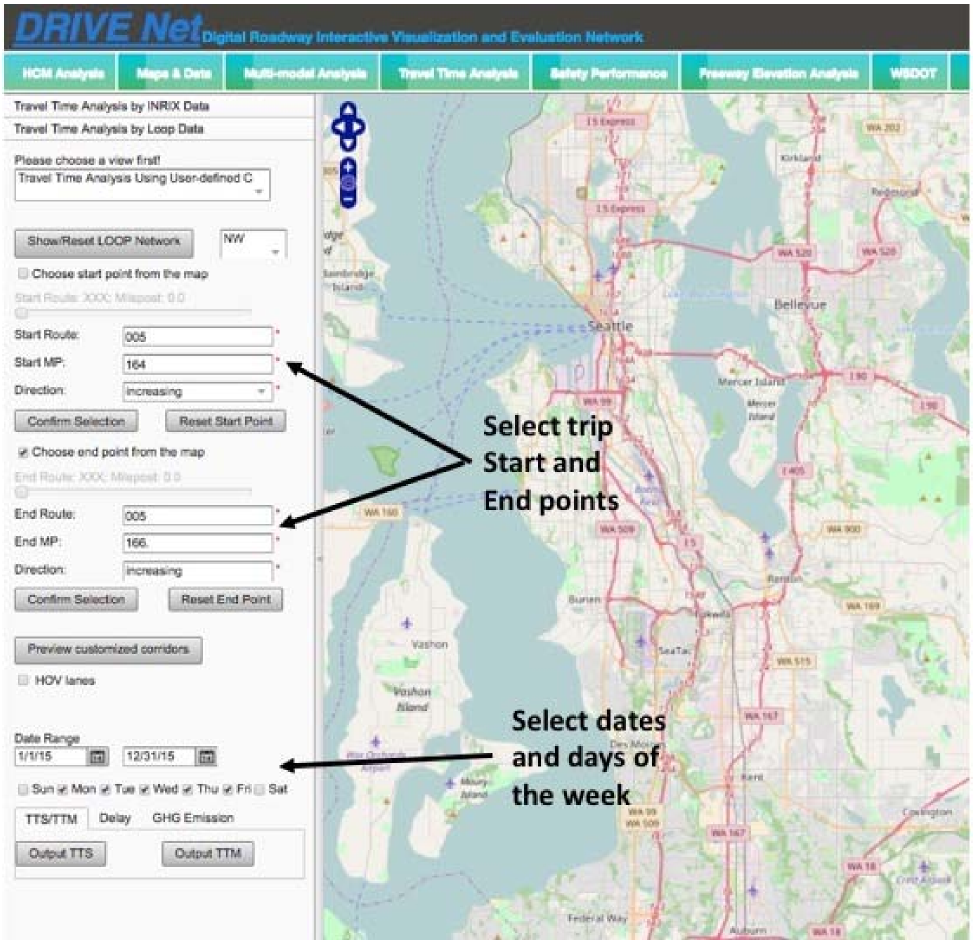

Figure 7: Ad Hoc Trip Travel Time Selection Options

If users are not sure of the route and milepost for their desired start and end points, they can also select the start and end points from the map. To use this functionality, they check the box "Choose start point from the map". Before doing this, they must first select the Show Reset Loop Network button. When users select a point on the map, the map indicates the road segment selected. (Note that the system uses predefined segments and thus does not start trips at the exact point that users may desire.) If users are satisfied by the selected road segment shown on the map on the screen, they click on the Confirm Selection button. If not, they click on the Reset Start Point button and repeat the map selection process, or they enter their desired point by typing in the route and milepost as described earlier.

Once both start and end points have been selected, users should select the "Preview Customized Corridor" button, which will cause the screen to display the trip for which travel times will be computed. This is important to ensure that the trip desired is actually the trip the system will be producing. The DRIVE Net ad hoc trip routing system is capable of routing trips along the entire WSDOT state route system. It can route trips from one roadway to another. For some trips, the routing algorithm can choose paths that are not the desired trips. It is also possible, especially when choosing the route from the map to inadvertently select an increasing roadway when a decreasing roadway is desired. When this later event happens, the selected trip will be shown exiting the freeway at the nearest interchange and reentering the roadway in the direction required to complete the trip as specified. Thus, the map display makes it obvious that the entered directions were not the desired direction. Users can then correct start/end point and direction selections before requesting data.

Once users are satisfied with their ad hoc trip definition, they can select the dates for which travel time statistics are desired, and the specific days of the week for which data are being requested. They then can choose either the summary outputs (the Output TTS button), or the daily travel time outputs (Output TTM) at the bottom of the menu.

Finally, in Figure 6 above, the options can be seen to obtain travel time data using either the data WSDOT purchased from INRIX or the NPMRDS data. These systems are functional but are considered research efforts, and only have limited amounts of data available to them.

Task 8: Load Data, Code and Test Database, Update Functionality

In the initial project review, it was determined that DRIVE Net had not been successfully uploading WSDOT's 20-second freeway data. When combined with the shift in priorities to bringing DRIVE Net on-line to replace TRACFLOW, the effort to load data into DRIVE Net was restricted to bringing the available freeway loop data into the system, completing the data quality tests, and then updating the functionality in the system needed to use these data.

As a consequence, the system did not attempt to resolve all of the issues associated with bringing WSDOT's crash and incident response databases into DRIVE Net so that those data would also be up to date. Neither did the project attempt to upload all of the NPMRDS data that have been provided by USDOT to WSDOT over the past two years. The project did develop plans for performing those tasks. These plans are discussed in Chapter 4.

Task 9: Code the Desired Multi-Parameter Reliability Reports

This task was removed from the project in order to concentrate the project's resources on helping ensure that DRIVE Net could take over as the primary tool for freeway performance reporting.

Task 10: Test and Refine the Reporting Tools

This task was used to test and refine the reporting capabilities described in Task 7. It resulted in multiple changes to the user interface in order to make the system easier to use.

Task 11: Develop Enhanced L07 Analytical Capabilities

This task was removed from the project due to a lack of time and resources due to the effort required to make DRIVE Net's freeway reporting system more sustainable for future operations.

Task 12: Test and Refine the L07 Tools

This task was removed from the project due to a lack of time and resources due to the effort required to make DRIVE Net's freeway reporting system more sustainable for future operations.

Task 13: Work with State and MPO Staff on Implementation

This task was removed from the project due to a lack of time and resources due to the delays in making DRIVE Net's functionality stable. The project ended before extensive training could be undertaken.

Task 14: Develop Training Materials

This task was removed from the project due to a lack of time and resources due to the delays in making DRIVE Net's functionality stable. The project ended before extensive training could be undertaken.

Task 15: Provide Training to WSDOT and MPO Staff

This task was removed from the project due to a lack of time and resources due to the delays in making DRIVE Net's functionality stable. The project ended before extensive training could be undertaken.

Task 16: Evaluate the Effectiveness of the Software Tools and Their Implementation

The software was not fully implemented by the end of this project. The software has considerable potential, but to date it has not been able to deliver that potential as part of WSDOT's routine business processes.

CHAPTER 4
CURRENT STATUS OF DRIVE NET

This Chapter summarizes the current operational status of the DRIVE Net software system.

SUMMARY

The DRIVE Net system consists of a number of disparate modules. Each of those modules provides useful functionality about a specific topic. However, with the exception of the urban freeway system and the transit route display, the use of each of those systems is restricted to a fixed research data set. Within those specified data sets, the analytical functions contained with DRIVE Net typically work well, although some functions fail periodically due to various server issues and need to be restarted by Star Lab staff.

The urban freeway performance reporting software is capable of receiving ongoing data. However, there remain several manual tasks which must be performed by Star Lab staff, and when these staff are otherwise occupied, these tasks do not take place. Consequently, at this point in time, the system can report performance statistics through December 31, 2016. Data for 2017 are available, but have yet to be run through the quality assurance system and uploaded into the primary database to allow access to those data. This operation currently requires manual intervention.

Given the data available on the DRIVE Net servers, the software currently produces all of the statistics produced by the TRACFLOW system. In addition to a lack of 2017 data, the major limitation in the ability of DRIVE Net to replace TRACFLOW for WSDOT reporting is that the list of pre-defined travel time corridors has not been updated in DRIVE Net to include the full list of travel time corridors reported in the Corridor Capacity Report and that are computed and reported on WSDOT's Travel Time web page (http://www.wsdot.com/traffic/traveltimes/default.aspx?region=seattle&direction=all)

The primary limitation in the system is the lack of dedicated staff required to maintain the software, run periodic data uploads and troubleshoot issues as they occur. Resources are lacking to hire and support the required dedicated staff.

Data and functionality available in the system are described below.

URBAN FREEWAY LOOP DATA

Urban freeway loop data are available for the NW and Olympic Regions from 2012 through 2016. (Note that data availability varies from location to location.) Data are available from SW Region from August 2016 through December 2016. No data have yet been loaded into DRIVE Net from Eastern Region. A series of loop data quality control algorithms is performed in the backend on all loop data that have been loaded into DRIVE Net. The quality control algorithms check for: 1) time segmentation error, 2) cross talk, 3) loop stuck on or off conditions,

4) communications error, 5) sensitivity and detector health issues, and 6) other missing data mechanisms.[3]

These processed data are available for use producing the performance measures reported under the Task 4 sub-heading in Chapter 3.

Additionally, a HCM 2010 Level of Service (LOS) module and mobile sensing data analysis module are incorporated into DRIVE Net for freeway performance measures and pedestrian trajectory reconstruction respectively. This functionality uses a different version of the freeway performance data set.

SUPPORTING DATA FOR THE URBAN FREEWAY LOOP DATA

The initial project design anticipated bringing additional data into the DRIVE Net system. Considerable work was performed to determine how to perform those updates. This section of Chapter 4 briefly discusses these data sets which allow for more informative roadway performance reporting.

WSDOT GIS Data – Currently One Year (2012) of Roadway Geometry Data

One of the major improvements to DRIVE Net code was to revise the ad hoc travel time routing algorithm to work with multiple GIS files. Multiple files are needed to track changes in roadway geometry over time. That is, if a re-alignment is performed (e.g., a new interchange is built on a freeway) the routing performed for years prior to that realignment needs to be different than the routing after that realignment.

Changes were made in the DRIVE Net routing algorithm so that it could determine the year for which data were required for each travel time request, and then access the correct GIS file in order to use that file to perform the required routing. To support this function, it was agreed with WSDOT staff that a single GIS file would be used for each year. That file would contain the "end of year" roadway configuration for each state route. That information would then be conflated to the routable network used for travel time routing.

While the code to perform this routing has been constructed, tested, and shown to work, the conflation process requires work as WSDOT's standard GIS files are not routable. (WSDOT does have a routable network, but it is not directly associated with their linear referencing system.) Thus, the routable networks must be conflated to the WSDOT GIS files. This work was not performed for this project with the exception of the initial network. However, the DRIVE Net code is now capable of routing over networks that change over time.

WITS Data 2002 – 2013

A copy of the Washington Incident Tracking System (WITS) data for 2002 to 2013 is currently stored on the DRIVE Net servers. These data are accessed by the Safety Performance Regression and Incident Induced Delay computations found under the Safety Performance tab on the DRIVE Net home page.

As part of this project, discussions were held with WSDOT staff about uploading new WITS data to DRIVE Net. It was determined that the WSDOT ROADS database, which includes some data from the Washington State Patrol's computer aided dispatch system is the

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[3] See WSDOT Research Report, WA.RD 854.1, DRIVE Net Phase II: Online Moving Washington Platform for Network-wide System Operations, Monitoring, and Analysis, by Wang, Yinhai, et. al., December 2016 for additional information on the quality assurance process.

better source of information. These data can be obtained as an SQL file from WSDOT's Transportation Data, GIS and Modeling Office.

Obtaining these data was not formally attempted as part of this project, as it required a change to the underlying incident database currently stored in DRIVE Net, and this task was not prioritized high enough to be funded.

Freeway Elevation Data for Interstates

DRIVE Net has a copy of a roadway elevation data set that was developed for USDOT. The data set provides elevation data for all Interstates in the nation. An application allows the extraction of that data for any interstate, given a starting and ending milepost.

OTHER RESEARCH DATA SETS

A strength of DRIVE Net is that it has the ability to store, link, and analyze a variety of data sets. This section describes the data currently stored in DRIVE Net. Updated versions of these data could be added to the database if the resources to perform those updated were available. The other data currently stored and accessible to the public in DRIVE Net includes the following:

- Park and ride data from 2013, including the name, size, and geographic location of all park and rides in the state
- Transit routes serving King County, regardless of which public transit agency provides those services, are extracted from the OneBusAway API and published on a map within DRIVE Net.
- Bike and pedestrian counts. Data from counters located on ten trails are present from early in 2015 to early in 2016. The exact start and end dates differ from counter to counter, but no data are present after January 2016.
- Car2Go vehicle locations for all vehicles that are available for use is plotted from the national Car2Go API. Car2Go data are available for Seattle, Portland, and 12 other cities.
- Pedestrian path movement data are available from a research project which explored the ability to use mobile WiFi sniffing devices to determine pedestrian paths through the UW campus. Two data sets exist, one from March 4, 2013 and one from April 20, 2010.
- Some data from the City of Seattle is stored on DRIVE Net. Data include WiFi sniffer data as a subset of SDOT controlled intersection, travel times based on earlier license plate recognition cameras and software. The application which describes these data was functioning at the time this report was written, so the geographic and temporal extent of these data sets is unknown.

COMPARISON OF DRIVE NET AND TRACFLOW RESULTS

A wide variety of direct comparison were made between DRIVE Net outputs and TRACFLOW outputs. In most cases, these results mirrored each other, but showed minor differences. Specific attention was paid to the travel time computations since the travel time computations are a major part of the Congestion Capacity Report.

Figure 8 illustrates typical outcomes from the comparison of DRIVE Net and TRACFLOW travel time computations. The results are similar in shape and height. The first three corridors shown in Figure 8 show that the two systems produce reasonably similar travel time results. The last one, which is from the I-405 and I-90 GNB trip from Issaquah to Bellevue shows that there is a noticeable difference between the two results. An in-depth investigation of this result showed that the reason was not a calculation problem, but the defined starting and ending points of the trip from Issaquah to downtown Bellevue are different between DRIVE Net and TRACFLOW.

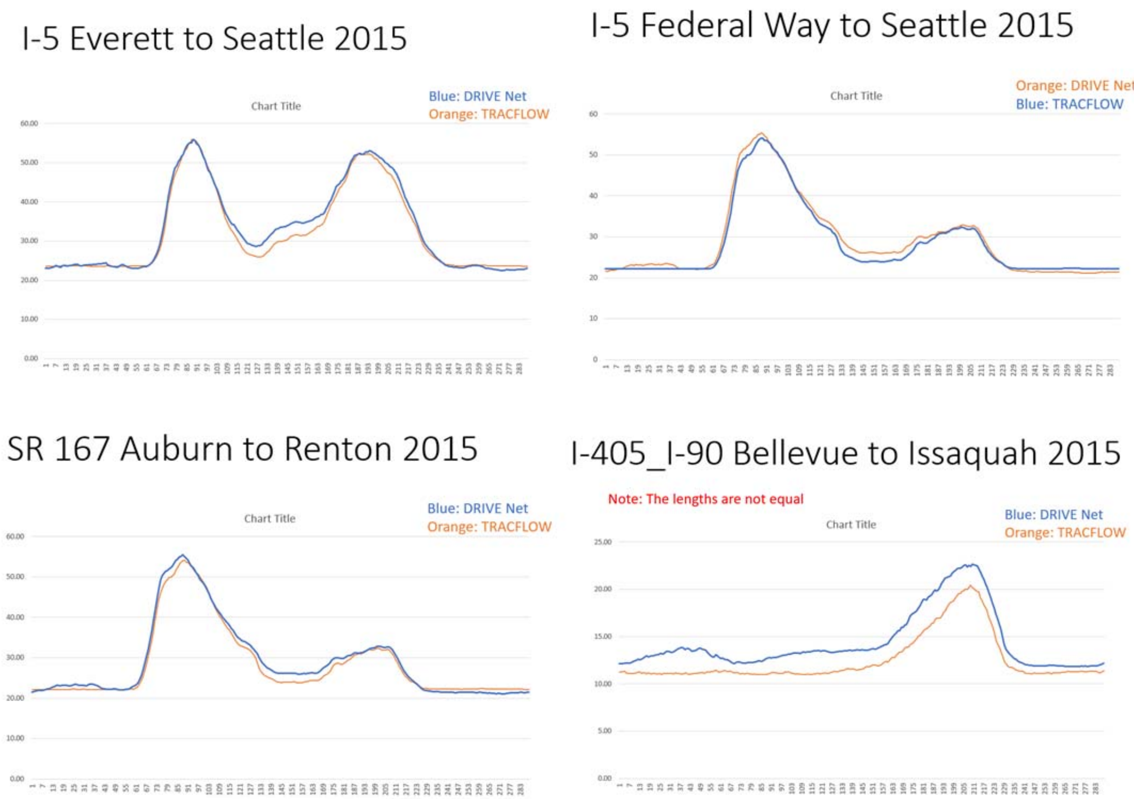

Figure 8: Comparison of DRIVE Net and TRACFLOW Travel Times

A number of factors contribute to the differences in DRIVE Net and TRACFLOW outputs. In the fourth case above, the definition of the DRIVE Net trip is longer than the trip as defined by TRACFLOW. In part, this is because the GIS file DRIVE Net uses to identify the location of loops has placed several loops in the wrong physical location. As can be seen in Figure 9, DRIVE Net has located detectors at mile posts 10.9 and 8.38 are within the I-90/I-405 interchange, and included both of them in the Issaquah to Bellevue trip. TRACFLOW's trip exits I-90 onto the ramp to I-405 at milepost 10.9 (see Figure 10.) The result is that the virtual distance vehicles travel when performing the TRACFLOW trip is shorter than the virtual distance being traveled by the DRIVE Net trips for this particular Grey Notebook trip.

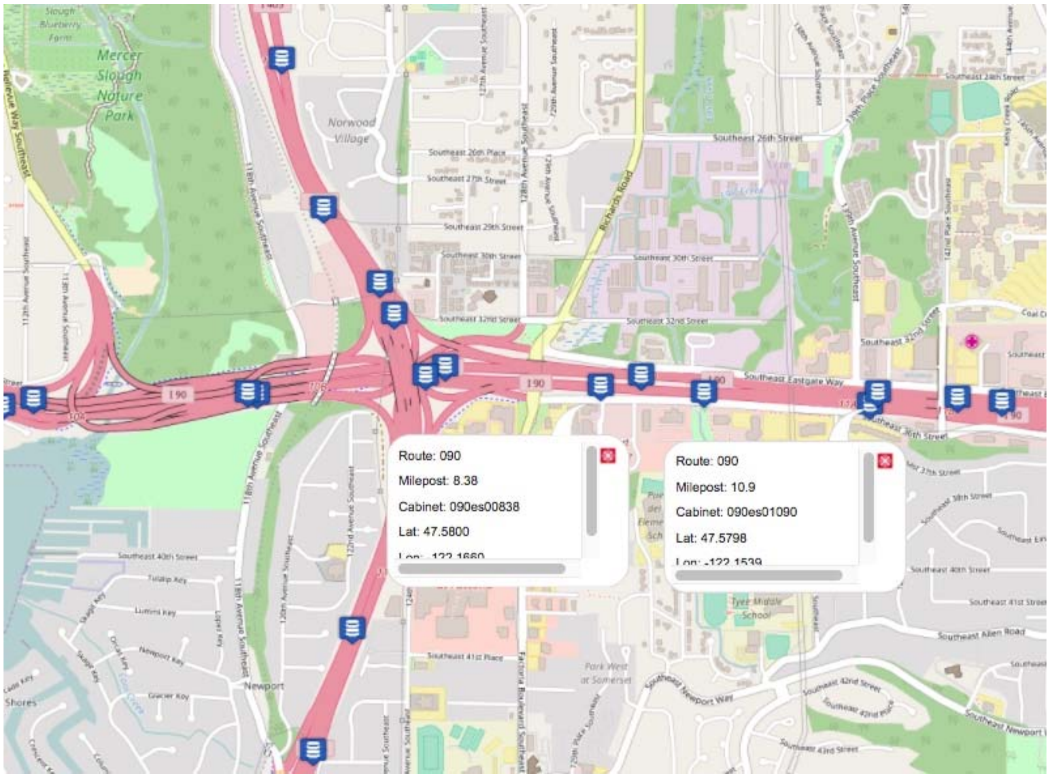

Figure 9: Loop Locations on I-90 on DRIVE Net

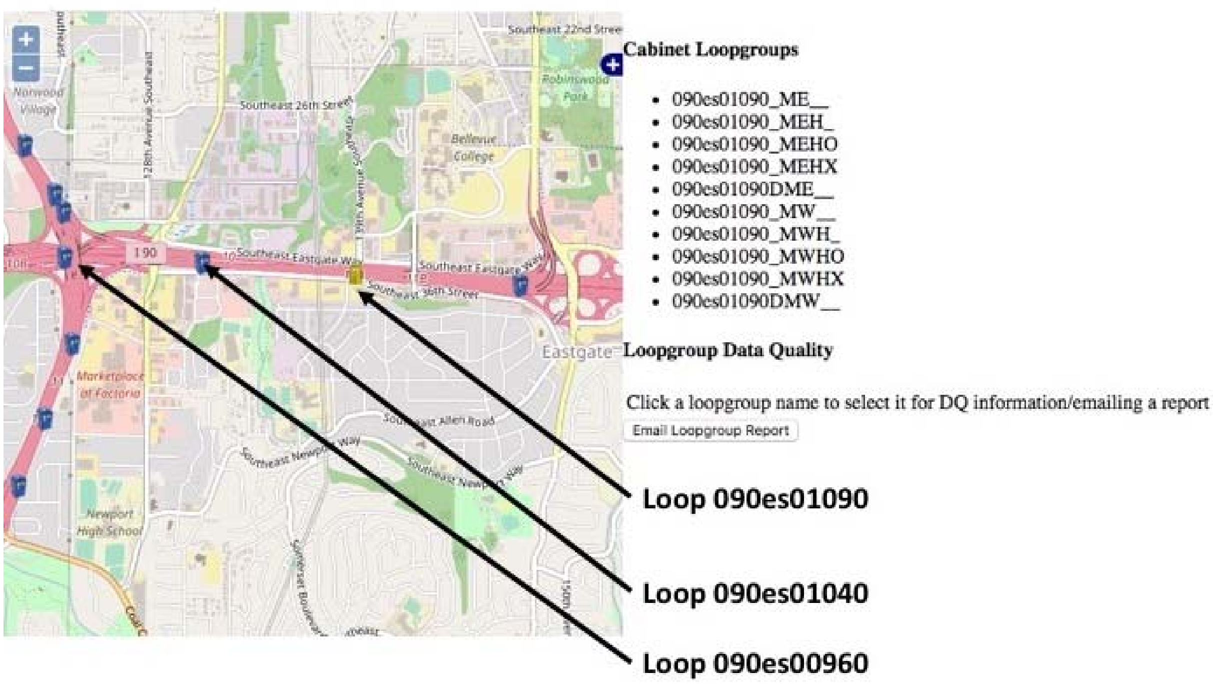

Figure 10: TRACFLOW Loop Locations on I-90

When DRIVE Net and TRACFLOW do use the exact same set of loops in a travel time computation, the DRIVE Net trips tend to be slightly faster. This is because TRACFLOW caps vehicle speeds at the speed limit. DRIVE Net does not cap speeds, other than as part of the quality assurance testing, which removes extreme speeds. The result is that during uncongested time periods, DRIVE Net produces and uses roadway speeds that exceed the speed limit. This means that travel times are shorter than TRACFLOW travel times for the same distance. Even when both systems compute the same speed during congestion, DRIVE Net tends to produce faster travel times, because vehicles exceed the speed limit after they clear congestion and "make up" some of the time they lost in congestion.

In this case, the assumptions built into DRIVE Net more accurately report actual travel behavior. TRACFLOW speeds are capped at the speed limit because a decision was made in the late 1990's to not report travel times faster than the speed limit. Thus "free flow speed" at night is being reported by TRACFLOW as signaling that a traveler can "drive the speed limit or faster if they want." In contrast, DRIVE Net reports the average speed being driven on the facility.

As a result of these differences in how data are handled, DRIVE Net will produce slightly different travel time estimates than are currently being reported by WSDOT, even if the two systems are given exactly the same data.

In other comparisons done between the two systems, the location specific volume and speed estimates produced by the two systems are typically very similar. Differences at specific locations are generally only observed in those cases where

1) DRIVE Net's faster speeds are not capped
2) the DRIVE Net loop sensitivity adjustments produce slightly different speed calculations than the unadjusted values used by TRACFLOW, or
2) one of the two systems identifies volume data as being invalid, but the other accepts those data as being valid. Because the two systems use different quality assurance tests the outcomes of these tests are occasionally different.

The last major difference is in the corridor summaries of volume, speed, and frequency of congestion. The TRACFLOW system interpolates between loop locations in order to produce an estimate (volume, speed, or frequency of congestion) every half mile. DRIVE Net does no interpolation. Instead it produces estimate at the mileposts where loops are located.

The DRIVE Net version of this important corridor performance matrix (time of day by location) is easier to use to track loop performance and the exact location of congestion.

In summary, the two systems produce slightly different performance reports for the same requested outputs. When using the same input data, the two systems produce comparable outputs where DRIVE Net's travel times are typically slightly faster than those reported by TRACFLOW. However, for travel times, there are often a variety of minor differences in which loops are selected for use in the travel time computations. This can result in slightly different length trips being computed by the two systems, and those different trip lengths can result in more substantial difference in the reported travel time reliability outputs.

CHAPTER 5
REVIEW OF SHRP2 L05 DOCUMENTATION

This section performs a brief review of the SHRP2 L05 documentation. SHRP2 L05 is the document "Guide to Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes." While not directly associated with the development of DRIVE Net, the intended use of DRIVE Net is to help meet the needs identified in the SHRP2 L05 report. Thus, the following comments are made about that report as proposed in the initial proposal for this project.

In summary, the findings of this project do not highlight any major changes to the material found in the L05 report. At most, the authors of this report might add some additional emphasis to points that are already made in the current L05 documentation. These points are given below.

ADDED EMPHASIS ON SETTING RELIABILITY TARGETS

The WSDOT has already heavily incorporated reliability into their planning process. The initial driving force behind this project was the desire to improve the availability of roadway reliability measures statewide. However, it needs to be clear that the planning process must consider many topics. Thus, while the setting of performance targets for roadway reliability is good in that they can identify deficiencies consistently across the state, those deficiencies are just one of many factors which are considered in the planning process.

TRAVEL TIME RELIABILITY STATISTICS ARE NOT RELIABLE IF THEY CAPTURE THE TRAVEL EXPERIENCES OF THE PUBLIC

One of the major events which caused changes in the work plan for this project was the public reaction to WSDOT's performance reporting for the new I-405 Express Toll Lanes project. WSDOT reported perfectly accurate results in terms of the reliability measures it published. However, those reported measures did not capture the travel experiences of significant segments of the traveling public. The travel times and travel time reliability measures reported by WSDOT captured only the impacts of the new HOT lanes on trips traveling the length of the corridor. Shorter trips occurring within the corridor experienced very different changes in congestion and travel reliability. This difference in what was reported versus what was experienced by many travelers resulted in a loss of public confidence in the statistics being reported by WSDOT, and a commensurate loss in confidence that WSDOT was being truthful about their intentions and decision making.

This was not the fault of their mathematics. It was the fault of the segmentation chosen for reporting. This topic is covered in Chapter 2 of the L05 report (page 24), but the project team believes that more emphasis needs to be placed on this topic.

When reporting travel time reliability, it is important that the measures being reported describe the experiences of the public. This means understanding when sub-segments of a given corridor experience different operating conditions and discussing those differences as part of the reliability reporting. It also means that "routine reporting" of travel time reliability measures must sometimes be supplemented by "secondary measures" when those measures are necessary to describe changing conditions in the corridor.

It is easy to always report the same measures. This is good for trend reporting. Unfortunately, the key trends occurring on the road may not be captured by these routinely reported statistics. Agencies need to be aware of these types of outcomes, and be prepared to "change the report" in order to more effectively discuss the conditions the public is experiencing.

NEW DATA SOURCES PRODUCE DIFFERENT NUMBERS

While dealing with the "public credibility issue" the I-405 reporting thrust into the spotlight, WSDOT also became sensitive to having to change previously published numbers. For example, having previously published a delay estimate for a corridor for a given year based on "best available data" the agency was reluctant to report a different number at a later date, even when new data, or improved computational methods now produce a more accurate historical delay value.

Yet, the reality of the ever changing availability of transportation data, and the resulting changes in the techniques used to produce performance reports means that these "restatements" of historical performance are necessary.

The Texas Transportation Institute (TTI) has been producing its mobility report for more than two decades now. Every time new data become available (most recently TTI added vehicle probe data to their process), or a new analytical technique is used in order to improve the accuracy of their delay estimates, TTI must re-state their historic estimates. These appear as footnotes in their reported tables

Agencies need to be able to embrace the fact that the vast majority of travel time reliability measures are inexact, even when they are computed from large amounts of data. Agencies need to acknowledge up-front that all such estimates are "best available estimates", not absolute values. Consequently, agencies need to have a plan for re-stating these values when better data or techniques allow improved reporting.

At the same time, agencies need to continue to report performance, even when they know their data are imperfect. As the old saying goes, "don't let the perfect be the enemy of the good." Emphasizing this point would be a good addition to the L05 report.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The DRIVE Net online data analytics system shows significant promise, but at this time, it is still not a stable business enterprise system. Significant improvements in the sustainability of the underlying software was achieved as part of this project. Major improvements were completed with respect to the software's ability to automatically:

- account for the changing availability of loop data (when loops work, when and where loops exist) over time
- incorporate changing roadway networks in the routing algorithm, as route alignments change over time
- account for the mixed availability of loop data during the computation of annual statistics (i.e., an old loop works from Jan 1 to Sept 15, and then is replaced by a nearby loop for the period Sept 16 to Dec 31)
- handle changes in roadway alignment.

Other improvements to the DRIVE Net system include:

- more data storage and better disaster recovery capabilities are built into the data storage system
- an improvement in the suite of freeway performance metrics available for use within the freeway performance reporting sections of the database.

Finally, this project resolved major system architecture decisions necessary for further expansion of the DRIVE Net system. These include:

- the concept of storing a single "end of year" version of the WSDOT GIS Roadway file for use in tracking and accommodating changing roadway geometric features and linear referencing attributes for Washington state routes. The annual "end of year" GIS file should be available by the end of March.
- determined that in order to store crash data over time, the crash data need to have their primary location be associated with X/Y coordinates, so that these coordinates can be retroactively associated with the WSDOT linear referencing system prior to their aggregation during analysis. (This is necessary to ensure that historical crashes are associated with the correct points in space when changes in roadway alignment cause the linear referencing system to change the milepost assigned to a specific X/Y point given changes in roadway geometry upstream of that point.
- determined that having access to WSDOT's GIS workbench
- The MILETRAF file is the best source of annual average daily traffic volume for state routes for which traffic management data are not available.
- If 24-hour time of day curves are required, the "best estimate" available from the Transportation Data and GIS Management Office is found in the Highway Segment Analysis Program.

- The best source of incident data is now from ROADS database.

Despite these improvements, the DRIVE Net system is still not ready to serve as the business enterprise system of WSDOT. The biggest hurdle is the lack of a designated staff position, where the primary duties of that individual are to;

- operate and maintain the DRIVE Net code,
- routinely upload data,
- determine when data have not successfully uploaded and resolve the issues preventing the data upload,
- respond to disk failures and other operational concerns,
- respond to requests from WSDOT for new "defined" travel time routes by building those trips and adding them to "pick lists" in the DRIVE Net menu system.

The addition of permanent staff, who can develop and apply institutional knowledge of the system will greatly improve the responsiveness of the system, and provide a focal point from which decisions can be made about continuing improvements to the system. That is, someone intimately familiar with the system would be able to provide considerable insight into how significant specific improvements would be, and thus help immeasurably in prioritizing those improvements.

Historically, much of the DRIVE Net development has been performed by graduate students. These individuals generally are very bright, and bring considerable enthusiasm to DRIVE Net improvements. But their tenure at the university is generally short, and their primary task as a graduate student is research, not system operations. The result is that the people operating DRIVE Net tend to have relatively little institutional knowledge about the system. This slows down response times for fixing problems, and makes it more likely that tasks will be forgotten as system operation transfers from one student to another over time.

RECOMMENDATIONS

At the time this report was written, DRIVE Net still has a distance to go to serve as WSDOT's business enterprise system for production of roadway performance measures. DRIVE Net has considerable promise for becoming that system, but it is not currently in that state. Currently it is an excellent research platform, but the operation of the system is not stable enough for routine use by WSDOT and MPO staff.

The most important step necessary to achieve business operational status would be to hire at least one permanent, full time, developer and system manager that reported routinely to WSDOT, and was able to prioritize system improvements that delivered key WSDOT products. That individual would be responsible for the day-to-day tasks that currently can fall through the cracks, and that can eventually result in unstable operation of lack of data. Graduate students working on research projects could serve as back-up to this individual, but a full time, dedicated position is needed to ensure that response time to issues which are of importance to WSDOT are handled as quickly as possible.

This individual would also be tasked with adding minor improvements to the system, such as creating the additional trips reported in the Corridor Capacity Report and then adding those trips to the "pick list" on the user interface. They would also be tasked with checking the outcome of those new reporting capabilities to ensure that the data quality for locations not checked under this contract were meeting WSDOT's expectations.

The functionality of meeting all routine, current reporting – not just the historical Grey Notebook reporting currently available – is necessary before DRIVE Net can be used as a replacement for TRACFLOW.

Currently DRIVE Net does not have a user function that allows users to add and store a trip definition to the user interface. This task must be performed by the system administrator and/or a system programmer. This same problem exists within TRACFLOW, but because TRACFLOW has been the source of much of this reporting by WSDOT, these trips have been added over time. DRIVE Net has yet to have these trips added. The specific trips that need to be added include:

- HOV+REV (reversible lane) trips for I-5 (i.e., those HOV trips which use the reversible lanes when they are open in a given direction)
- the revised I-90 HOV trips using the new full time HOV lanes (the center lane is now closed)
- Olympic Region general purpose trips on I-5
- HOV standard performance reporting using the 45 mph HOV lane performance standard, as opposed to the 35 mph "bad trip" standard used for GP lanes

While these additions were proposed as part of this project, resource limitations prevented those tasks from being accomplished.

Once these added trips are available, tested, and functioning, the full time system developer/operator could then move on to other improvements desired by WSDOT. Being full time, with only DRIVE Net to focus on, would also ensure that WSDOT staff had a single point of contact for problems they encountered. This would then highlight for the developer the relative importance of different future improvements.

APPENDIX A
DRIVE NET ARCHITECTURE

A complete report on the architecture of DRIVE Net can be found in a separate volume, *TRACFLOW Migration: Architecture and Implementation*, WA-RD 873.2. It is considered a working document and is subject to modification as changes to DRIVE Net continue to be performed over time.

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