HERS-ST In-House Reports

Table of Contents

Oregon Department of Transportation

Reliability Performance Analyses Using HERS-ST Phase II – Delay

January 2016

Prepared by:
Oregon Department of Transportation
Planning Section
Transportation Planning Analysis Unit

Transportation Planning Analysis Unit
Transportation Development Division, Salem, Oregon

For more information about the *Reliability Performance Analyses Using HERS-ST: Phase II - Delay*, contact:

Richard Arnold P.E., Senior Transportation Analyst
Transportation Planning Analysis Unit
Oregon Department of Transportation
555 13th Street N.E., Suite 2
Salem, Oregon 97301-4178
richard.arnold@odot.state.or.us

Acknowledgements

Special thanks go to Richard Margiotta, Ph.D., for providing constructive comments and suggestions.

 This project was funded in part by the Federal Highway Administration, U.S. Department of Transportation.

Table of Contents

List of Figures

List of Tables

List of Acronyms

AADT	Annual Average Daily Traffic
AES	Average effective speed
APLVM	Aggregate Probabilistic Limiting Velocity Model
BI	Buffer Index
CMS	Congestion Management System
DOW	Day of the Week
FFS	Free-flow speed
FHWA	Federal Highway Administration
HCM2000	2000 Highway Capacity Manual
HCM2010	2010 Highway Capacity Manual
HERS-ST	State version of the Highway Economic Requirements System
HPMS	Highway Performance Monitoring System
MAP-21	Moving Ahead for Progress in the 21st Century
MOY	Month of the Year
MPH	Miles per hour
ODOT	Oregon Department of Transportation
PBPP	Performance-Based Planning and Programming
PTI	Planning Time Index, also known as TTI_{95}
SHRP 2	Strategic Highway Research Program
TOD	Time of the Day
TPAU	Transportation Planning Analysis Unit
TTI	Travel Time Index, also known as TTI_{50}
TTI_m	Overall Mean Travel Time Index
TTI_{50}	50th Percentile of TTI
TTI_{80}	80th Percentile of TTI
TTI_{95}	95th Percentile of TTI, also known as PTI
VCR	Volume-to-capacity ratio
VMT	Vehicle miles traveled
VPH	Vehicles per hour
VPHPL	Vehicles per hour per lane

THIS PAGE LEFT INTENTIONALLY BLANK

Executive Summary

The state version of the Highway Economic Requirements System (HERS-ST) is a complex modeling tool that has been successfully used by state agencies to analyze highway deficiencies for programming and planning purposes. Though most of the focus on the HERS-ST model revolves around the selected improvements, the associated funding elements, and the benefit-cost analysis, many of the internal calculations within the model can also be useful for analysis. This report looks at a reasonable approach for using the internal delay calculations within a roadway system reliability analysis.

HERS-ST evaluates three types of delay: zero-volume delay, incident delay and congestion delay, where:

- Zero-volume delay is the delay associated with traffic control devices.
- Incident delay is the delay associated with crashes.
- Other congestion (or recurring) delay is the average delay due to non-incident congestion.

The FHWA has identified several primary causes or events that account for most delay on a roadway system:

- Inadequate base capacity (40%)
- Incidents (25%)
- Weather (15%
- Work zones (10%)
- Special events (5%)
- Traffic control devices (5%)

HERS-ST can provide reasonable analysis for inadequate base capacity (40%), incidents (25%), and traffic control devices (5%), which make up 70% of the causes of delay on most roadway systems. The effects of weather, work zones, and special events can be evaluated by adjusting the capacity and/or demand input data. The probabilities and impacts from the various delay events can be modeled through an automated batching process that can run numerous scenarios associated with the likelihood that different combinations of delay events occur.

HERS-ST does not directly calculate performance measures associated with reliability analysis, such as Travel Time Index (TTI) and Planning Time Index (PTI), however the delay elements from HERS-ST outputs can be used in post-processing analysis to develop TTI and PTI values.

THIS PAGE LEFT INTENTIONALLY BLANK

Introduction

HERS-ST

The state version of the Highway Economic Requirements System (HERS-ST)[1] is a highly sophisticated highway deficiency analysis tool developed by the Federal Highway Administration (FHWA) that allows states to identify long-term investment needs and performance, and to evaluate the impacts of alternative highway investment levels on the state highway system.

The national version of HERS has been used by the FHWA since the early 1990s to provide estimates of investment requirements for the nation's highway system in the biennial Condition and Performance (C&P) Report to the United States Congress.

The HERS-ST model is an enhanced version of the HERS-National. The logical structure of the two versions is identical, as are most of the input requirements; both models utilize the highway section dataset in the Highway Performance Monitoring System (HPMS) format. The user-friendly Graphical User Interface (GUI) and certain input/output features are the primary differences that distinguish HERS-ST from HERS-National.

A simply summary of the HERS-ST modeling process is as follows:

- Identifies highway condition and performance levels.
- Identifies deficiencies through the use of engineering principles.
- Identifies a set of alternative improvements to correct deficiency.
- Determines a benefit-to-cost ratio for each potential improvement.
- Selects and implements the most economically attractive improvement for each deficiency based on available funding and the resulting improved performance condition.

The HERS-ST model consists of six complex sub-models:

- Fleet Composition Model
- Widening Feasibility Model
- Capacity Model
- Pavement Deterioration Model
- Speed Model
- Travel Forecast Model

The model only identified deficiencies based on capacity and pavement issues. The overall analysis process predicts a wealth of information on a number of performance characteristics and indicators, such as speed, delay and high level safety criteria that are essential for estimating long-range performance and conditions on the roadway system.

[1] http://www.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.cfm

This report is the second part of a four part analysis where different performance indicators are evaluated. Part One evaluated the outputted base year speed characteristics from the model, as compared with observed data. The report also discussed the potential application of the outputted future year speed characteristic as indicators to inform on future system performance for given scenario conditions.

Part Two evaluates the various delay characteristics, as they relate to both base and future analysis years. The discussion continues further to evaluate ways to incorporate the HERS-ST delay predictions into reliability calculations.

Part Three will look at the analysis associated with safety elements within HERS-ST. The latest version of HERS-ST allows for greater flexibility in calibrating the crash rates to local conditions.

Part Four evaluates future performance on the system associated (with or without) proposed improvement projects. This report will identify and evaluate future conditions in light of the targets associated with the previous three reports.

These all are important elements in HERS-ST analysis because they contribute to the development of travel time and user cost for a given scenario.

Planning

There are a number of national goal areas being discussed under the Moving Ahead for Progress in the 21st Century (MAP-21) program, including safety, infrastructure, congestion, reliability and freight elements. The federal rulemaking process for the MAP-21program is still ongoing so there are many unknowns yet to be anticipated. There is considerable discussion and pro-action on these topics, both through the Strategic Highway Research Program (SHRP 2) and the 2010 Highway Capacity Manual (HCM2010). Numerous analytical procedures are being actively developed, including analysis and software procedures, but the data requirements are significantly large.

The HERS-ST model tool is a natural fit for the infrastructure and congestion elements of MAP-21. Depending on the formal adoption of the MAP-21 rules, some minor adjustments to the HERS-ST modeling process could enhance the model’s ability to satisfy the congestion, safety, reliability, and/or freight elements.

The greatest contribution the HERS-ST model has to offer to the planning process is the tools ability to evaluate future performance conditions of the roadway system associated with or without proposed improvement projects. HERS-ST is an excellent tool choice for identifying and evaluating future performance conditions in light of the baseline and future targets defined through the long-range planning process. This is critical in light of the national push for performance-based planning and programming (PBPP). “PBPP attempts to ensure that transportation investment decisions are made - both in long-term planning and short-term programming of projects - based on their ability to meet established goals[2].”

The HERS-ST model is an excellent tool for assessing base and future MAP-21 performance targets associated with pavement and congestion performance on a roadway system, and with some modifications could be applicable to safety, reliability, and freight elements. HERS-ST is also a natural choice for the scenario analysis and strategic planning expectations associated with PBPP.

The HERS-ST model is extremely useful for assessing long-range needs on a highway system and evaluating investment trade-offs. Some of the types of traditional questions HERS-ST is designed to address include:

- What level of capital expenditure is justified on benefit-cost grounds?
- What user cost level will result from a given stream of investment?
- What investment level is required to maintain user cost levels?
- What are the user cost and fiscal impacts of varying the investment stream (e.g., postponing improvement of backlog deficiencies)?
- What are the tradeoffs between capital investment and the performance of the highway system? If total investment is less than the economically efficient level, how much is lost in lower benefits?
- What is the cost, over 20 years, of correcting all existing and accruing highway deficiencies?
- Given a certain investment scenario, what percentage of the vehicle miles traveled (VMT) will be on roads with conditions below a minimum tolerable standard?
- What level of capital investment is needed to achieve or maintain the targets defined under MAP-21? Under constrained funding, how much of the system can achieve the target performance?
- For PBPP, how many resources should be allocated to achieve specific performance targets?

Reliability

There are a number of national performance areas being discussed under the MAP-21 program. This report will center on the elements associated with travel time reliability. Travel time reliability is simply a way to describe the variation of travel time encountered by a traveler on a roadway segment associated with both the expected and unexpected delay.

The FHWA has identified several primary causes that account for most delay on a roadway system[3]:

---

[2] FHWA (US Department of Transportation, Performance Based Planning and Programming Guidebook, September 2013, https://www.fhwa.dot.gov/planning/performance_based_planning/pbpp_guidebook/

[3] https://ops.fhwa.dot.gov/aboutus/opstory.htm; these estimates are a composite of many past and ongoing congestion research studies and are rough approximations.

- Inadequate base capacity (40%)
- Incidents (25%)
- Weather (15%
- Work zones (10%)
- Special events (5%)
- Traffic control devices (5%)

The first bullet, inadequate base capacity, has traditionally been accounted for through the Congestion Management System (CMS[4]) approach, which tracks and evaluates congestion issues, such as bottlenecks. Congestion delay, also known as recurring delay, has historically been the primary focus for most transportation engineers, accounting for only 40% daily recurring delay encountered by travelers, particularly during peak travel periods.

The recurring delay is often taken into consideration by most travelers because they expect certain levels of traffic congestion at specific locations during various time periods throughout the day (i.e., bottleneck locations).

The remaining five bullets identify what is new with reliability analysis. These elements are considered "non-recurring delay" and account for 60% of the overall delay on the roadway system. The non-recurring delays are the unexpected elements that the traveler encounters by chance. Reliability analysis within MAP-21 is focused towards addressing the additional 60%.

Through MAP-21 there is much discussion on this topic and analytical procedures are being proposed. Though the exact rulemaking process has not been completed, there are a number of terms like Travel Time Index, Planning Time Index and Misery Index that are being discussed as ways to describe the reliability performance on a roadway system.

There could be three critical levels of analysis needed to be satisfied:

- Defining and setting performance targets.
- Measuring existing performance of the roadway system (i.e., what's on the ground today) with respect to the targets.
- Evaluating future performance conditions, in lieu of the performance targets.

Analysis Process

This is the second of a four part analysis process that investigates the relevance and potential application of the HERS-ST model in evaluating existing and forecasting future System Reliability Performance.

---

[4] The Transportation Equity Act for the 21st Century (TEA-21), enacted in 1998, required states to develop congestion management systems as a systematic process for managing congestion. https://www.fhwa.dot.gov/tea21/sumcov.htm

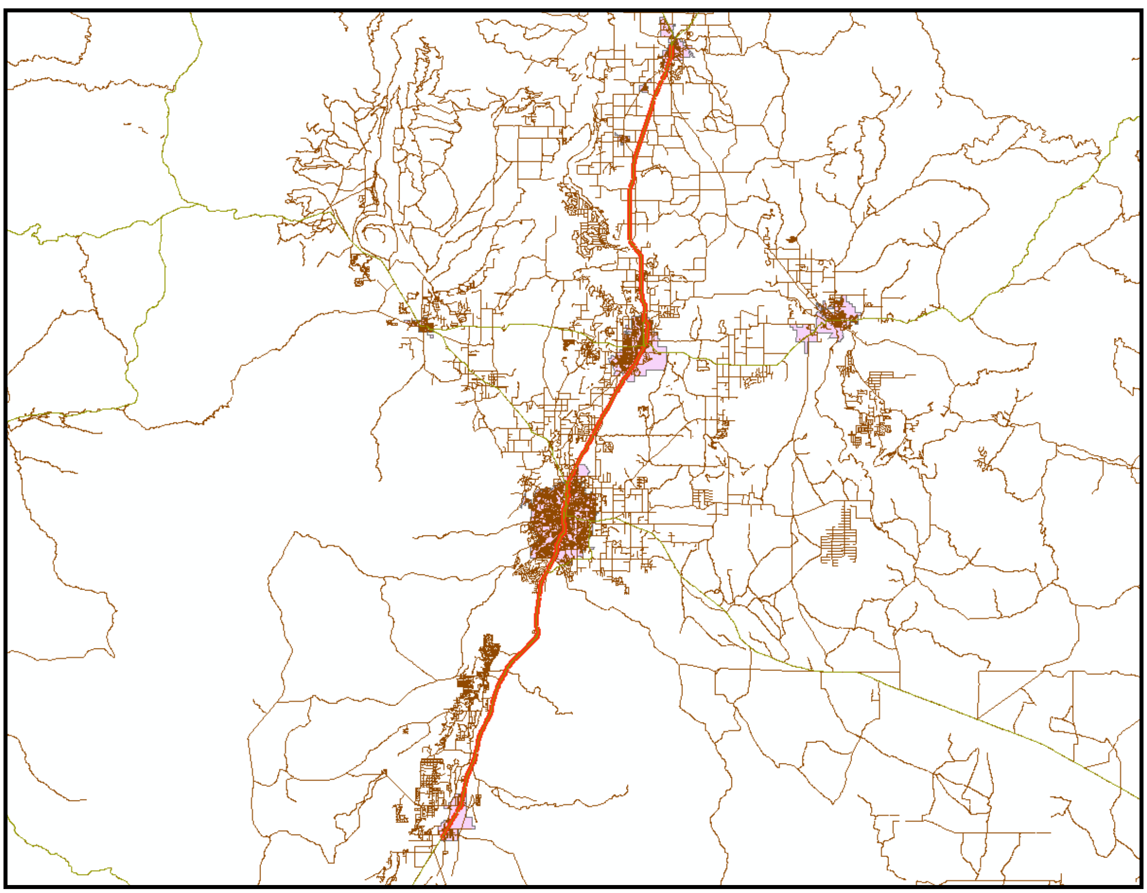
Phase Two evaluates the base and forecast future delay on the system, with the intention of exploring ways to examine potential future system conditions, and then relate the results back to MAP-21 targets.

This is a critical concept as there are limited ways to project future conditions in order to determine how the future improvement combinations align with MAP-21 targets set during a base year. The objective here is to develop a high level tool for forecasting delay associated with any number of future improvements.

The Corridor

The US-97 corridor is located in Central Oregon (see Figure 1), and extends south from the Jct. US-26 in Madras, Oregon to Jct. OR-31 south of La Pine, Oregon. The corridor spans a distance of 74 miles, and passes through four incorporated cities: Madras, Redmond, Bend and La Pine, as well as one unincorporated area known as Terrebonne. The two largest population centers are the cities of Bend and Redmond, with 2013 populations of 81,200 and 27,400, respectively. The two smaller urban areas are Madras and La Pine, with 2013 populations of 6,400 and 1,700, respectively.

Figure 1: US-97 Corridor through Central Oregon



The alignment is considered high desert with rolling hills and minor curves. The weather is generally dry, but does experience freezing conditions during winter months. In addition, the central Oregon area has significant recreational aspects which can result in large seasonal swings in the traffic demand on the roadway system throughout various weekends and much of the summer and winter months.

A summary of the section length and VMT for the various categories can be found in Table 1, which splits out the data into three general terms: the corridor as a whole; rural vs. urban; and eight individual segments defined by the urban boundaries. The table also provides a breakdown of the VMT growth between the 2014 and 2034 analysis years, and the percent change in VMT for the annual and 20-year timeframes.

Table 1: Corridor Length and VMT Summary (million VMT)

	Section Length		VMT - 2014		VMT - 2034		VMT % Change	
	Miles	%	VMT	%	VMT	%	20-Year	Annual
Corridor	73.72	- -	457	- -	614	- -	34	1.49
RURAL	50.04	68	264	58	364	59	38	1.61
URBAN	23.68	32	193	42	250	41	30	1.31
Madras	1.92	3	13	3	15	2	9	0.42
Rural01	22.10	30	95	21	131	21	39	1.65
Redmond	5.39	7	44	10	59	10	34	1.49
Rural02	7.78	11	78	17	105	17	35	1.51
Bend	10.54	14	113	25	149	24	32	1.40
Rural03	17.40	24	84	18	118	19	40	1.71
La Pine	5.83	8	22	5	27	4	21	0.96
Rural04	2.76	4	8	2	10	2	24	1.08

Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

The corridor carried 457 million VMT for the 2014 base year, and forecasts 614 million VMT for the 2034 future analysis year. The total corridor shows an average 20-year VMT growth of 34%, at an annual growth rate of 1.49%. Two-thirds of the corridor alignment is identified as rural, and caries 60% of the traffic. The split is roughly the same for both the 2014 base and 2034 analysis years. The VMT growth is higher in rural than in urban areas.

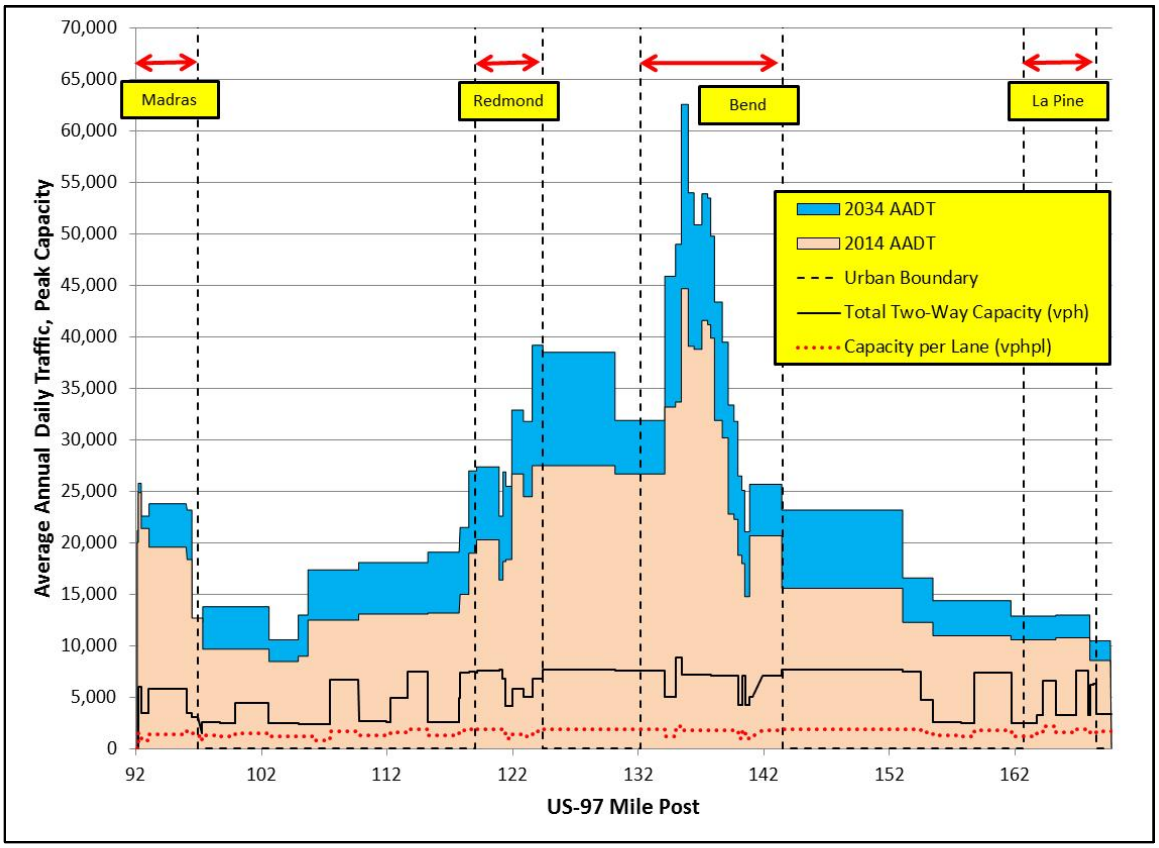
The Redmond and Bend urban areas and the rural area (Rural02) between the two, have an annual average growth that is similar to the total corridor's annual average. This area of the corridor makes up one third of the total corridor mileage, but carries half of the total VMT.

The rural segments between Madras and Redmond (Rural01) and between Bend and La Pine (Rural03) show a higher than average 20-year VMT growth, at 39% and 40%, respectively.

The roadway segment through the Madras area is designated a one-way couplet between mile posts 92 and 93.5. All analysis results for the two alignments have been aggregated together for this report. The 20-year VMT growth for Madras and La Pine is well below the 34% average VMT growth for the entire corridor, at 9% and 21%, respectively. Because the segments passing through these two urban areas are located at the outer edges of the total corridor area and only carry 10% of the total VMT, issues and changes to the roadway system within these areas should not significantly contribute to the overall travel within the corridor.

The comparison of 2014 and 2034 Annual Average Daily Traffic (AADT) along the US-97 corridor is shown in Figure 2. A summary of the total AADT growth between the two analysis years is defined as the area between the two curves.

Figure 2: Comparison of 2014 and 2034 AADT on US-97

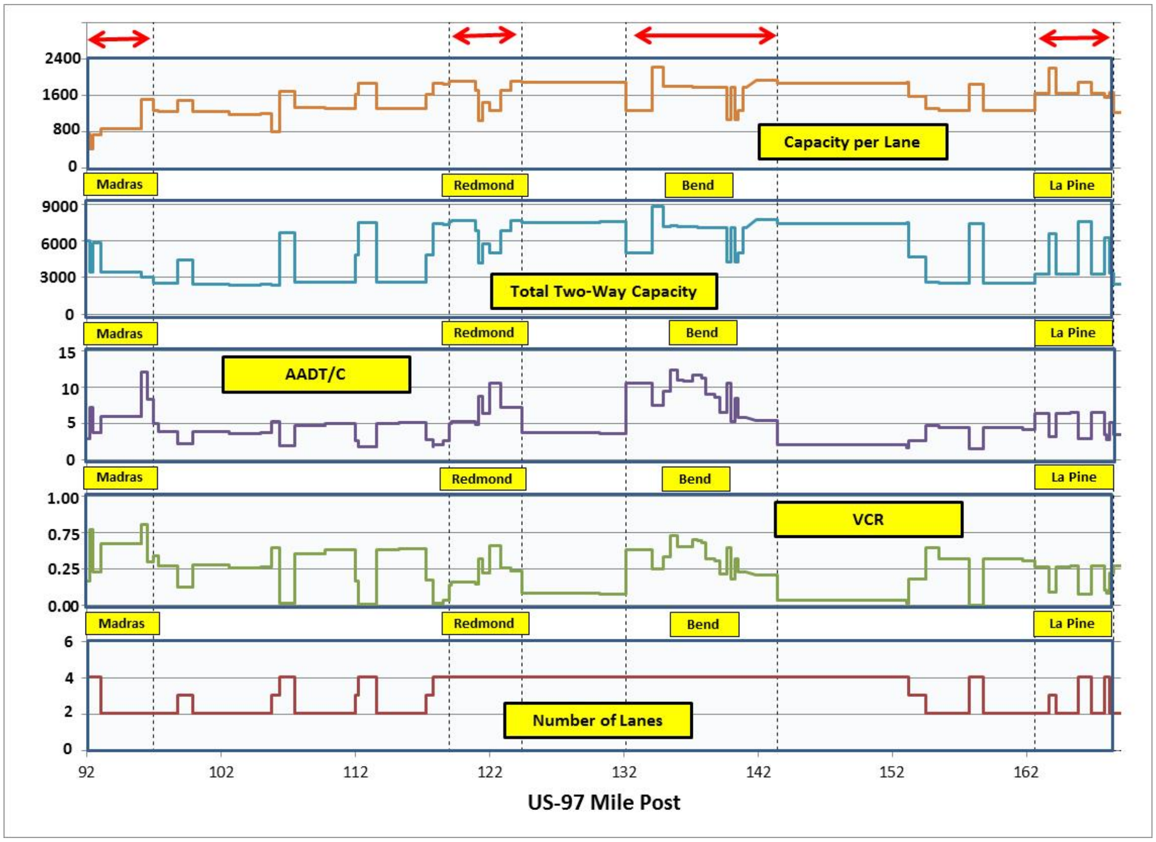


The total two-way capacity, and capacity per lane values, are also provided in Figure 2 as a point of reference; both are peak period capacities.

For rural segments HERS-ST calculates capacity as a two-way peak capacity, whereas for urban segments the capacity is a one-way (or by direction) peak capacity. To simplify the comparison between rural and urban areas, all capacities on urban segments are converted to a total two-way peak capacity (i.e., solid black line). The total two-way peak capacity varies from 1,530 to 8,860 vehicles per hour (vph). The capacity per lane (i.e., dotted red line) serves as a quick double-check on the reasonability of the capacity calculations; the capacity per lane varies from 760 to 2,220 vehicles per hour per lane (vphpl).

The concept is expanded in Figure 3, which shows a quick comparison of the roadway characteristic profiles on US-97. The x axis represents the corridor alignment, identified by mile posting. The four urbanized segments are identified. The data elements include, in order from bottom up: the number of lanes, the volume-to-capacity (VCR), the annual average daily traffic to capacity ratio (AADT/C), the total two-way capacity and the capacity per lane. All data reflects the existing system condition as currently on the ground for the 2014 base year.

Figure 3: Comparison of 2014 Roadway Characteristic Profiles on US-97



As an example, Figure 3 can assist to quickly identify the location of the three passing lanes in the rural segment between the urban areas of Madras and Redmond (i.e., Rural01) and the corresponding VCR and AADT/C values for said locations.

The bottom graph in Figure 3 shows that nearly half of the US-97 corridor is four lanes, including the entire roadway segment through and between the Redmond and Bend areas, and half the rural segment down to La Pine.

HERS-ST Analysis

A full sample (100%) HPMS formatted dataset was developed for the US-97 corridor, where each data record represents a specific segment, with the expansion factor set to unity. The base year was defined as 2014, with a 20-year future analysis year of 2034. The model was run with four 5-year funding periods; however none of the interim years are reviewed for this report. The initial scenario for this analysis was defined as a "No Build" scenario, where only pavement improvements were allowed by the HERS-ST model. The widening feasibility was set to zero for both the user parameter settings and the HPMS input dataset in order to restrict HERS-ST from adding lanes during the 20-year analysis period.

The HERS-ST model utilizes the Capacity Model, based on the HCM2010 formulas, to analyze recurring delay by evaluating congestion issues and simulating roadway improvements to alleviate congestion bottlenecks. The state improvement file option adds a critical level of reality check to the needs analysis. The congestion analysis accounts for 40% of the causes of delay, as identified by the FHWA.

FHWA developed a report in 2013[5] that provides some basic guideline on adjustment factors that can be applied to free flow speed, capacity and demand elements to account for the probability of various conditions on the roadway system, such as weather, special events and work zone. HERS-ST does not have a direct process for evaluating the probabilities of changes in demand and capacity associated with incremental changes in weather conditions and the addition of special events. However, there is a feature that is available within HERS-ST that can assist for this type of analysis.

HERS-ST has a unique State Override feature that allows the user to supplement the highway data and to override the improvement decisions that HERS-ST makes on any given roadway section, which in turn can impact system performance conditions. The State Override switch was originally designed to allow the user to turn on/off HERS-ST improvements and add unique state specific improvements as alternatives. One of the user inputs into the state override file details the adjusted capacity of the roadway system associated with the override improvement. This feature will allow the user to perform the capacity adjustments discused in the 2013 FHWA report.

A batching process can be developed and utilized to run a number of probability scenarios that adjust the capacities within the state override file, reflecting the probability of different roadway capacity and demand probability.

The HERS-ST model performs a high level evaluation of the cost of work zone delay. As of this writing, ODOT has not performed any review or testing of this feature, but hopes to have more information soon on its added value to the performance analysis.

[5] Federal Highway Administration. *"Guide for Highway Capacity and Operations Analysis of Active Transportation and Demand Management Strategies,"* FHWA-HOP-13-042, Washington, D.C., June 2013.

The HERS-ST model contains a number of sub models, such as speed, safety and congestion that perform a large number of internal calculations in order to assess and evaluate current and future conditions and performance on a roadway system. Some of the results of the internal calculations are only used to feed other sub model calculations and the internal numbers are discarded at the end of the model run. Other results are reported out to the analyst.

One of the key sets of results useful for reliability analysis is the delay element set, which is also tied to the safety and congestion analysis. HERS-ST evaluates three types of delay: zero-volume delay, incident delay and congestion delay, which is reported out as "Hours of Delay per 1,000 VMT".

- Zero-volume delay is the delay associated with traffic control devices. This is the expected delay that a single vehicle would encounter even if it were the only vehicle on the road. Zero-volume delay only exists for sections controlled with stop signs or traffic signals and is not calculated for uncontrolled sections.
- Incident delay[6] is the delay associated with crashes. HERS-ST estimates delay due to crashes through a secondary (or inferred) process where the HERS-ST model estimates the delay cost of crashes and then back-calculates the delay estimates due to crash incidents from the cost calculations.
- Other congestion (or recurring) delay is the average delay due to non-incident congestion.

The HERS-ST model does a good job projecting and evaluating future conditions on a roadway system. Though the model is not designed to provide and evaluate travel-time or planning-time indexes that are used within reliability analysis, there are post processing methods that can be useful for this work.

Scenario Development

Looking at FHWA's list of six primary causes of delay, the HERS-ST analysis can reasonably account for the traffic control devices (zero volume delay), the incidents (incident delay), and the inadequate base capacity (other congestion delay) elements of delay. Though the contribution of the weather, work zone and special events delay can not be directly modeled through HERS-ST, there are ways to work around these minor limitations. The HERS-ST analysis can be enhanced by utilizing scripted batch processes to apply various probability adjustment factor to the capacity and demand elements, within the input data, to develop probabilistic scenarios to account for various weather, work zone and special event conditions.

Two capacity reduction scenarios were developed as examples for this report: an 8% reduction and a 15% reduction, reflecting medium rain and medium snow, respectively. A batching process was developed to run the files with adjusted capacities within the

[6] The HERS Incident Delay is a default input for FREEVAL-RL, being developed as part of SHRP 2 (https://www.trb.org/Main/Blurbs/169594.aspx)

state override file, reflecting the probability of different roadway capacity and demand probability. A batch processing discussion can be found in Appendix B.

Discussion

Zero-Volume Delay

Zero-volume delay is the delay associated with traffic control devices, which accounts for about 5% of the delay encountered by a traveler. This is the expected delay that a single vehicle would encounter even if it were the only vehicle on the road. Zero-volume delay is only associated with sections controlled with stop signs or traffic signals located within urbanized areas.

Figure 4 identifies the magnitude and location of the zero-volume delay on the US-97 corridor alignment.

This analysis is based on existing system conditions on the ground in 2014. It does not include the new signalized intersections added on US-97 within the City of La Pine. In addition, the analysis does not include the future intersection improvement projects scheduled within the Bend and Madras areas. Several of the Bend improvements will replace existing signals with interchange connections. The removal of signals will have significant reduction of future zero-volume delay on the system.

The scenario assumes that all future traffic signal configurations, such as type of signals, percent green time and turning lanes, remains the same in the future analysis year, as that defined in the base year. The zero-volume delay values could change in the future, depending on alternative scenarios that include potential signal upgrades or timing improvements.

Because the analysis assumes no changes to the signalized roadway system the future zero-volume delay rate should be identical to the base year zero-volume delay rate. The difference between the areas in Figure 4 is directly due to the increased AADT.

Figure 4: Zero-Volume Delay Profile – Base and Future Analysis Years

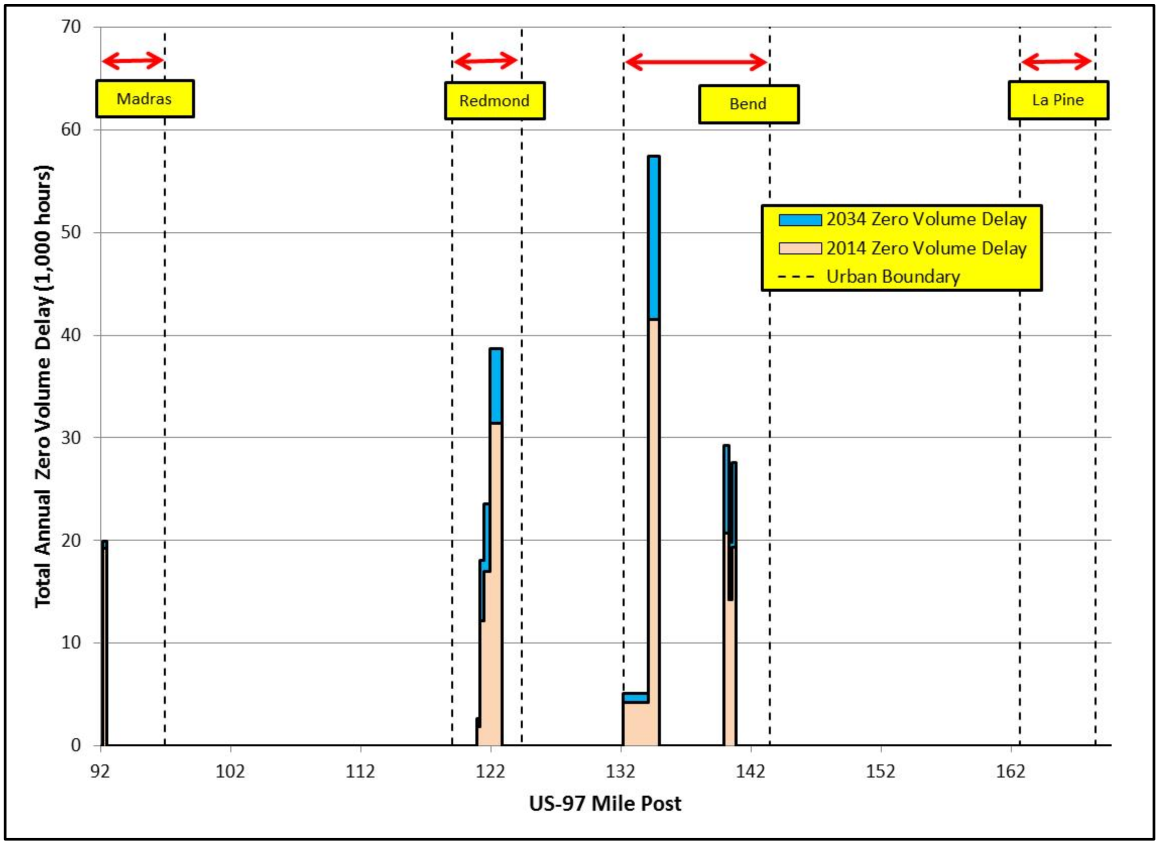


Table 2: Zero-Volume Delay Percent Difference (1,000 hours)

	2014		2034		20-Year	
	TOTAL	%	TOTAL	%	DIFF	%Diff
Corridor	184.5	--	247.8	--	63.4	34
RURAL						
URBAN	184.5	100	247.8	100	63.4	34
Madras	21.8	12	22.8	9	1.0	5
Rural01						
Redmond	62.5	34	84.8	34	22.3	36
Rural02						
Bend	100.1	54	140.2	57	40.1	40
Rural03						
La Pine						
Rural04						

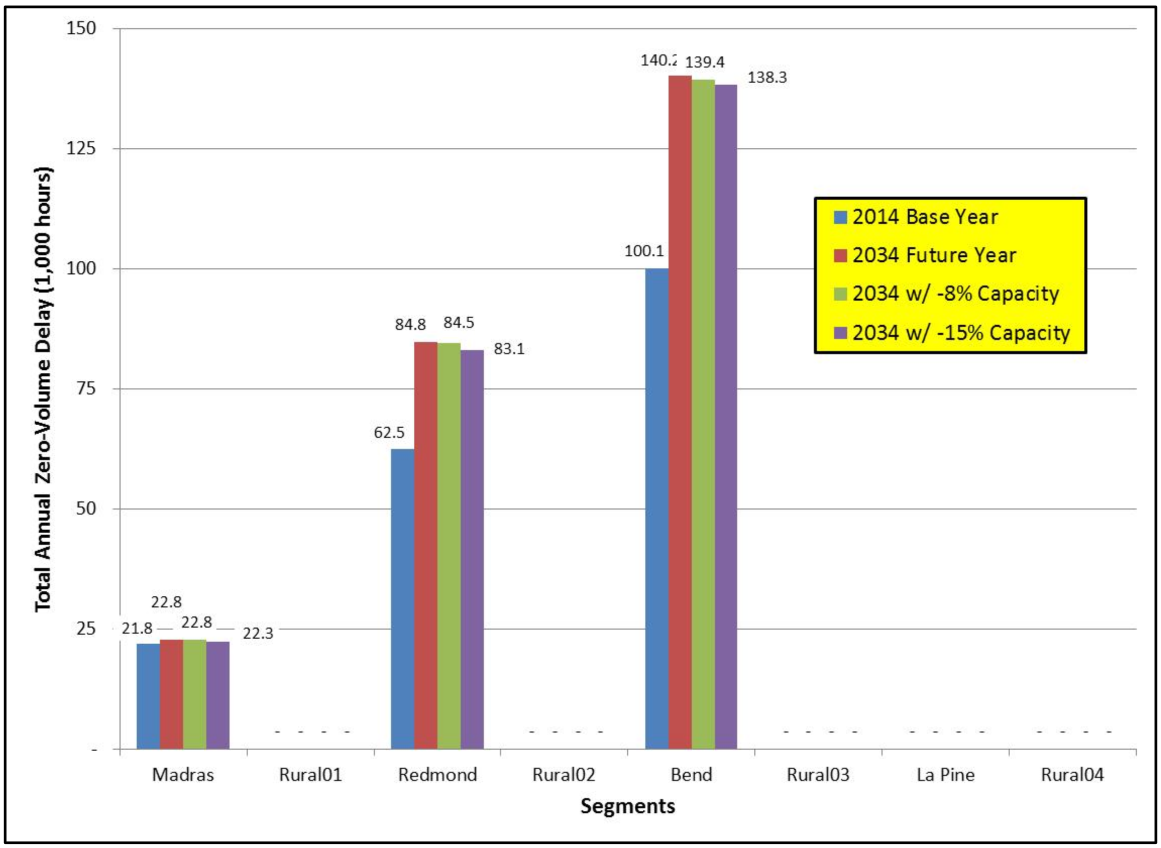
Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

The summary of the zero-volume delay for the various segments of the corridor are shown in Table 2. Over one-half of the delay is within the Bend area, which carries one-fourth of the total VMT for the corridor (see Table 1). One-third of the delay is found in the Redmond area (with 10% VMT), and half again is found in the Madras area (with 3% VMT). These delay percentages appear to be reasonable when considering the proportional VMT within each of the three areas (see Table 1). The 20-year growth seems to be closely associated with the 20 year increase in VMT; as an example, the Redmond area shows a 34% 20-year growth in VMT area and a 36% growth in zero-volume delay over the same period of time.

Results of the two capacity reduction scenario, as shown in Figure 5, indicates minor reduction in the hours of delay at the different locations. The analysis only looks at capacity reduction for the future year condition, whereas similar type results could be expected had the capacity reduction been applied to the base year.

Figure 5: Zero-Volume Delay – Comparison with Capacity Reduction Scenarios



Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

Incident Delay

Incident delay is the delay associated with crashes. HERS-ST estimates delay due to crashes through a secondary (or inferred) process where the HERS-ST model estimates the cost of crashes and then back-calculates the delay estimates associated with crash incidents from the cost calculations.

Figure 6: Incident Delay Profile – Base and Future Analysis Years

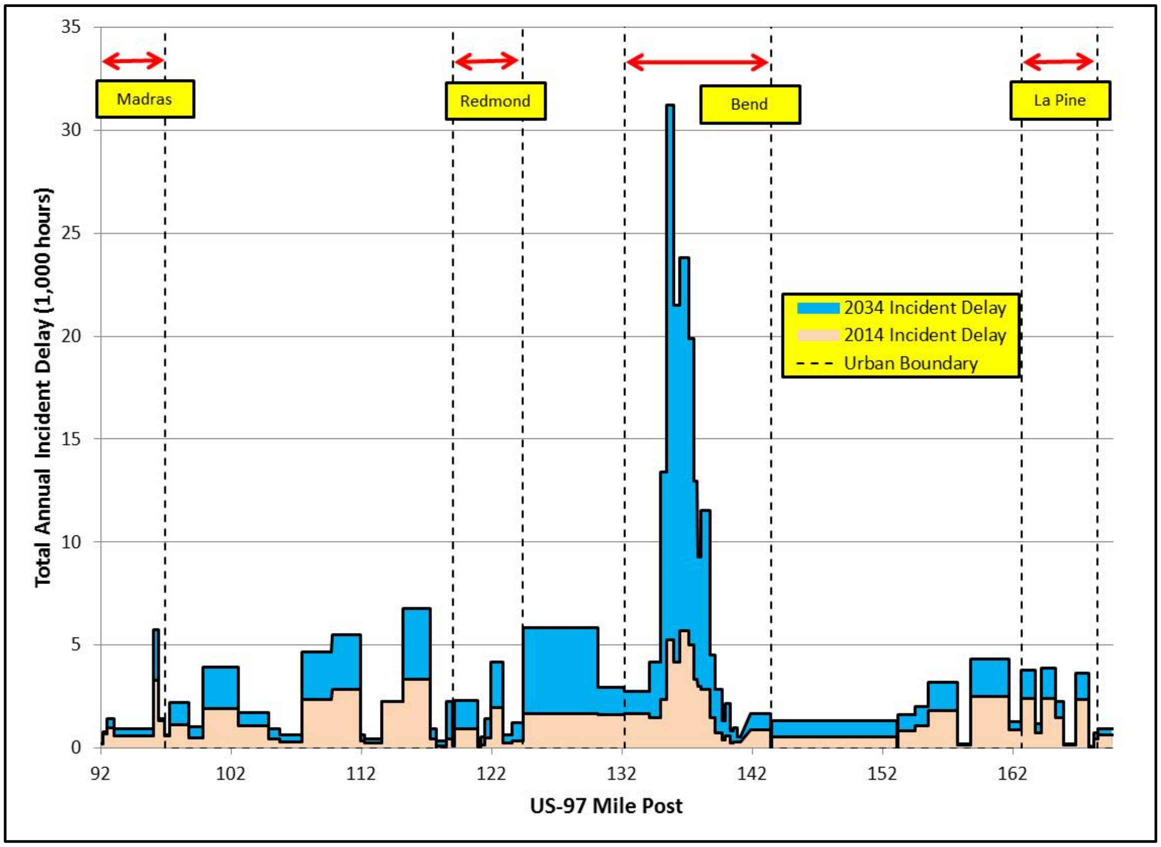


Figure 6 shows the profile of the average incident delay for the 2014 base and 2034 future analysis years, plotted along the corridor alignment. The largest increase in incident delay is located within the Bend urban boundaries, where the future incident delay is three times higher than the incident delay during the base year.

The summation of the total difference in the incident delay between the two analysis years on the roadway corridor is the area between the two curves.

The future capacity improvements feature was turned off for this analysis and not included in these results. This is a key point because this measure is directly associated with the predictive roadway safety, which is more indirectly associated with roadway geometry and capacity issues, such that future capacity improvements would alter the results of this study.

A summary of incident delay for the various categories is shown in Table 3. For the 2014 base year 67% of the incident delay is found in the urban area, which increases slightly to 77% for the future analysis period. The urban incident delay is double the rural incident delay in the 2014 base year, and three times as large in the 2034 future year. The urban area with the highest base year incident delay is the Bend area at 43% and 63% for the 2013 and 2034 analysis years, respectively. This would be expected because the Bend area has both significantly higher VMT and more corridor mileage than the other urban areas.

The Madras and La Pine areas have about the same amount of incident delay for both the base year and the future analysis year. There is twice as much incident delay in the Madras and La Pine areas, as compared with the Redmond area. The major factor contributing to this difference is probably associated with the alignment characteristics because the Redmond area employs considerably stronger access control elements which significantly reduce the incident.

Table 3: Incident Delay Percent Difference (1.000 hours)

	2014		2034		20-Year	
	TOTAL	%	TOTAL	%	DIFF	%Diff
Corridor	92.1	--	267.0	--	174.9	190
RURAL	30.5	33	62.0	23	31.5	103
URBAN	61.5	67	205.0	77	143.4	233
Madras	7.3	8	10.7	4	3.3	45
Rural01	18.7	20	37.3	14	18.5	99
Redmond	4.3	5	11.0	4	6.7	157
Rural02	3.3	4	9.0	3	5.8	175
Bend	39.8	43	167.2	63	127.4	320
Rural03	7.9	8	14.8	5	6.9	87
La Pine	10.1	11	16.1	6	6.0	60
Rural04	0.6	1	1.0	0	0.3	55

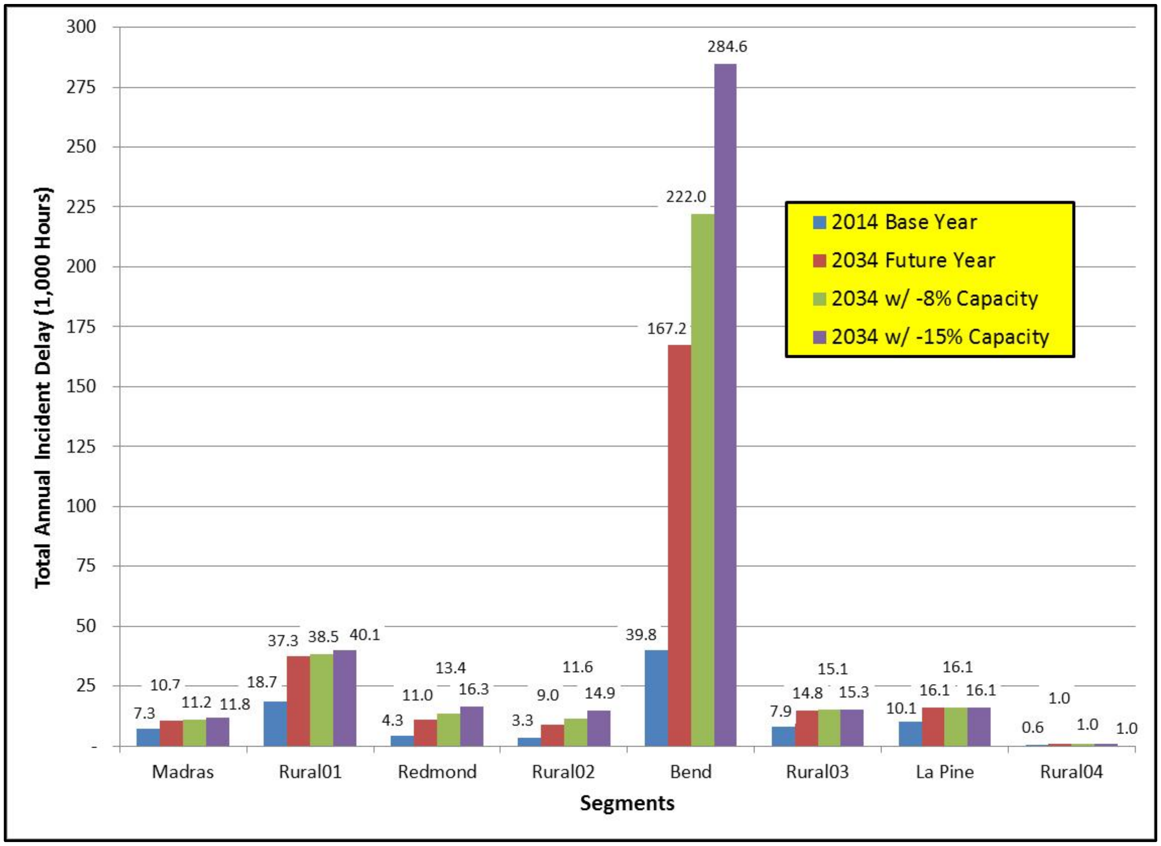
Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

The 20-year percent difference (%DIFF) represents the magnitude of the change over the 20-year analysis period. A doubling of a value is equivalent to a 100% increase for said value. The average incident delay for the overall corridor almost triples (increases 190%) over the 20-year analysis period. Most of this is due to the changes in the Bend area. This is an interesting point when considering the VMT growth is only 34% (see Table 1) for the same 20-year period of time. Evaluating the corridor by rural and urban area categories shows the average incident delay doubles in the rural areas, while increasing by three and a half times for urban areas.

This is seen in Figure 7, which shows the values for the difference analysis years stacked side by side. The annual total incident delay for the Bend area is substantially greater than any other area.

Figure 7: Incident Delay – Comparison with Capacity Reduction Scenarios



Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

Table 4: Corridor Incident Delay Summary, with/without Bend Area (1,000 hours)

Annual Total Incident Delay				
	2014	**2034**	**2034 w/ -8% Capacity**	**2034 w/-15% Capacity**
w/ Bend	92.1	267.0	328.9	400.1
wo/ Bend	52.2	99.8	106.8	115.5
Annual Average Incident Delay				
	2014	**2034**	**2034 w/ -8% Capacity**	**2034 w/-15% Capacity**
w/ Bend	11.5	33.4	41.1	50.0
wo/ Bend	7.5	14.3	15.3	16.5

Table 4 shows a summary of the annual total and annual average incident delay for the entire corridor, with and without the inclusion of the Bend area. The annual total incident delay is 92.1 and 267 (x 1,000) hours for the 2014 and 2034 analysis periods, respectively. However, if the Bend area is removed from the analysis, the annual total incident delay is reduced by almost half for the 2014 base year and by a third for the 2034 future year. This suggests that incident delay within the Bend area plays a major role in the total incident delay analysis for the corridor.

A similar evaluation of the annual average incident delay reveals much of the same. The annual average values are 11.5 and 33.4 (x 1,000) hours; the numbers are about halved when the Bend area is removed. In general, most all areas seem to have values near the level of the annual average without Bend, with the exception of the rural segment between Madras and Redmond (Rural01), which is well over twice the annual average without Bend.

Incident delay outside of the Bend area does not seem to change significantly when the reduced capacity scenarios are added to the analysis. A future year capacity reduction of 8%, which is similar to medium rain, increases the annual total incident delay by 7% when the Bend area is omitted from the analysis, but the increase is 23% when the Bend area is included. Similarly, the future year capacity reduction of 15%, which is similar to medium snow, increases the annual total incident delay by 15% when the Bend area is omitted from the analysis, but the increase is 50% when the Bend area is included. The contribution from the reduced capacity scenarios on the incident delay element plays out most significantly within the Bend area than anywhere else on the US-97 corridor.

NOTE: The reduced capacity scenarios are run as examples of the batch analysis process. The next steps would be to define all potential incident events, assign probabilities of occurrence to said events, run additional analysis and summarize results.

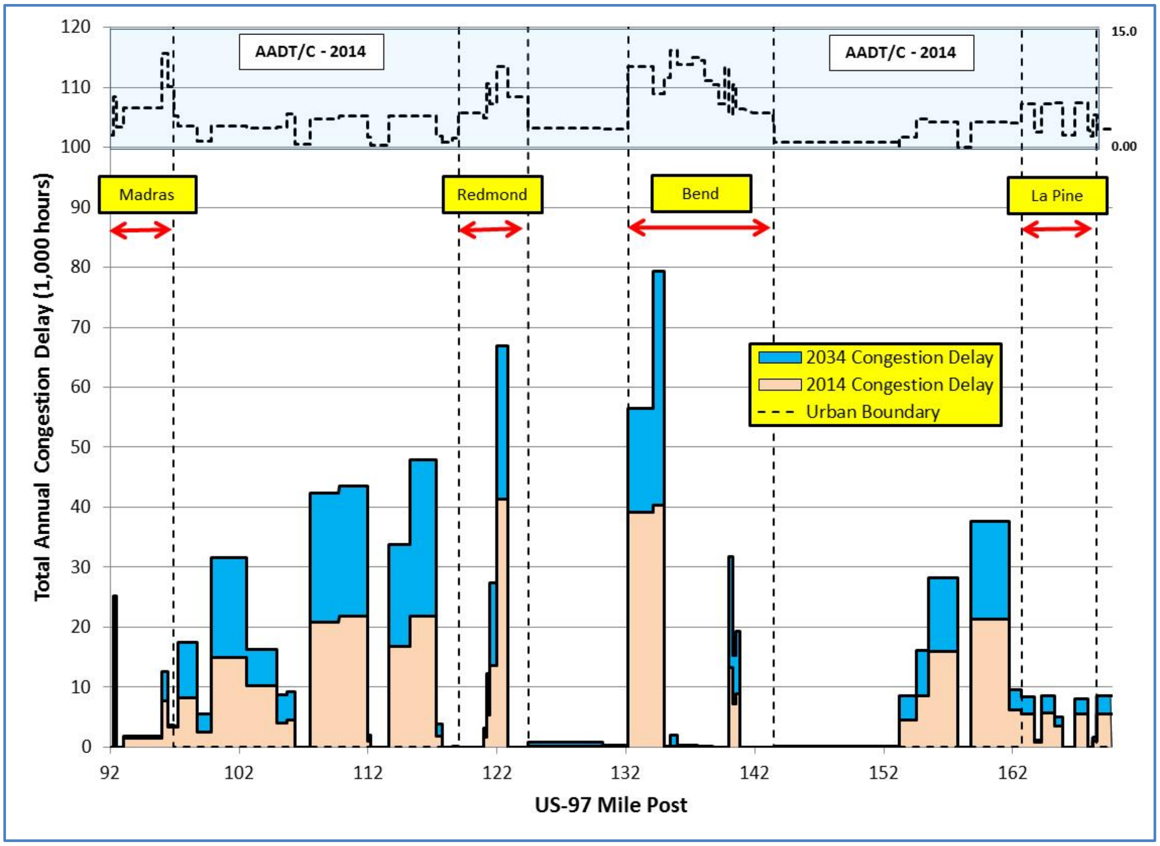
Other Delay

Other delay, also known as congestion or recurring delay, is the average delay due to non-incident congestion. HERS-ST evaluates average daily delay per 1,000 VMT as a function of the ratio of AADT/C.

The HERS-ST future capacity improvements option was turned off for this analysis and not included in these results. This is a key point because this measure is directly associated with the roadway capacity such that future capacity improvements would alter the results of this study.

Figure 8 shows the profile of the average other congestion delay for the base and future years, plotted along the corridor alignment. In addition, the 2014 AADT/C profile is inserted for reference purpose to give a better understanding on how congestion delay aligns with the volumes and capacity of the roadway system. The summation of the total congestion delay on the roadway corridor between the two analysis years is the area between the two curves.

Figure 8: Other (Congestion) Delay Profile – Base and Future Analysis Years



Because the congestion delay is defined as a function of AADT/C, an increase in capacity will result in a substantial decrease in delay. The decline of congestion delay within the rural segments (i.e., the valleys) is directly associated with the location of the multi-lane segments, known as passing lanes.

Table 5 shows the summary of the other congestion delay for the various categories. The percentage split between rural and urban is 46-54% for the 2014 base year, and almost 50-50 for the 2034 future year. The corridor alignment percentage split between rural and urban is 67-33% (see Table 1). The average (unweighted) AADT/C for the 2014 base year is 3.4 and 7.2 for the rural and urban areas, respectively.

The average other congestion delay increases 80% over the 20-year analysis period for the overall corridor.

The two areas with the largest congestion delay are the rural area between Madras and Redmond (Rural01) and the urban Bend area. Rural01 appears to have 20% more congestion delay for the 2014 base year then what is found in the Bend area, and 34% more in the 2034 future year. The average (unweighted) AADT/C for the 2014 base year is 3.5 and 8.7 for these two areas, rural and urban, respectively. The average AADT/C for Bend is over twice that for Rural01. The biggest factors to explain the reason why the congestion delay for rural Rural01 is higher than the urban Bend are the geometric alignment and segment lengths. Rural01 is rolling terrain with the segment length twice that for Bend; Bend is a fairly flat terrain.

The two urban areas with the highest congestion delay are the cities of Bend and Redmond, at 109 and 62 (x 1,000) hours, respectively. The future year congestion appears to increase by 50% for the Redmond area, while doubling for the Bend area.

Though the rural area between Redmond and Bend (Rural02) increases by 196%, the actual value is so low that it should be considered insignificant.

Table 5: Other (Congestion) Delay Percent Difference (1,000 hour)

	2014		2034		20-Year Diff	
	TOTAL	%	TOTAL	%	DIFF	%Diff
Corridor	426	--	767	--	341	80
RURAL	195	46	376	49	182	93
URBAN	232	54	391	51	159	69
Madras	38	9	42	5	4	10
Rural01	132	31	266	35	134	101
Redmond	62	15	110	14	48	77
Rural02	0	0	1	0	1	196
Bend	109	26	206	27	97	88
Rural03	57	13	100	13	44	78
La Pine	22	5	33	4	11	49
Rural04	6	1	9	1	3	53

Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

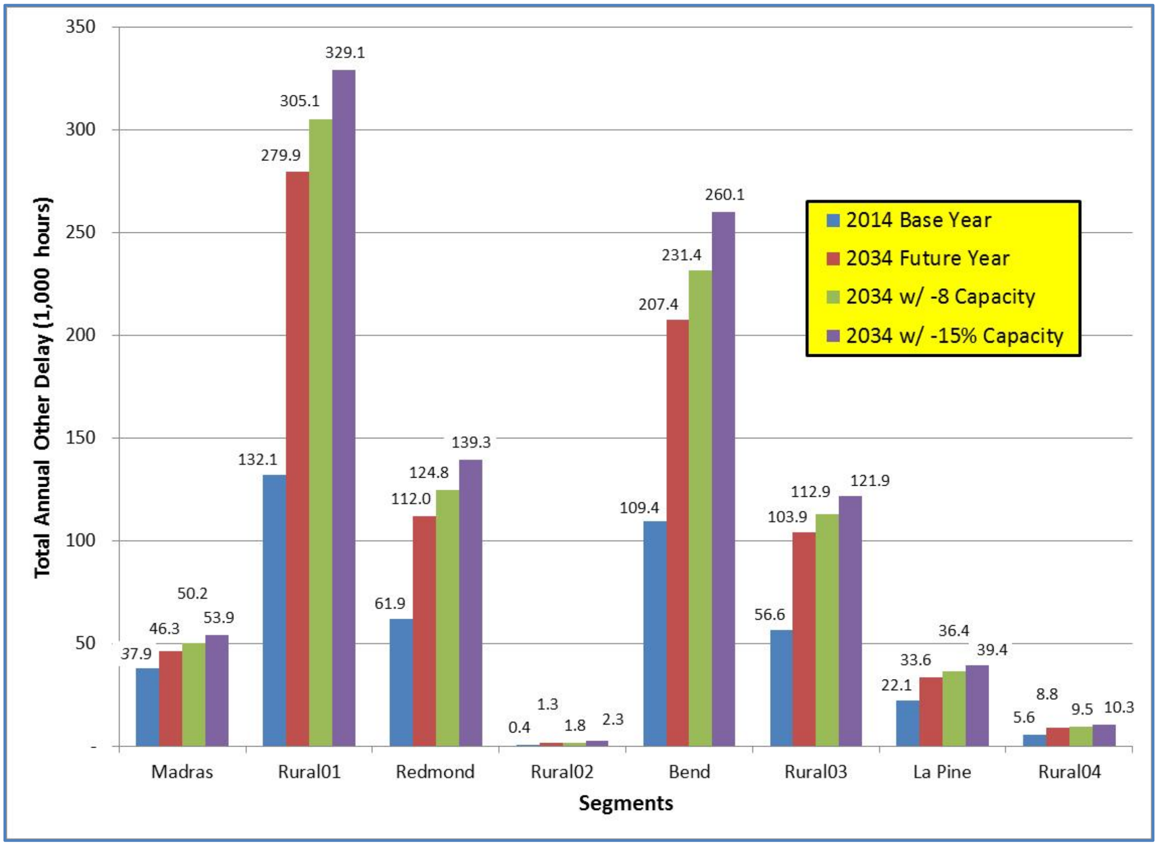
Table 6: Corridor Congestion Delay Summary, with/without Bend Area (1,000 hours)

Annual Total Congestion Delay				
	2014	2034	2034 w/ -8% Capacity	2034 w/-15% Capacity
w/ Bend	426.1	793.0	872.2	956.3
wo/ Bend	316.6	585.7	640.8	696.3
Annual Average Congestion Delay				
	2014	2034	2034 w/ -8% Capacity	2034 w/-15% Capacity
w/ Bend	53.3	99.1	109.0	119.5
wo/ Bend	45.2	83.7	91.5	99.5

Table 6 shows a summary of the annual total and annual average congestion delay for the entire corridor, with and without the inclusion of the Bend area. The annual total congestion delay is 426.1 and 793.0 (x 1,000) hours for the 2014 and 2034 analysis periods, respectively. However, if the Bend area is removed from the analysis, the annual total congestion delay is reduced by a quarter for both the 2014 base year and the 2034 future year. This suggests that congestion delay within the Bend area only plays a minor role in the total congestion delay analysis within the overall corridor.

A similar evaluation of the annual average congestion delay reveals much of the same. The annual average values are 53.3 and 99.1 (x 1,000) hours; the numbers are 15% lower when the Bend area is removed.

Figure 9: Other (Congestion) Delay – Comparison with Capacity Reduction Scenarios



Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

Congestion delay outside of the Bend area does not seem to change significantly when the reduced capacity scenarios are added to the analysis. A future year capacity reduction of 8% (i.e., medium rain) increases the annual total congestion delay by 10%, with or without inclusion of the Bend area. Similarly, the future year capacity reduction of 15% (i.e., medium snow) increases the annual total congestion delay by 20%, with or without inclusion of the Bend area. The contribution from the reduced capacity scenarios on the congestion delay element does not appear to be any more significant within the Bend area than anywhere else on the US-97 corridor.

Figure 9 shows the base and future year values for the congestion delay stacked together.

Total Delay

Total Delay is the summation of the three individual delay elements: zero-volume, incident and other congestion.

Figure 10: Total Delay Profile – Base and Future Analysis Years

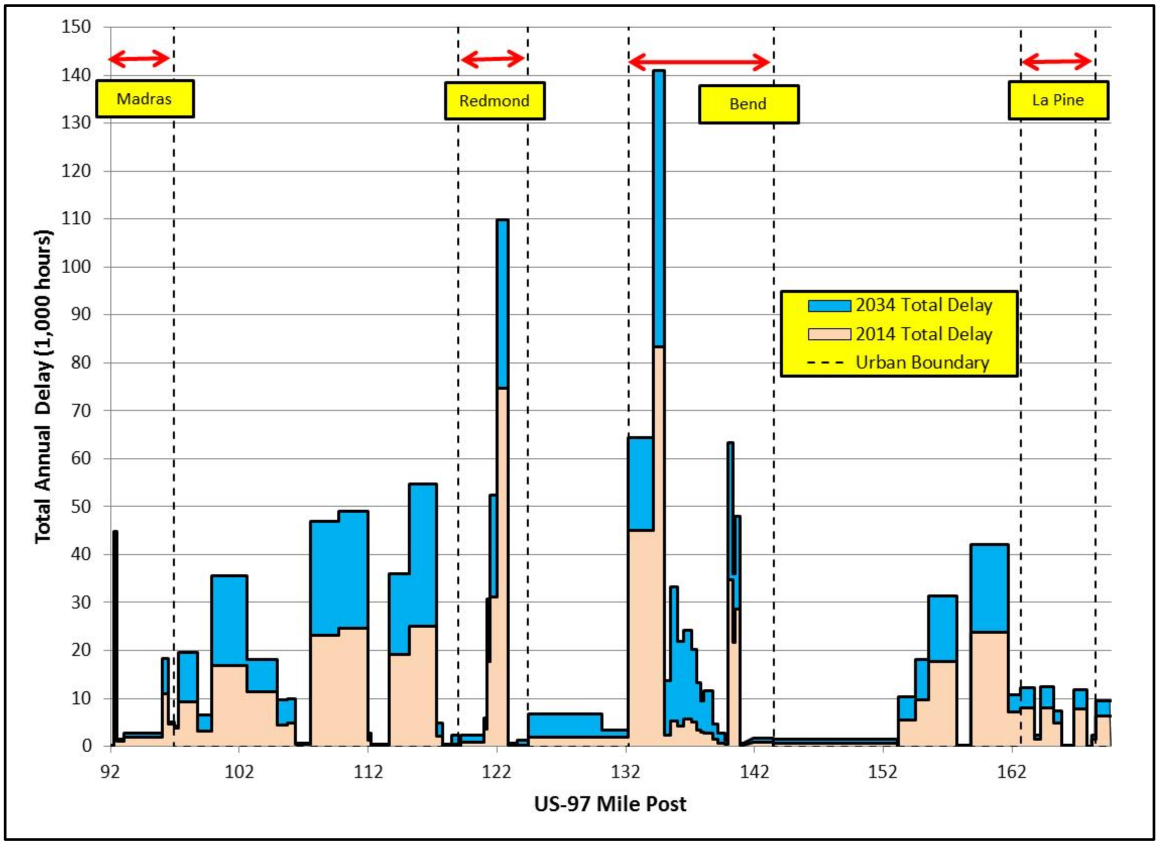


Figure 10 shows the profile of the average total delay for the base and future years, plotted along the corridor alignment. The summation of total delay between the two analysis years on the roadway corridor is the area between the two curves.

Table 7 shows the summary of total delay for the various categories. Two thirds of the total delay is found in the urban area, which seems fairly consistent across the 20-year analysis period.

For the 2014 base year, the Bend area shows the most total delay, at 249.4 (x 1,000) hours, which is about twice that for the Redmond area, at 128.7 (x 1,000) hours, and four times that for the Madras area. The trend is similar for the 2034 future year, with some slight exaggeration in the percentages.

Table 7: Total Delay Percent Difference (1,000 hour)

	2014		2034		20-Year Diff	
	TOTAL	%	TOTAL	%	DIFF	%Diff
Corridor	702.6	--	1,308.0	--	605.4	86
RURAL	225.2	32	455.9	35	230.7	102
URBAN	477.3	68	852.1	65	374.7	79
Madras	67.1	10	79.7	6	12.6	19
Rural01	150.9	21	317.1	24	166.2	110
Redmond	128.7	18	207.8	16	79.2	62
Rural02	3.7	1	10.4	1	6.7	182
Bend	249.4	35	514.8	39	265.5	106
Rural03	64.5	9	118.7	9	54.2	84
La Pine	32.2	5	49.7	4	17.5	54
Rural04	6.2	1	9.7	1	3.5	57

Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

For the overall corridor, the total delay almost doubles (i.e., 86%) over the 20-year analysis period. The average percent difference for the urban areas is 79%, with the Bend area being highest at 106%, while the Madras area is lowest at 19%. The average percent difference for the rural areas is 102%, with the Rural02 being highest at 182%, while the Rural04 is lowest at 57%. The actual values for Rural02 and Rural04 are low and considered insignificant for the corridor analysis.

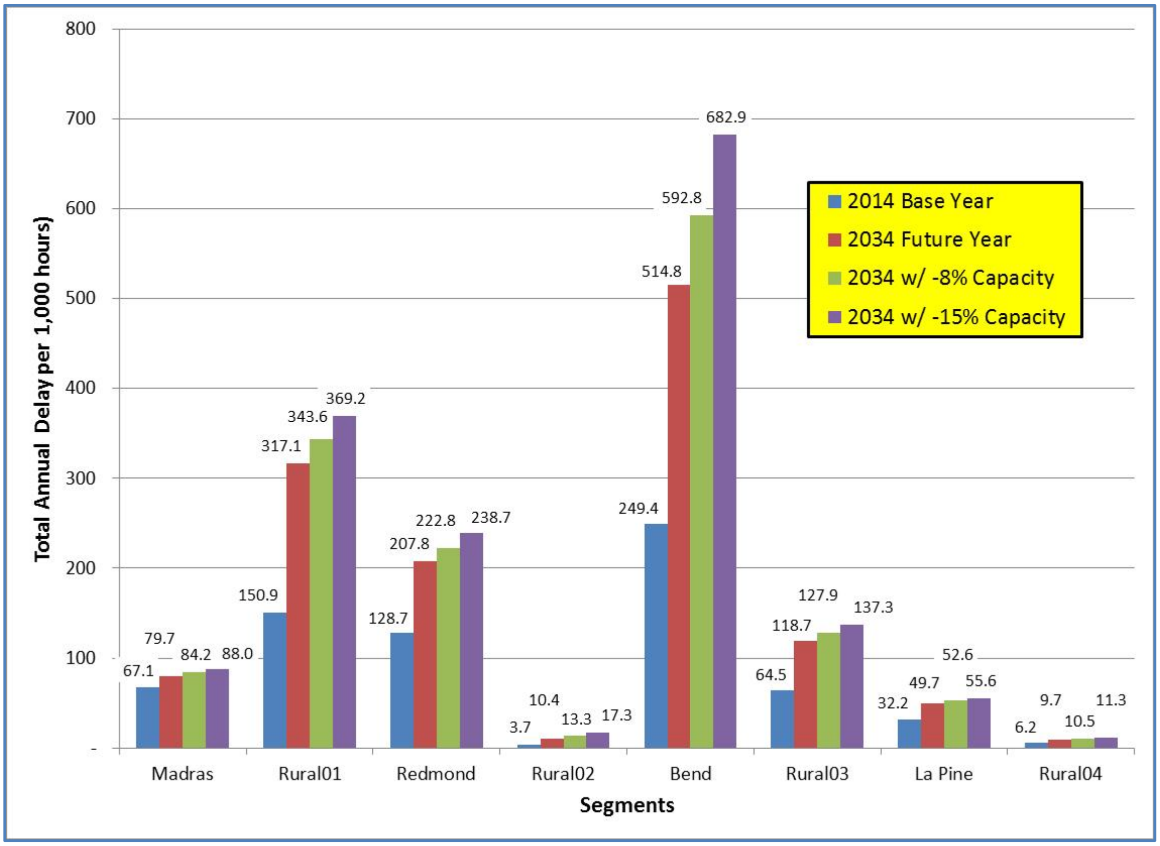
Table 8: Corridor Total Delay Summary, with/without Bend Area (1,000 hours)

Annual Total Delay				
	2014	2034	2034 w/ -8% Capacity	2034 w/-15% Capacity
w/ Bend	702.6	1,308.0	1,447.7	1,600.3
wo/ Bend	453.2	793.1	854.9	917.3
Annual Average Total Delay				
	2014	2034	2034 w/ -8% Capacity	2034 w/-15% Capacity
w/ Bend	87.8	163.5	181.0	200.0
wo/ Bend	64.7	113.3	122.1	131

Table 8 shows a summary of the annual total and annual average total delay for the entire corridor, with and without the inclusion of the Bend area. The annual total delay is 702.6 and 1,308 (x 1,000) hours for the 2014 and 2034 analysis periods, respectively. However, if the Bend area is removed from the analysis, the annual total delay is reduced by a third for both the 2014 base year and 2034 future year. This suggests that total delay within the Bend area only plays a minor role in the total delay analysis within the overall corridor.

A similar evaluation of the annual average total delay reveals much of the same. The annual average values are 87.7 and 163.5 (x 1,000) hours. The numbers are about 25% lower when the Bend area is removed.

Figure 11: Total Delay – Comparison with Capacity Reduction Scenarios



Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

Total delay outside of the Bend area does not seem to change significantly when the reduced capacity scenarios are added to the analysis. A future year capacity reduction of 8% (i.e., medium rain) increases the annual total delay by 10%, with or without inclusion of the Bend area. Similarly, the future year capacity reduction of 15% (i.e., medium snow) increases the annual total delay by 20%, with or without inclusion of the Bend area. The contribution from the reduced capacity scenarios on the total delay element does not appear to be any more significant within the Bend area than anywhere else on the US-97 corridor.

Figure 11 shows the base and future year values for the congestion delay stacked together.

The future capacity improvements feature was turned off for this analysis and not included in these results. This is a key point because this measure is directly associated with the projected roadway safety and capacity, such that future capacity improvements would alter the results of this report. This serves as a reference in the case of no further capacity enhancement.

Predictive Tool

HERS-ST can be used as a predictive tool to evaluate the future performance indicators for delay on the roadway system. Based on a no build scenario, total delay on the corridor is expected to increase by 86% over the 20-year analysis period (see Table 7), which represents a 3.16% annual growth in total delay. However, because the corridor has many different segments, some with more rural characteristics, and others with more urban type, it makes more sense to evaluate the corridor at the eight unique segment levels identified throughout all tables in this report.

Madras

The Madras area segment shows a 19% increase in total delay over the 20-year analysis period, which represents a 0.87% annual growth in total delay. Eight to 10% of the total delay for the total corridor is associated with the Madras area. The proportional split for the three delay categories is 33%, 11%, 57% for base year, and 29%, 13%, 58% for future analysis year, for zero-volume, incident and other congestion, respectively. This suggests that about one third of the delay in Madras is associated with the signals, 60% is associated with congestion and 12% is tied to incidents.

Rural01

The segment between Madras and Redmond (Rural01) shows a 110% increase in total delay over the 20-year analysis period, which represents a 3.78% annual growth in total delay. Twenty one to 24% of the total delay for the total corridor is associated with the Rural01 area. Because this is a rural section, there is no zero-volume delay. The proportional split for the two remaining delay categories is 12% and 88% for both base year and future analysis year, for incident and other congestion, respectively. Though the percent splits seem consistent across the different analysis periods, the congestion delay seems high for the area. Similar proportional splits are found in Rural03 and Rural04.

Redmond

The Redmond area segment shows a 62% increase in total delay over the 20-year analysis period, which represents a 2.43% annual growth in total delay. Sixteen to 18% of the total delay for the total corridor is associated with the Redmond area. The proportional split for the three delay categories are 49%, 3%, 48% for base year, and 41%, 5%, 54% for future analysis year, for zero-volume, incident and other congestion, respectively. This suggests that just under half of the delay in Redmond is associated with the signals, and half is associated with congestion, leaving a small sliver of delay tied to incidents.

Rural02

The segment between Redmond and Bend (Rural02) is a major commuting route between housing in Redmond and employment in Bend. The roadway is multilane and functions more like an expressway rather than a principal arterial. One percent of the total delay for the total corridor is associated with the Rural04 area. Because this is a rural section, there is no zero-volume delay. The proportional split for the two remaining delay categories is 88% and 12% for both base year and future analysis year, for incident and other congestion, respectively. It is interesting to note these proportional splits are directly opposite of what is seen in Rural01, Rural03 and Rural04.

Bend

The Bend area segment shows a 106% increase in total delay over the 20-year analysis period, which represents a 3.69% annual growth in total delay. Thirty five to 39% of the total delay for the total corridor is associated with the Bend area. The proportional split for the three delay categories is 40%, 16%, 44% for base year, and 27%, 32%, 40% for future analysis year, for zero-volume, incident and other congestion, respectively. The signal delay decreases about the same amount the incident delay increases. Only the congestion delay appears consistent across the 20-year analysis period. The signal and incident delay decreases/increases about the same 15%, respectively.

Rural03

The segment between Bend and La Pine (Rural03) shows an 84% increase in total delay over the 20-year analysis period, which represents a 3.10% annual growth in total delay. Nine percent of the total delay for the total corridor is associated with the Rural03 area. Because this is a rural section, there is no zero-volume delay. The proportional split for the two remaining delay categories is 12% and 88% for both base year and future analysis year, for incident and other congestion, respectively. Though the percent splits seem consistent across the different time periods, the congestion delay seems high for the area. Similar proportional splits are found in Rural01 and Rural04.

La Pine

The La Pine area segment shows a 54% increase in total delay over the 20-year analysis period, which represents a 2.19% annual growth in total delay. Four to 5% of the total delay for the total corridor is associated with the La Pine area. Because there are no signals within the La Pine area, there is no zero-volume delay. The proportional split for the two remaining delay categories is 31% and 69% for base year, and 32% and 68% for future analysis year, for incident and other congestion, respectively. The proportional splits are consistent across the time periods, and suggests that about one third of the delay in La Pine is associated with incidents, while two thirds of the delay is attributed to congestion.

NOTE: At the time of the analysis there were no signalized intersections located on US-97 within the La Pine area. Since that time a signal has been installed at the intersection of US-97 and 1st Street.

Rural04

The segment between La Pine and OR-30 (Rural04) shows a 57% increase in total delay over the 20-year analysis period, which represents a 2.27% annual growth in total delay. One percent of the total delay for the total corridor is associated with the Rural04 area. Because this is a rural section, there is no zero-volume delay. The proportional split for the two remaining delay categories is 10% and 90% for base year and future analysis year, for incident and other congestion, respectively. Though the percent splits seem consistent across the different time periods, similar proportional splits are found in Rural03 and Rural04.

Reliability

Travel time reliability is an attempt to quantify the uncertainty in travel times that a traveler might experience from day to day, across different times of day. Travel times can vary considerably by time of day (TOD), day of the week (DOW) and month of the year (MOY) simply because of changes in traffic demand and/or capacity associated with congestion, incident, weather and work zones. Everyday congestion is common and most travelers expect and plan for some level of delay based on when and where they are going. However, the unexpected delay encountered by a traveler due to such things as weather, incidents and work zones can have a significant impact on the effectiveness of the transportation system. Travel time reliability measures attempt to account for the unexpected elements that an average travel time cannot capture.

A sketch planning method approach is highlighted in the Technical Reference for The Second Strategic Highway Research Program (SHRP 2) Project L05 *Incorporating Reliability Performance Measures into the Transportation Planning Program Process*[7]. This technical reference in Chapter 2 provides an overview of what travel time reliability is and why it is important. A discussion on the tools and methods for estimating reliability are presented in Chapters 3 and 4 and includes the application of sketch-planning tools and other approaches utilizing simulation. The methodical process for development reliability analysis is discussed in Chapter 5. The previous discussion on using HERS-ST as a tool for evaluating delay should be used as a replacement for Chapters 3 and 4 in the SHRP 2 Project L05 report.

The SHRP 2 Project *C11: Reliability Analysis Tool: Technical Document*[8] is an enhancement of the SHRP 2 L05 Project. The C11 report provides guidance on the application of the data-poor reliability prediction equations initially described in the SHRP 2 L05 report. A review of the data elements listed on page 10 of the C11 technical document suggests that a standard HPMS dataset would suffice for analysis. HERS-ST is a complex modeling tool that utilizes the HPMS dataset format.

The application of HERS-ST as a predictive tool for evaluating existing and future delay on a roadway system has been discussed in the previous sections. Reliability introduces the element of variation in travel time that is encountered daily on the roadway system; i.e., variation due to weather, incidents or work zone. There are a number of proposed

[7] Cambridge Systematics, Inc. *SHRP 2 Project L05: Incorporating Reliability Performance Measures into the Transportation Planning and Programming Process, Technical Reference*. Strategic Highway Research Program (SHRP 2), Transportation Research Board of the National Academies, 2014. https://www.trb.org/Main/Blurbs/168856.aspx

[8] Cambridge Systematics, Inc., Weris, Inc., and Economic Development Research Group, Inc. *SHRP 2 Project C11: Reliability Analysis Tool: Technical Documentation*. Strategic Highway Research Program (SHRP 2), Transportation Research Board of the National Academies, January 2013

performance measures being discussed at the national audience level, and the MAP-21 guidelines are due to be released in the next few months.

Performance Measures

This section will focus on three specific performance measures: Travel Time Index (TTI), Planning Time Index (PTI), and the Buffer Index (BI).

TRAVEL TIME INDEX

TTI measures the travel time mobility of the roadway system during the peak period. TTI is a rough indicator of the severity of congestion, and is defined as the ratio of the average travel time during the peak period to the free-flow travel time, where free-flow is an off-peak period of unobstructed traffic flow.

$$TTI = \frac{\text{Peak Average Travel Time}}{\text{Free} - \text{Flow Travel Time}}$$

A TTI of unity indicate the average peak travel time is the same as the free flow travel time mean that there is no delay on the system. A TTI of 1.25 indicated that the average peak travel time is 125% of the free-flow travel time. This suggests that it should take 25% longer to travel the roadway segment during the peak period than it would under uncongested conditions. As an example, a trip that would normally take 8 minutes during the off-peak period would take 10 minutes during the peak period.

The average peak travel time is typically used for the TTI calculations, but occasionally the same term will be used to represent various percentile travel time measures, such as the 80th or 95th percentiles. For such cases there should be a clear indication of the differences, such as TTI_{50} for the 50th percentile TTI, TTI_{80} is the 80th percentile TTI and TTI_{95} is the 95th percentile TTI.

The Overall Mean Travel Time Index (TTI_m) equation was developed for the SHRP 2 Project to incorporate both the congestion (recurring) and incident delay. These delay elements have been previously discussed in this report. The following equations from the SHRP 2 Project C11 report have been utilized in this analysis:

$$TTI_m = 1 + FFS * (RecurringDelayRate + IncidentDelayRate)$$

Where:

RecurringDelayRate – Aggregated Other Congestion Delay Rate from HERS-ST sectional output
IncidentDelayRate – Aggregated Incident Delay Rate from HERS-ST sectional output

$$TTI_{50} = 4.01224/\{(1 + e(^{1.7417- 0.93677 * TTIm})^{(1/0.82741)}\};\ TTI_{50} >= 1.0$$

$$TTI_{80} = 5.3746/\{(1 + e^{(-1.5782- 0.85867 * TTIm)})^{(1/0.04953)}\}; TTI_{80} >= 1.0$$

PLANNING TIME INDEX

PTI is a measure for travel time reliability and is an indicator of the variability in the average peak travel time. It is a special case of TTI in that it is typically computed as the 95th percentile of TTI. It reflects the near-worst case travel time and is an indicator of how much total time a traveler should allow to ensure their arrival on-time 95% of the time. As an example, for a commuter it is the total travel time needed to ensure an on-time arrival to work 19 days out of 20; this would allow a commuter to be late to work one day out of the month. PTI is also referred to as TTI_{95}.

$$PTI = \frac{\text{95th Percentile Peak Travel Time}}{\text{Free} - \text{Flow Travel Time}}$$

As an example, a PTI of 2.50 indicated that the average peak travel time is 250% of the free-flow travel time. Using this PTI, if a commuter can only be late to work one day a month they need to plan for a 20 minute travel time during the peak period for a trip that would normally take 8 minutes during the off-peak period, in order to ensure they arrive to work on time 19 out of 20 days.

The following equation from the SHRP 2 Project C11 report has been utilized in this analysis:

$$TTI_{95} = 1 + 3.6700 * \ln(TTI_m)$$

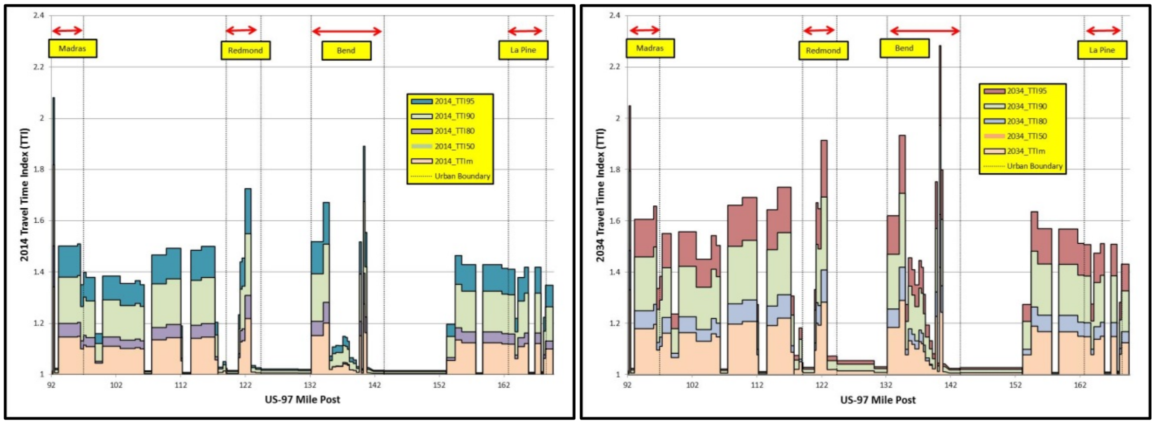
NOTE: The TTI_m and TTI_{95} were originally proposed in SHRP 2 L03 "Data Poor" Equations, whereas TI_{80} and TTI_{50} were developed specifically for SHRP 2 C11.

The Travel Time Index profiles for the different percentile, for the 2014 and 2034 analysis periods, are provided in Figure 12. The two graphs are plotted at the same vertical scale to simplify the comparison.

All two-lane rural segments and signalized urban segments show the largest amount of variation in travel time, regardless of the percentile levels evaluated.

Figure 12: Travel Time Index Profile on US-97

(a) 2014 **(b) 2034**



Utilizing the various equations from the C11 report, the daily TTI's for the mean, 50%, 80%, and 95% are calculated and provided in Table 9. The typical TTI calculations are a comparison of peak-period travel time to free-flow travel time. The analysis in the report is associated with daily TTI, not peak period TTI.

The TTI_{95} (also known as PTI) corridor level values are 1.21 and 1.31 for base and future years, respectively. However, with a corridor length of 74 miles, the reference travel time to traverse the entire corridor is almost an hour and half (i.e., ninety minutes). Because the corridor passes through different rural and urban roadway characteristics, an evaluation of the various performance measures will have limited meaning at this level of analysis. It is more practical to look at the value for the individual area.

Table 9: Travel Time Index Summary – Mean, 50%, 80% and 95%

	2014				2034			
	TTI_m	TTI_{50}	TTI_{80}	TTI_{95}	TTI_m	TTI_{50}	TTI_{80}	TTI_{95}
Corridor	1.06	1.03	1.12	1.21	1.09	1.05	1.18	1.31
Madras	1.11	1.07	1.08	1.38	1.13	1.08	1.25	1.43
Rural01	1.10	1.05	1.13	1.33	1.14	1.08	1.28	1.47
Redmond	1.06	1.04	1.08	1.21	1.09	1.05	1.17	1.29
Rural02	1.01	1.00	1.00	1.02	1.01	1.00	1.03	1.05
Bend	1.07	1.03	1.09	1.24	1.12	1.07	1.24	1.41
Rural03	1.04	1.02	1.06	1.15	1.06	1.03	1.11	1.20
La Pine	1.08	1.04	1.11	1.29	1.10	1.06	1.21	1.36
Rural04	1.09	1.04	1.12	1.32	1.12	1.06	1.24	1.41

The TTI_{95} for all segments for both base and future years is provided in Table 10. The reference travel time is the travel time at the poste speed. The travel time based on the TTI_{95} is TT_{95} and Added Time is the difference in travel time between TT_{95} and the reference travel time.

Table 10: Planning Time Index Summary – 2014 & 2034

	Length	Reference	2014			2034		
	(miles)	Travel Time (min)	TTI_{95}	Travel Time @ TTI_{95} (min)	Added Time (min)	TTI_{95}	Travel Time @ TTI_{95} (min)	Added Time (min)
Corridor	73.72	88.8	1.21	111.9	18.6	1.31	120.8	27.1
Madras	1.92	6.5	1.38	9.6	2.5	1.43	9.9	2.8
Rural01	22.10	24.7	1.33	32.9	8.2	1.47	36.3	11.7
Redmond	5.39	6.4	1.21	8.8	1.4	1.29	9.3	1.8
Rural02	7.78	8.5	1.02	8.7	0.2	1.05	8.9	0.4
Bend	10.54	13.4	1.24	18.2	3.2	1.41	20.5	5.6
Rural03	17.40	20.9	1.15	24.1	3.2	1.20	25.1	4.1
La Pine	5.83	8.2	1.29	10.5	2.4	1.36	11.1	3.0
Rural04	2.76	0.2	1.32	0.3	0.1	1.41	0.3	0.1

Using the Bend area as an example in Table 10, the US-97 alignment through Bend is 10.54 miles in length. Assuming that a traveler maintains the speed limit along the entire length (i.e., not needing to slow down or stop at the signalized intersections) they should normally be able to traverse the segment in 13.4 minutes. The PTI (i.e., TTI_{95}) for the Bend area is 1.24 and 1.41 for the 2014 and 2034 analysis years, respectively. Using PTI to account for the variability in the travel time, the traveler should allow an additional 3.2 minutes @ $TTI_{95} = 1.24$ to ensure traversing the entire Bend area 95% of the time for the 2014 base year. The additional time surges to 5.6 minutes for the 2034 future analysis year with $TTI_{95} = 1.41$. A traveler in 2034 should expect to take an additional 2.5 minutes (i.e., 75% increase in the additional travel time) to achieve the same 95th percentile travel time as observed in 2014.

NOTE: These values only cover travel on US-97 and do not include potential delay on other streets off US-97.

BUFFER INDEX

BI is closely related to the PTI. It is typically considered the percentage of extra time that a traveler needs to add to a trip to ensure a 95% on time arrival. It is the cushion of travel time that reasonably accounts for the worst travel conditions due to the varying congestion and delay issues on the transportation system.

$$BI = \frac{\text{95th Percentile Peak Travel Time} - \text{Average Travel Time}}{\text{Average Travel Time}}$$

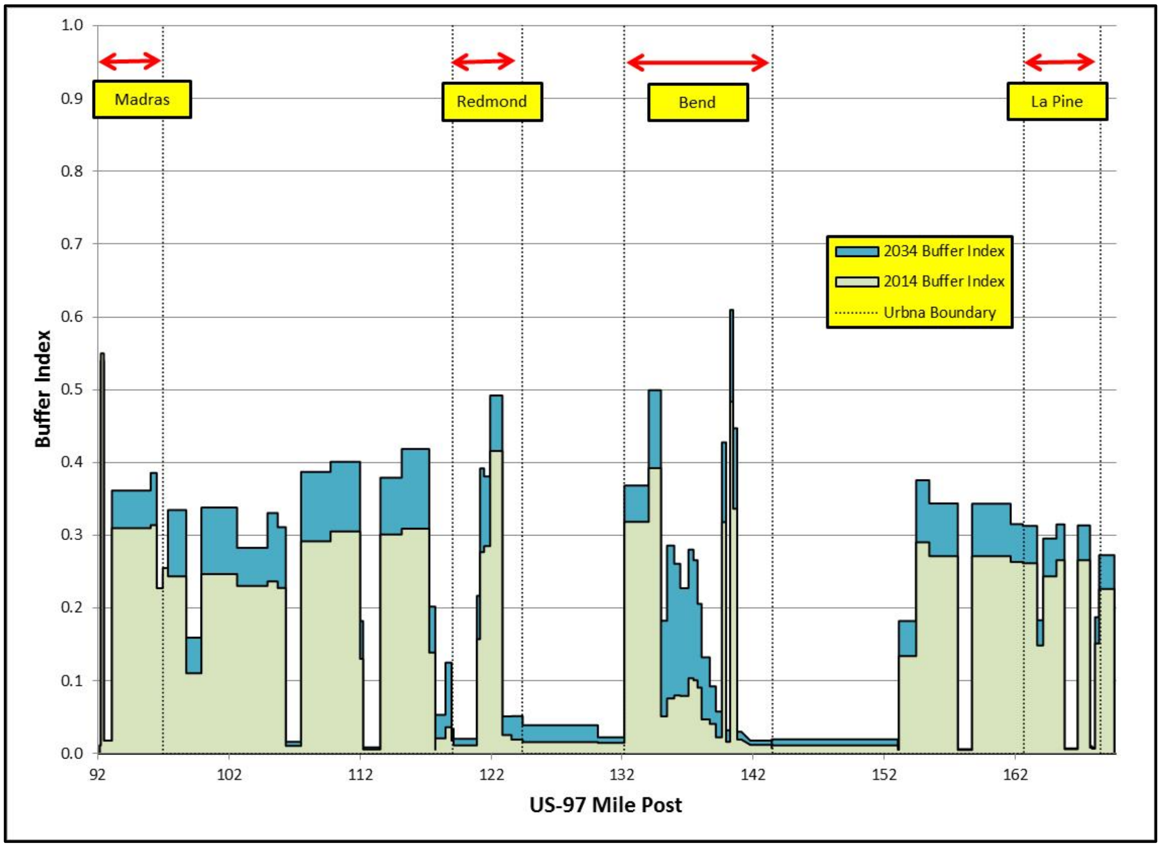
The BI is a percent factor that provides the buffer time when applied to the average travel time. Using the numbers from the PTI example, with a 95th percentile peak travel time of 20 minutes and an average travel time of 8 minutes, the BI is 1.5. The extra cushion of time is the BI times the average travel time (1.5*8), or 12 minutes.

The following equation from the SHRP 2 Project L05 report has been utilized in this analysis:

$$\text{Buffer Index} = (TTI_{95} - TTI_m) / TTI_m$$

The buffer index profile is provided in Figure 13 as a quick way to evalaute the locations that show the greatest variation in travel time on the corridor alignment for the 2014 and 2034 analysis periods.

Figure 13: Buffer Index Profile on US-97



The difference in BI between the 2014 and 2034 analysis periods is the area under the 2034 curve in Figure 13, minus the area under the 2014 curve. A summary of the average BI for each analysis year, weighted by VMT, and the percent difference between the analysis years are provided by area in Table 11.

Table 11: Buffer Index Summary* – 2014 & 2034

	2014 (%)	2034 (%)	%Diff
Corridor	13	18	40
Madras	22	25	13
Rural01	21	28	34
Redmond	13	17	28
Rural02	2	4	128
Bend	15	25	68
Rural03	10	12	22
La Pine	19	22	20
Rural04	21	26	22

* Weighted by VMT

Where:

Rural01 – Segment between Madras and Redmond
Rural02 – Segment between Redmond and Bend
Rural03 – Segment between Bend and La Pine
Rural04 – Segment between La Pine and Jct. OR-31

Using Rural02 as an example, the average BI is 128% higher in 2034 than in 2014. A quick look at Figure 13 reveals that the percent difference is uniformally spread across three quarters of the Rural02 alignment, however, the overall averages are small indicating that there is little variation in travel time through this area.

The average BI for the Bend area is 68% higher in 2034 than in 2014. A quick look at Figure 13 reveals that the percent difference is not uniformally spread across the Bend area; this is a simple approach to highlight the segments on the corridor alignment with the greatest varation in 2014 and 2034.

Conclusion

The HERS-ST model is an excellent tool for evaluating base and future year performance criteria, such as delay. The tool is a good choice for assessing base and future MAP-21 performance targets associated with pavement and congestion, and also demonstrates exceptional potential for reliability applications. HERS-ST is also a good choice for the scenario analysis and strategic planning expectations associated with PBPP.

HERS-ST can provide reasonable analysis for inadequate base capacity (40%), incidents (25%), and traffic control devices (5%), which make up 70% of the causes of delay on most roadway systems. The effects of weather, work zones, and special events can be evaluated by adjusting the capacity and/or demand input data. The probabilities and impacts from the various delay events can be modeled through an automated batching process that can run numerous scenarios associated with the likelihood that different combinations of delay events occur.

Though HERS-ST does not directly calculate performance measures associated with reliability analysis, such as Travel Time Index (TTI) and Planning Time Index (PTI), the delay elements from HERS-ST outputs can be used in post-processing analysis to develop TTI and PTI values.

There are proposed intersection improvements for US-97. A signalized intersection added in La Pine, and two signalized intersections in Bend were to be replaced with interchanges. Since the completion of the project analysis the signal has been added in La Pine. The proposed intersection changes in Bend have not been completed. These improvements would influence the 2034 analysis.

References

Cambridge Systematics, Inc. *SHRP 2 Project L05: Incorporating Reliability Performance Measures into the Transportation Planning and Programming Process, Technical Reference*. Strategic Highway Research Program (SHRP 2), Transportation Research Board of the National Academies, 2014. https://www.trb.org/Main/Blurbs/168856.aspx

Cambridge Systematics, Inc., Weris, Inc., and Economic Development Research Group, Inc.. *SHRP 2 Project C11: Reliability Analysis Tool: Technical Documentation*. Strategic Highway Research Program (SHRP 2), Transportation Research Board of the National Academies, January 2013

Federal Highway Administration. *"Guide for Highway Capacity and Operations Analysis of Active Transportation and Demand Management Strategies,"* FHWA-HOP-13-042, Washington, D.C., June 2013.

Federal Highway Administration. "*HERS-STv5: Highway Economic Requirements System – State Version: User Guide,"* Washington, D.C.: US DOT/FHWA, September 2014

Federal Highway Administration. 2006. "*Highway Economic Requirements System – State Version: Technical Report,"* Washington, D.C.: US DOT/FHWA, August 2005

APPENDIX A – General HERS-ST Analysis Concepts[9].

Average Speed

The speed procedure within HERS-ST is based on a simplified version of the Aggregate Probabilistic Limiting Velocity Model (APLVM) and covers two distinct processes, free-flow speed (FFS) and average effective speed (AES). The FFS estimation is developed to reflect the average unconstrained speed that exists on the highway system in the absence of any other traffic or geometric influences. The FFS estimates are then adjusted to account for the effects of grades, congestion delay and traffic control devices to produce the AES for each roadway segment.

Several key data elements affect speed, including vehicle type, curves, grades, pavement surface quality, speed limits, congestion and traffic control devices. There are three controlling factors in the APLVM that potentially limit the free speed on a roadway section: curves, pavement roughness and posted speed limit. All of these factors have the potential of lowering the sectional speed estimate.

A vehicle traveling through a curved roadway section is subject to a centrifugal force that acts against the vehicle, forcing it to leave the curved path of the roadway. The higher the vehicular speed entering the curve, the heavier the vehicle, and the sharper the curvature of the road, the greater the external force acting upon the vehicle. This results in a reduced FFS for the roadway section.

When the pavement is smooth and the curvature is low (below two degrees) the average speed is governed by the posted speed limits. This model does not explicitly consider enforcement.

HERS-ST evaluates speed individually for each of the seven vehicle types, per direction of travel, than aggregates the individual speeds to calculate operating and travel time costs.

HERS-ST evaluates delay based on six types of highway characteristics associated with number of lanes and the type and presence of traffic control devices:

- Sections with stop signs, covering urban arterials with unsignalized intersections.
- Sections with traffic signals, covering urban arterials with signalized intersections.
- Sections with stop signs and traffic signals, covering both urban arterials with unsignalized intersections and urban arterials with signalized intersections.
- Free-flow sections, one lane per direction, covering two-lane rural sections
- Free-flow sections, three-lane two-way, covering two-lane rural sections and modified freeways and multilane rural highways.
- Free-flow sections. Two or more lanes per direction, covering freeways and multilane rural highways.

---

[9] HERS-ST model uses six internal models: Fleet Composite Model, Widen Feasibility Model, Capacity Model, Pavement Deterioration Model, Speed Model and Travel Forecast Model

Average Delay

There are three kinds of delays estimated in HERS-ST:

- Zero-volume delay is the delay associated with traffic control devices. This is the expected delay that a single vehicle would encounter even if it were the only vehicle on the road. Zero-volume delay only exists for sections controlled with stop signs or traffic signals and is not calculated for uncontrolled sections.
- Incident delay is the delay associated with crashes. HERS-ST estimates delay due to crashes through a secondary (or inferred) process where the HERS-ST model estimates the delay cost of crashes and then back-calculates the delay estimates due to crash incidents from the cost calculations.
- Other congestion (or recurring) delay is the average delay due to non-incident congestion.

Total daily traffic is broken into three phases, or demand periods, for all delay and speed analysis:

- Peak period analysis in the peak direction.
- Peak period analysis in the counter-peak direction.
- Off peak analysis in both directions.

Capacity

HERS-ST calculates peak capacity as a two-way capacity for rural roadway segments with fewer than four lanes. The peak capacity is a one-way (peak direction) capacity for urban and rural multi lane roadway segments.

The general capacity analysis is based on the "Procedures for Estimating Highway Capacity" found in Appendix N of the HPMS Field Manual[10], updated to incorporate algorithms from the 2000 Highway Capacity Manual (HCM2000).

Volume-to-Capacity Ratio (VCR)

HERS-ST incorporates revised HCM2000 equations to calculate peak-hour capacity for each roadway segment, for each travel direction. The model then estimates a VCR for the peak and counter-peak directions separately for signalized arterials or for free-flow sections with two or more lanes per direction.

Total peak traffic is broken into two phases for all VCR calculations:

- Peak period analysis in the peak direction.
- Peak period analysis in the counter-peak direction.

[10] https://www.fhwa.dot.gov/ohim/hpmsmanl/appn.cfm.

APPENDIX B – HERS-ST Batching Process

There are two types of output provided by HERS-ST, Section Condition analysis and System Condition analysis. It is important to distinguish between the two because there are significantly different delay analysis elements available to the analyst based on which type of output is selected.

The Section Condition output provides detailed analysis of the highway system at the dataset record level (i.e., for each section of input data) for each funding period (generally 5 years). The output provides a section-by-section description of numerous data elements such as type of deficiencies evaluated, and type and cost of improvements simulated. The total daily traffic is broken into three demand periods for all capacity, speed and delay analysis: peak period in the peak direction, peak period in the counter-peak (opposite) direction and off-peak. However, the peak/off-peak analysis is only available for multilane roadways (2 lanes or more per direction). Only the average speed, capacity and delay are available for standard two-lane, two-way highways.

The System Conditions output aggregates the detailed record level data (section data) identified in the Section Condition data to a level, aggregated by functional classification and funding period. The System Condition analysis provides an aggregated analysis for the entire system (be it a corridor system or a representation of some type of district or region boundary area) for the entire analysis period (generally 20 years). The output table describes the system information or statistics such as the total vehicle miles of travel, total cost of improvements, simulated pavement conditions, and the total amount of delay on the system.

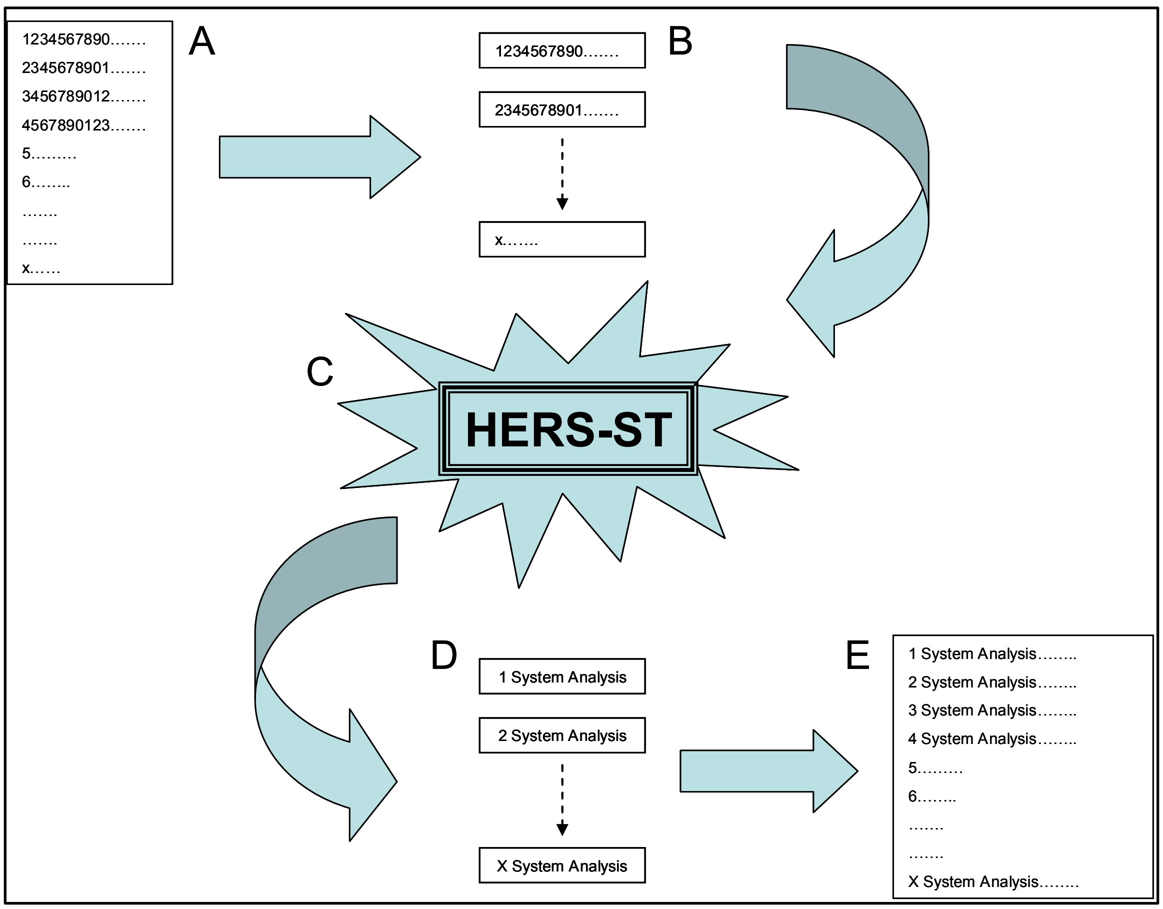
For CMS, the most important set of data elements produced from the System Conditions are associated with delay. There are three kinds of delay estimated in HERS-ST: zero, incident, and congestion. Zero-volume delay is the delay associated with traffic control devices (stop signs and traffic signals). Zero-volume is the expected delay that a single vehicle would encounter even if it were the only vehicle on the road. Zero-volume delay only exists for sections controlled with stop signs or traffic signals, and is not calculated for uncontrolled sections. Incident delay is the delay associated with crashes. HERS-ST estimates delay due to crashes through a secondary (or inferred) process, where first HERS-ST model estimates the delay cost of crashes, and then back-calculates the delay estimates due to crash incidents from the cost calculations. Congestion (or recurring) delay is the average delay due to non-incident congestion.

There are two delay procedures used within HERS-ST. The first process is used for all freeways, sections with traffic signals (no stop signs), and other multi-lane sections where there are two or more lanes per direction of traffic flow. These delay procedures generated delay estimates for incident delay (and the “NonIncident Travel Rate”, which is the inverse of speed) during the three demand periods; peak, counter-peak and off-peak at the sectional level (i.e., Section Condition output). The second process is used to generate separate estimates of zero-volume delay, incident delay and recurring congestion delay at the system level for all other roadway configurations, which are predominately two-lane, two-way highways (i.e., System Condition output).

NOTE: The zero volume, incident and congestion delay elements can only be gathered from the System Condition output.

A number of data elements required for the performance measure calculations are automatically outputted in the sectional condition data files. However, several key delay data elements are only available at the aggregated system condition level. In order to capture the key delay information at the individual disaggregated record level, each record must be analyzed as a pseudo dataset using HERS-ST. In order to accomplish this, the initial HPMS formatted dataset must be parsed out to a number of single record HPMS datasets, each containing a single row of data.

Figure B-1: HPMS Dataset Parsing Analysis Process



ODOT developed a parsing process, using R-script, to:

- disaggregate the original HPMS dataset into individual datasets,
- run a batch program for HERS-ST analysis and
- (re)aggregate the individual System Condition output back into a dataset that can be linked back to the original HPMS dataset.

This parsing or disaggregated process can be seen in Figure B-1, and will be quickly described below.

The process begins with a standard HPMS dataset, identified as A, (see Figure B-1).

As an example, if there were 500 records in the original HPMS dataset, this process would parse out the data into 500 separate HPMS datasets, each dataset containing one single record (i.e., row of data), shown as B. Each individual HPMS dataset is then run through HERS-ST (see C) to develop the delay elements identified in the System Condition output (see D**).** In this example, the HERS-ST batch process evaluates 500 datasets and creates 500 separate outputs; the R-script joins (or aggregates) the individual HPMS datasets back to a single dataset level to match the original HPMS dataset; and the 500 individual files are aggregated back into a single file containing 500 records (see E**)**. At this point the redeveloped dataset contains the delay elements for each record, which are only available at the higher system level. Each individual record is treated as if they were an entire system unto themselves.

Oregon Department of Transportation

US 97 Benefit-Cost Analyses Using HERS-ST

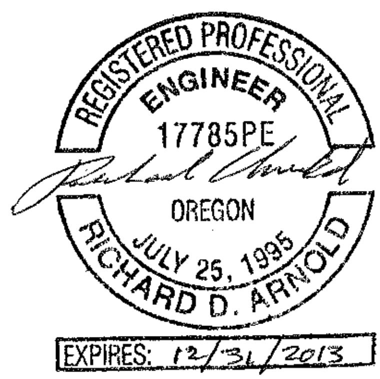
Rev November 2013

Prepared by:
Oregon Department of Transportation
Planning Section
Transportation Planning Analysis Unit

Transportation Planning Section
Transportation Development Division, Salem, Oregon

For more information about the *US 97 Benefit-Cost Analyses Using HERS-ST*, contact:

Richard Arnold P.E., Senior Transportation Analyst
Transportation Planning Analysis Unit
Oregon Department of Transportation
555 13th Street N.E., Suite 2
Salem, Oregon 97301-4178
richard.arnold@odot.state.or.us



 This project was funded in part by the Federal Highway Administration, U.S. Department of Transportation.

Table of Contents

List of Figures

List of Tables

List of Acronyms

AADT	Average Annual Daily Traffic
AES	Average effective speed
APLVM	Aggregate Probabilistic Limiting Velocity Model
BCR	Benefit-Cost Ratio
BMPO	Bend Metropolitan Planning Area
CRAC	Crash Costs
EIS	Environmental Impact Statement
FFS	Free-flow speed
FHWA	Federal Highway Administration
HCM	Highway Capacity Manual
HERS-ST	State version of the Highway Economic Requirements System
HPMS	Highway Performance Monitoring System
MPH	Miles per hour
ODOT	Oregon Department of Transportation
OPC	Operating Costs
ROW	Right-of-way
RV	Residual Value
TPAU	Transportation Planning Analysis Unit
TTC	Travel Time Costs
TUC	Total User Costs
VCR	Volume-to-capacity ratio
VMT	Vehicle miles traveled

Executive Summary

Over the past decade, the northern area of the City of Bend has undergone considerable business growth and change. The area known locally as the "Cooley Triangle" has been the location of choice for many retail organizations moving into this Central Oregon community. With growth comes traffic and increased congestion, which only adds to the current congestion issues. The location makes it extremely attractive for future retail development, which will result in greater congestion. Traffic analysis of this area is important for planning how the area develops, grows and flows.

This project analysis evaluated changes in long-range system performance measures and looked at economic benefits for improving the roadway system based on a generic benefit-cost ratio (BCR) concept. A number of system performance measures were evaluated using the state version of the Highway Economic Requirements System (HERS-ST). Based on the BCR concept, the analysis looked at economic benefits for two roadway scenarios:

- The No-Build Scenario was the existing roadway system, with no signal or widening improvements.
- The Build Scenario added a new bypass alignment, as well as some moderate widening and intersection signalization improvements, on several roadway systems within the immediate area.

The HERS-ST model evaluated each scenario as if it were operational at the beginning of the analysis period. The analysis addressed the question, "What is the long-range system user costs and performance for this condition?"

The regional significance of the US 97 bypass project and five roadway alignments were identified as key transportation facilities for analysis within the immediate area of the proposed project. Both Build and No-Build scenario datasets were developed for the five alignments and the HERS-ST model was used to evaluate and compare the system condition and performance for each alignment, as well as the total user costs. The average segment peak speed, peak delay, and volume-to-capacity ratio (VCR) analyses showed reasonable improvement for the Build scenario, as compared with the No-Build scenario.

The performance improvements are due to the added bypass alignment and the other improvements to the local infrastructure that enhance the flow in and through the project area. The bypass alignment pulls a large number of trips off the existing US 97 alignment that are considered "pass-through" trips because they do not stop within the project area. Pulling the pass-through trips out of the general flow has advantages both to the general performance of the regional system and to safety and travel cost savings as well. As a result of the improved flow, the travel time, operational costs and crash costs are reduced for the general users of the facilities, which can be directly measured with the BCR analysis.

The capital improvement cost was evaluated using two different contingency costs: 25% and 40%. The analysis showed a BCR range of 1.48 and 1.40 for a 25% and 40% contingency, respectively. These numbers are rough estimates for high level planning purposes. A detailed analysis should be conducted to develop a precise BCR.

THIS PAGE LEFT INTENTIONALLY BLANK

Introduction

Over the past decade, the northern area of the City of Bend has undergone considerable business growth and traffic change. The area known locally as the "Cooley Triangle" has been a continued location of choice for many retail organizations moving into this Central Oregon community. With growth comes increased traffic and its associated congestion. There are existing congestion issues in this area, and its attractiveness for additional retail development will only lead to greater congestion issues in the future. Traffic analysis of the area is important in planning for the area's development, growth and traffic flow.

Numerous studies have been developed for this northern Bend area over the years, resulting in the US 97/20 Refinement Plan. The plan indicated a need for a new bypass around the area rather than reliance on improvements to the existing facility to meet all the traffic needs. This plan transitioned into the US 97 Bend North Corridor Environmental Impact Statement (EIS), which looked at many different project scenarios before settling on the east corridor alternative.

The original costs for the larger-scale alternative solutions recommended to address the transportation needs were estimated at $350-$400 million, which far exceeded the region's available funding stream for the next 20 years, so the likelihood of full funding seemed unlikely. The project team sought to investigate smaller-scale solutions that would begin to address the system needs at a more reasonable cost. The HERS-ST analysis was undertaken to help inform decision-makers on the range of funding levels that could produce the highest value to the state[1].

HERS-ST Process

The HERS-ST model uses an input dataset formatted in the standard Highway Performance Monitoring System (HPMS), where each data record represents a unique roadway segment. The analyst defines the timeframe for the HERS-ST analysis period. The general analysis consists of four five-year funding periods for a total 20-year analysis period.

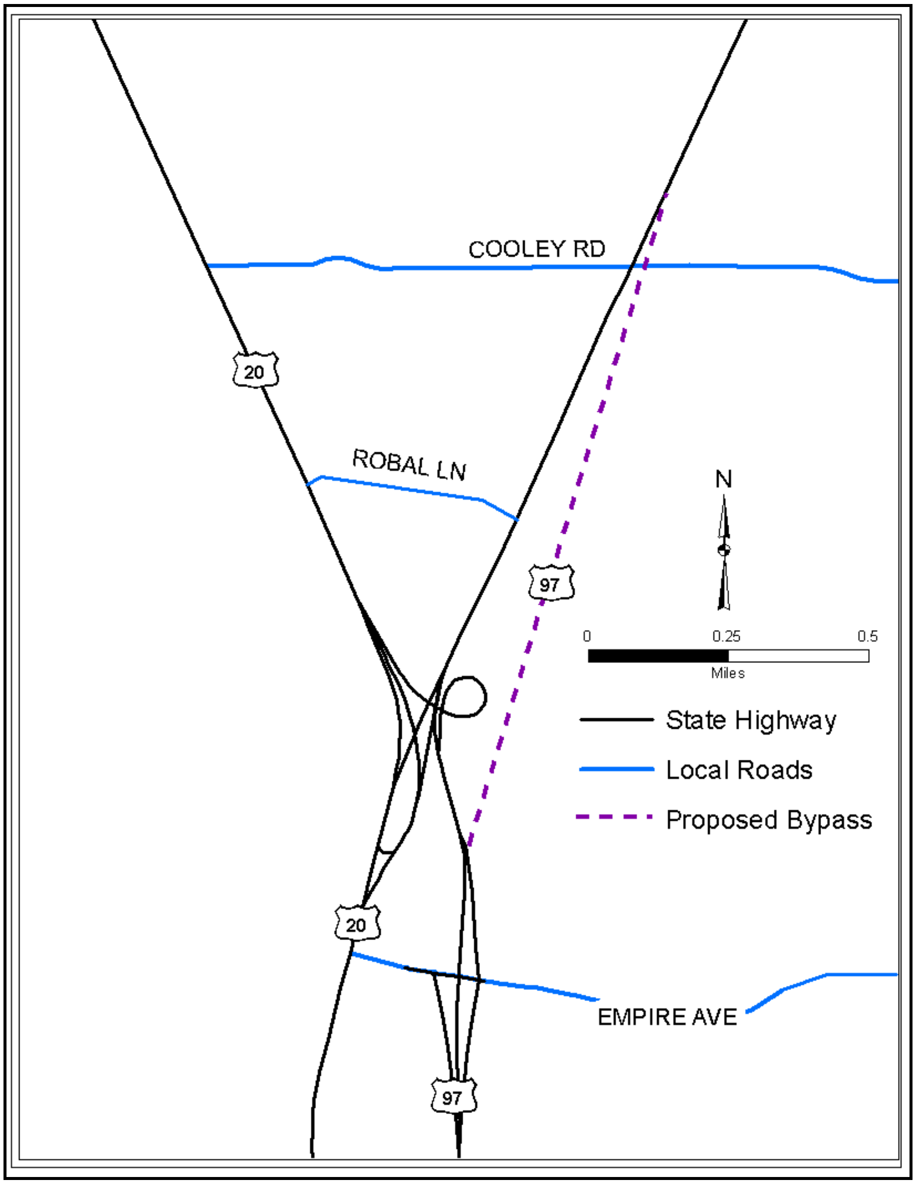
For each funding period, the HERS-ST model evaluates the individual data record one at a time, independent of all other records, to determine potential pavement or capacity deficiencies on the roadway system, as defined by the user. For each deficiency, the HERS-ST model uses a benefit-cost analysis process to evaluate a number of potential improvements to determine economically cost-effective solutions to correct the problem. The best economical improvement is then implemented and simulated in the analysis and the resulting system performance is reported.

[1] This analysis covers the roadway segments within the project footprint.

Analysis Data

The project is located in the north-central area of the Bend Metropolitan Planning Area (BMPO), known locally as the "Cooley Triangle" (see Figure 1). Though the project area currently has congestion issues, the specific location is extremely attractive for retail development, which will result in greater congestion issues in the future. Traffic analysis for this area is essential to evaluate future traffic flows in and through the project area.

Figure 1: US 97 Bend North Corridor (i.e., Cooley Triangle) Study Area



Two scenarios were analyzed for this project:

- No-Build: Reference case reflects the existing system, assuming no additional improvements beyond routine maintenance.
- Build: New bypass alignment, with various local road improvements.

The project improvements include a north-south bypass alignment (see Figure 1), which is situated to the east of the existing US 97 alignment, as well as additional intersection and alignment improvements made to US 20 and other local roadways.

In order to capture the total impacts of the proposed project analysis, the HERS-ST analysis evaluates five individual roadway alignments within the project area:

- US 97: Bowery Lane – Butler Market Road;
- US 20: Old Bend-Redmond Highway – Mervin Sampels Road;
- Cooley Road: US 20 – Boyd Acres Road;
- Empire Avenue: US 20 – Boyd Acres Road;
- Robal Road: Britta Street – Nels Anderson Road.

The base year for the project is 2016 and the horizon year is 2036, which reflects the 20-year analysis period for the project. For a direct comparison both scenarios utilize the same time periods.

The No-Build scenario is the base case that reflects the existing system layout, assuming that no improvements are made other than routine maintenance. Separate HERS-ST input datasets were built for each of the five roadway alignments. The dataset development process began with importing key traffic data elements provided by the Transportation Planning Analysis Unit (TPAU), such as base and horizon year average annual daily traffic (AADT), truck percentages for single units and combinations, peak hour traffic factors, direction factors, signal control locations and lane configurations The input data was checked using the Oregon Department of Transportation's (ODOT) video log and on-line mapping images to ensure that the data correctly reflects the existing condition.

The pavement condition was defined as "perfect" at the beginning of the analysis period in order to minimize improvement analysis within HERS-ST and to avoid introducing an additional complication factor in the BCR analysis. It was generally assumed that the pavement condition would continue to deteriorate over the 20-year analysis period and that resurfacing would be required at or near the end of the analysis period. The local costs for resurfacing, when warranted, use national improvement costs.

The Build scenario is based on the "Alternative East DS2 Modified" traffic analysis data provided by TPAU. Various data element changes were applied to the Build scenario dataset to reflect the proposed project improvements for the roadway systems. The easterly bypass alignment was coded as an urbanized expressway with full access control, and the number of lanes and speed values were coded as two lanes per direction and 45 miles per hour (mph), respectively.

The five roadway alignments were run independently for the two scenarios. There were a total of ten HERS-ST model runs for this analysis project. The purpose of the analysis was to evaluate the relative differences in several key performance measures and the total costs between the two scenarios. The No-Build scenario was the reference datum for comparison with the Build scenario.

In order to develop a reasonable BCR, the user, agency and external costs were collected and compared through a post-process analysis outside of the HERS-ST model. The post-process discussion is presented in Appendix B.

Analysis Process

The Build and No-Build scenarios were run through the Federal Highway Administration (FHWA) HERS-ST (ver. 4.5) modeling software with the primary purpose of developing performance measures and total user costs for each scenario in order to facilitate comparisons.

The HERS-ST model was only allowed to identify pavement deficiencies and simulate resurfacing improvements on the roadway system, as warranted. The global widening feasibility flag was set to "one" so that no additional widening would be allowed on the roadway segments throughout the 20-year analysis period. This ensured that no additional improvement factors were introduced into the analysis to alter evaluations of the performance measures and total user costs.

To simplify the analysis, individual roadway alignments for each scenario were run independently. The post-processing compared performance measures and cost for the Build scenario against the No-Build scenario to evaluate the potential benefits associated with the project. Keeping the timeframe identical for two scenarios reduced the need to discount the improvement benefits back to different time periods and facilitated the post-process analysis of the results.

General Discussion

As a general assumption, the No-Build scenario for all alignments assumes no changes to alignment geometry over the 20-year analysis period. Traffic volumes will increase resulting in greater congestion, reduced travel speeds and increased delay.

The HERS-ST analysis identifies three broad classes of costs: user costs, agency costs and external costs. In all cases for this project analysis, HERS-ST incorporates national values for the various costs and rates. A detailed description of the various costs is presented in Appendix A.

The Total User Cost (TUC) is a sum of three subcategories: Travel Time Costs (TTC), Operating Costs (OPC) and Crash Costs (CRAC). The TTC is simply the cost of travel. The OPC is a function of numerous variables that can be adjusted by the analyst and includes the cost to the user of fuel and oil consumption, tire wear, vehicle maintenance and repair, and depreciation. The benefit associated with an increase in the speed is likely to be balanced with a disbenefit associated with an increase in vehicle operating costs. CRAC and crash rates are a function of safety issues on the roadway system. By removing conflict points, both crash rates and costs are generally reduced.

Agency costs are closely associated with the reduction in the cost of routine maintenance. External costs are a reflection of pollution damages associated with vehicle emissions. HERS-ST employs a set of tables to specify the national average cost of air pollutant emissions on each functional class generated per vehicle-mile, by vehicle class, and operating at various speeds. HERS-ST uses the projected mix of vehicle classes and the average speed of travel on each section to determine the average cost of emissions per vehicle-mile. This value is then multiplied by the total vehicle-mile forecasts to calculate the total cost of air pollutant emissions generated by travel on the section.

The benefits for this project are defined as a reduction in costs as a result of the implementation of an improvement, which is measured as the difference in total 20-year costs between the No-Build scenario and the Build scenario. The summation of the three cost elements for the No-Build scenario is subtracted from the summation of the same three elements for the Build scenario. The result is defined as a benefit (if positive) or disbenefit (if negative). Of the three cost categories (i.e., user costs, agency costs and external costs) the user costs control the benefits calculations, making up 99% of the total costs. Though the agency and external costs are important for other considerations, changes to user costs are essential for defining BCR.

US 97 User Costs

The No-Build scenario evaluated the existing US 97 alignment, whereas the Build scenario included both the “new” US 97 bypass alignment in addition to the “old” original alignment. The old highway segment was included in the Build scenario for the solo purpose of being able to capture the complete performance differences between the two scenarios that is associated with shifting of trips from the “old” to the “new” alignment. As an example, using a point just south of the Cooley Road intersection on the existing roadway, the 2036 AADT is 50,800 for the No-Build scenario and 23,000 for the Build scenario. This would suggest that 27,800 trips (55%) shift to the “new” bypass alignment defined in the Build scenario. However, the Build scenario analysis shows 42,000 trips on the “new” bypass, immediately adjacent to the point on the existing alignment. When the traffic on the “new” bypass is summed with the traffic on the “old” alignment, the Build scenario shows a 30% increase in total north-south flow through the area just south of Cooley Road.

In reality, a phenomenon called induced demand factors into the analysis such that as the roadway capacity on a system improves and traffic movement is freed, additional trips will be attracted to and through the area.

There are two components for the US 97 Build scenario. The first component compares the flows exclusively on US 97 between the two scenarios, i.e., the traffic flow that shifts from one alignment to the other. With the inclusion of the bypass alignment, the overall flow will be good, the speeds will be higher and the congestion and delay will be reduced, significantly improving the performance conditions on the rerouted US 97. The second, and more important component, is an analysis of how the performance on the existing alignment changes once the bypass is introduced into the analysis.

It is important to keep in mind that the 42,000 trips on the “new” bypass are predominately pass-through trips that do not stop within the study area, whereas the remaining 23,000 trips on the “old” alignment are coming from, or going to, places within the study area. It is important to track both alignments.

Analysis on the US 97 alignment reflects a 25% increase in system capacity to the current roadway system with the addition of the “new” US 97 bypass alignment in the Build scenario. The Build scenario shows a 9% increase in total peak VMT at the end of the 20-year analysis period. The VMT increase is due to the significant shift in travel from the “old” 3rd Street alignment to the “new” bypass alignment.

Using national safety statistics, HERS-ST evaluates the safety element of the roadway improvement by projecting changes in three crash rates: property damage only, injuries and fatalities. The three crash rates are defined within HERS-ST as the rate of which crashes, injuries and fatalities occur per 100 million VMT. Because the bypass alignment is expected to include controlled access to the system, the alignment analysis anticipates a significant reduction in conflict points, resulting in a reduction to the projected crash rates for the roadway system. The reduction crash rate ranges from 13% for fatalities (per 100 million VMT), to 20% for other injuries. This equates to an overall 15% net reduction in crash costs over the 20-year analysis period.

The reduction in the crash rates also contributes to a 41% reduction in average hours of incident delay. The inclusion of the access control element for the bypass alignment also results in a 10% reduction of zero-volume delay associated with intersections and stop/start cycles. The other-delay, which is generally associated with congestion, is reduced by 45% because of the shifting of trips to the bypass alignment. The bypass pulls the through trips from the 3rd Street alignment that fronts the shopping area and improves the travel flow for both alignments.

Over 99% of the total 20-year costs are associated with the TUC, which accounts for the travel time, operating and crash costs for the roadway alignment. The total 20-year TUC for the Build and No-Build scenarios are $1,457 million and $1,515 million, respectively, resulting in a 4% net saving (or benefit) in user costs between the two scenarios. Even though the VMT and the lane miles are increased for the Build scenario, the total user costs declines. This is directly associated with the improved overall flow on the system through the area, such as the access control element that reduces the conflict points and the stop/start cycles, and the shifting of through trips from the congested areas to a higher speed system.

US 20 User Costs

The Build scenario improvements include widening on US 20 and the addition of a signal at Cooley Road.

The Build scenario shows a net benefit of 7% ($53,600,000) when the total costs are compared with the No-Build scenario on US 20. The induced demand factor associated with the Build scenario increases the overall traffic flow by 8% on the US 20 roadway system, which equates to a reduction of 1% and 44% for the TTC and CRAC, respectively. The system improvements also demonstrate a 62% and 40% reduction in average hours of both incident and congestion delay, respectively.

Cooley Road User Costs

The Build scenario improvements include a new signal at US 20 and a four lane widening of the sections from US 97 west to Hunnell Road and from US 97 east to Boyd Acres Road.

The difference in total cost between the Build and No-Build scenarios show a net benefit of 8% ($14,300,000), which indicates the improvements to the Cooley Road produce a positive impact to the traffic flow in the area. The 20-year peak VMT for the Build scenario is reduced by 4%, which equates to a reduction of 9% for the TTC, 7% for the OPC and 2% for the CRAC. The system improvements also demonstrate a 36% reduction in average hours of both incident and congestion delay.

Empire Avenue User Costs

The Build scenario improvements include a new signal at the US 97 south bound on-ramp.

The Build scenario shows a net benefit of 6% ($13,300,000) when the total costs are compared with the No-Build scenario on Empire Avenue. The 20-year VMT for the Build scenario is reduced by 6%, which equated to a reduction of 11% and 4% for the TTC and OPC, respectively. Though there appears to be a slight increase in CRAC of 2%, which seems to be associated with the additional signalization improvements, the zero-delay only increased by 4%, while the average hours of incident delay are reduced by 55% and congestion delay are reduced by 32%.

Robal Road User Costs

For Robal Road, the Build scenario shows a net benefit of 9% when the total costs are compared with the No-Build scenario, which is a savings of -$4,700,000. The 20-year peak VMT for the Build scenario is reduced by 1%, which results in a 10% reduction for TTC, a 7% reduction for OPC and a 6% reduction for CRAC. The zero-delay decreased by 6%, while the average hours of incident delay are reduced by 51% and congestion delay is reduced by 34%.

Benefit-Cost Summary

All five roadway alignments demonstrate a cost savings benefit by virtue of the reduction of total costs (see Table 1).

Table 1: Percent Difference in Total Costs – 20-Year Summary[2]

Percent Reduction in Total Costs (%) Between Build and No Build Scenarios					
Costs Categories	**US 97**	**US 20**	**Cooley Rd**	**Empire Ave**	**Robal Rd**
Total User **(x $1,000)**	-4% (-$60,150)	-7% (-$53,740)	-7% (-$14,270)	-5% (-$13,280)	-9% (-$4,710)
Agency* **(x $1,000)**	38% ($2,000)	21% ($10)	37% ($10)	20% ($2)	0% ($0)
External **(x $1,000)**	1% (-$80)	3% (-$110)	-7% (-$50)	-4% (-$30)	-6% (-$10)
Total Costs **(x $1,000)**	-3% (-$58,100)	-7% (-$53,600)	-8% (-$14,300)	-6% (-$13,300)	-9% (-$4,700)

* Maintenance costs increase due to the new and improved

Because the TUC accounts for 99% of the total costs, changes within the agency and external costs contribute very little to the overall benefit analysis. Ignoring the latter two for the moment, the TUC can be primarily broken into three areas: TTC, OPC, and CRAC. The general ranges are 50-60% for TTC, 20-35% for OPC and 15-25% for CRAC. Of these three groupings, the contribution of the TTC is approximately twice the contribution of OPC and about three times that of CRAC. This suggests that though the TTC costs are the controlling factor, they are not overwhelmingly so, as compared with the TUC's overwhelming influence on the total cost calculations. This makes for an interesting dilemma because the general expectation is that as travel flow improves on a

[2] A negative number represents a reduction in costs and a positive number is an increase in costs.

system; the TTC would inversely decrease, resulting in travel time savings. However, as the travel flows increase (i.e., higher speeds), so does the OPC (i.e., higher operating costs) for a given scenario. Using the US 97 values in Table 2 as an example, the TTC decreases by 4% as a result of building the bypass alignment; the traffic flow throughout the area improves, while at the same time the OPC increases by 2%.

Table 2: Percent Difference in Total User Costs – 20-Year Summary[3]

Percent Reduction in Total User Costs Between Build and No Build Scenarios					
Costs Categories	**US 97**	**US 20**	**Cooley Rd**	**Empire Ave**	**Robal Rd**
Travel Time (TTC)	-4	-1	-9	-11	-10
Operating (OPC)	2	7	-7	-4	-7
Crash (CRAC)	-15	-44	-2	2	-6
Total User Costs **(x $1,000)**	-4% (-$60,100)	-7% (-$53,700)	-7% (-$14,300)	-5% (-$13,300)	-9% (-$4,700)

Residual Value

The final factor in the BCR equation is the residual value (RV), which addresses the capital value of the project that remains at the end of the analysis period and covers continued future value of improvement beyond the analysis period. This is an important asset management measure that attempts to capture a pseudo-salvage value of an improvement discounted back to the beginning of the analysis timeframe (similar to getting credit for the unused portion of an investment).

For the purpose of this analysis, the RV is a function of the capital improvement cost. The estimated construction costs were provided with two construction cost contingencies, 25% and 40%. It will be assumed that the total project costs cover the $76.6 million purchase price for procuring right-of-way (ROW) for the Build scenario; $9.4 million of the construction costs are dedicated to structural construction (i.e., overpasses and ramps); and the remaining $46.8 million accounts for standard earthwork, pavement construction and overlay costs, signalized intersections and general additional construction costs. Construction and preliminary engineering is expected to cost between 20-25% of the total construction costs; these costs are not included in RV.

Right-of-Way

The Asset Management Unit acknowledges that the value of land has an indefinite life. However, they prefer to treat it from an accounting perspective as a land asset rather than as a residual value. Because the ultimate purpose of this analysis is to look specifically at the project's costs and benefits, the ROW is assumed 100% RV. The land that is acquired as part of the project costs will not lose its value and can be sold for

[3] A negative number represents a reduction in costs and a positive number is an increase in costs.

development at a later time if the roadway were to be removed. Any loss in value is assumed to be negligible and is ignored.

Utilities costs are also included in this category, such that the total estimated ROW costs are $80.45 million, of which 100% is RV.

Bridge/Structures

ODOT has changed how they account for infrastructure assets. A residual value is no longer used for bridges. A useful life of 75 years is assigned for new structures. Because this project analysis period only covers 20 years, all structures, at a minimum, will still have 55 years of service value. A web review found an 80% RV is used, so this analysis applies the 80% RV for all bridges/structures.

Retaining and sound walls are also included in this category, such that the total estimated Bridge/Structure costs are $7.55 million, of which 80% is RV.

Roadway

The overall analysis assumes that the pavement condition is perfect for all roadway surfaces at the beginning of the 20-year analysis period. It is anticipated that each alignment will need to be resurfaced at the end of the 20-year analysis period, but that assumption is beyond the scope of this analysis. This assumes the value of the roadway surface will be low at the end of the analysis period. The Asset Management Unit places a 50% RV on the roadway surface layers, but excludes the subsurface foundation layer from RV consideration. The subsurface foundation layers are treated in a similar manner as other structures and are assigned a useful life of 75 years. For the new bypass alignment, the foundation layer will still have 55 years of service value remaining at the end of the 20-year analysis period.

The above reasoning does not seem to consider an RV for the existing roadway alignment. The pavement material can be ground up and recycled. Clearly the road cannot be moved to another location, but its existence will reduce the cost for future generations to (re)build a road at the current location because the land has been acquired, graded, and an aggregate base has been laid.

For high-level planning, this category is considered a "catch-all" for other construction elements, such as signals and other safety features, so a 50% RV is assumed.

Frontage roads and other street improvements are included in this category, such that the total estimated Roadway costs are $46.8 million, of which 50% is RV.

Benefit-Cost Ratio

The capital improvement costs include construction and preliminary costs and unknown contingencies, none of which are included in the RV analysis. The contingencies are provided as bookend, with a 25% and a 40% range; the two ranges are evaluated separately in Tables 3 & 4, respectively.

The benefit-cost ratio (BCR) is the total net benefit of an improvement (defined as a reduction in total costs) plus residual value, divided by the capital cost of the improvement. The summary of costs and benefits are provided in Tables 3 & 4.

Table 3: Summary of BCR – 25% Contingency Costs

Roadway	No-Build ($)	Build ($)	Diff ($)
US 97	1,514,900,000	1,456,800,000	58,100,000
US 20	825,100,000	771,500,000	53,600,000
Cooley Rd.	203,000,000	188,700,000	14,300,000
Empire Ave.	244,000,000	230,700,000	13,300,000
Robal Rd.	54,500,000	49,800,000	4,700,000
Total	**2,841,500,000**	**2,697,500,000**	**144,000,000**
Total Net Benefit			$ 144,000,000
Residual Value			$ 111,400,000
Total Capital Improvement Cost (25% Contingency)			$ 172,600,000
Benefit-to-Cost-Ratio (BCR)			1.48

The BCR for the 25% contingency is 1.48, which is greater than 1.00, so the project has a positive BCR for building.

Table 4: Summary of BCR – 40% Contingency Costs

Roadway	No-Build ($)	Build ($)	Diff ($)
US 97	1,514,900,000	1,456,800,000	58,100,000
US 20	825,100,000	771,500,000	53,600,000
Cooley Rd.	203,000,000	188,700,000	14,300,000
Empire Ave.	244,000,000	230,700,000	13,300,000
Robal Rd.	54,500,000	49,800,000	4,700,000
Total	**2,841,500,000**	**2,697,500,000**	**144,000,000**
Total Net Benefit			$ 144,000,000
Residual Value			$ 111,400,000
Total Capital Improvement Cost (40% Contingency)			$ 182,500,000
Benefit-to-Cost-Ratio (BCR)			1.40

The resulting BCR for the improvement scenario is over one, meaning that the improvement scenario has an acceptable value.

Conclusion

The regional significance of the US 97 bypass project was reviewed and the HERS-ST model was used to evaluate the performance and user costs on five roadway alignments within the immediate area of the proposed project, including the actual bypass alignment.

Two scenarios were developed, reflecting the No-Build and Build conditions, and the results were compared. The average segment speed, delay, and VCR analyses showed reasonable improvement for the Build scenario, as compared with the No-Build scenario. The performance improvements are due to the added bypass alignment and the other improvements to the local infrastructure that improve the flow in and through the project area.

The bypass alignment pulls a large number of trips off the existing US 97 alignment because these trips do not stop within the project area. These are considered "pass-through" trips because they are using the facility to travel from one end of the project area to the other with minimal interruptions. Pulling the pass-through trips out of the general flow has advantages to the general performance of the regional system as a whole, and also to safety and travel cost savings. As a result of the improved flow, the travel time and operational and crash costs are reduced for the general users of the facilities, which can be directly measured with the BCR analysis.

Two capital improvement costs were evaluated, where the difference was in the projected contingency costs. The analysis found a BCR range of 1.40 and 1.48 for a 40% & 25% contingency, respectively. These numbers are rough estimates for high level planning purposes. A detailed analysis should be conducted to develop a precise BCR.

References

U.S. Department of Transportation: Federal Highway Administration. 2005. "Highway Economic Requirements System – State Version: Technical Report," August 2005

U.S. Department of Transportation: Federal Highway Administration. 2006. "Highway Economic Requirements System – State Version: User Guide," May 2006

APPENDIX A – General HERS-ST Analysis Concepts

Average Speed

The HERS-ST model consists of a number of individual complex sub-models, including Pavement Deterioration, Safety, and Speed Models[4]. The primary focus for this report is the speed model procedures, as the majority of the US 97 analysis is centered on speed and delay calculations.

The speed procedure within HERS-ST is based on the Aggregate Probabilistic Limiting Velocity Model (APLVM) and covers two distinct processes, free-flow speed (FFS) and average effective speed (AES). The FFS estimation is developed to reflect the average unconstrained speed that exists on the highway system in the absence of any other traffic or geometric influences. The FFS estimates are then adjusted to account for the effects of congestion delay and traffic control devices to produce the AES for each roadway segment.

Several key data elements affect speed, including vehicle type, curves, grades, pavement surface quality, speed limits, congestion and traffic control devices. There are three controlling factors in the APLVM that potentially limit the free speed on a roadway section: curves, pavement roughness and posted speed limit. All of these factors have the potential of lowering the sectional speed estimate.

A vehicle traveling through a curved roadway section is subject to a centrifugal force that acts against the vehicle, forcing it to leave the curved path of the roadway. The higher the vehicular speed entering the curve, the heavier the vehicle, and the sharper the curvature of the road, the greater the external force acting upon the vehicle. This results in a reduced FFS for the roadway section.

When the pavement is smooth and the curvature is low (below two degrees) the average speed is governed by the posted speed limits. This model does not explicitly consider enforcement.

Average Delay

There are three kinds of delays estimated in HERS-ST:

- Zero-volume delay is the delay associated with traffic control devices. This is the expected delay that a single vehicle would encounter even if it were the only vehicle on the road. Zero-volume delay only exists for sections controlled with stop signs or traffic signals and is not calculated for uncontrolled sections.
- Incident delay is the delay associated with crashes. HERS-ST estimates delay due to crashes through a secondary (or inferred) process where the HERS-ST model

[4] HERS-ST model uses six internal models: Fleet Composite Model, Widen Feasibility Model, Capacity Model, Pavement Deterioration Model, Speed Model and Travel Forecast Model

estimates the delay cost of crashes and then back-calculates the delay estimates due to crash incidents from the cost calculations.
- Other congestion (or recurring) delay is the average delay due to non-incident congestion.

Total daily traffic is broken into three phases, or demand periods, for all delay and speed analysis:
- Peak period analysis in the peak direction.
- Peak period analysis in the counter-peak direction.
- Off peak analysis in both directions.

Volume-to-Capacity Ratio (VCR)

HERS-ST incorporates revised Highway Capacity Manual (HCM) equations to calculate peak-hour capacity for each roadway segment, for each travel direction. The model then estimates a VCR for the peak and counter-peak directions separately, for signalized arterials or for free-flow sections with two or more lanes per direction.

Total peak traffic is broken into two phases for all VCR calculations:
- Peak period analysis in the peak direction.
- Peak period analysis in the counter-peak direction.

Total User Costs

For travel time costs, HERS-ST incorporates national U.S. Department of Transportation values of time per person for personal and business travel. The operating costs evaluate vehicle operating costs as a function of cost for fuel and oil consumption, tire wear, vehicle maintenance and repair and mileage-related depreciation. The safety costs use national crash rates to estimate the number of crashes and severity for improved and unimproved roadway segments.

The benefits for each variable are defined as a reduction in costs as a result of the implementation of an improvement. Some improvements might show a savings in one variable, such as travel time, while showing an increased cost (disbenefit) in another variable, such as increased fuel consumption. A reduction in the summation of all three costs is defined as the total benefit for the selected improvement.

Agency Costs

Agency costs include the cost of routine maintenance. A selected improvement may or may not be associated with a reduction in roadway maintenance costs. HERS-ST evaluates this measure for the current funding period and evaluates the potential reduction of improvement costs in future years resulting from the improvement.

External Costs

The HERS-ST model uses national values to estimate the costs to society, such as the costs associated to vehicular emissions (air pollutants) resulting from the implementation of a selected improvement. The air pollution costs are measured as the difference between total pollution costs generated by the forecast volumes of travel on the section under unimproved and improved conditions. Because the cost of air pollutant emissions per vehicle-mile varies by both travel speed and vehicle class, this effect can be negative or positive depending on how a proposed improvement influences forecast travel volumes, the mix of vehicle types and travel speeds.

Capital Improvement Costs

HERS-ST identifies segment deficiencies, evaluates a series of improvements that will correct the condition, and estimates the cost of the highway improvement. The capital improvement costs are simply the construction costs for the selected improvements. When analyzing the economic attractiveness of a potential improvement, the improvement cost is used as the denominator in the benefit-cost equation.

Residual Value (RV)

The little known part of the BCR equation is in the residual value of an improvement. The residual value is the capital value of the improvement that still remains at the end of the final analysis period, and is credited back as the unused portion of the investment. The residual value for an improvement is discounted back to the initial year of the analysis period and treated as a benefit.

Benefit-Cost Ratio (BCR)

HERS-ST defines the benefit-cost ratio of a highway improvement as the discounted sum of the present value benefits for the user, agency and environment divided by the implementation costs of the improvement. For BCR analysis, HERS-ST recognizes four broad classes of costs:

- User costs are the costs incurred by the highway user and include travel time costs, operating costs, and safety costs (i.e., crash costs).
- Agency costs are the on-going roadway maintenance costs borne by the administrative agency responsible for the highway section.
- External costs (emissions costs) are the social costs passed to the non-users of the highway system.
- Residual value is the capital value of the improvement that still remains at the end of the final analysis period.
- Capital improvement costs are the estimated construction costs of the improvement.

The analyst can change many variables and factors[5] within the HERS-ST model that influence user, agency and external costs. The HERS-ST procedure estimates the incremental costs and benefits of each potential improvement for each period of the benefit-cost analysis period, as well as the residual value of the improvement at the end of the analysis period. For BCR, the benefits of an improvement are defined as a reduction in user, agency and external costs as the result of implementing an improvement, and are measured as the difference in costs between the no-improved case and the improved case. The cost variable is the estimated capital improvement cost.

In theory, any project with BCR greater than one is considered a worthy project. However, for this report the HERS-ST BCR is used to reveal the value of a set of alternative projects related to each other.

[5] User parameters affect deficiency levels, design standards, improvement costs, auto and truck growth factors, funding and performance constrains, and weights for highway performance goals.

APPENDIX B – The Process for Evaluating Benefit-Cost Ratio

The overall HERS-ST dataset represented the opening year of the project (2016), which is the condition of the roadway system after the improvements were made. The horizon year is the end of the 20-year analysis period (2036). In order to capture the flow of the traffic through the area, the roadway segments of the project were split out by the following five designated roadway corridors and analyzed separately:

1. US 97: Bowery Lane – Butler Market Road
2. US 20: Old Bend-Redmond Highway – Mervin Sampels Road
3. Cooley Road: US 20 – Boyd Acres Road
4. Empire Avenue: US 20 – Boyd Acres Road
5. Robal Road: Britta Street – Nels Anderson Road

There were two approaches used for calculating BCR.

First Approach

During the initial analysis setup, the analyst determines the number of years and funding periods needed for the HERS-ST model runs. The HERS-ST outputs the condition of the system at the end of each of the defined funding periods. The standard HERS-ST analysis usually evaluates four 5-year funding periods (FP) over a 20-year project analysis period, so with a 2016 base year the standard HERS-ST model evaluates the roadway system conditions over the following four FP:

- FP1: 2017 – 2021
- FP2: 2022 – 2026
- FP3: 2027 – 2031
- FP4: 2032 - 2036

The HERS-ST model evaluates each funding period separately and then outputs data elements representing key system conditions and performance measures at the end of the funding period. In this analysis, the HERS-ST output covers the years 2021, 2026, 2031 and 2036. Because the data for each funding period represents a single year, the results need to be expanded to reflect the total value over the 5-year period.

The first approach simply multiplies the individual cost values at the end of each funding period by a factor of five to simulate a total 5-year cost for that funding period. This approach is subsequently applied for each funding period and all values are summed to achieve a 20-year cost.

Step 1 – Gather the System Output

The HERS-ST model run automatically saves the System Level analysis data (SS1) in the HERS.SS1; which is a standard comma delimited (CSV) text file. The SS1 data was pulled into an Excel spreadsheet and the system summary data was aggregated and analyzed (see Table 5).

Table 5: Summary of Roadway Conditions & Costs for US 97, Build Scenario

	Base Year	At End of Five Year Funding Periods			
	2016	**2021**	**2026**	**2031**	**2036**
Segment Miles	12.7	12.7	12.7	12.7	12.7
VMT (1000)	57,597	63,288	68,733	74014	79,360
Average Speed (mph)	47.1	46.9	46.7	46.5	46.2
Average Delay (Hours per 1000 VMT)					
Zero-Volume Delay	0.310	0.329	0.346	0.359	0.369
Incident Delay	0.202	0.245	0.298	0.366	0.454
Other Delay	0.300	0.325	0.348	0.375	0.410
Total Delay	0.812	0.899	0.991	1.100	1.234
Total Costs ($ per 1000 VMT), except Agency*					
Total User Costs	1016	1028	1042	1059	1067
– Travel Time Costs	522	527	532	539	548
– Operating Costs	358	363	371	380	378
– Crash (Safety) Costs	135	137	138	139	140
Agency Costs*	0	281	667	993	885
External (Emissions) Costs	5.36	5.36	5.36	5.35	5.34
Rate of which crashes/injuries/fatalities occur (per 100 million VMT)					
Property Damage Only	207.2	209.8	211.7	213.6	215.4
All Injuries	82.9	84.0	84.8	85.6	86.3
Fatalities	1.04	1.05	1.05	1.06	1.06

* Exception: Agency Costs are $ per mile

Step 2 – Highlighting Vehicles Miles Traveled and Miles Data

The System Level analysis provides the various costs that are used within the BCR calculations. Both the Total User Costs and External Costs values are provided as “Dollar per 1,000 VMT” and the Agency Costs values are provided as “Dollar per Mile”. The Vehicle Miles Traveled (VMT) and Miles data is needed to convert all costs to the same units.

Step 3 – Calculate Total User Costs

The Total User Costs (TUC) is the total cost to the user of the system and is a summation of the Travel Time Costs (TTC), the Operating Costs (OPC) and the Crash (or Safety) Costs (CRAC). The units are “Dollar per 1,000 VMT”. The TUC for each FP reflects the total user costs at the end of each FP. The TUC is converted to dollars and then multiplied by five to develop an assumed total average for the entire five year period. The final TUC for the 20-year analysis period is the summation of all TUC for all four FP. The example data in Table 5 is from the model run for the Build scenario on US 97.

- FP1 ➔ $1,028 ($/1000VMT) * 63,288 (1000VMT) * 5 Years ➔ $325,300,000
- FP2 ➔ $1,042 * 68,733 * 5 ➔ $358,100,000
- FP3 ➔ $1,059 * 74,014 * 5 ➔ $391,900,000
- FP4 ➔ $1,067 * 79,360* 5 ➔ $423,400,000

- TUC_{Build} ➔ FP1 + FP2 + FP3 + FP4 ➔ $1,498,700,000 (for this scenario)

This step is calculated separately for the No-Build and Build scenarios. Following the same steps for the No-Build scenario, the $TUC_{No\text{-}Build}$ is $1,549,000,000. The total TUC for the Build scenario is 3% less than for the No-Build scenario.

Step 4 – Calculate Total Agency Maintenance Costs

The Agency Maintenance Costs (MNT) is the average annual maintenance costs to the local jurisdiction that owns the roadway system. This cost is generally associated with on-going maintenance costs other than resurfacing. The units are "Dollar per Mile" (i.e., centerline miles). The TUC for each FP reflects the total user costs at the end of the each FP. The MNT is converted to dollars and then multiplied by five to develop an assumed total average for the entire five year period. The final MNT for the 20-year analysis period is the summation of all MNT for all four FP.

- FP1 ➔ $281 ($/Mile) * 12.7 (Mile) * 5 Years ➔ $17,850
- FP2 ➔ $667 * 12.7 * 5 ➔ $42,350
- FP3 ➔ $993 * 12.7 * 5 ➔ $63,050
- FP4 ➔ $885 * 12.7 * 5 ➔ $56,200

- MNT_{Build} ➔ FP1 + FP2 + FP3 + FP4 ➔ $179,450 (for this scenario)

The initial input data calls for a perfect roadway system at the beginning of the 20-year analysis, so the early maintenance costs are lower based on the assumption of an excellent pavement condition. As the traffic flows grow, and the pavement conditions deteriorate, the MNT increases. Note the HERS-ST model simulated a pavement improvement for the fourth FP, which is why MNT for FP4 is less than for FP3. The HERS-ST improvement will be discussed in Step 6.

Step 4 is calculated separately for the No-Build and Build scenarios. Following the same steps for the No-Build scenario, the $MNT_{No\text{-}Build}$ is $129,950. The total MIN for the Build scenario is 38% greater than for the No-Build scenario.

Step 5 – Calculate Total External Emissions Costs

The External Emissions Costs (EMIC) is the average pollution damage costs.

- FP1 ➔ $5.36 ($/1000VMT) * 63,288 (1000VMT) * 5 Years ➔ $1,700,000

- FP2 ➔ $5.36 * 68,733 * 5 ➔ $1,800,000
- FP3 ➔ $5.35 * 74,014 * 5 ➔ $2,000,000
- FP4 ➔ $5.35 * 79,360 * 5 ➔ $2,100,000

- $\text{EMIC}_{\text{Build}}$ ➔ FP1 + FP2 + FP3 + FP4 ➔ $7,600,000 (for this scenario)

Step 5 is calculated separately for the No-Build and Build scenarios. Following the same steps for the No-Build scenario, the $\text{EMIC}_{\text{No-Build}}$ is $7,500,000. The total EMIC for the Build scenario is 2% greater than for the No-Build scenario.

Step 6 – Add HERS-ST Improvement Costs

One of the primary assumptions at the beginning of the 20-year analysis period is that the pavement surface is brand new for the entire roadway system, equating to a perfect pavement condition. As traffic on the system increases throughout the analysis period, the wear and tear on the roadway system intensifies and the pavement condition deterioration rate escalates.

HERS-ST model was allowed to perform additional resurfacing improvements, if the analysis deemed the action to be required. For larger volume roadways, with higher pavement deterioration, the HERS-ST model simulates pavement resurfacing in the FP4; this is never an issue for lower volume roads. The units are $1,000. Note that this is a one time improvement cost and should not be multiplied by five.

- FP1 ➔ $0 ➔ $0
- FP2 ➔ $0 ➔ $0
- FP3 ➔ $0 ➔ $0
- FP4 ➔ $3,178.1 * 1,000 ➔ $2,900,000

- $\text{HERS-ST}_{\text{Build}}$ ➔ FP1 + FP2 + FP3 + FP4 ➔ $2,900,000 (for this scenario)

Step 6 is calculated separately for the No-Build and Build scenarios. Following the same steps for the No-Build scenario, the $\text{HERS-ST}_{\text{No-Build}}$ is $ 900,000.

Step 7 – Calculate Total Costs for Scenario

For each scenario the total costs are simply a summation of Steps 3 - 6.

- $\text{TUC}_{\text{Build}}$ ➔ $1,498,700,000 (Step 3)
- $\text{MNT}_{\text{Build}}$ ➔ $179,450 (Step 4)
- $\text{EMIC}_{\text{Build}}$ ➔ $7,600,000 (Step 5)
- $\text{HERS-ST}_{\text{Build}}$ ➔ $2,900,000 (Step 6)

- Total 20-year Costs ➔ $1,509,000,000 (for this scenario)

Following the same steps for the No-Build scenario, the total No-Build scenario costs are $1,558,000,000, which is 3% greater than for the Build scenario.

Second Approach

The First Approach assumes that the funding period costs are constant across each 5-year FP. However, the VMT will increase over time, across each funding period, as the economical activities grow throughout the area. Though this first approach serves as a quick response process, it also introduces a small level of error into the overall total costs.

The Second Approach assumes a linear growth between the known data points. In this case the known points are the costs at the beginning of the 20-year analysis period (i.e., 2016, which is also considered the base year), and the costs at the end of each of the five FP. The costs for each interim year (i.e., one, two, three, four, etc.) are calculated using a linear regression approach. Then all yearly costs are summed to develop the total 20-year costs. This approach more closely matches the analysis process within the HERS-ST model, which generally utilizes a linear growth process to determine yearly traffic volumes throughout the 20-year analysis period. Note that the traffic growth process within the HERS-ST model can be adjusted by the analyst; any changes made to the HERS-ST process should also be applied to this approach.

Step 8 – Calculate Linear Costs

The FP data elements are defined as the control years; a linear regression process is then used to develop the costs for the interim years. The control years are 2016, 2021, 2026, 2031 and 2036.

Using TUC as a quick example, the 2016 column represents the condition of the system at the beginning of the 20-year analysis period. The VMT_{2016} is 57,597 (x1000), and the TUC_{2016} calculates to be $58,500,000. The 2021 column represents the condition of the system at the end of the first funding period. Using a VMT_{2021} of 63,288 (x1000), the TUC_{2021} calculates to be $65,100,000. The unknown TUC_{2017} through TUC_{2020} values are developed from a linear trend between the known data points TUC_{2016} and TUC_{2021}.

Example:

- TUC_{2016} ➔ $58,500,000 (Control Point)
- TUC_{2017} ➔ $59,800,000
- TUC_{2018} ➔ $61,100,000
- TUC_{2019} ➔ $62,400,000
- TUC_{2020} ➔ $63,800,000
- TUC_{2021} ➔ $65,100,000 (Control Point)

The same process is repeated to develop the other interim year costs for the TUC, as well as for all interim year costs for MNT and EMIC. The different costs for the interim year for the US 97 Build scenario are shown in Table 6. The same process is applied for all scenarios.

Table 6: Summary of Interim Year Costs for US 97, Build Scenario

YEAR	TUC	MNT	EMIC
*2016**	*58,500,000*	*0*	*309,000*
2017	59,800,000	1,100	315,000
2018	61,100,000	1,700	321,000
2019	62,400,000	2,400	327,000
2020	63,800,000	3,000	333,000
*2021**	*65,100,000*	*3,600*	*339,000*
2022	66,400,000	4,500	345,000
2023	67,700,000	5,500	351,000
2024	69,000,000	6,500	356,000
2025	70,300,000	7,500	362,000
*2026**	*71,600,000*	*8,500*	*368,000*
2027	73,000,000	9,300	374,000
2028	74,300,000	10,100	379,000
2029	75,700,000	11,000	385,000
2030	77,000,000	11,800	390,000
*2031**	*78,400,000*	*12,600*	*396,000*
2032	79,600,000	12,300	402,000
2033	80,900,000	12,100	407,000
2034	82,200,000	11,800	413,000
2035	83,400,000	11,500	418,000
*2036**	*84,700,000*	*11,200*	*424,000*
SUM	**1,446,400,000**	**158,000**	**7,400,000**

* Control Years

For each scenario the total costs are simply a summation of columns and rows.

- Total User Costs➔ $1,446,400,000
- Total Agency Costs ➔ $158,000
- Total External Costs➔ $7,400,000
- Total HERS-ST Improvement Costs➔ $2,900,000 (from Step 6)

- Total Scenario Costs ➔ $1,456,800,000

Following the same steps for the No-Build scenario, the total No-Build scenario costs are $1,514,900,000, which is 4% greater than for the Build scenario.

Step 9 – Total Cost Difference between Approaches

Using the US 97 analysis, the difference between the two approaches varies from 2.8% for the No-Build scenario to 3.6% for the Build scenario. In both cases, the total costs for the second approach are 3-4% lower than those developed through the first approach. This difference is the error that is introduced through the first approach by assuming the costs are constant across the 5-year FP.

It is not clear how significant this error might be. On one hand the first approach is simple to develop and apply, but on the other hand, the growth assumptions in the second approach more closely match the data analysis within the HERS-ST model. The 3-4% error does not seem much on its own, but it appears more significant when compared with the fact that there is only a 4% difference in total costs between the Build and No-Build scenarios. However, this will only be an issue when the final BCR is close to "unity", because a BCR less than one is not an acceptable project. The overall analysis process defined here is for planning analysis, and a more detailed approach is required for project level analysis.

For this project, the second approach was used to develop the BCR.

Step 10 – Net Benefit

The net benefit is the difference between the total scenario costs associated with the Build scenario, minus the total costs associated with the No-Build scenario. A negative difference means that the total costs for the build scenario are less than the total costs for the no-build scenario, and that the improvements saves money. A negative difference represents a benefit in the benefit-cost calculations; a positive difference between the two represents a disbenefit. The roadway section costs data for US 97 is shown in Table 7.

Table 7: Net Benefits for US 97 – Example (using second approach)

COSTS	NO-BUILD ($)	BUILD ($)
Total User Costs	1,506,500,000	1,446,400,000
Agency Costs	114,000	158,000
External Emission Costs	7,300,000	7,400,000
HERS-ST Improvement Costs	900,000	2,900,000
Total Costs	1,514,900,000	1,456,800,000
	Total Costs for Build Scenario	1,456,800,000
	Total Costs for No-Build Scenario	1,514,900,000
	Net Benefit	**-58,100,000**

As shown in Table 7, the improvements to US 97 demonstrate a 3% decrease in total costs on the roadway system, resulting in a positive net benefit for US 97.

But this is not the entire story. Improvements were made to other roadway alignments as part of this project, including roadway extensions, additional travel lanes, left & right turn refuges and upgrades to intersection controls. All five roadway sections, as shown in Table 8, demonstrated a net benefit. The greater benefits associated with US 97 and US 20 can be directly attributed to the significantly larger VMT found on the two roadways.

Table 8: Net Benefit Summary – All Roadways

ROADWAY	NO-BUILD ($)	BUILD ($)	BENEFIT ($)
US 97	1,514,900,000	1,456,800,000	58,100,000
US 20	825,100,000	771,500,000	53,600,000
Cooley Road	203,000,000	188,700,000	14,300,000
Empire Avenue	244,000,000	230,700,000	13,300,000
Robal Road	54,500,000	49,800,000	4,700,000
Total	**2,841,500,000**	**2,697,500,000**	**144,000,000**

Step 11 – Residual Value

Residual Value is an Asset Management element that attempts to capture the value of a project at the end of the analysis period. For this analysis, it is assumed that the project will have reasonable levels of future value for ROW, structures and roadway beyond the analysis period. The future value is evaluated and defined as a benefit.

Right-of-Way:
For this analysis, we will assume that ROW has 100% RV value. The land that is acquired for the project can be resold at a later time for development if the roadway were to be removed. Loss in value is assumed to be negligible, if at all.

Bridge/Structures:
The design life of the structures is generally about 75 years. At a minimum, the structure will still have 55 years of service value available at the end of the analysis period. Because the basic structure exists, with proper maintenance it will have significantly more value, as compared to starting over and building a new structure. This analysis will assume an RV of 80%.

Roadway:
The overall analysis is starting with perfect pavement. It is assumed that the various roadways will need to be resurfaced at the end of the 20-year analysis period. The HERS-ST model is allowed to make pavement improvements during the analysis period as needed, but modernization improvements are not allowed.

Without some level of on-going pavement improvements, the value of the roadway surface will be reduced at the end of the 20-year analysis period. However, aside from grinding and recycling the pavement surface, the roadway cannot be physically picked up and moved to another location; so its existence makes it easier to (re)build in the future. The land has been acquired, cleared and graded and an aggregate base has been laid, which reduces the cost for future generations to build upon. This section is also a great catch-all for other construction elements, and is assumed to include signals and other safety elements.

Step 12 – Benefit- Cost Ratio

The Benefit Cost Ratio is simply an accumulation of all the data elements discussed above. Keeping in mind that there are a number of assumptions associated with this analysis, the general BCR development is as follows:

$$BCR = (\text{Net Benefit} + \text{Residual Value}) / (\text{Total Project Costs})$$

where the Total Net Benefit comes from Step 10 (see Table 8) and the Residual Value comes from Step 11.

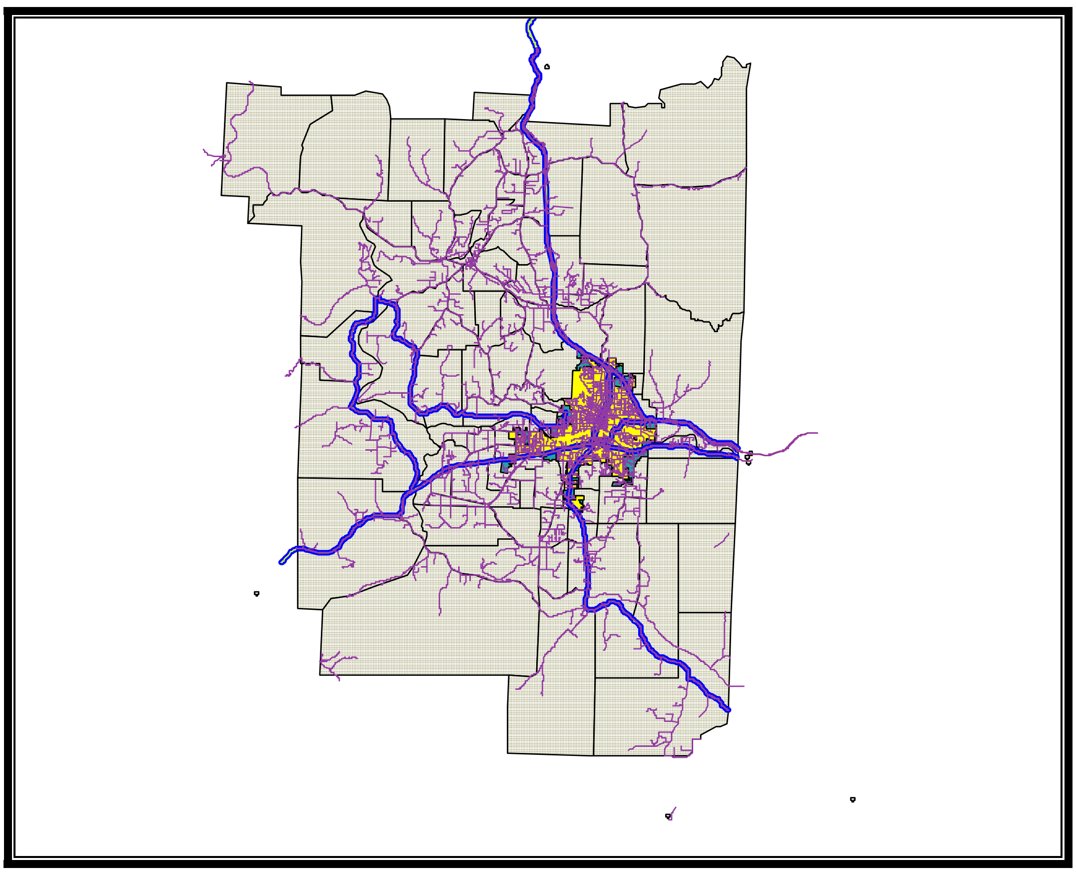
Table 9

HERS-ST in Grants Pass
A Brief Introduction

We currently have a dataset that contains all state roadway segments for Josephine County. Eventually, we intent to develop a HERS-ST dataset that covers the entire roadway network defined in the Grants Pass Travel Demand Model, and tie the two models together for analysis. With the two models, we can run various policy and application scenarios through the travel demand model and output sectional volumes for the different roadways within the network, and then apply those volumes to the HERS-ST model to identify potential long range deficiencies and improvements on the roadway system, associated with a specific scenario. This will provide an additional tool that can be used for decision-makers.

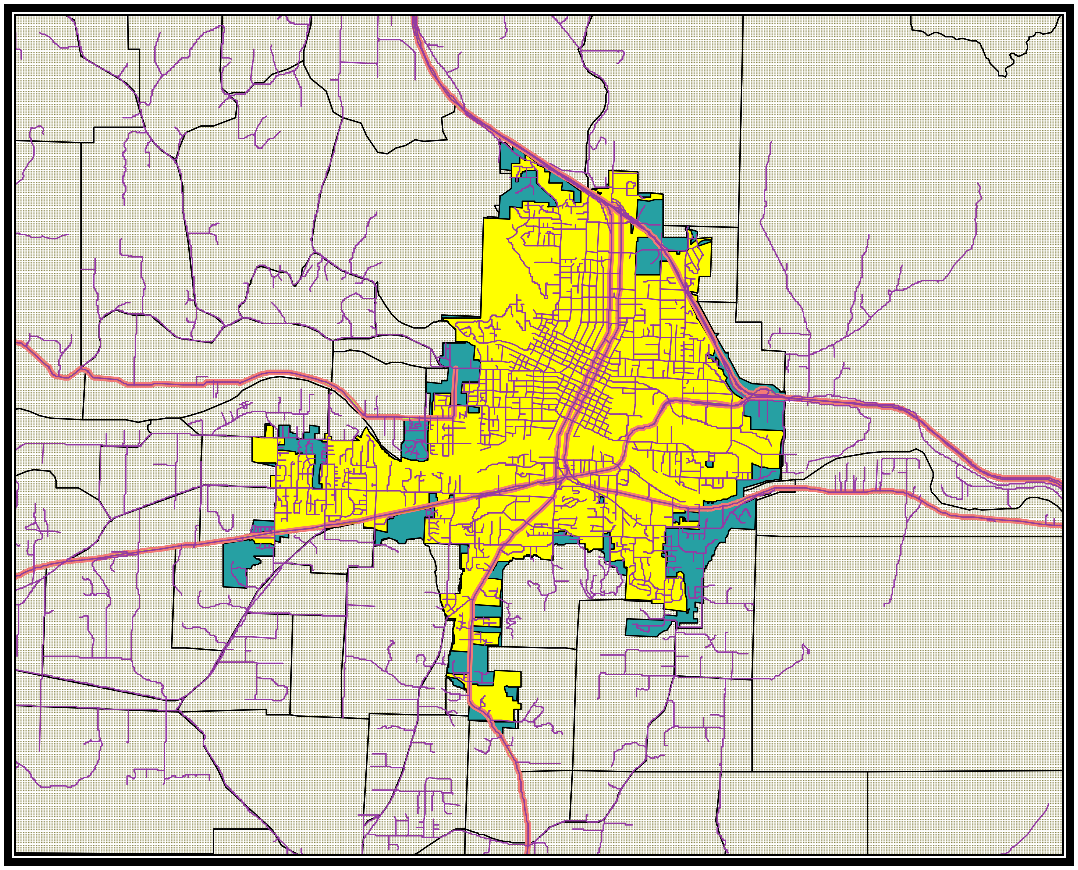
As a test, the existing CMS dataset (base year 2006), was used to identify deficiencies and improvements from the HERS-ST model. Though there are four types of analysis process that HERS-ST can perform (see Users Guide), the Full Needs Analysis was selected for this test as a base for highlighting the HERS-ST model. Note, HERS-ST identifies long-range deficiencies on the system and selects improvements based on economic benefit-cost analysis; a number of parameters can be adjusted by the Analyst but default values were used in for this example. Again, the CMS dataset is not currently tied to the Grants Pass model; the results here were simply superimposed over the model area.

Figure 1 – General Grants Pass Travel Demand Model Area, with HERS-ST dataset superimposed (in Blue).



HERS-ST in Grants Pass
A Brief Introduction

Figure 2 – City of Grants Pass Modeling Area, with HERS-ST dataset superimposed (in Light Purple).

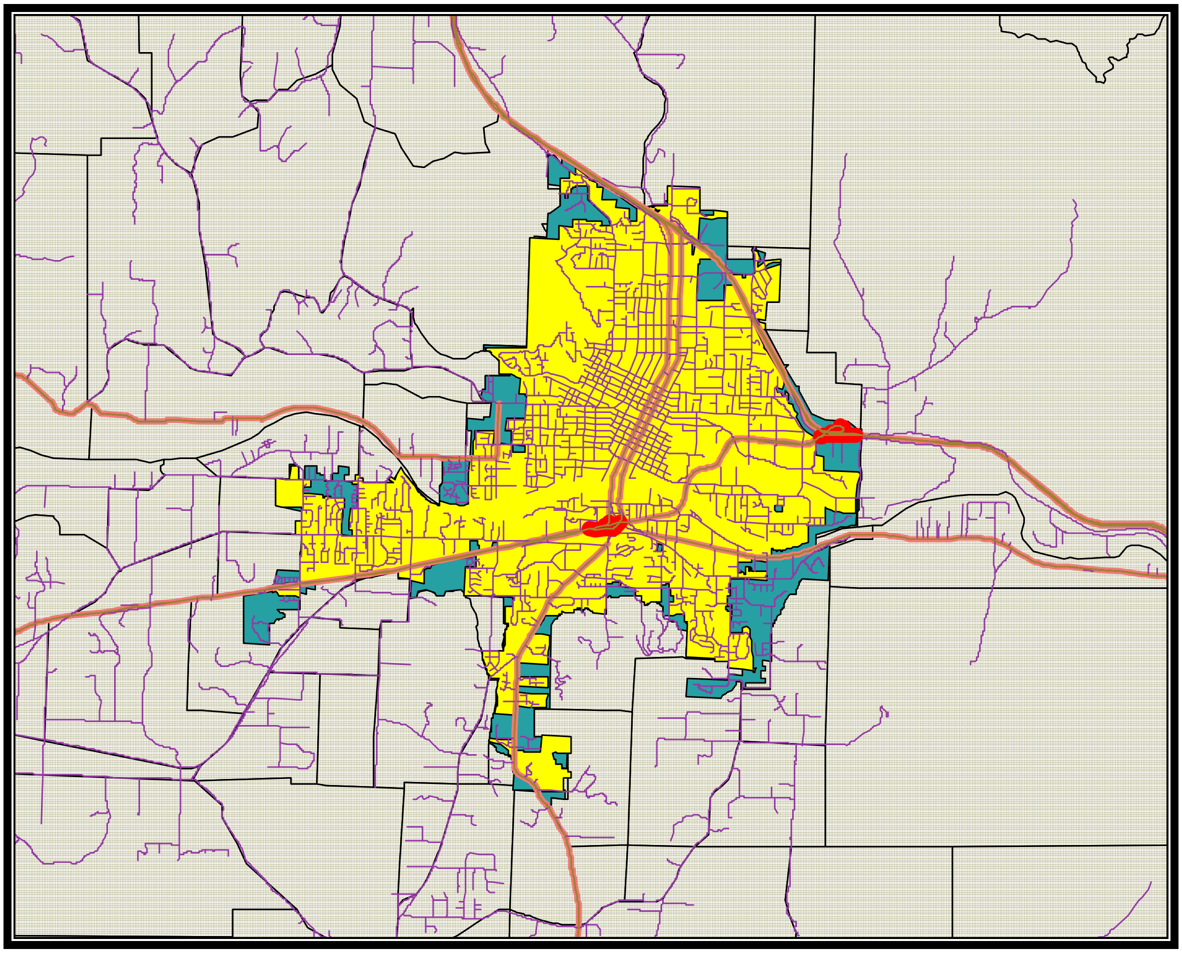


There is a considerable amount of information that can be gathered from the HERS-ST data, both from the data input and output. The purpose of the paper is to simply highlight the modeling tool, and to generate interest. Additional information will be provided in the near future; it was our intent to highlight this during the recent Grants Pass Model Outreach, but was not able to do so at that time because of scheduling issues.

Note that we have developed a data tie between HERS-ST and the RVMPO travel demand model, and are currently utilizing the joined model analysis for several projects in the RVCOG area. Our eventual intent is to make this tool available for all modeling areas covered under TPAU travel demand models.

For this test, the HERS-ST model evaluated four 5-year Funding Periods, covering a 20-year Analysis Period:
FP #1 – 2006 – 2011,
FP #2 – 2012 – 2016,
FP #3 – 2017 – 2021,
FP #4 – 2022 – 2026.

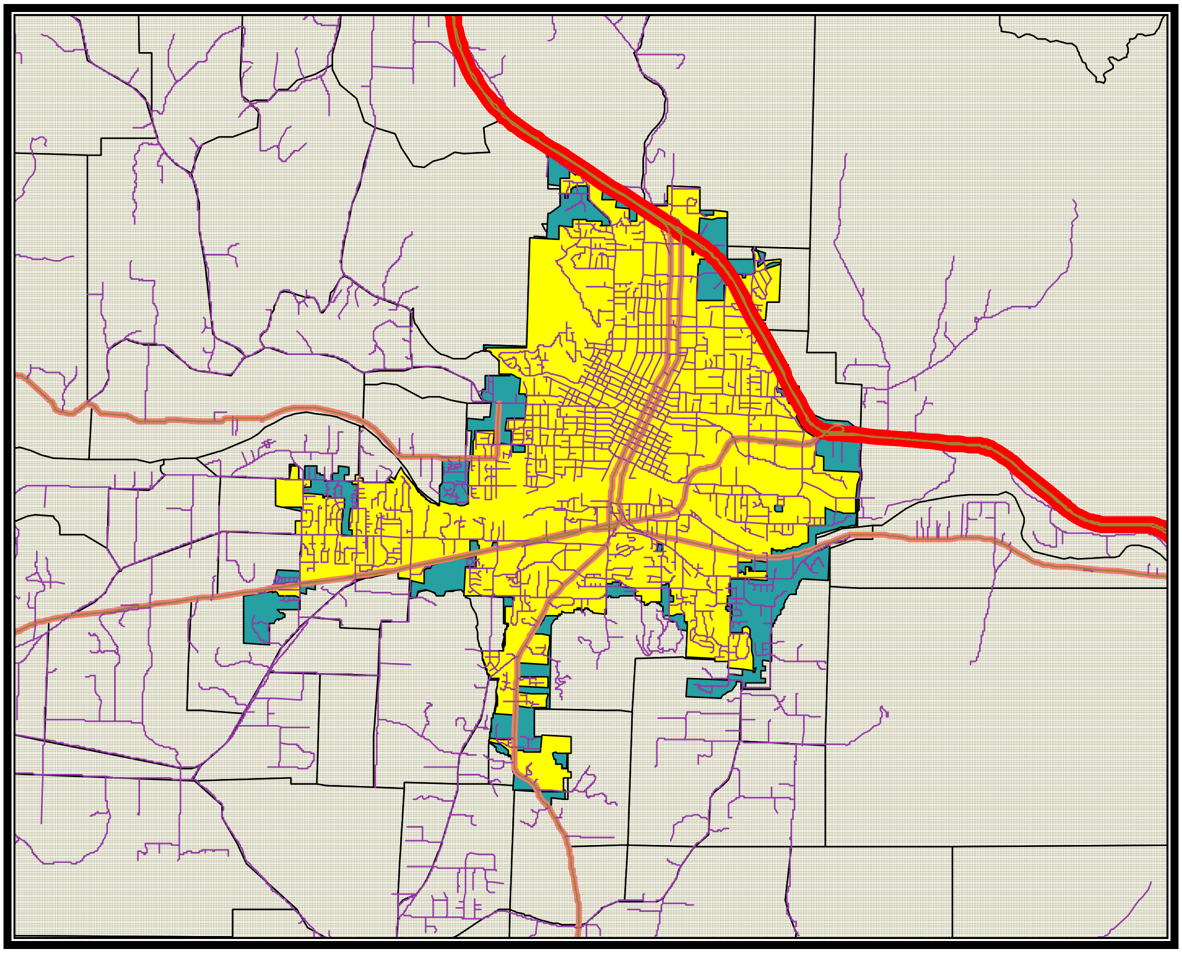
Figure 3 – First Funding Period improvements defined from HERS-ST, superimposed (in Red).



For the first funding period, HERS-ST identified several projects within the greater Grants Pass area, as shown in Figure 3. A detailed evaluation would show the type of improvement.

Note that HERS-ST model simulates these improvements at this point and continues on with the analysis in subsequent funding period, as if these improvements had been made. Future performance measures, such as pavement condition, v/c, speeds, congestion and delay analysis, all assume that the system has been updated to reflect these improvements.

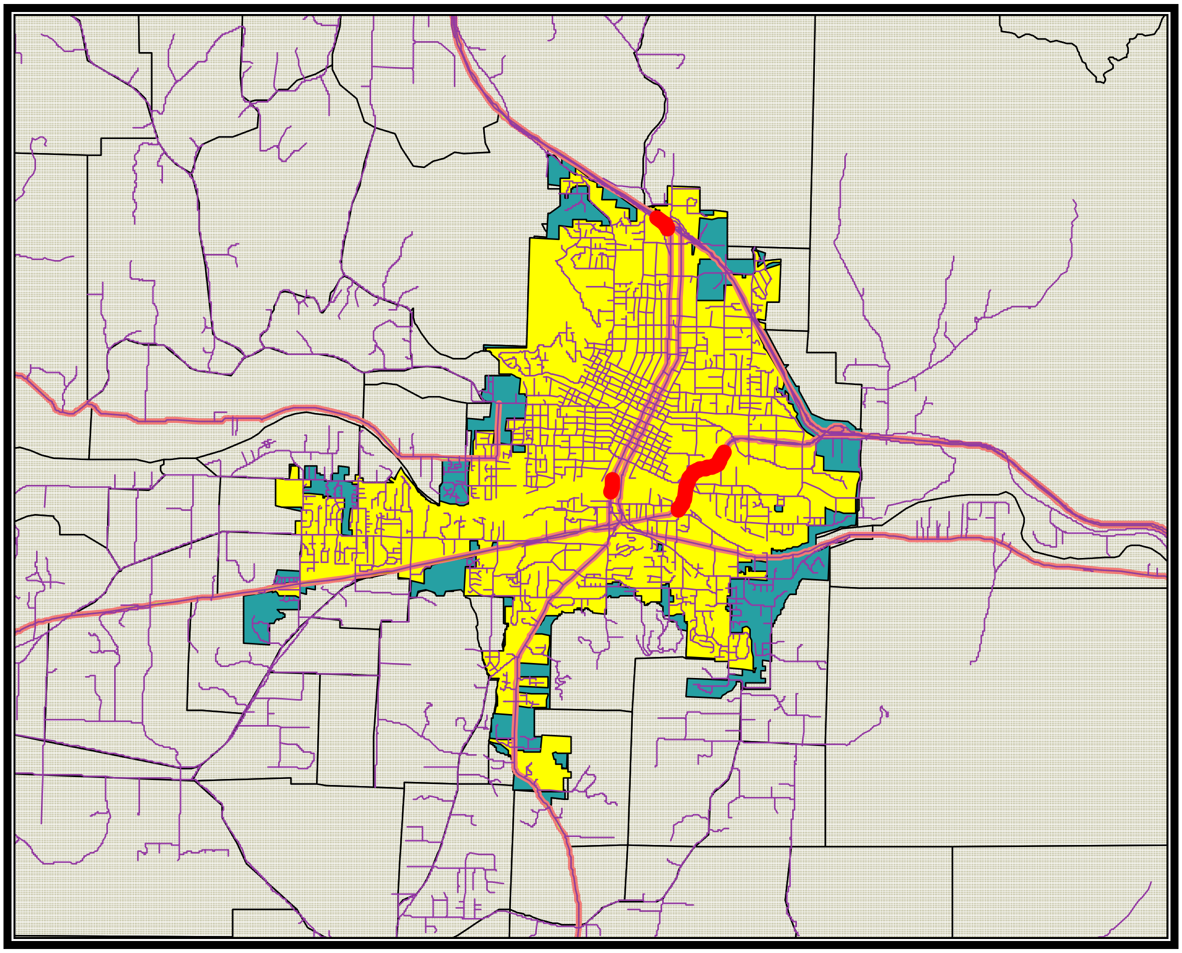
Figure 4 – Second Funding Period improvements defined from HERS-ST, superimposed (in Red).



For the second funding period, HERS-ST identified a number of improvements for the Interstate 5 system, as shown in Figure 4.

Note that based on the criteria used within this modeling scenario, there were no improvements identified within the Grants Pass Travel Demand Model area for the third funding period.

Figure 5 – Fourth Funding Period improvements defined from HERS-ST, superimposed (in Red).



For the fourth funding period, HERS-ST identified several projects within the greater Grants Pass area, as shown in Figure 5.

Conclusion:

We will provide more information on the analysis as time permits. Several points that are useful for City and County personnel are:

- There are a number of key system performance measures that can be pulled out of the HERS-ST model and used in the decision-making process,
- The data currently exists for the state highway system, and can be provided upon request,
- There are several great advantages for tying the HERS-ST model with the Grants Pass Travel Demand model – write-ups are available from TPAU,
- The software is developed for FHWA, has national acceptance, and is available for FREE. Support is available for FREE too.

HERS-ST DATA ITEMS

Data Development Categories (1-Easy, 2-Moderate, 3-Difficult)

Catgr	#	Variable Name	Description
1	1	Yr	Year
1	2	State	State Code
1	3	Metric	Reporting Units (English or metric)
1	4	Cnty	County Code
1	5	SecID	Section Identification
1	6	Sample	Is Standard Sample
n/a	*7*	*Donut*	*Is Donut Sample*
n/a	8	SCF [1]	State Control Field
n/a	*9*	*Grouped*	*Is Section Grouped*
n/a	10	LRSID [1]	LRS Identification
n/a	11	BegMP [1]	LRS Beginning Point
n/a	12	EndMP [1]	LRS Ending Point
1	13	RurUrb	Rural/Urban Designation
n/a	*14*	*UrbSampTech*	*Urbanized Area Sampling Technique*
n/a	*15*	*UrbAreaCode*	*Urbanized Area Code*
n/a	*16*	*NonAttainCode*	*NAAQS Nonattainment Area Code*
1	17	FC	Functional System Code
1	18	GFC	Generated Functional System Code
n/a	*19*	*NHS*	*National Highway System*
1	*20*	*Unblt*	*Planned Unbuilt Facility*
n/a	*21*	*InstRtNum*	*Official Interstate Route Number*
n/a	*22*	*RouteSign*	*Route Signing*
n/a	*23*	*RouteSignQual*	*Route Signing Qualifier*
n/a	*24*	*SingRtNum*	*Signed Route Number*
n/a	*25*	*GovOwn*	*Governmental Ownership*
n/a	*26*	*SpecSys*	*Special Systems*
1	27	FT	Type Of Facility (One Way Or Two Way)
n/a	*28*	*TrkRoute*	*Designated Truck Route*
n/a	*29*	*Toll*	*Toll*
1	30	SLEN	Section Length
n/a	*31*	*DonutGrpID*	*Donut Area Sample AADT Volume Group Identifier*
n/a	*32*	*StdGrpID*	*Standard Sample AADT Volume Group Identifier*
3	33	AADT	Annual Average Daily Traffic
1	34	TLanes	Number Of Through Lanes
2	35	IRI [2]	International Roughness Index
2	36	PSR [2]	Present Serviceability Rating (Pavement Condition)
1	37	HOV	High Occupancy Vehicle Operations
n/a	*38*	*HWSurvSysA*	*Electronic Surveillance*
n/a	*39*	*HWSurvSysB*	*Metered Ramps*
n/a	*40*	*HWSurvSysC*	*Variable Messages Signs*
n/a	*41*	*HWSurvSysD*	*Highway Advisory Radio*
n/a	*42*	*HWSurvSysE*	*Surveillance Cameras*
n/a	*43*	*HWSurvSysF*	*Incident Detection*
n/a	*44*	*HWSurvSysG*	*Free Cell Phone*
n/a	*45*	*HWSurvSysH*	*On-Call Service Patrol*
n/a	*46*	*HWSurvSysI*	*In-Vehicle Signing*
1	47	SampID	HPMS Sample Identifier
n/a	*48*	*DonutExpFact*	*Donut Area Expansion Factor*
1	49	ExpFac	Standard HPMS Sample Expansion Factor
1	50	Surf	Surface/Pavement Type
2	51	SNorD	Structural Number or Slab Thickness
1	52	Climate	General Climate Zone

Catgr	#	Variable Name	Description
1	53	ImpYr	Year Of Surface Improvement
1	54	LaneW	Lane Width
1	55	Access	Type of Access Control
1	56	MedT	Median Type
1	57	MedW	Median Width
1	58	ShldT	Shoulder Type
1	59	RShldW	Right Shoulder Width
1	60	LShldW	Left Shoulder Width
1	61	PkPark	Peak Parking
1	62	WdFeas	Widening Feasibility
1-3	63	LCurveA	Length of Class A Curves
1-3	64	LcurveB	Length of Class B Curves
1-3	65	LcurveC	Length of Class C Curves
1-3	66	LcurveD	Length of Class D Curves
1-3	67	LcurveE	Length of Class E Curves
1-3	68	LCurveF	Length of Class F Curves
1	69	HorAln	Horizontal Alignment Adequacy
1	70	Terrn	Type Of Terrain
1	71	VerAln	Vertical Alignment Adequacy
1-3	72	LGradeA	Length of Class A Grades
1-3	73	LGradeB	Length of Class B Grades
1-3	74	LGradeC	Length of Class C Grades
1-3	75	LGradeD	Length of Class D Grades
1-3	76	LGradeE	Length of Class E Grades
1-3	77	LGradeF	Length of Class F Grades
1-2	78	PSD	Percent Passing-Sight Distance
1	79	WDS [3]	Weighted Design Speed
1	80	SpdLim	Posted Speed Limit
1	81	PcPkSu	Peak Percent of Single-Unit Trucks
3	82	PcAvSu	Average Daily Percent of Single-Unit Trucks
1	83	PcPkCm	Peak Percent of Combination Trucks
3	84	PcAvCm	Average Daily Percent of Combination Trucks
3	85	KFac	K-Factor
1	86	DFac	Directional Factor
1	87	PLanes	Number Of Peak Lanes
1	88	LTurn	Left Turning Lanes
1	89	RTurn	Right Turning Lanes
n/a	*90*	*SigType*	*Prevailing Type of Signalization*
1	91	PctGrn	Percent Green Time
1	92	NSig	Number of At-Grade intersections - signals
1	93	NStop	Number of At-Grade intersections - stop signs
1	94	NOInts	Number of At-Grade intersections - other
1	95	PkCap [3]	Peak capacity
1	*96*	*VSF*	*Volume/Service Flow Ratio*
3	97	FAADT	Future AADT
1	98	FAADTYr	Year of Future AADT

(*Items not used by HERS-ST are shaded blue and italic*)

1. Variable copied to output files but not otherwise used by HERS-ST (values passed through).
2. HERS-ST requires either IRI or PSR. If both are provided, the PSR/IRI indicator identifies the value to be used.
3. Optional inputs - will be calculated by HERS-ST if not coded.

Data Development Categories (1-Easy, 2-Moderate, 3-Difficult)

Catgr	#	Description	Potential Source
1	1	Year of Record	Default
n/a	2	State Code[1]	Default
n/a	3	Route Identifier[1]	Database/Default
n/a	4	Beginning Point[1]	Database/Default
n/a		Ending Point[1]	Database/Default
n/a	6	Section Length	Calculated
1	7	Functional System	Database
1	8	Urbanized Code	Database/Default
1	9	Facility Type	Database/Maps
n/a	10	Structural Type	Default = 0
1	11	Access Control	Database/Calc
1	12	Governmental Ownership	USED???????
1	13	Number Of Through Lanes	Database/Maps
1	14	High Occupancy Vehicle Type	Database/Default
1	15	High Occupancy Vehicle Lanes	Database/Default
1	16	# Peak Lanes	Database/Calc
1	17	# Counter Peak Lanes (Urban Only)	Database/Calc
1	18	Right Turning Lanes (Urban Only)	Database/Maps
1	19	Left Turning Lanes (Urban Only)	Database/Maps
1	20	Posted Speed Limit	Database/Maps
n/a	*21*	*Toll Charged*	*Not Used*
n/a	*22*	*Toll Type*	*Not Used*
n/a	*23*	*Route Number*	*Not Used*
n/a	*24*	*Route Signing*	*Not Used*
n/a	*25*	*Route Qualifier*	*Not Used*
3	26	Annual Average Daily Traffic	Database
3	27	AADT, Single-Unit Trucks	Database
3	28	Peak Percent, Single-Unit Trucks	Database
3	29	AADT, Combination Trucks	Database
3	30	Peak Percent, Combination Trucks	Database
3	31	K-Factor	Database/Default
1	32	Directional Factor	Database/Default
3	33	Future AADT	Database
1	34	Year of Future AADT	Database
n/a	35	Type of Signalization	USED???????
1	36	Percent Green Time	Database/Default
1	37	Number of At-Grade intersections - Signals	Database
1	38	Number of At-Grade intersections - Stop Signs	Database
1	39	Number of At-Grade intersections - Other	Database
1	40	Lane Width	Database/Maps
1	41	Median Type	Database/Maps
1	42	Median Width	Database/Maps
1	43	Shoulder Type	Database/Maps
1	44	Right Shoulder Width	Database/Maps
1	45	Left Shoulder Width	Database/Maps
1	46	Peak Parking (Urban Only)	Database/Calc
n/a	*47*	*Widening Obstacle*	*Not Used*
1	48	Widening Potential	Database/Calc
3	49	Length of Class A Curves (Rural Only)	Database/Default
3	50	Length of Class B Curves (Rural Only)	Database
3	51	Length of Class C Curves (Rural Only)	Database
3	52	Length of Class D Curves (Rural Only)	Database
3	53	Length of Class E Curves (Rural Only)	Database

Catgr	#	Description	Potential Source
3	54	Length of Class F Curves (Rural Only)	Database
1	55	Type Of Terrain (Rural Only)	Database/Calc
3	56	Length of Class A Grades (Rural Only)	Database/Default
3	57	Length of Class B Grades (Rural Only)	Database
3	58	Length of Class C Grades (Rural Only)	Database
3	59	Length of Class D Grades (Rural Only)	Database
3	60	Length of Class E Grades (Rural Only)	Database
3	61	Length of Class F Grades (Rural Only)	Database
3	62	Percent Passing-Sight Distance (Rural Only)	Database/Calc
1-2	63	IRI[2]	PMS
1-2	64	IRI Year	PMS
1-2	65	IRI Month	PMS
1-2	66	PSR[2]	PMS
1-2	67	Surface/Pavement Type	PMS
1-2	68	Rutting	PMS
1-2	69	Faulting	PMS
1-2	70	Cracking Percentage	PMS
1-2	71	Cracking Length	PMS
1-2	72	Year of Last Improvement	PMS
1-2	73	Year of Last Construction	PMS
1-2	74	Last Overlay Thickness	PMS
1-2	75	Thickness, Rigid	PMS
1-2	76	Thickness, Flexible	PMS
1-2	77	Base Type	PMS
1-2	78	Base Thickness	PMS
1	79	General Climate Zone	Database/Default
1	80	Soil Type	Database/Default
1	81	County Code	Database
1	82	National Highway System	Default
1	83	Future Facility	Default
n/a	*84*	*STRAHNET Type*	*Not Used*
n/a	*85*	*Designated Truck Route*	*Not Used*
n/a	*86*	*Volume/Service Flow Ratio[3]*	*Not Used*
n/a	87	Peak Capacity[3]	Default = 0
n/a	88	Weighted Design Speed[3]	Default = 0
n/a	89	Vertical Alignment Adequacy[3]	Default = 0
n/a	90	Horizontal Alignment Adequacy[3]	Default = 0
n/a	*91*	*Volume Group*	*Not Used*
n/a	92	Sample Expansion Factor	Default = 1
n/a	93	State Control Field[1]	
n/a	94	Local Cost Factor	Default = 1
n/a	95	User Defined Field 1[1]	
n/a	96	User Defined Field 2[1]	
n/a	97	User Defined Field 3[1]	
n/a	98	User Defined Field 4[1]	
n/a	99	Structure Number	Default = 5

(*Items not used by HERS-ST are shaded blue and italic*)

1. Variable copied to output files but not otherwise used by HERS-ST (values passed through).
2. HERS-ST requires either IRI or PSR. If both are provided, the PSR/IRI indicator identifies the value to be used.
3. Optional inputs - will be calculated by HERS-ST if not coded.

HPMS Date Items Used for HERS-STv4.2

INTRODUCTION

The purpose of this project is to develop joint analysis between the HERS-ST Deficiency Model and the RVMPO Travel Demand Model; the former model is developed and maintained by FHWA, while the latter model is developed and maintained by Oregon DOT. The deficiency model will be used to evaluate long-range (i.e., twenty year) needs on the roadway system, while the travel demand model addresses transportation changes on the roadway system, according to land-use and employment changes. The deficiency model evaluates a single HPMS formatted record at one time, and is ignorant of any other changes to the system. The travel demand model will dissipate traffic across the system, based on scenario changes, but it does not identify deficiencies on the system, nor does it simulate improvements and evaluate performance based on improvements. Each model works completely independent and covers completed different analysis. Joining the two models together makes good sense.

UNIVERSE & STANDARD SAMPLE DATA

Universal data - certain basic inventory information is required to be reported for all open-to-traffic, public road systems in the universe portion of the HPMS data set (**Items 1-46**). Sample data - additional detailed information is required for a statistically chosen sample of roadways on major functional systems. The additional detailed data are reported for the standard sample portion of the HPMS data set (**Items 47-98**).

SUMMARY

In order to tie RVMPO with HERS-ST, a complete HPMS dataset covering the entire RVMPO network must be developed. In essence, we need a 100% sample HPMS dataset. Past analysis has shown that the HPMS sample data is strongest for higher functional classified roadways; Interstate system is represented much better than the Collector system.

For the purpose of joining the two models, it is questionable whether or not each RVMPO roadway section needs to be included. The HPMS sample data was overlaid with the RVMPO network to determine what data was already available, and an analysis of what segments still needed data developed. A large number of the roadway mileage (79%) not covered by HPMS sample dataset was classified as "local".

HPMS DATA

Item 1 — Year of Data (Numeric; Integer)

Enter the four digits of the calendar year for which the data apply. **Since this is a tie with RVMPO, the default input should be 2006, the reference year for the RTP development.**

Default data	2006 (Model Reference Year)

Item 2 — State Code (Numeric; Codes)

The State FIPS code is used in the HPMS database to identify the reporting State. Enter the State FIPS code; **note that this will not influence the HERS-ST analysis.**

HPMS Date Items Used for HERS-STv4.2

Default data	41 - Oregon

Item 3 — Reporting Units - Metric or English (Numeric; Codes)

Code for all sections to indicate the units used to report measured and other measurement related data items. There can be no mixing of units within the data set.

Default data	0 – English Units

Item 4 — County Code (Numeric; Codes)

The FIPS county code permits analysis and mapping of information at a sub-State level. Enter the three-digit FIPS county code; **note that this will not influence the HERS-ST analysis.**

Default data	29 – Jackson County

Item 5 — Section Identification (Character Field)

This item must contain a 12-character countywide unique identifier. **This is generally a concatenate of the Road Number and the Beginning Milepoint — note that this must be a unique value.**

Item 6 — Is Standard Sample? (Numeric; Codes)

This data item is used by the software to indicate if a section is a standard sample. **In order for HERS-ST to analyze the data, this MUST be coded as "1".**

Default data	1 – Sample Section

Item 7 — Is Donut Sample (Numeric; Codes)

This data item is not used for HERS-ST. Code the default to reduce HERS-ST outputs errors.

Default data	0 – Not a Donut Sample

Item 8 — State Control Field (Character Field)

This is a data item of up to 100 alphanumeric characters for State use for identification or any other purpose. **This is a pass through item for HERS-ST, so use it to help identify data location.**

Item 9 — Is Section Grouped? (Numeric; Codes)

This data item is not used for HERS-ST. Code the default to reduce HERS-ST outputs errors.

Default data	0 – Individual Section

HPMS Date Items Used for HERS-STv4.2

Item 10 — LRS Identification (Character Field)

This item is used to reference HPMS information to the map location of road sections. This is a twelve character field that is essential for identifying and mapping data, use accordingly.

Code	0	1	2	3	4	5	6	7	8	9	0	1

Item 11 — LRS Beginning Point (Numeric; Decimal)

This item is used to reference HPMS information to the map location of road sections. It should represent the beginning of the section.

Code	1	2	3	.	4	5

Item 12 — LRS Ending Point (Numeric; Decimal)

This item is used to reference HPMS information to the map location of road sections. It should represent the end of the section.

Code	1	2	3	.	4	5

Item 13 — Rural/Urban Designation (Numeric; Codes)

This item permits analysis and mapping of information at a sub-State level. Code the value best describing the area**; should be easy to identify from various mapping or other data sources.**

Code	Description
1	Rural Area
2	Small Urban Area (Population 5,000 to 49,999)
3	Small Urbanized Area (Population 50,000 to 199,999)

Item 14 — Urbanized Area Sampling Technique (Numeric; Integer)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 15 — Urbanized Area Code (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 16 — NAAQS Nonattainment Area Code (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 17 — Functional System Code (Numeric; Codes)

This item permits analysis and mapping of information by highway functional system. Code the value that represents the functional system upon which the section is located; **should be easy to identify from various mapping or other data sources.**

Code	Description	Code	Description
RURAL		URBAN	
1	Principal Arterial - Interstate	11	Principal Arterial - Interstate
2	Principal Arterial - Other	12	Principal Arterial-Other Freeways &
6	Minor Arterial	14	Principal Arterial - Other
7	Major Collector	16	Minor Arterial
8	Minor Collector	17	Collector

Item 18 — Generated Functional System Code (**Software Calculated**)

This item is encoded by the HPMS software based on the Functional System (Item 17); **it is easy to calculate external of HERS-ST.**

Code	Description	
	RURAL	URBAN
1	Interstate	Interstate
2	Other Principal Arterial	Other Freeways and Expressways
3	Minor Arterial	Other Principal Arterial
4	Major Collector	Minor Arterial
5	Minor Collector	Collector
6	Local	Local

Item 19 — National Highway System (NHS) (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	1 – On NHS

Item 20 — Planned Unbuilt Facility (Numeric; Codes)

For simplicity sake, use default value, not sure how HERS-ST uses this data.

Default data	1 – On NHS and Open

Item 21 — Official Interstate Route Number (Character Field)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 22 — Route Signing (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 23 — Route Signing Qualifier (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 24 — Signed Route Number (Character Field)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 25 — Governmental Ownership (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 26 — Special Systems (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	0 – Default

Item 27 — Type of Facility (Numeric; Codes)

This item is used to determine whether a roadway or structure is a one- or two-way operation. It is used in investment requirements modeling to calculate capacity and estimate roadway deficiencies and improvement needs, in the cost allocation pavement model, and in the national highway database. **Since, the network for RVMPO is based on one-way links (EMME2 version only) the default data should be used.**

Default data	1 – One-way

Item 28 — Designated Truck Route (Numeric; Codes)

This data item is not used for HERS-ST.

Default data	0 – Not Truck Route

Item 29 — Toll (Numeric; Codes)
This data item is not used for HERS-ST.

Default data	0 – Non-Toll Route

Item 30 — Section Length (Numeric; Decimal)

This item should be the report length (miles), as measured along the centerline of the roadway. In older versions, this item was compared for consistency against the summed values identified as Grade and Curve lengths. **This item can most easily be defined as the difference between the Ending LRS (Item 12) and Beginning LRS (Item 11).**

Code	1	2	3	.	4	5

Item 31 — Donut Area Sample AADT Volume Group Identifier (Numeric; Integer)
This data item is not used for HERS-ST.

Default data	0 – Default

Item 32 — Standard Sample AADT Volume Group Identifier (Numeric; Integer)
This data item is not used for HERS-ST.

Default data	0 – Default

Item 33 — Annual Average Daily Traffic (AADT) (Numeric; Integer)

Enter the section AADT for the data year. For two-way facilities, provide the AADT for both directions. All counts must reflect application of day of week, seasonal, and axle correction factors, as necessary. Growth factors must be applied if the AADT is not derived from current year counts. **For the purpose of this project, the AADT will be provided as output from the RVMPO model. Since all section records are one-way, this data will be reported as one-way.**

Item 34 — Number of Through Lanes (Numeric; Integer)

This item provides basic inventory information on the amount of public road supply. Code the number of through lanes according to the striping, if present, on multilane facilities, or according to traffic use or State/local design guidelines if no striping or only centerline striping is present.

Enter the prevailing number of through lanes in both directions carrying through traffic in the off-peak period. **Since the HERS-ST sections will be matched to RVMPO, the number of through lanes should be consistent with that is coded in RVMPO.**

Item 35 — Measured Pavement Roughness (IRI) (Numeric; Decimal)

This item provides information on pavement surface roughness on selected roadway sections. Code the International Roughness Index (IRI) for paved sections in accordance with minimum reporting specifications contained in Table IV-3 of the HMS Field Manual. **This information should be obtained from Pavement Management System, maintained by the local jurisdictions.**

Item 36 — Present Serviceability Rating (PSR) (Numeric; Decimal)

This item provides information on pavement condition on selected roadway sections. It is used in investment requirements modeling to estimate pavement deterioration, section deficiencies, and needed improvements. Code a PSR or equivalent value, to the nearest tenth (x.x). **This information should be obtained from Pavement Management System, maintained by the local jurisdictions.**

Note: A sample section must have either PSR (Item 36) or IRI (Item 35) reported.

Item 37 — High Occupancy Vehicle (HOV) Operations (Numeric; Codes)

This item is used to identify those roadway sections with HOV operations. Code this data item for all sections to best reflect the nature of existing HOV operations.

Default data	0 – No HOV Lanes

Items 38-46 — Highway Surveillance Systems (Numeric; Codes)

The data for these items is not used for HERS-ST.

Default data	0 – Default

Item 47 — Sample Identifier (Character Field)

The sample identifier is a statewide or countywide unique 12-character alphanumeric code that cannot change once it has been assigned. **For simplicity, reuse the same value as used for Section Identification (Item 5).**

Item 48 — Donut Area Sample Expansion Factor (Software Calculated)

The data for these items is not used for HERS-ST.

Default data	0 – Default

Item 49 — Standard Sample Expansion Factor (Software Calculated)

Expansion factors are used to expand sampled data to represent the universe from which the sample is drawn. **Since the goal for this project is to have a one-to-one relationship with**

RVMPO, the expectation is to have a 100% sample dataset. If, as discussed on the opening, the alternative decision is to develop coverage of the system at some level below 100%, this assessment will need to be reevaluated.

Default data	1 – 100% Sample

Item 50 — Surface/Pavement Type (Numeric; Codes)

Enter the code which best represents the type of surface on the section. Unless more information is known about the type of surface and the base, the two default values are defined for bituminous and Concrete (which is probably on found on the interstate)

Code	Description
1	**Gravel (un-paved)**
4	**High type flexible**—mixed bituminous or bituminous penetration pavement.
5	**High type rigid**—Portland cement concrete (PCC) pavement.

Item 51 — SN or D (Numeric; Decimal)

This item provides specific information about the pavement section in terms of structural number [SN] for flexible pavement or thickness (depth) [D] for rigid pavement on sample roadway sections. Code this numeric item for all standard sample sections. Enter SN to the nearest tenth (xx.x) and D to the nearest inch (xx.0). When known, enter the actual value; otherwise code a typical value for the functional system and pavement type based upon historic data or State practice. The SN or D value should reflect the last improvement on the section. **This information should be obtained from Pavement Management System, maintained by the local jurisdictions.**

Item 52 — General Climate Zone (**Software Set**)

It is not clear how this data is used by HERS-ST, however, for RVMPO, use Default.

Default data	3 – Default

Item 53 — Year of Surface Improvement (Numeric; Integer)

It is not clear how this data is used by HERS-ST, however, for RVMPO, use Default.

Default data	0 – Default

Item 54 — Lane Width (Numeric; Decimal)

This item is a measure of existing lane width on sample roadway sections. Enter the prevailing through lane width to the whole foot (x.0). **Depending on the ultimate purpose for this analysis, this item can be coded with a default width. The analyst defines the allowable level of deficiency, and as such must decide how close is "close enough". The choice is to go out a**

measure every section, or one can use various data sources (such as a video log or Goggle Earth) to guesstimate the width.

Item 55 — Access Control (Numeric; Codes)

This item is a measure of the degree of access control on sample roadway sections. Code the type of access control for all standard sample sections.

Code	Description
1	**Full Access Control**: Preference given to through traffic movements by providing interchanges with selected public roads and by prohibiting crossing at grade and direct driveway connections.
2	**Partial Access Control**: Preference given to through traffic movement. In addition to interchanges, there may be some crossings at-grade with public roads, but direct private driveway connections have been minimized through the use of frontage roads or other local access restrictions. Control of curb cuts is not access control.
3	**No Access Control**: Include all sections that do not meet the criteria above.

Item 56 — Median Type (Numeric; Codes)

This item is a characterization of the type of median on sample roadway sections. Code the type of median for all standard sample sections.

Code	Description
1	Curbed
2	Positive Barrier
3	Unprotected
4	None

A positive barrier normally consists of a guardrail or concrete barrier, but could consist of thick, impenetrable vegetation. Turning lanes or bays are not considered medians unless the turning lanes/bays are cut into an existing median at intersections, entrance drives, etc; a continuous turning lane is not a median. Use code "3" if an unprotected median is at least 4 feet wide; otherwise, use code "4," None. **Depending on the ultimate purpose for this analysis, this item can be coded with a default median type. The analyst must decide how close is "close enough". The choice is to go out a measure every section, or one can use various data sources (such as a video log or Goggle Earth) to guesstimate the type.**

Item 57 — Median Width (Numeric; Decimal)

This item is a measure of existing median width on sample roadway sections. Enter the predominant median width including left shoulders, if any, measured between the inside edges of the through lanes, to the nearest foot (x.0). Enter "0.0" where Item 56 is coded "4." Enter "999.9" where the median width is 30 meters or 100 feet or greater. Ignore turning bays cut into the median. **Depending on the ultimate purpose for the analysis, this item can be coded with**

a default width. The analyst must decide how close is "close enough". The choice is to go out a measure every section, or one can use various data sources (such as a video log or Goggle Earth) to guesstimate the width.

Item 58 — Shoulder Type (Numeric; Codes)

This item provides information on the type of existing shoulders on sample roadway sections. If left and right shoulder types differ on a divided facility, code the right shoulder type as the predominant type. If there is a shoulder in front of a barrier curb, code the shoulder type and width, but do not code as a shoulder the area behind a barrier curb. Ignore mountable curbs for reporting purposes; if there is a shoulder either in front of or behind a mountable curb, code the shoulder type and width. If the section has parking abutting the through lane, there cannot be a shoulder; if a bike lane abuts the through lane, there cannot be a shoulder unless it is a combined shoulder/bike lane. If there is parking on one side of a divided roadway and a shoulder or a curb on the other side, code both parking and shoulder type and width accordingly. A shoulder cannot exist between a traffic lane and a parking lane. If a bike lane or parking is completely separated from the roadway, it should not be considered.

Code	Description
1	None: No shoulders or curbs exist.
2	Surfaced shoulder exists (bituminous concrete or Portland cement concrete surface).
3	Stabilized shoulder exists (stabilized gravel or other granular material with or without admixture).
4	Combination shoulder exists (shoulder width has two or more surface types; for instance, part of the shoulder width is surfaced and a part of the width is earth, etc.).
5	Earth shoulder exists.
6	Barrier curb exists; no shoulders in front of curb.

Depending on the ultimate purpose for this analysis, this item can be coded with a default type. The analyst defines the allowable level of deficiency, and as such must decide how close is "close enough". The choice is to go out a measure every section, or one can use various data sources (such as a video log or Goggle Earth) to guesstimate the type.

Item 59 — Right Shoulder Width (Numeric; Decimal)

This item measures the existing shoulder width on sample roadway sections. It is used in investment requirements modeling to calculate capacity and estimate needed improvements. Enter the width of the right shoulder to the nearest whole foot (x.0). Code "0.0" if no right shoulder exists. Include rumble strips and gutter pans in shoulder width. **Depending on the ultimate purpose for this analysis, this item can be coded with a default median type. The analyst must decide how close is "close enough". The choice is to go out a measure every section, or one can use various data sources (such as a video log or Goggle Earth) to guesstimate the type.**

Item 60 — Left Shoulder Width (Numeric; Decimal)

This item measures the existing shoulder width on sample roadway sections. It is used in investment requirements modeling to calculate capacity and estimate needed improvements. On divided highways, enter the width of the left (median) shoulder to the nearest whole foot (x.0). Code “0.0” where no left shoulder exists or if the section is undivided. Include rumble strips and gutter pans in shoulder width. **Depending on the ultimate purpose for this analysis, this item can be coded with a default median type. The analyst must decide how close is “close enough”. The choice is to go out a measure every section, or one can use various data sources (such as a video log or Goggle Earth) to guesstimate the type.**

Item 61 — Peak Parking (**Urban Data Item**) (Numeric; Codes)

This item provides specific information about the presence of peak parking on urban sample roadway sections. Enter the code that best reflects the type of peak parking that exists on the section. Code to reflect permitted use; code permitted parking even if the section is not formally signed or striped for parking. If parking is actually beyond the shoulder or the pavement edge where there is no shoulder, use code “3” for no parking. If parking lanes are legally used for through traffic or turning lanes during the peak-hour, code the appropriate in-use condition.

Code	Description
0	Not Applicable; Section is Rural
1	Parking Allowed One Side
2	Parking Allowed Both Sides
3	No Parking Allowed or None Available

Since the data for this item is limited, we calculate parking based on the Speed (Item 80). It is assumed that parking is allowed for roadways with Speed < 30mph (thought to be CBD area).

Item 62 — Widening Feasibility (Numeric; Codes)

This item provides a measure of whether it is feasible to widen an existing sample section. Enter the code which best represents the extent to which it is feasible to widen the existing road. Consider mainly the physical features along the roadway section, such as large single family residences or office buildings, shopping centers and other large enterprises, severe terrain, cemeteries, wet lands, and park land, as well as where widening would be otherwise cost or environmentally prohibitive. Do not consider restrictions because of current right-of-way width, State practices concerning widening, politics, or projected traffic.

The code is to represent the lanes that could be added in both directions; e.g., if a lane could be added for each direction of the roadway, then use code “4”; if one full lane only can be added, use code “3”; if only minor widening or widening narrow lanes can occur, use code “2”. Restriping to narrower lanes, resulting in an additional lane on a multilane facility, does not constitute widening feasibility. When coding this item, also consider medians and other areas already within the right-of-way to be available for widening.

Depending on the ultimate purpose for this analysis, this item can be coded with a default value. The analyst must decide how close is “close enough”. The easiest way to collect this data is by using one of several data sources (such as a video log or Goggle Earth) to guesstimate the feasibility.

Code	Description
1	No Widening is Feasible
2	Yes, Partial Lane
3	Yes, One Lane
4	Yes, Two Lanes
5	Yes, Three Lanes or More

Items 63-68 — Curves by Class (Numeric; Decimal)

These items provide specific information regarding the length of horizontal curves by degree of curvature for sample sections. Code for paved rural arterials and urban principal arterials. Curves by class may be coded for other functional systems if the data are available; code "0.0" when curve data are not reported. When this item is not reported for the required rural systems, code Horizontal Alignment Adequacy (Item 69).

Each curve and tangent segment is coded as a separate curve; segments are summed by curve class to obtain the total length in each class. Report the sum of the class lengths for each of the six curve classes in miles; **the sum of all curve lengths must equal the section length**.

Item	Curve Classes			Length of Curves in Class (to 3 decimals) xx.xxx
	Curve Class	Radius Length (Metric)	Degree of Curvature (English)	
63	A	506+	0.0- 3.4	——
64	B	321- 505	3.5-5.4	——
65	C	206- 320	5.5- 8.4	——
66	D	126- 205	8.5-13.9	——
67	E	61- 125	14.0-27.9	——
68	F	<61	28+	——

Basically, we can assume that urban roadways are fairly level, for this analysis.

Item 69 — Horizontal Alignment Adequacy (**Rural Data Item**) (**Software Calculated**)

This item provides information about the adequacy of horizontal alignment when curve data are not reported. Code for all paved sample sections unless Curves by Class (Items 63 - 68) are coded for the section. If curves by class are coded, horizontal alignment adequacy will be calculated for paved sections from the curve data. Use the following codes:

Code	Description
0	Curve data are reported or this item is not required for the section.
1	All curves meet appropriate design standards for the type of roadway. Reduction of curvature would be unnecessary even if reconstruction were required to meet other deficiencies (i.e., capacity, vertical alignment, etc.).

Code	Description
2	Although some curves are below appropriate design standards for new construction, all curves can be safely and comfortably negotiated at the prevailing speed limit on the section. The speed limit was not established by the design speed of curves.
3	Infrequent curves with design speeds less than the prevailing speed limit on the section. Infrequent curves may have reduced speed limits for safety purposes.
4	Several curves uncomfortable or unsafe when traveled at the prevailing speed limit on the section, or the speed limit on the section is severely restricted due to the design speed of curves.

Basically, we can assume that urban roadways are fairly level, for this analysis, code "0" for urban roadways.

Item 70 — Type of Terrain (**Rural Data Item**) (Numeric; Codes)

This item provides information on the type of terrain through which the sampled roadway passes. For all rural sample sections, enter the code that best characterizes the terrain classification for the sampled roadway. In coding this item, consider the terrain of an extended length of the roadway upon which the sample is located rather than the grade on the specific sample section by itself. The extended roadway section may be several miles long and contain a number of upgrades, downgrades, and level sections; for long sample sections, such as rural freeway samples extending between interchanges, the extended roadway section and the sample section may be the same. Code according to the following table:

Code	Terrain Type
0	Not Applicable; this is an Urban Section.
1	**Level**: Any combination of grades and horizontal or vertical alignment that permits heavy vehicles to maintain the same speed as passenger cars; this generally includes short grades of no more than 2 percent.
2	**Rolling**: Any combination of grades and horizontal or vertical alignment that causes heavy vehicles to reduce their speeds substantially below those of passenger cars but that does not cause heavy vehicles to operate at crawl speeds for any significant length of time.
3	**Mountainous**: Any combination of grades and horizontal or vertical alignment that causes heavy vehicles to operate at crawl speeds for significant distances or at frequent intervals.

Item 71 — Vertical Alignment Adequacy (**Rural Data Item**) (**Software Calculated**)

This item provides information about the adequacy of vertical alignment when grade data are not reported. Code for all paved sample sections unless Grades by Class (Items 72 - 77). If grades by class are coded, vertical alignment adequacy will be calculated for all paved sections from the grade data. Use the following codes:

Code	Description
0	Grade data are reported or this item is not required for the section.

Code	Description
1	All grades (rate and length) and vertical curves meet minimum design standards appropriate for the terrain. Reduction in rate or length of grade would be unnecessary even if reconstruction were required to meet other deficiencies (i.e., capacity, horizontal alignment, etc.).
2	Although some grades (rate and/or length) and vertical curves are below appropriate design standards for new construction, all grades and vertical curves provide sufficient sight distance for safe travel and do not substantially affect the speed of trucks.
3	Infrequent grades and vertical curves that impair sight distance or affect the speed of trucks (when truck climbing lanes are not provided).
4	Frequent grades and vertical curves that impair sight distance or severely affect the speed of trucks; truck climbing lanes are not provided.

Basically, we can assume that urban roadways are fairly straight, for this analysis, code "0" for urban roadways.

Items 72-77 — Grades by Class (Numeric; Decimal)

These items provide specific information regarding the length of vertical grades by percent gradient for sample sections. Code for paved rural arterials and urban principal arterials. Grades by class may be coded for other functional systems if the data are available; code "0.0" when grade data are not reported. When this item is not reported for the required rural systems, code Vertical Alignment Adequacy (Item 71).

Each grade and flat segment is coded as a separate segment; segments are typically measured between vertical points of intersection (VPI) and summed by grade class to obtain the total length in each class. Report the sum of the class lengths for each of the six grade classes in miles; **the sum of all grade lengths must equal the section length**. Report the following data:

Item	Grade Class	Grade Classes by Gradient (Percent)	Length of Grades in Class (to 3 decimals) xx.xxx
72	A	0.0-0.4	——
73	B	0.5-2.4	——
74	C	2.5-4.4	——
75	D	4.5-6.4	——
76	E	6.5-8.4	——
77	F	8.5+	——

Basically, we can assume that urban roadways are fairly straight, for this analysis (we've generally accounted for curves in the RVMPO Node/Link Network.

Item 78 — Percent Passing Sight Distance (**Rural Data Item**) (Numeric; Integer)

This item provides specific information on the percent of the sample section meeting the sight distance requirement for passing. Code this numeric item for all rural, paved two-lane sample sections. Enter the percent of the section length that is striped for passing. Where there is a discernable directional difference, code for the more restrictive direction. Code "0" for nonapplicable sections as well as for very curved or very hilly sections without passing zones. **Use the roadway stripping to calculate the percent of passing. This only is applied on two-lane roads, where passing required traveling in the lane for opposite traffic. For 3+lanes, passing can be done without moving into opposing lanes, so it should be coded as non-passing. Also, most urban roadways will most likely be non-passing. For urban, code "0".**

Item 79 — Weighted Design Speed (**Software Calculated**)

This item is a calculated value that provides a design speed weighted by the length of individual horizontal curves and tangents in a sample section. This item is calculated by the HPMS software from curve data; when curve data are not provided, a default value based upon functional system and facility type is used as shown in the following table. **This data should be easy to calculate.**

Facility Type	Functional Class								
	1	2	6	7	11	12	14	16	17
Multilane Divided	70	70	70	65	70	70	70	60	55
Multilane Undivided	70	70	70	60	70	70	70	55	45
2/3 Lane	70	70	65	60	70	65	65	55	45

Item 80 — Speed Limit (Numeric; Integer)

This item provides information on the posted speed limit on sample sections. Enter the daytime speed limit for automobiles posted or legally mandated on the greater part of the section. **This data should be easy to identify from various mapping or other data sources.**

Item 81 — Percent Peak Single Unit Trucks (Numeric; Integer)

This item provides information on truck use on a sample section. Code this item with the percent from **Item 82** unless the State has determined that the percent of trucks in the peak period is different from the average daily percent trucks. **For simplicity, use the same value as coded in Item 82, until more specific data is available.**

Item 82 — Percent Average Daily Single Unit Trucks (Numeric; Integer)

This item provides information on truck use on a sample section. Code single unit truck traffic as a percentage of section AADT to the nearest whole percent. This value should be representative of all single unit truck activity over all days of the week and seasons of the year as a percent of total annual traffic. Single unit trucks include **vehicle classes 4 through 7** (buses through four-or-more axle, single-unit trucks). **This information should be collected from existing count data, or other data sources. This item will be close to zero for urban roadway of low classification, such as local and/or collector – it is assumed that there will be little truck traffic on low classification routes.**

Item 83 — Percent Peak Combination Trucks (Numeric; Integer)

This item provides information on truck use on a sample section. Code this item with the percent from **Item 84** unless the State has determined that the percent of trucks in the peak period is different from the average daily percent trucks. **For simplicity, use the same value as coded in Item 84, until more specific data is available.**

Item 84 — Percent Average Daily Combination Trucks (Numeric; Integer)

This item provides information on truck use on a sample section. Code combination truck traffic as a percentage of section AADT to the nearest whole percent. Combination trucks include **vehicle classes 8 through 13** (four-or-less axle, single-trailer trucks through seven-or-more axle, multi-trailer trucks). **This information should be collected from existing count data, or other data sources. This item will be close to zero for urban roadway of low classification, such as local and/or collector – it is assumed that there will be little truck traffic on low classification routes.**

Item 85 — K-Factor (Numeric; Integer)

This item provides the design hour volume as a percent of AADT for a sample section. Code the K-factor for the section to the nearest percent. The K-factor is the design hour volume (30th highest hour) as a percentage of the annual average daily traffic. Section specific values are requested. If not available, use values derived from continuous count station data on the same route or on a similar route with similar traffic in the same area. The K-Factor normally ranges from 6 to 18 percent. **This information should be collected from existing count data, or other data sources.**

Item 86 — Directional Factor (Numeric; Integer)

This item provides the percent of design hour volume flowing in the peak direction on a sample section. Enter the percentage of the design hour volume (30th highest hour) flowing in the peak direction. Code "100" for one-way facilities. Section specific values are requested. The directional factor normally ranges from 50 to 70 percent. **This information should be collected from existing count data, or other data sources.**

Item 87 — Number of Peak Lanes (Numeric; Integer)

This data item is used to provide information on the number of lanes used in the peak hour direction of flow on a sample section. Code the number of through lanes used in the peak period in the peak direction. For rural 2- or 3-lane sections, code the number of through lanes in both directions in the peak period. The number of peak lanes is used in the HCM-based capacity calculation procedure. **This information should be easy to collect from various mapping or other data sources.**

Items 88-89 — Left/Right Turning Lanes (**Urban Data Items**) (Numeric; Codes)

These items provide information on the presence of turning lanes at a typical intersection on a sample section. Enter the code from the following tables that best describes the peak-period turning lane operation on the inventory section. Where peak capacity for a section is governed by a particular intersection that is on the section, code the turning lane operation at that location; otherwise code for a typical intersection. Code turning lanes and the percent green time for the same intersection. Include turning lanes that are located at entrances to shopping centers, industrial parks, and other large traffic generating enterprises as well as public cross streets. Code a continuous turning lane with painted turn bays as a continuous turning lane. **This**

information should be easy to collect from various mapping or other data sources.

Item 88 — Left Turn Lane Codes (Numeric; Codes)

Code	Description
0	Not applicable; this is a rural section or **no intersections exist on the section.**
1	Turns permitted; multiple exclusive left turning lanes exist. Through movements are prohibited in these lanes. Multiple turning lanes allow for simultaneous turns from all turning lanes.
2	Turns permitted; a continuous exclusive left turning lane exists from intersection to intersection. Through movements are prohibited in this lane.
3	Turns permitted; a single exclusive left turning lane exists.
4	Turns permitted; no exclusive left turning lanes exist.
5	No left turns are permitted during the peak period.

Item 89 — Right Turn Lane Codes (Numeric; Codes)

Code	Description
0	Not applicable; this is a rural section or **no intersections exist on the section**.
1	Turns permitted; multiple exclusive right turning lanes exist. Through movements are prohibited in these lanes. Multiple turning lanes allow for simultaneous turns from all turning lanes.
2	Turns permitted; a continuous exclusive right turning lane exists from intersection to intersection. Through movements are prohibited in this lane.
3	Turns permitted; a single exclusive right turning lane exists.
4	Turns permitted; no exclusive right turning lanes exist.
5	No right turns are permitted during the peak period.

Item 90 — Prevailing Type of Signalization (**Urban Data Item**) (Numeric; Codes)
The data for these items is not used for HERS-ST.

Default data	0 – Default

Item 91 — Typical Peak Percent Green Time (**Urban Data Item**) (Numeric; Integer)

This item provides information on the typical through lane percent green time in effect at intersections on a sample section. Enter the percent green time in effect during the peak period for through traffic at signalized intersections for the direction of travel on the inventory section; percent green time may be coded for rural sections on an optional basis. Where peak capacity for a section is governed by a particular intersection that is on the section, code the percent green time at that location; otherwise code for a typical intersection. Code the percent green time for the same intersection where Items 88 and 89 are coded. Code "0" if no signalized intersections exist or if the section is rural. Use results of a field check of several peak period light cycles to determine a "typical" green time for traffic actuated/demand responsive traffic signals. Ignore separate green-arrow time for turning movements.

Oregon DOT does not currently have a signal database, so this item is generically populated for massive database development. In essence, when Item 92 contains any value greater than zero, it is assumed that the Green Time is split 50-50. Sensitivity testing should be conducted to see how different values will influence the analysis.

Items 92-94 — Number of At-Grade Intersections (Numeric; Integer)

These items provide a count of the number of intersections and traffic controls on the sample section. Code the number of intersections on the inventory route according to the following table. Include at-grade intersections at entrances to shopping centers, industrial parks, and other large traffic generating enterprises. **This information should be easy to collect from various mapping or other data sources.**

Item	Description
92	**Signals**: Enter the number of at-grade intersections with a signal controlling traffic on the inventory route. A signal that cycles through red, yellow, and green for all or a portion of the day should be counted as a signalized intersection. If none, enter "0."
93	**Stop Signs**: Enter the number of at-grade intersections with a stop sign controlling traffic on the inventory route. A continuously operating, flashing red signal should be counted as a stop sign control. If none, enter "0".
94	**Other or No Controls**: Enter the number of at-grade intersections where traffic on the inventory route is not controlled by either a signal or a stop sign; or is controlled by other types of signing; or has no controls. A continuously operating, flashing yellow signal should be considered as "other or no control." If none, enter "0."

Item 95 — Peak Capacity (**Software Calculated**)

This item provides existing peak hour capacity for a sample section. The rural and urban peak capacity values are calculated by procedures in the HPMS software provided to the States. The procedures used in the software for determining highway capacity conform to the Highway Capacity Manual (HCM). The capacity calculations are based on service flow rates for level of service E.

All urban capacity is for the peak direction as is rural capacity for freeways and other multi-lane facilities. If a rural facility has 2 or 3 lanes with one-way operation, it is considered to be a multi-lane facility for determining capacity. The capacity for rural facilities with 2 or 3 lanes and two-way operation is for both directions.

Item 96 — Volume/Service Flow Ratio (V/SF) (**Software Calculated**)

This item is a computed value reflecting peak hour congestion for a sample section. **This value is generated by the HPMS software from HPMS data.**

Item 97 — Future AADT (Numeric; Integer)

This item provides forecast AADT information for a sample section. Code the forecasted two-way AADT for the year coded in Item 98, Year of Future AADT. The intent is to include a 20-year forecast in the HPMS but the estimate may be for some other period of time within an 18 to 25 year time span. This item may be updated at any time but must be updated when the forecast falls below 18 years. **For the purpose of this project, the FADT will be provided as output from the RVMPO model. Since all section records are one-way, this data will be reported as one-way.**

Item 98 — Year of Future AADT (Numeric; Integer)

This item provides the year for which the AADT has been forecast. It is used to normalize the forecast AADT to a consistent 20-year horizon. Enter the four-digit year for which Future AADT (Item 97) has been forecasted. This cannot be for less than 18 years nor more than 25 years from the data year (Item 1). **For the purpose of this project, the FADT year will be based on the RVMPO future year scenario.**