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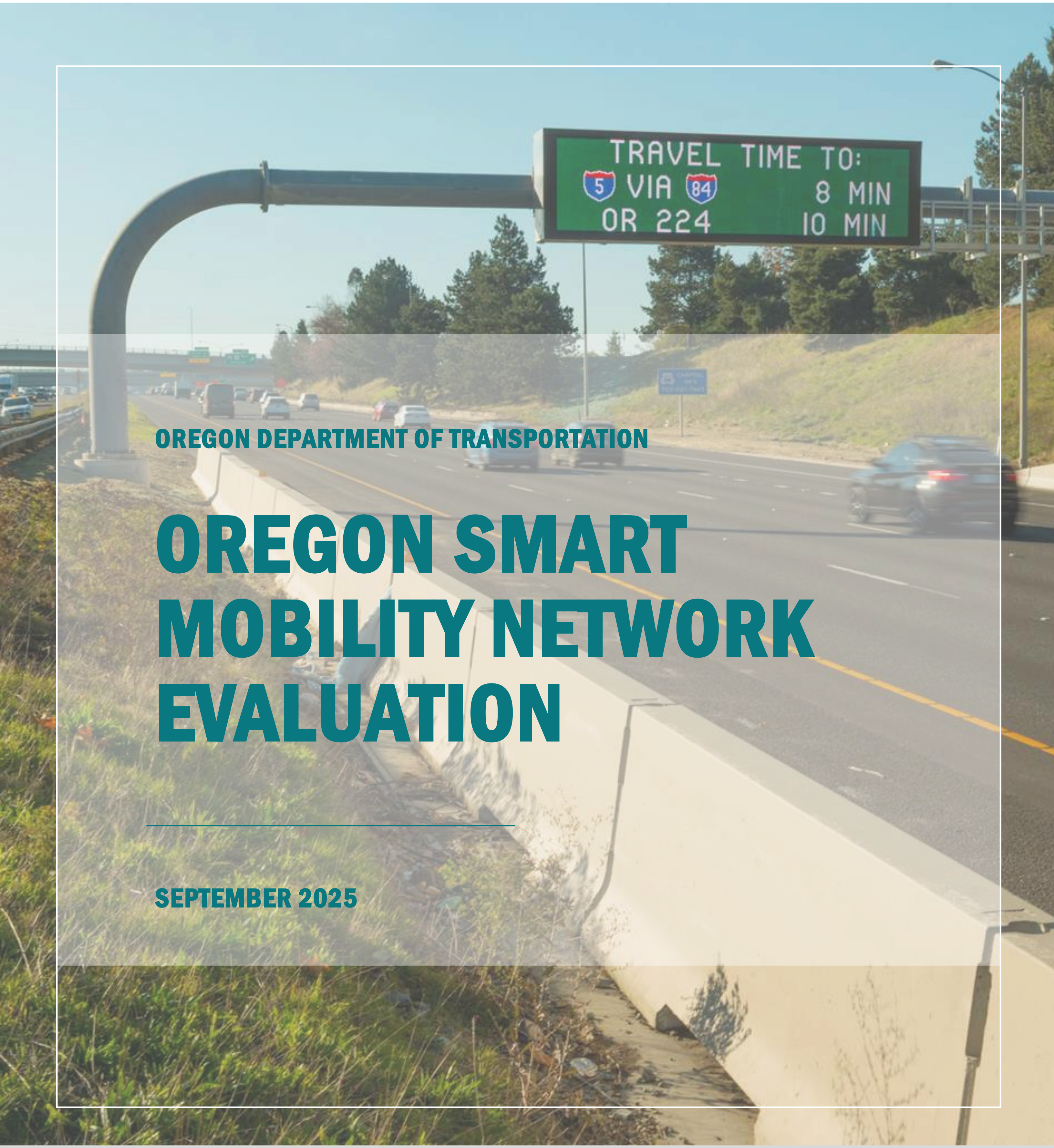

OREGON DEPARTMENT OF TRANSPORTATION

OREGON SMART MOBILITY NETWORK EVALUATION

SEPTEMBER 2025

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1 Introduction

The Oregon Smart Mobility Network project was a series of infrastructure and technology deployments funded by the Federal Highway Administration's Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant.

The primary objective of the Oregon Smart Mobility Network project was to demonstrate how a connected, data-driven transportation network could enhance safety and efficiency, while addressing anticipated traffic increases associated with Oregon's population growth, through the strategic deployment of technologies in the state's most congested areas

The project helped prepare, manage and recover the system during periods of congestion or adverse weather. The project helped prepare for growth in congestion by ensuring necessary tools and strategies were in place and had been tested. The project supported system management that provided tools and technologies in active traffic management and road weather management to support system operators and the system users. The project also deployed tools and technologies that helped the system recover from disruptions such as crashes or other incidents or adverse weather conditions.

The project included collaboration with multiple local jurisdictions, including the City of Portland, Washington County, the City of Bend, transit agencies, TriMet, and state agencies including Oregon State Police.

Figure 1.1 shows the locations of the deployments.

The deployments included:

1. I-205 Active Traffic Management
2. OR 212/224 Arterial Corridor Management
3. NE Airport Way Arterial Corridor Management
4. Next Generation Transit Signal Priority (TSP)
5. Cornelius Pass Arterial Corridor Management
6. US 97 Road Weather Management
7. City of Bend Colorado/Arizona Couplet Automated Traffic Signal Performance Measures (ATSPMs)
8. UAS Crash Reconstruction
9. Multimodal Integrated Corridor Management Architecture[1]

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[1] Not evaluated in this report.

The deployments were geographically spread out around the state and in different contexts. There were projects in the Portland Metro Area (1,2,3,4, and 5), projects in suburban areas (2 and 5), projects on rural highways (6), projects in a small Metropolitan Planning Organization (7). The UAS Crash reconstruction could be applied statewide.

The deployments were funded by a $12 Million ATCMTD grant, the maximum grant award, and a $19.2 Million investment of state and local funds. Total project cost was $31.2 Million.

This report is an assessment of eight of the intelligent transportation system (ITS) deployments installed in the Oregon Smart Mobility program.

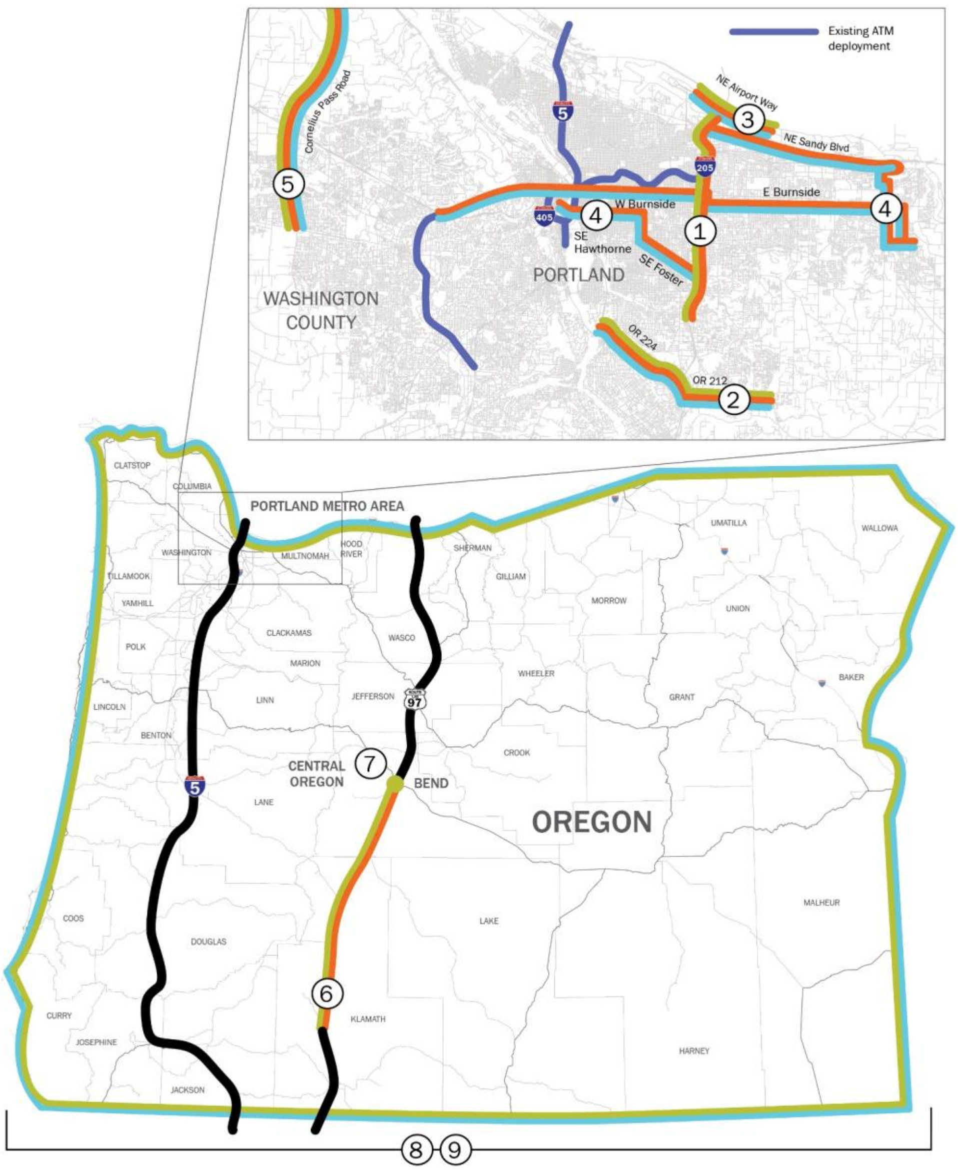


FIGURE 1.1: PROGRAM GEOGRAPHIC AREA: PROGRAM GEOGRAPHIC AREA

Specific deployments evaluated in this report include:

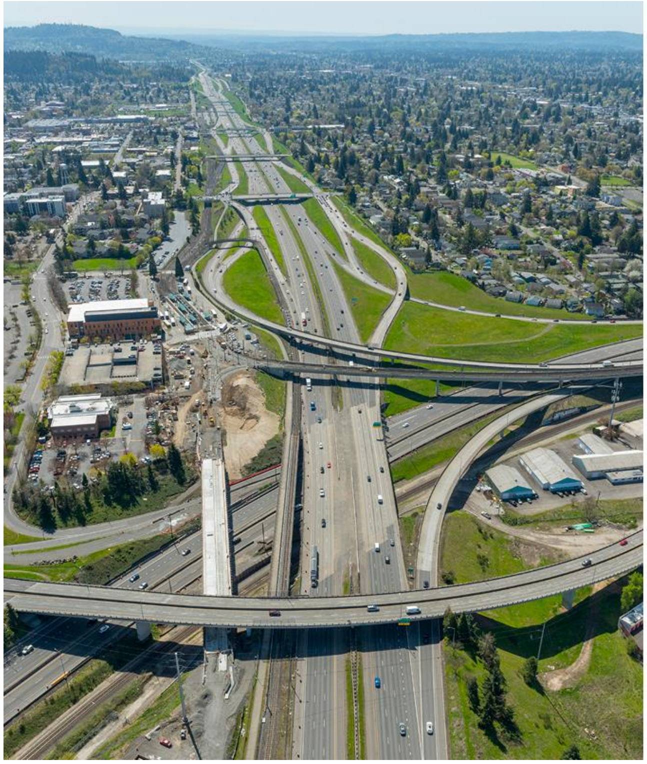
- An Active Traffic Management (ATM) system on I-205, incorporating variable message and advisory speed signs, ramp metering, mainline detection, and supporting ITS infrastructure.
- Automated Traffic Signal Performance Measures (ASTPMs), freight detection enhancements, signal controller upgrades, and a pedestrian call extension system along Cornelius Pass Road.
- Communications infrastructure expansion along NE Airport Way, video detection and video management server upgrades, and signal controller upgrades.
- A regionally integrated, centralized transit signal priority system deployed by TriMet.
- A road weather management system on US 97 using variable speed limit infrastructure, RWIS stations, radar sensors, VMS signs, and the expansion of the Oregon TripCheck travel information system.
- Conversion of six signalized intersections in Bend to ATSPM-capable operation through controller and detection upgrades.
- UAS-based crash reconstruction systems deployed at five Oregon State Police regions.

This report documents the evaluation of these systems based on performance measures such as operational improvements including reduction in delay and improvements in travel time reliability, and safety benefits including crash reduction or reductions in near-misses, and red-light-running measured via video analytics. The evaluation includes interviews with operational staff on the benefits and challenges of ATSPM implementation. It includes analysis of before and after data, benefit-cost evaluations in accordance with USDOT guidance, and an assessment on the system's effectiveness.

2 I-205 ATM System Evaluation Report

INTRODUCTION

This report evaluates the before and after implementation data for the I-205 Active Traffic Management (ATM) project. The report describes the safety, mobility, and operational effects of the system. This project was funded with $30.7 million dollars of State of Oregon House Bill 2017 funds delivered to the Oregon Department of Transportation. $14 million of the project's construction budget was used as a state match for the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant by the Oregon Department of Transportation (ODOT) for its Oregon Smart Mobility Network.



LEFT: AERIAL I205 AT GATEWAY, TOP RIGHT: GLISAN STREET SIGN BRIDGE OVER I-205 NORTH, BOTTOM RIGHT: KILLINGSWORTH NORTHBOUND CONNECTION

Source: ODOT

PROJECT DESCRIPTION

The ODOT I-205 Active Traffic Management (ATM) project included three major improvements: 1) the construction of a new, northbound auxiliary lane between the entrance ramp from US 26 Powell Boulevard (MP 19.58) to the exit ramp to westbound I-84 (MP 20.99); 2) pavement preservation of I-205 between MP 18.60 and MP 21.53; and 3) the installation of an Automated Traffic Incident Management and Real-Time Sign System between MP 16.30 and 25.60 in both the northbound and southbound directions. Figure 1.1 shows the extent of the project area.

The goal of the project was to address persistent congestion and safety issues in the corridor and improve travel time and travel time reliability.

NORTHBOUND AUXILIARY LANE

The northbound auxiliary lane was constructed from the entrance ramp onto I-205 from US26 Powell Boulevard at MP 19.58 to the exit ramp from I-205 to westbound I-84. The lane was constructed to remedy severe congestion identified in ODOT planning efforts conducted several years prior. The incorporation of the new lane into the existing freeway system was accomplished without the purchase of additional right-of-way by performing most of the widening towards the median of the freeway and limiting the right shoulder work to only what was necessary and fit within the existing physical constraints.

The project included widening the northbound pavement section (in varying widths) to accommodate the addition of the new auxiliary lane, as well as the necessary realignment of the freeway travel lanes and entrance and exit ramps. The northbound pavement section was widened towards the outside (right side) of the freeway from the Division Street entrance ramp (MP 19.90) to just north of the Glisan Street overpass (MP 21.20). It was necessary to remove and replace existing light poles, concrete gore islands, two sign bridges, overhead signage, roadside signage, overpass slope paving, ramp meter detectors, an automated traffic recorder, and additional devices.

Pavement Preservation

Pavement preservation was performed on I-205 northbound from MP 18.60 to MP 21.53. The work included grinding off the existing 2.5-inch-thick sacrificial asphalt wearing course atop the underlying concrete pavement and replacing with a new 2.5-inch-thick Level 4, 0.5 inch asphalt concrete pavement wearing course with PG 74-22ER binder. Additionally, new pavement markings were placed. Within the limits of the new northbound auxiliary lane, the alignment of the new lane lines was adjusted to delineate the new lane alignments and additional pavement markings, and pavement markings with different patterns were placed to accommodate the additional lane.

Included in the pavement preservation section was a minor amount of bridge preservation work which occurred on the northbound Powell Boulevard Structure (Str. #13531) and the northbound Division Street Structure (Str. #13528).

Active Traffic Incident Management and Real-Time signs

The project also included the installation of an Active Traffic Incident Management System (ATIM), including Real-Time message signs in both directions of I-205 between MP 16.30 and MP 25.60, as well as the installation of Variable Message Signs (VMS), Variable Advisory Speed Signs (VAS), cameras, radar detection, and road and weather station (pavement temperature, relative humidity, air temperature, visibility, wind speed and direction, grip factor of pavement, and pavement classification (dry, water, ice, slush, snow or frost). The ATIM System was installed on a mixture of existing sign supports, existing overpass structures, new truss sign support structures, new monotube sign support structures and new monotube sign bridges at 11 separate sites throughout the corridor.

Key components of the project included:

- Northbound Auxiliary Lane
- Active Traffic Management (ATM) System
- Variable message signs
- Variable advisory speed signs
- Vehicle detection
- Fiber optics communications

The project was constructed and deployed during the period of February 2019 through November 2019.

FIGURE 2.1: PROJECT AREA MAP

PROJECT BACKGROUND

ODOT's 2020 Traffic Performance Report noted that I-205 has Hours of Congestion similar to I-84 and US 26 "with nearly half the day experiencing congestion in both directions."

It also indicated that "I-205 NB in the PM Peak has one of the lowest average speeds in the region indicative of persistent severe congestion."

The report also noted that there was a high frequency of crashes in the corridor, particularly near the interchange with I-84.

Corridor Operations

The I-205 corridor operates with the peak directions towards I-84 in the morning peak and away from I-84 in the afternoon peak. The afternoon peak from I-84 to the Glenn Jackson Bridge over the Columbia River is northbound. The afternoon peak from Johnson Creek Boulevard to I-84 is southbound.

EVALUATION

EVALUATION GOALS, OBJECTIVES AND QUESTIONS

ODOT provided the Federal Highway Administration with evaluation goals, objectives, and questions as part of the ATCMTD grant process. These are shown in Table 2.1.

TABLE 2.1: EVALUATION GOALS, OBJECTIVES AND QUESTIONS

GOAL AREA	DESCRIPTION/OBJECTIVES	EVALUATION QUESTION
IMPROVE SAFETY	Reduce Traffic Crashes	Do the improvements affect incident rates on I-205 between the Glenn Jackson Bridge and Johnson Creek Boulevard?
IMPROVE MOBILITY	Improve travel time reliability	Is the variability of average travel times decreased on I-205 between Glenn Jackson Bridge and Johnson Creek Boulevard during the evening weekday peak hour?
IMPROVE OPERATIONS	Mitigate recurring bottlenecks	Is the I-205 segment between the Glenn Jackson Bridge and Johnson Creek Boulevard able to accommodate more vehicles at the same service level?

DATA COLLECTION

Before data was collected from January 2017 through December 2018. *After* data was collected from January 2021 through December 2022. The data collection periods avoided the period when the system and the auxiliary lanes were being installed. The data collection periods also avoided the period when traffic volumes were most affected by the pandemic.

DKS screened the data sets for completeness and quality, performed preliminary statistical analysis, and determined the evaluation periods for the *before* and *after* analysis, providing a minimum of six months of data in each evaluation period to summarize meaningful traffic trends. The actual evaluation periods were dependent on results of the data screening.

Typically, six months of data is considered amply sufficient for travel time reliability analysis. The analysis picked the most representative six months of data that showed how the corridor typically operated. The six months of *after* data was chosen to avoid the impacts of the COVID pandemic on traffic volumes. The six months of *before* data was then chosen to match the period and season of the *after* data. The comparison of six months *before* and *after* data was representative of the project's effect on the corridor. Had there been no pandemic and two years of data were used for the analysis, results would not have been expected to be of meaningful difference.

DKS developed performance measures that could answer the evaluation questions and determine whether the evaluation objectives were met. The performance measures and associated data type necessary to evaluate objectives are shown in Table 2.2.

TABLE 2.2: PERFORMANCE MEASURES AND DATA TYPES

EVALUATION QUESTION	PERFORMANCE MEASURES	ASSOCIATED DATA TYPE
Do the improvements affect incident rates on I-205 between the Glenn Jackson Bridge and Johnson Creek Boulevard?	• Traffic Incident Rate	• Incident Logs • Traffic Volumes
Is the variability of average travel times decreased on I-205 between Glenn Jackson Bridge and Johnson Creek Boulevard during the evening weekday peak hour?	• Average Travel Time • 95th Percentile Travel Time • Buffer index • Planning Time Index	• Freeway Segment Lengths • Travel Speed/Time at 5 Minute Intervals
Is the I-205 segment between the Glenn Jackson Bridge and Johnson Creek Boulevard able to accommodate more vehicles at the same service level?	• Vehicle Density • Vehicle-Miles Travelled	• Freeway Segment Lengths • Traffic Volumes • Travel Speed

The evaluation used ODOT Incident Logs instead of reported crashes because of the significant delay in processing reported crashes. This allowed the safety analysis to be completed much sooner than if the analysis relied on reported crash reports. The data in this report are incidents that were logged into ODOT's incident reporting system as crashes. Incidents were recorded by ODOT dispatchers from reports from Incident Responders or local agency emergency responders. From the report, the dispatcher would note whether the incident was a crash or other event, such as a disabled vehicle. Also, due to incident data only getting recorded if the severity of a crash is fatal, assessing changes in crash severity is challenging. The data sources for each data type are shown in Table 2.3.

TABLE 2.3: DATA SOURCES

DATA TYPES	DATA SOURCE
Freeway segment lengths	Google Earth
Incident logs	ODOT dispatch system
Traffic volumes	PORTAL – Official transportation data archive for the Portland Metro area
Speed/travel time	INRIX data via Regional Integrated Transportation Information System (RITIS)

DATA ANALYSIS

TRAFFIC INCIDENT RATE

In the two years from January 2017 through December 2018, there were 1373 incidents in the segment that could be characterized as crashes. In the two years from January 2021 through December 2022, there were 597 incidents in the segment that could be characterized as crashes. These are shown in Table 2.4.

The DKS teamed compiled all recorded incidents coded in the Incident Response system as crashes. ODOT's Incident Responders and Dispatchers had standard operating procedures and guidelines for reporting incidents as crashes. Incident reports should be consistent across the time frame of the report as the procedures had not changed. The other category were crashes that required an investigation for reasons other than a fatality—crashes where a motorist struck an animal, such as a deer, and crashes where the motorist damaged ODOT property such as a sign post or guardrail.

TABLE 2.4: BEFORE AND AFTER INCIDENTS AND RATES

INCIDENT TYPE	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	PERCENTAGE CHANGE IN THE NO. OF INCIDENTS	INCIDENT RATE (PER 100 MILLION VMT) (BEFORE)	INCIDENT RATE (PER 100 MILLION VMT) (AFTER)	PERCENTAGE CHANGE
CRASH	1330	529	-60.2%	98.91	44.38	- 55.1%
FATAL CRASH	9	11	22.2%	0.67	0.92	37.3%
OTHER	34	57	67.6%	2.53	4.78	88.9%
TOTAL	1373	597	-56.5%	102.10	50.08	-52.0%

Overall, there was a significant decrease in the number of incidents and the increase in fatal crashes in the *after* period was likely statistical variation. Since fatal crashes are relatively rare events compared to the overall number of crashes, small changes in the number can appear to have a large percentage increase. Similarly, the changes in the number of other crashes were statistical variation, given their low number relative to the total number of crashes.

REPORTED CRASHES

In the *after* evaluation, ODOT crash data for 2022 became available sooner than anticipated. This allowed the project team to compare incident data with actual reported crash data. Table 2.5 shows actual crash data. While the crash data is different from the Incident Data, it does show a dramatic decrease in the number of crashes in the *after* period.

TABLE 2.5: BEFORE AND AFTER CRASHES

INCIDENT TYPE	NO. OF CRASHES (BEFORE)	NO. OF CRASHES (AFTER)
FATAL CRASH	2	5
SERIOUS INJURY CRASHES	13	42
MODERATE INJURY CRASHES	61	191
MINOR/POSSIBLE INJURY	373	243
PROPERTY DAMAGE ONLY	997	363
TOTAL CRASHES	1446	844

TABLE 2.6: BEFORE AND AFTER AADT AND VMT

	BEFORE	AFTER
AADT	170,560	151,200
VMT	672,347,520	596,030,400

The Average Annual Daily Traffic (AADT) and the Vehicles Miles Traveled (VMT) declined in the *after* period. It is unknown why this decrease occurred and beyond the scope of the evaluation to determine so. Table 2.6 shows the *before* and *after* AADT and VMT. The AADT was used to calculate the Incident Rate.

TRAVEL TIME

In the six-month periods from January 2018 through June 2018 and January 2022 through June 2022, DKS calculated travels times and travel time reliability. The team evaluated the following measures: Average Travel Time, 95th Percentile Travel Time, Buffer Index, Planning Time Index.

These measures are defined as follows:

Average Travel Time is the mean travel time necessary to traverse the segment. It is computed by adding all the travel times in the data set and dividing the sum by the number of data points. The time is reported in minutes.

95th Percentile Travel Time is a measure of how bad travel times are on the heaviest travel days, on 95 days in 100 the motorist's travel time is less than this time. The measure is reported in minutes.

Buffer Index represents the extra buffer that travelers would need to add to their average travel time when planning trips to ensure on time arrival. It is computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time.

Planning Time Index represents the total travel time that should be planned when an adequate buffer time is included over the free-flow speed.

I-205 SB AUXILIARY LANE AND VARIABLE SPEED SIGNS

Source: ODOT

As previously stated, six months of data provided sufficient analysis for travel time reliability analysis. The analysis picked the most representative six months of data to show how the corridor typically operated. The six months of *after* data was chosen to avoid the impacts of the COVID pandemic on traffic volumes. The six months of *before* data was then chosen to match the period and season of the *after* data. The comparison of six-month *before* and *after* data was representative of the project's effect on the corridor. Had there been no pandemic and two years of data were used for the analysis, results would not have been expected to be of meaningful difference.

Table 2.7 displays the results for northbound I-205 and Table 2.8 displays the results for southbound I-205.

The variability of the average travel time increased in the northbound direction; however, the average travel time decreased significantly (11.4 percent or 2.5 minutes.) The 95th percentile travel time increased by 0.3 minutes (18 seconds.) The other reliability measured worsened in the northbound direction as well. The buffer index increased by 40 percent, and the planning time index increased by 5.7 percent. The relatively high increase in the buffer index could be attributed to the large decrease in the average travel time. The buffer index is computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time. In this case the 95th percentile travel time nearly stayed the same, but the average travel time decreased significantly, increasing the buffer index. Alternatively put, the worst-case scenario remained relatively unchanged, while the average or typical performance improved significantly. One potential explanation for this is that bottlenecks outside the study or traffic backing up onto the freeway from other roadways impacted travel time reliability.

TABLE 2.7: TRAVEL TIME FOR I-205 NORTHBOUND EVENING PEAK HOUR (4:20 PM TO 5:20 PM)

PERFORMANCE MEASURE	BEFORE	AFTER	PERCENTAGE CHANGE
CORRIDOR AVERAGE TRAVEL TIME (MIN.)	26.7	23.7	- 11.4%
95TH PERCENTILE TRAVEL TIME (MIN.)	40.5	40.8	0.7%
BUFFER INDEX	0.51	0.72	40.1%
PLANNING TIME INDEX	3.60	3.81	5.7%

TABLE 2.8: TRAVEL TIME FOR I-205 SOUTHBOUND EVENING PEAK HOUR (3:50 PM TO 4:50 PM)

PERFORMANCE MEASURE	BEFORE	AFTER	PERCENTAGE CHANGE
CORRIDOR AVERAGE TRAVEL TIME (MIN.)	20.4	17.9	- 12.5%
95TH PERCENTILE TRAVEL TIME (MIN.)	34.6	29.5	- 14.8%
BUFFER INDEX	0.70	0.65	- 6.6%
PLANNING TIME INDEX	3.08	2.76	- 10.6%

I-205 NB AUXILIARY LANE

Source: ODOT

DENSITY AND VOLUMES

DKS calculated density and volumes. Volume and density were used to help determine if I-205 could accommodate more vehicles at the same service level. *Volume* is expressed as the number of vehicles per hour passing a specific point. The term *flow* means the equivalent hour rate at which vehicles pass over a given point during a given time interval of less than hour—in this case, 15 minutes. *Density* is the number of vehicles occupying a certain space. In this case, density is the number of vehicles per mile.

To determine if the segment is accommodating more vehicles at the same service level, DKS compared the relationship between volumes and densities in the before and *after* conditions, showing a generalized relationship between flow (volume) and density on freeways.

Theoretically, data points of volume-density values for a specific facility would fall on a curve similar to Figure 2.2. When comparing the volume-density relationships from the *before* and *after* conditions, the data points would form two different curves representing the *before* and *after* conditions, respectively. Increased volumes at the same density level would indicate that more vehicles were being accommodated at the same service level. That is, if the volumes in the *after* conditions were higher than the *before* conditions, relative to the same density values, the findings indicate that the vehicles are being accommodated at the same service level.

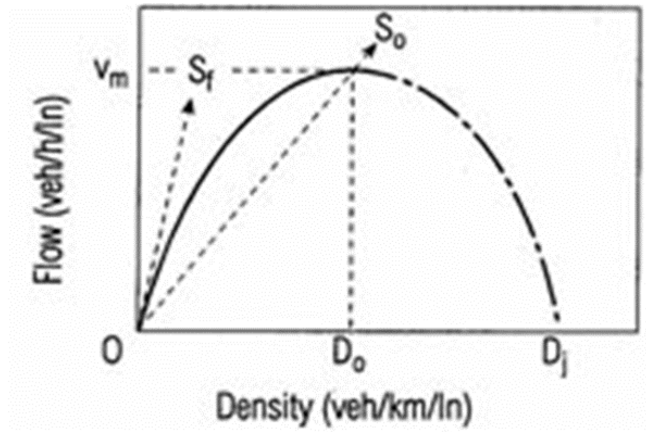


FIGURE 2.2: GENERALIZED RELATIONSHIP BETWEEN FLOW AND DENSITY ON UNINTERRUPTED FLOW FACILITIES

Source: FHWA Traffic Control Systems Handbook

The freeway segment of analysis was divided into three sections, and the volume-density relationship was reported for each direction of each section, for both the a.m. and p.m. peak periods. The a.m. peak period was 6 a.m. to 9 a.m. The p.m. peak period was 3 p.m. to 6 p.m. The sections were defined as follows:

- **Section 1:** Glen Jackson Bridge to US 30/Sandy Blvd.
- **Section 2:** US 30/Sandy Blvd. to I-84
- **Section 3:** I-84 to Johnson Creek Blvd.

The sections were selected based on the number of lanes, the presence of auxiliary lanes and the available locations of count stations.

DKS created scatter plots of volume and density for each direction of each section, from the a.m. and p.m. peak periods.

- For each section, the team pulled six months of data including speed data in 15-minute intervals and averaged by the time bins.
- Density was calculated for 15-minute intervals.
- Each segment had an average flow for each 15- minute interval. The data was from PORTAL volume stations and provided to the team already aggregated.

Density was then calculated with the average flow and average speed for each 15-minute interval.

Each analysis period (e.g., a.m. before, from 6 a.m. – 9 a.m.), included 12 data points representing the average density and flow for 15-minute intervals in the three-hour time period.

The scatter plots include discrete data points that would reflect the facility's flow-density relationship, similar to what is shown in Figure 2.3. The scatter plots show that volumes are generally higher in the *after* condition relative to the density level.

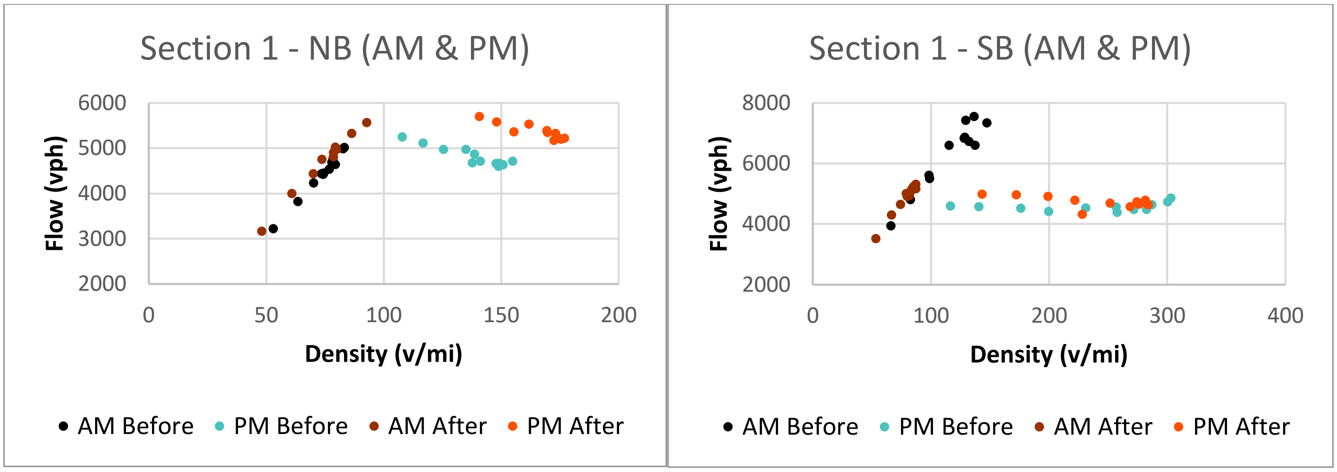


FIGURE 2.3: SECTION 1 FLOW AND DENSITY SCATTER PLOT

In Section 1, the data showed higher volumes in the *after* conditions relative to densities, for both directions, and in both the a.m. and p.m. peak periods. In the southbound direction, the a.m. peak period volumes were lower in the *after* condition. When the flow exceeds 6,000 vph, densities cannot be compared due to having no data in the *after* condition. At data points where comparable densities exist in the a.m. peak period (between 50-100 v/mi), volumes were higher in the *after* conditions.

Therefore, the results indicate that both directions of Section 1 were able to accommodate more vehicles at the same service level in the *after* conditions.

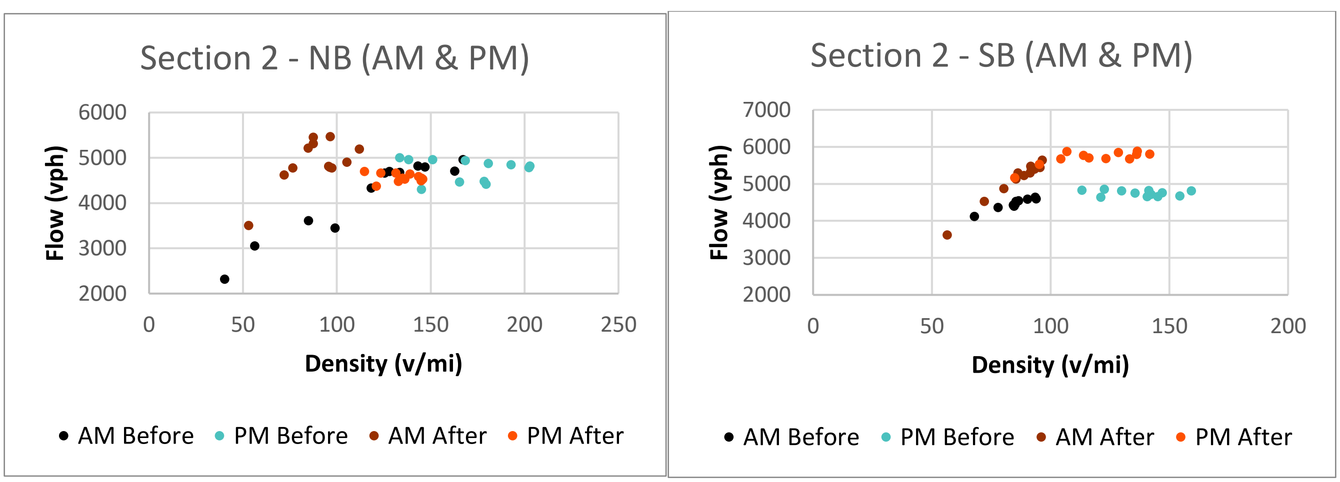


FIGURE 2.4: SECTION 2 FLOW AND DENSITY SCATTER PLOT

In Section 2, the northbound direction also showed higher volumes in the *after* conditions, relative to densities, for the a.m. peak period. However, no significant increase in volumes was shown for the p.m. peak period.

The southbound direction clearly showed higher volumes in the *after* conditions, relative to densities, in both the a.m. and p.m. peak periods.

Overall, the data showed that both directions of Section 2 were able to accommodate more vehicles at the same service level in the *after* period.

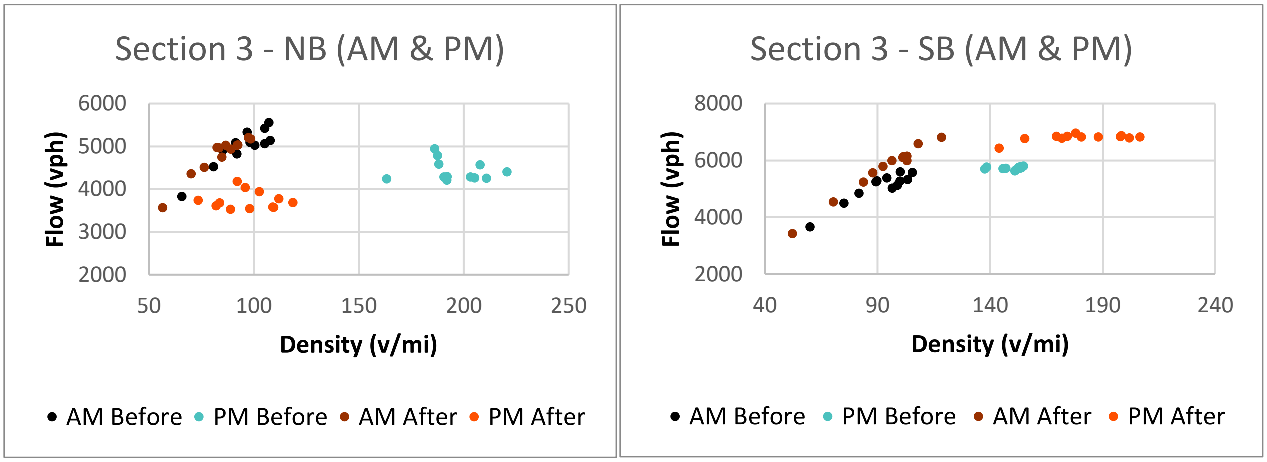


FIGURE 2.5: SECTION 3 FLOW AND DENSITY SCATTER PLOT

In Section 3, similar volumes were accommodated in the *after* conditions in the northbound a.m. peak period at similar densities. The northbound p.m. peak period had lower volumes at lower densities in the *after* conditions. Due to the different density ranges for the p.m. periods, it was inconclusive whether the northbound direction was able to accommodate more vehicles at the *same* service level.

The southbound direction accommodated higher volumes at similar density levels in the *after* conditions in both the a.m. and p.m. peak periods.

Overall, the section appeared to be accommodating more vehicles at the same service level, particularly in the southbound direction.

The evaluation of volume and density showed that all three sections of the freeway segment were able to accommodate either a similar or higher level of vehicles at the same service levels.

BENEFIT/COST

DEVELOPMENT OF BENEFIT/COST

Benefits were developed from the safety and delay impacts to the project. Costs were determined by the project development and construction cost of the project.

The total project cost was $30.7 million ($36,533,000 when adjusted to 2023 dollars).

Safety benefits were derived from the crash or incident reduction in the project limits. ODOT developed the cost of crashes based on severity and these were applied to the reduction in crashes.

The costs of delay reduction were determined by the cost of delay that ODOT developed for *The Value of Travel-Time: Estimate of the Hourly Value of Time for Vehicles* in Oregon 2023.

BENEFIT OF REDUCTION IN DELAY

The team calculated the monetary value of travel time savings using data from ODOT's *Estimated Value of One Hour of Travel Time Savings by Vehicle Class* (2025), the most recent version of the report. This analysis focused on the weekday p.m. peak period from 3:00 p.m. to 6:00 p.m. Monetary values were assigned to different vehicle classes based on classification counts, and distinct hourly volumes were applied for each peak hour. Volume data was sourced from two count stations: the northbound Powell ramp (Station ID 2DS153) and the southbound Killingsworth Street location (Station ID 2R025).

Table 2.9 below shows the value of reduced travel time per day for each direction during the peak hours, and the annual benefit of reduction in delay. The total annualized benefit from the reduction in delay combining both directions was estimated at $12,799,049.44.

TABLE 2.9: ANNUALIZED BENEFIT OF REDUCTION IN DELAY

DIRECTION	VALUE OF REDUCED TRAVEL TIME PER DAY	WORKDAYS PER YEAR	ANNUAL BENEFIT OF REDUCTION IN DELAY
NORTHBOUND	-$1,085, $5,930, $8,588	260	$3,492,700.36
SOUTHBOUND	$7,685, $10,655, $17,454	260	$9,306,349.09
TOTAL	$6,600, $16,585, $26,042	260	$12,799,049.44

BENEFIT OF REDUCTION IN CRASHES

Safety benefits were derived from the crash or incident reduction within the project limits. While crash severity data was available, due to the relatively short time frame where crash data was available in the *after* period, it was decided not to rely on the severity data. To remain conservative due to lack of available data regarding crash severity and the uncertainty of reduction in crashes, the team assumed that all crashes were property damage only and assigned an economic value to the crash of $24,800. This was the value that ODOT had updated for its benefit costs analysis as of 2023[2].

TABLE 2.10: BENEFITS OF CRASH REDUCTION

CRASHES	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	REDUCTION AMOUNT	COST PER CRASH	ANNUAL BENEFIT
CRASHES	1373	597	776	$24,800	$19,244,800

The total annual benefit associated with the reduction in the cost of crashes was $19,244,800.

TOTAL BENEFITS AND BENEFIT COST

The total costs of the project were $30.7 million (36.5 million when adjusted to 2023 dollars.) The service life of these ITS devices was assumed to be ten years.

The total discounted benefits of the reduction in delay and reduction in crashes were $253,494,968.

The team followed USDOT guidance by using the spreadsheet tool from the online Benefit Cost Analysis Guidance (2025 Update). As noted, the team used ODOT values for the cost of crashes and the value of travel time. The cost of maintenance and operations for this project was $49,026. Using the USDOT guidance a discount rate of 3.1 percent was applied to both the safety and time travel savings benefits for each of the ten individual years following the completion of the project.

This results in a Benefit/Cost Ratio of 7.04 and a net present value of $217,506,588. Table 2.11 shows the Total discounted benefits, costs, net present value, and the benefit cost ratio as discussed above.

TABLE 2.11: BENEFIT COST RESULTS

TOTAL DISCOUNTED BENEFITS	TOTAL DISCOUNTED COSTS	NET PRESENT VALUE	BENEFIT COST RATIO
$253,494,968	$35,988,380	$217,506,588	7.04

The project enabled automated data collection along the corridor, streamlining travel time and speed studies and signal timing adjustments. However, no empirical data was currently available to validate these improvements.

[2] Jiguang Zhao, Ph.D., P.E. Traffic Safety Engineer, Christina McDaniel-Wilson, P.E. State Traffic Safety Engineer, *Updated Crash Costs for Highway Safety Analysis*, August 25, 2023

FINDINGS

ASSESSMENT OF OVERALL SYSTEM PERFORMANCE

The segment had fewer incidents, improved travel times and reliability, and was accommodating more vehicles at the same service level.

Do the improvements affect incident rates on I-205 between the Glenn Jackson Bridge and Johnson Creek Boulevard?

Yes, the number of incidents coded as crashes was dramatically reduced in the after condition. A significant portion of the reduction could be attributed to the ATM system and the auxiliary lanes. From the data that was available, it was not possible to attribute specific crash reductions to one improvement or the other, or whether the improvements acted in concert.

Is the variability of average travel times decreased on I-205 between Glenn Jackson Bridge and Johnson Creek Boulevard during the evening weekday peak hour?

The variability of travel times decreased in the southbound direction. The average travel time decreased by 12.5 percent. The 95th percentile travel time decreased by 14.8 percent. The buffer index and planning time index improved by 6.6 and 10.6 percents, respectively.

The variability of the average travel time increased in the northbound direction; however, the average travel time decreased significantly (11.4 percent or 2.5 minutes.) The 95th percentile travel time increased by 0.3 minutes (18 seconds.) The other reliability measured worsened in the northbound direction as well. The buffer index increased by 40 percent, and the planning time index increased by 5.7 percent. The relatively high increase in the buffer index could be attributed to the large decrease in the average travel time. The buffer index was computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time. In this case, the 95th percentile travel time nearly stayed the same, but the average travel time decreased significantly, increasing the buffer index. Alternatively put, the very worst day remained about the same, but the typical day got much better.

Is the I-205 segment between the Glenn Jackson Bridge and Johnson Creek Boulevard able to accommodate more vehicles at the same service level?

Overall, all sections of the freeway segment were able to accommodate either a similar or higher level of vehicles at the same service levels.

IDENTIFICATION OF ISSUES

Overall, the ATM system appears to be operating very well. The ‘after’ performance has led to reduced crashes and improved travel times.

It is difficult to say what the specific effects of the ATM system are in isolation. That is to say, are the improvements in safety and travel times because of the ATM system, the installation of the auxiliary lanes or do the changes operate in concert? While implementing the various elements of the project individually (i.e.,the auxiliary lanes and the ITS technology) would have allowed the team to isolate the effects of the improvements individually, this would have been extremely inefficient from a project development perspective. Road users would have been subject to multiple years of construction and ODOT would have had to manage multiple construction contracts.

The pandemic and its effect on traffic made the analysis more challenging. The team had to analyze changes in volumes and determine a time period less affected by the pandemic.

The length of time to get complete crash data required the use of incident data as a surrogate. While incident data was quite robust and it was clear which incidents were crashes, there was no severity data beyond whether the crash resulted in a fatality or not. Further evaluation should include actual crash data when available.

The freeway speed and volume data found in the PORTAL system was extremely valuable to the analysis team.

ODOT followed a system engineering approach for the ATM projects, including roadside technology and software. This approach reduced the risk of potential issues during implementation.

RECOMMENDATIONS FOR OPERATIONS

The implementation of the ATM system appeared to have a positive effect on safety performance. Further research and evaluation on the safety effects of ATM system to determine the safety impact could lead to development of specific crash modifications factor for the installation of ATM systems.

While overall the project was beneficial to safety, operation, and mobility, further evaluation of the speed, volume, and travel times should be considered. Given the effects of the implementation of the ATM system were intertwined with the implementation of the auxiliary lane, further evaluation to help determine if the benefits were from the ATM system, removing bottlenecks with the auxiliary lanes or if the effects were additive would help ODOT understand how to mitigate bottlenecks in the future more cost effectively.

Evaluation of the US 97 Bend to La Pine variable speeds system in this project will evaluate a weather-based system in a more rural context.

Finally, it should be noted that ODOT delivered over a dozen such Active Traffic Management projects statewide prior to this project. ODOT standardized field equipment and software used statewide for ATM operations, regardless of whether the project was urban/congestion-based or rural/mountainous for weather-based needs. Many of the lessons learned and improvements have already been addressed in earlier projects and software upgrade efforts.

I-205 REAL TIME TRAVEL TIME SIGN

Source: ODOT

3 ODOT OR 212/224 Arterial Corridor Management

INSTALLED PTZ CAMERA

PROJECT BACKGROUND

The modifications to the traffic signals provided opportunities to collect data related to corridor performance, including implementing automated traffic signal performance measures, improving vehicle and freight detection at signalized intersections, and improving network communication. Total project cost was $2,800,000.

CORRIDOR OPERATIONS

Traffic volumes ranged from 30,000 to 37,000 vehicles per day on OR 224, and from 25,000 to 44,000 on OR 212.

The morning peak period was westbound towards I-205 and downtown Portland. The afternoon peak was eastbound.

EVALUATION

GOALS, OBJECTIVES AND QUESTIONS

The goals of the project included improving safety, mobility, and operations. The objectives of the *before* and *after* evaluation were to measure how well the improvements achieved these goals. Table 3.1 summarizes the project goals and specifically how the goals were to be evaluated.

TABLE 3.1: PROJECT GOALS AND EVALUATION OBJECTIVES

GOAL AREA	GOAL DESCRIPTION	EVALUATION OBJECTIVE
#1 IMPROVE SAFETY	Reduce crash potential in the corridor	Determine if red-light-running and/or near-miss events were reduced.
#2 IMPROVE MOBILITY	Improve travel time reliability	Determine if the variability of average travel speeds within the OR 212/224 corridor improved.
#3 IMPROVE OPERATIONS	Improve travel time Improve vehicle and freight detection Improve response time for detection outages	Determine if the improvements affected average travel speeds within the OR 212/224 corridor. Determine if the ATSPMs were useful in monitoring and managing corridor operations. Determine how the availability of the ATSPMs change the response time to detect outages.

EVALUATION PERIODS

The Oregon ATCMTD Project Evaluation Plan estimated that the project would be deployed from October 2019 to December 2020. The project was delayed until 2022. The *before* and *after* evaluation periods were 2021-2022 and 2023-2024, respectively.

Each *data collection period* covered a one-year time frame, aiming to capture the most available data for evaluation purposes. Based on the actual project deployment schedule and evaluation data availability, DKS screened the data sets for completeness and quality, performed preliminary statistical analysis, and determined the evaluation periods for the *before* and *after* data were:

Before data collection period: July 2021 through June 2022

After data collection period: July 2023 through June 2024.

The goal was to have a minimum of six months of data in each evaluation period to summarize meaningful traffic trends, and the actual evaluation periods depended on results of the data screening.

PERFORMANCE MEASURES

Based on the evaluation objectives of the projects, the following performance measures were proposed and summarized in Table 3.2. A brief description of the data type associated with each performance measure is also listed in the table.

TABLE 3.2: PERFORMANCE MEASURES AND DATA SOURCES

EVALUATION OBJECTIVE	PERFORMANCE MEASURES	ASSOCIATED DATA TYPE
#1: DETERMINE IF RED-LIGHT-RUNNING AND/OR NEAR-MISS EVENTS WERE REDUCED	a) Number of red-light-running b) Near-miss events	ATC controller reports – red clearance extensions The number of incidents reported as crashes
#2: DETERMINE IF THE VARIABILITY OF AVERAGE TRAVEL SPEEDS WITHIN THE OR 212/224 CORRIDOR IMPROVED	c) Average speed and travel time d) 95th percentile speed e) Buffer index f) Planning time index	Roadway segment lengths Weekday PM peak hour, travel speed/time at 5-minute intervals
#3: DETERMINE IF THE IMPROVEMENTS AFFECTED AVERAGE TRAVEL SPEEDS WITHIN THE OR 212/224 CORRIDOR	c) Average speed and travel time	Roadway segment lengths Weekday PM peak hour, travel speed/time at 5-minute intervals
#4: DETERMINE IF THE ATSPMS WERE USEFUL IN MONITORING AND MANAGING CORRIDOR OPERATIONS	g) Qualitative Assessment of ATSPMs as “High”, “Moderate”, “Minimal” or “Not Useful”.	Individual signal system operators and manager assessments
#5: DETERMINE HOW THE AVAILABILITY OF THE ATSPMS CHANGE THE RESPONSE TIME TO DETECT OUTAGES	h) Detection Outage Response Times	Signal maintenance logs On board signal diagnostics and high resolutions signal data

Additional considerations in using these performance measures in the *before* and *after* evaluation are described in the following sections.

A) NUMBER OF RED-LIGHT RUNNING ACTIVITIES

The number of red-light running activities was to be used to measure the safety goal. However, video analytics were not deployed in the *before* condition; therefore, *before* and *after* data could not be collected. DKS used crash data to assess safety and evaluated phase termination data to evaluate red-light-running risk.

B) NUMBER OF NEAR-MISS EVENTS

Similar to the red-light running activities, the number of near-miss events was to be used to measure the safety goal. Video analytics were not deployed, so *before* and *after* data could not be collected. Instead, crash data was analyzed as a substitute indicator.

C) AVERAGE TRAVEL SPEED

Average travel speed was used to measure the effectiveness of the mobility goal, specifically for the weekday evening peak hour. DKS evaluated the data for non-holiday weekday (Monday – Friday), during the hours of 3 p.m. to 6 p.m., and determined the most appropriate 60-minute period for the evaluation.

D) 95TH PERCENTILE TRAVEL TIME

Similar to the average travel time, the 95th percentile travel time aggregated data for the same time period, and reported the metric for non-holiday weekday (Monday – Friday), during the peak 60-minute period within the hours of 3 p.m. to 6 p.m.

The 95th Percentile Travel Time was a measure of the severity of travel time delays on the heaviest travel days. On 95 days out of 100, the motorist's travel time would be less than this time. The measure was reported in minutes.

E) BUFFER INDEX AND F) PLANNING TIME INDEX

Buffer Index and Planning Time Index was calculated based on the average travel time, free-flow travel time, and 95th percentile travel time. Therefore, these metrics were also reported for the same peak 60-minute period.

Average travel speeds were used to measure the effectiveness of the mobility goal, specifically for the weekday evening peak hour. DKS evaluated the data for non-holiday weekday (Monday – Friday), during the hours of 3 p.m. to 6 p.m., and determined the most appropriate 60-minute period for the evaluation.

The buffer index was the extra buffer travelers would need to add to their average travel time when planning trips to ensure on-time arrival. It was computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time.

The planning time index was the total travel time that should be planned when an adequate buffer time was included over the free-flow speed.

95th Percentile Travel Time, Buffer Index, and Planning Time Index were all measures of travel time reliability.

G) INTERVIEW DATA

This was a qualitative assessment of ATSPMs by operators. Staff who were responsible for maintenance, operations, and management of signals were to assess how useful they found ATSPMs as *High*, *Moderate*, *Minimal* or *Not Useful*.

One virtual interview was conducted that included Region 1 and Headquarters Signal Timing staff. Follow-up discussions were held with Region 1 staff on the specifics of how they used ATSPMs.

H) DETECTOR OUTAGE RESPONSE TIMES

The measure was the difference in time between when the outage was detected vs. responded to. The response time comprised two factors: One was the length of time necessary to detect the outage; the second was the length of time necessary to address the outage.

OTHER DATA SOURCES (ATSPM)

The team used a variety of ATSPM data for analysis. The list of performance measures relevant to the analysis, a brief definition, and how it was used is shown in Table 3.3.

TABLE 3.3: ATSPMS

ATSPM	DEFINITION	HOW IS IT USED
VEHICLE ACTUATIONS	The detection of vehicles passing through a detection zone (detector) that triggers a change in the traffic signal timing.	The number of vehicle actuations would be used to identify anomalies in detector health. For instance, low numbers of actuations during the peak period may indicate a detector issue.
PHASE TERMINATIONS	The reason a traffic signal phase changes from green to red (or from active to inactive). These reasons can include gap-out, max-out, force-off, or a skip.	Compared phase terminations with dilemma zone data to evaluate the potential for red-light-running reduction.
SPLIT FAILURE	When a traffic signal phase fails to serve all of its demand within a single cycle.	A tool to identify problems at an intersection that may be caused by detector failure.
DETECTOR ALARM	An alarm provided to the user when the detector is operating outside preidentified parameters.	Evaluate how detector alarms helped staff respond to detector outages.
DETECTOR OCCUPANCY	The ratio of time a detector is occupied (i.e., has a vehicle presence) to a specific time period.	A tool for diagnosing detector failures.
DILEMMA ZONE ACTUATIONS	The number of times a detection device was activated because the approach speed of the vehicle and the timing of the signal phase was such that a vehicle could not safely stop before the stop line or proceed through the intersection during the amber interval.	A tool to understand the red-light-running potential at intersections.

DATA COLLECTION APPROACH

DATA TYPES AND SOURCES

Table 3.4 summarizes the data sources and how they were acquired for each data type identified above. The collection process was a collaboration between the consultant and ODOT.

TABLE 3.4: DATA SOURCES

DATA TYPE	DATA SOURCE	RESPONSIBLE PARTY
HIGHWAY SEGMENT LENGTHS	Google Earth or GIS	DKS
INCIDENT LOGS	ODOT dispatch system	DKS/ODOT
SPEED/TRAVEL TIME	INRIX data via RITIS	DKS
QUALITATIVE SURVEY (INTERVIEW)	Interview with ODOT	DKS
SIGNAL MAINTENANCE LOGS	ODOT	DKS/ODOT
ON BOARD SIGNAL DIAGNOSTICS AND HIGH RESOLUTION SIGNAL DATA	ODOT	DKS/ODOT

DATA PROCESSING AND REVIEW

This section summarizes data quality, processing, and completeness checks performed for each data source.

ROADWAY SEGMENT LENGTHS

Segment lengths were taken from the GIS shapefile matching the INRIX XD data segments and were verified using Google Earth. Highway segment lengths may include mainline segments and ramp or connector links if needed. Segment lengths may be aggregated and consist of multiple INRIX XD segments.

INCIDENT LOGS

Incident data was requested directly from ODOT. Incident data was reviewed to ensure there were no outliers, and all data was recorded as expected. DKS worked with ODOT to understand any potential discrepancies in the data before using it for analysis.

DKS identified incidents that were coded as crashes. The crash data was used as a surrogate for red-light-running and near-miss data. The team further refined the data to evaluate crashes within 200 feet of signalized intersections to increase the likelihood of identifying crashes related to traffic signals. While the crash evaluation was not a perfect surrogate for red-light-running and near-misses, it was likely that they were correlated. That is, if there were fewer crashes, there were likely to be fewer red-light-running and near-miss incidents.

SPEED AND TRAVEL TIMES

DKS downloaded travel time and speed data from RITIS, which contained INRIX segment-based speed data. The higher resolution XD segments were used for this analysis. Note that INRIX updates its XD segment map twice a year and care should be taken to use the same map version and segmentation for both *before* and *after* time periods. INRIX data was downloaded in five increments based on the list of study segments to be used in the analysis.

INTERVEW DATA

The team completed an interview of signal system operators, managers, and timing staff. The interview was qualitative in nature and aggregated subjective assessments.

SIGNAL MAINTENANCE LOGS

This data was from ODOT traffic signals and an ITS database called MicroMain. It provided the time span from when the maintenance crew was notified of the detector failure to when the detector was repaired if the call was recorded in MicroMain. Outage detection and repair times could be compared before and after the project.

ON BOARD SIGNAL DIAGNOSTICS AND HIGH-RESOLUTION SIGNAL DATA

ATSPM data from signals can be requested directly from ODOT and provided data on how ODOT staff troubleshoot detector outages remotely. It was also used to determine phase termination as a surrogate safety measure. Additionally, a component of ATSPM capability includes dilemma zone actuation designed to capture the safety and operational challenges at signalized intersections, particularly for vehicles approaching during the yellow phase.

DATA ANALYSIS

TRAFFIC INCIDENTS

In the year from July 2021 through June 2022, there were 50 incidents in the OR 212 segment and 68 incidents in the OR 224 segment that could be characterized as crashes. In the *after* period, there were 44 and 47, respectively. These are shown in Table 3.5 and Table 3.6. In addition, the number of incidents that were within 200 feet of the improved signalized intersections for the *before* and *after* period are shown in Table 3.7 below.

The DKS teamed compiled all recorded incidents that were coded in the Incident Response system as crashes. ODOT's Incident Responders and Dispatchers had standard operating procedures and guidelines for reporting incidents as crashes. Incident reports should have remained consistent across the time frame of the report as the procedures had not changed. The Other category were crashes that required an investigation for reasons other than a fatality, crashes where a motorist struck an animal such as a deer, and crashes where the motorists damaged ODOT property (e.g., a signpost or guardrail).

OR 212 saw a decrease in the number of incidents (12 percent decrease), shown in Table 3.5 below.

OR 224 saw a large decrease in the number of incidents (30.9 percent decrease). Although there was a decrease in the number of incidents, the *after* period recorded a fatal crash on the corridor. The large percentage increase in fatal crashes is a result of the number of fatal crashes increasing from zero to one. These results are shown in Table 3.6 below.

Incidents at the signalized intersections increased at OR 212 by 5 incidents. Conversely, the incidents at the signalized intersections at OR 224 decreased by nine.

TABLE 3.5: OR 212 BEFORE AND AFTER INCIDENTS

INCIDENT TYPE	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	PERCENTAGE CHANGE IN THE NO. OF INCIDENTS	INCIDENT RATE (PER 100 MILLION VMT) (BEFORE)	INCIDENT RATE (PER 100 MILLION VMT) (AFTER)	INCIDENT RATE PERCENTAGE CHANGE
CRASH	49	42	-14.3%	45.1	42.1	-6.65%
FATAL CRASH	N/A	N/A	N/A	N/A	N/A	N/A
OTHER	1	2	100%	0.92	2.01	54.2%
TOTAL	50	44	-12.0%	46.0	44.1	-4.13%

TABLE 3.6: OR 224 BEFORE AND AFTER INCIDENTS

INCIDENT TYPE	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	PERCENTAGE CHANGE IN THE NO. OF INCIDENTS	INCIDENT RATE (PER 100 MILLION VMT) (BEFORE)	INCIDENT RATE (PER 100 MILLION VMT) (AFTER)	INCIDENT RATE PERCENTAGE CHANGE
CRASH	67	45	-32.8%	53.2	39.9	-25%
FATAL CRASH	0	1	100%	0	0.89	N/A
OTHER	1	1	0	0.80	0.89	10.1%
TOTAL	68	47	-30.9%	54.1	41.7	-22.9%

TABLE 3.7: INCIDENTS WITHIN 200FT OF SIGNALIZED INTERSECTIONS

OR212 (BEFORE)	OR212 (AFTER)	OR224 (BEFORE)	OR224 (AFTER)
22	27	40	31

PAIRED T-TEST

DKS performed a paired T-test to understand the statistical significance of the reduction in crashes at the intersection. The team mapped *before* and *after* crashes at the individual signalized at each of the 22 intersections.

The crashes are shown in the "barbell" chart in Figure 3.1. At most intersections, the change in crashes was relatively small (i.e., 1 or 2) crashes. There was a reduction of 7 crashes at Johnson Road and a reduction of 6 crashes at 135th Avenue. There was an increase of 14 crashes at 82nd Drive.

In the *before* period, Johnson Road had the greatest number of crashes, with 16. In the *after* period, 82nd Drive had the greatest number of crashes.

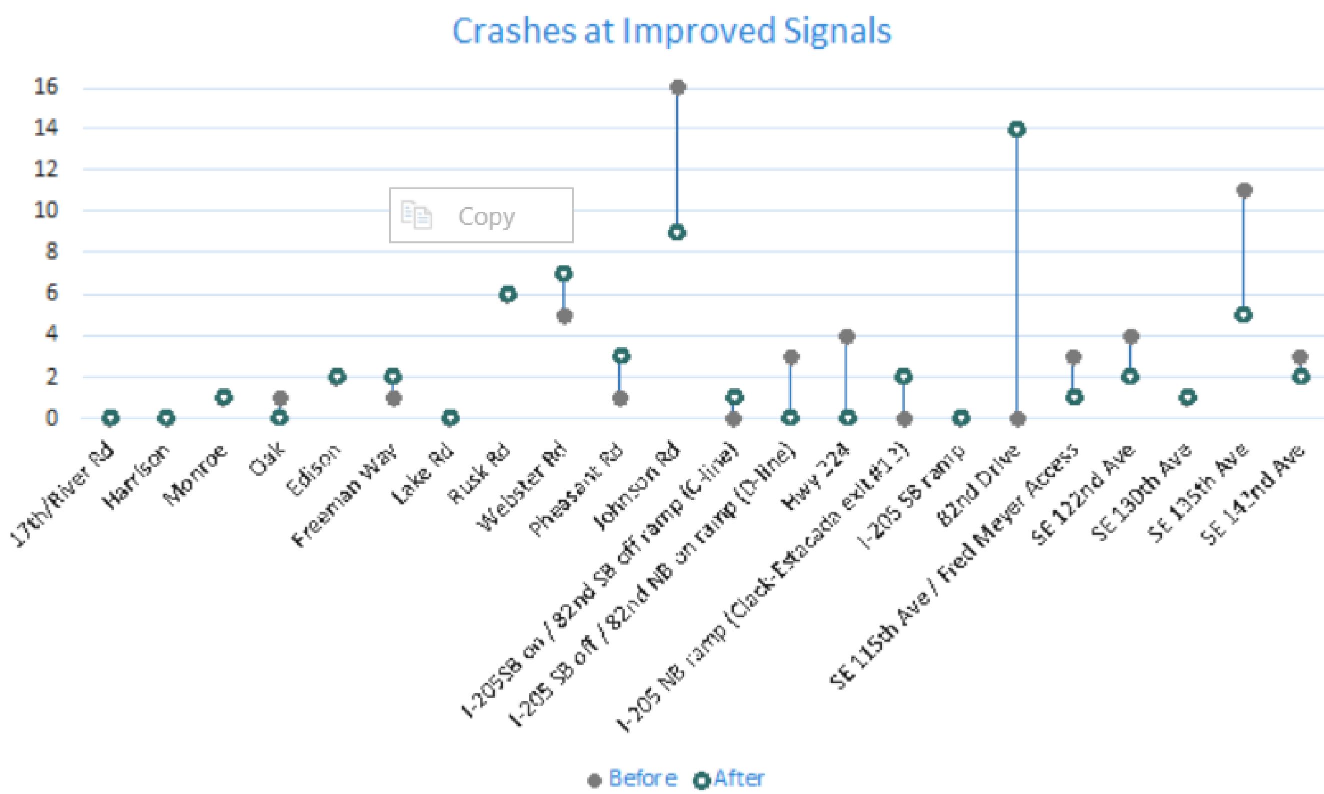


FIGURE 3.1: CRASHES AT SIGNALIZED INTERSECTIONS BEFORE AND AFTER

The team then completed a paired T-Test to understand the statistical significance of the changes in the number of crash set. The results for the paired t-test are shown in Table 3.8.

TABLE 3.8: PAIRED T-TEST RESULTS

MEASURE	BEFORE CRASHES	AFTER CRASHES
MEAN	2.82	2.64
VARIANCE	15.77	12.72
OBSERVATIONS	22	22
PERASON CORRELATION	0.45	
HYPOTHESIZED MEAN DIFFERENCE	0	
DF	21	
T STAT	0.22	
P(T≤T) ONE-TAIL	0.42	
T CRITICAL ONE-TAIL	1.72	
P (T≤T) TWO-TAIL	0.83	
T CRITICAL TWO-TAIL	2.08	

The low t-statistic and the relatively high P values led the team to conclude that there was significant uncertainty in the data. At this point, it was not clear whether the reduced number of crashes was related to the intersection treatments or random variability in the data. *Before* and *after* crash data over a longer period of time would be required to determine the efficacy of the treatments.

TRAVEL SPEED/TIME

Table 3.9 shows the time periods the data was collected for OR 212. The length of the corridor was 3.13 miles.

TABLE 3.9: DATA COLLECTION PERIODS – WEEKDAYS 3:50 P.M. – 4:50 P.M. PEAK HOUR

SEGMENT	DATE
BEFORE	7/1/2021 to 6/30/2022
AFTER	7/1/2023 to 6/30/2024

For OR 212 Eastbound, free flow and average speed increased. Free flow and average travel time decreased as a result of the increased speeds. 95th percentile speed decreased. The 95th percentile travel time increased, as did the buffer index and the planning time index. For eastbound traffic, reliability worsened in the p.m. peak.

For OR 212 Westbound, free flow and average speed increased. Free flow and average travel time decreased similarly. 95th percentile travel speed increased, 95th travel time decreased, as did the buffer index and the planning time index. For westbound traffic, average speed, travel time, and reliability improved in the p.m. peak.

The travel speed and times for OR 212 are shown in Table 3.10.

TABLE 3.10: OR 212 SPEED AND TRAVEL TIME

		FREE FLOW SPEED (MPH)	AVERAGE SPEED (MPH)	95TH PERCENTILE SPEED (MPH)	FREE FLOW TRAVEL TIME (MIN)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
EB	BEFORE	35.39	21.73	33.30	5.30	8.64	11.21	0.30	2.11
	AFTER	37.09	21.93	32.70	5.06	8.56	11.34	0.32	2.24
WB	BEFORE	37.62	30.14	35.52	4.99	6.23	7.46	0.20	1.49
	AFTER	38.64	31.00	37.20	4.86	6.06	7.16	0.18	1.47

OR 212 eastbound average travel times decreased by less than one percent, and westbound travel times decreased by 2.7 percent. The 95th percentile travel times also decreased for westbound and increased for eastbound. Buffer Index and Planning Time Index increased for eastbound and decreased for westbound traffic.

Figure 3.2 and Figure 3.3 show the changes in speeds and travel times, respectively. These are the same values as Table 3.10 but shown as a histogram for comparison of the relative differences.

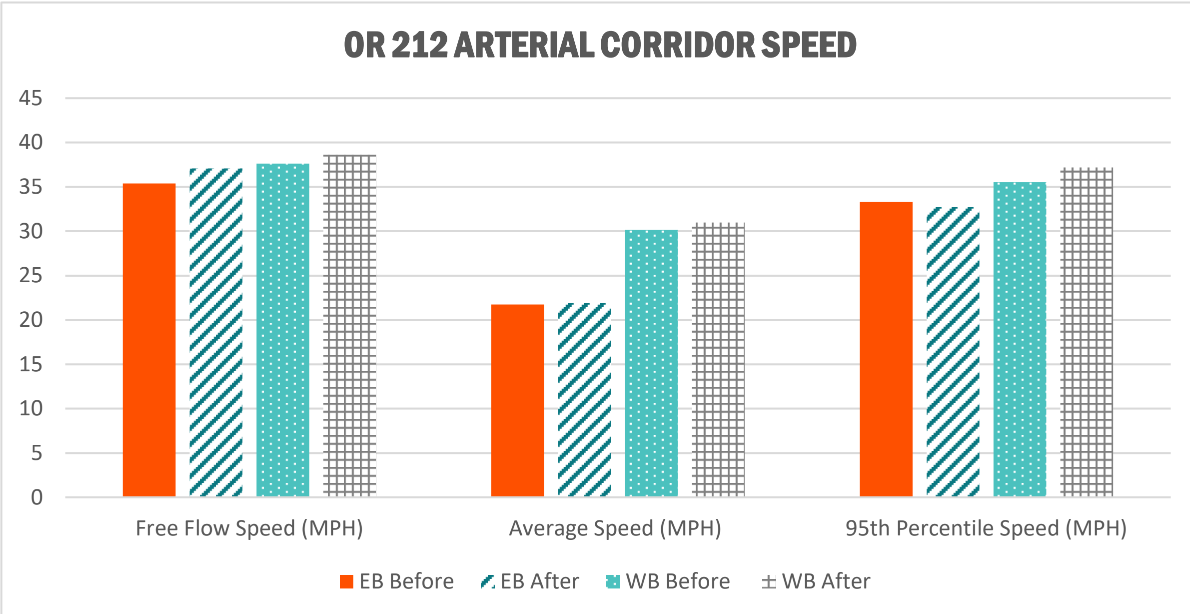


FIGURE 3.2: OR 212 ARTERIAL CORRIDOR SPEED

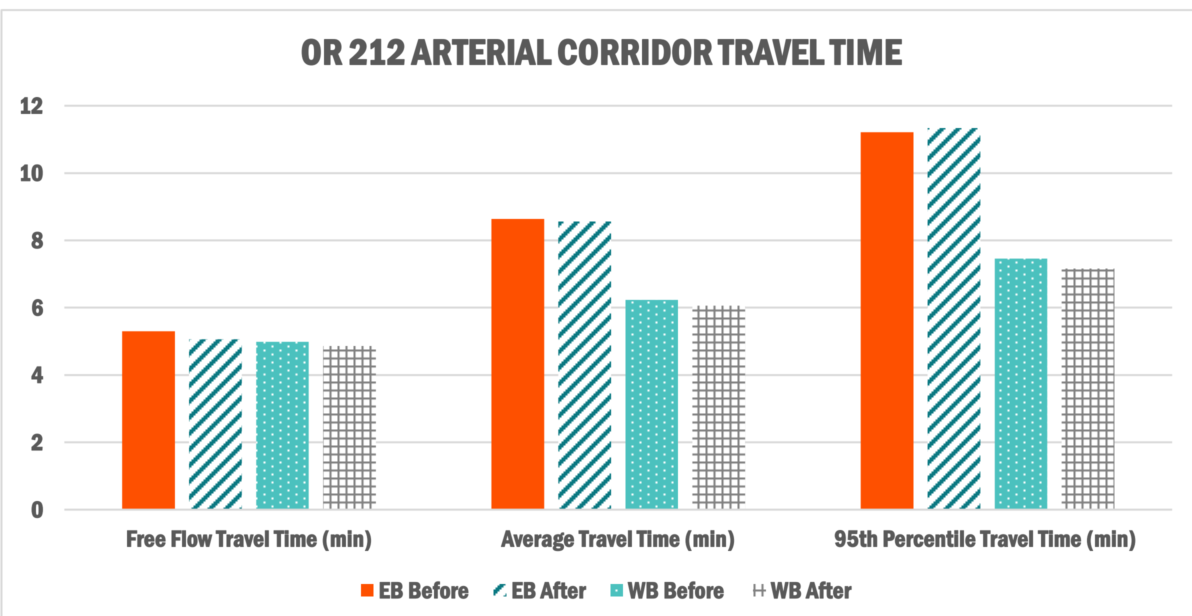


FIGURE 3.3: OR 212 ARTERIAL CORRIDOR TRAVEL TIME

The percent changes in the average and 95th percentile travel times and the buffer and planning indices are shown below in Table 3.11.

TABLE 3.11: PERCENT CHANGE IN OR 212 TRAVEL TIMEA AND RELIABILITY

	% CHANGE AVERAGE TRAVEL TIME	% CHANGE 95TH PERCENTILE TRAVEL TIME	% CHANGE BUFFER INDEX	% CHANGE PLANNING TIME INDEX
EASTBOUND	0.9%	-1.2%	-6.7%	-6.2%
WESTBOUND	2.7%	4.0%	10.0%	1.3%

It is possble that free flow travel speeds increased and free flow travel times decreased because of improved signal coordination and operations. There were no changes to roadway geometry that would have influenced free flow speeds. The speed limit on the highway did not change.

Table 3.12 shows the time periods for the data collection. The length of the corridor was 4.26 miles.

TABLE 3.12: DATA COLLECTION PERIODS - WEEKDAYS 3:50 PM – 4:50 P.M. PEAK HOUR

SEGMENT	DATE
BEFORE	7/1/2021 to 6/30/2022
AFTER	7/1/2023 to 6/30/2024

OR 224 eastbound had an increase in free flow speed, but a decrease in average speed. As a result, average travel times increased. The 95th percentile speed increased. All of the reliability measures also worsened.

For OR 224 westbound, the free flow speeds increased slightly, but the average speed decreased. The average travel time increased as a result. The 95th percentile speed decreased. The 95th percentile travel time, the buffer index, and the planning time index all increased slightly. The results are shown in Table 3.13.

TABLE 3.13: OR 224 SPEED AND TRAVEL TIME

		FREE FLOW SPEED (MPH)	AVERAGE SPEED (MPH)	95TH PERCENTILE SPEED (MPH)	FREE FLOW TRAVEL TIME (MIN)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
EB	BEFORE	44.03	31.45	37.86	5.80	8.13	10.16	0.25	1.75
	AFTER	44.41	30.28	38.03	5.75	8.44	10.76	0.27	1.87
WB	BEFORE	42.68	34.68	38.49	5.99	7.37	8.12	0.10	1.36
	AFTER	42.75	34.29	38.37	5.98	7.45	8.28	0.11	1.39

Figure 3.4 and Figure 3.5 show the changes in speeds and travel times, respectively. These are the same values as Table 3.13 but shown as a histogram for comparison of the relative differences.

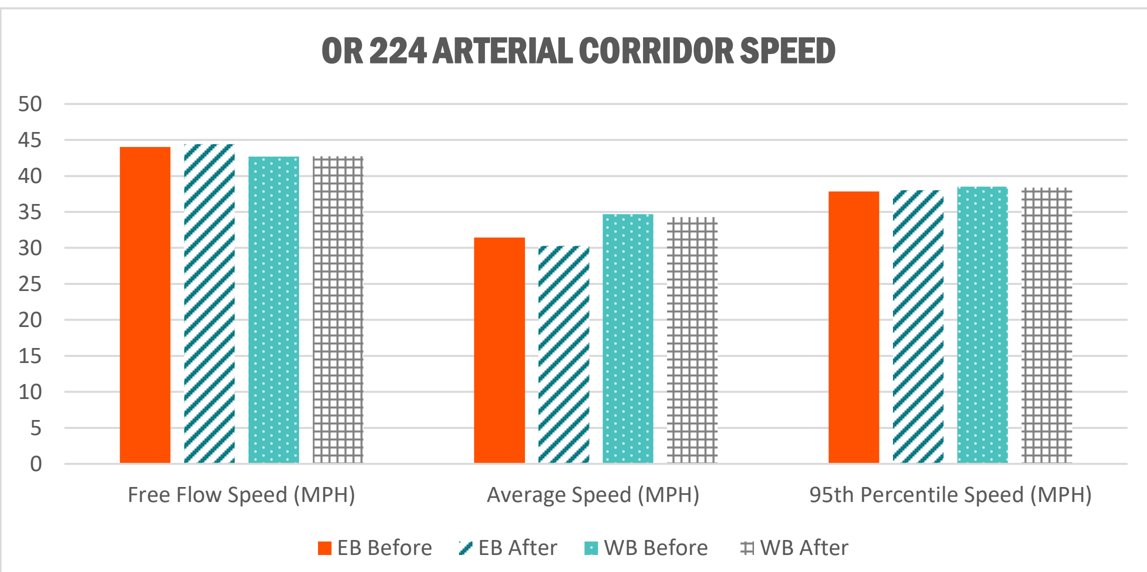


FIGURE 3.4: OR 224 ARTERIAL CORRIDOR SPEED

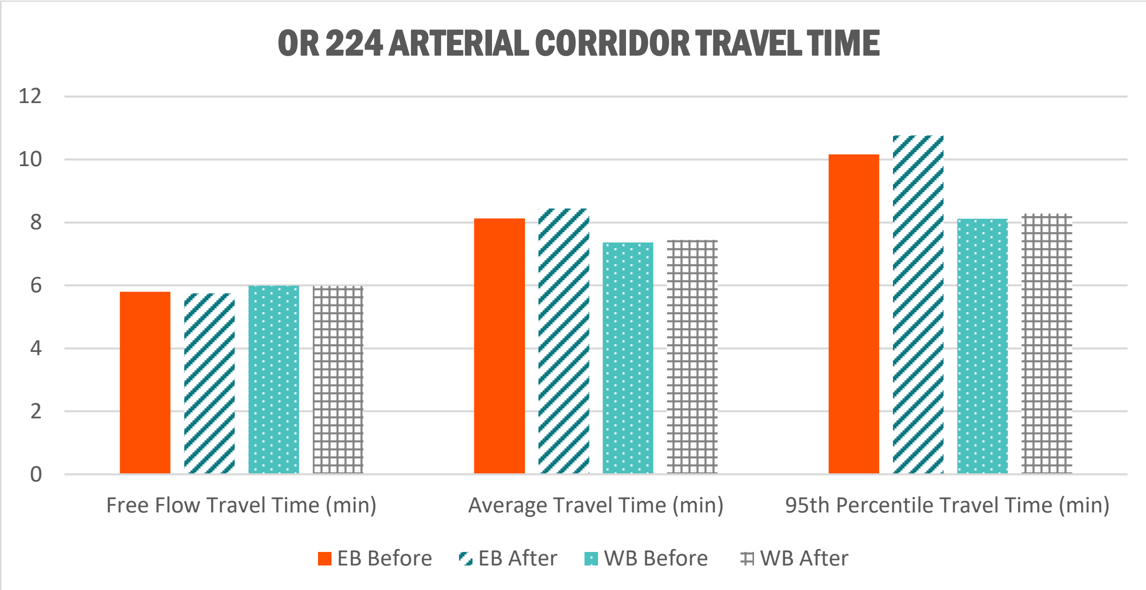


FIGURE 3.5: OR 224 ARTERIAL CORRIDOR TRAVEL TIME

The percent changes in the average and 95th percentile travel times and the buffer and planning indices are shown below in Table 3.14.

TABLE 3.14: PERCENT CHANGE IN OR 212 TRAVEL TIME AND RELIABILITY

	% CHANGE AVERAGE TRAVEL TIME	% CHANGE 95TH PERCENTILE TRAVEL TIME	% CHANGE BUFFER INDEX	% CHANGE PLANNING TIME INDEX
EASTBOUND	-3.8%	-5.9%	-8.0%	-6.9%
WESTBOUND	-1.1%	-2.0%	-10.0%	-2.2%

The free flow speeds on OR 224 increased slightly. Average travel time, 95th percentile travel time, buffer index, and planning time index worsened for both eastbound and westbound directions.

OR 224 Arterial Corridor Speed showed that average speed had increased, free flow speed decreased, and the 95th percentile speed remained at comparable values. OR 224 Arterial Corridor Time displayed a slightly increase free flow travel time and decreased in average travel time and 95th percentile travel time, suggesting that the vehicles entering the corridor were getting through the intersection faster.

DETECTOR OUTAGE AND RESPONSE TIMES

ODOT used a combination of methods to detect and respond to detector outages. They employed an asset management database tool called MicroMain to track work orders for traffic signals and ITS devices. MicroMain was not universally used by all staff involved in traffic signal maintenance and operations, so the database was not complete. ODOT staff also used ATSPMs to detect detector outages. The process for using ATSPMs is described below.

MICROMAIN

When a device fails or needs maintenance, a ticket is created in MicroMain. Tickets may be created by maintenance technicians or dispatchers in the transportation operations center. Unfortunately, this system does not completely track maintenance requirements. Some repairs may not be included in the database. For instance, if signal operations staff identify a potential issue with detection, the operator may contact a signal maintenance electrician directly who would resolve the issue. The call may not be entered in MicroMain. The detector outages in MicroMain are more likely to come from external calls such as the public, law enforcement and local public works employees.

Detector outages are shown in Table 3.15 displaying the date and time a ticket was created for an outage and the completion date and time when the outage was repaired. The amount of time in days it took to address the repair is also shown. The outages in the table were parsed by the team and confirmed that outages occurred due to detector failure. These incidents were detected by users of the roadway, testing the cabinets, and local law enforcement.

Detector response times varied widely along the two corridors in both the *before* and *after* period. Repairs ranged from half a day to complete to over one year. The *after* period was observed to have fewer incidents of detector outages. The cause of the decrease could be that there were less outages on the corridors, or that they were not being recorded in MicroMain when electricians identified the issue.

It is important to note that there were two components of detector outage and response times. One was the time it took to detect the outage, and the second was the time it took to repair the detector outage. ATSPMs would help with the identification of detector outages but would not help with the response times. The response times were limited by the staffing constraints and workload of the Region’s electrical maintenance staff.

TABLE 3.15: DETECTOR OUTAGE AND RESPONSE TIMES

Before Period (7/1/2021 - 6/30/2023)				
ITEM_Code	ITEM Name	Time to Complete (days)	CREATED Date	COMPLETED Date
2B064	TS OR212 @ 82nd Dr MP05.03	12.0	7/1/2021	7/13/2021
2B053	TS OR224 (Milwaukie Expressway) @ Edison St MP01.32	11.6	7/21/2021	8/2/2021
2B056	TS OR224/OR212 @ Rusk Road MP2.72	0.5	8/19/2021	8/20/2021
2B054	TS OR224 (Milwaukie Expressway) @ Freeman Way MP01.90	33.1	3/17/2022	4/19/2022
2B063	TS OR224 (Milwaukie Expressway) @ Lawnfield Rd MP04.66	61.7	2/16/2022	4/19/2022
2B049	TS OR224 (Milwaukie Expressway) @ Harrison St MP0.68	143.4	1/29/2022	6/22/2022
2B064	TS OR212 @ 82nd Dr MP05.03	378.9	7/20/2021	8/3/2022
2B064	TS OR212 @ 82nd Dr MP05.03	103.0	4/22/2022	8/3/2022
2B055	TS OR224 (Milwaukie Expressway) @ Lake Road MP02.38	262.1	3/25/2022	12/12/2022
2B064	TS OR212 @ 82nd Dr MP05.03	17.8	1/20/2023	2/7/2023
2B068	TS OR212 @ Evelyn 102nd MP05.47	38.5	1/7/2023	2/15/2023
After Period (7/1/2023 - Present)				
2B065	TS OR212 @ SE 122nd/OR224 MP6.56 Clackamas	0.6	11/14/2023	11/14/2023
2B054	TS OR224 (Milwaukie Expressway) @ Freeman Way MP01.90	121.7	8/27/2023	12/27/2023
2B069	TS OR212 @ Fred Meyer MP06.20	42.9	11/14/2023	12/27/2023
2B054	TS OR224 (Milwaukie Expressway) @ Freeman Way MP01.90	N/A	8/15/2023	N/A
2B054	TS OR224 (Milwaukie Expressway) @ Freeman Way MP01.90	N/A	9/4/2023	N/A

The sample size was very small, but the detector outage times were reduced in the *after* period. This indicated that outage times were reduced.

Because of the relatively small sample size, DKS worked with ODOT staff to assess how they used ATSPMs to diagnose and respond to detector outages.

USE OF ATSPMS FOR DETECTOR OUTAGE

The DKS team discussed the use of ATSPM data with ODOT signal operations staff to determine when there were potential detection issues such as outages. Signal operations staff described their process.

ODOT staff would receive a complaint from the field or an alarm, which could be coming from the public emergency, responders, local agency staff, or ODOT staff. The signal operations staff would review the signal on the Kinetics screen, which was their central signal system software. Figure 3.6 shows an example of the screen.

Signal Name: 2B065: OR224@122nd Express Way:

FIGURE 3.6: EXAMPLE KINETICS SCREEN

The staff looked at the detector tools, including looking for alarms. They began troubleshooting to determine if the problem was detector-based or operational. They might ask signal maintenance staff to replace cables or reset detectors.

The screen shot shown in Figure 3.7 would note whether a detector alarm was activated or not. The fix could be simple or complex. The specific type of alarm w shown at the bottom of the figure. *No Activity* meant that the detector was not registering any data. This could be a detector failure, or it could be related to a lane closure. *Max Presence* on a side street likely meant that the detector had failed in some way. *Erratic Activations* was based on the history of activations and how current activations related to it. Communications might mean there was a bad DLC cable.

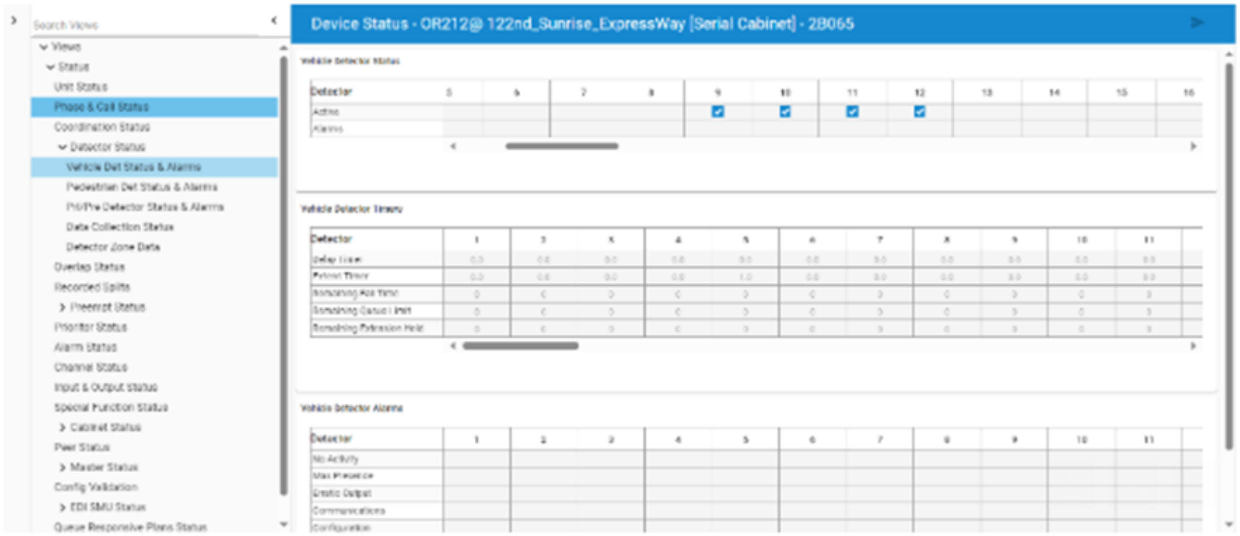
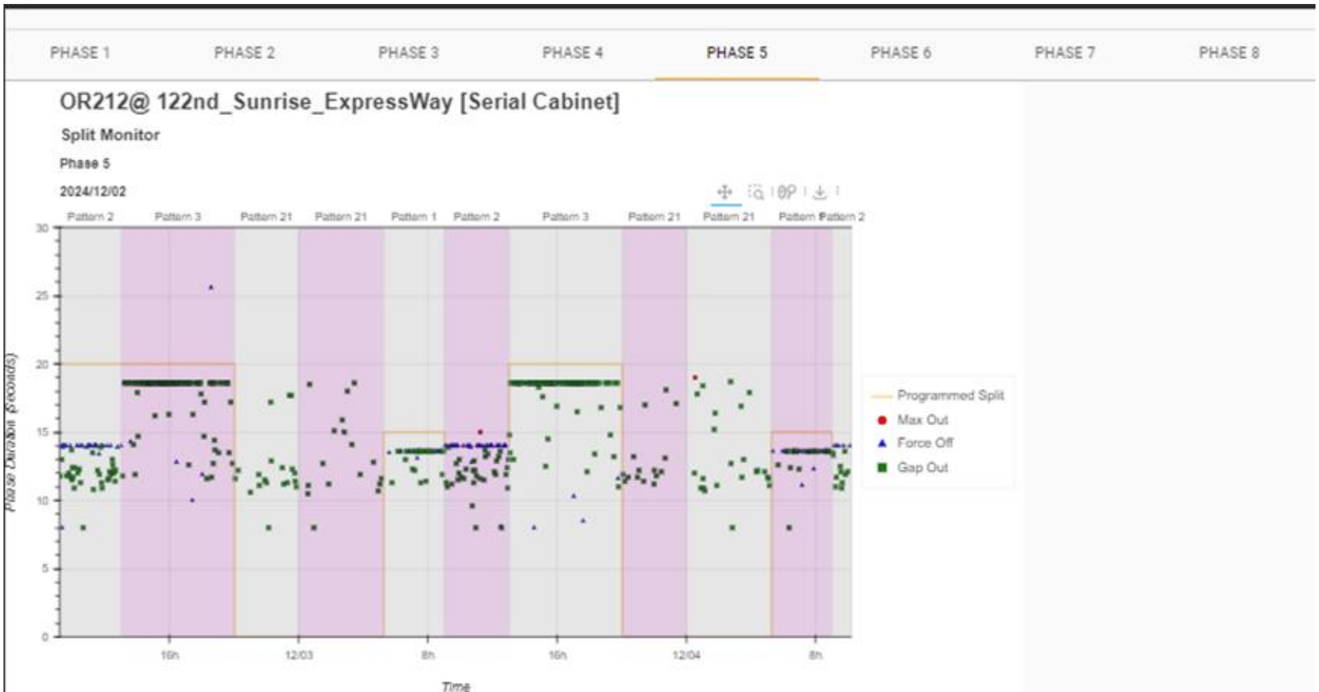


FIGURE 3.7: OR 224 DETECTOR ALARM

The screen shot in Figure 3.8 shows a report that signal operations staff could use to begin troubleshooting whether the problem was operational or detector-based. For instance, if a signal was maxing out, it could be either detector or heavy traffic on a particular phase of the intersection. If the signal was gapping out on the mainline, it could be a detector, based on the time of day. During peak periods, the signal was unlikely to gap out on the mainline. If there were many force offs, signal timing may needed to be adjusted.

FIGURE 3.8: ATSPM REPORT SCREEN

Figure 3.9 below shows the phase termination data of specific phases at a given signal. This helped operation staff determine whether the signal was operating as expected, if there was a timing issue or if there were potential detector issues. As an example, Pattern 1 was gapping out for the side street (Phase 5). If the side street was consistently maxing out, it may have meant a detector was stuck on.



	From	To	Maximum Split	85 Percentile Split	Average Split	Minimum Split	Percent Max Out	Percent Force Off	Percent Gap Out	Percent Unknown
0	2024-12-02 09:12:00	2024-12-04 10:12:29	25.600000	18	15	8.000000	0%	29%	70%	0%

	Pattern	From	To	Maximum Split	85 Percentile Split	Average Split	Minimum Split	Percent Max Out	Percent Force Off	Percent Gap Out	Percent Unknown
0	Pattern 2	2024-12-02 09:12:00	2024-12-02 13:01:24	14.000000	14	12	8.000000	0%	48%	51%	0%
1	Pattern 3	2024-12-02 13:01:24	2024-12-02 20:01:30	25.600000	18	17	10.000000	0%	18%	81%	0%
2	Pattern 21	2024-12-02 20:01:30	2024-12-02 23:59:59	17.700000	14	12	8.000000	0%	0%	100%	0%
3	Pattern 21	2024-12-02 23:59:59	2024-12-03 05:15:25	18.600000	17	13	8.000000	0%	0%	100%	0%
4	Pattern 1	2024-12-03 05:15:25	2024-12-03 09:00:22	13.600000	13	13	11.300000	0%	50%	50%	0%
5	Pattern 2	2024-12-03 09:00:22	2024-12-03 13:01:09	15.000000	14	12	8.000000	1%	50%	47%	0%
6	Pattern 3	2024-12-03 13:01:09	2024-12-03 20:01:27	18.600000	18	17	8.000000	0%	23%	76%	0%
7	Pattern 21	2024-12-03 20:01:27	2024-12-03 23:59:59	18.100000	16	13	11.200000	0%	0%	100%	0%
8	Pattern 21	2024-12-03 23:59:59	2024-12-04 05:15:37	19.000000	17	13	8.000000	4%	0%	95%	0%
9	Pattern 1	2024-12-04 05:15:37	2024-12-04 09:00:26	13.600000	13	13	8.000000	0%	45%	54%	0%
10	Pattern 2	2024-12-04 09:00:26	2024-12-04 10:12:29	14.000000	14	12	10.900000	0%	31%	68%	0%

FIGURE 3.9: PHASE TERMINATION

Figure 3.10 shows the occupancy of detectors. Signal operations staff would use this in combination with cabinet prints to look for anomalies in detector occupancy. For example, low levels of occupancy on a mainline detector would be indicative of a problem. Similarly high levels of occupancy on a side street approach at times of low traffic could be indicative of a problem as well. Anomalies could be identified by looking at the time of day and expected traffic on an approach. Individual lanes or approaches could be evaluated by selecting only the detectors from the desired approach or lane.

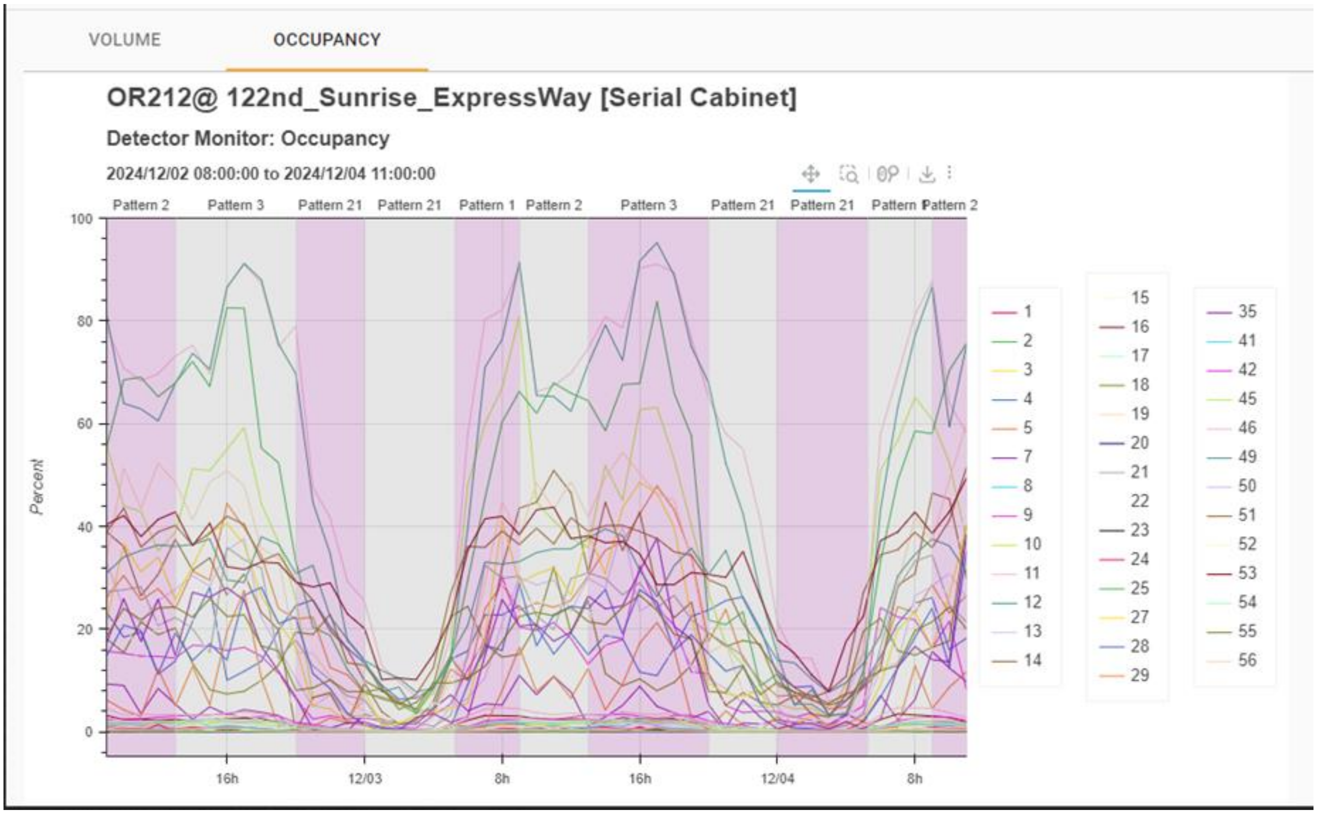


FIGURE 3.10: DETECTOR OCCUPANCY

Similarly, Figure 3.11 below shows the average amount of time a detector was occupied during a specific time period. This could also be used to look for anomalies in the data. For instance, low levels of occupancy on a mainline approach could indicate a detector failure while high levels of occupancy on a side street approach during traffic periods could indicate that a detector was stuck on.

Time

	From	To	Average Occupancy
0	2024-12-02 08:00:00	2024-12-04 11:00:00	13.312691

	From	To	Device	Detector	Average Occupancy
0	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	1	0.441993
1	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	2	1.270752
2	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	3	1.067048
3	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	4	16.743355
4	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	5	21.979357
5	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	7	4.584804
6	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	8	0.729194
7	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	9	12.374129
8	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	10	34.315577
9	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	11	57.576471
10	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	12	53.461710
11	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	13	16.642538
12	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	14	21.929521
13	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	15	0.854303
14	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	16	1.738671
15	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	17	1.054031
16	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	18	15.225490
17	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	19	28.423584
18	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	20	0.024455
19	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	21	18.465251
20	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	22	14.169390
21	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	23	0.040305
22	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	24	0.137309
23	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	25	42.977996
24	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	27	20.127941
25	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	28	13.929630
26	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	29	5.958170
27	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	35	13.383333
28	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	41	0.032843
29	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	42	1.910512
30	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	45	0.052560
31	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	46	2.455447
32	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	49	27.177070
33	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	50	1.381863
34	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	51	29.813072
35	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	52	1.607898
36	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	53	31.167157
37	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	54	1.341939
38	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	55	15.629684
39	2024-12-02 08:00:00	2024-12-04 11:00:00	OR212@ 122nd_Sunrise_ExpressWay [Serial Cabinet]	56	0.311275

FIGURE 3.11: AVERAGE DETECTOR OCCUPANCY

Figure 3.12 and Figure 3.13 show more detailed phase termination data. Again, this could be used to look at specific phase and time of day to determine if there were anomalies in the data and whether those anomalies might have been detection based or operational. For instance, if the phase was always terminated by a pedestrian in suburban area, that could indicate that the pedestrian push button had failed and had failed "On." Likewise, Max Outs at low volume periods could indicate that a vehicle detector was stuck on.

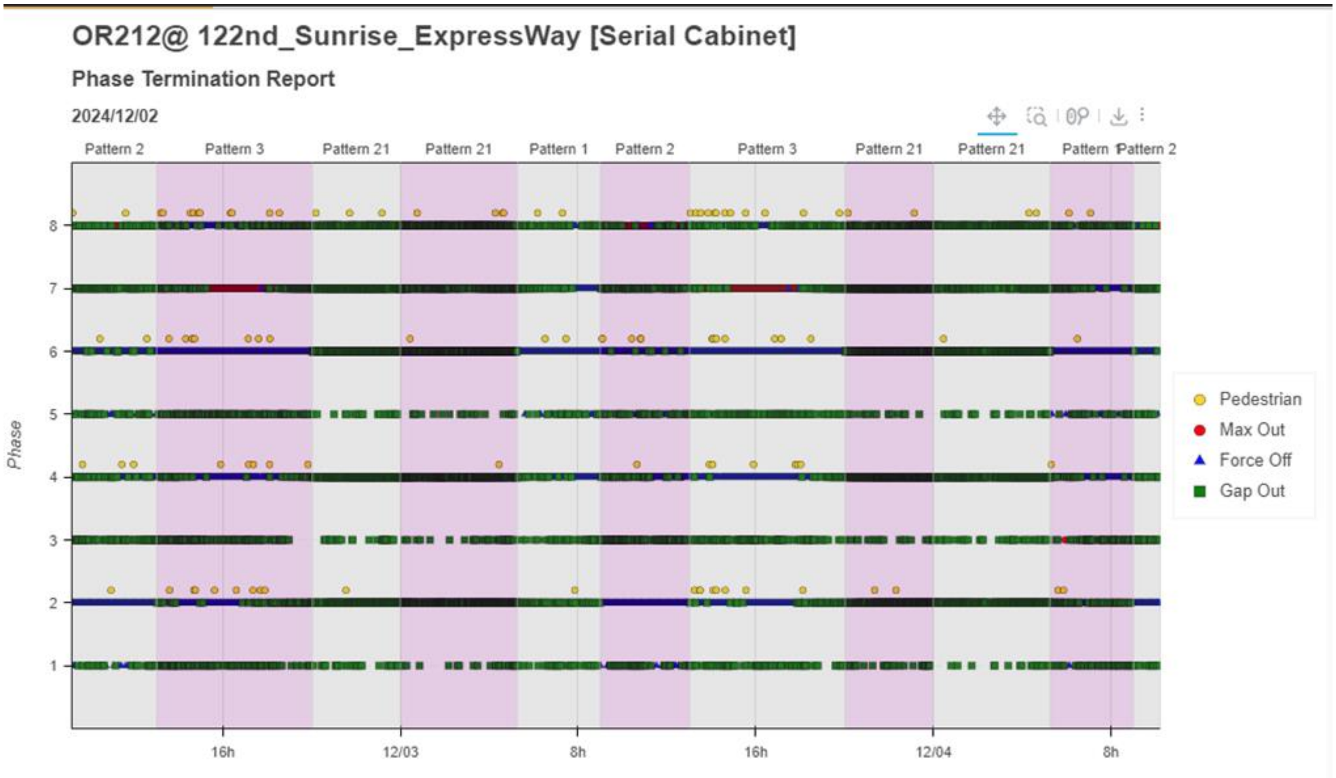


FIGURE 3.12: PHASE TERMINATION REPORT

	Name	From	To	Ped Services	Phase Services	Force Off	Max Out	Gap Out
0	Total	2024-12-02 09:12:00	2024-12-04 10:12:29	0	10714	3232	661	6821

	Phase Number	Ped Services	Phase Services	Force Off	Max Out	Gap Out
0	1	0	429	103	0	326
1	2	0	2007	727	41	1239
2	3	0	584	15	66	503
3	4	0	1936	747	26	1163
4	5	0	528	155	2	371
5	6	0	2008	903	28	1077
6	7	0	1680	285	267	1128
7	8	0	1542	297	231	1014

	Name	From	To	Ped Services	Phase Services	Force Off	Max Out	Gap Out
0	Pattern 2	2024-12-02 09:12:00	2024-12-02 13:01:24	0	855	479	123	253

	Phase Number	Ped Services	Phase Services	Force Off	Max Out	Gap Out
0	1	0	38	17	0	21
1	2	0	138	138	0	0
2	3	0	73	0	15	58
3	4	0	138	106	5	27
4	5	0	62	30	0	32
5	6	0	138	127	0	11
6	7	0	138	57	0	81
7	8	0	130	4	103	23

FIGURE 3.13: PHASE TERMINATION DATA

Overall, ODOT's signal operations staff indicated that no specific report would tell the operator whether there was a detector outage. Rather, the reports provided an overall picture that helped determine whether an issue might be detector outage or some other operational problem.

The staff did believe that the use of ATSPMs supported improved troubleshooting. It was difficult to make a quantitative assessment of the improvement because there was no data collected (either before the implementation of ATSPMs or after) on the amount of time it took to determine if there was a detector outage.

DILEMMA ZONE ACTUATION DETECTION

ODOT staff provided DKS with 14 days of radar dilemma zone actuation counts from five of the signalized intersections along the study corridor. These intersections were along OR 224 and SE Webster Road, SE Pheasant, SE 82nd Drive, SE 130th Avenue, SE 135th Avenue, and SE 142nd Avenue. The locations of the intersections are shown in Figure 3.14.

The dilemma zone data was helpful in understanding how the detection system might lead to reduced red-light-running, by assessing how frequently the system was activated.

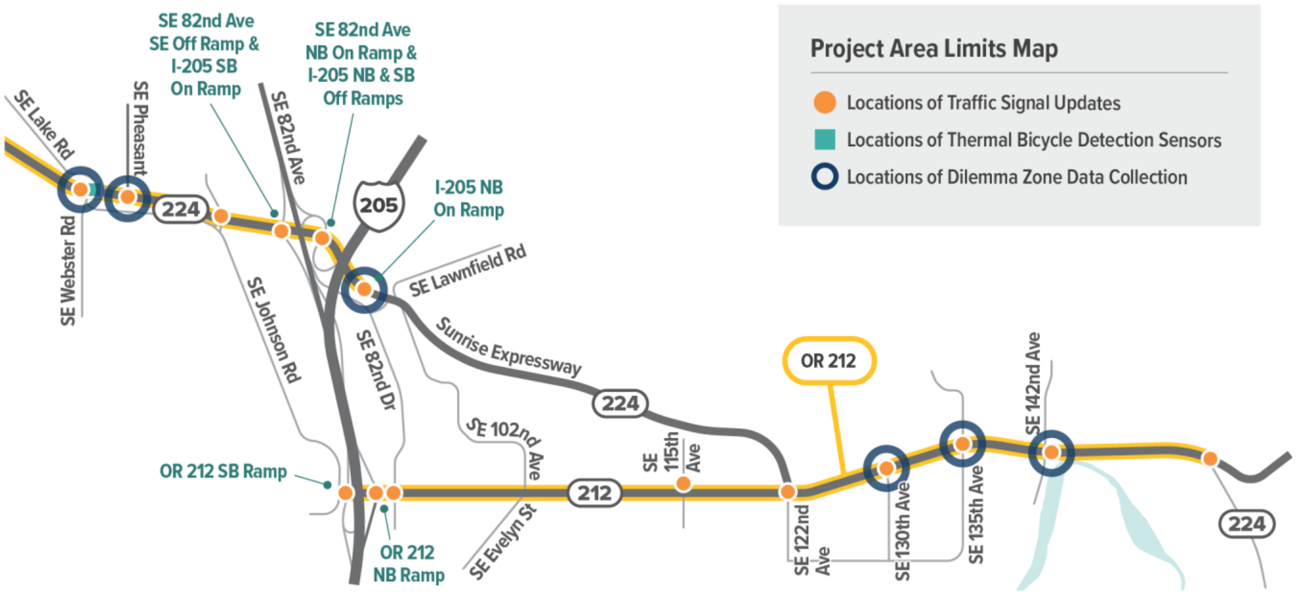


FIGURE 3.14: DILEMMA ZONE INTERSECTION DATA LOCATIONS (CIRCLED INSTERSECTIONS)

The dilemma zone occurred when a vehicle approached an intersection during the yellow phase and driver behavior was uncertain whether to stop or proceed through the intersection. Particularly for highways such as the OR 212/224 corridor, the dilemma zone was most commonly activated by vehicles traveling at higher speeds. To understand driver behavior between the five intersections, the provided actuation data was analyzed with descriptive statistics, and also through GIS spatial analysis to compare and contrast differences.

The dilemma zone detection system is dynamic. The radar unit assessed the size and speed of approaching vehicles at a range of 600 to 900 feet from the stop bar. Based on the size and speed of the approaching vehicle, the system would make a call to the controller. (Larger vehicles, would be assumed to be trucks with a longer stopping distance.) The system would prevent the signal from gapping out for that phase but not forcing off or maxing out. Unfortunately, there was only one output file for the data, so trucks and cars were counted together.

Actuation data provided date, time, and total count of actuations in the dilemma zone per 15-minute intervals. Additionally, it included direction of intersection travel, phase of signal, and signal cycle behavior such as gap out, max out, and force off. For broader purposes, only east and west bound traffic that coincided with OR 224 were analyzed, phases 2 and 6 respectively; various phasing of side streets were not evaluated. The total number of actuations per signal cycle (gap out, max out, force off), per phase of travel (east or west bound) were binned by hour to create a full 24-hour day that was averaged across the length of the study period. As an example, weekend activations during Saturday and Sundays for both directions are shown in Figure 3.15 below at the intersection of 82nd Drive and OR 224, where an Interstate 205 on ramp begins.

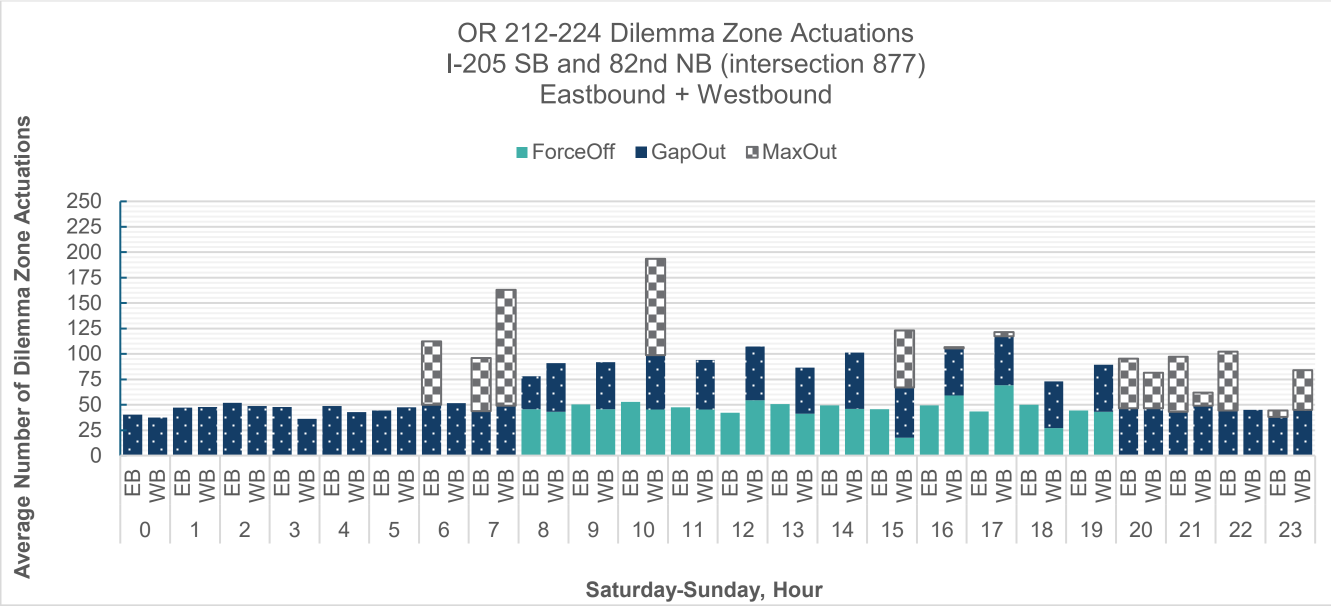


FIGURE 3.15: WEEKENED DILEMMA ZONE ACTIVATIONS ALONG OR 212/224 AND 82ND DR

Here, gap outs in blue with white polka dots remained relatively steady in the early morning hours. Force offs in green began at 8 a.m. and continue through to 7 p.m., indicating coordinated timing programming. Yet max outs, where a signal reaches its maximum allowable green time potentially because there is a steady stream of vehicles, showed spikes particularly in the westbound direction, at 7 a.m. and 10 a.m., and 3 p.m. The 7 a.m. and 10 a.m. dilemma zone actuations were also far greater in numbers than the rest of the averaged hours or direction of travel.

Weekday dilemma zone actuations were generally observed to be much higher. Figure 3.16 visualizes this spatially across all of the intersections by showing the total number of actuations per weekend and per weekday, by direction of travel. Total actuations were binned according to the range in the data from least to highest, creating three buckets (*small*, *medium*, *large*).

Even with both west and east bound directions combined during the weekend periods (seen in purple), the number of dilemma zone actuations was far lower than during Monday through Friday in either direction for any of the five intersections studied. Counts were comparable during weekdays for both directions with the exception of SE 130th Avenue and SE 142nd Avenue, where there were fewer dilemma zone actuations for east bound travel lanes.

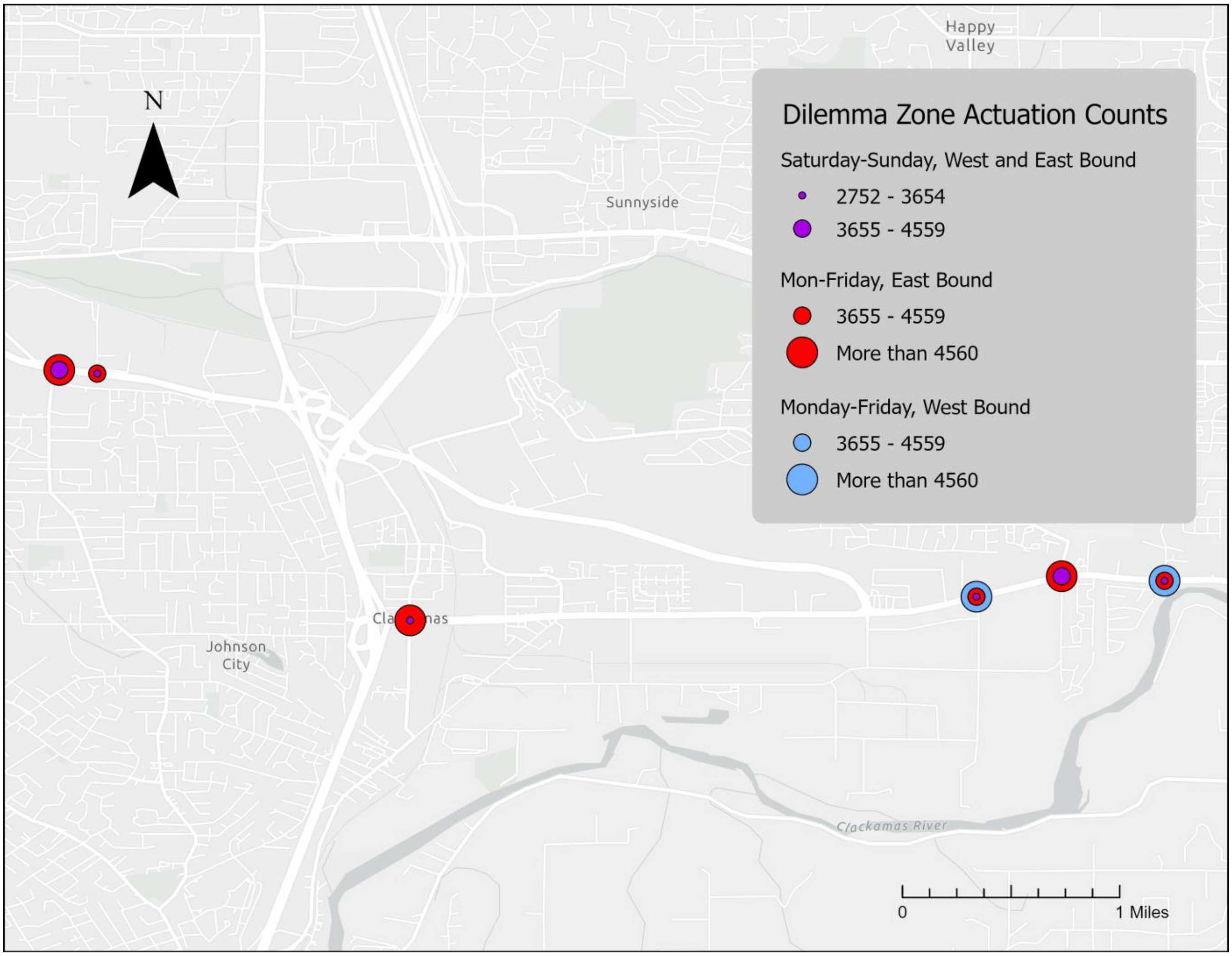


FIGURE 3.16: TOTAL NUMBER OF ACTUATIONS PER WEEKDAY AND WEEKDAY, BY DIRECTION OF TRAVEL

USEFULNESS OF ATSPMS

INTERVIEW BACKGROUND

To identify how ATSPMs were utilized for OR 212/224 Arterial Corridor Management, the Consultants met with signal operations staff from ODOT's Region 1 and interviewed them regarding their use of ATSPMs.

The questions were designed to determine who within the agency used ATSPMs, the level of effort the agency exerted to use ATSPMs, the results of the use of ATSPMs, and the ATSPM's affected agency processes.

The interview results are summarized below.

USE OF ATSPMS

The users of the ATSPMs were signal timers and performance management staff. The metrics were used in the assessment and modification of signal operations. ATSPMs were used weekly, usually when they received citizen calls. Before ATSPMs, the attendees answered that signal operation assessments happened monthly. The performance measures used were *Split Monitor*, *Pedestrian Delay*, *Turning Movement Counts*, *Arrivals on Red*, and *Yellow* and *Red Actuations*. ATSPMs were also being used to respond to citizen calls, for special events, real time operations, and before/after studies.

LEVEL OF EFFORT

Interviewees answered that it was easier and more efficient to use ATSPMs versus traditional methods. The efficiency of the ATSPMs implied a significant saving of time/resources assessing and reporting signal operations.

RESULTS

Attendees answered positively about the results of using ATSPMs. Operational objects were aligned with ATSPM metrics and reports. They were able to assess the effectiveness of ATSPMs due to the information either being in PDF or Excel format. Attendees were assessing/reporting signal operations more frequently with ATSPMs than with previous methods. The use of ATSPMs allowed the agency to improve their ability to report on existing measures with visualization of specific phases.

PROCESSES

The agency had no official process or policies on how to use ATSPMs. They developed new best practices and replaced previous processes. The use of ATSPMs has not led to any process changes. They were able to change the way they documented signal operations and now showed coordination diagrams for the electricians, red-light-running, and traffic volumes. Additional performance measures were adopted due to the use of ATSPMs.

SUMMARY

Region 1 staff reported that they have used ATSPMs to improve signal and corridor performance. Much use of the data was reactive in response to complaints, and they were still looking to improve the use of ATSPMs in their internal processes. They did note that the use of ATSPMs replaced past practices and led to overall improvement. Staff linked their use of ATSPMs to a Power BI dashboard that ODOT's Traffic Section developed.

Staff in Region 1 did not describe the use of ATSPMs to determine if there was a detector outage in the interview but did describe the process in subsequent discussions. This was an indication that they were growing in their ability to use ATSPM data and integrate into their processes.

INSTALLED RADAR DETECTION

BENEFIT/COST

DEVELOPMENT OF BENEFIT/COST

Benefits were developed from the safety and delay impacts to the project. Costs were determined by the project development and construction cost of the project. The goal of this effort was to develop conservative order of magnitude benefit cost information from data that was already collected and with little additional analysis.

For instance, the benefits of reduction in delay area applied only to the PM peak period because that was what the project team analyzed per the project evaluation plan. Additional benefits would accrue from the AM peak periods, or any other time congestions thresholds were exceeded, and the system was activated.

Annual operational costs were not included because relative to the $2.8 million capital cost, changes in operational costs would be relatively insignificant.

BENEFIT OF REDUCTION IN DELAY

The team developed the monetary value of the reduction in travel time using values from ODOT's *Value of Travel Estimates*.[3] The latest version of this report was published in February 2025. The costs were applied to the reduction in average travel time during the peak period from 3 p.m. to 6 p.m. on weekdays.

The annualized cost of the increase in delay was $67,000. Table 3.16 shows the annualized cost of the increase in travel time. The increased costs are shown as negative benefits.

TABLE 3.16: REDUCTION IN DELAY

DIRECTION	ANNUAL BENEFIT OF REDUCTION IN DELAY (OR 212)	ANNUAL BENEFIT OF REDUCTION IN DELAY (OR 224)	ANNUAL BENEFIT OF REDUCTION IN DELAY (COMBINED)
WESTBOUND	$99,400.28	-$61,859.57	$37,540.71
EASTBOUND	$78,442.93	-$182,448.77	-$104,005.84
TOTAL	$177,843.21	-$244,308.34	-$66,465.13

The limitations of the benefit/cost analysis were that safety improvements at traffic signals may have come at the expense of operational efficiency, leading to increased costs. For instance, dilemma zone extensions designed to reduce red-light-running could impact the efficiency of a traffic signal or traffic system.

Additionally, the analysis focused on evaluating PM peak period travel times. Signals operating near capacity during the PM peak may have limited potential for operational improvements through Automated Traffic

[3] ODOT Transportation Development Division Planning Section, Transportation Planning Analysis Unit. "Value of Travel Time Estimates," February 2025

Signal Performance Measures (ATSPMs). However, ATSPMs could be more effective in optimizing signal operations during the AM peak or off-peak periods.

BENEFIT OF REDUCTION IN CRASHES

Safety benefits were derived from the crash or incident reduction in the project limits. While crash severity data was available, due to the relatively short time frame where crash data was available in the *after* period, it was decided not to rely on the severity data. The team assumed that all crashes were property damage only and assigned an economic value to the crash of $24,800. This was the value that ODOT developed in a memo titled *Updated Crash Costs for Highway Safety Analysis*[4] in August 2023. The memo can be found in Appendix 1.

The team also compared incident data. Similarly, only the overall reduction in incidents was reviewed and it was assumed that all crashes were property damage only for the purposes of calculating benefits. Table 3.17 shows the costs of crashes based on incidents reported as crashes and reported crashes.

TABLE 3.17: BENEFITS OF CRASH REDUCTION

CRASHES	REDUCTION IN SIGNAL CRASHES (OR 212)	REDUCTION IN SIGNAL CRASHES (OR 224)	TOTAL CRASH REDUCTION	COST PER CRASH	TOTAL ANNUAL BENEFIT
CRASHES	-5	9	4	$24,800	$99,200

The total benefit in the reduction in the cost of crashes was $99,200.

TOTAL BENEFITS AND BENEFIT COST

The total annual benefit of the reduction in delays and reduction in crashes was approximately $32,735. The total costs of the project were $2,800,000 ($3,010,000 when adjusted for 2023 dollars). The service life of these ITS devices was assumed to be ten years. The total discounted benefits of the reduction in delay and reduction in crashes were $270,795. The team followed USDOT guidance by using the spreadsheet tool from the online Benefit Cost Analysis Guidance (2025 Update). As noted, the team used ODOT values for the cost of crashes and the value of travel time. The team assumed that annual maintenance and operations costs were $1,650. Using USDOT guidance, a discount rate of 3.1 percent was applied to both the safety and time travel savings benefits for each of the ten individual years following the completion of the project.

This resulted in a Benefit/Cost Ratio of 0.09 and a net present value of -$2,695,426. Table 3.18 shows the Total discounted benefits, costs, net present value, and the benefit cost ratio as discussed above.

[4] Zhao, Jiguan Ph.D, P.E., ODOT Traffic Roadway Section “Updated Crash Costs for Highway Safety Analysis,” August 25, 2023

TABLE 3.18: BENEFIT COST RESULTS

TOTAL DISCOUNTED BENEFITS	TOTAL DISCOUNTED COSTS	NET PRESENT VALUE	BENEFIT COST RATIO
$270,795	$2,966,221	-$2,695,426	0.09

While the project did not provide a benefit/cost ratio over 1.0, the project did offer a number of qualitative benefits. The project enabled automated data collection along the corridor, streamlining travel time and speed studies and signal timing adjustments. Some of the features added to the signals in the corridor, such as dilemma zone detection and extensions, were likely to reduce red-light-running at the expense of travel times.

FINDINGS

ASSESSMENT OF OVERALL SYSTEM PERFORMANCE

The following section summarizes the answers to the evaluation question.

Are red-light-running events and/or near-miss events reduced?

While it was not possible to definitively say whether red-light-running events and/or near-miss events were reduced, crashes at signalized intersections were reduced in the *after* condition slightly. It was likely that some of the crash reduction was based on reduced red-light-running. It was also likely that near-misses were highly correlated with crashes, so near-misses were likely reduced.

The use of video analytics could identify red-light-running and near-miss events. These could be completed in conjunction with changes to signal operations. In addition, a full assessment of *before* and *after* crash data would show changes in crash type or severity.

Is the variability of travel speed within the OR 212/224 corridor improved?

The variability of travel speed as measured by the 95th Percentile Speed, Buffer Index, and Planning Time Index improved in some cases but worsened in others. On OR 212 eastbound, all measures showed improvement. On OR 212 westbound, all measures worsened. OR 224, all measures worsened although some of the changes were very minor. Overall reliability measures did not improve.

Do the improvements affect average travel speeds within the OR 212/224 corridor?

Average travel speeds increased on OR 212 in both directions in the PM Peak period. This increase in travel speeds resulted in a cumulative decrease in travel time of 0.25 minutes when the eastbound and westbound travel time decrease was added together. Average travel speeds on the OR 224 portion of the decreased in both directions in the PM peak period. This decrease in travel speeds resulted in a cumulative increase in travel time of 0.39 minutes when the eastbound and westbound travel time increase was added together.

How useful are ATSPMs for monitoring and managing corridor operations?

Currently, ODOT staff use ATSPMs to improve signal operations. The data feeds Power BI reports that are used to address signal timing concerns. Review of signal operations is still generally reactive, and complaint-driven rather than proactive.

As ATSPMs are more fully integrated into the ODOT's work processes and as staff develop more expertise in their use, managing corridor operations will improve. Staff have seen efficiency gains, particularly on troubleshooting. They can remotely log on to view performance measures and begin to address issues.

Figure 3.17 shows an example of a Power BI report used by ODOT for ATSPMs. The example shows split failures at a specific traffic signal.

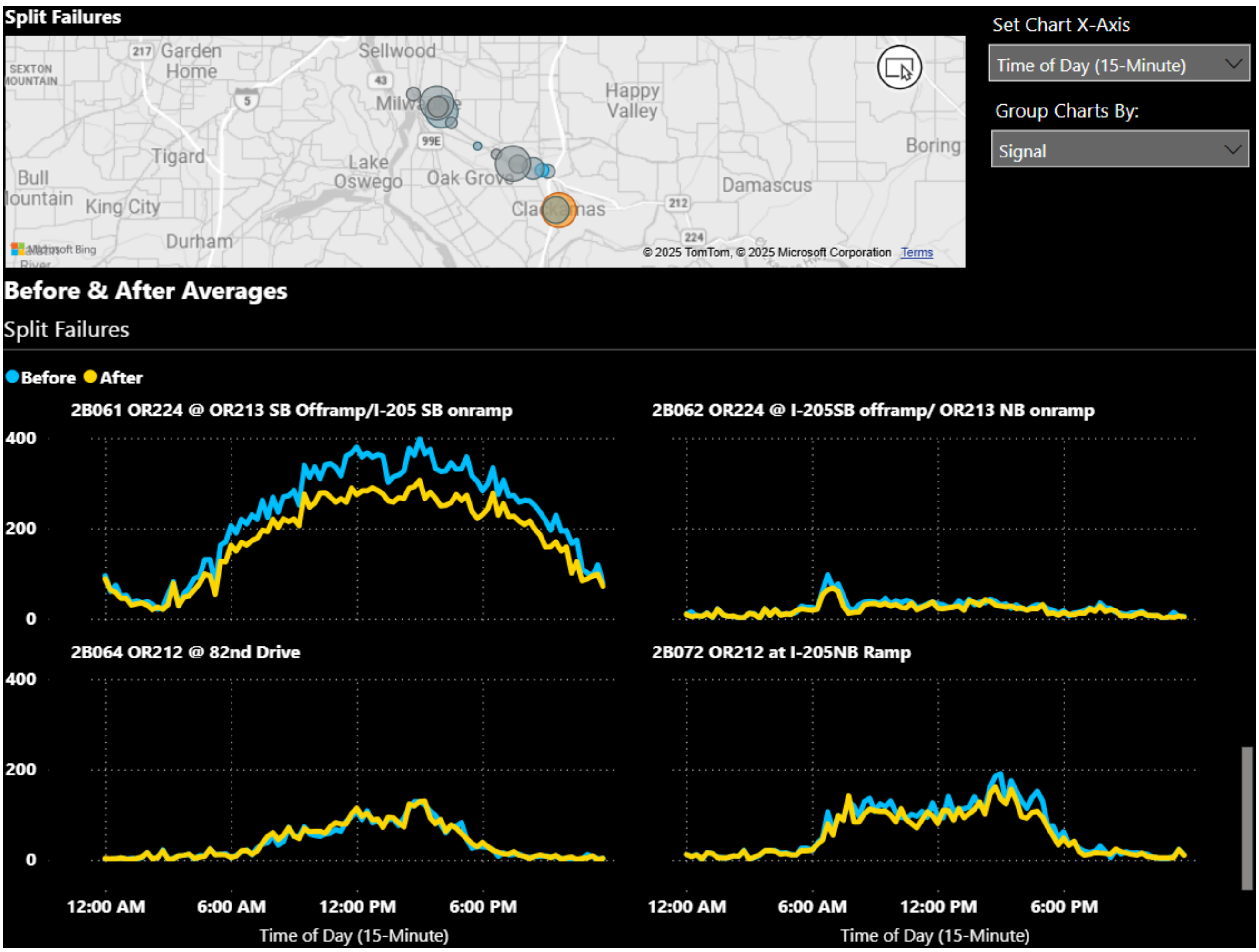


FIGURE 3.17: POWER BI REPORT

Additionally, Figure 3.18 provides a clear visualization of typical split failure. There was a significant spike in split failures between March 27 and April 6, most prominently in Phase 1 and 2, followed by sustained high levels through late April. This abrupt increase suggested a potential operational issue which could have caused an excessive number of max outs, preventing proper phase termination.

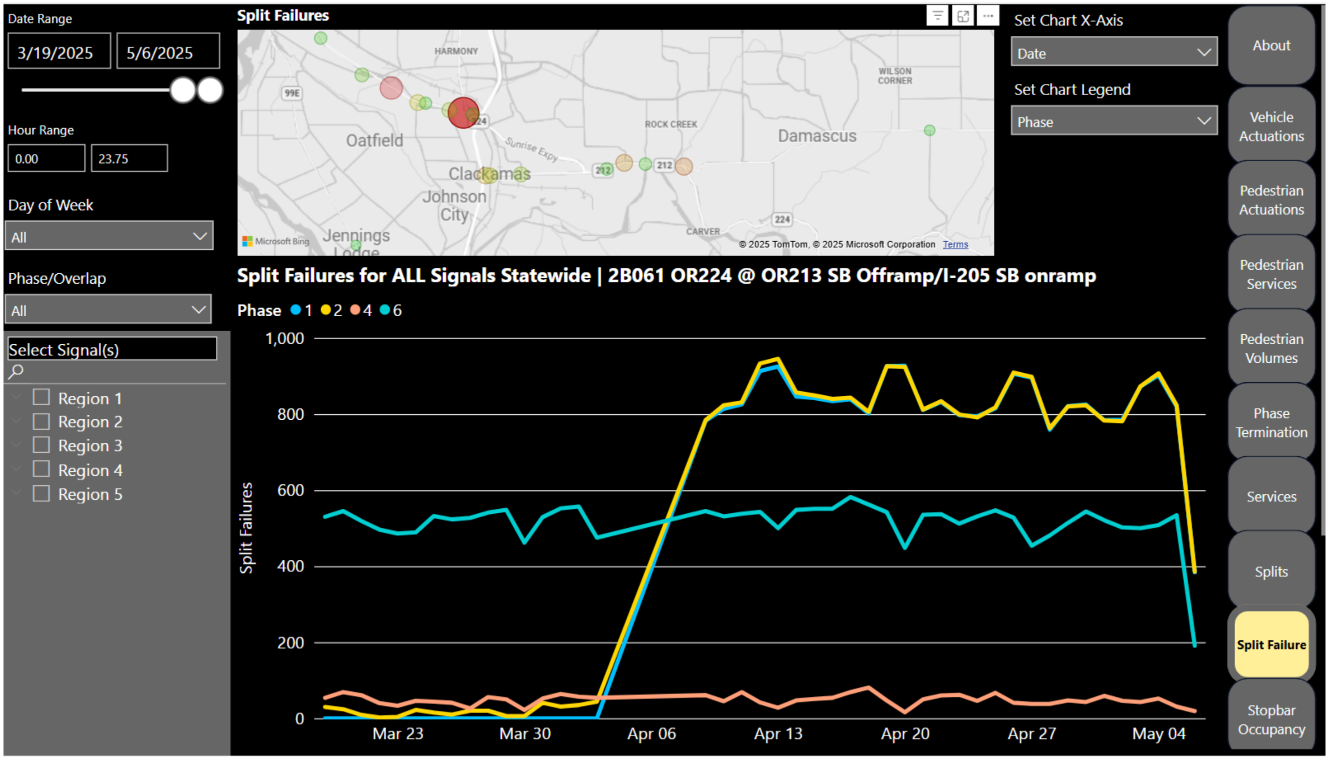


FIGURE 3.18: POWER BI SPLIT FAILURE

How does the availability of ATSP's change the response to time to detection outages?

The sample size was very small, but the detector outage times were reduced in the *after* period.

Anecdotally, signal operations staff reported that they were able to identify detection outages via a combination of user feedback and review of ATSPM data. They were also able to clarify when a complaint was not actually a detector outage, but some other concern.

Continued use of MicroMain as an asset management tool would allow ODOT to track response and repair time for detector outages over time. This would allow the agency to potentially understand changes in performance or see incremental improvement over time.

IDENTIFICATION OF ISSUES

The signal improvements appeared to be operating well, particularly in the westbound direction and in regard to safety. The OR 224 section had a reduction in crashes while travel times on OR 212 were generally improved.

ODOT staff identified the need to continue to develop expertise in the use of ATSPM data and to develop standard reports and integrate the use of ATSPM data into work practices. ODOT staff were using ATSPMs to help improve response to detector outages.

As noted previously, the lack of *before* data related to video analytics presented challenges in the evaluation. Surrogate data such as incidents reported as crashes and dilemma zone data was used to understand safety performance around red-light-running. However, it was an imperfect substitute, and impossible to tell whether the reduction in crashes was related to red-light-running.

Similarly, there was not a large enough sample size of detector outages in the *after* period to complete a quantitative analysis. While detector failures appeared to be infrequent, tracking them in MicroMain would have allowed a substantive analysis of changes in performance.

RECOMMENDATIONS FOR OPERATIONS

ODOT should seek opportunities to support the implementation of ATSPMs. For instance, providing training for operations staff on data utilization would be beneficial. Some standard reports for ATSPM data have been created, but additional work remains to be done. Reports showing the benefits of ATSPMs at a higher level would be helpful in ensuring the agency continues to invest in the technology. Efforts should be made to ensure that ATSPMs are used to proactively address operational issues, rather than relying on traditional reactive methods.

Overall, the agency should seek opportunities to use ATSPM to support and improve their culture of operational improvement.

4 NE Airport Way Arterial Corridor Management System

PROJECT DESCRIPTION

This City of Portland NE Airport Way Arterial Corridor Management project expanded several existing Intelligent Transportation Systems (ITS) improvements along Airport Way between 82nd Avenue and Riverside Parkway. The expanded ITS infrastructure included expansion of CCTV monitoring cameras, truck priority, detection improvements for ATSPMs, and traffic signal controller and signal timing upgrades. The project also installed fiber optic cable to provide high-speed communications to the ITS devices and traffic signal controllers. The ITS devices and traffic signal controllers were integrated into the transportation operation center of the City of Portland and the CCTV cameras were incorporated into ODOT's video management system and the TripCheck website. The project was part of the larger City of Portland and Regional Advanced Traffic Management System (ATMS) and maximized the benefits to the corridor by selectively installing equipment to minimize cost.

Key components of the project included:

- CCTV cameras and video management server upgrades
- Communications infrastructure
- Non-invasive detection improvements and ATSPMs implementation
- ATC controllers and signal timing improvements
- Total project cost was $1,373,669. The construction cost was $1,031,190.

The project was constructed and deployed during the period from December 19, 2022, through June 19, 2023.

LEFT: INSTALLATION OF FIBER OPTIC CABLE; RIGHT: TRAFFIC SIGNAL CONTROLLER UPGRADES

CORRIDOR OPERATIONS

The Airport Way corridor has two through lanes in each direction. There is a mixture of continuous two-way turn lanes, dedicated left turn lanes at signals and landscaped median. The corridor has traffic volumes that exceeded 23,000 vehicles per day in 2023 count data.

Adjacent land uses include hotels, light industrial and warehousing, and some retail.

The Airport Way corridor has unusual peaking characteristics. The eastbound direction had very similar volumes in both the a.m. peak periods and the p.m. peak periods. The westbound direction had higher volumes in the p.m. peak periods.

EVALUATION

EVALUATION GOALS, OBJECTIVES AND QUESTIONS

The goals of the project included improving safety, mobility, and operations. The objectives of the before-and-after evaluation were to measure how well the improvements achieved the project goals. Table 4.1 summarizes the project goals and specifically how the goals were evaluated.

TABLE 4.1: PROJECT GOALS AND EVALUATION OBJECTIVES

GOAL AREA	GOAL DESCRIPTION	EVALUATION OBJECTIVE
#1 IMPROVE SAFETY	Reduce crash potential in the corridor	Determine if red-light-running and/or near-miss events were reduced.
#2 IMPROVE MOBILITY	Improve travel time reliability	Determine if the variability of travel times within the corridor were reduced.
#3 IMPROVE OPERATIONS	Improve the efficiency of system operations Enhance real-time traveler information	Determine how useful the ATSPMs are for monitoring and managing corridor operations. Determine if an appropriate amount of vehicle diversion takes place in conjunction with announced incidents and special events.

EVALUATION METHODOLOGY AND PERFORMANCE MEASURES

EVALUATION PERIODS

The *Oregon ATCMTD Project Evaluation Plan* estimated that the project would be deployed from October 2019 to December 2020. The *before* and *after* evaluation periods were planned to be 2017-2018 and 2021-2022, respectively. However, construction did not start until August 2022.

Based on the actual project deployment schedule and evaluation data availability, the following periods were used for the data collection:

Before data collection period: July 2021 through June 2022

After data collection period: July 2023 through June 2024.

Each data collection period covered a one-year time frame, aiming to capture the most available data for evaluation purposes. DKS screened the data sets for completeness and quality, performed preliminary statistical analysis, and determined the evaluation periods for the *before* and *after* analysis. The goal was to have a minimum of six months of data in each evaluation period to summarize meaningful traffic trends, and the actual evaluation periods were dependent on results of the data screening.

PERFORMANCE MEASURES

Based on the evaluation objectives, the following performance measures were proposed and summarized in Table 4.2. A brief description of the data type associated with each performance measure is also listed in the table.

TABLE 4.2: PERFORMANCE MEASURES AND DATA SOURCES

EVALUATION OBJECTIVE	PERFORMANCE MEASURES	ASSOCIATED DATA TYPE
#1: DETERMINE IF RED-LIGHT-RUNNING AND/OR NEAR-MISS EVENTS WERE REDUCED	a) Number of crashes	Portland Police Bureau Crash Reports
#2: DETERMINE IF THE VARIABILITY OF TRAVEL TIMES WITHIN THE CORRIDOR WERE REDUCED	b) Average speed and travel time c) 95th percentile speed d) Buffer index e) Planning time index	Roadway segment lengths Travel speed/time information, 5-minute intervals
#3: DETERMINE HOW USEFUL THE ATSPMS ARE FOR MONITORING AND MANAGING CORRIDOR OPERATIONS	f) Qualitative Assessment of whether operators found ATSPMs “High”, “Moderate”, “Minimal” or “Not Useful”	Survey of signal system operators and managers assessments

Additional considerations in using these performance measures in the *before* and *after* evaluation are described in the following sections.

A) NUMBER OF CRASHES

Originally the number of red-light-running and near-miss events was to be measured using video analytics. Unfortunately, the corridor was not video recorded in the *before* period. Instead, the number of crashes was used to measure the safety goal. DKS reviewed *before* and *after* crash reports for the signalized intersections in the corridor based on Portland Police Bureau crash data.

B) AVERAGE SPEED AND TRAVEL TIME

Average travel speed and average travel time were used to measure the effectiveness of the mobility goal, specifically for the weekday evening peak hour. DKS evaluated the data for non-holiday weekdays (Monday – Friday) during the hours of 3 p.m. to6 p.m. and determined the most appropriate 60-minute period for the evaluation. This period was selected by identifying the 15-minute interval with the lowest travel speeds along the corridor, indicating the highest level of congestion during the peak, and using this as the basis for determining the overall peak period. The peak hour was identified as 4:00 p.m. to 5:00 p.m.

C) 95TH PERCENTILE TRAVEL TIME

Similar to the average travel speed, the 95th percentile travel time was aggregated for the same time period and reported for non-holiday weekday (Monday – Friday) during the peak 60-minute period within the hours of 3 p.m. to 6 p.m.

D) BUFFER INDEX AND E) PLANNING TIME INDEX

Buffer Index and Planning Time Index were calculated based on the average travel time, free-flow travel time, and 95th percentile travel time. Therefore, these metrics were also reported for the same peak 60-minute period.

E) QUALITATIVE ASSESSMENT SURVEY DATA

This was a qualitative assessment of ATSPMs by operators. Staff who were responsible for maintenance, operations, and management of signals were surveyed to assess whether they found the usefulness of ATSPMs as *High*, *Moderate*, *Minimal*, or *Not Useful*.

DATA COLLECTION APPROACH

DATA TYPES AND SOURCES

Table 4.3 summarizes the data sources and how they were acquired for each data type identified above. The collection process was a collaboration between the consultant and the City of Portland.

TABLE 4.3: DATA SOURCES

DATA TYPE	DATA SOURCE	RESPONSIBLE PARTY
ROADWAY SEGMENT LENGTHS	Google Earth or GIS	DKS
CRASH REPORTS	Portland Police Bureau	DKS
SPEED/TRAVEL TIME	INRIX data via RITIS	DKS
QUALITATIVE ASSESSMENT	Survey	DKS

DATA PROCESSING AND REVIEW

This section summarizes data quality, processing, and completeness checks performed for each data source.

ROADWAY SEGMENT LENGTHS

Segment lengths were taken from the GIS shapefile matching the INRIX XD data segments and were verified using Google Earth. Roadway segment lengths included mainline segments. Segment lengths could be aggregated and consisted of multiple INRIX XD segments.

INCIDENT LOGS

Incident and special event data were requested directly from ODOT and PBOT. Neither agency was able to provide this data because they do not collect it.

DKS was able to use the City of Portland open-source 911 data from the Portland Police Bureau (PPB), which could be filtered for traffic crashes to determine the number of crashes from the *before* and *after* periods[5].

SPEED AND TRAVEL TIMES

DKS downloaded travel time and speed data from RITIS which contained INRIX segment-based speed data. The higher resolution XD segments were used for this analysis. Note that INRIX updates its XD segment map twice a year and care was taken to use the same map version and segmentation for both the *before* and *after* time periods. INRIX data was downloaded in five-minute increments based on the list of study segments.

Quality checks were performed by creating speed contour plots, which were heatmaps of the speeds along the study segments by time of day. They showed where the delays or bottlenecks occurred along the study corridor by time of day and could be used to identify any speed anomalies. Speed data was reviewed for outliers at the XD segment level before aggregating as needed for the performance measures.

INTERVIEW DATA

DKS staff interviewed signal system operators, managers, and timing staff. The data was qualitative in nature and aggregated subjective assessments.

DATA ANALYSIS

RED-LIGHT-RUNNING AND NEAR-MISSES

The original intent of the project was to measure red-light-running and near-misses using video analytics data. Unfortunately, the intersections were not analyzed with video analytics in the *before* condition, so a direct *before* and *after* analysis was not possible. The team explored other ways to measure improvements in red-light-running and near-misses specifically, and changes in safety generally.

One way to evaluate safety would be to look at overall crashes. ODOT's crash data was not yet available for the *after* condition. The team again utilized PPB 911 call data for this portion of analysis. The data was open source and available to anyone through the City of Portland's Open Data. The team downloaded the calls that were coded as traffic crashes on Airport Way in the *before* and *after* periods with the totals shown below in Table 4.4.

The 911 data did not provide any details regarding the mechanics of the crash. The data provided the date and time of the call, whether it was crash, and the location by description and latitude and longitude of the location. From the data, the DKS team could determine whether a crash was near a signal, but not whether the crash was signal-related.

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[5] Portland Open Data, https://www.portland.gov/police/open-data/police-dispatched-calls

TABLE 4.4: TOTAL TRAFFIC CRASHES IN BEFORE AND AFTER PERIODS (PPB 911 DATA)

CRASHES (BEFORE)	CRASHES (AFTER)	REDUCTION IN CRASHES	PERCENT REDUCTION
110	92	18	16.36%

The team then further refined the crashes that occurred within 200 feet of a signalized intersection in the *before* and *after* periods. The number of crashes *before* and *after* are shown below in Table 4.5.

TABLE 4.5: TOTAL TRAFFIC CRASHES WITHIN 200 FEET OF SIGNALIZED INTERSECTION (PPB 911 DATA)

CRASHES (BEFORE)	CRASHES (AFTER)	REDUCTION IN CRASHES	PERCENT REDUCTION
48	34	14	29.17%

To validate the *before*-period 911 incident data, the team compared it with the official ODOT crash reports database for the period from July 2021 to June 2022. The team was unable to cross-reference the *after*-period crashes because ODOT crash data for the year 2024 was not available at the time of the evaluation. This comparison helped with the accuracy of reported crash trends along the corridor. The total number of crashes along the corridor, as well as those occurring within 200 feet of the corridor, and injury type, are summarized in Table 4.6 and Table 4.7, respectively.

It was difficult to attribute a portion of the crash reduction to the improvements made in the project without more detailed *before* and *after* crash data. It was likely that red-light-running and near-misses were reduced if the overall number of crashes at or near the signal were reduced. Signal timing was adjusted based on ATSPMs and that may have had an impact on the safety at specific signals due to circumstances such as improved platooning or increased arrivals on green.

TABLE 4.6: TOTAL TRAFFIC CRASHES IN BEFORE PERIOD (ODOT CRASH DATA)

CRASHES (ODOT)	INJURY SEVERITY A (SEVERE)	INJURY SEVERITY B (MODERATE)	INJURY SEVERITY C (MINOR)	PROPERTY DAMAGE ONLY
49	1	11	14	23

TABLE 4.7: TOTAL TRAFFIC CRASHES WITHIN 200 FEET OF SIGNALIZED INTERSECTIONS (ODOT CRASH DATA)

CRASHES (ODOT)	INJURY SEVERITY A	INJURY SEVERITY B	INJURY SEVERITY C	PROPERTY DAMAGE ONLY
24	1	6	7	10

There was a significant discrepancy between crashes with slightly over 50 percent fewer crashes reported to ODOT's official crash database for the corridor than to the 911 system, and 50 perfect fewer crashes reported to ODOT in proximity of signals. This could be explained by the nature of crash reporting in Oregon.

Drivers were not required to submit crash reports for crashes with minor damage, less than $2,500 per vehicle. In some cases, there could have been 911 calls for crashes where the drivers did not submit crash reports. Also, in a jurisdiction of the size of Portland, PPB may not have submitted crash reports to ODOT when the damage was minor, and they were unable to determine fault upon response.

VARIABILITY OF TRAVEL TIMES

The time periods when travel time and speed measures were collected are shown in Table 4.8. The team reviewed the variability of travel times in the peak period in both directions (Table 4.9). Additionally, the identified time period remained consistent throughout the study, as congestion levels during these hours did not shift in the *after* period.

PTZ CAMERA FOOTAGE

TABLE 4.8: DATA COLLECTION PERIOD - WEEKDAYS 3:00 P.M. TO 6:00 P.M. – PEAK HOUR 4:00 P.M. – 5:00 P.M.

CORRIDOR LENGTH = 5.01 MILES	
PERIOD	Date
BEFORE	07/01/2021 to 06/30/2022
AFTER	07/01/2023 to 06/30/2024

INSTALLATION AT NE 122ND AVE

Table 4.9 presents the baseline and post-performance measures along NE Airport Way. These measures were also visually represented in Figure 4.1 and Figure 4.2 for easier comparison.

In the eastbound direction, average travel speeds decreased by 5.3 percent. The 95th travel speeds saw a smaller decrease of 2.1 percent. Average travel times increased by less than half a minute (5.6 percent increase). The 95th percentile travel time, the buffer index, and planning time index all improved. The 95th percentile travel time and the planning time index changed by less than 1 percent. The buffer index saw a 21.9 percent decrease. The buffer index was computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time. In this case the 95th percentile travel time nearly stayed the same, but the average travel time had increased, decreasing the buffer index. The typical peak hour got slightly worse.

The westbound direction saw an increase in the average and 95th percentile travel speeds of 5.2 percent and 1.9 percent, respectively. There was a decrease in the average travel time and improvement in 95th percentile travel time, the buffer index, and planning time index. The average travel time decreased by 4.9 percent, and the 95th percentile travel time decreased 10.6 percent. The buffer index decreased 18.2 percent. The planning time index decreased as well by 10.2 percent. The evaluation suggests that in the westbound direction, both the worst and typical peak hours improved.

It is possible that the *before* period, which started in July 2021, was impacted by reduced travel related to the pandemic.

As noted above, the eastbound travel times generally worsened. Traffic volume data did not show large traffic volume changes. There were no large construction projects that would have diverted traffic onto this section of Airport Way. It was possible that travel times in the eastbound directions worsened due to signal timing adjustments that improved travel time and reliability in the opposing direction.

TABLE 4.9: NE AIRPORT WAY TRAVEL SPEED AND TRAVEL TIME

		FREE FLOW SPEED (MPH)	AVERAGE SPEED (MPH)	95TH PERCENTILE SPEED (MPH)	FREE FLOW TRAVEL TIME (MIN)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
EB	BEFORE	37.48	30.83	35.72	7.96	9.67	12.78	0.32	1.61
	AFTER	37.48	29.21	34.96	7.96	10.21	12.76	0.25	1.60
WB	BEFORE	35.54	26.07	33.52	8.46	11.53	16.62	0.44	1.97
	AFTER	35.83	27.43	34.15	8.39	10.96	14.86	0.36	1.77

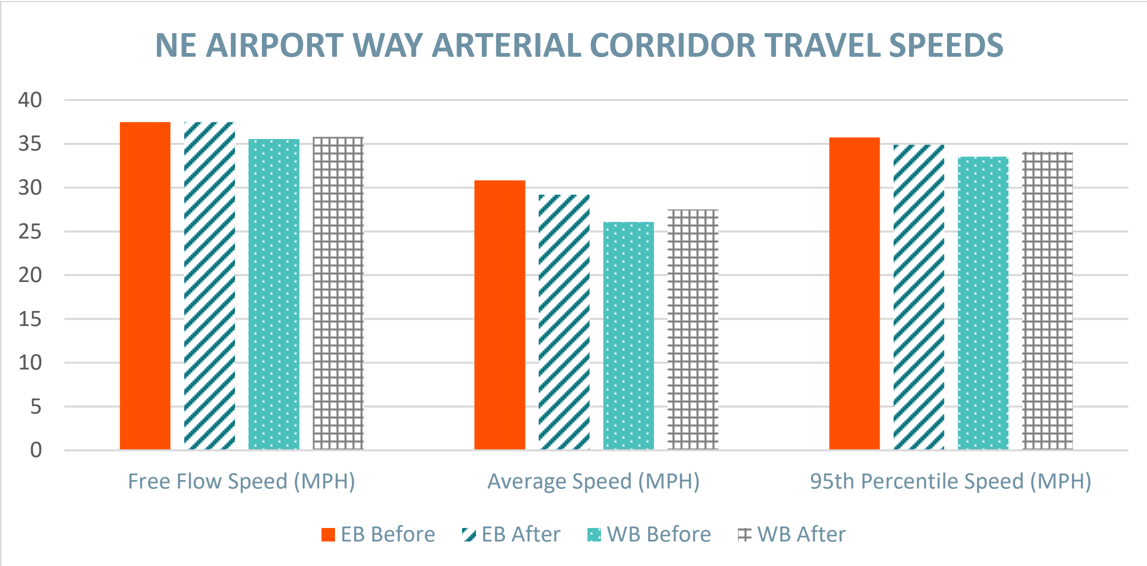

FIGURE 4.1: NE AIRPORT WAY ARTERIAL CORRIDOR TRAVEL SPEEDS

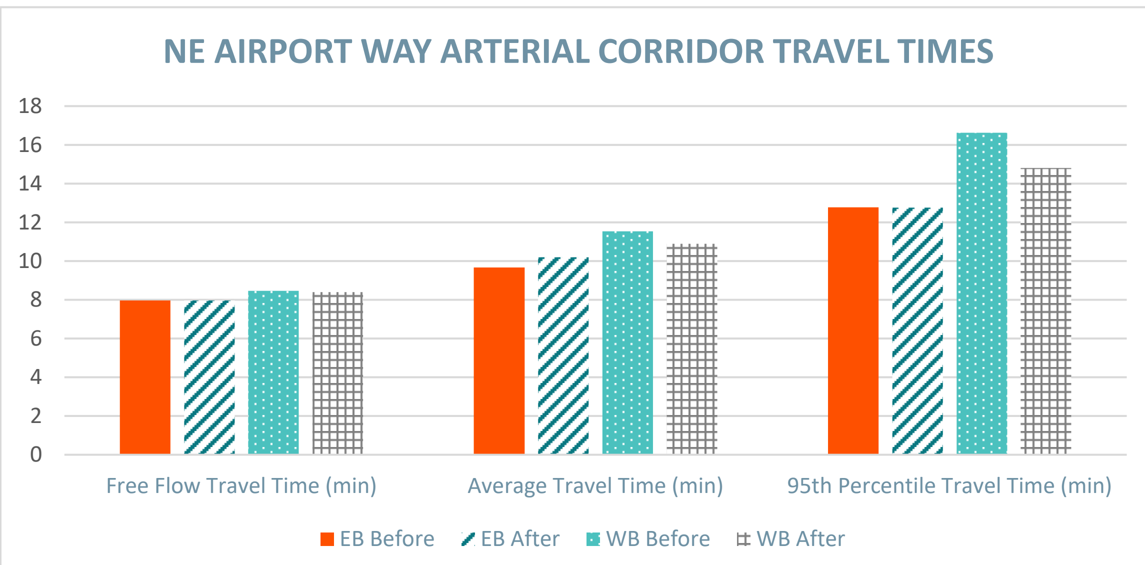

FIGURE 4.2: NE AIRPORT WAY ARTERIAL CORRIDOR TRAVEL TIMES

Table 4.10 shows the percentage change in the average travel time, 95th percentile travel time, buffer index, and planning time index.

TABLE 4.10: PERCENTAGE CHANGE IN TRAVEL TIME AND RELIABILITY MEASURES

	AVERAGE TRAVEL SPEED (MPH)	95TH PERCENTILE TRAVEL SPEED (MPH)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
EASTBOUND	-5.3%	-2.1%	5.6%	-0.2%	-21.9%	-0.6%
WESTBOUND	5.2%	1.9%	-4.9%	-10.6%	-18.2%	10.2%

USEFULNESS OF ATSPMS

INTERVIEW BACKGROUND

To identify how ATSPMs are utilized for NE Airport Way, the Consultants met with signal operations staff from the City of Portland and interviewed them regarding the implementation of ATSPMs on Airport Way.

The interview questions were designed to determine how widespread the use of ATSPMs were, how they impacted the level of effort by agency staff, the results of the use of ATSPMs, and how the use of ATSPMs changed agency processes.

The interview results are summarized below.

USE OF ATSPMS

Interviewees stated that signal timers were frequent users of ATSPMs, with other groups having access available to the ATSPM data. ATSPMs were used to assess and modify signal operations. The interviewees relied on Google traffic maps and split logger/failures from Trans Suite occasionally in the past to assess signal performance. In addition, ATSPMs were also used to troubleshoot maintenance tasks such as detector failure. They did not use any specific metrics to address signal operations. Interviewees used the ATSPMs weekly for a high-level look at overall system operation.

LEVEL OF EFFORT

Attendees answered that it was slightly easier to use ATSPMs versus traditional methods. They stated it depended on what they were doing. It did save time, from the prepared reports, as well as from the maintenance staff knowing whether it was a physical or software issue.

RESULTS

The agency could align operational objectives with ATSPM metrics/reports. Although they do not have the reports yet, they are developing them now. They would be able to document and quantify the effectiveness of ATSPM use. The frequency of assessing/reporting signal operations increased with the use of ATSPMs compared to past practices. ATSPMs led to improved signal operations at the intersection level, but were unsure about the corridor level. It reduced delay, though they had not documented the improvements. The use of ATSPMs made it easier to get information and troubleshoot for technicians.

PROCESSES

Interviewees said that they had changed some processes based on the implementation of ATSPMs. They assessed and reported signal operations more frequently. They could use probe data from RITIS to assess *before* and *after* performance that have been adjusted based on ATSPM data. They were still in the process of figuring out how to help manage traffic for special events. They also needed to figure out the correct audience for their measures and developed reports for that audience.

The City does not have a process or policy on how to use ATSPMs. It has not yet led to any formal changes in the process, documentation/reporting of signal operations, or the adoption of additional performance measures. ATSPMs have supplemented past practices, becoming another source of data for the city. Collaboration between work units has improved thanks to ATSPM data being shared.

SUMMARY

The city is using ATSPMs to improve signal operations, particularly at the level of the individual signal level, rather than the corridor level. ATSPMs were used to improve maintenance responsiveness. The city was still working to fully integrate ATSPMs into their work process and develop reports to support that effort. The city was laying the groundwork for future proactive signal timing opportunities. ATSPMs saved time for troubleshooting and were much more efficient, which better served the corridors when issues were reported.

VEHICLE DIVERSION

Vehicle diversion was not possible to measure with current data. The project was modified from its original scope. Variable messages signs to alert motorists of incidents, and special events were not installed in the project. It was not possible to alert motorists in real time other than in-car or phone-based navigation systems.

Also, there were no systemic counts taken in the *before* period. Signal-based detection could provide count data on Airport Way, but there was not a similar capability on potential alternate routes.

BENEFIT OF REDUCTION IN DELAY

The team developed the monetary value of the reduction in travel time using values from ODOT's *Estimated Value of One Hour of Travel Time Savings by Vehicle Class*[6] published in 2025, the latest version of this report. The costs were applied to the reduction in average travel time during the peak period from 3 p.m. to 6 p.m. on weekdays as shown in Table 4.10 above. The reduction in peak hour delay was assumed to be the same across the entire peak period from 3:00 PM to 6:00 PM. Traffic volumes were developed from ODOT's

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[6] ODOT Transportation Development Division Planning Section, Transportation Planning Analysis Unit. "Value of Travel Time Estimates," February 2025

Oregon Traffic Count Database.[7] Values were assigned to cars and trucks based on classification counts from the same database Per the FHWA guidance, and cost of delay values were assigned to passenger cars and trucks. In the classification counts, Classes 1 through 3 were counted as passenger cars while Class 4 and above were counted as trucks. The monetary value of the delay in the peak period was assumed to be the total monetary value for the entire day. The value of the delay was annualized by multiplying the daily value by 260 working days in a year.

The benefit of the reduced travel time eastbound was negative because travel times increased slightly. Eastbound volumes were lower than westbound volumes in the afternoon peak.

The annualized benefit of the reduction in delay was $114,543, as shown in Table 4.11.

TABLE 4.11: ANNUALIZED BENEFIT OF REDUCTION IN DELAY

DIRECTION	VALUE OF REDUCED TRAVEL TIME PER DAY	WORKDAYS PER YEAR	ANNUAL BENEFIT OF REDUCTION IN DELAY
WESTBOUND	$1,521.91	260	$395,695.48
EASTBOUND	-$1,081.35	260	-$281,152.05
TOTAL	$440.55	260	$114,543.43

BENEFIT OF REDUCTION IN CRASHES

Safety benefits were derived from the crash or incident reduction within the project limits. While crash severity data was available, due to the relatively short time frame where crash data was available in the *after* period, it was decided not to rely on the severity data. To remain conservative due to lack of available data regarding crash severity from the PPB 911 data and the uncertainty of reduction in crashes, the team assumed that all crashes were property damage only and assigned an economic value to the crash of $24,800. This was the value that ODOT developed in a memo titled *Updated Crash Costs for Highway Safety Analysis*[8] in August 2023.

TABLE 4.12: BENEFITS OF CRASH REDUCTION

CRASHES	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	REDUCTION AMOUNT	COST PER CRASH	ANNUAL BENEFIT
CRASHES	48	34	14	$24,800	$347,200

The total annual benefit associated with the reduction in the cost of crashes was $347,200.

[7] https://ordot.public.ms2soft.com/tcds/tsearch.asp?loc=Ordot&mod=TCDS

[8] Zhao, Jiguan Ph.D, P.E., ODOT Traffic Roadway Section “Updated Crash Costs for Highway Safety Analysis,” August 25, 2023

TOTAL BENEFITS AND BENEFIT COST

The total costs of the project were $1,289,173 ($1,373,669 when adjusted for 2023 dollars). The service life of these ITS devices was assumed to be ten years.

The total discounted benefits of the reduction in delay and reduction in crashes was $3,911,040.

The team followed USDOT guidance by using the spreadsheet tool from the online Benefit Cost Analysis Guidance (2025 Update). As noted, the team used ODOT values for the cost of crashes and the value of travel time. The team assumed that maintenance and operations costs were $880. Using the USDOT guidance, a discount rate of 3.1 percent was applied to both the safety and time travel savings benefits for each of the ten individual years following the completion of the project.

This resulted in a Benefit/Cost Ratio of 2.85 and a net present value of $2,537,371. Table 4.13 shows the Total discounted benefits, costs, net present value, and the benefit cost ratio as discussed above.

TABLE 4.13: BENEFIT COST RESULTS

TOTAL DISCOUNTED BENEFITS	TOTAL DISCOUNTED COSTS	NET PRESENT VALUE	BENEFIT COST RATIO
$3,911,040	$1,373,669	$2,537,371	2.85

Additionally, the project enabled automated data collection along the corridor, streamlining travel time and speed studies and signal timing adjustments.

FIBER OPTIC INSTALLATION

HARDWARE INSTALLATION

FINDINGS

ASSESSMENT OF OVERALL SYSTEM PERFORMANCE

Are red-light-running events and/or near-miss events reduced?

While it was not possible to definitively say whether red-light-running events and/or near-miss events were reduced, crashes at signalized intersections were reduced in the after condition. It was likely that some of the crash reduction was based on reduced red-light-running. It was also likely that near-misses were highly correlated with crashes, so near-misses were likely reduced.

Is the variability of travel times reduced?

Reliability of travel time improved based on all measures in both directions. The reliability improvements were more pronounced westbound than eastbound.

How useful are ATSPMs for monitoring corridor operations?

Currently city staff are using ATSPMs to improve signal operations, primarily at the level of the individual signal, rather than at the corridor level. ATSPMs were used to improve maintenance responsiveness. The city was still working to fully integrate ATSPMs into their work process and developed reports to support that effort. The city was laying the groundwork for future proactive signal timing opportunities. ATSPMs saved time for troubleshooting and were much more efficient at serving the corridors when issues were reported.

As ATSPMs w more fully integrated into the City's work processes and as city staff develop more expertise in their use, managing corridor operations will improve.

While city staff believe that ATSPMs are more useful at the individual signal level, the data showed some benefits were accruing at the corridor level.

Does an appropriate amount of vehicle diversion take place in conjunction with announced incidents and special events?

This was not possible to measure with current data. The project was modified from its original scope. Variable messages signs to alert motorists of incidents and special events were not installed as part of the project. It was not possible to alert motorists in real-time, other than in-car or phone-based navigation systems.

Also, there were no systemic counts taken in the *before* period. Signal-based detection could provide count data on Airport Way, but there was not similar capability on potential alternate routes.

IDENTIFICATION OF ISSUES

The signal improvements appeared to be operating well, particularly in the westbound direction and in regard to safety.

City staff identified the need to continue to develop expertise in the use of ATSPM data and develop standard reports and integrate the use of ATSPM data into work practices.

The project budget did not allow the city to fully implement the project. The dynamic message signs required to provide traveler information during special events and incidents were not included in the project. Similarly, count stations were not installed. Count stations on Airport Way, as well as reasonable alternative routes, would be required to understand traffic diversion fully.

RECOMMENDATIONS FOR OPERATIONS

The city should seek opportunities to support the implementation of ATSPMs. For instance, providing training for operations staff on data utilization would be beneficial. Some standard reports for ATSPM data have been created, but additional work remains to be done. Reports that show the benefits of ATSPMs at a higher level aimed at City executive staff would be helpful in ensuring the agency continues to invest in the technology. Efforts should be made to ensure that ATSPMs are used to proactively address operational issues, rather than relying on the traditional reactive methods.

Overall, the agency should seek opportunities to use ATSPM to support and improve their culture of operational improvement.

5 TriMet Next Generation Traffic Signal Priority

INTRODUCTION

This report provides a summary and evaluation of the Tri-County Metropolitan Transportation (TriMet) Next Generation Transit Signal Priority (Next-Gen TSP) Pilot Project. This project was implemented concurrently with the TriMet Division FX project providing high-capacity transit service between Downtown Portland and Gresham, Oregon.

TSP, and the associated public safety Emergency Vehicle Preemption, used technology to give preferential traffic signal timing to prioritized vehicles, like buses and emergency responders, to reduce red light delay and increase the probability of arriving at a green light. Traditionally, TSP involved placing receivers alongside traffic signals and infrared emitters or GPS radios on prioritized vehicles. While functional, traditional TSP systems are often time-consuming to set up, requiring specialized equipment with ongoing maintenance costs. TriMet's legacy TSP system uses Opticom infrared emitter and detection technology that is set up conditionally to turn on when a bus is more than 90 seconds behind schedule and turn off when the bus is less than 30 seconds behind schedule. The Infrared TSP system's line-of-sight requirement limits its ability to grant priority, as the vehicle must be within range of the transmitted signal. Infrared operations also have maintenance obligations to ensure the detection equipment is clean and the line-of-sight is free of vegetation growth. Another challenge with traditional TSP systems is the lack of automated system performance measures leading to a lack of understanding of performance by system operators. This has often led to a "set it and forget it" approach where the long-term operational status of the TSP function is unknown. Extensive data logging and time-consuming data analytics are often necessary to understand the benefits and impacts of a TSP system operation. However, the increasing ubiquity of reliable large-scale communication access has provided the opportunity to bring about a more intelligent TSP system.

This next generation Transit Signal Priority system, often called Next-Gen TSP or more commonly Cloud-Based TSP, leverages cloud-based technology using cellular communications to collect real-time data on the location and speed of prioritized vehicles. This performance data is then tracked and processed in cloud servers where artificial intelligence (AI) is used for a much more accurate prediction of the estimated time of arrival of the priority vehicle to the traffic signal. The system can prioritize buses through corridors while learning over time about optimal timing for bus stops and signals, improving the reliability and performance of bus transit and, most importantly, improving the passenger experience. Unlike the previous TriMet Opticom system architectures, Cloud-Based TSP is capable of utilizing existing modern traffic signal and communications infrastructure, thereby easing implementation and reducing maintenance costs. Notably, TriMet was the first West Coast agency that went through a competitive procurement process to select a Cloud-Based TSP system

Concurrently with the Next–Gen TSP pilot project, TriMet launched their first bus rapid transit line, the Division FX project, to provide faster and more reliable service along one of TriMet's highest ridership lines. In addition to providing riders with enhanced bus performance, the Division FX project brought many safety and modernization improvements to the community, through access management, enhanced bicycle and pedestrian infrastructure, new pedestrian signals, fiber communications, and traffic signal system upgrades. This initiative targeted a 15-mile stretch of Division Street, aiming to enhance roads, boost bus efficiency, expand bike and pedestrian access, and revitalize the surrounding neighborhoods. The use of the Cloud-Based TSP system was a critical element to the success for the Division FX project. Within the first six months, the Division FX system observed a 70 percent reduction in signal delay as compared to the prior Line 2 with the Legacy TSP system. This translated to an average of six minutes saved over the 15-mile length of the route for each direction, demonstrating its effectiveness in achieving Division FX's goal of increased bus efficiency.[9]

PROJECT DESCRIPTION & BACKGROUND

PROJECT VISION

The TriMet NextGen TSP Pilot Project had the goal of improving transit service speed and reliability, while minimizing the impact on other modes and maintaining or improving the safety provided by the traffic signals to all road users. The larger system vision of this project was for the system to be scalable and adaptable region-wide with no (or minimal) new on-board hardware and no (or minimal) new road-side equipment. This system needed to provide TSP requests and updates early and often with accurate estimated time of arrivals (ETAs). Configurable and varying levels of prioritization were important, while utilizing a centralized platform with robust performance analytics.

STUDY APPROACH

This project took a high-level approach to identify and assess potential TSP system expansion and upgrades in TriMet's service area. The study gathered the input of TriMet staff, as well as input from the local and state agencies that managed the traffic signal system, to identify user needs, evaluate various TSP technologies, and define system requirements for a next-generation TSP system.

FUNCTIONAL ARCHITECTURE

TriMet set out to procure a state-of-the-art Centralized Transit Signal Priority System to be built around an Intelligent Preemption and Priority Control Application. The general system architecture requirements were as follows:

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[9] "TriMet to temporarily turn off FX2's traffic signal priority for time-savings test," by Tyler Graf (2023, Link).

- This central software needed to be configured with necessary vehicle provisions, relative priority settings, conditional preemption/priority parameters, and intersection location information.
- As supported vehicles traveled throughout the supported region, vehicle data would be sent to the central software, which would then process the vehicle data by applying any necessary relative priority and conditional factors to determine the appropriate time to send a preemption or priority request to a particular intersection.
- The preemption or priority request would be formatted into an appropriate message structure and then sent to the appropriate transportation agency's central traffic signal software system, which would then act upon the preemption or priority request based on its pre-configured settings.
- Throughout this process, the Intelligent Preemption and Priority Control Application would store specific log data for retrieval and analysis using management software.
- The system would process preemption[10] and priority control messages from transit buses, and would then authenticate and prioritize vehicle message requests.
- Preemption and priority request behaviors would be configurable based on time of day, direction of travel, service level, route, passenger count, and on-schedule status.
- Preemption and priority requests sent from the cloud solution to traffic signal controllers used the NTCIP 1211 protocol in accordance with the following object definitions:
  - (a) priority request;
  - (b) priority update; and
  - (c) priority clear.

PROCUREMENT

TriMet went through a competitive request for proposal (RFP) process to select a vendor for the cloud-based TSP system. TriMet drafted the RFP documents with support from the consultant team and collaboration from numerous regional traffic agency partners. Several of these traffic agency partners also participated in the proposal evaluation process considering both the price and technical components of each proposal.

VENDOR SELECTION

The TriMet-led selection panel selected LYT out of four submittals as the vendor to provide the cloud-based TSP system for TriMet's Next-Gen TSP Pilot Project. LYT's technology analyzed mobility data to optimize road infrastructure using a 100 percent software-defined, cloud-based solution. This technology was hardware agnostic and worked across jurisdictions. LYT's solution seamlessly integrated with TriMet's CAD/AVL system by INIT. The LYT system worked with the region's networked traffic signals after some architecture modifications, which were required by the traffic agency partners. This modification included the introduction of a firewall that was used as a message filter or gateway between LYT's infrastructure and the traffic signal

[10] Emergency Vehicle Preemption (EVP) functionality was not defined in technical detail in TriMet's TSP procurement. It was a requirement that EVP be able to be supported by the selected system. During implementation, the highest levels of priority setting were reserved for EVP. Technical details of how EVP may be implemented in the future will need to be defined in a separate project.

controllers, to ensure that only preapproved messages could be sent to the controllers. The system's machine learning allows the system to achieve TSP while minimizing signal delay. Since the system did not require hardware at the intersection and the cloud software enabled instant updates, the launch could be done in days, not months.

IMPLEMENTATION AND TESTING

As part of the implementation process, an extensive "multi-gate" testing and verification process was used to validate and test each component of the system and/or combination of components into subsystems. Successful passing of each gate was a requirement for TriMet and the agency traffic partners. Early testing gates were often completed in a controlled lab environment at a partner traffic agency, most notably, the Portland Bureau of Transportation (PBOT). Later phases were then completed with traffic controllers in the field. The following test gates were included in the process:

- **Gate 0A – INIT Data Integrity Test**: Verified completeness and level of conformity of INIT (TriMet's CAD/AVL vendor) to published spec.
- **Gate 1A – Maestro Comm Test**: Verified connectivity between traffic agency-installed Maestro (a LYT device) and LYT cloud.
- **Gate 1B – Controller Comm Test**: Verified ability to obtain phasing information from traffic agency bench controller(s) and LYT cloud.
- **Gate 2 – Firewall Test**: Verified firewall ability to filter traffic between Maestro and traffic agency bench controller(s).
- **Gate 3 – Controller TSP Logic Test**: Verified ability of traffic agency bench controller(s) to correctly process and receive multiple TSP requests/ETA updates from simulated TriMet bus data with differing levels of priority.
- **Gate 4 – Prototype Field Test**: Verified ability of traffic agency bench controller(s) to correctly process and receive multiple TSP requests/ETA updates from deployed TriMet buses with differing levels of priority.
- **Gate 5 – Network Connectivity Test**: Verified ability to obtain phasing information from traffic agency field controller(s) and LYT cloud.
- **Gate 6 – Field Test**: Verified ability of field controller(s) to correctly process and receive multiple TSP requests/ETA updates from simulated TriMet bus data with differing levels of priority
- **Gate 7 – Full System Test**: Verified ability of traffic agency field controller(s) to correctly process and receive multiple TSP requests/ETA updates from deployed TriMet buses with differing levels of priority.

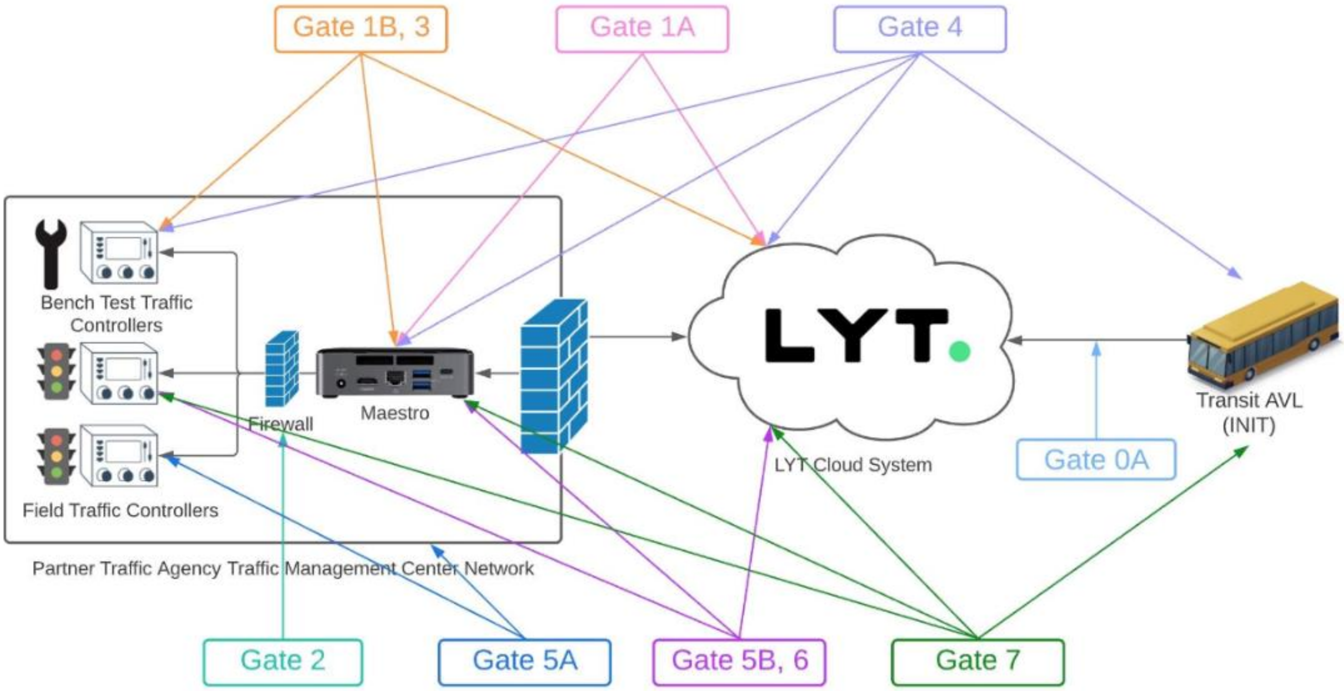


FIGURE 5.1: TRIMET CLOUD-BASED TSP MULTI-GATE TESTING PROCESS[11]

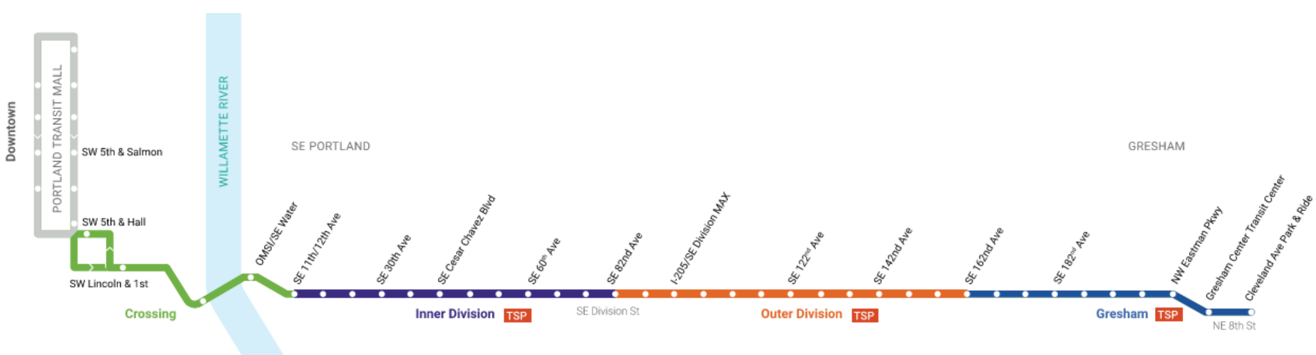


FIGURE 5.2: PILOT IMPLEMENTATION CORRIDOR

The corridor for the Division Street Transit Project (also known as the FX2-Division project) was selected as the pilot implementation corridor for the LYT system to support a concurrent BRT project installation. The corridor is a 15-mile stretch of Portland's Southeast Division Street connecting Gresham to downtown Portland. The project team focused on this corridor because it maintained a high level of transit ridership, was listed in the City's "High Crash Network", and passed through some of the City's most disadvantaged neighborhoods. Along with the FX2 Division project came new fiber communication, traffic controller

[11] TriMet buses communicate with both TriMet's CAD/AVL system and with the Next Gen TSP system utilizing cellular communications and an on-board router. This router had recently been upgraded by TriMet through a separate project.

upgrades to advanced traffic controllers (ATCs), and new firmware with Q-Free's MAXTIME. These project elements were critical components for the cloud-based TSP system. The FX2 project also included several unique transit features, such as bus-only signal phases at queue jump locations that utilize TSP operations to call the phases. Cloud-based TSP was implemented along 12 miles of total BRT corridor. The Downtown and River Crossing segments did not implement TSP due to the existing fixed-time traffic signal controllers and mix-operational environment with light rail transit (LRT) and many other bus lines. For the segments that did implement cloud-based TSP, Inner Division represented a more urban environment with a 2-3 lane cross-section, whereas Outer Division and Gresham segments operated along a more suburban car-centric 5-lane cross-section.

PROJECT TEAM

TriMet. A public transportation agency serving the Portland, Oregon metropolitan area operating bus, light rail, and commuter rail services.

DKS Associates. A consulting firm specializing in transportation planning, traffic engineering, and related services for public and private clients. For this project, DKS Associates led the Cloud-Based TSP system procurement and provided project management services throughout the project. In addition to the Cloud-Based TSP Project, DKS Associates also provided a range of services for the Division FX2 project including transportation planning, traffic engineering, corridor planning, operations modeling, roadway design, and fiber optic network design.

Kittelson & Associates. A consulting firm specializing in transportation planning and traffic engineering. For this project, Kittelson & Associates provided support services during the procurement process and then led an independent on/off study after implementation to assess the system performance.

LYT. A technology company that leverages cloud-based solutions and machine learning to optimize traffic flow for cities and transit agencies, improving efficiency and reducing congestion. LYT was a key partner in the Division FX project, providing the Cloud-Based TSP technology that enabled transit signal priority along the route.

INIT. A global leader in transit technology providing solutions such as computer-aided dispatch (CAD) and automatic vehicle location (AVL) and advised the project team on the installation and configuration of CAD/AVL to integrate with TriMet's dispatch system.

Q-Free. A global supplier of intelligent transportation systems (ITS) specializing in tolling, traffic management, and connected vehicle solutions. Q-Free developed MAXTIME: intersection control software with smart mobility built-in. This controller software allowed PBOT to program advanced algorithms and logic to better serve all modes of transportation.

Siemens. A provider of interconnected and IT-based mobility information systems. Siemens contributed to communication needs between existing traffic signal cabinets and TSP.

Wi-Tronix. A provider of integrated technology to improve operational efficiency, service reliability, and safety. Wi-Tronix provided an onboard event recorder, Violet Edge, to compile TSP needs and successes.

Digi. A networking and Internet of Things (IoT) hardware manufacturer. Digi contributed to the project by providing mobile router technologies which enhanced real-time computer-aided dispatch, automated vehicle location, and electronic fare collection.

PARTNERSHIPS

The Project was a partnership that drew on many years of experience from all parties. These partners were technical experts that developed algorithms and provided perspective on implementation of the new functionalities. The regional traffic signal agencies were key partners in the procurement and implementation of the Cloud-Based TSP project and included the following:

Portland Bureau of Transportation (PBOT). A city agency responsible for planning, building, managing, and maintaining Portland's diverse transportation system by focusing on safety, accessibility, and sustainability for all users. PBOT has been an essential partner in the TSP installation efforts with Peter Koonce laying the foundations of TSP 25 years ago. For this project, PBOT played an important role in the initial planning stages and in deciding which TSP system to implement. PBOT helped write the RFP and was part of the selection committee to determine the appropriate vendor. In particular, Mark Haines, ITS Engineer, created custom logic that improved signal efficiency and performance for both pedestrians and transit.

Oregon Department of Transportation (ODOT). A state agency responsible for planning, building, and maintaining Oregon's transportation system, including highways, roads, bridges, and public transit. ODOT prioritizes safety, efficiency, and sustainability to ensure a reliable and accessible transportation network. Galen McGill, Jason Shaddix, and Doug Spencer were instrumental in coordinating all of the projects and collaborating with the Federal Highway Administration (FHWA).

City of Gresham. Jim Gelhar, Traffic Signals Engineer, led the agency in performing the testing of the Palo Alto cybersecurity systems. These findings were paramount in understanding the uses and needs of substantial cybersecurity systems.

Division FX Project Team. Michael Kiser, TriMet Project Director, led the project team in implementing the TriMet FX Division Transit Project. The project improved travel between Downtown Portland, Southeast Portland, East Portland, and Gresham by implementing a Cloud-Based TSP system alongside the bus rapid transit corridor.

Additionally, to complete a full review of the FX2-Division route corridor and its varying context, the team collaborated with local jurisdictions, including Washington County and the City of Hillsboro on this project.

EVALUATION GOALS, OBJECTIVES, AND QUESTIONS

ODOT provided the FHWA with evaluation goals, objectives, and questions as part of the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant process, shown in Table 5.1. These are addressed in the Analysis and Findings section of this report. The evaluation questions presented below have been revised from the initial grant application, where the original questions for improved reliability and mobility focused on transit travel speeds; however, speed data was not readily available, and the questions were revised to reflect changes in average transit travel time and travel time reliability utilizing travel time data from TriMet's Automated Vehicle Location (AVL) system.

TABLE 5.1: EVALUATION GOALS, QUESTIONS, AND PERFORMANCE MEASURES

GOAL AREA	EVALUATION QUESTION	PERFORMANCE MEASURES
IMPROVE RELIABILITY	Is the variability of bus average travel time decreased on the corridors where the TSP is implemented during the weekday evening peak hour?	Bus On-Time Arrivals
IMPROVE MOBILITY	Are the bus average travel times decreased on the corridors where the TSP is implemented during the weekday evening peak hour?	Bus Average Travel Time

DATA COLLECTION

Data analysis over three scenarios (3) was performed to provide information on changes in the experience of bus riders, motorists, pedestrians, and bicyclists. The Division FX BRT project included multiple physical and operational changes such as bus stop relocation or removal, bus rerouting, new signalized pedestrian crossings, access management, bus-only lanes and signals, and implementation of TSP. Due to the many changes, a typical "before and after" study was not useful for identifying TSP benefits, and it was instead necessary to conduct data gathering with the on/off scenarios.

This project also had another unique variable, which is described in the analysis tables and content below as "PBOT logic on/off." The long duration estimated time of arrival (ETA) of 120 seconds provided by the LYT system, as compared to traditional legacy TSP systems (infrared or GPS) with 15-30 seconds ETA, allowed for several opportunities to improve how various modes were prioritized in the controller and served prior to the bus arrival. To take advantage of this additional time, PBOT staff needed to develop custom logic programmed at the traffic signal controller as the controller firmware was unable to accommodate the desired operation using the built-in feature set. The PBOT logic referred to this custom logic that performed several functions, including supporting the competing multimodal requests for signal timing (bike, ped, transit, and auto), but also supporting PBOT's modal prioritization goals. For example, with the long ETA, the logic could identify an approaching bus and serve a pedestrian crossing phase to improve access to transit without impact the arrival of the bus. It was this type of custom operation that as afforded by the cloud TSP system, which would not be possible with a legacy TSP system. The logic also addressed a State of Oregon Administrative Rule that did not allow for phase skipping with bus operations, in a manner that met the rule requirement while achieving many of the same benefits of phase skipping. For example, at a bus queue jump signal phase, the controller as programmed to lead and lag the adjacent through phase, but only one phase was served depending on when in the cycle the bus arrived. PBOT wanted to explore what additional operational benefits were or were not achieved with this custom logic, in order to consider the value of the internal effort as the agency moved forward with subsequent TSP corridors.

The analysis utilized TriMet's automated vehicle location (AVL) data. This data provided bus operational details and location updates with an average reporting interval of around four seconds. The primary focus of the analysis relied on the GPS location, timestamp, and the relationship to bus stops as reported in the AVL data to generate the following performance measures as detailed in Table 5.2:

TABLE 5.2: PERFORMANCE MEASURE DATA TYPES & SOURCES

PERFORMANCE MEASURE	DATA SOURCE	APPLICABLE EVALUATION QUESTIONS
ON-TIME ARRIVAL	TriMet On-time Performance (OPT) Data Report (TriMet internal report based on TriMet AVL and schedule data)	Q1
AVERAGE TRAVEL TIME	TriMet Automated vehicle location (AVL) processed via LYT with the use of GPS location, time stamp, and stop relationship	Q2

Additional performance measures were evaluated in the TriMet On/Off Study[12] to assess the benefits and impacts to motor vehicles, pedestrian and bicycles by looking at segment travel times with INRIX data and automated signal performance measures utilizing signal controller log data. The On/Off Study found no significant impact or benefits to other modes of travel and were therefore not detailed further in this summary of the pilot project.

The AVL data and subsequent performance measures were recorded over a three-week period capturing the following scenarios of TSP on and off and PBOT logic on and off (Table 5.3). Data was also reported by segments as shown in Figure 5.3. Note the Downtown and (River) Crossing segments did not utilize TSP as previously described, and the PBOT logic was only implemented in the Inner and Outer Division segment, except for two ODOT jurisdiction intersections along Outer Division where the agency elected to not implement the logic. The City of Gresham also elected to not implement the PBOT logic to simplify the project configuration.

TABLE 5.3: SCENARIO DATES

NUMBER	SCENARIO NAME	DATES
1	TSP off/PBOT logic off	May 16 – May 20, 2023
2	TSP on/PBOT logic off	May 21 – May 24, 2023
3	TSP on/PBOT logic on	May 25 – June 2, 2023

Note: TSP was maintained "on" at three intersections (117th Ave, 148th Ave, and 162nd Ave) where the bus was required to utilize a queue jump signal following near-side bus stops that was only activated with a call from the TSP system. Additionally, at some intersections (117th Ave, 119th Ave, 122nd Ave, 142nd Ave, 145th Ave, 148th Ave, and 162nd Ave) with bus signals, aspects of the PBOT logic were maintained "on" as it was required for reliable function of the bus signal to avoid the controller from holding the priority phase too long. This aspect of the logic was no longer necessary as the Q-Free MAXTIME controller firmware provided an update (version 2.14) that resolved this issue without logic. Scenario 3 included additional data collection days as there was holiday mid-period that needed to be removed.

[12] "Background, Methodology, and Results of TSP On/Off Scenarios on FX2-Division Technical Memorandum," by Wright et al. (2023)

ANALYSIS FINDINGS

This section details the analysis findings of the performance measures to answer the evaluation questions.

IMPROVE RELIABILITY (QUESTION #1)

Is the variability of the bus average travel time decreased on the corridors where the TSP is implemented during the weekday evening peak hour?

Over the entire route (including non-TSP segments), buses were on time more often with TSP on than without (76 percent vs. 66 percent, respectively). This represents a ten percent increase in on-time arrival performance with the presence of cloud-based TSP. In segments with TSP, the improvement was even greater (78 percent vs. 64 percent). But TSP was associated with higher percentages of early arrivals toward the end of the routes.

When looking at individual segments and analysis scenarios as shown in Figure 5.3, the overall percentage of on-time arrivals increased from the first scenario (without TSP or PBOT logic) with TSP and/or PBOT signal timing logic, 65 percent versus 76 percent. The overall percentage of on-time arrivals with TSP on and PBOT logic off was the same as with PBOT logic on. All segments had an increase in on-time arrivals with TSP and/or PBOT signal timing logic except the Downtown Segment to Portland (which did not have TSP deployed), which had a large increase in trips arriving early. On the Downtown segment to Portland, with TSP and PBOT signal timing logic, the on-time arrivals decreased from 56 percent of buses to 46 percent, compared to when TSP and PBOT signal timing logic were off.

The percentage of early arrivals increased with TSP and PBOT logic. The largest increases occurred in the Downtown segment to Portland (from 13 percent of buses to 47 percent) and the Gresham segment to Gresham (from three percent of buses to 27 percent). The percentage of late arrivals decreased in all segments with TSP and PBOT logic. The largest decrease on the percentage of late arrivals was from 59 percent of buses to 22 percent in the Gresham segment to Gresham.

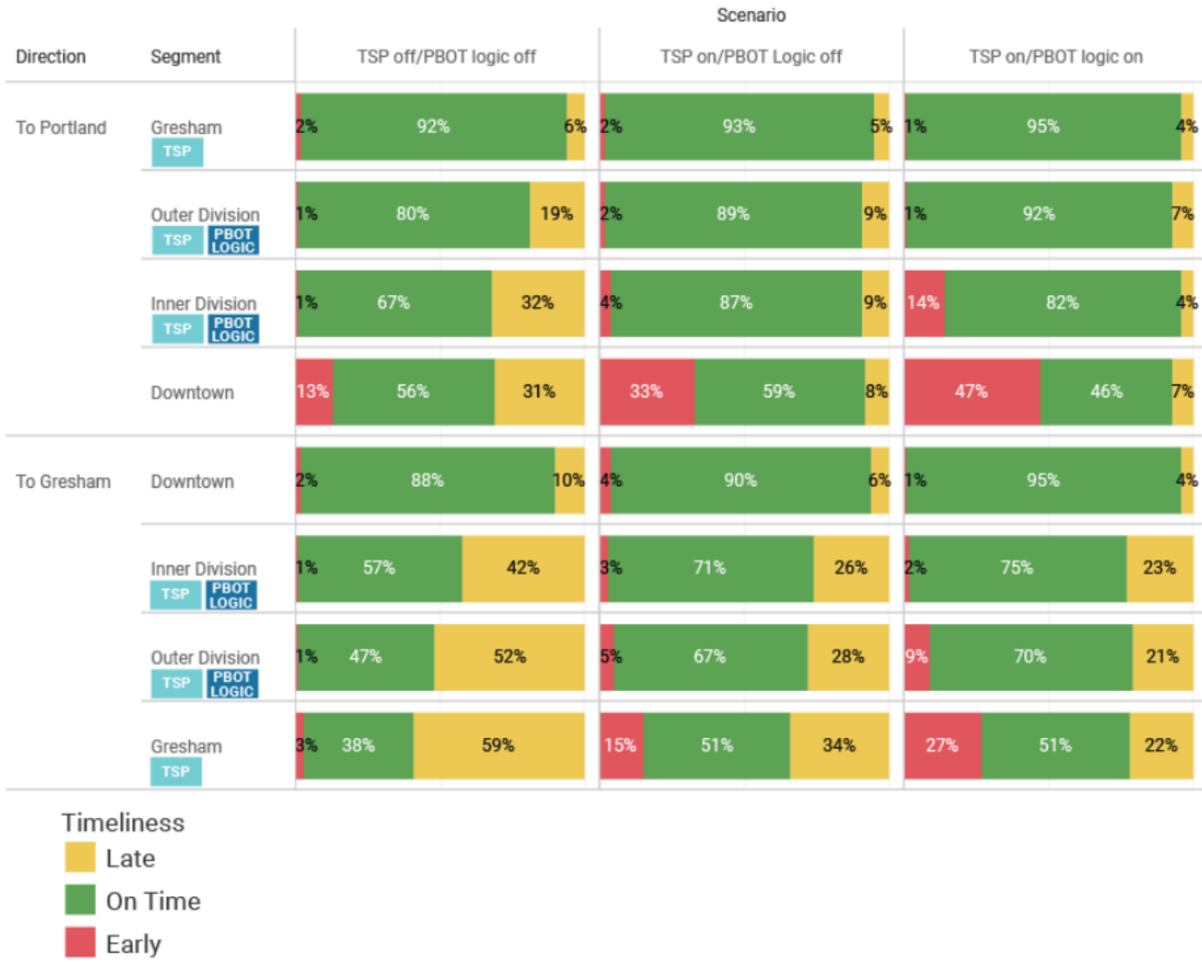


FIGURE 5.3: BUS ON-TIME PERFORMANCE

IMPROVE OPERATIONS (QUESTION #2)

Are the bus average travel times decreased on the corridors where the TSP is implemented during the weekday evening peak hour?

Over the course of a peak period round-trip on FX2, bus riders saved 8.2 minutes with TSP, a reduction of six percent. On the three segments with TSP, travel times were reduced by 8.8 minutes (nine percent). Travel times on the segments without TSP observed little change, as expected.

The bus travel time for each segment and scenario is shown in Figure 5.4. In general, bus travel time was similar on the Downtown and Crossing segments in all scenarios. TSP was not implemented on these segments, so this observation was expected. In general, bus travel time was faster on the Inner Division, Outer Division, and Gresham segments after the implementation of TSP and the PBOT logic.

After implementation of TSP (but without the PBOT signal logic) travel time was reduced by about 5 percent on segments with TSP implemented (Inner Division, Outer Division, and Gresham); however, impacts varied by time period, direction, and segment. During the a.m. peak period, travel time on the Outer Division segment was reduced by 7 percent for buses travelling towards Portland and 13 percent for buses travelling towards Gresham.

With the addition of the PBOT logic, travel time was further reduced by an additional five percent on segments with PBOT logic implemented (Inner Division, Outer Division) for a total of a ten percent reduction. However, impacts varied by time period, direction, and segment. The PBOT logic was not implemented on signals in the Gresham segment. During the a.m. peak period, travel time on the Inner Division segment was reduced by 13 percent for buses travelling towards Portland and ten percent for buses travelling towards Gresham compared to the travel time when TSP was turned off.

Buses on the FX2-Division route did not extend stop dwell time to realign the bus with the schedule. Therefore, it was not expected for bus stop dwell time to change with the implementation of TSP or PBOT logic. Bus stop dwell time was plotted in Figure 5.4 to highlight the portion of segment travel time the bus spends at bus stops and confirm that bus dwell time remains consistent across the scenarios. For example, for bus trips to Gresham on Outer Division during the a.m. peak period, when TSP was off, travel time for the segment was about 16 minutes. Buses typically spent about 2.5 minutes of the 16 minutes at bus stops. When TSP was turned on and PBOT logic was turned on the bus typically spent 2.5 minutes of the 13-minute travel time at bus stops. Considering the time spent at bus stops accounts for one variable that may impact segment travel time and helps isolate the benefits of implementing TSP and PBOT logic.

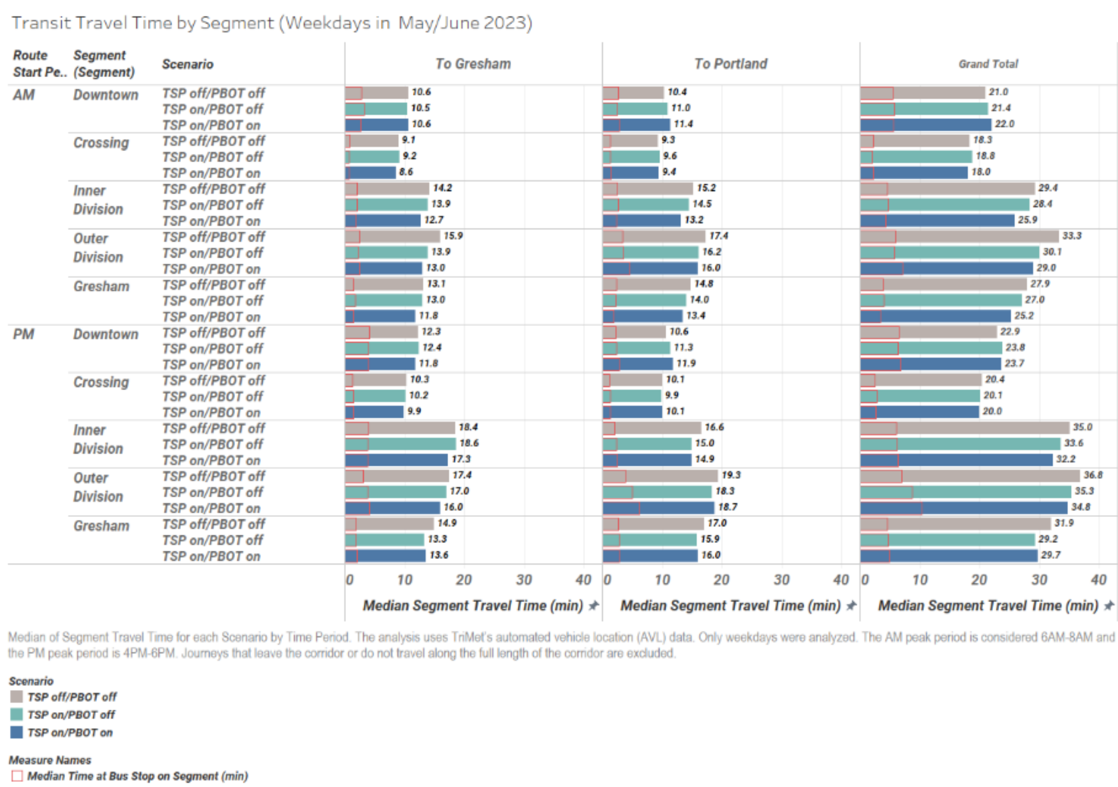


FIGURE 5.4: BUS SEGMENT TRAVEL TIME BY SCENARIO

BENEFIT/COST

The TSP system was implemented concurrently with a BRT project on the Division corridor. The benefits of reduction in travel time and user delay from the TSP were impossible to separate from the benefits of implementing BRT. It was not possible to do a traditional benefit/cost analysis of the TSP project since the monetary value of the benefits of the TSP system could not be calculated independently of the BRT project. This section describes the costs of the TSP and the quantitative and qualitative benefits of the TSP and BRT systems.

PROCUREMENT, DEPLOYMENT AND OPERATIONAL COSTS

The TriMet Cloud-Based TSP Pilot Project was funded through ODOT via the FHWA ATCMTD grant and local match provided by TriMet. The total cost for this project was $6,380,000 ($4 million in TriMet funding in $2.38 million in federal grant funds). These funds were allocated to several key project elements:

- 54% – TSP Vendor: System setup and provision of services for a period of 5-years;
- 28% – Consultant Team Support: Support for the procurement of the TSP vendor, pilot implementation, on-going monitoring, and program management;
- 14% – Siemens LRT System Testing: Systems development and testing of cloud-based TSP for LRT
- 4% – INIT CAD/AVL System Update: Update of CAD/AVL system to provide probe data to TSP cloud.

For the TSP Pilot corridor, much of the signal and communication infrastructure, including fiber installation and controller upgrades, were paid for by the Division Transit BRT Project, a Federal Transit Authority Small Starts Project. This allowed TriMet to maximize federal funding by utilizing various grants to help complete the BRT project. These improvements included an oversized 432 ribbon fiber cable to accommodate a range of stakeholder needs, including signal connectivity for TSP operations. All traffic signal controllers along the corridor were also upgraded to Advanced Traffic Controllers (ATCs) with Q-Free MAXTIME firmware.

BENEFITS & SAVINGS

It was commonly held that TSP was an effective tool in enhancing transportation systems. First, TSP often reduced travel time for transit users. The U.S. Department of Transportation (USDOT) attributed an 8 to 12 percent time savings on routes using TSP.[13] Further, TSP had been found to improve schedule reliability.[14] Lastly, USDOT noted that TSP's increased efficiency led to significant cost savings.[15] A study by USDOT found

[13] "Multimodal Fundamental Course," by Washington State Department of Transportation

[14] "Transit signal priority reduced average bus travel times by 7.5 and 15 percent along major bus corridors in Los Angeles and Chicago, respectively," by U.S. Department of Transportation (2013)

[15] "Transportation Systems Management and Operations Benefit-Cost Analysis Compendium," by U.S. Department of Transportation (2020)

that TSP reduced fuel and maintenance costs due to decreased vehicle use.[16] In its debut year, FX2-Division served 40 percent more riders than the preceding year.[17]

BUS TRAVEL TIME

TSP's many benefits led to its integration into the FX2-Division project. As described in the Analysis Findings section, the implementation of cloud-based TSP as part of the TriMet FX2-Division project resulted in a six percent overall average travel time savings and nine percent on just the segments with TSP, consistent with the national findings of TSP savings. In addition, on-time arrival performance was increased by ten percent.[18]

FUEL

The travel time savings additionally resulted in operational cost savings for TriMet with a reduction in fuel consumption. During the TSP on/off study, TriMet saved approximately 680 gallons of fuel per week, representing a 13 percent reduction in fuel consumption. This represents annual fuel savings of approximately $90,000 for the FX-2 line with TSP. This dollar value was based on the TriMet May 2023 price for diesel of $2.54 per gallon.

PASSENGER TRAVEL TIME AND VALUE OF TIME

The passenger experience was evaluated looking at the total Annual Peak Period Passenger Travel Time Savings and the Annual Peak Period Passenger Value of Travel Time Savings. The data and calculations for these performance measures are detailed in Table 5.4. In 2023 approximately 179,000 riders rode the Division FX with an average trip length of 3.1 miles. As a result of the cloud-based TSP, these passengers collectively saved approximately 2,500 hours of travel time in 2023. This represents a total savings of nearly $50,000 based on the United States Department of Transportation (USDOT) Value of Travel Times Savings (VVTS) of $19.40 per hour for all purposes local travel.

TABLE 5.4: PASSENGER TRAVEL TIME AND VALUE OF TIME SAVINGS DATA

BUS ROUTE AVERAGE PEAK PERIOD TRAVEL TIME SAVINGS (MM:SS)

DIRECTION	AM	PM
TO GRESHAM	6:15	4:45
TO PORTLAND	3:45	2:00

Source: Background, Methodology, and Results of TSP On/Off Scenarios on FX2-Division, Kittelson & Associates (August 22, 2024)

[16] "Comprehensive Evaluation of Transit Signal Priority System Impacts Using Field Observed Traffic Data," by Wang et al. (2008)

[17] "Evaluating FX2, First year of operations", by Keeling et al. (2023)

[18] "Background, Methodology, and Results of TSP On/Off Scenarios on FX2-Division Technical Memorandum," by Wright et al. (2023)

AVERAGE PASSENGER TRIP LENGTH (MILES)

LENGTH	MILES
TOTAL ROUTE LENGTH	15
AVERAGE PASSENGER TRIP LENGTH	3.1

Source: TriMet Route Ridership Report, 2023

2023 PEAK PERIOD RIDERSHIP (PERSONS PER PEAK PERIOD)

DIRECTION	AM	PM	TOTAL
TO GRESHAM	23,640	69,435	93,075
TO PORTLAND	55,875	29,760	85,635
TOTAL	79,515	99,195	178,710

Source: TriMet Bus Loads By Trip Report, 2023

2023 PEAK PERIOD PASSENGER TRAVEL TIME SAVINGS (HOURS)

DIRECTION	AM	PM	TOTAL
TO GRESHAM	505	1,125	1,630
TO PORTLAND	710	205	915
TOTAL	1,215	1,330	2,545

*Source: Bus Route Average Peak Period Travel Time Savings * 2023 Peak Period Ridership*

VALUE OF TRAVEL TIME SAVINGS (2023)

	$ / HOUR
ALL PURPOSES LOCAL TRAVEL VTTS PER HOUR	$19.40

Source: United States Department of Transportation (USDOT) 2016 Revised Value of Travel Time Guidance. 2023 inflation adjustment based on US Census 2023 Median household Income of $80,610

2023 PEAK PERIOD PASSENGER VALUE OF TRAVEL TIME SAVINGS ($)

DIRECTION	AM	PM	TOTAL
TO GRESHAM	$9,785	$21,800	$31,585
TO PORTLAND	$13,760	$3,970	$17,730
TOTAL	$23,545	$25,770	$49,315

*Source: 2023 Peak Period Passenger Travel Time Savings * Value of Travel Time Savings*

EQUIPMENT MAINTENANCE

There was no maintenance cost for the Clouse TSP system as there was no roadside equipment and no maintenance beyond maintenance already covered for TriMet's onboard systems present before the Cloud TSP project. There were determined to be no substantial savings on maintenance with the Cloud TSP system over the legacy TSP system for TriMet. The legacy TSP system utilized infrared emitters on the buses and receivers on the signals. It was determined that the emitters on the buses are effectively cleaned with regular bus washes and therefore there was no extra effort saved by not needing the emitters. The signal agencies were responsible for maintaining the receivers. The infrared Opticom system is still in use for emergency vehicle preemption and the receivers are cleaned during regular signal maintenance, as such there was no savings by no longer using the receivers as part of the TSP system.

NETWORK

As part of the network setup, TriMet made an investment to protect against future data costs for the data bandwidth needs of the cloud TSP system. TriMet refined the communications path by changing to a Google Protocol Buffer to simplify the information exchange protocol. While TriMet did have an unlimited data plan with Verizon, the availability of this plan in the future is unknown, and this change in the communications allowed for reduced bandwidth needs, while also being more secure and utilizing a non-proprietary and an actively supported open standard. The cost for this communications setup was approximately $50 thousand to the on-board data system provider, INIT, and $25 thousand to LYT, for the configuration of the cloud side of the communications.

PBOT and ODOT incurred significant operational costs to set up network administration for the system. The agencies could not break out staff costs associated with this effort. Costs included the development of intergovernmental agreements, networking configuration, and testing.

MONITORING AND ANALYTICS

Further benefits were realized with the dashboard portal. The portal allowed for more cost-effective operations, where TSP could be constantly monitored in terms of both overall system performance and specific issue detections. Since the portal was web-based, it was openly available to all traffic partners and allowed them to immediately identify potential issues at specific locations. This provided a great benefit over the legacy TSP system where remote access and automotive performance measures were not available, often resulting in an unknown status of system condition and performance.

NON-TRANSIT PERFORMANCE

Non-Transit performance measures were assessed as part of TriMet's On/Off Study, including motor vehicle travel time along the transit corridor and cross street travel time.

The On/Off study resulted in the following key findings:

- There was no significant difference in motor vehicle travel time along the corridor with differences in segment travel time no greater than 36 seconds (less than 5 percent) in difference.

Cross corridor vehicles travel times remained relatively constant for all scenarios. The greatest increase in cross vehicle travel time was six seconds (11 percent). Some intersections experienced a slight decrease in cross vehicle travel time with the TSP on.

AWARDS

Several prestigious organizations have recognized the innovative work of TriMet and its partners in developing and implementing Cloud-Based TSP technology. Both Digi International and the Institute of Transportation Engineers (ITE) awarded TriMet for their achievements in improving transit efficiency and sustainability through cutting-edge transportation solutions.

Digi International, a global Internet of Things (IoT) technology company, recognized organizations committed to sustainability through their Green Tech Customer Innovation Awards. In 2024, TriMet won Digi International's award for the Intelligent Transportation category for their bus fleet management, with their Cloud-Based TSP work playing a key role.[19]

ITE hosts the Excellence in Transportation Awards to recognize outstanding achievements in transportation and the vital role transportation professionals play in shaping communities. In recognition of their work on Cloud-Based TSP for the Division Transit project, the team was the recipient of a 2023 Transportation Achievement Award for its ability to use advanced transportation technologies to better address human needs.[20] An article detailing the FX2-Division project and its successful implementation was published in the August 2023 edition of the ITE Journal.[21]

LESSONS LEARNED & CONSIDERATIONS

This section lists several lessons learned and additional considerations for a cloud-based TSP implementation, sorted by topic in Table 5.5.

TABLE 5.5: LESSONS LEARNED & CONSIDERATIONS

IMPLEMENTATION STRATEGIES	
PILOT CORRIDOR IMPLEMENTATION	• The Division FX project corridor was selected as the Cloud-Based TSP pilot corridor as it was TriMet's first bus rapid transit (BRT) line and the Cloud-Based TSP solution offered increased performance and reliability to meet the goals of the Division FX project. While this TSP pilot project was successful in allowing the Division FX Project to achieve performance goals, implementing a pilot Cloud-Based TSP system concurrently on a new construction transit system that involved a new bus fleet, new communications infrastructure, new traffic signal

[19] "Digi International Reveals 2024 Green Tech Customer Innovation Award Winners," by Digi International (2024).

[20] "2023 Excellence in Transportation Awards," by the Institute of Transportation Engineers (ITE) (2023).

[21] ITE Journal, August 2023, page 27

IMPLEMENTATION STRATEGIES	
	installations/modifications, and new and complex multi-modal traffic signal phasing made it a challenge to independently assess the performance of the Cloud-Based TSP system, while also concurrently implementing and testing substantial new infrastructure. It also increased the challenges in meeting project timelines. TriMet ultimately was able to provide a full assessment by doing an independent on/off study approximately 8 months after the start of service by measuring transit and traffic signal performance with the system off for 2 weeks as compared to the operational TSP system. • It is recommended for other agencies to consider implementing a pilot Cloud-Based TSP corridor along an existing transit line with known and tested infrastructure, thus reducing the variables associated with the TSP project itself. This would help with accelerated project implementation timelines and cleaner ability to assess the benefits of the TSP system itself in isolation.
SPOT/SELECT LOCATIONS	• TSP can be successfully implemented at single locations or along short segments. However, the context of the surrounding corridor needs to be considered to avoid downstream delay impacts. Implementing TSP at only a few locations along a well-coordinated signalized corridor may result in downstream delay increases by disrupting the vehicle platoon progression where the priority vehicle may arrive substantially out of sync with the green band, offsetting upstream travel time savings.
QUEUE JUMP AND BUS-ONLY SIGNAL PHASING	• Substantial lengths of priority lane treatments are recommended leading up to a queue jump phase to provide enough distance to bypass adjacent lane traffic queues that results in enough travel time and reliability savings to offset any delay impacts associated with waiting for the bus queue jump signal phase. • Cloud-Based TSP calls for a queue jump phase may be placed up to 2 minutes before the bus arrival. During less congested periods it may be more efficient for an operator to merge into an adjacent through lane upstream of a traffic signal with a queue jump, however there is risk that the queue jump phase call may result in the through lane green phase being terminated and potentially stopping a bus that has merged. To avoid this situation and to eliminate the need for operators to make a judgment-based decision, there is a standard operating procedure (SOP) that all operators must use the queue jump phase where present, regardless of adjacent traffic conditions, unless otherwise directed by dispatch. • Bus-only signal phase operations along the Cloud-Based TSP corridor implementations are called only by TSP from LYT. If communications are lost to the controller, then TSP is unable to place the call, and the bus will be unable to be served by the bus-only phase. When communications are lost, the LYT system provides an alert that is routed to dispatch where they instruct the operator to merge upstream of a queue jump operation. TriMet will work with signal agency partners on future installations of Cloud-Based TSP at bus-only signal phases to identify redundant communication solutions to avoid the need for dispatch intervention.

ITS ARCHITECTURE/COMMUNICATIONS	
COMMUNICATIONS REDUNDANCY	• Providing reliable and resilient communications to the traffic signals is critical to the success of continued, efficient, and reliable Cloud-Based TSP operations. The Division FX project utilized a fiber collapsed ring architecture where redundancy is provided by using different individual fibers within the same cable. This approach was cost effective, but resulted in vulnerabilities to full communication loss through cable breaks. Future Cloud-Based TSP implementations recommend a full redundant ring architecture that provides an alternate path back to the central hub that is physically separated from the other ring segments. • Providing redundant ring structures for future implementations can substantially impact the cost of future TSP implementations depending on the length of communications needing to be constructed and whether the lines are aerial or underground in conduit.
TRAFFIC SIGNAL LATENCY	• Traffic signal latency measures the time it takes for data to travel to and from traffic signals. High latency can result in inefficient operations. While latency can be manually tested in the field, this can be time consuming. TriMet and the traffic signal agency partners are able to leverage LYT's Live Operations Portal to monitor measured signal latency in real-time. Locations with high latency are flagged and alert the system operators of potential issues. [NOTE: communications latency between bus and traffic signal controllers was not identified as a problem with the solution as deployed by TriMet along Division.] • High traffic signal latency can be an issue for some traffic signals connected using cellular or copper communications. While copper communications are often sufficient for Cloud-Based TSP operations, they are more prone to latency issues than fiber communications. All future communications installations to support Cloud-Based TSP are recommended to be fiber.
CYBERSECURITY	• Firewalls were required by partner traffic signal agencies to maintain satisfactory network security.

TRAINING	
VIDEO	• It is recommended that bus agencies record how the bus-only lane is intended to work on video prior to TSP implementation, for training purposes. • Take videos at the beginning of the project of a bus running the entire route in each direction.
OPERATOR	• Provide ample training opportunities for operators and budget sufficient time to complete the training programs.

DOCUMENTATION	
OVERALL DOCUMENTATION	• Create a comprehensive Operations and Maintenance manual so maintenance, operators, dispatch, training, and other staff understand the elements and operations of the cloud-based TSP system. • Consider developing formal documentation about how to use the LYT portal and any new features as they arise. • Work with signal agency staff early to identify any controller firmware custom logic needs to accommodate any unique phasing needs. • Conduct a "No TSP" study period prior to turning on the TSP system in order to have an accurate before/after study or have a planned and scheduled off period after opening should TSP also be part of a new transit line and TSP is critical to the success of opening a new project. • Involve signal agency partners in the beginning of the project with a stakeholder kick-off meeting.
PRE-PROJECT CONFIGURATIONS	• Formally approve all testing documentation in the earliest phase of the project. • Have clear documentation about roles and responsibilities to help plan staff and sequence work appropriately. (i.e. When will roles change? Who is implementing things and maintaining items? When does handoff occur?)
TIMING	• Streamline process for collecting intersection data including configuration and timing databases through a data collection plan. • Work directly with the signal controller firmware developer to test new firmware versions. • Signal agency to document and share with transit agency and other peer signal agencies any custom signal logic necessary to implement TSP or advanced features that complement TSP.
SAFETY CERTIFICATION	• Understand safety certification in the early stages of the project. • Do the LYT Maestro configuration early. Educate personnel on how Maestro works and how to configure with firewalls.

SCHEDULE	
SCHEDULE	• Define opportunities for testing concurrent with construction. • Provide a clear scope and schedule prior to construction so that it may be integrated into the overall strategy. • Have LYT monitor the before-TSP data period. Collect data for a minimum of two weeks with no TSP, then turn TSP on and continue to collect data. • Plan for delays in construction schedule. Testing of the TSP system was planned to be done months ahead of the BRT project opening; however, due to delays in the fiber construction and subsequent traffic signal controller installation by signal agency staff, this left only a matter of weeks to complete the testing of the TSP system. Despite the delay, the testing was successfully completed by the opening of the BRT project. • When signal agency staff are implementing signal timing, staff time needs to be scheduled to account for developing and testing TSP-specific signal timing. • Coordinate early with agency IT departments and network security efforts.

TESTING	
TESTING	• Testing is a crucial step of the process that requires close coordination between the transit agency, signal agencies, TSP vendor, signal vendor, and the consultant team. • Produce a TSP integration test plan in advance. Determine early on who is going to be involved and what needs to be done. • Having signal agency staff and the LYT team all together on a test vehicle was instrumental in the beginning. • Anticipate schedule impacts of initial learning curve of testing procedure. • Consider developing a Memorandum of Understanding (MOU) between TSP and signal vendor to allow for efficient communication and collaboration. • Provide ongoing monitoring of signal and TSP operations after implementation to identify and document any deficiencies that may arise from firmware bugs or miscoding in the controller firmware. • On the controller, ensure there are sufficient ports available for LYT. • Ahead of testing, have bus operator training staff scheduled for testing. • An ideal testing environment would include a TV/display showing what the TSP is doing in real-time allowing the testing team and other stakeholders to observe the operations. This testing display can be configured in both an office environment and on a test bus. • Consider robust public education, especially for the bus only lanes. The public perception is often, "is that bus going through a red light?"

NEXT STEPS

SYSTEM WIDE IMPLEMENTATION

The project's success strongly supports the wider adoption of an equitable Cloud-Based TSP implementation as grant and agency funds become available, especially on high-frequency corridors like Line 72 on Portland's 82nd Avenue and Line 33 on McLoughlin Boulevard, which are already slated for implementation. Discussion was also underway about applying Cloud-Based TSP along Portland's MAX Light Rail, with particular interest in Hillsboro's 185th corridor. TriMet was actively identifying future Cloud-Based TSP locations in partnership with Better Bus and collaborating with Nelson Nygaard on an FX (BRT) Master Plan likely to incorporate this technology.

As the Cloud-Based TSP network expands, its efficiency will increase due to greater coordination across the system. Along with the continued implementation of Cloud-Based TSP, considering the implementation of the Sydney Coordinated Adaptive Traffic System (SCATS) could be beneficial. While Cloud-Based TSP focuses on improving the efficiency of specific vehicles, SCATS focuses on general traffic optimization. To provide an enhanced transportation system, Cloud-Based TSP and SCATS could work together to improve overall transportation efficiency.

Given the anticipated expansion of Cloud-Based TSP, ongoing evaluation of its effectiveness is crucial, particularly its impact on other modes of transit.

EXPANDING TO NEW MODES

As part of the implementation testing of the LYT system, a proof of concept was evaluated for implementing the technology on the light rail transit (LRT) system. LYT and Wi-Tronix, TriMet's vendor for onboard train information, explored the feasibility of using their light rail AVL feed from four trains equipped with Wi-Tronix Violet devices. LYT and Wi-Tronix validated the data available through the existing Wi-Tronix API and confirmed that LYT could retrieve basic telemetry data for the four test trains with the Violets: vehicle ID, timestamp latitude/longitude, speed, and bearing. The following improvements to the API were identified that would make it suitable for LYT TSP:

- Route ID: The existing Wi-Tronix API does not provide route ID. Providing a train route ID would enable LYT to determine when a train is eligible for TSP and use the collected data in LYT's machine learning model training.
- Push-based architecture: Wi-Tronix's API made data available through a mechanism that requires LYT to send a pull request every second for new data. Changing this architecture to automatically push new data to LYT as it becomes available would make transmission more efficient with lower latency.
- Schedule adherence: the existing Wi-Tronix API does not provide schedule adherence. Providing schedule adherence would enhance LYT's machine learning models and enable LYT to determine when to apply conditional business rules centered on scheduled adherence if required by TriMet.

With this proven proof of concept, TriMet will be exploring applications for Cloud-Based TSP with LRT, such as pre-preemption calls to run traffic clear-out traffic phases or serve pedestrians ahead of a preemption call. Beyond bus and LRT applications, there is an opportunity to explore the use of Cloud-Based TSP to paratransit and streetcar applications. Paratransit is a critical service offered by TriMet to a transit-dependent population who would benefit from increased service speed and reliability offered by the Cloud-Based TSP system. Further considerations for paratransit applications will need to consider the Oregon Administrative Rules (OAR) and the ability of paratransit to legally use TSP, as well as fleet equipment needs. The City of Portland operates the Portland Streetcar, a predominately mixed-traffic streetcar system. This system is prone to traffic signal delay given the mixed-flow operations and would greatly benefit from Cloud-Based TSP. Furthermore, as more discrete systems are integrated in the cloud-based system, there will be more opportunities to improve multi-modal traffic optimizations as all road usage needs will be easily visible and available for analysis.

SCATS INTEGRATION

There are several adaptive traffic signal systems in the Portland Metro Region that use the Sydney Coordinated Adaptive Traffic System (SCATS). This system coordinates traffic signals along a route optimizing cycle lengths and green times using real-time detector inputs. While this system does offer TSP inputs, the SCATS system is not NTCIP 1211 compliant and is therefore not compatible with the LYT TSP technology. TriMet currently operates several lines through these SCATS systems, but does not operate TSP. It is possible, however, for SCATS to utilize the legacy infrared system to operate TSP with SCATS. Through TriMet's Better Bus Program, TriMet is working with LYT and the SCATS vendor, TransCore, to explore alternatives to provide the connectivity needs to operate Cloud-Based TSP with SCATS.

EXPANDED AUTOMATED PERFORMANCE MEASURES

TriMet is looking to expand the features available on the LYT dashboard to be able to monitor additional performance measures that will be used to assess ongoing performance over time as well as support reporting to stakeholders and the public on the system improvements. These performance measures will also be used to seek grant opportunities for further system-wide implementation. Currently, TriMet is seeking to monitor fleet fuel consumption and calculated emissions to provide new insights into maintenance and operations costs, and environmental impact. As the fleet upgrades over time, future measures may include battery health and consumption.

6 Washington County Cornelius Pass Road Arterial Corridor

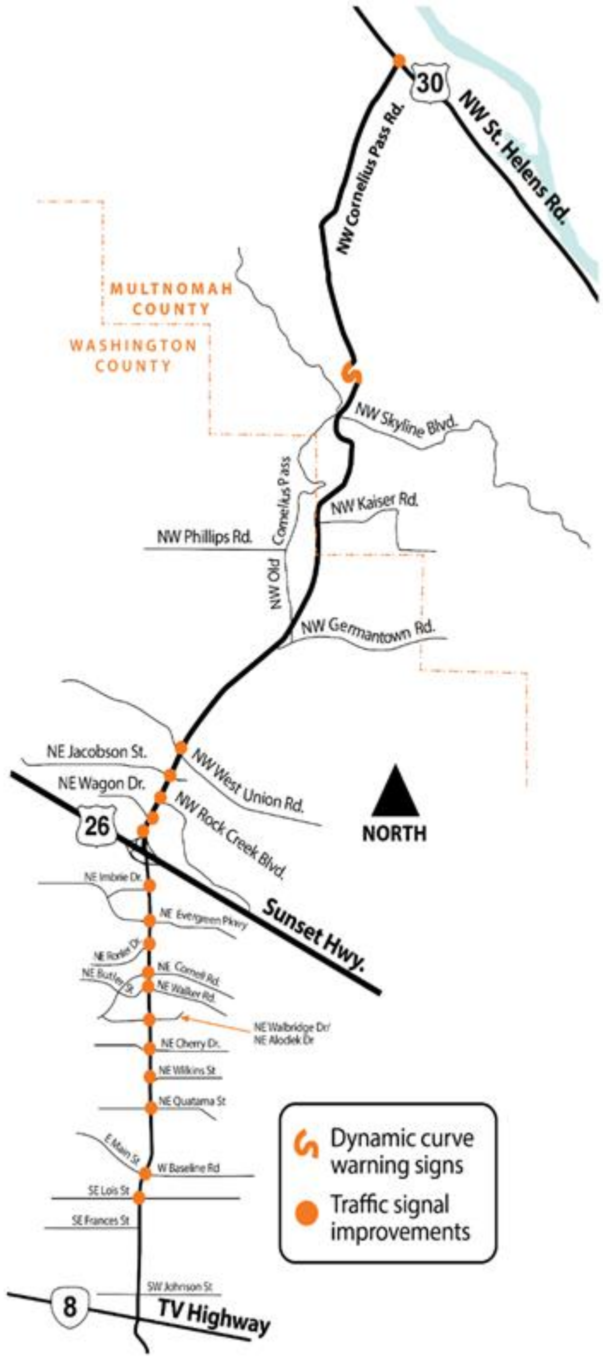
PROJECT DESCRIPTION

This Washington County Cornelius Pass Road Arterial Corridor Management project implemented a variety of Intelligent Transportation System (ITS) treatments to enhance safety and mobility on Cornelius Pass Road from US 30 to TV Highway. The ITS components installed were two rural curve warning systems with a road and weather information station and a camera for locations with the most run off the road crashes, and cellular connection to advise of weather conditions near the high elevation points on Cornelius Pass Road. A variety of signalized intersections were modified to enhance the ability to detect pedestrians and improve operations. Key components of the traffic signal improvements of the project include:

- Battery back-up systems
- Pedestrian-bicycle counting and bike detection confirmation systems
- Adaptive pedestrian safety system
- Red light crash mitigation system
- Traffic signal controller upgrades and re-timing
- Firmware development to support adaptive pedestrian and red-light-running
- Central traffic signal software licenses for Washington County

Figure 6.1 shows the extent of the project area.

FIGURE 6.1: PROJECT AREA MAP – WASHINGTON COUNTY CORNELIUS PASS ROAD ARTERIAL CORRIDOR MANAGEMENT



The objectives of the project were to develop, implement, and operate the Cornelius Pass Road Corridor Arterial Management treatments within budget, on-schedule, and accomplish the expected safety and mobility benefits along this rural, suburban key regional roadway connection. The project treatments along Cornelius Pass Road were expected to enhance traveler information regarding crash events, weather events, and travel time, which, in turn, would enhance mobility and reduce delays and emissions. The project is expected to enhance freight mobility and safety by the implementation of truck extensions at specific locations along Cornelius Pass Road.

The treatments should have enhanced safety by reducing the frequency and magnitude of:

- Run off the road crashes (curve warning system, weather information system),
- Red-light-running related crashes (red light crash mitigation system)
- Bike and pedestrian failure to obey traffic signal device events (adaptive pedestrian safety system)[22]
- Vehicle-pedestrian crashes (adaptive pedestrian safety system)
- Crashes during weather events, such as heavy rain, snow, ice (VMS and weather stations)
- Crashes due to missed trends in operations, such as near-misses (bike-pedestrian performance system and ATSPMs, truck priority and transit priority)
- The project was constructed and deployed during the period of September 2022 through January 2023. Total project cost was $2.7 million.

PROJECT BACKGROUND

As part of this Washington County Cornelius Pass Road Arterial Corridor Management project, two rural curve warning systems, and several traffic signals were upgraded. The goals of the project included improving safety and enhancing mobility.

The project was originally supposed to include a variable message sign (VMS) on northbound Cornelius Pass near US 26 to alert motorists on Cornelius Pass Road of weather events and incidents. The VMS was deleted from the project due to cost, utility, and right-of-way conflicts.

CORRIDOR OPERATIONS

The corridor operates differently in different sections. The northern section of the corridor is a rural two-lane highway that connects the Beaverton and Hillsboro areas with US 30. The corridor acts a conduit for people commuting from the St. Helens and Scappoose area to tech firms in Washington County.

The southern portion of the corridor from NW West Union Road to Tualatin Valley (TV) Highway is an urban signalized corridor providing access to US 26 and commercial and employment destinations in Beaverton and Hillsboro.

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[22] While bike detection systems were installed in this project, cycling outcomes were not evaluated for this project.

North of US 26 the northbound peak is in the afternoon with traffic heading away from US 26 towards residential areas north of the highway or towards US 30. The southbound peak is in the morning with traffic heading towards US 26.

South of US 26 both the northbound and southbound peaks are in the afternoon, although the northbound peak is significantly higher. There are approximately 2,000 vehicles in the northbound peak hour versus 1,500 vehicles in the southbound peak hour.

EVALUATION

EVALUATION GOALS, OBJECTIVES AND QUESTIONS

The goals of the project included improving traveler information, improving safety, improving mobility, and improving operations. The objectives of the before-and-after evaluation were to measure how well the improvements achieved the project goals. Table 6.1 summarizes the project goals and specifically how the goals were evaluated.

TABLE 6.1: EVALUATION GOALS, OBJECTIVES AND QUESTIONS

GOAL AREA	DESCRIPTION/OBJECTIVES	EVALUATION QUESTION
IMPROVE SAFETY	Reduce speed in vicinity of curve warning systems Reduce crash potential within the corridor Reduce weather related crashes	Determine if the average and median speed through the horizontal curve is reduced. Determine if red-light-running and/or near-miss events are reduced. Determine how effective weather messaging and VMS alerts are in reducing weather-related crashes in the corridor
IMPROVE MOBILITY	Improve travel time reliability	Determine if the variability of average travel speeds has decreased on Cornelius Pass Road from US 30 to TV Highway during the weekday evening peak hour.
IMPROVE OPERATIONS	Improve freight travel time Improve pedestrian service operations	Determine if the variability of average travel speeds has decreased on Cornelius Pass Road from US 30 to TV Highway during the weekday evening peak hour. Determine how many times the pedestrian system is activated by mode: call cancellation mode and interval extension mode.

PERFORMANCE MEASURES

Table 6.2 shows the performance measures and data sources that were used to evaluate project performance. Video analytics were to be used to help determine *before* and *after* red-light-running events and near-misses. Unfortunately, the signals were not recorded in the *before* period. As a result, a *before* and *after* comparison could not be completed. In lieu of video analytics, the team used crash reports from the Washington County Sheriff's Office to evaluate *before* and *after* crashes.

TABLE 6.2: PERFORMANCE MEASURES AND DATA SOURCES

EVALUATION OBJECTIVE	PERFORMANCE MEASURES	ASSOCIATED DATA TYPE
1. **DETERMINE IF THE AVERAGE AND MEDIAN SPEED THROUGH THE HORIZONTAL CURVE WERE REDUCED**	a) Average speed b) Median speed c) 95th percentile speed	• Travel speed/time at 5-minute intervals
2. **DETERMINE IF RED-LIGHT-RUNNING AND/OR NEAR-MISS EVENTS WERE REDUCED**	d) Number of red-light running activities e) Number of near-miss events	• Crash Reports • ATC controller logs - red clearance extensions
3. **DETERMINE IF THE VARIABILITY OF AVERAGE TRAVEL SPEEDS DECREASED ON CORNELIUS PASS ROAD FROM US30 TO TV HIGHWAY DURING THE WEEKDAY EVENING PEAK HOUR**	f) Average speed g) 95th percentile speed h) buffer index i) planning time index	• Road segment length • travel speed/time at 5-minute intervals
4. **DETERMINE HOW OFTEN AND TO WHAT MAGNITUDE WERE TRUCK EXTENSION AND PRIORITY SERVICE GRANTED**	j) Number of requested and granted truck priority services	• ATC controller logs – truck priority extension
5. **DETERMINE NUMBER OF TIMES THE PEDESTRIAN SYSTEM WAS ACTIVATED BY MODE, EITHER CALL CANCELLATION MODE OR INTERVAL EXTENSION MODE**	k) Number of pedestrian call cancellations l) Number of pedestrian interval extensions	• Pedestrian actuations system logs

Additional considerations in using these performance measures in the *before* and *after* evaluation are described in the following sections.

A) AVERAGE SPEED AND B) MEDIAN SPEED

For the southern portion of the corridor, average and median travel speeds were used to measure the effectiveness of the mobility goal, specifically for the weekday evening peak hour. We propose to evaluate the data for non-holiday weekday (Monday – Friday), during the hours of 3 p.m. to 6 p.m., and determine the most appropriate 60-minute period for the evaluation.

The curve warning site included a side fire radar unit capturing speeds, volumes, and occupancy. An analysis of the radar data was used to show if motorists were slowing down for the curves. Speeds from the radar unit were used to measure average and median speed.

C) 95TH PERCENTILE SPEED

Similar to the average travel speed, the 95th percentile speed aggregated data for the same time period, and report the metric for non-holiday weekday (Monday – Friday), during the peak 60-minute period within the hours of 3 p.m. to 6 p.m.

D) BUFFER INDEX AND E) PLANNING TIME INDEX

Buffer Index and Planning Time Index was calculated based on the average speed/travel time, free-flow speed/travel time, and 95th percentile speed/travel time. Therefore, these metrics were also reported for the same peak 60-minute period.

F) NUMBER OF RED-LIGHT-RUNNING ACTIVITIES

Number of red-light-running activities was used to measure against the safety goal. For each location where red-light crash mitigation system was deployed, the red-extension events in the *after* period were summarized.

H) CURVE WARNING INCIDENT RATE

Due to the substantially lagging availability of crash data, we proposed to use traffic incident data to measure the effect of curve warning messages. The traffic incident was calculated as the number of incidents at a given location (a roadway segment, in this case.)

I) NUMBER OF REQUESTED AND GRANTED TRUCK PRIORITY SERVICES

This metric was used to measure against the operations goal. ATC controller logs recorded the truck priority requests and grants. We summarized how often this service was requested and granted during the after period.

J) NUMBER OF PEDESTRIAN CALL CANCELLATIONS AND K) NUMBER OF PEDESTRIAN INTERVAL EXTENSIONS

This metric was used to measure against the operations goal. The pedestrian actuations system recorded pedestrian call cancellations and pedestrian interval extensions. We summarized the number of activities recorded by the system, by mode, during the *after* period.

The pedestrian call cancellation system was ultimately not implemented because the potential operational benefits did not seem to outweigh the potential safety risks.

EVALUATION PERIOD

Based on the actual project deployment schedule and evaluation data availability, the following periods were used for data collection. Each *data collection period* aimed to capture the most available data, within the project timeline, for the evaluation purposes.

- *Before* data collection period: July 2021 through June 2022
- *After* data collection period: July 2023 through June 2024

DKS then screened the data sets for completeness and quality, performed preliminary statistical analysis, and determined the evaluation periods for the *before* and *after* analysis. The goal was to have a minimum of six months of data in each evaluation period to summarize meaningful traffic trends, and the actual evaluation periods were dependent on the results of the data screening.

DATA COLLECTION APPROACH

DATA TYPES AND SOURCES

Table 6.3 summarizes the data sources and how they were acquired for each data type identified above. The collection process was a collaboration between the consultant, ODOT, and Washington County.

TABLE 6.3: DATA SOURCES

DATA TYPE	DATA SOURCE	RESPONSIBLE PARTY
ROADWAY SEGMENT LENGTHS	Google Earth or GIS	DKS
INCIDENT LOGS AND CRASH DATA	ODOT dispatch system and Washington County Sherrif's Office	DKS/ODOT/ Washington County
SPEED/TRAVEL TIME	INRIX data via RITIS Sidefire Radar	DKS/ODOT
CONTROLLER LOGS OF RED CLEARANCE AND TRUCK PRIORITY EXTENSION	ATC system	Washington County
PEDESTRIAN ACTUATION LOGS	Pedestrian actuation system	Washington County

DATA PROCESSING AND REVIEW

This section summarizes data quality, processing, and completeness checks performed for each data source.

ROADWAY SEGMENT LENGTHS

Segment lengths were taken from the GIS shapefile matching the INRIX XD data segments and was verified using Google Earth. Freeway segment lengths could include mainline segments and ramp or connector links if needed. Segment lengths could be aggregated and consist of multiple INRIX XD segments.

INCIDENT LOGS AND CRASH REPORTS

Incident data was requested directly from ODOT. Incident data was reviewed to ensure that there were no outliers, and all data is recorded as expected. DKS worked with ODOT to understand any potential discrepancies in the data before using it for analysis.

Additionally, DKS requested crash data from Washington County Sheriff's Office at the signalized intersections. This was crash data that was submitted to ODOT for inclusion in the statewide database. There was a time lag before the ODOT data was available.

SPEED AND TRAVEL TIMES

DKS downloaded travel time and speed data from RITIS which contained INRIX segment-based speed data. The higher resolution XD segments were used for this analysis. Note that INRIX updates its XD segment map twice a year and care should be taken to use the same map version and segmentation for both *before* and *after* time periods. INRIX data was downloaded in five and 15-minute increments based on the list of study segments to be used in the analysis.

After the data was downloaded, quality checks were performed by creating speed contour plots, which were heatmaps of the speeds along the study segments by time of day. They showed where the delays or bottlenecks occurred along the study corridor by time of day and were used to identify any speed anomalies. Speed data was reviewed for outliers at the XD segment level before it was aggregated as needed for the performance measures.

Speed data in the curves was provided by ODOT from side fire radar that was installed as part of the project.

ATC CONTROLLER LOGS

Controller log data was requested from Washington County at the relevant signalized intersections along the study corridor. Specifically, the log data contained information on red clearance intervals and truck priority extensions. This data was reviewed for outliers and DKS worked with the County to review any potential discrepancies before using the data for analysis.

PEDESTRIAN ACTUATION SYSTEM LOGS

Pedestrian actuation data was requested from Washington County at all relevant signalized intersections along the study corridor. Data was requested at each individual actuation point as there were multiple locations per signal. Specific data points that were collected were pedestrian interval extensions. This data was reviewed for outliers and DKS worked with the County to review any potential discrepancies before using the data for analysis.

RESULTS

EVALUATION OF THE ITS SYSTEM IN THE HORIZONTAL CURVES

The results for the ITS System in the horizontal curves were evaluated separately from the traffic signal improvements as the performance measures were different, and the system did not impact the signals.

SPEEDS IN THE HORIZONTAL CURVES

To assess the impact of the curve warning signs on vehicle speeds through the horizontal curve at M.P. 2.85 and 3.13, the team evaluated the speed of vehicle traffic with the signs on and with the signs turned off.

Speeds were not collected systematically before the system was installed. It was not possible to do a true *before* and *after* study. ODOT provided data from the system with the system active or "ON" from February 18, 2023 through February 28, 2023. (February 18-19 and February 25-16 were weekends. All other days were weekdays. A significant snowstorm hit the Portland region on February 22nd and 23rd. Nighttime temperatures were below freezing on the nights of February 24th and February 25th. As a result, the team excluded February 22nd through 25th data from the analysis because drivers would likely reduce their speed because of the presence or potential presence of snow and ice on the roadway.)

The signs were deactivated or "OFF" for the period of April 3, 2023, through April 17, 2023. (April 8-9 and April 15-16 were weekends.) All other days were weekdays.

A review of rain gauge data at the nearby Skyline School indicated rainfall from days evaluated in February were consistent with the April time period. Temperatures were above freezing in both periods.

Table 6.4 below shows the difference in average and median speeds. In all cases the average and median speeds were reduced with the signs "ON". The average speed reduction ranged from one percent to five percent while the median reduction ranged from three percent to 14percent.

TABLE 6.4: WASHINGTON COUNTY CORNELIUS PASS ROAD - AVERAGE AND MEDIAN SPEEDS WITH CURVE WARNING SYSTEM

	SIGNS OFF (APRIL 2023)		SIGNS ON (FEB. 2023)		PERCENTAGE CHANGE	
	AVERAGE SPEED (MPH)	MEDIAN SPEED (MPH)	AVERAGE SPEED (MPH)	MEDIAN SPEED (MPH)	AVERAGE SPEED	MEDIAN SPEED
2.85 SB						%
WEEKDAY	31.9	33.8	31.1	32.0	-3%	-5%
WEEKEND	36.7	37.2	34.7	31.9	-5%	-14%
3.13 SB						
WEEKDAY	29.2	30.7	28.8	29.7	-1%	-3%
WEEKEND	33.2	33.7	31.9	32.6	-4%	-3%
3.13 NB						
WEEKDAY	34.5	34.7	33.6	33.7	-3%	-3%
WEEKEND	35.9	35.9	34.0	34.2	-5%	-5%
2.85 NB						
WEEKDAY	36.4	36.4	35.3	35.3	-3%	-3%
WEEKEND	38.1	38.0	36.4	36.8	-4%	-3%

On average, travel speeds decreased more on the weekends than on the weekday, four versus two miles per hour (mph). In the southbound direction median weekend speeds decreased by 14 percent versus 3 percent in the northbound direction. The implemented system achieved the project goal of reducing speeds in the vicinity of curve warning systems.

TRAVEL TIMES ON THE RURAL SECTION OF CORNELIUS PASS ROAD

The analysis question asked about the variability of travel times on Cornelius Pass Road from US 30 to the Tualatin Valley Highway (TV Highway, OR 8). The nature of the project was that many of the signals were improved at the southern end of the project from TV Highway to NW West Union Road. North of NW West Union Road to US 30, the corridor is primarily rural. The only improvement in this area was the curve warning system. This would likely have a small effect of reducing the speeds on Cornelius Pass Road. The team was concerned that including the rural and urban sections would make it difficult to distinguish the impacts of the signalized intersection improvements.

Table 6.5 shows the time in which the speed data was collected. The speeds and travel time for the p.m. peak hour in the rural segment are shown in Table 6.6. The same data is reflected in a bar graph in Figure 6.2 and Figure 6.3.

TABLE 6.5: DATA COLLECTION PERIODS - WEEKDAYS NB 4:20 – 5:20 P.M. PEAK HOUR, SB 3:00 – 4:00 P.M. PEAK HOUR

CORRIDOR LENGTH = 7.13 MILES (NW W UNION RD TO HWY 30)

SEGMENT	DATE
BEFORE	7/1/2021 to 6/30/2022
AFTER	7/1/2023 to 6/30/2024

TABLE 6.6: CORNELIUS PASS ROAD (RURAL SEGMENT)

		FREE FLOW SPEED (MPH)	AVERAGE SPEED (MPH)	95TH PERCENTILE SPEED (MPH)	FREE FLOW TRAVEL TIME (MIN)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
BEFORE	**NB**	41.08	36.59	40.93	10.42	11.69	14.41	0.23	1.38
	SB	40.65	38.88	42.56	10.53	11.01	12.21	0.11	1.16
AFTER	**NB**	42.54	35.13	40.06	10.06	12.18	14.77	0.21	1.47
	SB	42.19	38.58	42.46	10.14	11.09	12.45	0.12	1.23

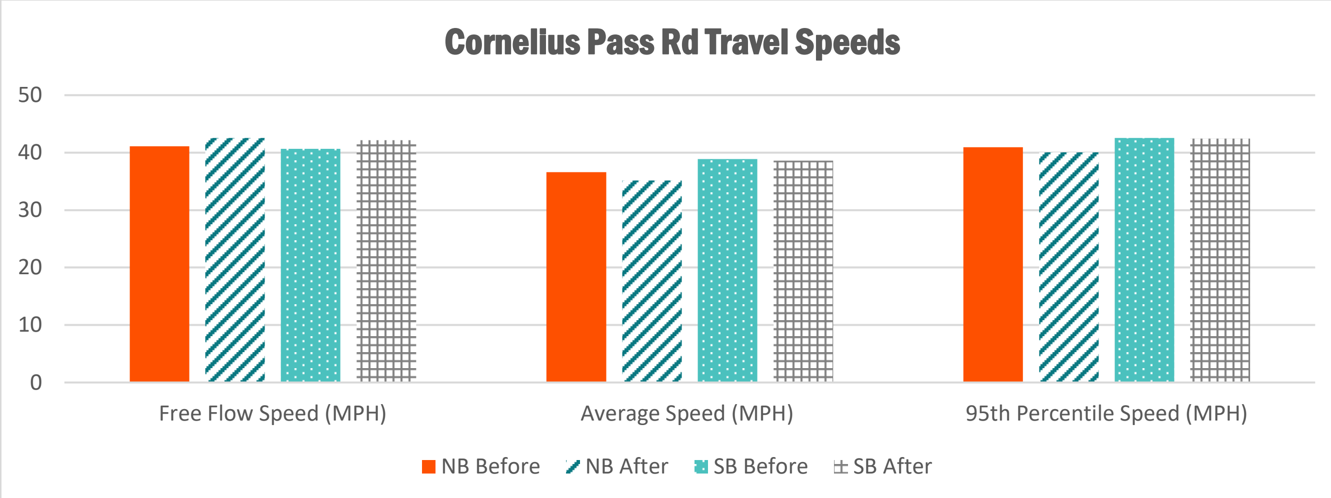

FIGURE 6.2: CORNELIUS PASS ROAD RURAL TRAVEL SPEEDS

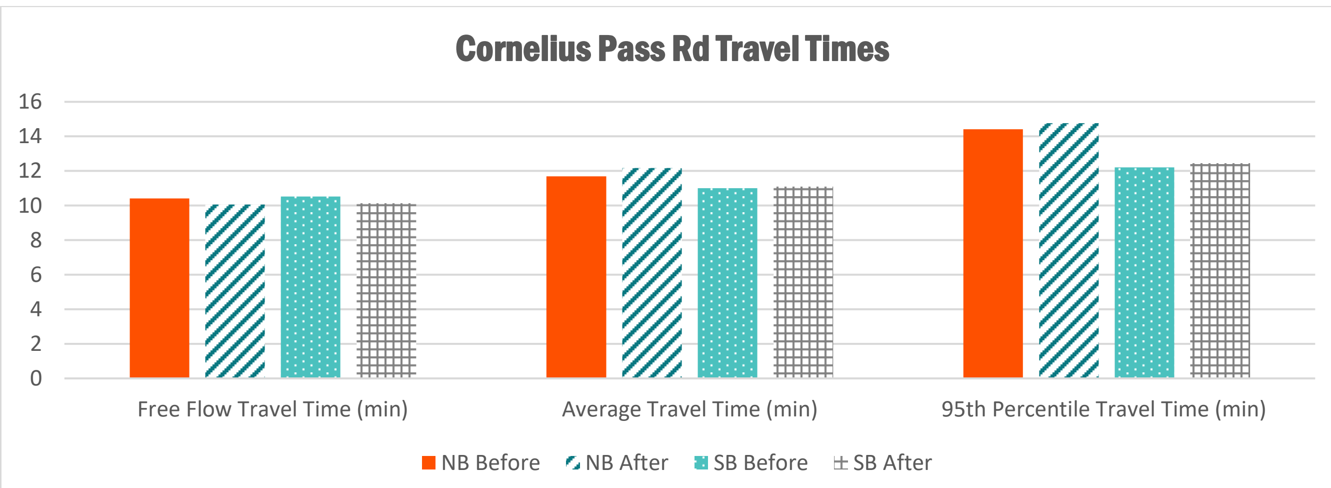

FIGURE 6.3: CORNELIUS PASS ROAD RURAL TRAVEL TIMES

In the rural section, the variability of travel times mostly increased. The section became slightly less reliable. The 95th percentile travel time and the planning time index increased slightly in both directions. The buffer index decreased slightly northbound and increased slightly southbound.

As noted previously, the only change in this segment was the implementation of the curve warning system that generally lowered speeds in the curves. This would account for at least some of the changes in travel time. There was no growth in traffic volumes in the rural portion of the corridor, so changes in traffic volumes were unlikely to have impacted travel times.

CURVE WARNING SIGN INSTALLATION

WEATHER RELATED MESSAGES AND CRASHES IN THE HORIZONTAL CURVES

The goal of this performance measure was to determine how effective weather messaging and VMS alerts were in reducing weather-related crashes in the corridor. Unfortunately, a northbound VMS on Cornelius Pass Road was eliminated from the project due to costs, as well as right-of-way and utility impacts. This VMS would have provided specific information to travelers on the road and weather information. In lieu of this, the team evaluated wet weather crashes in the *before* and *after* condition. The team also reviewed VMS messages on nearby highways that would provide information to travelers using Cornelius Pass Road.

CRASH METHODOLOGY

The evaluation used ODOT Incident Logs from its dispatch software instead of reported crashes because of the significant delay in processing reported crashes from the Department of Motor Vehicles (DMV). This allowed the safety analysis to be completed much sooner than if the analysis relied on official crash reports. The data in this report were incidents that were logged into ODOT's Incident Reporting System and logged as crashes. Incidents are recorded by ODOT dispatchers from reports from ODOT Incident Responders or local agency emergency responders. The dispatcher would note in the report whether the incident was a crash or something else such as a disabled vehicle. Unfortunately, the incident data only noted the severity of the crash if it was fatal. As a result, assessing changes in crash severity was challenging. For this report, when the term "crash" is used, it represents an incident reported as a crash. The analysis below only applies to the segment of Cornelius Pass Road under ODOT's jurisdiction, from US 30 (MP 0.00) to US 26 (7.85).

CRASHES IN THE HORIZONTAL CURVES

In the horizontal curves, there were a total of two crashes in the *before* period and ten in the *after*. As a comparison, Table 6.7 below shows the number of crashes in the *before* and *after* period at the horizontal curve (MP 2.75-3.25) and the part of the corridor under ODOT jurisdiction. Table 6.8 below shows the count of attributes of each crash including roadway conditions, rain during the day, and rainfall during the crash hour. In a few cases, rainfall data was not available.

The *after* period was observed to have more crashes than the *before* period both in the horizontal curve and the corridor. There was also more rain during the day and crash hour in the after period.

TABLE 6.7: CRASHES ON THE HORIZONTAL CURVE VS CRASHES ALONG THE CORRIDOR

SEGMENT	BEFORE	AFTER
HORIZONAL CURVE	2	10
CORRIDOR	33	46

TABLE 6.8: CRASHES ON THE HORIZONTAL CURVE BY ATTRIBUTE

STUDY PERIOD	RAIN DURING THE DAY	NO RAIN DURING THE DAY	RAIN DURING CRASH HOUR	NO RAIN DURING CRASH HOUR	NO DATA
BEFORE	2	0	0	2	0
AFTER	5	2	3	4	3

Crashes may have increased in the *after* period because of normal statistical variation in the number of crashes or there may have been more periods of wet weather. Another possibility is that ODOT took jurisdiction of the highway on March 31, 2021. 911 Dispatchers may not have integrated this information and were less likely to report incidents to ODOT's Dispatch Center in the *before* period than the *after* period.

CORRELATION WITH REPORTED CRASHES

ODOT has official reported crash data through December 31, 2022, available. This period covers the *before period* of the analysis. The team compared incidents reported as crashes in the *before* period with actual reported crashes.

For the entire segment, there were 32 reported crashes compared with 33 incidents reported as crashes. Of those 32, eight were reported occurring when the pavement was wet. 14 of the 32 crashes were property damage only while 18 were reported as injury crashes with 30 total injuries occurring.

The segment in the curve (MP 2.75 to 3.25) had four total reported crashes compared to two incidents reported as crashes. Of the four crashes, one was reported as occurring in wet conditions. Three of the four crashes reported injuries.

VMS MESSAGES

ODOT has two permanent VMS messages that would likely provide travelers who might use Cornelius Pass Road. One is US 26 westbound just east of the 185th Avenue Interchange. The Cornelius Pass Road Interchange is the next exit to the west after NW 185th Avenue. In both the *before* and *after* period the VMS provided no messages regarding road and weather information on Cornelius Pass Road. It did provide information when Cornelius Pass Road was closed for a crash or construction.

There is also a sign on eastbound US 30 just west of the junction with Cornelius Pass Road. Similarly, the sign provided information when Cornelius Pass Road was closed or delayed by a crash or road construction; however, the sign did not provide specific road and weather information on Cornelius Pass Road. In the *after* period, it did provide nine warnings of icy conditions compared to none in the *before* condition, but those warnings were not specifically for Cornelius Pass Road.

EVALUATION OF THE TRAFFIC SIGNAL IMPROVEMENTS

SAFETY AT TRAFFIC SIGNALS

This section covers the safety evaluation of the traffic signal upgrades.

CRASH EVALUATION

The team evaluated crashes at the signalized intersections in the corridor. All of these had controller upgrades. The team used Washington County Sheriff's Office crash reports. The crashes covered the following intersections:

- NE Imbrie Drive
- NE Evergreen Parkway
- NE Ronler Drive
- NE Cornell Road
- NE Walker Road/Northeast Butler Street
- NE Walbridge Drive/ Northeast Aloclek Drive
- NE Cherry Drive
- NE Wilkins Street
- NE Quatama Street
- W Baseline Road/E Main Street
- SE Lois Street

The number of crashes in the before and after conditions are shown below in Table 6.9:

TABLE 6.9: CRASHES AT IMPROVED SIGNALIZED INTERSECTIONS

SEGMENT	BEFORE	AFTER
SIGNALIZED SECTION	33	28

The team then looked at signals where specific safety measures were implemented. Table 6.10 shows the specific intersections and the crash history.

TABLE 6.10: CRASHES AT TRAFFIC SIGNALS

SIGNAL	IMPROVEMENTS	BEFORE	AFTER
NE IMBRIE DR	Truck Extension, Red Extension, Bike detection	2	3

SIGNAL	IMPROVEMENTS	BEFORE	AFTER
NE EVERGREEN PKWY	Truck Extension, Red extension, Pedestrian Extension	6	6
NE CORNELL RD	Truck Extension, Red Extension	13	9
W BASELINE RD/E MAIN ST	Truck Extension, Red Extension, Pedestrian Extension	7	9
NE QUATAMA ST	Bike Detection	5	1
TOTAL		33	28

RED CLEARANCE EXTENSION (RCE)

Washington County provided RCE data to the DKS team. They provided a week of data from the following intersections.

- SE Cornelius Pass Road at W Baseline Road/E Main Street
- NE Cornelius Pass Road at NE Cornell Road
- NE Cornelius Pass Road at NE Evergreen Parkway
- NE Cornelius Pass Road at NE Imbrie Drive

Washington County provided RCE's were averaged over the weekday period from Tuesday-Thursday, and the weekend period (Figure 6.4-6.6).

The RCE would in all cases extend the red time for a particular phase. If a phase reached its maximum green time, it borrowed green time from the next phase. If that phase maxed out, the signal would go into transition and be out of coordination until it transitioned back into coordination.

NE CORNELIUS PASS ROAD & NE IMBRIE DRIVE

NE Imbrie Drive saw more RCEs in the southbound direction than other movements at the intersection, particularly during the weekday morning peak. Weekend activity was lower, indicating possible commuter-related traffic patterns or a relationship between higher traffic volumes in the peak period with increased RCE. The southbound direction had random arrivals since this was the beginning of the coordinated section for the southbound direction. This may lead to more activations of the RCE than northbound. This was the end of the coordinated section for the northbound direction and most of the northbound arrivals were within the green band. Further investigation into volumes, speeds, and detector placement could clarify this directional trend.

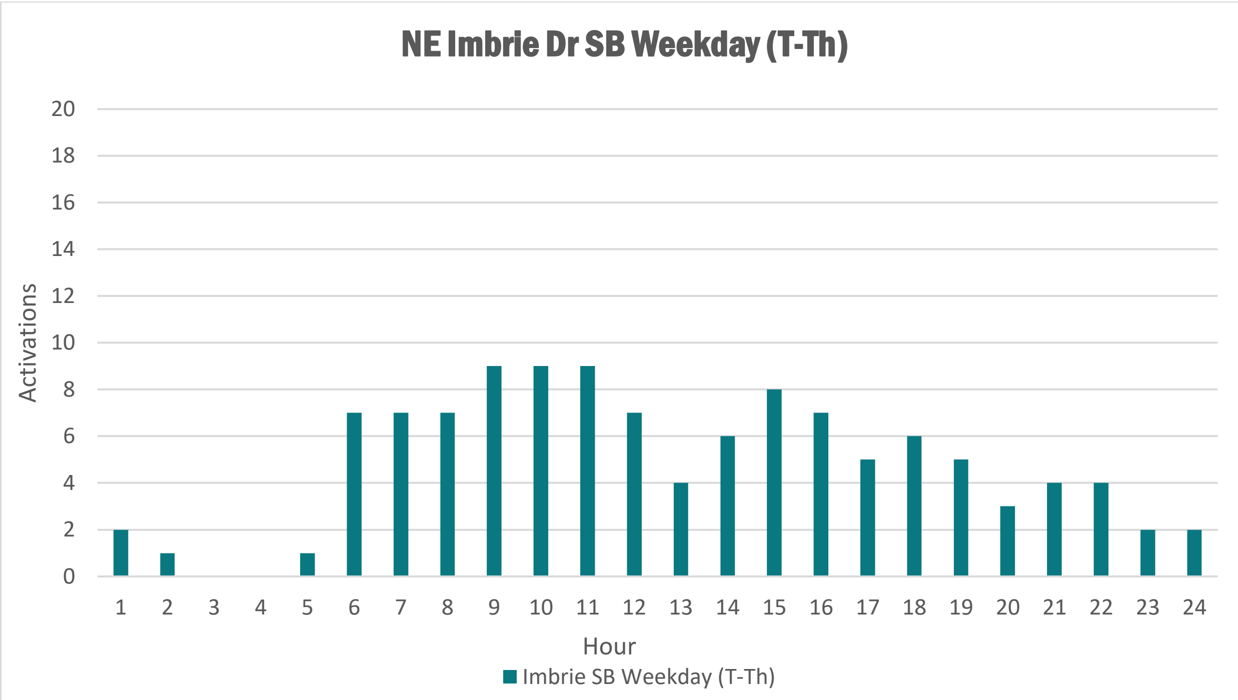

FIGURE 6.4: SOUTHBOUND RCE ACTIVATIONS AT NE IMBRIE DRIVE

CORNELIUS PASS ROAD & NE EVERGREEN PARKWAY

NE Evergreen Parkway showed a consistently higher number of RCEs than other signals along Cornelius Pass Road, especially in the northbound direction, with activity increasing during the midday and tapering into the night. Southbound RCEs were lower but steady throughout the day. This pattern was similar on both weekdays and weekends. Despite being a large, high-volume intersection (similar to Cornelius Pass Road & NE Cornell Road), NE Evergreen Parkway had significantly more RCEs, suggesting possible issues with driver behavior, detection setup, or signal operations. Additional data on 85th percentile speeds, vehicle types, crash history, and detector configuration would help explain the elevated RCEs. The intersection was very large and was in the middle of the corridor. Balancing progression in both the northbound and southbound directions may lead to an entire platoon not making it through the intersection, resulting in activation of the RCE. False calls, especially at night, may also be contributing factors.

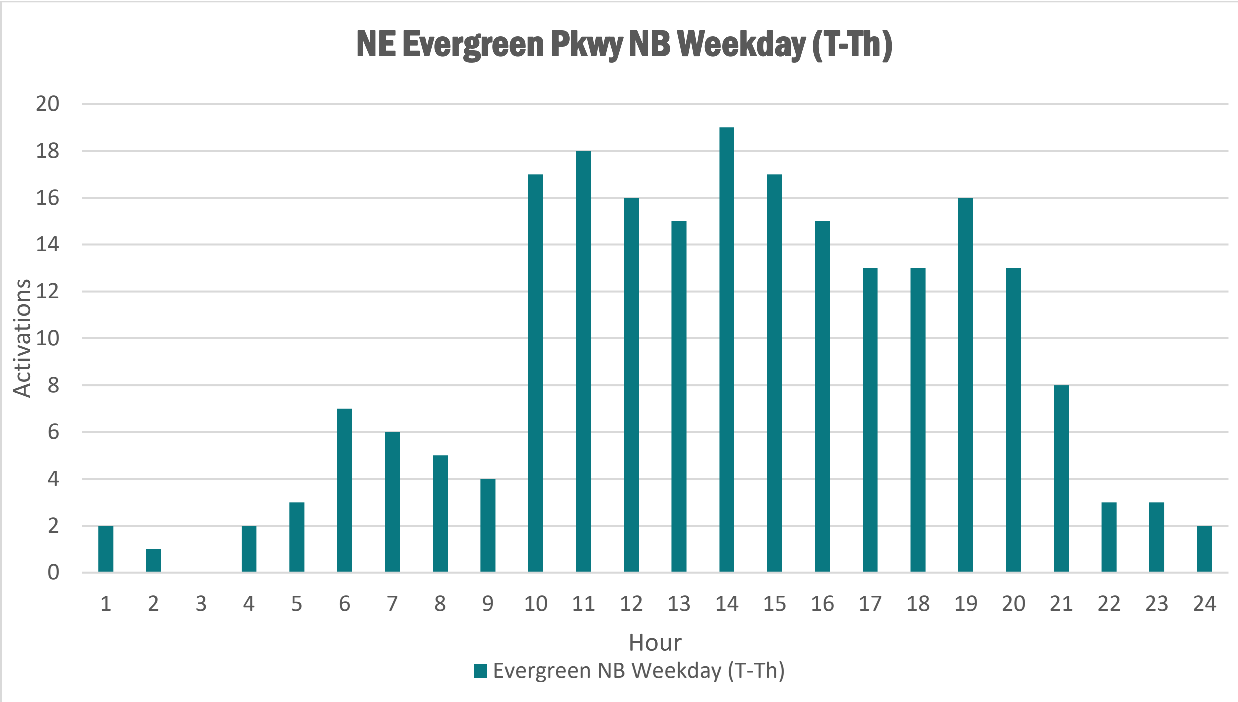

FIGURE 6.5: NORTHBOUND RCE ACTIVATIONS AT NE EVERGREEN PARKWAY

CORNELIUS PASS ROAD & NE CORNELL ROAD

NE Cornell Road showed minimal RCE activations across all directions. The only notable activity as on the northbound approach during weekdays, and even then, counts were significantly lower than at the other intersections.

CORNELIUS PASS ROAD & W BASELINE ROAD/E MAIN STREET

W Baseline Road experienced an increase in the number of RCEs as volumes increased throughout the morning. This could indicate high speeds, or detection issues. The westbound approach also showed higher numbers of RCEs during the midday, which suggested that review of traffic behavior, detection zones, and timing settings on that leg could determine the cause.

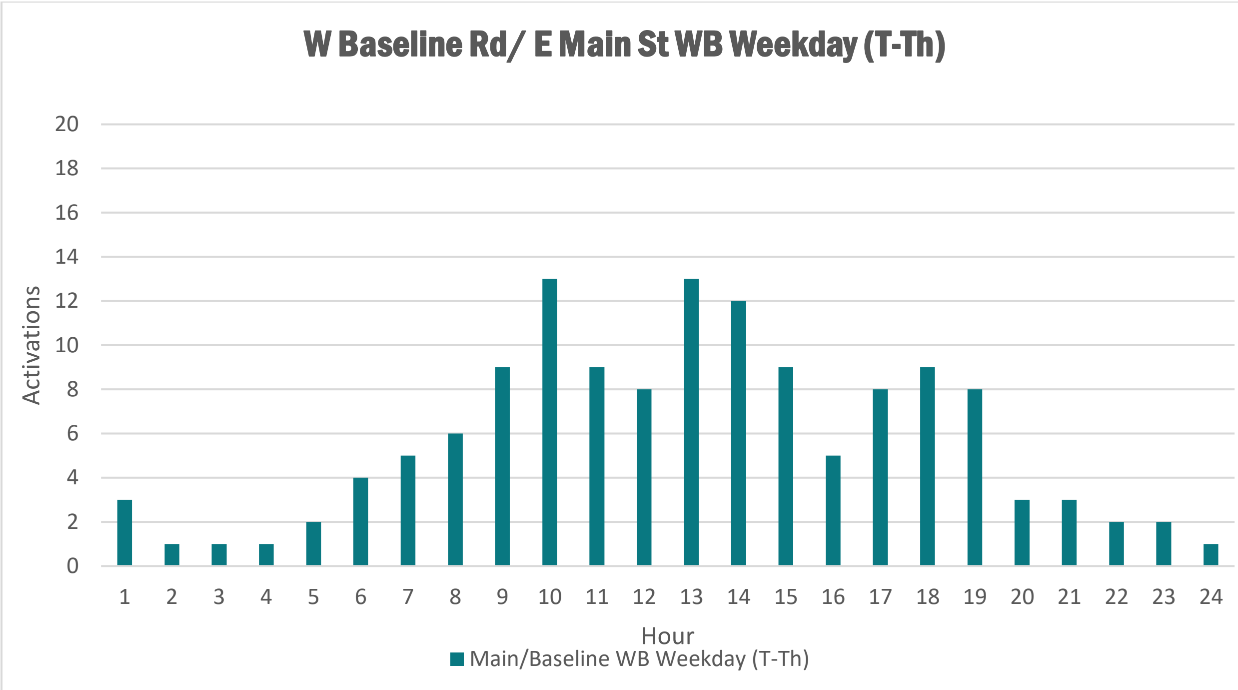

FIGURE 6.6: WESTBOUND RCE ACTIVATIONS AT W BASELINE ROAD/E MAIN STREET

TRUCK EXTENSION

Washington County provided example truck extension data from Cornelius Pass Road at NE Imbrie Drive from the Wavetronix detector at the signal. The detector data showed when the criteria for truck extension was met based on vehicle speed, and length. The data did not say when the signal phase was actually extended.

The data indicated that the detector was detecting trucks but did not indicate how often signal phases were being extended.

Discussion with County staff indicated that an alarm would need to be set in the signal controller to identify truck extensions. They were not sure if that was possible and had not investigated setting up the alarm to date.

PEDESTRIAN EXTENSION

The County installed pedestrian extension technology at the intersection of Cornelius Pass Road and NE Evergreen Parkway and the intersection of Cornelius Pass Road and W Baseline Road/E Main Street. The detectors were set up to support pedestrians crossing Cornelius Pass Road at NE Evergreen Parkway. The detectors were set up to detect pedestrians crossing W Baseline Road/E Main Street at the intersection with Cornelius Pass Road.

The detectors support pedestrian call extension and pedestrian call cancellation. Both the call extension and cancellation were supported by passive pedestrian detection.

Pedestrian call extension extended the Solid Don't Walk (SDW) when a pedestrian either entered the crosswalk during the Flashing Don't Walk (FDW) phase, when pedestrians were moving at a slower pace than the MUTCD guideline of 3.5 feet per second or when a large group of pedestrians entered the intersection. The goal of pedestrian extension was to maximize pedestrian safety, by minimizing the potential for vehicle-pedestrian conflicts.

Pedestrian call cancellation resulted from a pedestrian pressing the push button, but abandoning the detection zone because they jaywalked, crossed elsewhere, or chose not cross. The goal of pedestrian call cancellation was to maximize operational efficiency for motor vehicles by limiting unnecessary calls for pedestrians who did not wish to cross the street.

Staff at Washington County provided a week of pedestrian extension data at the intersections of Cornelius Pass Road and NE Evergreen Parkway and W Baseline Road/E Main Street for the week of March 31, 2025. On weekdays, extension was only required in the 8 p.m. hour. This may indicate the pedestrian extension zone was stuck on for a part of the hour. The extension would likely stick because of a sensor error. If the pedestrian sensor malfunctioned and stuck on, the pedestrian extension would come on every time the push button was activated. See Figure 6.7.

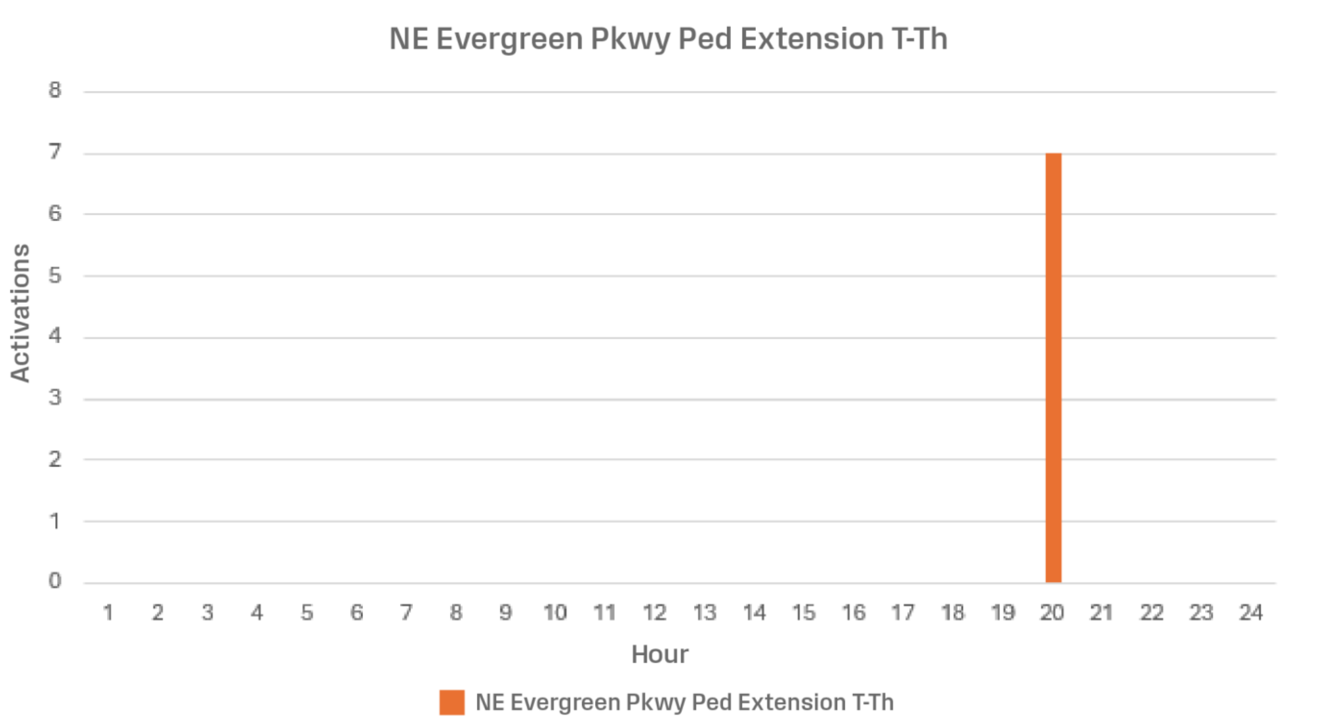

FIGURE 6.7: CORNELIUS PASS ROAD AT NE EVERGREEN PARKWAY WEEKDAY PEDESTRIAN EXTENSIONS

On the evaluation weekend there was more demand for pedestrian extension, but the calls were confined to the noon and 9 p.m. hours. Again, this may indicate an issue with the pedestrian extension zone being stuck on during these periods. See Figure 6.8.

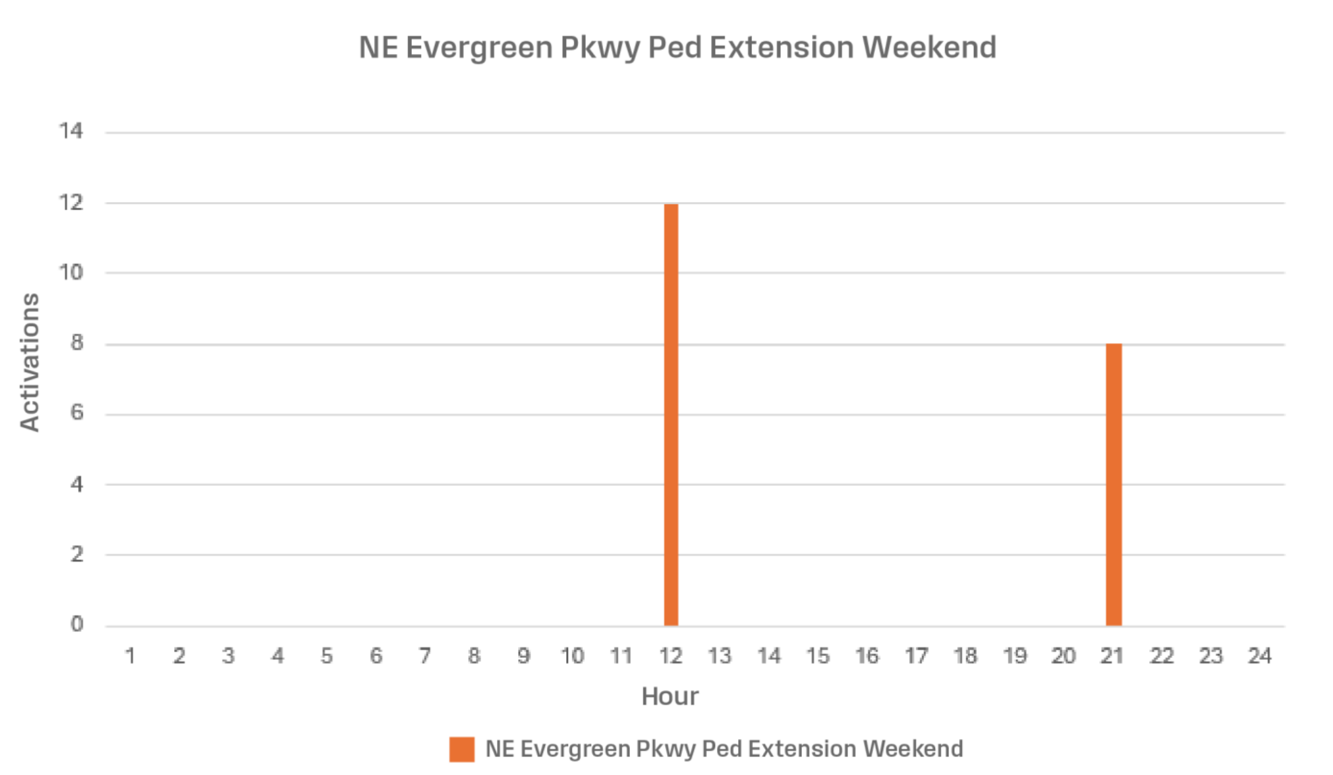

FIGURE 6.8: CORNELIUS PASS ROAD AT NE EVERGREEN PARKWAY WEEKEND PEDESTRIAN EXTENSIONS

The County also provided extension data for E Main Street. In this case, the extensions were for pedestrians crossing E Main Street not Cornelius Pass Road. Figure 6.9 shows activations throughout the day on weekdays.

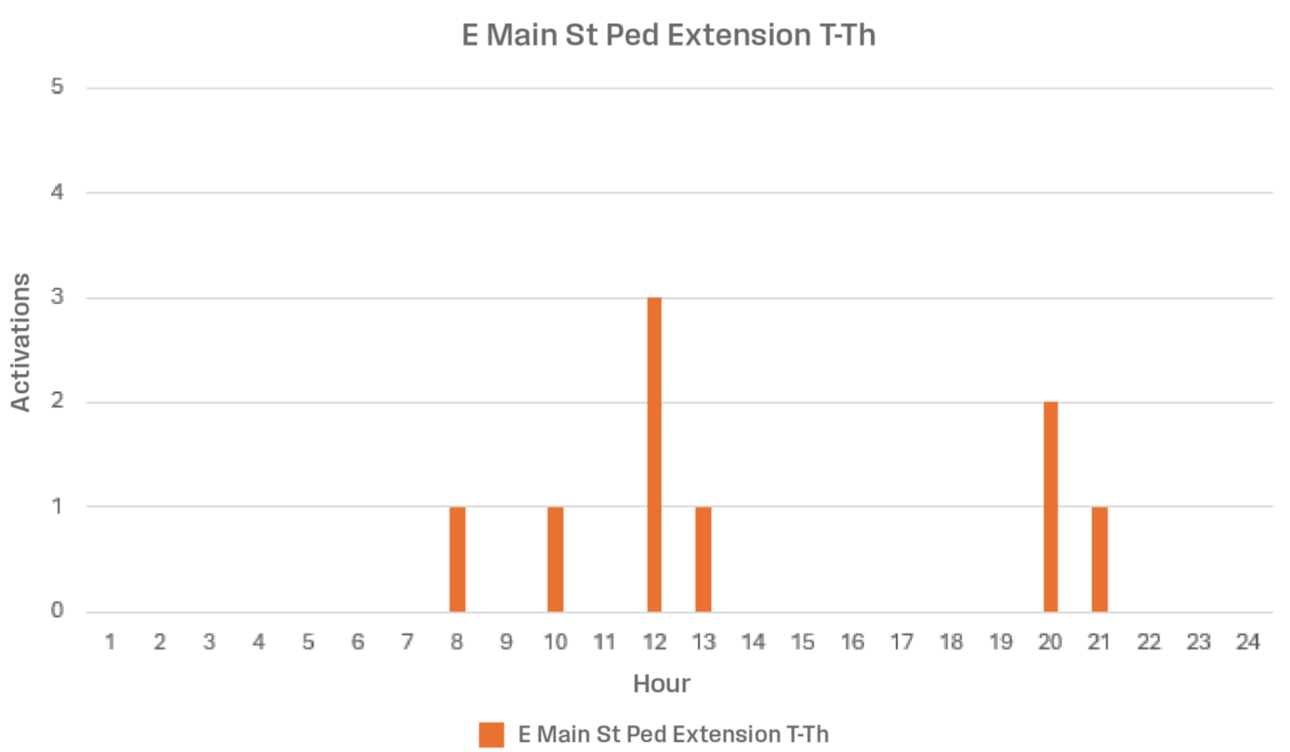

FIGURE 6.9: CORNELIUS PASS ROAD AT E MAIN STREET WEEKDAY PEDESTRIAN EXTENSIONS

Extensions on the weekend were limited to 2 a.m., 11 a.m., and 11 p.m. hours. Again, this may indicate an issue with the pedestrian extension zone being stuck on during the 2 a.m. and 11 p.m. hours See Figure 6.10.

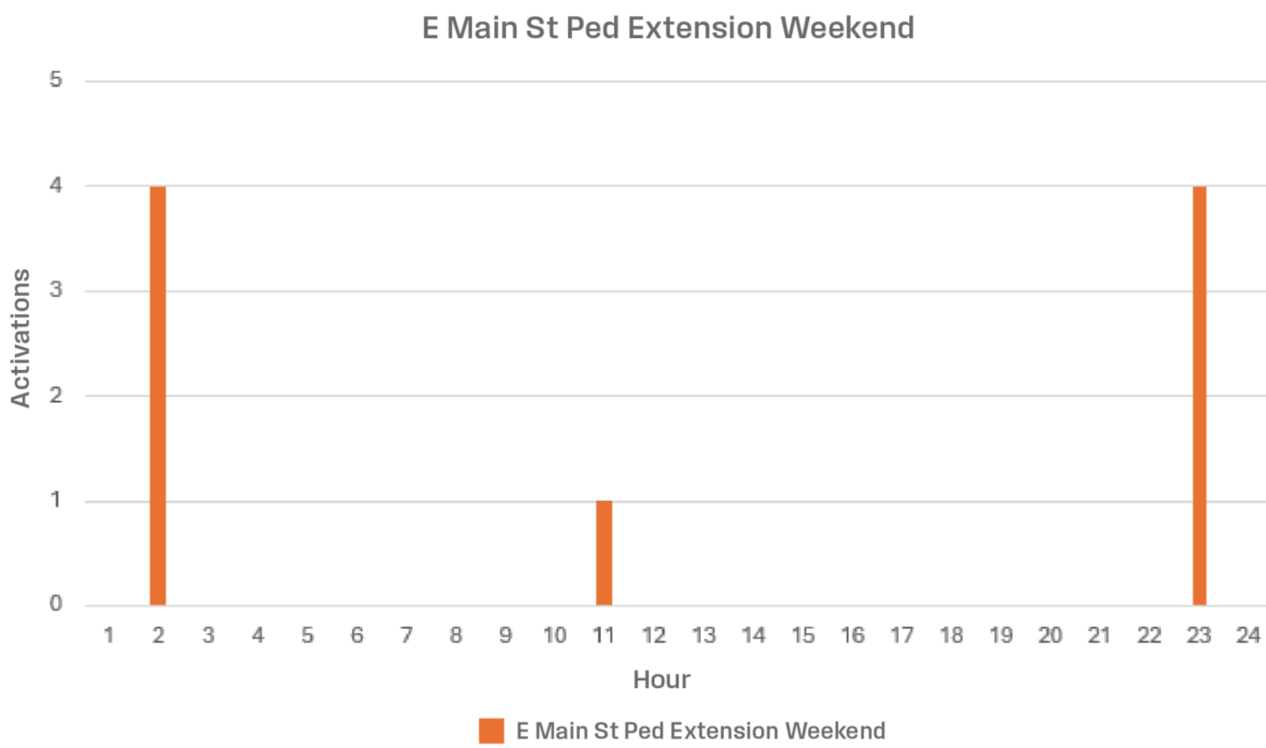

FIGURE 6.10: CORNELIUS PASS ROAD AT E MAIN STREET WEEKEND PEDESTRIAN EXTENSIONS

PEDESTRIAN EXTENSION EVALUATION

The County worked with Oregon State University (OSU) to evaluate the effectiveness of the pedestrian call extension system (PCES).

OSU evaluated the pedestrian extension function at the signalized intersection of Cornelius Pass Road and Johnson Street[23]. The study included installing FLIR TrafiOne thermal sensors integrated with custom traffic signal controller logic, was designed to detect pedestrians still within the crosswalk at the end of the "flashing don't walk" (FDW) interval and extend the "solid don't walk" (SDW) interval by one second. Video data was collected before FLIR installation (August 11–15, 2024; 230 observations) and after FLIR

[23] Washington County and Oregon State University Research Collaboration, Project #6: Evaluation of Pedestrian Call Extension System at An Actuated Traffic Signal, Hurwitz et al

installation (February 23–27, 2025; 166 observations). Pedestrian crossing behaviors, PCES results, pedestrian delay, and vehicular stop time delays were recorded, transcribed, and analyzed.

The evaluation attempted to answer the following questions:

- How accurate is the PCES at a four-way actuated traffic signal?
- How does pedestrian behavior change with increasing exposure to the PCES at a four-way actuated traffic signal?
- To what extent does the PCES increase vehicular delay and reduce pedestrian delay?

In the *before* and *after* stages, temporary cameras were installed to record pedestrian movements in 12-hour intervals for five days. CountCam 4 units developed by StreetLogic Pro were secured at locations surrounding the intersection and scheduled to record during the periods of interest. Four cameras were positioned around the study location to capture the entire crosswalk, pedestrian indication, and vehicular traffic. Example views taken from two of the installed cameras are shown in Figures 6.11-6.13. These cameras, installed on the SE and NW corners of the intersection, allowed the two crossings of interest to be evaluated. Both were high-definition cameras that allowed researchers to observe pedestrians pressing the push button and view of the pedestrian indication with synchronized timestamps.

FIGURE 6.11: OPTICAL CAMERA FOOTAGE AT STUDY INTERSECTION

FIGURE 6.12: OPTICAL CAMERA FOOTAGE AT STUDY INTERSECTION

FIGURE 6.13: OPTICAL CAMERA FOOTAGE AT STUDY INTERSECTION

As noted, the study observed existing conditions in the *before* period from April 11, 2024, to August 15, 2024. The *after* period was evaluated two weeks after implementation from February 23, 2025, to February 27, 2025.

How accurate is the PCES at a four-way actuated traffic signal?

The PCES activated 94 times, 56.6 percent of observed pedestrian crossings, with 100 percent accuracy in detecting pedestrians who warranted an extension based on the designed criteria. The system was effective for slower-paced pedestrians, as the average crossing time exceeded the allotted pedestrian signal phase. For a normal-paced pedestrian, the system provided a margin of safety, particularly for those who entered during the FDW phase versus on the WALK phases.

How does pedestrian behavior change with increasing exposure to the PCES at a four-way actuated traffic signal?

Most of the pedestrians started to walk in response to the display of the walk signal. This was a busy intersection and fewer vehicle gaps were available. This led to lower numbers of jaywalkers. There were very few pedestrians who finished crossing after the FDW ended and the SDW started in both the *before* and *after* conditions. It is not possible to note a change in behavior.

To what extent does the PCES increase vehicular delay and reduce pedestrian delay?

The average vehicle delay increased from 31.3 seconds in the *before* period to 43.1 seconds in the *after* period when the PCES was activated. Average vehicle delay was 37.2 seconds in the *after* period when the PCES was not activated.

The average pedestrian delay increased from 45.7 seconds in the *before* period to 55.7 seconds in the *after* period when the PCES was activated. Average pedestrian delay was 47.1 seconds in the *after* period when the PCES was not activated. There was an increase in pedestrian delay because extending the pedestrian phase in one cycle often required reducing time in the next cycle, thereby increasing waiting time for subsequent pedestrians. This highlighted the fundamental trade-off of the PCES: enhancing current pedestrian safety versus maintaining optimal operational efficiency.

SPEED AND TRAVEL TIME (SIGNALIZED CORRIDOR)

This section discusses the speed and travel time evaluation of the signalized or urban section of the Cornelius Pass Road.

The urban segment of Cornelius Pass Road runs from TV Highway to West Union Road. The corridor contained several traffic signals and a major interchange with US 26. The signals in this corridor were upgraded to receive upgraded detection and advanced traffic controllers. Table 6.11 shows the analysis period.

ODOT traffic volume data showed a 2.5 to 3 percent growth in AADT from 2023 to 2024 at three different locations in the corridor. Growth in peak hour traffic was not tracked.

TABLE 6.11: DATA COLLECTION PERIODS - WEEKDAYS 3:40 – 4:40 P.M. PEAK HOUR

CORRIDOR LENGTH = 4.87 MILES (T.V. HWY. TO NW W UNION RD)	
SEGMENT	DATE
BEFORE	7/1/2021 to 6/30/2022
AFTER	7/1/2023 to 6/30/2024

Table 6.12 shows the travel speed and time in the *before* and *after* condition. Average speed decreased in both directions. Consequently, average travel time increased slightly.

In this section, the reliability measures were mixed. The 95th percentile travel time increased in both directions, as did the planning time index. The buffer index decreased in both directions, however. The goal of the project was to improve safety by reducing red-light-running and reducing pedestrian conflicts. The emphasis of the project was not to improve travel time or reliability so ATSPMs were not necessarily used to reduce delay, improve throughput or improve arrivals on green.

The travel times may be impacted by the RCE and pedestrian extension systems. As noted above, the RCE on the side street may reduce green time for the mainline. RCE on either the main line or the side street would take the signal out of coordination for a period of time. Similarly, the pedestrian extension may reduce green time for the mainline in response to slow crossing pedestrians or pedestrians who cross on the FDW.

TABLE 6.12: CORNELIUS PASS ROAD (URBAN SEGMENT)

		FREE FLOW SPEED (MPH)	AVERAGE SPEED (MPH)	95TH PERCENTILE SPEED (MPH)	FREE FLOW TRAVEL TIME (MIN)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
BEFORE	**NB**	34.02	27.14	30.97	8.58	10.75	12.37	0.15	1.44
	SB	33.31	26.27	30.27	8.77	11.12	12.85	0.16	1.47
AFTER	**NB**	34.35	25.60	29.62	8.5	11.4	13.02	0.14	1.53
	SB	33.52	25.69	29.63	8.72	11.37	12.89	0.13	1.48

Figure 6.14 and Figure 6.15 show the same speed and travel time information graphically.

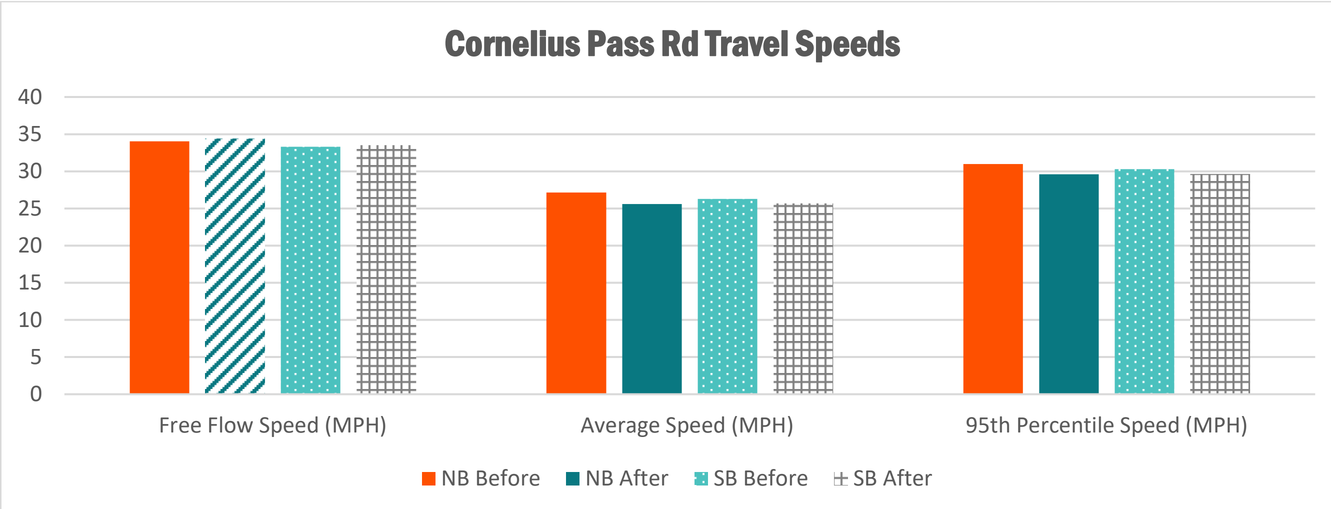

FIGURE 6.14: CORNELIUS PASS ROAD URBAN TRAVEL SPEEDS

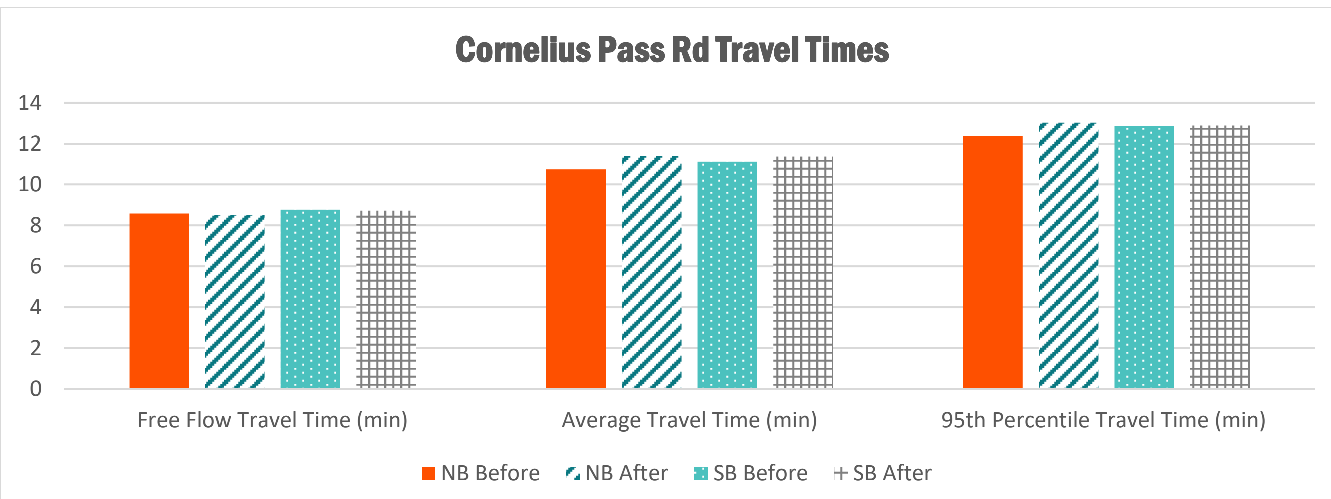

FIGURE 6.15: CORNELIUS PASS ROAD URBAN TRAVEL TIMES

BENEFIT/COST

BENEFITS OF REDUCTION IN DELAY

The team developed the monetary value of the reduction in travel time using values from ODOT's *Estimated Value of One Hour of Travel Time Savings by Vehicle Class*[24] published in 2025, the latest version of this report. The costs were applied to the reduction in average travel time during the peak period from 3 p.m. to 6 p.m. on weekdays as shown in Table 6.12 above. The reduction in peak hour delay was assumed to be the same across the entire peak period from 3p.m. to 6p.m. Traffic volumes were developed from ODOT's Oregon Traffic Count Database.[25] Values were assigned to cars and trucks based on classification counts from the same database. Per the FHWA guidance, cost of delay values was assigned to passenger cars and trucks. In the classification counts, Classes 1 through 3 were counted as passenger cars while Class 4 and above were counted as trucks. The monetary value of the delay in the peak period was assumed to be the total monetary value for the entire day. The value of the delay was annualized by multiplying the daily value by 260 working days in a year.

The reduction in delay was calculated using only the urban section of Cornelius Pass Road from Tualatin Valley Highway to NW West Union Road, where traffic signal improvements were implemented. This was because travel time and speed changes were expected to occur where traffic signal improvements were made. In contrast, no improvements were made along the remainder of the corridor, so conditions before and after the project in those areas were expected to be effectively the same. Changes in travel time in the rural section of the corridor would likely be independent of the project.

The benefit of the reduced travel time northbound and southbound was negative because travel times increased slightly. Northbound volumes were lower than southbound volumes in the afternoon peak.

The annualized cost of the increase in delay was $465,939.63, as shown in Table 6.13.

TABLE 6.13: ANNUALIZED BENEFIT OF REDUCTION IN DELAY

DIRECTION	VALUE OF REDUCED TRAVEL TIME PER DAY	WORKDAYS PER YEAR	ANNUAL BENEFIT OF REDUCTION IN DELAY
NORTHBOUND	-$1,260.31	260	-$327,679.46
SOUTHBOUND	-$531.77	260	-$138,260.17
TOTAL	-$1,792.08	260	-$465,939.63

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[24] ODOT Transportation Development Division Planning Section, Transportation Planning Analysis Unit. "Value of Travel Time Estimates," February 2025

[25] https://ordot.public.ms2soft.com/tcds/tsearch.asp?loc=Ordot&mod=TCDS

BENEFITS OF REDUCTION IN CRASHES

Safety benefits were derived from the crash or incident reduction within the project limits. While crash severity data was available, due to the relatively short time frame where crash data was available in the *after* period, it was decided not to rely on the severity data. The team assumed that all crashes were property damage only because of the lack of availability of crash severity data. The team assigned an economic value to the crash of $24,800. This was the value that ODOT developed for its safety program and was validated and used in other ODOT projects such as applying for safety funding.[26]

The benefits of crash reduction shown in Table 6.14 below highlight the reduction in crashes for the signals with improvements, excluding the crashes at the horizontal curve. The cost of crash reduction of the horizontal curve warning system from M.P. 2.85 and 3.13 are shown in Table 6.15. The values were separated because the systems were distinctly different, and the team wanted to isolate the benefits and cost of each individual system.

TABLE 6.14: BENEFITS OF CRASH REDUCTION FOR THE IMPROVED SIGNALS

INCIDENT TYPE	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	REDUCTION AMOUNT	COST PER CRASH	ANNUAL BENEFIT
CRASHES	33	28	5	$24,800	$124,000

The total annual benefit associated with the reduction in the cost of crashes for the signalized segment was $124,000.

TABLE 6.15: BENEFITS OF CRASH REDUCTION FOR THE HORIZONTAL CURVE

INCIDENT TYPE	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	REDUCTION AMOUNT	COST PER CRASH	ANNUAL BENEFIT
CRASHES	2	10	-8	$24,800	-$198,400

The total annual cost associated with the reduction in the cost of crashes for the horizontal curve was $198,400. The horizontal curve segment saw an increase of eight crashes in the *after* period. One factor leading to an increase could be based on incident response data. Crash data was based on ODOT incident response data. ODOT took jurisdiction of this portion of Cornelius Pass Road from Multnomah County in March of 2021. The *before* period analysis started in July of 2021. It was possible that the corridor was not fully integrated in ODOT's Incident Response program during the *before* period. For instance, if the 911 center did not reach out to ODOT's Dispatch, there may have been fewer calls than the *after* period. It was possible given the small number of crashes that it was a statistical anomaly.

[26] ODOT Transportation Planning Analysis Unit, *Values of Travel Time Estimates*, February 2025, Table 1, https://www.oregon.gov/odot/Planning/Documents/Value_of_Travel_Time_Estimates.pdf

Combining the cost of the crash reductions along the section of Cornelius Pass Road with signalized improvements and the horizontal curve, the total dollar amount equated to a total annual cost of $49,600.

TOTAL BENEFITS AND BENEFIT COST

To calculate the total benefits and benefit cost of the project, the team followed USDOT guidance by using the spreadsheet tool from the online Benefit Cost Analysis Guidance (2025 Update). As noted, the team used ODOT values for the cost of crashes and the value of travel time. Maintenance and operations costs for the curve warning system was $3,062. The signal improvements were not expected to incur any additional costs beyond those already associated with maintaining existing infrastructure while the maintenance costs of the ITS devices related to the traffic signals and the traffic signal upgrades were assumed to be $1,870. The ongoing maintenance costs were assumed to be consistent with the conditions before this project, and while there may have been minor costs due to inflation, these were considered negligible for the purpose of this analysis. As a result, no incremental maintenance and operation costs were included in the benefit-cost evaluation. In addition, it would have been very difficult to calculate the difference in cost for maintenance and operation of the City's original practices versus using ATSPMs now. Using the USDOT guidance a discount rate of 3.1 percent was applied to both the safety and travel time savings benefits for the ITS device's ten years of service life.

Three separate benefit-cost analyses were conducted to identify the individual and combined benefits of the systems installed as part of this project. The first analysis evaluated the horizontal curve warning system implemented between milepoints 2.85 and 3.15. The second analysis focused on the area with traffic signal improvements. The third analysis combined the total benefits of both systems along Cornelius Pass Road. The total benefits, costs, net present value, and benefit-cost ratio for each analysis are summarized in Table 6.16, Table 6.17, and Table 6.18.

The capital cost of installing the curve warning system was $350,987. The service life of the ITS devices was assumed to be ten years.

TABLE 6.16: BENEFIT COST RESULTS OF THE HORIZONTAL CURVE WARNING SYSTEM

TOTAL DISCOUNTED BENEFITS	TOTAL DISCOUNTED COSTS	NET PRESENT VALUE	BENEFIT COST RATIO
-$1,612,873	$345,883	-$1,958,756	-4.66

The capital cost of installing the signal improvements was $2,551,513. The service life of the ITS devices was assumed to be ten years.

TABLE 6.17: BENEFIT COST RESULTS OF THE TRAFFIC SIGNAL IMPROVEMENTS

TOTAL DISCOUNTED BENEFITS	TOTAL DISCOUNTED COSTS	NET PRESENT VALUE	BENEFIT COST RATIO
-$2,749,027	$2,514,402	-$5,263,429	-1.09

The total costs of the project were $2.8 million (adjusted to $2.97 million for 2023 dollars). The service life of these ITS devices was assumed to be ten years.

The benefits per year for the total project were calculated by combining the annual benefit from delay and crash reductions on the urban section, with the annual crash reduction benefit from the curve warning system on Cornelius Pass Road. The combined value was an annual cost of $545,272.

TABLE 6.18: BENEFIT COST RESULTS OF THE TOTAL PROJECT

TOTAL DISCOUNTED BENEFITS	TOTAL DISCOUNTED COSTS	NET PRESENT VALUE	BENEFIT COST RATIO
-$4,361,895	$2,860,285	-$7,222,180	-1.52

Although the benefit cost analysis for the project showed an annual cost and, therefore, net negative benefit in installing the project, the net negative benefit was primarily derived from an increase in crashes at the horizontal curves. Given the randomness and variability of crashes particularly in a short segment (0.5 mile), care should be taken before drawing conclusions. A longer period of *after* crash data would be required.

Overall, the system enabled automated data collection along the corridor, streamlining travel time and speed studies and signal timing adjustments. This could lead to better informed decision-making for the county and react accordingly to the data that the new system would provide. However, no empirical data was currently available to validate these improvements. In the curved section, the motorists were getting feedback about the appropriate speed.

FINDINGS

ASSESSMENT OF OVERALL SYSTEM PERFORMANCE

Is average and median speed through the horizontal curves reduced?

The average speed reductions through the curve depending on direction and day of the week ranged from 4 to 14 percent. Actual reductions in average speed ranged from 1.2 mph to 3.8 mph. The median speeds through the horizontal curves were reduced and 6 to 14 percent, respectively, depending on day of the week. Actual reductions in median speed ranged from 1.7 mph to 4.5 mph.

How effective is weather messaging and VMS alerts in reducing weather-related crashes in the corridor?

The VMS that was to provide this specific information was not installed. Nearby signs on other routes provided information about crashes and road construction in the corridor. Weather messaging was minimal and not specific to this corridor.

The crash data did not show that weather-related crashes were reduced, but the relatively small number of crashes and the short evaluation period meant that drawing a conclusion would be difficult.

Are red-light-running and/or near-miss events reduced?

Crashes went down at signalized intersections where improvements beyond a controller update were made. While the evaluations could not tie a specific reduction in red-light-running to the improvements, it was logical that the introduction of improvements such as red clearance extension, pedestrian call extension, truck extension, and the resulting reduction in crashes had a positive effect on red-light-running and near-miss events.

Has the variability of average travel speeds decreased on Cornelius Pass Road from US 30 to TV Highway during the weekday evening peak hour?

The variability of average travels speeds was not decreased on Cornelius Pass Road from US 30 to TV Highway. On the rural section from West Union Road to US 30, there were no project elements that would likely lead to a reduction in the variability of average travel speeds. The only improvement was the curve warning system.

On the urban signalized section, there was not an overall reduction in variability of average travel times. The buffer index improved, but the 95th percentile travel time and the planning time index worsened. While signal improvements were made, the goal of the improvements was to improve safety and not necessarily improve travel time.

How often is truck priority for freight vehicles employed on the Cornelius Pass Road corridor?

The analysis was unable to determine the frequency that truck priority was employed. Though the Wavetronix system was able to provide data on the number of truck detections, there was no output file in the traffic signal corridor to tell how often the extension or priority impacted traffic signal operations.

How many times is the pedestrian system activated (by mode: call cancellation mode and interval extension mode

Signal operation staff at Washington County provided information on pedestrian call extension data at two traffic signals. They provided a week of data. For most hours there were no call extensions. The most extensions were 12 in the noon hour at NE Evergreen Parkway. There were a number of late-night extensions at W Baseline Road/E Main Street, but these could be indicative of a detector stuck on.

IDENTIFICATION OF ISSUES

ITS CURVE WARNING SIGN

The elimination of the VMS sign on Cornelius Pass Road from the project made it difficult to measure the impacts of weather messages. The existing DMS on US 26 and US 30 were quite far from the curve in question and the number of travelers on those facilities using Cornelius Pass Road was relatively low. Also, since US 26 and US 30 are key commuter routes and high-capacity roadways, most of the messaging would have been geared to users on those routes.

Also, it was not possible to measure the impact of weather messaging that travelers received in other ways, such as traditional or social media.

The relatively small number of crashes in the curve in the *before* period made the safety evaluation challenging. Natural statistical variation in the number of crashes for the relatively short evaluation period could show an increase in crashes (as this did), though the system appeared to be working as intended. In this case, the activation of the sign appeared to have a positive effect on reducing speeds.

TRAFFIC SIGNAL IMPROVEMENTS

The OSU evaluation of the pedestrian call extension showed that the system was effective at identifying slow-moving pedestrians. The system did increase delays for motor vehicles. The pedestrian call cancellation system was ultimately not implemented because the potential operational benefits did not seem to outweigh the potential safety risks of cancelled pedestrian calls.

The team could see that the detectors were identifying trucks approaching the signal, but could not tell what the traffic signal was doing with the information.

Without detailed crash data, it was difficult to assess the effects of the improvements on red-light-running. Detailed crash data can take several years to accumulate. A detailed crash analysis would take at least two years of *after* data and was not part of the project's scope.

RECOMMENDATIONS FOR OPERATIONS

ITS CURVE WARNING SIGN

The addition of the VMS on Cornelius Pass Road would help with operations and weather messaging prior to the curves. The project is in development and should be in place in the near future.

Similarly, a more detailed look at high end speeds should be considered. It is possible that average and median drivers are reducing their speeds, but the fastest drivers are not.

TRAFFIC SIGNAL IMPROVEMENTS

A review of the OSU study on pedestrian call extension and cancellation system should be completed when the research is submitted to ensure the safety and operational tradeoffs are well understood.

The County should track truck extensions at the controller level to better understand the impact.

Since the evaluation of the pedestrian call extension and cancellation system has not been completed, the team was not able to see the results at the desired level. Data showed that though the extension system was making calls, the team lacks the detailed data and evaluation to determine how effective the system is in this location

The evaluation that OSU completed previously showed that the call extension and cancellation system had benefits, but the context was different at a signalized trail crossing versus a traditional four-legged traffic signal. It was likely the number and type of extensions would be different, as would the impact of the call cancellation.

Similarly, the team could see that detectors were identifying trucks approaching the signal, but could not tell what the traffic signal was doing with the information. Configuring an output file for the data would help provide meaningful data on the technology.

Combining red clearance extension data, truck extension, and pedestrian extension and cancellation data would allow the County to understand the safety and operational tradeoffs in the corridor.

7 ODOT US 97 Road Weather Management Evaluation

PROJECT BACKGROUND

US 97 in Central Oregon experiences high traffic volumes because it provides access to recreational attractions and businesses that generate significant economic activity for Central Oregon. It is also used as a route for people living in the Sunriver and La Pine areas to commute to employment centers in the Bend area. US 97 is a key freight corridor on the east side of the state and carries a high volume of commercial freight trucks. At times, adverse weather may close I-5 in Southern Oregon and Northern California. Commercial traffic may divert to US 97 to avoid the closures on I-5. The demand on US 97 during the winter leads to a high number of speed and weather-related crashes. The highway also experiences a significant number of snow and ice events in winters that require drivers to operate their vehicles in winter weather conditions. ODOT addressed this by implementing a road weather management system, as part of its statewide Active Traffic Management (ATM) system, that would span a large section of the highway, including areas with the highest observed crashes.

One of the contributing factors to crashes on the roadway was driving too fast for conditions, particularly during adverse weather, when many drivers failed to adjust their speeds accordingly. Road and weather information systems (RWIS installed on US 97 in the past provided information to travelers via ODOT's Trip Check website and real time information on dynamic message signs posted manually by dispatch operators. However, information during the winter was inconsistent and was difficult for drivers to access in real-time. As part of this SMART mobility project, this component project installed additional variable speed signs and dynamic message signs to provide travelers with real-time roadway conditions. The roadside sensors provided the data to ODOT's ATM software system and the system automatically posted the variable speed limits and weather-related traveler information on dynamic message signs. ODOT's ATM central software system could operate variable speed limits and advisory speeds based on both congestion conditions and road and weather conditions. ODOT has operated road and weather-based variable speeds since 2015. The agency installed similar road and weather systems at I-5 at Siskiyou Pass, I-84 at Cabbage Hill, US 26 at Mount Hood, and I-84 at Baker Valley.

LEFT: AERIAL US 97 AT EXIT 135; TOP, BOTTOM RIGHT: NEW VARIABLE SPEED LIMIT SIGNS BETWEEN BEND AND LA PINE

Source: ODOT

PROJECT DESCRIPTION

This ODOT US 97 Road Weather Management project deployed a weather-responsive variable speed system on US 97 from MP 143.68 to MP 164.17 as part of an overarching system that would ultimately extend to MP 243.22. The project was divided into three distinct segments based on weather severity, traffic volumes, and crash data. The segments were:

- Bend to La Pine (Priority #1): MP 143.68 to MP 164.17
- La Pine to Chemult (Priority #3): MP 164.17 to MP 204.10
- Chemult to Spring Creek Hill (Priority #2): MP 204.10 to MP 243.22

The project installed RWIS, which consisted of measuring wind speed and direction, temperature, humidity, dew point, grip factor of the road, visibility, road surface temperature, road surface classification, and amount of water, ice, and snow on the road. Radar sensors capable of measuring vehicle speeds, volumes, and occupancy, and dynamic message signs at sites 1-7 were also installed. The goal of the project was to address winter weather-related crashes and safety issues in the corridor to improve travel time and travel time reliability.

Variable speed limits have shown a decrease in winter weather-related crashes of up to 50 percent on I-80 in Wyoming. In addition to safety benefits, a variable speed system could provide secondary benefits.

- Real-time data from additional RWIS stations supported maintenance crew decisions regarding snow and ice control measures, which improved resource allocation efficiency.
- Additional traveler information was provided to ODOT's existing TripCheck system to support informed traveler decisions.

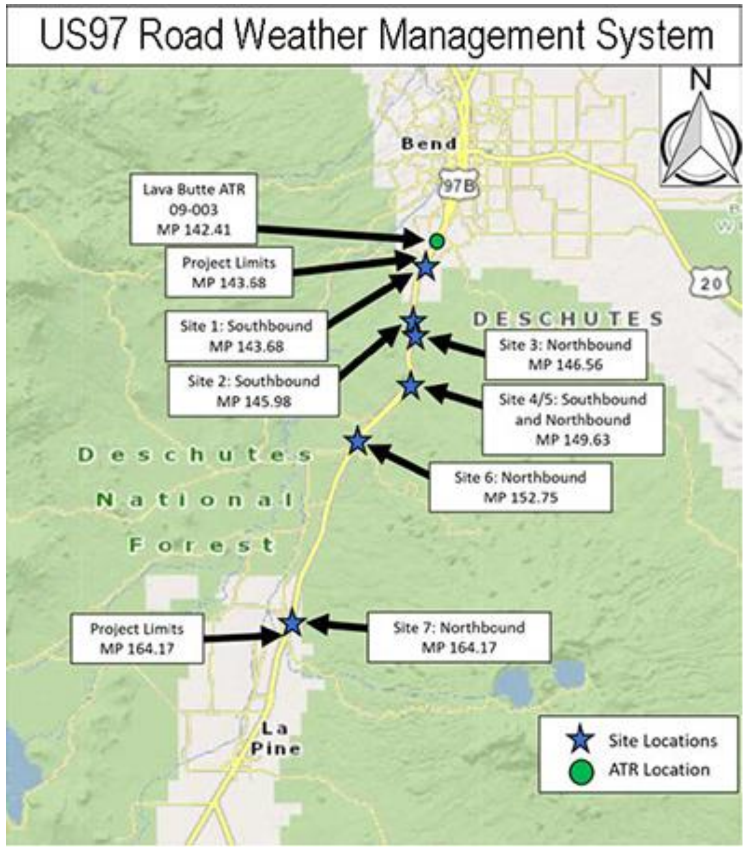


FIGURE 7.1: US97 VICINITY MAP OF BEND TO LA PINE

KEY COMPONENTS

Important components of the project included:

- Nonintrusive Road Surface Sensors capable of measuring the grip factor, visibility, road temperature and other surface conditions
- Road weather information systems for traditional atmospheric monitoring
- Variable speed signs
- Dynamic message signs (DMS)
- Radar sensors measuring speeds, volumes, and occupancy
- Supplementary signs
- Closed-circuit television cameras
- TripCheck travel information system expansion

The cost of the project was $3,250,000.

CORRIDOR OPERATIONS

US 97 is a four-lane divided highway, heading south from Bend. From the start of the project to the summit of Lava Butte Pass, it has a narrow median with a concrete barrier. From the summit of Lava Butte Pass to just north of Vandevert Road, the median widens out to a large median of more than 60 feet. South of Vandevert Road to the northern city limit of La Pine, the highway is a two-lane undivided highway with intermittent passing lanes.

The US 97 corridor south of Bend operates with a morning peak in the northbound direction as motorists commute to employment and educational centers in the regional hub of Bend from the Sunriver and La Pine areas. The afternoon peak is southbound away from Bend towards Sunriver and La Pine. Additionally on Thursday and Friday evenings, p.m. peak traffic increases with tourists heading from population centers in the Willamette Valley traveling to the resort area at Sunriver. Many of these travelers are less familiar with driving in adverse weather conditions and unaware that the weather can change dramatically while driving from Bend to Sunriver, ascending approximately 500 hundred feet up Lava Butte.

LEFT: VARIABLE SPEED LIMIT SIGN AT LAVA BUTTE, RIGHT: VARIABLE SPEED LIMIT SIGN AT BEND SCALES

OTHER CONSIDERATIONS

During the 2021 and 2022 construction seasons, ODOT completed the US 97: S. Century Drive (MP 153.12) to U.S. Forest Service Boundary (MP 156.05) Project. The project extended the four-lane divided section from S. Century to Vandevert Road and reconfigured the Vandevert Road intersection with US 97.

EVALUATION GOALS, OBJECTIVES AND QUESTIONS

ODOT provided the Federal Highway Administration with evaluation goals, objectives, and questions as part of the ATCMTD grant process, which are shown in Table 7.1.

TABLE 7.1: EVALUATION GOALS, OBJECTIVES AND QUESTIONS

GOAL AREA	DESCRIPTION/OBJECTIVES	EVALUATION QUESTION
IMPROVE SAFETY	Reduce traffic crashes Reduce crashes resulting from weather and congestion	Determine if the improvements affected crash rates and severity profiles on US 97 from MP 143 to MP 164. Determine if the improvements affected crash rates for crashes resulting from weather and congestion.
IMPROVE MOBILITY	Improve travel time reliability	Determine if the variability of average weekday and average weekend travel speeds decreased on US 97 between MP 143 and MP 164.
IMPROVE OPERATIONS	Provide real-time information about roadway and traffic conditions	Determine if the real time information about roadway and traffic conditions on US 97 between MP 143 and MP 164 was available to road users and private sector entities.

DATA COLLECTION

The data before the RWIS components were installed (*before* period) was collected from November 2020 through April 2022. The data after the installation (*after* period) was collected from November 2022 through April 2024. Each *data collection period* covered a two-winter time frame and aimed to capture the most available data for evaluation purposes. DKS then screened the data sets for completeness and quality and performed preliminary statistical analysis.

DKS developed performance measures that answered the evaluation questions and determined whether the evaluation objectives were met. The performance measures and associated data type necessary to evaluate objectives are shown in Table 7.2.

TABLE 7.2: PERFORMANCE MEASURES AND DATA SOURCES

EVALUATION OBJECTIVE	PERFORMANCE MEASURES	ASSOCIATED DATA TYPE
6. DETERMINE IF THE IMPROVEMENTS AFFECTED CRASH RATES AND/OR CRASH SEVERITY ON US97 FROM MP143 TO MP164	A. Traffic incident rate B. Incident severity profile	• Incident logs • Traffic volumes
7. DETERMINE IF THE IMPROVEMENTS AFFECTED CRASH RATES FOR CRASHES RESULTING FROM WEATHER AND CONGESTION	C. Traffic incident rate for weather D. Congestion-related incidents rates	• Incident logs • Traffic volumes
8. DETERMINE IF THE VARIABILITY OF AVERAGE WEEKDAY AND AVERAGE WEEKEND TRAVEL SPEEDS DECREASED ON US97 BETWEEN MP143 AND MP164	E. Average speed F. 95th percentile speed G. Buffer index H. Planning time index	• Road segment lengths • Weekday PM peak hour and weekend travel time information, 5-minute intervals
9. DETERMINE IF REAL TIME INFORMATION ABOUT ROADWAY AND TRAFFIC CONDITIONS ON US97 BETWEEN MP143 AND MP164 WAS AVAILABLE TO ROAD USERS AND PRIVATE SECTOR ENTITIES	I. Percent of time TripCheck displays real-time roadway and traffic conditions particularly when the speeds are reduced	• TripCheck availability of real-time roadway and traffic conditions

The evaluation used ODOT Incident Logs from its dispatch software instead of reported crashes due to the significant delay in processing reported crashes from the ODOT's Driver and Motor Vehicles (DMV) Services Division. This allowed the safety analysis to be completed more quickly than if the analysis relied on official crash reports. The data in this report were incidents logged into ODOT's Incident Reporting System as crashes. Incidents were recorded by ODOT dispatchers from reports from ODOT Incident Responders or local agency emergency responders. The dispatcher would note in the report whether the incident was a crash or something else (e.g., disabled vehicle). Unfortunately, the incident data only noted the severity of the crash if it was fatal. As a result, assessing changes in crash severity was challenging.

For this report, when the term "crash" is used, it represents an incident reported as a crash.

The data sources for each data type are shown in Table 7.3.

TABLE 7.3: DATA SOURCES

DATA TYPE	DATA SOURCE	RESPONSIBLE PARTY
HIGHWAY SEGMENT LENGTHS	Google Earth	DKS
INCIDENT LOGS	ODOT dispatch system	DKS/ODOT
SPEED/TRAVEL TIME	INRIX data via RITIS	DKS
TRIPCHECK AVAILABILITY OF REAL-TIME ROADWAY AND TRAFFIC CONDITIONS	TripCheck Website	DKS/ODOT

DATA ANALYSIS

TRAFFIC INCIDENT RATE

As noted above, *before* and *after* crashes were determined from ODOT Incident logs where incidents were coded as crashes not ODOT's official crash reporting system. In this report, except where otherwise noted, the term *crash* refers to an incident reported as a crash not an official reported crash.

The DKS team compiled all recorded incidents that were coded in the Incident Response system as crashes. ODOT's Incident Responders and Dispatchers had standard operating procedures and guidelines for reporting incidents as crashes. Incident reports should have remained consistent across the time frame of the report as the procedures had not changed. The *Other* category were crashes that required an investigation for reasons other than a fatality, crashes where a motorist struck an animal such as a deer, and crashes where the motorists damaged ODOT property (e.g., a signpost or guardrail).

In the two winter periods from November 2020 through April 2022, there were 290 crashes in the segment. These are shown in Table 7.4. In the two years from November 2022 through April 2024, there were 343 crashes. These are shown in Table 7.5.

TABLE 7.4: BEFORE INCIDENTS AND RATES

INCIDENT TYPE	NO. OF INCIDENTS NOV. 2020 – APRIL 2021	NO. OF INCIDENTS NOV. 2021 – APRIL 2022	NO. OF INCIDENTS (BEFORE)	INCIDENT RATE (PER 100 MILLION VMT) (BEFORE)
CRASH	124	148	272	65.14
FATAL CRASH	1	0	1	0.24
OTHER	10	7	17	4.07
TOTAL	135	155	290	69.45

Because crashes were higher in the *after* period, the team separated the data into individual winters to see if there were any *very high* or *low* crash winters. Crashes appeared to be relatively consistent winter to winter.

TABLE 7.5: AFTER INCIDENTS AND RATES

INCIDENT TYPE	NO. OF INCIDENTS NOV. 2020 – APRIL 2021	NO. OF INCIDENTS NOV. 2021 – APRIL 2022	NO. OF INCIDENTS (BEFORE)	INCIDENT RATE (PER 100 MILLION VMT) (BEFORE)
CRASH	167	151	318	75.15
FATAL CRASH	2	0	2	0.5
OTHER	11	12	23	5.44
TOTAL	180	163	343	81.06

Table 7.6 shows the total number of crashes in the *before* and *after* winters, the percentage change in the number of crashes, the crash rates, and the percentage change in the rates.

TABLE 7.6: BEFORE AND AFTER INCIDENTS AND RATES

INCIDENT TYPE	NO. OF INCIDENTS (BEFORE)	NO. OF INCIDENTS (AFTER)	PERCENTAGE CHANGE IN THE NO. OF INCIDENTS	INCIDENT RATE (PER 100 MILLION VMT) (BEFORE)	INCIDENT RATE (PER 100 MILLION VMT) (AFTER)	PERCENTAGE CHANGE
CRASH	272	318	16.9%	65.14	75.15	15.4%
FATAL CRASH	1	2	100%	0.24	0.47	95.8%
OTHER	17	23	35.3%	4.07	5.44	33.7%
TOTAL	290	343	18.3%	69.45	81.06	16.7%

There was an increase in the number of total incidents (18.3 percent). The increase in the number of fatal crashes in the *after* period could be a statistical variation, as fatal crashes are relatively rare events compared to the overall number of crashes, with small changes in the number appearing to have a large percentage change. The same factors influenced the percentage change of *Other* crashes. It as not specifically possible to determine the benefit of the VSL system independent of winter weather conditions. A very mild winter could result in a reduction of incidents because there were fewer periods where the roadway was impacted by snow and ice. Anecdotally, based on discussions with ODOT Maintenance Managers, the *after* winters were similar the *before* winters, but with more adverse weather in the spring (March and April) in the *after* period.

The team reviewed several additional factors that could explain why the number of crashes increased in the *after* period. The team reviewed roadway conditions for a correlation between road conditions and increased crashes. The team reviewed the northern segment from the City of Bend to S. Century Drive because the density of VSL signs was higher at the north end of the project between Bend and S. Century. The team then reviewed the crashes in the shorter segment by road conditions and compared crashes to the entire segment. The team reviewed traffic volumes to see if there was a correlation between changes in traffic volumes and crashes. Lastly, the team mapped crashes to see if patterns could be seen from the visual representation of crashes.

EVALUATION OF ROAD CONDITIONS

The evaluation of individual winter periods was performed by DKS team members. The number of crashes, roadway conditions, and weather conditions for each winter were evaluated to determine if the cause of the increase in crashes in the *after* period was a result of worsened roadway conditions.

ODOT maintenance teams reported road and weather conditions to dispatchers in the Regional Traffic Operations Center (TOC) during the winter. The dispatchers then entered the data into a database. These reports were called 12-37s for their numeric code in the radio communications callbook for the report.

A summary of 12-37 reports is shown in Table 7.7. The number of reports for each roadway condition was shown in each winter and the total for the *before* and *after* conditions. The percentage change of each condition is shown as well.

TABLE 7.7: ODOT 12-37 ROAD AND WEATHER REPORTS

ROADWAY CONDITION	2020-2021	2021-2022	TOTAL BEFORE	2022-2023	2023-2024	TOTAL AFTER	PERCENTAGE CHANGE
BARE PAVEMENT	515	446	961	298	403	701	-27%
BLACK ICE	6	0	6	8	16	24	300%
NO REPORT	18	27	45	1	0	1	-98%
PACKED SNOW	56	64	120	45	62	107	-11%
SLUSH, SNOWPACK BREAKING UP	28	16	44	14	11	25	-43%
SPOTS OF ICE	176	99	275	286	161	447	63%
STANDING WATER OR FLOODING ON ROADWAY	3	0	3	4	1	5	67%

The summary of 12-37's supported the anecdotal evidence that the *after* winters were slightly worse in the *after* period than in the *before* period. There were large percentage increases in "Black Ice" and "Spots of

Ice" and smaller percentage decreases in "Packed Snow" and "Slush, Snowpack, Breaking Up." There was a very large actual increase in "Spots of Ice" in the *after* condition.

The team identified which crashes occurred during specific roadway conditions to see if any pattern could be identified by comparing the dates and times of the 12-37 with the dates and times of the crashes.

Table 7.8 below shows the number of crashes for each winter categorized by roadway condition. The evaluation found that there was an increase in crashes during adverse roadway conditions from 214 crashes in the before, to 264 in the after (23.4 percent increase). The highest frequency of roadway conditions in this evaluation was "Spots of Ice" and "Packed Snow." The number of crashes occurring during "Spots of Ice" significantly increased in the after period (100 percent). Conversely, the frequency of "Packed Snow" crashes decreased afterwards (23.8 percent).

TABLE 7.8: CRASHES BY WINTER ROADWAY CONDITIONS FOR CORRIDOR OF US97

ROADWAY CONDITION	2020-2021	2021-2022	2022-2023	2023-2024
BARE PAVEMENT	31	45	47	33
BLACK ICE	2	0	4	18
PACKED SNOW	48	53	28	49
SLUSH, SNOWPACK BREAKING UP	17	18	19	7
SPOTS OF ICE	31	38	82	56
UNKNOWN/OTHER	6	1	1	0

Table 7.9 shows the summary during the entirety of the before and after periods along the corridor

TABLE 7.9: SUMMARY OF CRASHES ALONG THE CORRIDOR BASED ROADWAY CONDITIONS BEFORE AND AFTER

ROADWAY CONDITION	CRASHES ALONG CORRIDOR (BEFORE)	CRASHES ALONG CORRIDOR (AFTER)	PERCENTAGE DIFFERENCE
BARE PAVEMENT	76	80	5%
BLACK ICE	2	22	1000%
PACKED SNOW	101	77	-24%
SLUSH, SNOWPACK BREAKING UP	35	26	-26%
SPOTS OF ICE	69	138	100%
UNKNOWN/OTHER	7	1	-86%

One way to interpret the results was that the number of crashes during adverse roadway conditions increased in the *after* period. This suggested worsening winter conditions over time, which likely contributed to a rise in the number of crashes.

Table 7.10 shows the percentage change in the reported roadway condition versus the percentage change in the number of crashes.

TABLE 7.10: PERCENTAGE CHANGE IN THE NUMBER OF ROADWAY CONDITION AND CRASHES

ROADWAY CONDITION	PERCENTAGE CHANGE IN CONDITION	PERCENTAGE CHANGE IN CRASHES
BARE PAVEMENT	-27%	5%
BLACK ICE	300%	1000%
PACKED SNOW	-11%	-24%
SLUSH, SNOWPACK BREAKING UP	-43%	-26%
SPOTS OF ICE	63%	100%

In only one case was the reduction in crashes higher than the reduction in the reported condition with reports of “Slush, Snowpack Breaking Up” reduced by 11 percent and a 43 percent reduction in crashes.

EVALUATION OF THE NORTHERN SEGMENT

To further examine the increase in crashes after the installation of this project, DKS also evaluated the northern segment of US97 from mile point 143.68 to 152.75, the segment between Sites 1 and 6. The density of VSL signs was higher in this segment. The purpose of this was to observe any noticeable change in the number of crashes in the areas where motorists were specifically given more guidance on the speed. Table 7.11 shows the number of crashes for the *before/after* periods of the segment of interest and the project corridor. The percentage difference between the *before* and *after* for each of the roadway lengths is also listed. It was observed that the segment of interest saw a higher proportional increase in the number of crashes, with non-fatal crashes increasing by 32.5 percent and non-fatal crashes increasing by 16.9 percent for the corridor.

TABLE 7.11: COMPARISON OF CRASHES FROM MP 143.68 TO 152.75 AND THE ENTIRE CORRIDOR

CRASH TYPE	NO. OF CRASHES FROM MP 143.68 TO 152.75 (BEFORE)	NO. OF CRASHES FROM MP 143.68 TO 152.75 (AFTER)	PERCENTAGE DIFFERENCE	NO. OF CRASHES ALONG CORRIDOR (BEFORE)	NO. OF CRASHES ALONG CORRIDOR (AFTER)	PERCENTAGE DIFFERENCE
CRASH	132	175	32.5%	272	318	16.9%
FATAL CRASH	0	1	N/A	1	2	100%
OTHER	8	12	50.0%	17	24	41.1%
TOTAL	140	188	34.2%	290	344	18.6%

Table 7.12 below shows the comparison of the Percentage Difference of crashes between the segment from MP 143.68 to 152.75 to entire corridor.

TABLE 7.12: PERCENTAGE DIFFERENCE IN CRASHES BETWEEN SEGMENT OF INTEREST AND THE CORRIDOR

CRASH TYPE	PERCENTAGE DIFFERENCE	CRASH TYPE
CRASH	32.5%	16.9%
FATAL CRASH	N/A	100%
OTHER	50.0%	41.1%
TOTAL	34.2%	18.6%

Overall crashes increased more in the northern portion of the corridor than the entire corridor.

Table 7.13 below categorizes the crashes that occurred based on roadway condition during the time of the crashes and lists the percentage difference between the two values. Crashes that occurred during “Spots of Ice” saw a higher proportional increase in the segment of interest compared to the corridor. Both saw a significant increase in the number of “Black Ice” events (1,800 percent, 1,000 percent).

TABLE 7.13: NUMBER OF CRASHES BASED ON ROADWAY CONDITIONS FOR ALL OF US97 AND MP 143.68 – 152.75

ROADWAY CONDITION	CRASHES ALONG SEGMENT FROM MP 143.68 TO 152.75) (BEFORE)	CRASHES ALONG SEGMENT FROM MP 143.68 TO 152.75) (AFTER)	PERCENTAGE DIFFERENCE FOR MP 143.68 TO 152.75)	PERCENTAGE DIFFERENCE FOR CORRIDOR
BARE PAVEMENT	38	37	-3%	5%
BLACK ICE	1	19	1800%	1000%
PACKED SNOW	50	52	4%	-24%
SLUSH, SNOWPACK BREAKING UP	22	14	-36%	-26%
SPOTS OF ICE	29	64	121%	100%
UNKNOWN/OTHER	0	2	N/A	-86%

The number of crashes happening in the *after* periods for both the segment of interest and the corridor was observed to have increased compared to the *before* period. In addition, the number of black ice and spots of ice conditions increased according to the ODOT 12-37 data reported in this area. The percentage differences of the crash reports and the 12-37 roadway data were assessed based on their respective *before* and *after* periods to determine if there was a correlation between the changes observed in each and to see where there was an overrepresentation or underrepresentation of crashes by roadway conditions. Table 7.14 lists the percentage differences. Although they had both increased, the number of crashes saw a higher percentage increase compared to the 12-37 roadway condition reports. This could suggest that while there were harsher conditions on the road during the *after* period, the roadway conditions themselves could not justify the entire increase observed in the crashes.

TABLE 7.14: COMPARISON OF PROPORTIONAL INCREASES BETWEEN VSL ROADWAY CONDITIONS AND CRASHES

ROADWAY CONDITION	PERCENTAGE DIFFERENCE FOR CRASHES	PERCENTAGE DIFFERENCE FOR 12-37 ROADWAY REPORTS
BARE PAVEMENT	-3%	-27%
BLACK ICE	1800%	300%
PACKED SNOW	4%	-11%
SLUSH, SNOWPACK BREAKING UP	-36%	-43%
SPOTS OF ICE	121%	63%

There was very little correlation between the changes in the number of crashes and roadway conditions. The only condition where there appeared to be correlation was for the "Slush, Snowpack Breaking Up." Crashes in the "Black Ice" and the "Spots of Ice" conditions went up. The number of roadway conditions that specified "Black Ice" and the "Spots of Ice" conditions also increased by nearly as much of the crashes. Crashes on "Packed Snow" increased slightly while the condition was reported less frequently. Crashes on "Bare Pavement" decreased slightly while the condition was reported nearly 25 percent less.

The data suggested that ODOT may want to review the operations of the VSL system during periods of "Black Ice" and "Spots of Ice."

TRAFFIC VOLUMES

The team explored whether increases in traffic volumes were potentially a factor in the increase in the number of crashes. The team reviewed Average Annual Daily Traffic growth, year over year, and the average daily traffic per month for the winter months in the *before* and *after* period. There were months with increased volumes, but the growth was not across the board, and some months showed decreases.

COMPARISON TO ADJACENT SECTIONS

The team explored whether crashes increased in the *after* period on an adjacent segment compared to the *before* period. An increase in crashes on an adjacent segment would support the idea that the winter road conditions were worse in the *after* period.

The team examined the segment on US 97 from US 97 at the south end of La Pine (168.56) to the OR 58 Junction (MP 189.05). This rural segment was the same length as the study segment.

SEGMENT	NO. OF INCIDENTS	SEGMENT	NO. OF INCIDENTS
LA PINE – OR 58	84	141	67.9%

The 67.86 percent increase in the number of crashes in the adjacent section was larger than the 18.3 percent increase in the number of crashes in the study segment. This increase supported the idea that the *after* winters were worse than the *before* winters.

CRASH MAPPING

The team mapped crashes in the *before* and *after* conditions. The corridor was divided into the northern portion from Bend to S. Century, and the southern portion from S. Century to La Pine.

Figure 7.2 (left) shows crashes in the *before* period in the northern segment of the corridor, while the figure on the right shows the *after* crashes on the same corridor.

FIGURE 7.2: (LEFT): BEFORE CRASHES NORTHERN SEGMENT; (RIGHT): AFTER CRASHES NORTHERN SEGMENT

There was no obvious change in crash pattern between the *before* and *after* periods.

Figure 7.3 (left) below shows the *before* crashes in the southern segment of the corridor, while the figure on the right shows the *after* crashes on the same corridor.

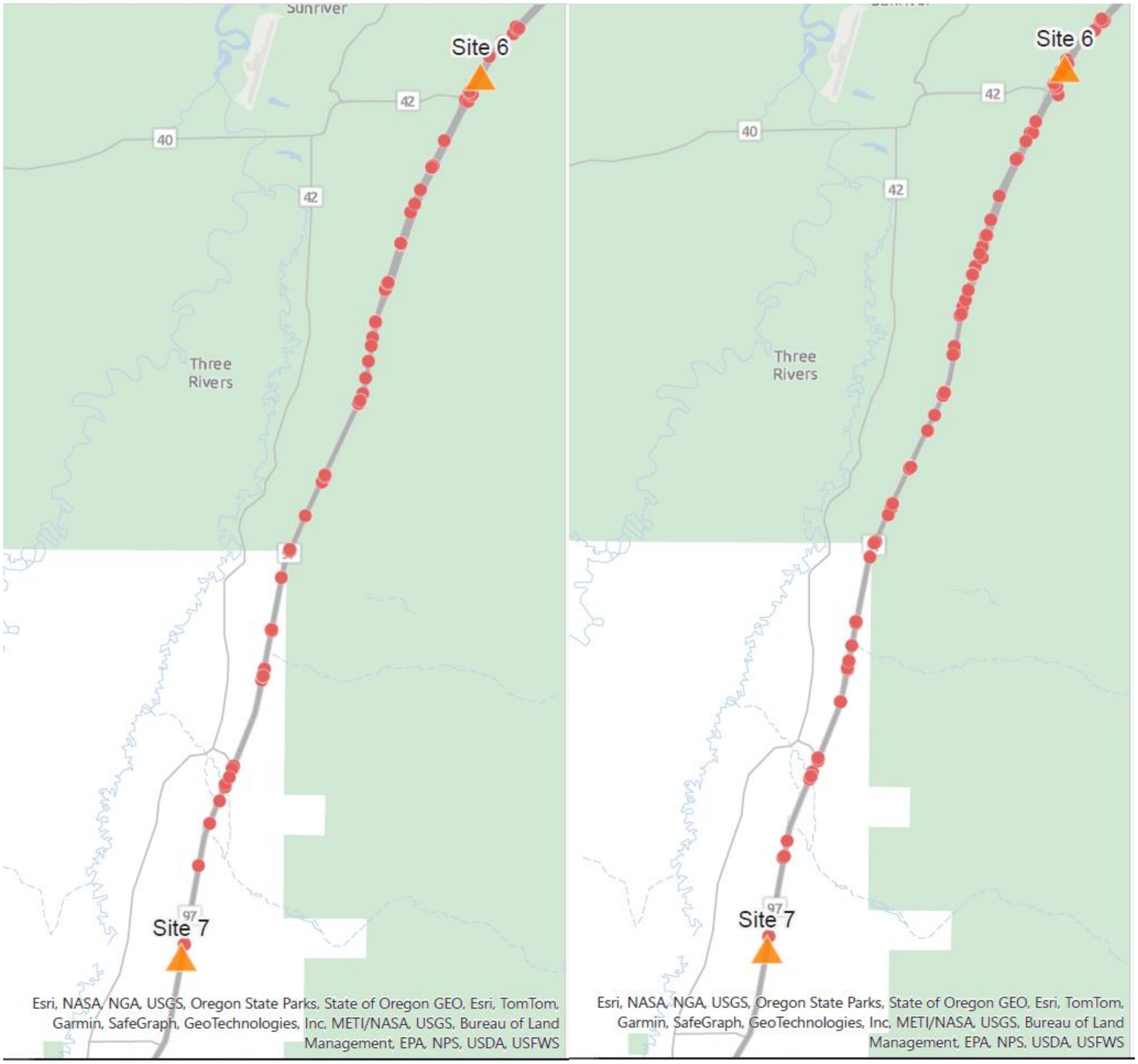


FIGURE 7.3: (LEFT): CRASHES SOUTHERN SEGMENT; (RIGHT): BEFORE AFTER CRASHES SOUTHERN SEGMENT

The crash mapping also did not show a decrease in crashes in the section that was widened between S. Century and Vandevert Road. A reduction in crashes, or at least severity, would be expected where the section was widened from two lanes to four with a wide median. Figure 7.4 shows the extent of the road widening project from the US 97: South Century Drive to US Forest Service Boundary Project.

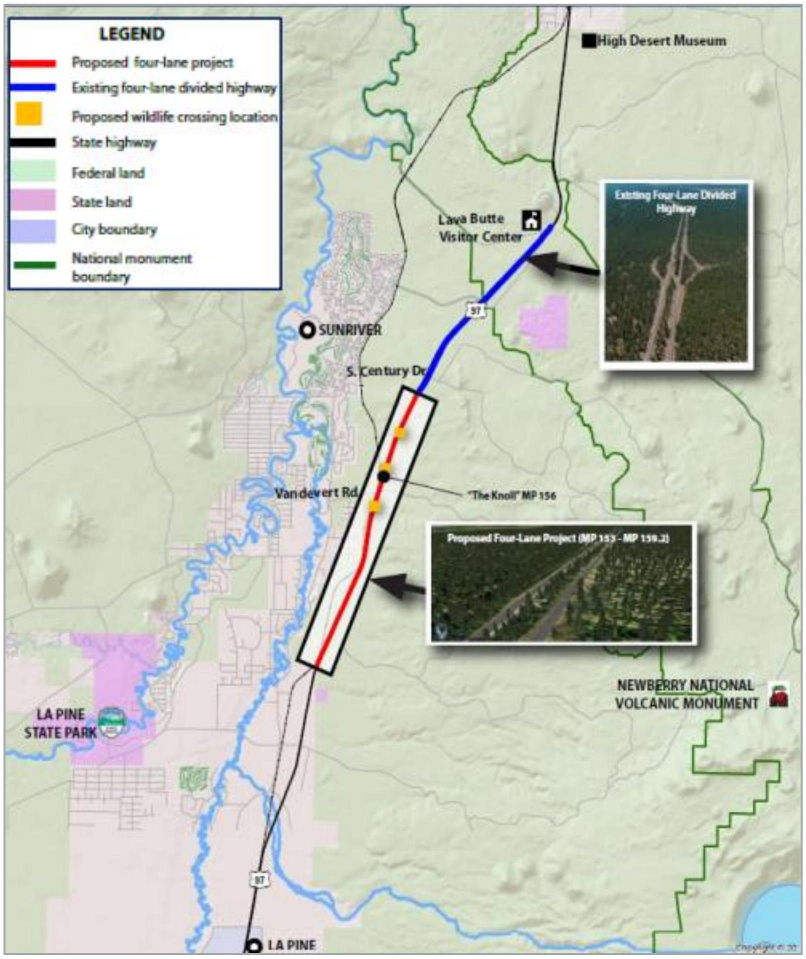


FIGURE 7.4: US 97: SOUTH CENTURY DRIVE TO US FOREST SERVICE BOUNDARY PROJECT

Source: ODOT

The mapping did show some hot spots that would help determine the optimal places to expand the system with additional weather sensors and speed signs.

CORRELATION WITH CRASH DATA

ODOT had official crash records available for the *before* period. To understand whether the Incident data was a surrogate for crash data, Table 7.15 below shows the number of reported crashes for the entire corridor in the *before* winters.

TABLE 7.15: BEFORE CRASHES

CRASH TYPE	NO. OF CRASHES (BEFORE)	NO. OF INCIDENTS REPORTED AS CRASHES (BEFORE)
FATAL	1	1
INJURY CRASHES	46	N/A
NO INJURY	46	N/A
TOTAL	93	290

There was a significant difference in the number of reported crashes and the number of incidents recorded as crashes, with a much higher number of incidents reported as crashes than officially reported crashes. This was likely due to ODOT's aggressive Incident Response program, focused on the US 97 corridor. In the winter, there were likely many cars that left the roadway in snow and ice conditions. These vehicles were likely to sustain minor or no damage. The incident was reported as a crash by ODOT's snowplow operators or incident responders. Because there was no damage, the driver was unlikely to report the crash.

TRAVEL SPEED

In the winter periods from November 2020 through April 2022 and November 2022 through 2024, DKS calculated travel speeds and travel time reliability. The team evaluated the following measures: Average Travel Speed, 95th Percentile Travel Speed, Buffer Index, and Planning Time Index.

These measures are defined as follows:

Average Travel Speed is the mean travel speed of motorists to traverse the segment. It is computed by adding all the travel speeds in the data set and dividing the sum by the number of data points. The time is reported in miles per hour (mph).

95th Percentile Travel Speed is a measure of the highest 5 percent of recorded speeds on the segment during the study period. The measure is reported in mph.

Buffer Index represents the extra buffer that travelers would need to add to their average travel time when planning trips to ensure on-time arrival. It is computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time.

Planning Time Index represents the total travel time that should be planned when adequate buffer time is included over the free-flow speed.

Collecting data on two winter periods for the *before* and *after* evaluation was sufficient for travel time reliability analysis. The analysis used six months of data from each winter (November through April). This was representative of how the corridor typically operated during winter conditions in the *before* and *after* periods. Table 7.16 shows the data collection periods.

TABLE 7.16: US 97 WEEKDAY TRAVEL SPEED/TIME DATA COLLECTION DATES

DATA PERIODS	DATE & TIME
BEFORE WINTERS	11/02/2020 to 04/30/2021 3:00 p.m. to 6:00 p.m.
	11/01/2021 to 4/29/2022 3:00 p.m. to 6:00 p.m.
BEFORE WINTERS	11/01/2022 to 04/28/2023 3:00 p.m. to 6:00 p.m.
	11/01/2023 to 04/30/2024 3:00 p.m. to 6:00 p.m.

Table 7.17 displays the results for the weekday travel speed and times in both northbound and southbound directions of the segment of US 97. The variability of speeds increased for both directions, with free flow speed and the 95th percentile speeds increasing slightly (around one mph), and the average speed decreasing slightly (less than one mph). Free flow travel times decreased, and average travel times remained largely unchanged. The 95th percentile travel time increased in the *after* period. Both the Buffer Time Index and Planning Time Index showed increases after the improvements were installed, suggesting reliability worsened slightly.

TABLE 7.17: US 97 WEEKDAY TRAVEL SPEED/TIME – 21.6 MILES

		FREE FLOW SPEED (MPH)	AVERAGE SPEED (MPH)	95TH PERCENTILE SPEED (MPH)	FREE FLOW TRAVEL TIME (MIN)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
BEFORE	**NB**	64.51	63.38	67.35	20.27	20.64	24.11	0.17	1.19
	SB	63.97	62.71	66.92	20.24	20.65	24.68	0.20	1.22
AFTER	**NB**	65.63	62.72	68.18	19.93	20.85	25.47	0.22	1.28
	SB	65.34	61.84	68.22	19.82	20.94	26.92	0.29	1.36

Figure 7.5 and Figure 7.6 show a graphical representation of changes in travel speeds and travel times.

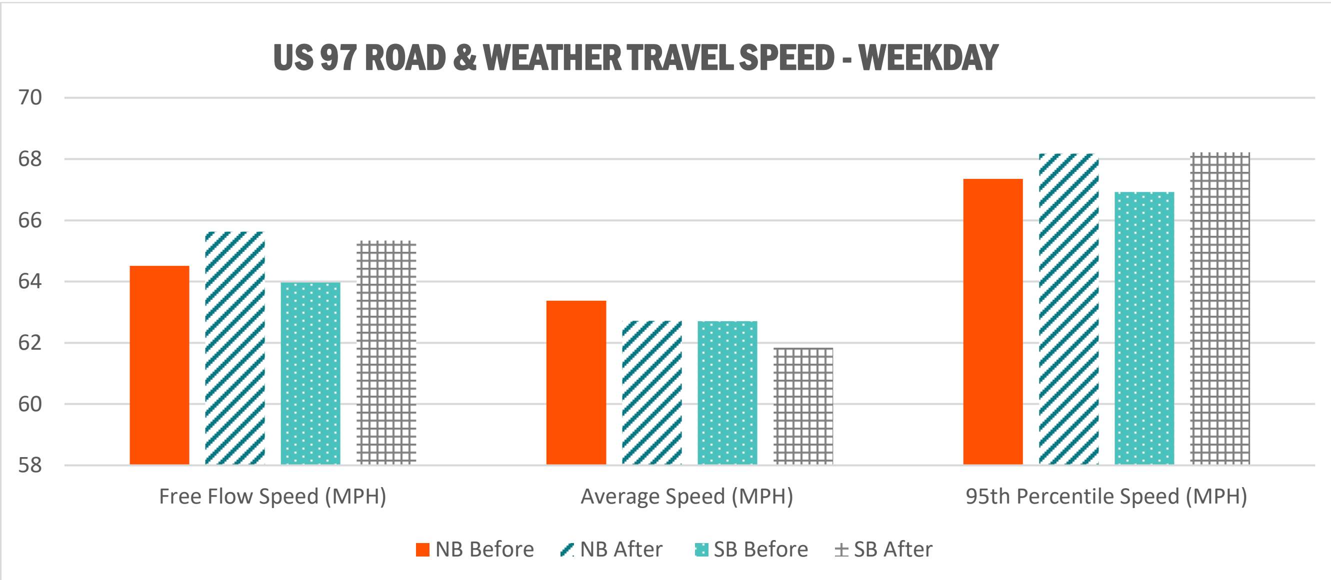


FIGURE 7.5: US 97 SPEED PERFORMANCE MEASURES FOR NB AND SB DIRECTIONS DURING WEEKDAY PEAK HOURS

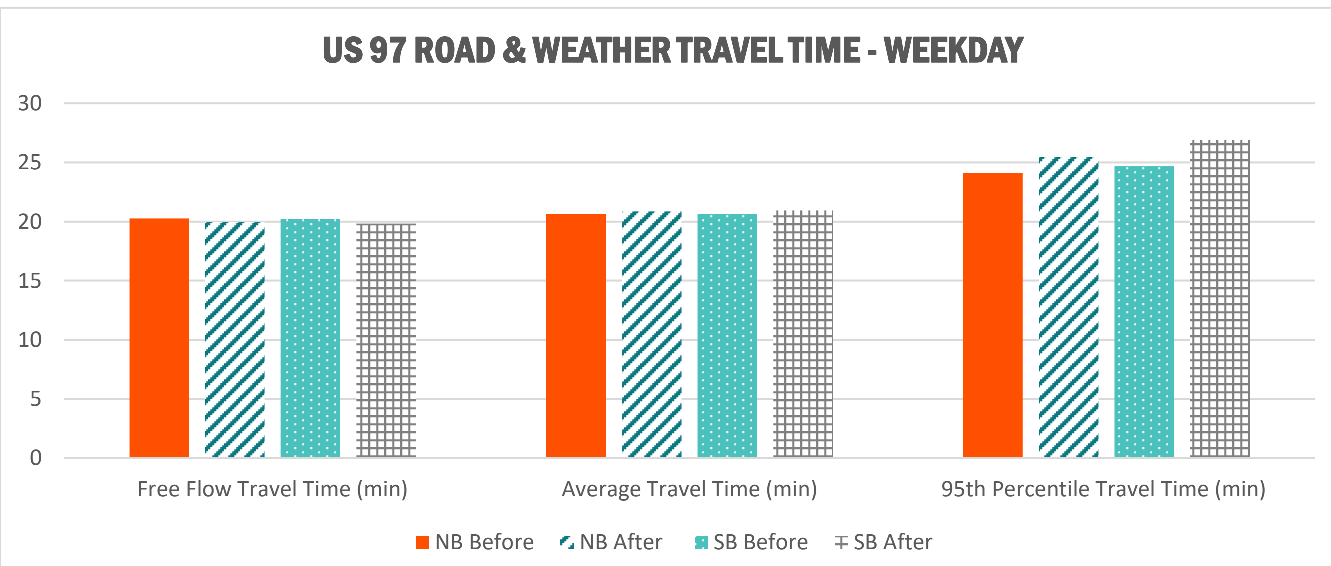


FIGURE 7.6: US 97 TRAVEL TIME PERFORMANCE MEASURES FOR NB AND SB DIRECTIONS DURING WEEKDAY PEAK HOURS

Table 7.18 shows the data collection periods for the weekend travel time/speeds.

TABLE 7.18: US 97 WEEKEND TRAVEL SPEED/TIME DATA COLLECTION DATES

DATA PERIODS	DATE & TIME
BEFORE WINTERS	11/01/2020 to 04/25/2021 9:00 a.m. to 6:00 p.m.
	11/06/2021 to 4/30/2022 9:00 a.m. to 6:00 p.m.
BEFORE WINTERS	11/05/2022 to 04/30/2023 9:00 a.m. to 6:00 p.m.
	11/04/2023 to 04/28/2024 9:00 a.m. to 6:00 p.m.

Table 7.19 below displays the results for the weekend travel speed and time for both northbound and southbound directions. The first weekends for the two *after* period winters were November 5th, and November 4th.

TABLE 7.19: US 97 WEEKEND TRAVEL SPEED/TIME – 21.6 MILES

		FREE FLOW SPEED (MPH)	AVERAGE SPEED (MPH)	95TH PERCENTILE SPEED (MPH)	FREE FLOW TRAVEL TIME (MIN)	AVERAGE TRAVEL TIME (MIN)	95TH PERCENTILE TRAVEL TIME (MIN)	BUFFER INDEX	PLANNING TIME INDEX
BEFORE	**NB**	64.51	64.57	67.87	20.27	20.26	21.98	0.09	1.08
	SB	63.97	63.35	67.19	20.24	20.44	23.04	0.13	1.14
AFTER	**NB**	66.01	64.42	68.30	19.82	20.30	24.10	0.19	1.22
	SB	65.34	63.44	68.04	19.82	20.41	24.41	0.20	1.23

Free flow speeds increased (around 1.5 mph) in both directions with a resulting reduction in free flow travel time. The average speed decreased slightly northbound and increased southbound, but the changes were very small (approximately 0.25 mph). The average travel time registered very little change due to the very small changes in average speed with northbound decreasing slightly and southbound increasing slightly. The 95th percentile speed increased (0.5-1 mph). The 95th percentile travel time increased as well. The buffer and planning time index both increased, suggesting slightly worsened reliability for this segment of US 97.

Figure 7.7 and Figure 7.8 show a graphical representation of changes in travel speeds and times.

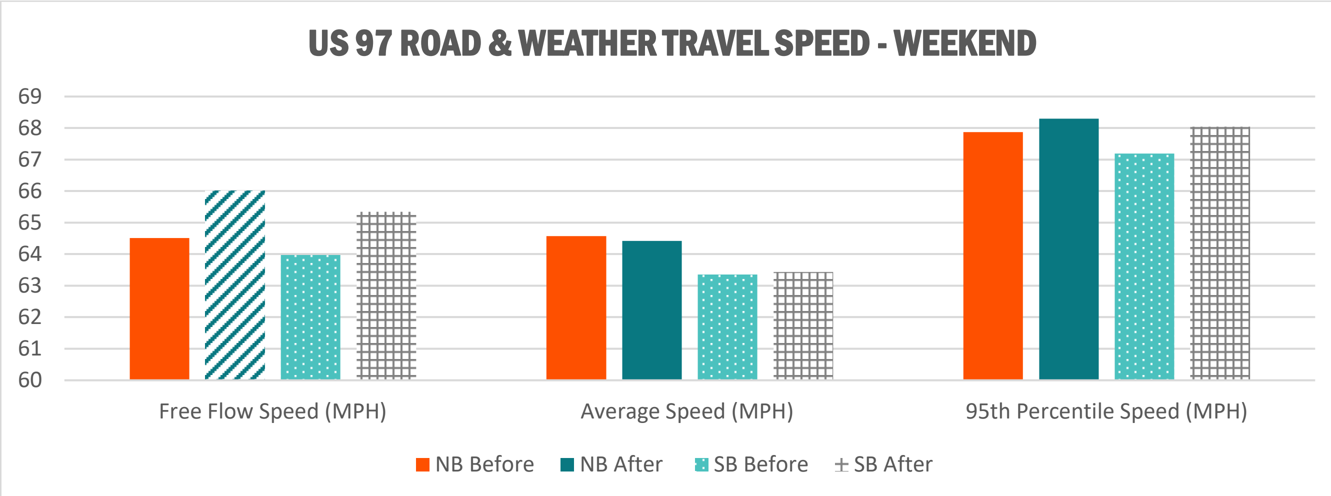


FIGURE 7.7: US 97 SPEED PERFORMANCE MEASURES FOR NB AND SB DIRECTIONS DURING WEEKEND PEAK HOURS

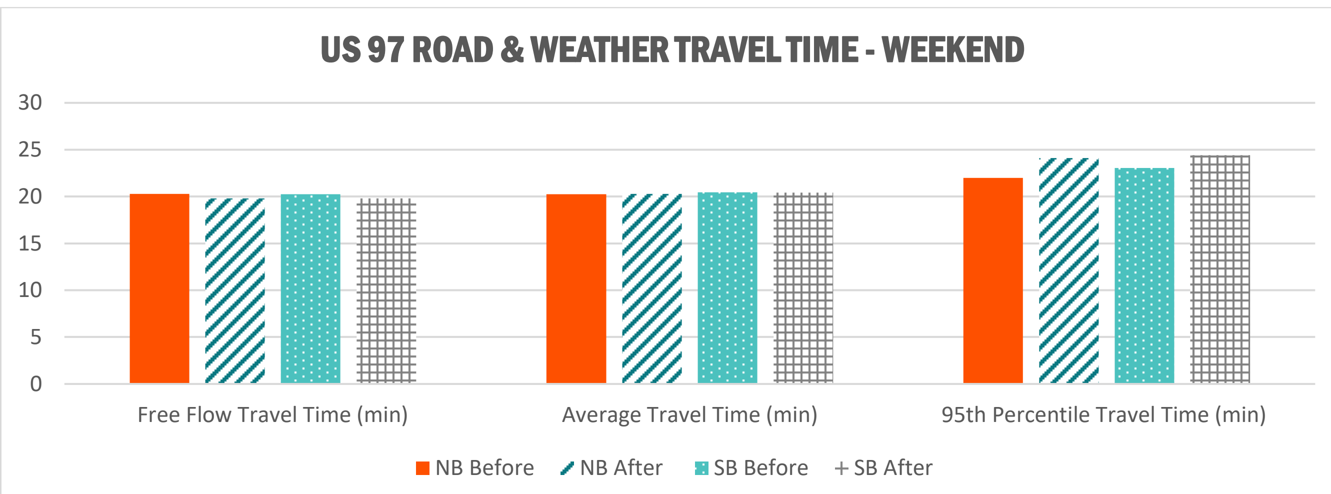


FIGURE 7.8: US 97 TRAVEL TIME PERFORMANCE MEASURES FOR NB AND SB DIRECTIONS DURING WEEKEND PEAK HOURS

TRIPCHECK: AVAILABILITY OF REAL-TIME ROADWAY AND TRAFFIC CONDITIONS

The Road and Weather Management project provided additional real-time information to motorists. The project installed new dynamic messages signs capable of showing the variable speeds, the reason for the variable speeds (such as ice), and other messages for incidents and special events. The DMS would be useful in other conditions such as fires, during crashes, or other incidents or special events.

Additionally, the system was able to provide additional real-time roadway information to ODOT's TripCheck website, TripCheck.com, to display real-time roadway conditions and traffic conditions. Real-time roadway conditions were provided to users at RWIS sites. Users could click on the RWIS icons and view the data provided by the RWIS in question. In Figure 7.9, the blue flags represent RWIS locations.

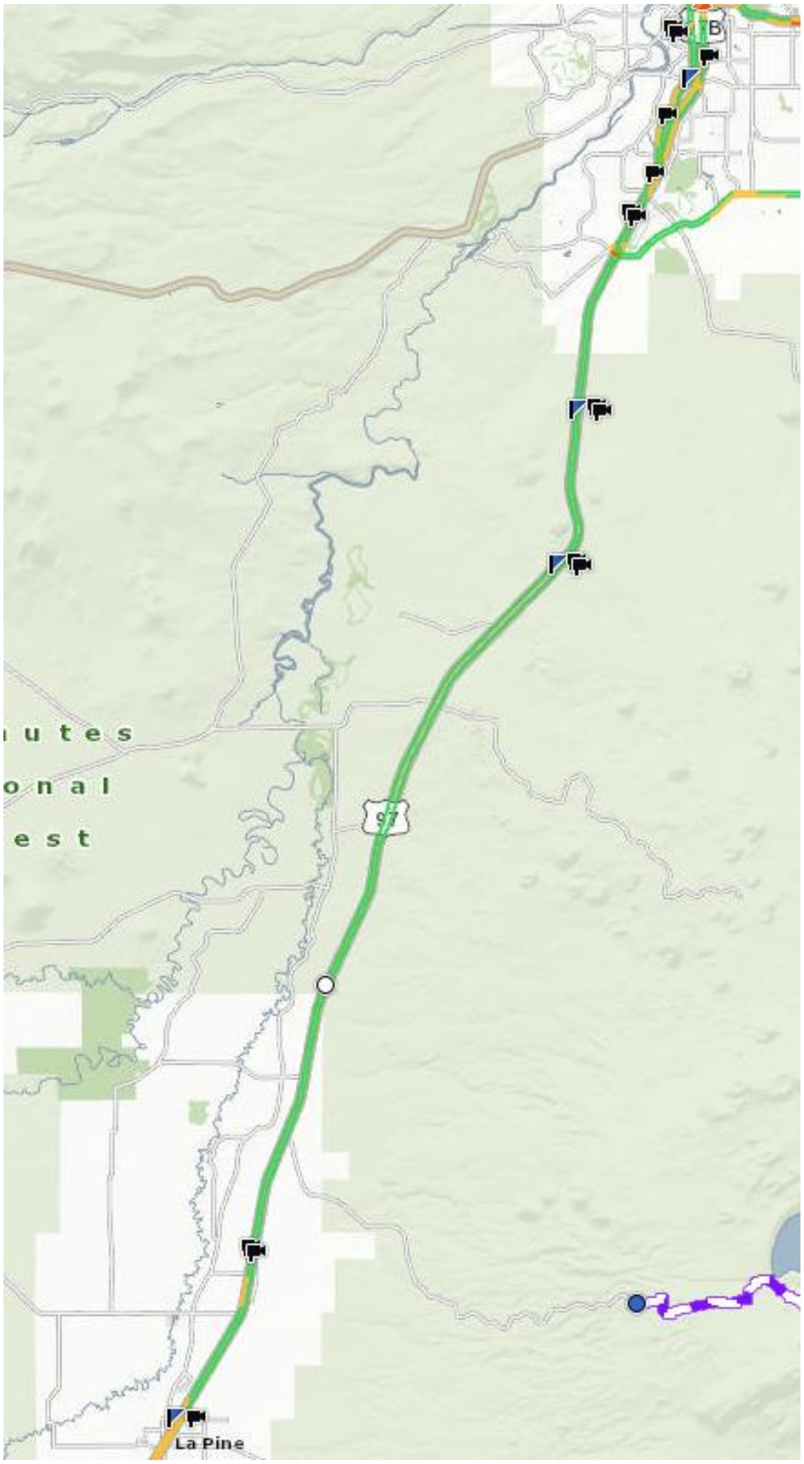


FIGURE 7.9: ODOT'S TRIPCHECK WEBSITE DISPLAYING ROADWAY CONDITIONS FOR US97

In Figure 7.10, the data provided to users at the US 97 NB RWIS is shown.

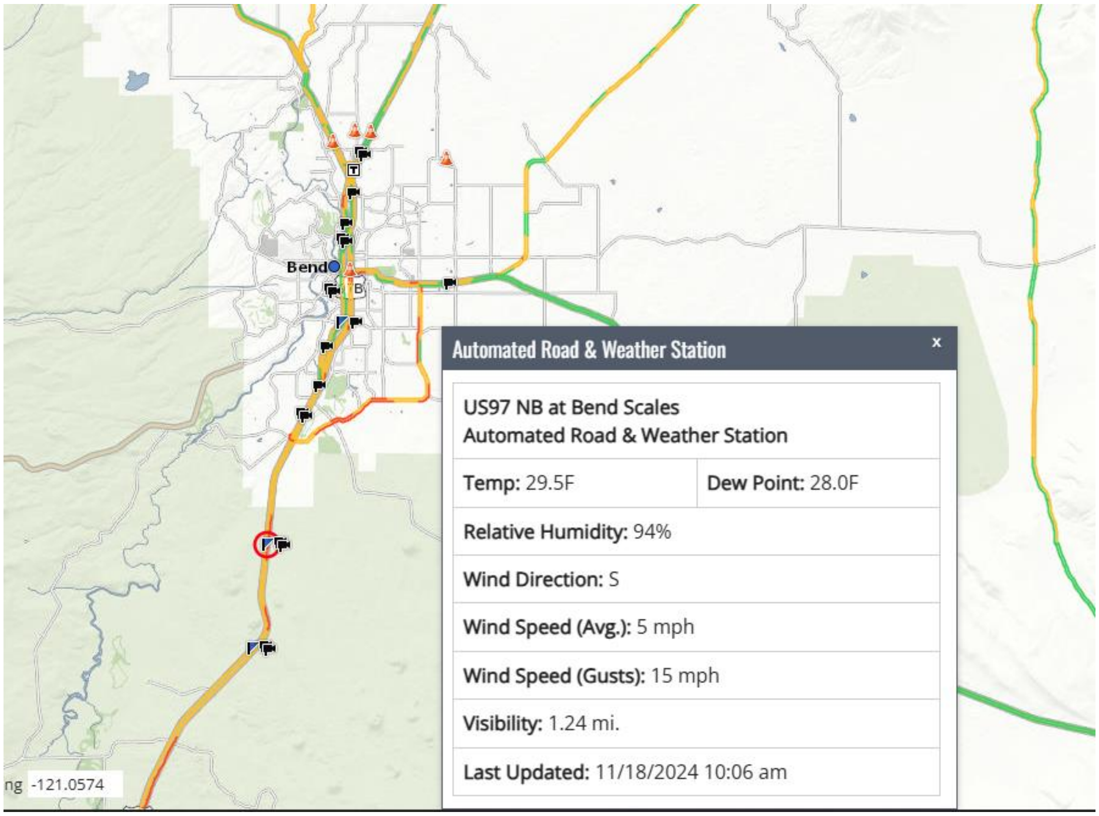


FIGURE 7.10: ODOT'S TRIPCHECK DISPLAYING ROADWAY INFORMATION FROM A RWIS STATION

By clicking on the camera icon, users could view still images from the roadway that were updated on a regular basis, approximately every five minutes. Figure 7.11 shows the US 97 at Lava Butte camera.

FIGURE 7.11: LIVE CAMERA FOOTAGE OF US97 SEGMENT AT LAVA BUTTE

Figure 7.12 displays the TripCheck map with the live traffic legend. Traffic conditions are shown in different colors with green representing free flow traffic, yellow representing light traffic, red for moderate traffic, and purple representing heavy traffic. The data source for live traffic is RITIS.

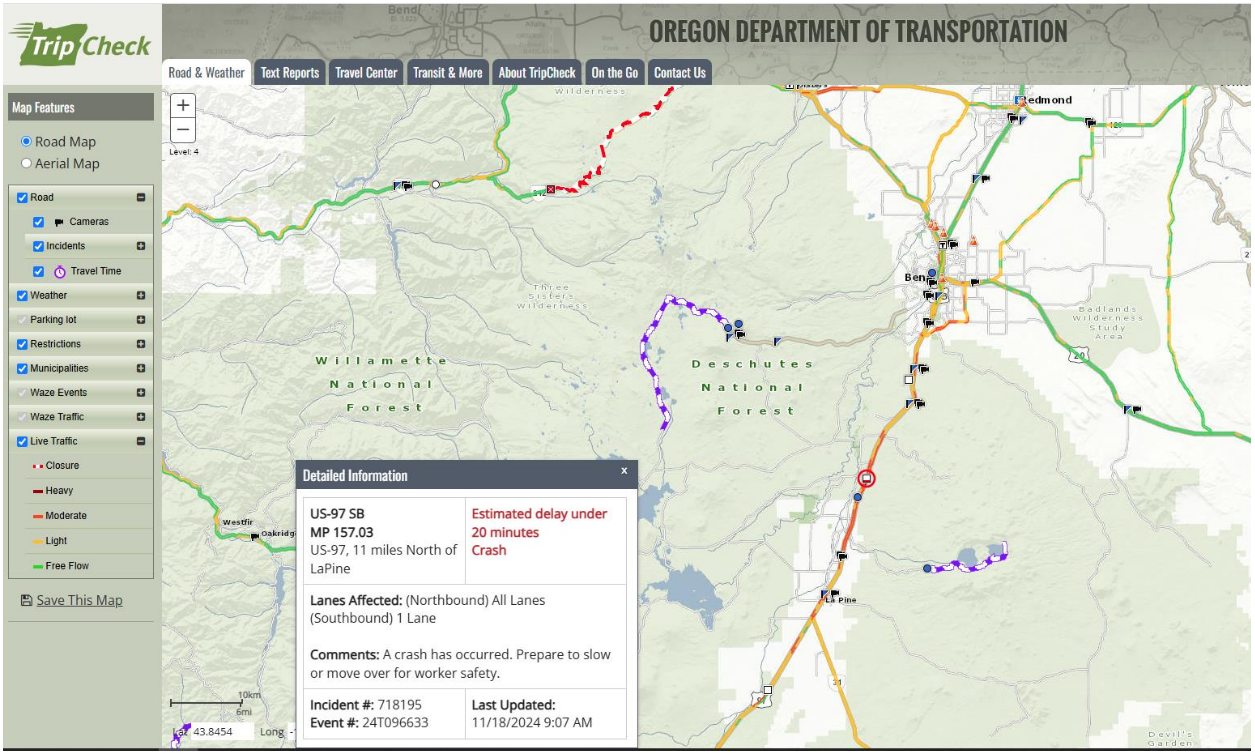


FIGURE 7.12: ODOT TRIPCHECK DISPLAYING TRAFFIC CONDITIONS

To assess the availability of real-time roadway and traffic conditions, DKS assessed the availability of up-time or down-time data from the cameras, RWIS and RITIS. ODOT could not provide down-time data for cameras. The RITIS platform assumed traffic speeds when there was little to no data being reported to it. For instance, in periods of no volumes, RITIS would report free flow speeds. An analyst could not go back and determine from the RITIS data alone if there were an event, such as a major crash that closed a facility.

DKS worked with ODOT staff to determine the frequency at which RWIS data should update in a day and ODOT staff provided a report showing how often the RWIS provided updates, then compared that number to how many updates should have been made in a day.

In the *before* condition, ODOT had an RWIS at Lava Butte. The project replaced this RWIS with a new RWIS and added additional RWIS at the South Bend Weigh Station (Bend Scales). In assessing the availability of real-time roadway conditions, the *after* condition was evaluated by determining that if either RWIS was available, then there was available data. In other words, in the *before* condition, in the event of RWIS failure at Lava Butte, no data was recorded. In the *after* condition, both RWIS stations would have to fail to provide no data.

To determine if the segment was displaying reliable travel information to motorists on the segment, DKS evaluated the total number of messages the dynamic message signs should display in a day to the actual number of messages displayed. The percentage of messages displayed compared to the total was defined in this report as the coverage. *Full coverage* were days where the dynamic message signs displayed more than 90 percent of the total messages it should have displayed, *partial* as between 50 percent to 90 percent, and *limited* as less than 50 percent of messages displayed.

ODOT consistently provided accurate information to travelers throughout the two winters after the installation of the additional dynamic message signs, ensuring reliable roadway conditions and recommending safe speeds throughout the segment of US 97. Within the RWIS network, both stations were never inoperational at the same time. At least one of the two VSL signs remained operational at full coverage (more than 90 percent of 720 messages displayed in a day) during the evaluation periods. Limited or partial coverage typically lasted about a week, with longer periods marked by the absence of any data. However, Bend Scales maintained full, uninterrupted coverage. Lava Butte was observed to have reduced coverage during the months of November, December, and January. Figure 7.13 and Figure 7.14 show the coverage at the new Lava Butte VSL sign for the first and second winters, respectively. Figure 7.15 and Figure 7.16 show the coverage at the Bend Scales location for the first and second winters, respectively.

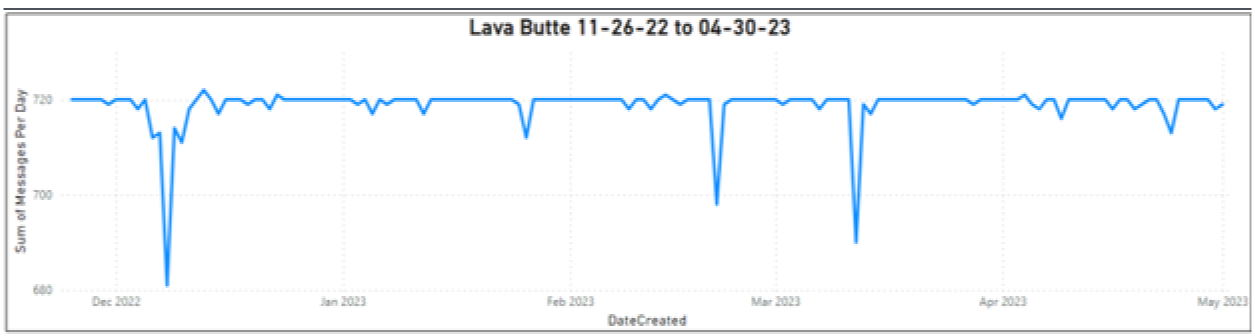


FIGURE 7.13: SUM OF MESSAGES DISPLAYED AT LAVA BUTTE 11/26/22 – 04/30/2023

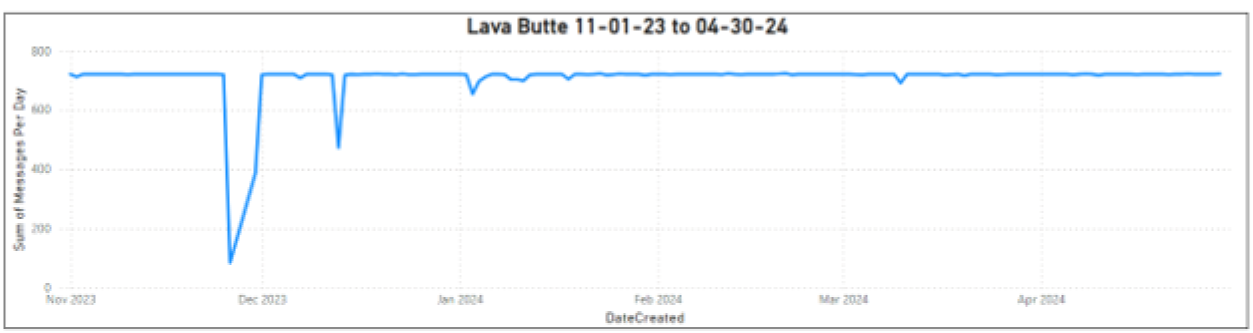


FIGURE 7.14: SUM OF MESSAGES DISPLAYED AT LAVE BUTTE 11/01/2023 – 04/30/2024

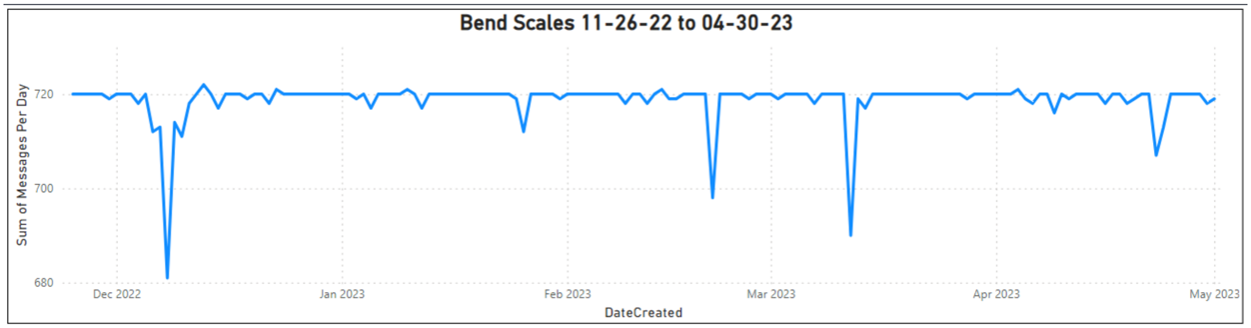


FIGURE 7.15: SUM OF MESSAGES DISPLAYED AT BEND SCALES 11/26/2022 – 04/30/2023

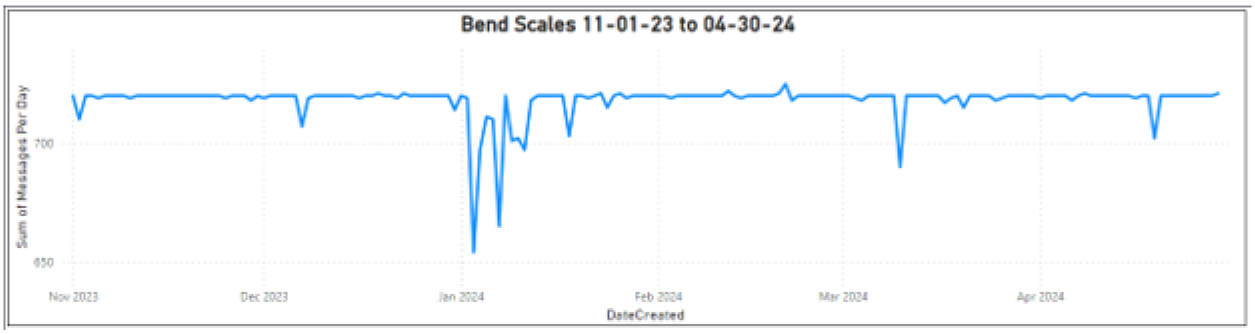


FIGURE 7.16: NUMBER OF MESSAGES DISPLAYED AT BEND SCALES 11/01/2023 – 04/30/2024

BENEFIT/COST

It was difficult to calculate the benefit/cost ratio for this project. Incidents reported as crashes did not decrease, and the team was unable to isolate the reasons why these crashes did not decrease. While the VSL system could operate both on weather-based or congestion, the congestion on this roadway was lower than a typical urban freeway. The system generally did not have to adapt for congestion, so travel time reliability messages were not affected.

The cost of the project was $3,250,000 ($3,493,750 when adjusted to 2023 dollars). The total project costs included design, construction, and the procurement and supply of equipment. Annual operation and maintenance costs were calculated to be $28,087.

Some noneconomic benefits are described below.

Many travelers to the area were not used to driving in the snow and ice conditions. Many people used this corridor to travel to winter recreation activities. The technology of the VSL system provided more information online for pre-trip decision-making. The VSL provided more information to motorists not used to driving in snow and ice on how much to moderate their speeds during inclement weather and degraded road conditions.

The weather could change rapidly in the corridor. South of Bend, the highway gains elevation quickly as the highway ascends to Lava Butte Pass. The system provided information to motorists about what to expect in advance of the condition developing.

ODOT staff received feedback from regular commuters of the section that they had grown to trust the VSL system to provide reliable information about the speed they should travel.

FINDINGS

ASSESSMENT OF OVERALL SYSTEM PERFORMANCE

Determine if the improvements affected crash rates and severity profiles on US 97 from MP 143 to 164.

The improvements did not appear to affect crash rates on US 97 from MP 143 to 164. Crashes went up in the *after* period. Given the relatively short duration of the *before* and *after* periods, two winters, winter weather could vary significantly. Anecdotally, ODOT staff with responsibility for managing winter operations felt that the weather was worse in the *after* period, particularly in late winter (March and April). It was difficult to validate this with weather and roadway condition data.

The team's review of road conditions did show there was an increase in road conditions impacted by winter weather, but the increase in crashes was proportionally larger than the increase in winter weather road conditions.

Determine if the improvements affected crash rates for crashes resulted from weather and congestion.

It was not clear whether the improvements affected crash rates. The VSL system adjusted speeds for weather only. There was no evidence that congestion caused the speed limit to adjust, though there were times when weather and crashes would have caused congestion.

Overall, it is not possible to isolate the specific effects of winter weather conditions or congestion on the corridor in the *before* or *after* condition.

The 67.86 percent increase in the number of crashes in the adjacent section to the south is larger than the 18.3 percent increase in the number of crashes in the study segment. This increase supports the idea that the *after* winters were worse than the *before* winters and that crashes may have been reduced by the implementation of the system.

Determine if the variability of average weekday and average weekend travel speeds decreased on US97 between MP143 and MP 164

Overall, the average speeds decreased slightly or remained about the same, but the variability of the corridor increased for both directions, decreasing the overall reliability. One possible reason for the increased variability was that drivers might react differently to variable speed signs. When the signs were active, some drivers could have slowed down in response. Conversely, when the signs were off, drivers might have sped up due to a perceived sense of confidence. Both scenarios contributed to higher variability, which in turn reduced the reliability of the travel times in the corridor, which was reflected in the increase in the buffer index. Also, drivers may have reacted differently to the VSL speeds based on their confidence operating their vehicle in snow and ice conditions. This could also have led to increasing variability of speeds.

Determine if real time information about roadway and traffic conditions on US97 between MP143 and MP164 was available to road users and private sector entities

The system provided additional real-time information to road users via dynamic message signs and variable speed signs. The installation of cameras also provided additional information. ODOT consistently provided accurate information to travelers after the installation of the VSLs at Lava Butte and Bend Scales throughout the segment of US 97. Within the RWIS network, there were no outage periods with overlap between the two sites. Throughout the study, one of the two RWIS remained operational to always provide traveler information.

During outages, limited or partial coverage typically lasted about a week, with longer periods marked by the absence of any data. However, Bend Scales maintained uninterrupted full coverage. Lava Butte was observed to have reduced coverage during the months of November, December, and January.

The installation of additional cameras in the corridor also provided more real-time roadway condition information to users, but it was not possible to quantify how much.

All information on ODOT website including camera images and RWIS information was available to private sector entities via ODOT's traveler information website, TripCheck.com, and its application programming interface (API).

IDENTIFICATION OF ISSUES

The crash data did not show a reduction in crashes with the installation of the VSL system. During the evaluation of the crash data and coordinating that information with the road conditions, the team noticed that there were outsized increases in the number of crashes during the periods where road conditions were reported as "Spots of Ice" and "Black Ice." These road conditions were, by definition, more intermittent than road conditions such as "Packed Snow" or "Slush, Snowpack Breaking Up." In these more intermittent road conditions, it might have been more difficult for the VSL to provide good speed information for the entire corridor. For instance, if the "Spots of Ice" or "Black Ice" were not at the sensor, the VSL may not reduce speed, and motorists may have been traveling too fast for conditions.

The section of US 97 from MP 152.75 to 155.9 (S Century Drive to Vandevert Road) had geometric improvements during the *before* period. These improvements extended the divided highway alignment from S. Century Drive to Vandevert Road, Despite the improvements aimed to improve safety, a similar frequency of crashes in the *after* period was still observed along this segment.

In addition, the crashes in this area were identified in clusters, notably at southbound locations before interchanges, along the divided highway, and at transitions of the undivided highway. The northbound direction also experienced crashes along the segment but at lower frequencies. The crashes at these locations suggested that there may have been other variables involved that were independent of roadway geometry, such as roadway condition or driver behavior.

RECOMMENDATIONS FOR OPERATIONS

From a technology standpoint, ODOT has delivered over a dozen such Active Traffic Management projects statewide prior to this project. ODOT has standardized the field equipment and software used statewide for ATM operations regardless of if the project is urban/congestion-based or rural/mountainous for weather-based needs. Many of the lessons learned and improvements have already been addressed in earlier projects and software upgrade efforts.

In terms of operating the system, ODOT may want to consider how the system operates when field personnel are reporting “Black Ice” and “Spots of Ice” and see how the system is operating during those conditions and review the algorithm for speed selection.

ODOT staff reviewed the system settings. They determined that the system settings used were the same settings that were used on a project on I-84 in Baker Valley in Eastern Oregon. I-84 has significantly more truck traffic than US 97. As such, the system was set up so that the right lane, (the slow lane or ‘B’ lane) was to be more responsive to changes than the left lane (passing lane or ‘A’ lane.)

On US 97, the system settings have now been modified so that both lanes are equally responsive to changes in conditions such as grip factor or visibility. Region staff will review to see if they believe the system becomes too reactive with too many speed reductions or if the reductions do not match the conditions.

ODOT may want to review crash locations and hot spots and see if additional sensors would help address these hot spots.

ODOT will likely expand the system by adding additional RWIS and VSL signs between S. Century and La Pine. Evaluating crash data may help with site selection for new devices.

When official crash reports become available, ODOT may want to review them to see if the system influenced reported crashes or crash severity. Additionally, this data may be helpful in determining where and how to expand the system.

8 City of Bend Colorado/ Arizona Couplet ATSPM's

PROJECT DESCRIPTION

The Colorado Avenue/Arizona Avenue couplet provides direct access from US 97 to many recreational attractions and businesses that generate a significant amount of capital for Central Oregon. The couplet is a heavily used commuter route. Additionally, due to the corridor's dual role of connecting people to employment centers and recreational opportunities, such as the connection to various events (i.e., festivals, concerts, weather driven recreation, etc.), traffic volume pattern shifts of all modes happen frequently resulting in long delays and increased crash potential.

TOP: NW ARIZONA AVE, BOTTOM: NW COLORADO AVE.

There are six signals located along this route. The signals were actuated but lacked communication infrastructure to support high resolution data, advanced traffic signal controllers, and detection to accommodate desired automated traffic signal performance measurement. The large number of multi-modal users would also benefit from the improved detection at these intersections. The six traffic signal-controlled locations were as follows:

- Southbound US 97 at Colorado Avenue
- Colorado Avenue at Bond Street
- Colorado Avenue at Wall Street
- Colorado Avenue at Industrial Boulevard
- Arizona Avenue at Wall Street
- Arizona Avenue at Bond Street

PROJECT PLAN

The intent of the City of Bend Colorado/Arizona Couplet ATSPMs project was to upgrade six in-place signals to be able to collect high resolution data for performance measurement. ATC controllers with Intelight's "MaxTime" software replaced in-place 2070 traffic controllers. A high bandwidth connection to the traffic signals was achieved via a direct underground fiber optic line that replaced a six-pair copper interconnect, using the in-place conduit system. Connections to the ODOT Central Signal System were achieved via communication switches at the traffic signals and a connection to the intersection of Southbound US 97 at Colorado Avenue that is currently being linked to a communications drop.

None of the signals in this corridor had communication infrastructure to support high resolution data collection, multi-modal detection for bicycles, or advance detection for activities outside of the stop bar zone prior to the project. Radar detection replaced video detection systems with layouts optimized to support corridor operational goals.

Additionally pan-tilt-zoom (PTZ) cameras were installed to allow for remote viewing of corridor performance. All devices listed above were procured through statewide use contracts and/or from ODOT conditional qualification product lists. ODOT hired an electrical contractor to install the devices.

This system is expected to support operations for access to locales such as Mount. Bachelor and the Three Sisters Wilderness Area, Hayden Homes Amphitheater, the Old Mill District, Oregon State University-Cascades, and various other destinations important to the region.

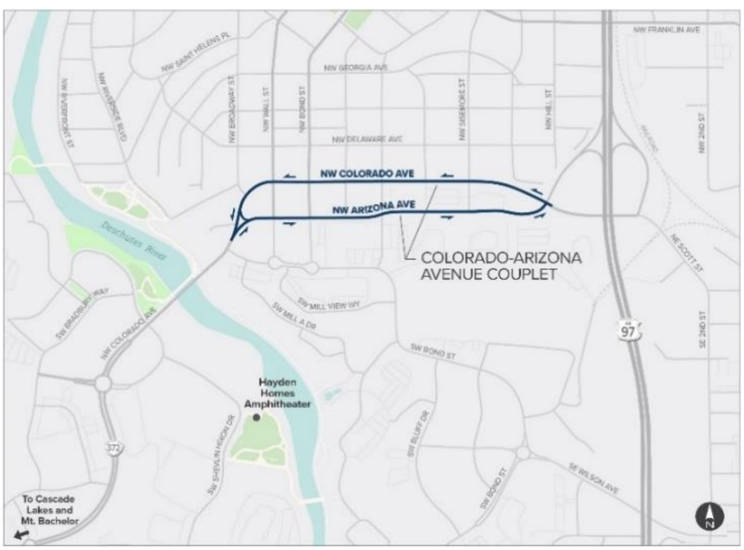


FIGURE 8.1: PROJECT AREA MAP -BEND COLORADO/ARIZONA COUPLET

Ultimately, the plan is to create a system that can support ATSPM and can be intertwined into Integrated Corridor Management (ICM) strategies for interrelated key corridors. The layout of the plan follows communication paths identified in the adopted Deschutes County ITS Plan that was completed in 2011 and updated in 2020. When fully built out, the communication infrastructure could be used to support future ITS devices.

The implementation of ATSPMs allowed signal timing staff to adjust signal timing to improve safety by reducing red-light-running and ensuring platoons progress through the signal.

PROJECT COMPONENTS

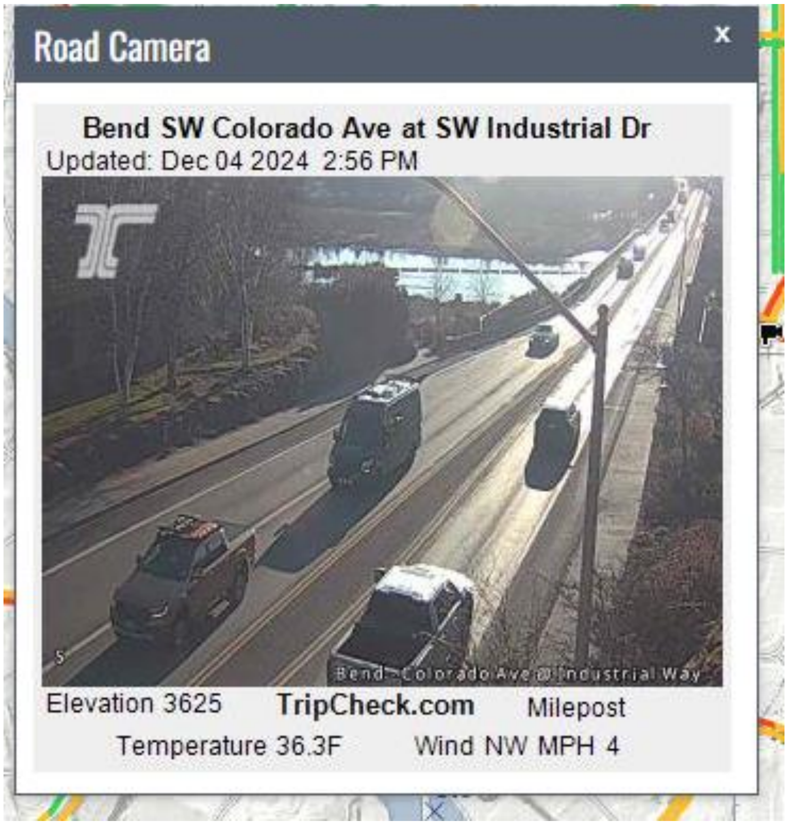


FIGURE 8.2: PAN-TILT-ZOOM CAMERA (PTZ)

- Installation of communication racks and switches to allow for connection to the ODOT Central Signal software (MaxView).
- Installation of ATC Controllers with connection to MaxView to collect high resolution data to process Automated Traffic Signal Performance Measures (ATSPM)
- Installation of new detection devices to improve data collection for ATSPMs
- Installation of pan-tilt-zoom cameras (PTZ) to improve situational awareness and visual confirmation of implementing ATSPMs.
- Replacing existing copper wire interconnect with fiber optic cable to increase bandwidth for improved data collection
- Updated signal timing for current traffic conditions.

The total project cost was $830,000.

PROJECT BACKGROUND

ODOT and the City of Bend have developed an ATSPM plan that collects data and gathers real-time visual information for the Colorado Avenue/Arizona Avenue couplet. This helps describe the congestion caused by various events (i.e. weather-impacted recreation, festivals, concerts, etc.) by evaluating based on performance measurements.

The consultants met with the operations staff from ODOT's Region 4 and the City of Bend and interviewed them about their experiences with ATSPMs after the installation of the project. The summaries can be found in the 'Usefulness of ATSPMs' section.

CORRIDOR OPERATIONS

The Colorado/Arizona Couplet operates with the peak direction westbound (Colorado) in the morning peak and the peak direction eastbound (Arizona) in the afternoon peak.

Traffic volumes in the morning westbound peak may spike in the winter when it snows, as Mount Bachelor is a popular local skiing destination.

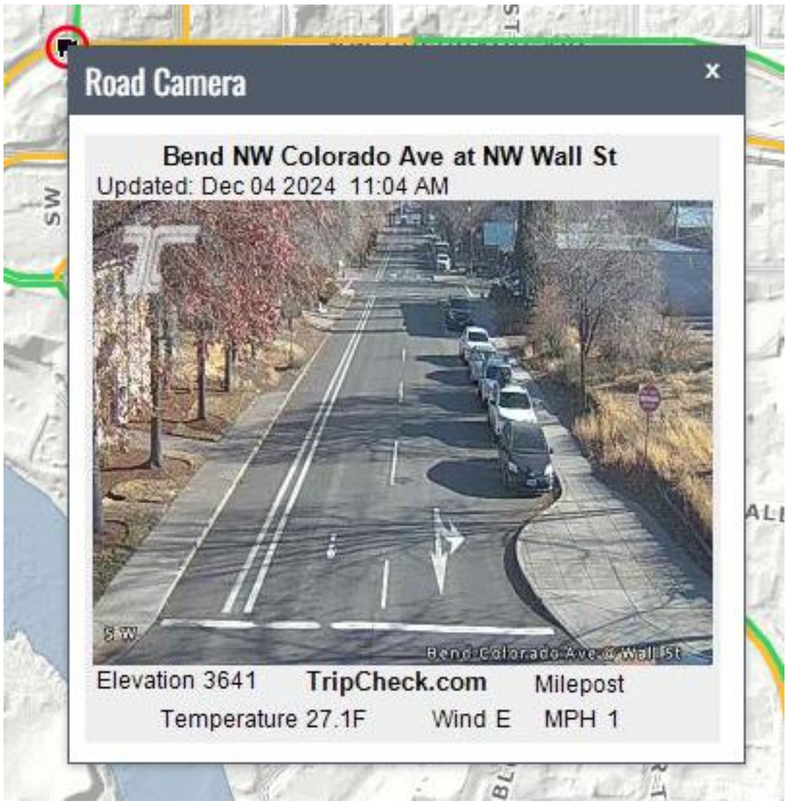


FIGURE 8.3: PAN-TILT-ZOOM CAMERA (PTZ)

Concerts at the Hayden Homes Amphitheatre cause peaking in the westbound direction in the evening peak as the concert arrival time often conflicts with the typical eastbound peak period.

The two primary north- south streets, Wall and Bond Streets, in the area operate as a couplet. Bond Street is one-way northbound, and Wall Street is one-way southbound.

The area has significant numbers of pedestrians and cyclists with manyd restaurants and coffee shops.

As part of the project, ODOT signal timing staff reduced the cycle length from 60 seconds to 56 seconds to reduce overall delay, particularly pedestrian delay.

EVALUATION GOALS, OBJECTIVES AND QUESTIONS

The goals of the project included improving safety, improving mobility, and improving operations. The objectives of the before-and-after evaluation were to measure how well the improvements achieved the project goals. Table 8.1 summarizes the project goals and specifically how the goals were evaluated.

TABLE 8.1: EVALUATION GOALS, OBJECTIVES AND QUESTIONS

GOAL AREA	DESCRIPTION/OBJECTIVES	EVALUATION QUESTION
IMPROVE SAFETY	Reduce crash potential in the corridor	Determine if red-light-running and/or near-miss events are reduced.
IMPROVE MOBILITY	Improve travel time reliability	Determine if the variability of average travel speeds within the corridor were reduced.
IMPROVE OPERATIONS	Improve vehicle and freight detection.	Determine how useful the ATSPMs were for monitoring and managing corridor operations.

EVALUATION METHODOLOGY AND PERFORMANCE MEASURES

EVALUATION PERIODS

Before data was collected from April 2021 through March 2022. The data collection avoided the period when the signal work was being completed, as well as area construction events that reduced capacity of the corridor. *After* data was collected from April 2023 through March of 2024.

PERFORMANCE MEASURES AND DATA TYPES

DKS developed performance measures that could answer the evaluation questions and determined whether the evaluation objectives were met. The performance measures and associated data type necessary to evaluate objectives are shown in Table 8.2.

TABLE 8.2: PERFORMANCE MEASURES AND DATA TYPES

EVALUATION OBJECTIVE	PERFORMANCE MEASURES	ASSOCIATED DATA TYPE
DETERMINE IF RED-LIGHT-RUNNING AND/OR NEAR-MISS EVENTS WERE REDUCED	Number of red-light running and near-miss events.	• Video and video analytics
DETERMINE IF THE VARIABILITY OF AVERAGE TRAVEL SPEEDS WERE REDUCED WITHIN THE CORRIDOR	Average Travel Time, 95th Percentile Travel Time, Buffer index, Planning Time Index	• Corridor segment lengths, Weekday PM peak hour travel speed/time information, 5-minute intervals
DETERMINE THE USEFULNESS OF ATSPMS FOR MONITORING AND MANAGING CORRIDOR OPERATIONS.	Qualitative assessment of whether operators find the value of ATSPMs “High”, “Moderate”, “Minimal” or “Not Useful”	• Signal system operators and managers assessments

DATA ANALYSIS

DATA SOURCES

Table 8.3 shows the data types and sources that the team used to determine how the project impacted the related performance measure.

TABLE 8.3: DATA SOURCES

DATA TYPE	DATA SOURCE
ROADWAY SEGMENT LENGTHS	Google Earth
VIDEO AND VIDEO ANALYTICS	Street Simplified Video
SPEED/TRAVEL TIME	INRIX data via Regional Integrated Transportation
QUALITATIVE SURVEY	Information System (RITIS)

SAFETY ANALYSIS

While the improvements in the projects were not likely to have a significant impact on safety, the team wanted to understand the impact on safety via surrogate data, video analytics of red-light-running data and near-miss events.

The timing of the *before* and *after* analysis did not allow for the use of official crash reports. Official crash reports from ODOT were only available through December 31, 2022. The safety analysis relied on other data sources. The proposed evaluation methodology was based on video and video analytics, which ODOT was able to provide via the firm Street Simplified. The analysis was supplemented by police reports of crashes on Colorado and Arizona Avenues.

DESCRIPTION OF STREET SIMPLIFIED AND METHODOLOGY

Street Simplified[27] is a firm that provides video safety analytics services and evaluation insights reports to states and local agencies. They attempt to identify near-misses and conflicts that do not result in a crash, so that agencies may preemptively address safety issues without needing to see historical crashes.

They collect short duration high quality videos agnostic of intersection control hardware/software which are processed with proprietary AI software. They then perform manual reviews of the footage to identify traffic conflicts. Cameras are installed at study areas at different angles to evaluate various events such as: Red-

[27] Street Simplified, Safety Analytics, https://www.streetsimplified.com/safety-analytics

Light-Running, Near-Misses, and Near-Misses with Bicyclists and Pedestrians. A description of their methodologies is summarized below.

Red-Light-Running events are characterized by roadway users crossing the stop bar after the corresponding signal to that movement turns red[28]. Light state estimates are accurate to +/- 0.1 seconds. Red-light-running includes vehicles, motorcyclists, buses, and cyclists using the roadway but does not include bicyclists and pedestrians crossing on red using the pedestrian crosswalk. Movements such as right/left on red (when permitted) are filtered out by the AI software and are not part of the red-light-running events.

Near-Misses are defined by Street Simplified's Post Encroachment Time, and a Time to Collision algorithm.

Post Encroachment Time (PET) is the time difference between two conflicting vehicles crossing the same point. A PET is calculated by taking two vehicles whose movements intersect and assigning the first vehicle to cross the point of intersection as t0, and the second vehicle to cross the same point as t1. The difference between t0 and t1 is the PET and is used for near-misses for conflict movements such as: through-through, left turn-through, and merging conflicts.

Time to Collision (TTC) is the time it would take for two vehicles to collide if the vehicles maintained their speeds.

For this evaluation, PET conflicts were identified in the interior of the intersection and were higher risk conflicts such as turning movements and multi-modal interaction. TTC conflicts generally approached conflicts such as potential rear-end crashes.

Quality Control

Events were aggregated using their AI interface and then checked for quality by manual review. The events tended to include false positives due to Street Simplified intentionally training the AI interface to be liberal when identifying conflicts. These false positives were resolved in the manual review section of the quality control process.

Figure 8.4-8.6 show different camera views from Street Simplified cameras and conflicts that Street Simplified identified.

[28] Street Simplified uses a similar methodology as ODOT for determining red-light running. However, ODOT requires radar zones to be set up at the stop bar to detect vehicle actuations.

FIGURE 8.4: STREET SIMPLIFIED CAMERA IDENTIFYING A RED-LIGHT RUNNING EVENT AT NW ARIZONA & NW COLORADO

FIGURE 8.5: STREET SIMPLIFIED CAMERA IDENTIFYING A THROUGH-THROUGH NEAR-MISS EVENT AT NW ARIZONA & NW COLORADO

FIGURE 8.6: STREET SIMPLIFIED CAMERA IDENTIFYING A PEDESTRIAN-VEHICLE NEAR-MISS EVENT AT NW COLORADO & NW BOND

Red-Light-Running and Near-Misses

Table 8.4 through Table 8.6 summarize the red-light-running (RLR) and near-miss events at the six project area intersections. Street Simplified video recorded the intersections in the *before* condition on March 2 and March 3, 2022. The *after* condition was video recorded on May 2 through May 4, 2023. The times the intersections were video recorded were not consistent, although all included the evening peak and most included the morning peak. Because the recording periods were not consistent, the collected Street Simplified data was normalized for the number of entering vehicles. For the RLR and near-miss events including motor vehicles, the number of events was divided by the number of vehicles to create a percentage of entering vehicles.

The weather in Bend can vary greatly between March and May. The team reviewed the weather data from National Oceanic and Atmospheric Administration (NOAA) Online Weather Data and Weather Underground because March 3, 2022, showed up as a data gap in the NOAA data. The weather on March 2, 2022, had a high of 58 degrees Fahrenheit and a low of 37 degrees. March 3, 2022, had a high of 49 degrees and a low of 29 degrees. There was no precipitation on either day.

May 2, 2023, had a high of 51 degrees and a low of 39 degrees. May 3, 2023, had a high of 67 degrees and a low of 43 degrees. May 4, 2024, had a high of 73 degrees and a low of 44 degrees. Both May 2nd and May 4th reported a trace of precipitation. The relatively high temperatures on May 3rd and 4th may have led to higher volumes of pedestrians and cyclists than normal for that time of year. The average high temperature for those days is in the mid-50s.

Table 8.4 summarizes the Street Simplified identified *before* and *after* RLR instances at the six study intersections. In the table, the percentages shown in Table 8.4 are based on the total number of vehicles entering the intersection during each period (before and after), and the calculation is shown in parentheses below each percentage.

TABLE 8.4: BEFORE AND AFTER RED-LIGHT-RUNNING EVENTS

INTERSECTION	NO. RED-LIGHT-RUNNING EVENTS (BEFORE)	PERCENTAGE OF RED-LIGHT-RUNNING (BEFORE)	NO. RED-LIGHT-RUNNING EVENTS (AFTER)	PERCENTAGE OF RED-LIGHT-RUNNING (AFTER)	PERCENTAGE INCREASE IN RED LIGHT VEHICLES AFTER TREATMENT
NW COLORADO & NW ARIZONA	6	0.10% (6/6016)	6	0.49% (6/1227)	390.3%
NW COLORADO & NW WALL	2	0.05% (2/3999)	19	0.54% (19/3521)	979.0%
NW ARIZONA & NW WALL	0	0.00% (0/8120)	52	0.42% (52/12460)	NA
SW COLORADO & SW INDUSTIAL	37	0.20% (37/18698)	38	0.19% (38/19625)	-5%
NW COLORADO & NW BOND	36	0.25% (36/14567)	88	0.61% (88/14529)	145.1%
NW ARIZONA & NW BOND	8	0.07% (8/10738)	22	0.29% (22/7534)	314.3%

Red-light-running has increased at nearly all the intersections after the signal upgrades. NW Colorado & NW Arizona saw a large decrease in the number of vehicles entering the intersection with the same number of RLR incidents. The intersection of SW Colorado and SW Industrial was the only intersection that showed a percentage decline. The percentage increase in RLR for this intersection after the treatment was highest with an increase of 979 percent.

In follow-up discussions with Street Simplified, they noted that in their experience, red-light-running on one-way streets was higher than on two-way streets. One potential reasoning was that motorists had a higher overall sense of safety and were likely to take on more risk on one-way streets. Also, on a one-way grid with well-coordinated signals, motorists knew that if they ran a yellow or red-light, they could potentially catch up to the platoon and move through the corridor without stopping so they perceived that there was an incentive to enter the intersection on a yellow or early red. While the one-way couplets were common to both the *before* and *after* condition, the signal timing was updated to shorten cycle lengths, resulting in more cycles per hour, which could potentially increase the frequency of yellow/red-light-running. It was likely that the relatively short analysis period contributed to the changes in red-light-running events. Longer evaluation periods in both the *before* and *after* periods would have provided increased certainty about actual changes in red-light-running activity.

Table 8.5 summarizes the number of near-miss events involving vehicles only. Again, the percentages shown are based on the total number of vehicles entering the intersection during each period (before and after), and the calculation is shown in parentheses below each percentage.

TABLE 8.5: BEFORE AND AFTER NEAR-MISSES WITH VEHICLE EVENTS

INTERSECTION	NO. OF NEAR-MISSES (BEFORE)	NEAR-MISSES (BEFORE)	NO. OF NEAR-MISSES (AFTER)	NEAR-MISSES (AFTER)	INCREASE IN NEAR-MISS % AFTER INSTALLATION (%-POINTS)	PERCENTAGE INCREASE IN NEAR-MISS % AFTER INSTALLATION
NW COLORADO & NW ARIZONA	106	0.63% (106/16804)	127	0.83% (127/15285)	0.20	31.7%
NW COLORADO & NW WALL	13	0.10% (13/13495)	36	0.31% (36/11619)	0.21	210.0%
NW ARIZONA & NW WALL	48	0.59% (48/8120)	54	0.43% (54/12460)	-0.16	-27.1%
SW COLORADO & SW INDUSTIAL	-34	0.74% (34/4590)	38	0.83% (38/4598)	0.09	12.2%
NW COLORADO & NW BOND	21	0.14% (21/14567)	79	0.54% (79/14529)	0.40	285.7%
NW ARIZONA & NW BOND	19	0.18% (19/10738)	40	0.35% (40/11534)	0.17	94.4%

The number of vehicle-vehicle near-misses generally increased after the installation of the project elements. The most notable intersections being NW Colorado & NW Wall, and NW Colorado & NW Bond with a 210 percent and 285.7 percent increase, respectively. The only intersection showing a decrease was the intersection of NW Arizona and NW Wall.

Street Simplified noted that in other locations they had studied, near-miss events increased after safety and/or operational improvements had been implemented. In Fairfax County, Virginia, Street Simplified evaluated intersection improvements and control intersections, where no improvements had been made, and noted that near-misses had increased similarly in both cases. Table 8.6 summarizes the number of near-miss events between vulnerable road users and vehicles. The percentages shown are based on the total number of bicyclists and pedestrians entering the intersection during each period (before and after), and the calculation is shown in parentheses below each percentage.

TABLE 8.6: BEFORE AND AFTER NEAR-MISS WITH PEDESTRIANS AND CYCLISTS

INTERSECTION	NO. OF NEAR-MISSES (BEFORE)	NEAR-MISSES PER ENTERING VRU -BEFORE (NEAR-MISS/ENTERING VEHICLE	NO. OF NEAR-MISSES (AFTER)	NEAR-MISSES PER ENTERING VRU (AFTER)	INCREASE IN NEAR-MISS % AFTER INSTALLATION (%-POINTS)	PERCENTAGE INCREASE IN NEAR-MISS % AFTER INSTALLATION
NW COLORADO & NW ARIZONA	40	30.0% (40/135)	64	25.6% (64/250)	-4.4	-14.7%

INTERSECTION	NO. OF NEAR-MISSES (BEFORE)	NEAR-MISSES PER ENTERING VRU -BEFORE (NEAR-MISS/ENTERING VEHICLE	NO. OF NEAR-MISSES (AFTER)	NEAR-MISSES PER ENTERING VRU (AFTER)	INCREASE IN NEAR-MISS % AFTER INSTALLATION (%-POINTS)	PERCENTAGE INCREASE IN NEAR-MISS % AFTER INSTALLATION
NW COLORADO & NW WALL	34	9.4% (34/360)	33	7.9% (33/418)	-1.5	-16.1%
NW ARIZONA & NW WALL	33	16.0% (33/211)	36	9.1% (36/396)	-6.9	-43.2%
SW COLORADO & SW INDUSTIAL	11	5.9% (11/185)	25	6.6% (25/381)	0.7	11.2%
NW COLORADO & NW BOND	36	7.4% (36/485)	122	14.3% (122/896)	6.9	93.2%
NW ARIZONA & NW BOND	87	15% (87/566)	137	13.6% (137/956)	-1.4	-9.3%

Overall, the proportion of near-misses with pedestrians and cyclists to total vehicles on the roadway decreased after installation despite the increase in the number of vehicles entering the intersections. The exception was NW Colorado & NW Bond and SW Colorado & SW Industrial with percentage point increases of near-misses of 6.9 and 0.7, respectively.

In addition, Street Simplified was now urging clients to collect seven days of *before* and *after* data to increase the size of the sample and reduce the amount of uncertainty. They also believed that a larger sample size of a week improved the quality of the data by reducing the amount of variation that could occur in single day sample.

CRASH DATA

As noted, the safety impact of the improvements was not expected to be large. ODOT staff adjusted the signal timing and the cycle lengths with the desire to reduce red-light-running at the end of the platoon. While the video analytics data showed some increases in red-light-running and near-misses, the team sought whether there were any changes in actual crash data.

To better understand the safety performance of the signalized intersection improvement, the team reviewed crash reports from the City of Bend Police Department from April 2021 through March 2022 and from April 2023 through March of 2024 from the City of Bend Police Department in the *before* and *after* conditions along the corridor, and specifically, at the project intersections. The team identified *before* and *after* crash data in the study area.

The crash data is shown below in Table 8.7.

TABLE 8.7: CITY OF BEND POLICE DEPARTMENT CRASH REPORTS

CRASHES (BEFORE)	CRASHES (AFTER)	REDUCTION IN CRASHES	PERCENT REDUCTION
26	12	14	53.8%

The team then reviewed the crashes that occurred at the project signalized intersections. The team reviewed the actual crash reports determining which crashes were related to the traffic signals. The number of crashes before and after at signalized intersections is shown below in Table 8.8. It is unclear to what extent the signal improvements contributed to reduced crashes.

TABLE 8.8: CRASHES AT SIGNALIZED INTERSECTIONS

CRASHES (BEFORE)	CRASHES (AFTER)	REDUCTION IN CRASHES	PERCENT REDUCTION
15	7	8	53.3%

TRAVEL TIME

In the one-year periods from April 2021 through March 2022 and from April 2023 through March of 2024, DKS calculated travels times and travel time reliability. The team evaluated the following measures: Average Travel Time, 95th Percentile Travel Time, Buffer Index, Planning Time Index.

After an initial evaluation showed higher travel times in the *after* period, the team consulted with ODOT and City of Bend staff. The City had issued lane closure permits to a developer for work within the right-of-way on Arizona and to the local gas company for a new service connection on Colorado. The evaluation was re-done with the dates of the lane closures removed from the analysis. The re-evaluation changed the outcomes slightly, but did not change the conclusions.

These measures are defined as follows:

Average Travel Time is the mean travel time necessary to traverse the segment. It is computed by adding all the travel times in the data set and dividing the sum by the number of data points. The time is reported in minutes.

95th Percentile Travel Time is a measure of the severity of travel times on the heaviest travel days. On 95 days out of 100, the motorist's travel time is less than this time. The measure is reported in minutes.

Buffer Index represents the extra buffer that travelers would need to add to their average travel time when planning trips to ensure on time arrival. It is computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time.

Planning Time Index represents the total travel time that should be planned when an adequate buffer time is included over the free-flow speed.

Table 8.9 shows the travel time performance measures in the *before* and *after* condition on Arizona Avenue, the eastbound one-way street in the afternoon peak.

TABLE 8.9: TRAVEL TIME FOR ARIZONA EASTBOUND EVENING PEAK PERIOD (3:00 PM TO 6:00 PM)

PERFORMANCE MEASURE	BEFORE	AFTER	PERCENTAGE IMPROVEMENT
CORRIDOR AVERAGE TRAVEL TIME (MIN.)	1.79	1.83	-2.23%
95TH PERCENTILE TRAVEL TIME (MIN.)	2.16	2.31	-6.94%
BUFFER INDEX	0.21	0.26	-2.38%
PLANNING TIME INDEX	1.50	1.68	-12.0%

The performance measures for Arizona Avenue were slightly worse in the *after* period.

Table 8.10 shows the travel time performance measures in the *before* and *after* condition on Colorado Avenue, the westbound one-way street in the afternoon peak.

TABLE 8.10: TRAVEL TIME FOR COLORADO AVENUE WESTBOUND EVENING PEAK PERIOD (3:00 PM TO 6:00 PM)

PERFORMANCE MEASURE	BEFORE	AFTER	PERCENTAGE IMPROVEMENT
CORRIDOR AVERAGE TRAVEL TIME (MIN.)	1.71	1.75	-2.34%
95TH PERCENTILE TRAVEL TIME (MIN.)	2.00	2.14	-8.00%
BUFFER INDEX	0.16	0.22	-37.5%
PLANNING TIME INDEX	1.59	1.65	-3.77%

The performance measures for Colorado Avenue were slightly worse in the *after* period.

One documented factor leading to the increase in travel times was the reduction in cycle lengths. This may have led to decreased throughput on Colorado and Arizona if green time was reduced.

Other possible reasons for the increased travel times on Colorado and Arizona could include:

- Increased traffic volumes on Colorado and Arizona,
- Increased side street traffic which reduced green time for Colorado and Arizona,
- Increases in the number of pedestrians at unsignalized crossings causing Colorado and Arizona traffic to yield,
- Queuing at the uncontrolled eastbound left to US 97 northbound on-ramp. This was outside the study area, but the left turn frequently queued back onto Arizona, and
- Queuing at the roundabout at the Colorado and Simpson. The roundabout was just outside the study area and queue spillback could have influenced travel time in the corridor.

As noted earlier in the report, ODOT staff reduced the cycle length from 60 seconds in an effort to reduce delay for all users, including pedestrians. The focus of the timing change was not specifically to reduce delay on Colorado and Arizona.

USEFULNESS OF ATSPMS

INTERVIEW BACKGROUND

The team developed a series of interview questions for ODOT and City of Bend staff engaged in signal operations. The team interviewed the signal operators in a group setting, allowing for detailed discussion. The interview participants were provided with the questions in advance.

The interview questions were designed to determine how widespread the use of ATSPMs were, how they impacted the level of effort by agency staff, the results of the use of ATSPMs, and how the use of ATSPMs changed agency processes.

The team conducted one interview with ODOT and City of Bend staff. There were two participants from ODOT's Region staff responsible for signal operations, one person from ODOT Headquarters Traffic Section who supported signal operations and ATSPM, and a City of Bend operations engineer.

The interview results are summarized below.

USE OF ATSPMS

The interviewees indicated that the primary users of ATSPMs were signal operations staff. Maintenance staff were beginning to use some of the features as they gained more familiarity with the Central Signal System. Signal operators were using the measures daily and using weekly summary reports. The primary measures used were the Purdue Phase Termination and the Split Monitor. They used ATSPMs to help troubleshoot maintenance tasks, most often detector failure. They used the system to follow up on complaints from motorists.

LEVEL OF EFFORT

Attendees answered that it was much easier to use ATSPMs versus traditional field signal evaluation methods. They could log on to a computer and see immediate performance reporting, indicating if there was a problem or not. Performance reporting could also help identify the level of effort to address the problem prior to troubleshooting. It did save time, especially eliminating driving time to the site, as they could troubleshoot remotely and prioritize when and where to go on- site, especially after citizen calls. An auto-generated, weekly e-mailed, Power BI report that captured the ATC high resolution data outputs was also helpful for saving time and facilitating tasks.

RESULTS

The interviewees reported that they had observed positive results from the use of ATSPMs. They could align operational objectives at each intersection with ATSPM metrics. They indicated that they could identify detector failure and faults sooner than with past practices. The use of ATSPMs had a side benefit of making it easier to input information into ODOT's traffic signal and ITS asset management system (MicroMain). As a result, more and better information was being inputted into MicroMain.

PROCESSES

Interviewees said that they had changed some processes based on the implementation of ATSPMs. However, the ATSPM outputs from MaxView and now Kinetics were still a bit cumbersome and required quite a bit of programming in those platforms. There as a desire for more streamlined ATSPM reporting from the Central Signal System. Still, they assessed and reported signal operations more frequently. They could also use probe data from RITIS to immediately assess *before* and *after* performance that had been adjusted based on ATSPM data. They were still processing how to use ATSPM data to help manage traffic for special events. Identifying the correct audience for their measures and developing reports catered for that audience still required refinement.

SUMMARY

Traffic signal operations staff have begun to implement ATSPMs to improve signal operations and maintenance. ATSPMs have led to improved response times to detector outages, collaboration among work units, and signal operations related to special or non-recurring events. To date, the use of ATSPMs has largely supplemented past work practices rather than replaced them. Additional effort will be required to fully integrate ATSPMs into signal operations practices.

BENEFIT/COST

DEVELOPMENT OF BENEFIT/COST

The assessment of benefits were quantitative and qualitative. The benefits evaluated were the changes in average travel time and the safety benefit of the reduction in crashes on the two roadways as well as qualitative benefits identified by ODOT staff.

The project cost was $830,000 (863,200 when adjusted to 2023 dollars).

BENEFITS OF REDUCTION IN DELAY

The team developed the monetary value of the reduction in travel time using values from ODOT's *Estimated Value of One Hour of Travel Time Savings by Vehicle Class*[29] published in 2025, the latest version of this report. The costs were applied to the reduction in average travel time during the peak period from 3 p.m. to 6 p.m. on weekdays as shown in Table 8.9 and 8.10 above. The reduction in peak hour delay was assumed to be the same across the entire peak period from 3:00 p.m. to 6:00 p.m. Traffic volumes were developed from ODOT's *Oregon Traffic Count Database*.[30] Values were assigned to cars and trucks based on classification counts from the same database. Per the FHWA guidance, cost of delay values were assigned to passenger cars and trucks. In the classification counts, Classes 1 through 3 were counted as passenger cars

[29] ODOT Transportation Development Division Planning Section, Transportation Planning Analysis Unit. "Value of Travel Time Estimates," February 2025

[30] https://ordot.public.ms2soft.com/tcds/tsearch.asp?loc=Ordot&mod=TCDS

while Class 4 and above were counted as trucks. The monetary value of the delay in the peak period was assumed to be the total monetary value for the entire day. The value of the delay was annualized by multiplying the daily value by 260 working days in a year.

The annualized cost of the increase in delay was approximately $36,000. Table 8.11 shows the annualized costs.

TABLE 8.11: REDUCTION IN DELAY

DIRECTION	VALUE OF REDUCED TRAVEL TIME PER DAY	WORKDAYS PER YEAR	ANNUAL BENEFIT OF REDUCTION IN DELAY
WESTBOUND (COLORADO)	-$60.96	260	-$15,848.93
EASTBOUND (ARIZONA)	-$76.96	260	-$20,010.10
TOTAL	-$137.92	260	-$35,859.03

BENEFIT OF REDUCTION IN CRASHES

Safety benefits were derived from the crash or incident reduction in the project limits. While crash severity data was available, due to the relatively short time frame where crash data was available in the after period, it was decided not to rely on the severity data. The team assumed that all crashes were property damage only and assigned an economic value to the crash of $24,800. This was the value that ODOT developed for its safety program. Table 8.12 shows the benefits of the reduction in crashes in dollars.

TABLE 8.12: BENEFITS OF CRASH REDUCTION

CRASHES	NO. OF CRASHES (BEFORE)	NO. OF CRASHES (AFTER)	REDUCTION AMOUNT	CRASHES	NO. OF CRASHES (BEFORE)
CRASHES	15	7	8	$24,800	$198,400

The total benefit annual in the reduction in the cost of crashes was $198,400.

TOTAL BENEFITS AND BENEFIT COST

The total project cost was $830,000 in 2022 and, after adjusting for inflation, was $863,200 in 2023 dollars. The service life of these ITS devices was assumed to be ten years.

The total discounted benefits of the reduction in delay and reduction in crashes were $2,420,174. This included the reduction in benefit caused by the increase in delay.

The team followed USDOT guidance by using the spreadsheet tool from the online Benefit Cost Analysis Guidance (2025 Update). As noted, the team used ODOT values for the cost of crashes and the value of travel time. The team calculated the annual operation and maintenance costs to be $660. Using USDOT guidance, a discount rate of 3.1 percent was applied to both the safety and time travel savings benefits for each of the ten individual years following the completion of the project.

This resulted in a Benefit/Cost Ratio of 2.80 and a net present value of $1,556,974. Table 8.13 shows the total discounted benefits, costs, net present value, and the benefit cost ratio as discussed above.

TABLE 8.13: BENEFIT COST RESULTS

TOTAL DISCOUNTED BENEFITS	TOTAL DISCOUNTED COSTS	NET PRESENT VALUE	BENEFIT COST RATIO
$2,420,174	$863,200	$1,556,974	2.80

QUALITATIVE BENEFITS

The primary benefit of the project has resulted from the implementation of ATC's, improved communication infrastructure, and the implementation of ATSPMs through Maxview and now Kinetics. These improvements have supported improved situational awareness for ODOT and City operations staff.

In the interview, staff noted improved response times to detector outages and an improved ability to deal with special events or other types of non-recurring congestion. They also noted the improved ability to assess the effects of timing changes.

Staff was able to evaluate and address some issues remotely without going out into the field to physically observe or fix the issues. This saved personnel time and vehicle costs of going on-site. It also reduced the safety risk to staff working in traffic. While these signals were only a ten or 15-minute drive from the ODOT and City offices, further benefits will accrue as more signals are brought onto the central signal platform. As an example, some signals in the ODOT Region, in Biggs and Klamath Falls, OR, are nearly a three-hour drive from the Region office. Avoiding field visits to these locations could save six hours of travel time.

The use of ATSPMs allows operations staff to refine signal timing based on real-time conditions rather than waiting months or years to collect data. They receive better data regarding asset data entered into their asset management system.

FINDINGS

ASSESSMENT OF OVERALL SYSTEM PERFORMANCE

Determine if red-light-running and/or near-miss events were reduced.

Overall, the number of red-light-running and near-miss events had not been reduced after the installation of the data collection devices within the short evaluation period. Conversely, the number of events has increased out of proportion to the number of vehicles entering the intersections; except for near-misses with pedestrians/bicyclists, which showed a percentage decrease for most intersections. This suggested that the installation of radar detection for pedestrians and cyclists led to a decrease in the number of events.

A possible factor that could have caused the increase in events was more aggressive driving during normal road conditions.

Determine if the variability of average travel speeds were reduced within the corridor.

The eastbound travel time for Arizona Avenue eastbound increased slightly as did the 95th percentile travel time and buffer index. The Planning Time Index increased slightly. The westbound travel times for Colorado Avenue also increased. Reliability measures slightly also worsened. Overall, the average travel speeds were not reduced within the corridor after the completion of this project. Possible reasons for this included:

- Increased traffic volumes on Colorado and Arizona,
- Increased side street traffic which reduced green time for Colorado and Arizona,
- Increases in the number of pedestrians at unsignalized crossing and signalized crossings with increased pedestrian push button actuations, causing Colorado and Arizona traffic to yield,
- Queuing at the uncontrolled eastbound left to US 97 northbound on-ramp. This was outside the study area, but the left turn frequently queued back onto Arizona, and
- Queuing at the roundabout at the Colorado and Simpson. The roundabout was just outside the study area and queue spillback could have influenced travel time in the corridor.

Determine the usefulness of ATSPMs were for monitoring and managing corridor operations.

An interview with ODOT and the City of Bend staff Bend concluded that ATSPMs were more effective for monitoring and managing corridor operations compared to previous practices. ODOT stated that ATSPMs were relatively easy to use, delivered positive results, but could still be improved. ATSPMs have led to improved response times to detector outages, collaboration among work units, and signal operations related to special or non-recurring events. They were also able to align ATSPMs with operational objectives.

IDENTIFICATION OF ISSUES

Overall, the combination of improvements appeared to be operating well. The relatively short length of the corridor, closely spaced traffic signals, external effects of traffic queuing into the corridor and the pedestrian activity on the corridor all served to limit the improvements in corridor travel time. The combination of improvements did enhance the ability of operations staff to manage the corridor.

The use of video analytics as a surrogate for safety data is in its infancy. The *before* and *after* data for near-misses and red-light-running was interesting to see. It was, however, not easy to put that data in context with other, similar intersections, especially in such short duration evaluation periods, nor was it easy identify the overall safety experience or what strategies, if any, operations staff should take to address the number of incidents. Increased use of the technology and insights captured used in conjunction with official crash reporting tools should lead to improved metrics over time.

RECOMMENDATIONS FOR OPERATIONS

ODOT should seek opportunities to support the implementation of ATSPMs. For instance, providing training for operations staff on data utilization would be beneficial. Some standard reports for ATSPM data have been created, but additional work remains to be done. Reports showing the benefits of ATSPMs at a higher level would be helpful in ensuring the agency continues to invest in the technology. Efforts should be made to ensure that ATSPMs are used to proactively address operational issues, rather than relying on traditional reactive methods.

Overall, the agency should seek opportunities to use ATSPM to support and improve their culture of operational improvement.

9 Unmanned Aircraft System Crash Reconstruction

PROJECT DESCRIPTION

The Oregon Department of Transportation (ODOT) assisted Oregon State Police (OSP) with procuring and implementing the equipment, software, and training needed to launch and maintain a successful small-unmanned aircraft system (sUAS) Reconstruction Program within OSP. This project was to evaluate the benefits of using sUAS for crash reconstruction as opposed to traditional methods. The project's intent was to enable OSP to clear incidents that required crash reconstruction more safely and quickly. Expected benefits included reducing roadway clearance and reducing time on scene (e.g., exposure to traffic) for the crash Reconstructionist. This project deployed five sUAS systems at the following locations:

- St. Helens OSP Region
- Salem OSP Region
- Central Point OSP Region
- La Grande OSP Region
- Ontario OSP Region

FIGURE 9.1: EXAMPLE OF INCIDENT ON A TWO-LANE HIGHWAY IN OREGON WITH A RECONSTRUCTION USING SUAS

PROJECT GOALS, OBJECTIVES, AND MEASUREMENTS

The FHWA ATCMTD grant required each project to have an evaluation plan shortly after the grant award, and a cooperative agreement signing between the agency and FHWA. The evaluation plan was to include project objectives, a list of evaluation criteria, and a description of data collection procedures for determining before/after results needed to report on the achievement of the project.

The following were the goals, objectives, evaluation questions, performance measures and methodology for the project. It was the basis for this evaluation report.

EVALUATION GOALS, OBJECTIVES, AND EVALUATION QUESTIONS

Goal: Improve Traffic Incident Management (TIM) Operations

Objectives: Reduce on-site TIM investigation time; improve efficiency of data collection activities.

PERFORMANCE MEASURES AND EVALUATION METHODOLOGY

Evaluation Question No. 1: Does the use of sUAS technology reduce the on-site traffic control time requirements?

Measures of Effectiveness: Median road clearance time.

Data Source/Method: Incident-related time logs from ODOT dispatch. The evaluation compared *before* and *after* datasets to determine the effect of sUAS technology on median road clearance time by crash severity.

Evaluation Question No. 2: Does the use of sUAS technology increase the efficiency of the data collection process?

Measures of Effectiveness: Number of mapped points per time on scene.

Data Source/Method: OSP and ODOT records of number of mapped points and the amount of time a collision reconstructionist spent at the collision scene. The evaluation compared *before* and *after* datasets to determine the effects of sUAS technology on the number of mapped points per time on scene.

PREVIOUS COLLABORATIONS

OSP previously worked with ODOT's Geometronics Unit in using robotic surveying Total Measure Stations for crash reconstruction. These previous collaborations gave OSP and ODOT the idea for this joint agency's project at the time of grant proposal writing. The Total Measure Station equipment listed below is the traditional means OSP uses for scene reconstruction and was used for comparison for this evaluation.

TRADITIONAL RECONSTRUCTION EQUIPMENT USED BY OREGON STATE POLICE

- TS-12 Robotic, one person surveying style total station utilizing auto-tracking technology
- SET550-RX, two-person surveying style total station
- SX-105T Robotic, one person surveying style total station utilizing auto-tracking technology

TRAINING AND PROCEDURES

The use of sUAS required additional training of staff. The Chief Pilot and Collision Reconstruction Unit (CRU) Sergeant had to establish procedures for legal compliance. Four District Lead Reconstructionist (DLR) completed certification and underwent additional training on geospatial and basic photogrammetry principles.

RESULTS

RECONSTRUCTION TIMES

Figure 9.2 shows the average duration from start to finish of a reconstruction sorted by equipment type. In the figures below, reconstructions are referred to as ‘recons.” Reconstruction duration is the time between when a CRU trooper arrives on scene until the reconstruction is reported complete. The reconstruction duration did not include travel time to the scene, initial photography, markings, general investigation prior to reconstruction or any activities after the reconstruction is complete.

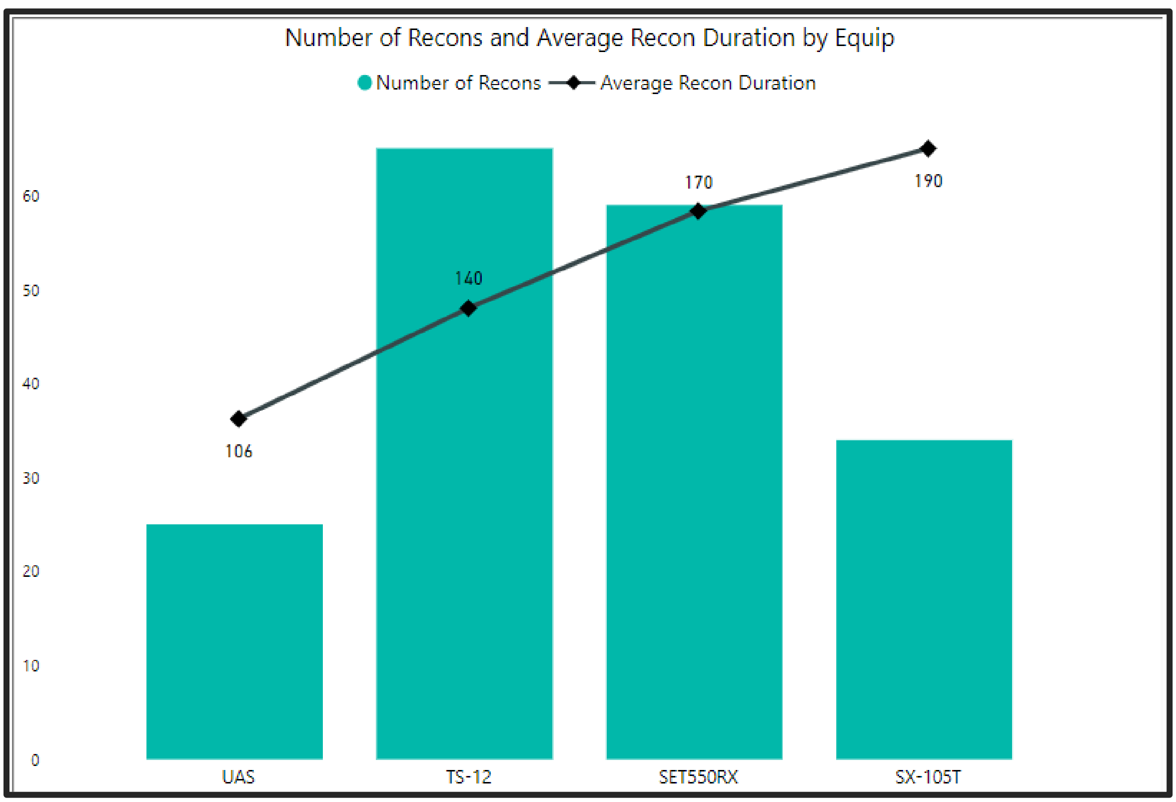


FIGURE 9.2: EQUIPMENT TYPE AND THEIR AVERAGE RECONSTRUCTION TIMES

186 crash reconstructions were evaluated for this project. 25 of those crash reconstructions utilized sUAS. The sUAS had an average reconstruction time of 106 minutes while traditional equipment had a weighted average reconstruction time of 162 minutes, an average reduction of 56 minutes. Crash scenes and equipment types were assigned based on geographic availability.

LANE CLOSURE TIMES

Lane closure times were also measured. Lane closure is the time from the start of the incident until all lanes are opened as reported by field personnel. As shown in Figure 9.3, the average lane closure duration using sUAS was 260 minutes. The weighted average lane closure duration for where traditional equipment was used was 258 minutes. For total lane closure time, there was negligible difference between the traditional methods versus the use of sUAS.

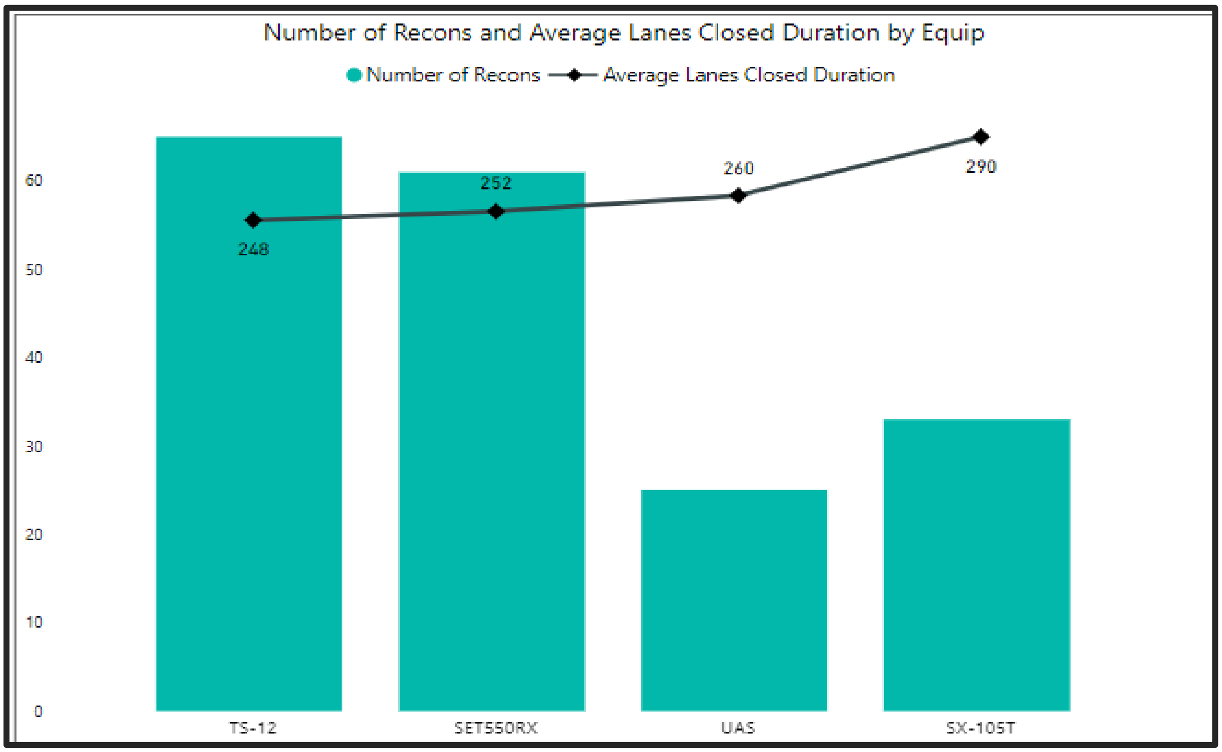


FIGURE 9.3: EQUIPMENT TYPE AND THEIR RESPECTIVE LANE CLOSURE DURATIONS

To understand why there was negligible difference in the average lane closure durations required examination of all the events and coordination required with a severe incident and clearing the scene. It included the time it took for a CRU trooper to arrive on scene, among many other factors. The data showed that the average arrival duration of a CRU trooper, not including sUAS, was 78 minutes. The weighted average arrival time for a sUAS equipped CRU trooper was nearly 87 minutes.

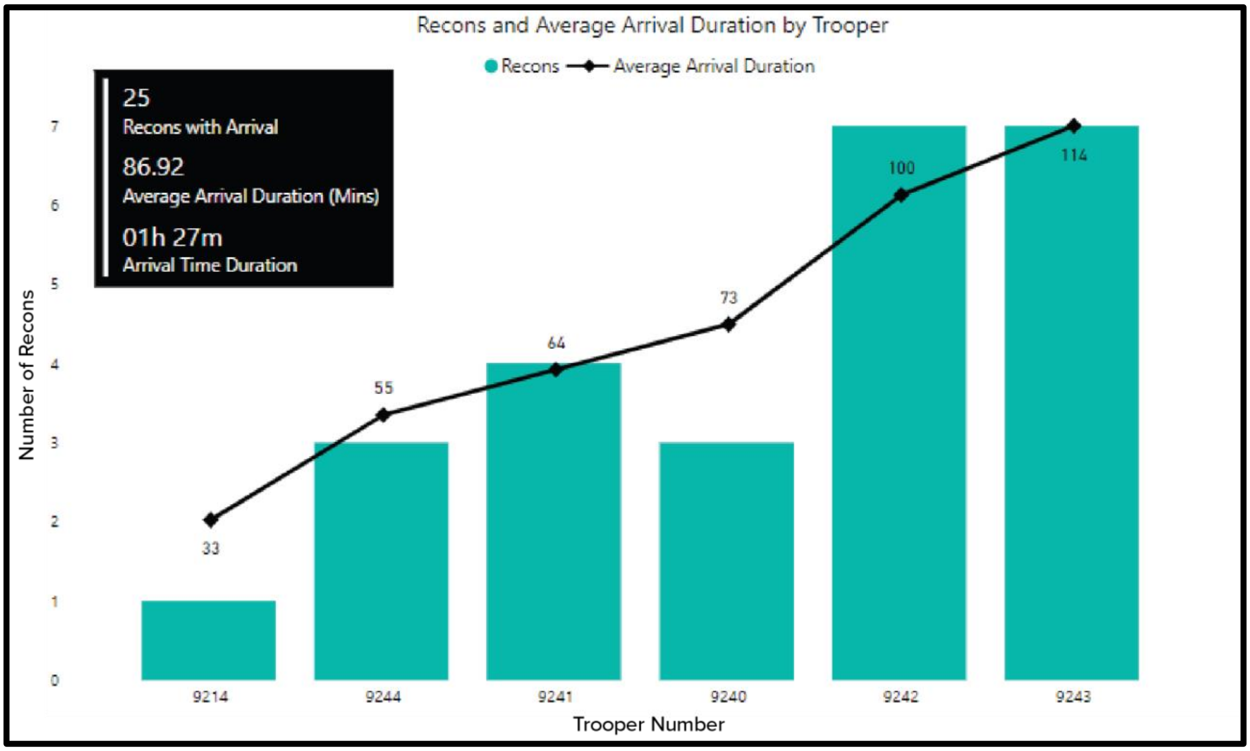


FIGURE 9.4: ARRIVAL DURATION WITH SUAS

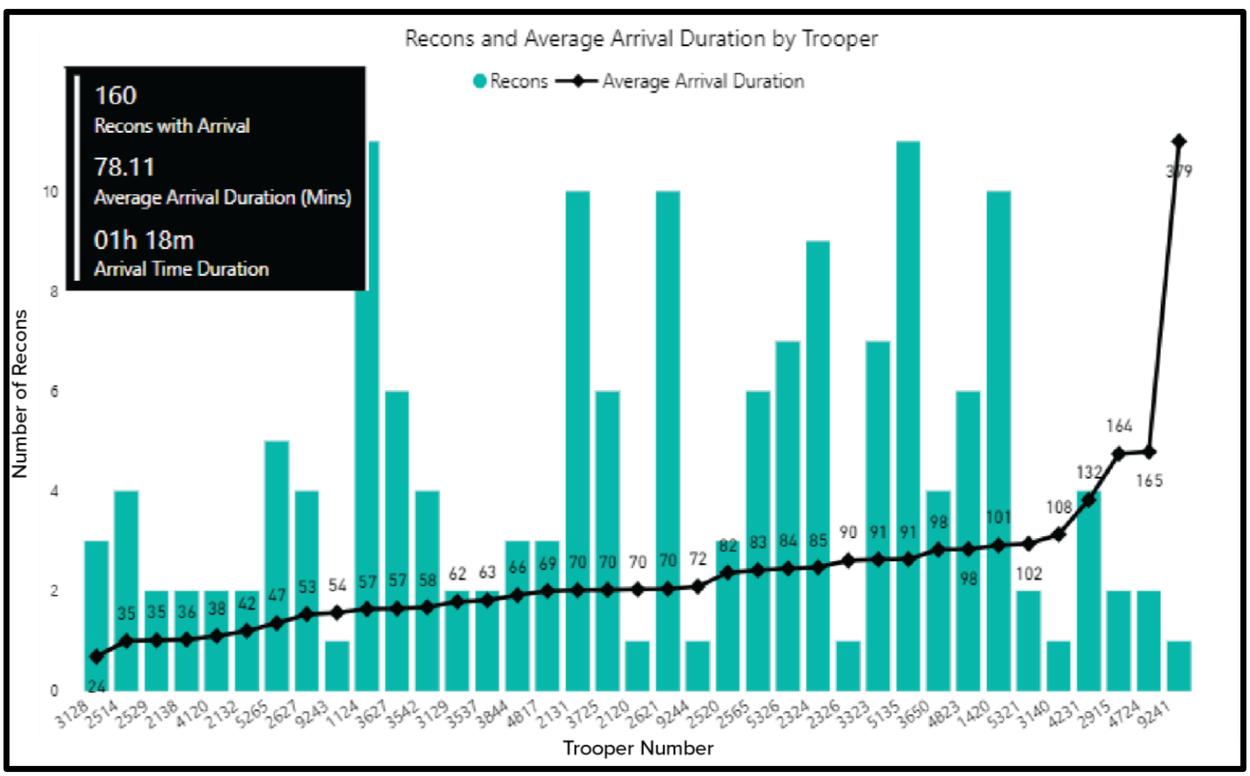


FIGURE 9.5: ARRIVAL DURATION NON-SUAS EQUIPMENT

Lane closure time included many variables involved in a severe incident. It was not an ideal measure for comparing the different technologies using ODOT's incident logs from its dispatch software system. With only five sUAS, the time it took for a reconstructionist to arrive on scene influenced the lane closure time and arrival times. Lane closure could also include how long it took emergency services and towing services to arrive on scene and clear the incident. These factors contributed to lane closure times.

With only five sUAS deployed across the state, the travel time to get a reconstructionist on scene could vary greatly depending on the location of the incident. With the deployment of more sUAS for crash reconstruction, OSP could drastically reduce the reconstruction time and increase the safety of its troopers.

SINGLE INCIDENT COMPARISON

One incident included both a Robotic Total Measure Station and sUAS for reconstruction. This incident was very complex and the initial reconstructionist was using a Robotic Total Measure Station. Due to the lengthy reconstruction time using the traditional equipment, the sUAS reconstructionist was requested to respond. The sUAS was over four hours faster to reconstruct the incident than then traditional Robotic Total Measure Station.

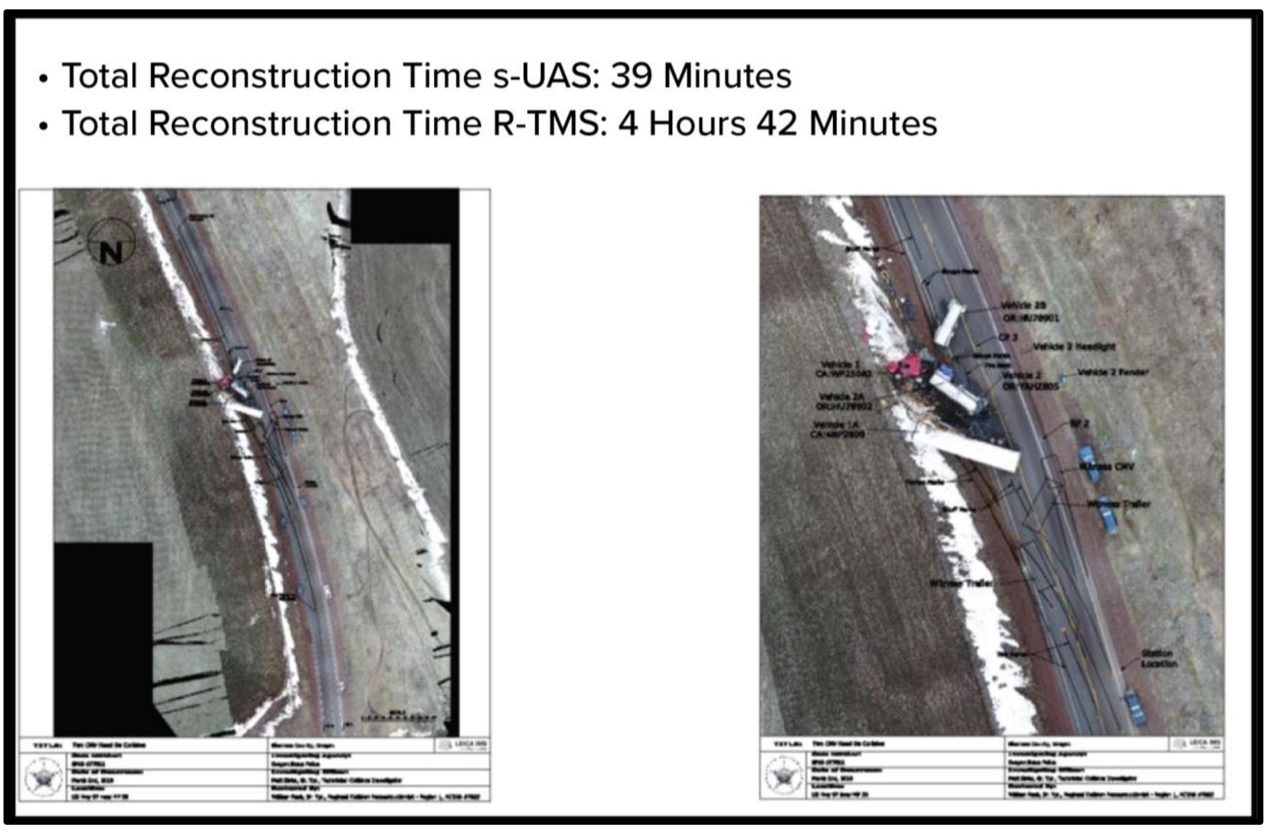


FIGURE 9.6: COMPARISON OF SUAS TO ROBOTIC TOTAL MEASURE STATION

DOES SUAS INCREASE THE EFFICIENCY OF THE DATA COLLECTION PROCESS?

In a test conducted by the Department of Public Safety Standards and Training, the sUAS collected over 20 million data points while other traditional methods only collected 90-200 data points. The sUAS also conducted several flights in the same time it took other methods to complete one reconstruction.

Additionally, the sUAS methodology reported standard deviations for every data point within a 1/9,000 of foot accuracy. Total measure station, manual or robotic, did not provide each data point's accuracy.

sUAS significantly reduces reconstruction time and has the potential to reduce highway closure times. Highway closure time is dependent on the amount of time that it takes the reconstructionist to arrive. This can vary by time of day, day of week, or location of the crash. Other factors influencing highway closure time include the time it takes the coroner to arrive in a fatal crash, the need for hazardous material clean up for a fuel spill or other hazardous material spill, or clean up a load spilled on the highway.

SUAS increases the quality of the data captured. The sUAS data is uniform and does not require the investigator to sort through the data as compared to other technologies.

LESSONS LEARNED

CONSIDERATIONS SPECIFIC TO POLICE AGENCY RECONSTRUCTION UNIT

Expected /Required Output or Deliverable

An OSP CRU standard deliverable defined as: A 2D diagram consisting of a photogrammetrically generated orthomosiac image scaled by, not less than, five control points captured by RTK GNSS (Real Time Kinematics – Global Navigation Satellite System) with a maximum solution tolerance of 0.039 feet, or in an arbitrary system when GNSS was not feasible.

Data Volume

This included data capture, transmission, storage, sharing/providing to stakeholders. During the evaluation period, the five active pilots generated approximately four terabytes of case data. This was an issue due to sUAS generating much more data, requiring a movement from DVD-R to SD cards.

Network Speed/Availability

OSP utilized centralized processing by one certified photogrammetry user. This resulted in a need to transmit raw field data for processing and a return of deliverables where individual file sizes could exceed four gigabytes (4 GB). The maximum amount of field data capture from a single case during the grant period was one hundred and ninety-one gigabytes (191 GB). Network stability certainly played a factor and created issues. During business hours, the OSP network was very slow, further creating data transmission issues. Under normal circumstances, hand delivery or other means were used to transfer data, not using the network.

Data Storage, Collection and Delivery

Data collected from scenes were stored on SD cards and submitted to evidence for proper storage and record retention.

The storage, transfer, and delivery to lead/other investigators and prosecutors were a routine issue. A Criminal Justice Information Systems (CJIS) compliant FTP site was not available at the time of the grant.

Data Processing

Processing data requires a software license with the photogrammetry software and a monthly service payment, annual license, or as a single perpetual license. Additionally, there can be annual Customer Care Programs for support and updates that come at an additional cost. Training and certification to use the software is an additional expense that requires consideration and budget prior to implementation.

COST / FUNDING

- Basic proficiency (ideal scenes) & KPI (Key Performance Indicators) are easy to train for because the comprehensive data set provides complete access to the scene to allow advanced analysis. Other technologies required a basic survey technology knowledge; sUAS can be used by anyone who understands the basics of the platform.
- Cost of equipment that is agency-enterprise-compatible can be prohibitive.
- Projected cost per unit to equip investigators with sUAS/GNSS technology is currently around $6,000 per CRU member. As a basis of comparison, R-TMS – Robotic cost $25,000 per CRU. Beyond initial deployment, annual calibration costs $2,500 per unit for R-TMS. Other total stations used by OSP cost approximately $10,000 per unit.

EQUIPMENT RELATED

- Size of equipment can be prohibitive in already-packed patrol cars.
- Challenges with the sUAS manufacturer and associated Qualified Entity Protocol (QEP), which must be maintained and applied for annually, can interfere with the ability to launch regardless of lawful flight authority.
- Maintaining software and hardware is a constant requirement.
- Robotic Total Measure Stations and terrestrial scanners will always have a place in forensic data capture. Incidents where sUAS were not used were, lack of connectivity, unjustifiable hazards, and on rare occasions, electromagnetic interference. For these reasons, sUAS is the most efficient and least-complex technology.

TRAINING

- Training to capture field data can be limited. Full understanding of reconstruction is not required.
- The training for new CRU members entails 32 hours of classroom/hands-on scenarios and education conducted during duty hours. This includes the usage of the sUAS in outdoor conventional and non-conventional applications for data capture.
- The 14 CFR Part 107 certification required by the Federal Aviation Administration is a prerequisite training requirement prior to OSP department training.

REGULATORY

- Funding and support for the administrative requirements is difficult.
- Compliance with the constantly changing regulatory environment without full time personnel is challenging.
- Hardware standardization and equipment obsolescence is difficult given the limits of government procurement processes. With some equipment becoming obsolete, the department is exploring other technologies and manufactures.

BEST PRACTICES | DATA CAPTURE AND ANALYSIS

Considerations for current and future implementation:

- What data is required to determine impact?
- Is there a way to automate the collection of that data without losing needed context?
- Would field staff (here CRU members) be able to prioritize data collection while managing complex, rapidly evolving conditions and considerations on-scene? Is that a good use of their energy/bandwidth? Is that a realistic expectation?
- Is there another way to capture the data? ODOT could update their CAD software to allow capture of additional attributes; however is that good use of their staff and resources.

OSP analysts should have provided updated CRU rosters and equipment lists as soon as those documents finalized after changes made.

DATA ANALYSIS

ODOT and OSP were able to leverage a shared CAD bus for data transmission. From previous efforts between the two agencies, a procedure was established whereby CRU members ensured the start and end times of their reconstruction work and the specific equipment used on scene was included in the OSP CAD data. This allowed ODOT to obtain raw incident data in a semi-automated fashion. ODOT then enriched that data based on receipt of periodically updated CRU personnel rosters and equipment inventories.

The plan was to leverage the previously established procedure for ODOT to collect data, receive updates, and perform analysis. However, the procedure was unreinforced with the CRU members before and during the grant period. Once ODOT performed initial analysis/visualization and OSP analyst was unable to locate specific data points within the visualization, ODOT/OSP determined that further detailed data review was necessary. OSP analyst conducted research in agency RMS (Records Management System) to verify, update, or correct data points.

Additional complexities that were discovered during data review by drilling down into OSP RMS data and reports:

- Some captured scenes were using a RTK GNSS tablet only, which was unexpected.
- Scenes mapped by multiple CRU members. Not clear in CAD data when every member arrived and/or started/completed scene documentation duties. This created some holes in the data collection requiring a further review.
- Deployed asset cases and sUAS mapping completed so quickly that ODOT did not have time to respond. This made the data unclear when comparing between ODOT and OSP since ODOT had no arrival time.
- The pilot was for ODOT maintained highways. Some incidents OSP assisted on were non-ODOT roadways, therefore data may have been collected then later removed.
- ODOT CAD data was not included for incidents when an incident was unknown to be fatal at the scene. Incidents with delayed fatal outcomes were not included.

In an effort to compare technology to technology wherever possible, complex incidents involving criminal investigations or HAZMAT that kept roadways closed for long durations and were not awaiting on-scene mapping were not included in the pilot study.

AGENCY AND PERSONNEL INVOLVED

OREGON DEPARTMENT OF TRANSPORTATION

- Traffic Incident Program Coordinator
- Traveler Information and Operations Performance Measures Program Coordinator

OREGON STATE POLICE

- Chief Pilot
- CRU Lieutenant
- CRU Sergeant
- CRU staff
- IT staff
- Procurement Staff
- Analyst

CONCLUSION

The implementation of this project was in the early days of sUAS integration into public safety and the National Airspace. This resulted in few examples to follow as a template for success. Even with the limited resources available, it has proven to be the most cost-effective and efficient method of scene data capture for OSP. This was especially true in circumstances of highway speed collisions resulting in evidence spanning a significant linear distance of roadways. Adequate prior planning brought about success. Additionally, sUAS technology continued to improve, and cost has continued to drop at a rapid rate. Airframes, capable of reliable data capture, were not purchasable for under the $1,000 price point and were significantly more compact and easier to use. This was a case where more expensive did not mean more effective. Understanding the scope of use for any sUAS purchase is important, as equipment can easily become obsolete before providing a significant return on investment. The landscape has changed significantly and resources have become readily available for public safety agencies looking to develop programs to expedite implementation and compliance.

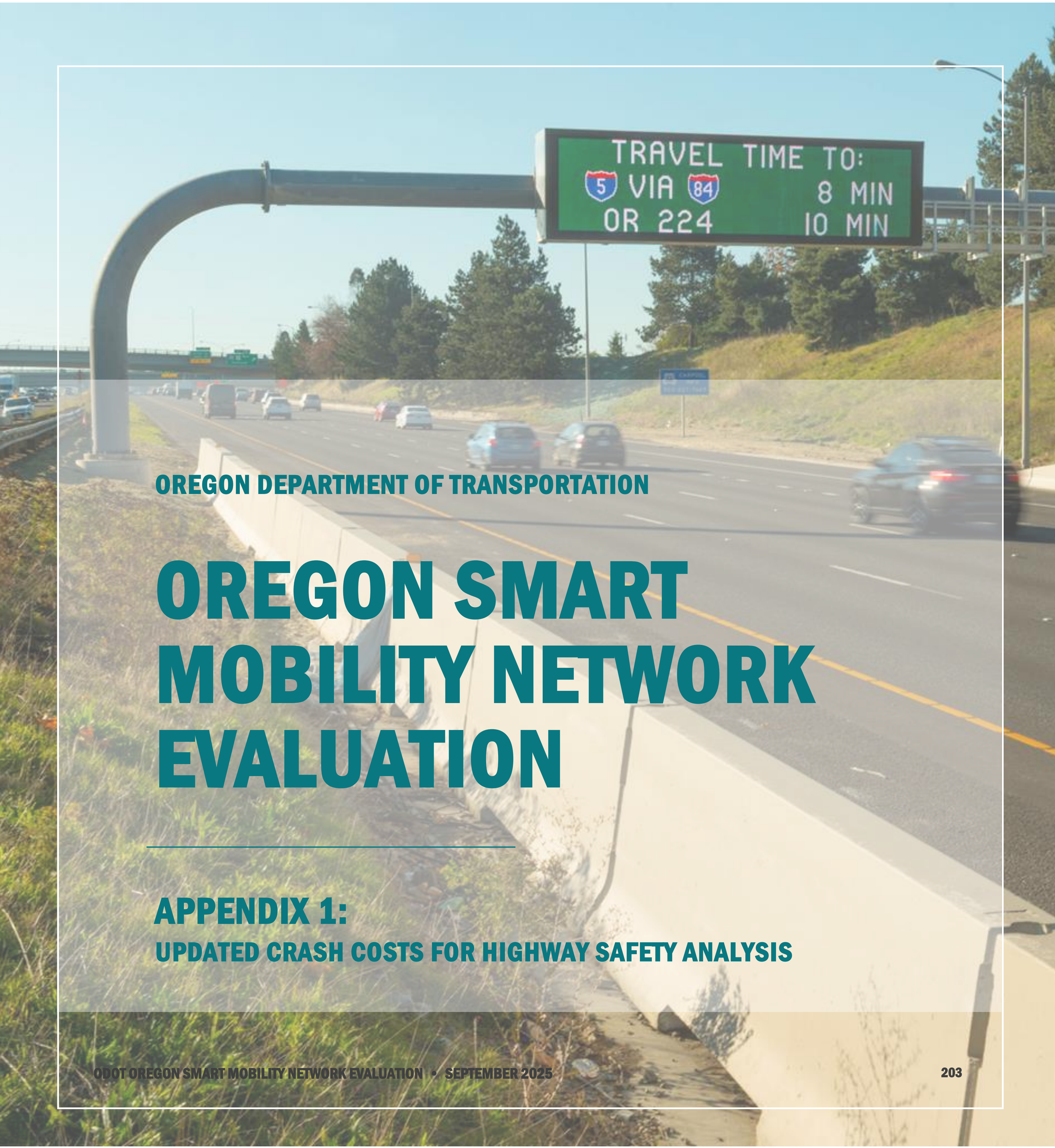
A key takeaway from this project was that severe incidents have many factors that impact lane closure times. This can include fire and ambulance services, towing services, traffic control by incident responders, witness investigation, initial scene investigation and marking, reconstruction of the incident, and many other aspects. Lane closure time is not a good performance measure for a crash reconstruction technology comparison project, especially with limited number of sUAS deployed across the state. Reconstruction time, however, removes these other incident variables and compares solely technology to technology. Figure 9.2 and the single incident comparison are good examples of the time savings that sUAS can have on reconstruction time.

From the success of this project, OSP is considering purchasing additional, more cost-efficient sUAS to those implemented in this project, aiming for wider statewide deployment. sUAS are considerably more cost-effective than the annual maintenance costs of the traditional total reconstruction station.

9 Case Studies

DATE / TIME	HIGHWAY	COUNTY	INCIDENT DESCRIPTION
02/20/2020 06:11 AM	I-5	Clackamas	During weekday morning traffic on I-5, near MP 285 in the congested Wilsonville area (Clackamas County), a commercial motor vehicle traveled from the SB lanes across the median through the cable barrier, into the NB lanes and collided with three passenger vehicles causing critical injuries. The scene was over 1,000 feet in length and documented via sUAS in approximately one hour, as opposed to an estimated Total Measure Station time of at least three hours.
02/23/2020 10:39 AM	I-5	Jackson	Near MP 23 on I-5 SB in Jackson County, a vehicle drifted from the slow lane into the median where the driver overcorrected, causing the vehicle to rollover across both SB lanes and come to rest on the west shoulder. The freeway closure was limited to 15 minutes for scene documentation via sUAS.
04/15/2020 05:04 PM	US 30	Columbia	A two-vehicle fatal collision occurred in the city of Rainier at the intersection of US 30 and East 5th Street (MP 46), in Columbia County, causing a full closure of US 30. Scene documentation via sUAS completed in less than 20 minutes. *Incident not present in ODOT data as it occurred within city limits.
05/07/2020 07:10 PM	US 97	Sherman	A commercial motor vehicle hauling over 50,000 pounds of potatoes rolled over while traveling on US 97, near MP 48 in rural Sherman County. The trailer struck a passenger vehicle resulting in a fatality. The scene was approximately a half-mile in length and complicated by curves, road grade, and surrounding topography. The scene cleared and the following day, multiple sUAS flights by two DLR completed without requiring traffic control by ODOT. The estimated time to, appropriately, document the scene using Total Measure Station estimated to exceed 8 hours.
07/05/2020 06:20 PM	SR 203	Union	Following a two-vehicle serious injury crash in Union County involving seven people (13-year-old was life-flighted), the intersection of SR 203 and Pierce Road completely closed to traffic for approximately 20 minutes to complete the sUAS flight. Scene and evidence documentation with Total Measure Station would have taken between 1.5 and 2 hours.
07/13/2020 03:39 PM	I-5	Jackson	After the RV pulled over a pickup onto its side it was towing NB on I-5 near MP 39 in Jackson County, causing a fatality, traffic was able to continue in one NB lane as the documentation and investigation conducted with sUAS. Complete roadway closure was not needed.
07/26/2020 05:46 PM	I-84	Malheur	A single-vehicle fatal crash on I-84 westbound near MP 364, northwest of Ontario, included the vehicle rolling over several times and coming to final rest in the center median. Application of sUAS required the closure of only a single lane, allowing one lane of I-84 westbound to remain open during scene documentation.
10/30/2020 03:17 PM	US 20	Lincoln	US 20 eastbound at MP 20, near the small town of Eddyville in Lincoln County, was the scene of a five-vehicle fatal crash that closed the entire roadway. sUAS capture time of the nearly 1,000-foot scene was approximately one hour, as compared to an estimated minimum of 4 hours to collect data using Total Measure Station.

Oregon Department of Transportation



OREGON DEPARTMENT OF TRANSPORTATION

OREGON SMART MOBILITY NETWORK EVALUATION

APPENDIX 1:

UPDATED CRASH COSTS FOR HIGHWAY SAFETY ANALYSIS