US 97 Parkway Plan Phase 2

Technical Memorandum #7 – Second Level Alternatives Evaluation

DRAFT

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SUMMARY

The Level 2 Evaluation builds on Level 1 evaluation[1] by applying a more comprehensive assessment of potential benefits and trade-offs associated with projects using a combination of qualitative and quantitative analysis and evaluation criteria. The key findings and proposed recommendations from the Level 2 Evaluation are presented by geography (Corridor Wide, North Study Area, Central Study Area, South Study Area) below. Preliminary results will be reviewed with the Project Management Team, the BMPO Policy Board and TAC, the Sounding Board and on-line open houses. This memorandum will then be revised to address stakeholder input and projects will be further prioritized for implementation as part of the Investment Strategy.

CORRIDOR WIDE PROJECTS

Ramp Meters

Ramp meter implementation strategies would need to consider multi-lane meters at the Empire Boulevard Southbound On-Ramp and the Colorado Avenue Northbound On-Ramp. Queue spillback impacts from ramp meters appear to be manageable on existing ramps, with some exceptions. A more dynamic analysis is needed to determine the fully balanced impacts of ramp meters, as the current analysis provides the worst-case local system and best-case ramp terminal results. Due to difficult to improve ramp length constraints, at a minimum the Revere Avenue Southbound On-Ramp and Colorado Southbound On-Ramp would need to either be triggered by mainline speed reductions/traffic density or located upstream of ramp curvature to ensure safe vehicle merging speeds. However, a ramp meter implementation strategy would likely involve similar methods for triggering ramp meters throughout the corridor. Overall, actual ramp meter locations would need to be evaluated in more detail on a case by case level due to several ramps not currently meeting standards.

Ramp meters have significant trade-offs on the City's system for reliability and shifting VMT onto the local system (particularly 3rd Street). Some of these impacts could potentially be addressed through signal improvements along 3rd Street. Under future traffic conditions, ramp meters have the potential to produce major improvements to Parkway operations and safety. Overall, this project performed well against the evaluation criteria, showing potential to achieve many of the project goals. Additional projects are needed to make ramp metering feasible (RIRO Closures and Improving Ramps to Standard Lengths) as well as the elimination of an at-grade intersection at Powers Road. Therefore, this project is recommended for inclusion in the implementation plan as a long-term solution, with a recommended next step of a concept of operations to determine the triggers and strategies need for effective operation.

RIRO Closures/Modifications

Based on a traffic operations screening analysis, closure of all right-in-right-out (RIRO) access except the exit at Hawthorne Avenue was evaluated. The exit at Hawthorne was maintained to provide continued access to downtown businesses via Oregon Avenue.

[1] US 97 Parkway Plan Phase 2: Technical Memorandum #6 First Level Alternatives Evaluation, July 9, 2019

This project would provide significant safety and mobility benefits to the Parkway by eliminating at-grade access points and reducing local short trips on the Parkway. The closures also increase the effectiveness of ramp meters in optimizing throughput and travel time reliability on the Parkway.

The closures do increase traffic demand on the local system, particularly on 3rd Street and Wall Street, as local trips shift off the Parkway. The City is already proposing a study to identify improvements to the "Z" (Wall/Revere/Division) as well as signal improvements to the 3rd Street corridor. Local system benefits included reductions in queuing on streets that formerly provided Right-On access to the Parkway.

This project is relatively inexpensive with minimal to no ROW impacts and is recommended to be implemented through a phased approach. Overall, this project performed well against the evaluation criteria, achieving many of the project goals, and is recommended for implementation.

Ramps Improved to Standard Lengths

The most sub-standard acceleration and deceleration lane length locations on the Parkway are the at-grade, RIRO intersections. If these were closed, the number of substandard locations on the corridor would significantly decrease.

This project provides some safety benefits along the corridor, reducing crashes at merge and diverge locations. This project would also be beneficial, although not required, to implement ramp metering on the corridor.

The costs of this project would vary widely depending on location and the methods used to gain additional width. While this project did not score particularly well against all the project goals, it also had no negative scores. A phased approach would be an effective way to implement this project, maximizing safety benefits will minimizing costs.

The following ramps are recommended for near-term improvement, based need (particularly safety) and on feasibility for near-term implementation (related to cost and ROW):

- SB US 97 to Hawthorne Ave
- SB US 97 to Reed Market Rd
- Revere Ave to NB US 97

The following additional ramps are also deficient and recommended for medium to long-term improvements due to cost and ROW constraints:

- Powers Road On-Ramps – Likely to be addressed through a grade separation project
- China Hat/Ponderosa acceleration/deceleration lanes – Likely to be addressed through a grade separation project
- Division Street from Reed Market Road to northbound US 97 – Could be addressed as part of the solution for the Reed Market Road Corridor
- Colorado Avenue Northbound On-Ramp – Potential to avoid bridge impacts by re-aligning bridge curvature.

Active Transportation Improvements

US 97 is a high-stress environment for people walking and biking in the corridor and creates a barrier for those desiring to travel east-west across the city. Providing low-stress alternative routes on City facilities that parallel US 97 is the preferred approach for accommodating north-south travel. However, enhanced pedestrian and bicycle crossings of US 97 that connect to the citywide low-stress network will be important for encouraging people to walk and bike.

The joint ODOT-City Bicycle and Pedestrian Working Group has identified several locations where enhancements are needed to existing crossings and where new crossings are needed to fill gaps. When all projects are completed, east-west connectivity will be significantly improved, making walking and biking a more feasible and attractive option. We have worked with the Bicycle and Pedestrian Working Group to identify the highest priority crossing locations for improvements.

Overall, this project performed well against the evaluation criteria, achieving many of the project goals, and is recommended for implementation.

Transportation Systems Management and Operations Projects

Weather Warning Systems, Variable Speed Signs, and Roadside Traveler Information Dissemination – Weather warning systems and variable speed signs are two of the highest scoring TSMO strategies and have a significant ability to cost-effectively improve safety and travel time reliability in the Parkway corridor. Roadside traveler information dissemination on its own may provide only minor benefits, but these three strategies complement each other and can share common infrastructure, making this a cost-effective package of improvements that are recommended for near-term implementation.

Incident Management – A comprehensive incident management program may be among the most effective TSMO strategies for reducing crashes and incident-related delay on the Parkway. Improvements could include enhancing inter-agency coordination, expanding detection and video monitoring coverage, and increasing the size of the responder fleet. The potential effectiveness of incident management could be improved by also implementing the strategies to widen shoulders to meet standard widths, as discussed below, and provide roadside traveler information. Overall, this project performed well against the evaluation criteria, achieving many of the project goals, and is recommended for implementation.

Shoulders Built to Standard Widths – Widening the Parkway shoulders to meet standard widths would provide space for law enforcement activity, disabled vehicles to pull over, bicycle travel, passage around incidents, opportunities for improved freight operations, potential transit use, and partial storage for snow removal. Wider shoulders would also enhance incident management, which is recommended as a key strategy for reducing non-recurring congestion and improving travel time reliability. This strategy may require a greater cost for implementation than many other TSMO strategies, but it can also be constructed in smaller phases to better align with available funding. This project is recommended for implementation.

Enhanced Traffic Signal Operations at Ramp Terminals and Traveler Information Signing – These TSMO strategies provide relatively limited benefits compared to other improvements considered, though safety benefits that can be achieved through enhanced traffic signal operations at ramp terminals can be substantial where ramp queues extend too close to the Parkway mainline. While not

recommended for stand-alone implementation, these are low-cost, effective improvements that could be easily implemented in the near-term as part of other projects or maintenance activity.

Traffic Signal Priority for Transit and Freight at Signalized Intersections on US 97 – Transit and Freight Priority at traffic signals can be effective for reducing delays for these modes of travel, but they don't score well against the project evaluation criteria because they provide benefits to only a limited number of project goals. Furthermore, with only three traffic signals on the Parkway mainline (at Cooley Road, Robal Road, and Powers Road) and the long-term plan to remove them in favor of grade-separated facilities, the degree of benefit that could be achieved may be limited. Therefore, these projects are recommended for short-term, interim implementation in conjunction the current ATC controller implementation plan at locations where transit lines and existing Parkway signals intersection intersect.

North Study Area

The US 97 North Corridor FEIS included an extensive evaluation and selection of a Preferred Alternative for improving travel conditions in the North Study Area. The complete set of improvements are very costly, but otherwise score very well against the evaluation criteria, confirming their ability to achieve the plan goals, and are recommended for implementation. Note that all the analysis and findings work completed in this study related to the FEIS includes the full Preferred Alternative and not the yet to be determined interim solution from the on-going North Corridor Study.

Central Study Area

US 97 Mainline Projects

The auxiliary lanes on southbound US 97 between Empire Boulevard and Butler Market Road and on northbound US 97 between 3rd Street and Empire Boulevard are included in the US 97 North Corridor FEIS. Both projects will be effective for relieving congestion in this area, providing more capacity than the expected demand and easing merging operations. Overall, these projects performed well against the evaluation criteria, achieving many of the project goals, and are recommended for implementation. Note that throughout all the alternatives analyzed, the demand on the northbound off-ramp to Empire Boulevard continues to show significant future growth, indicating a continued need to widen this ramp to two lanes, although the widening does not necessarily to extend onto the Parkway (i.e. a two-lane diverge is not needed).

Butler Market Road Projects

Southbound Frontage Road from Interchange to US 20 – This project provides mobility benefits to the Butler Market and Southbound Off-ramp, Division Street and 3rd Street, and Butler Market and 3rd Street intersections, along with crash reductions and potential for a new bike-pedestrian connection. This project performed well against the evaluation criteria, meeting many of the project goals, and is recommended for implementation.

Southbound Off-Ramp Terminal Traffic Control Options – Both the signal and roundabout projects performed well from a safety and mobility standpoint at the ramp terminal and score well against many of the project goals. Both options are feasible in combination with the southbound frontage road. The channelized two-stage left turn did not provide any significant benefits and did not perform well against

the project goals. Therefore, this channelization control concept is not recommended for implementation.

Traffic Control Options at Butler Market Road and 4th Street – Both the roundabout and the traffic signal performed well from a safety, mobility, and local travel time reliability at this location, while also relieving queuing impacts to the Butler Market/US 97 ramps. Overall, this project scored well against the project goals, and is recommended for implementation.

Note the final traffic control option identified through design at this location should consider compatibility with the final option selected for the southbound off ramp at Butler Market. In general, for closely spaced intersections, it is preferred to use the same control types at both locations to enhance performance, safety and efficiency.

Revere Avenue Projects

The Revere Avenue lane re-channelization project from 4th Street to Wall Street would reduce through capacity on Revere Avenue but would enhance bicycle facilities, provide dedicated left-turn lanes at Division Street, and create the ability to separate left-turn phases at Division Street and Revere Avenue during railroad closures to the east.

This project would result in a small degradation in capacity at the interchange ramp terminals, but the overall benefits may justify this. Also, it should be recognized that the project evaluation criteria may not be designed to fully describe the potential local benefits that could be provided by the proposed re-channelization. There is potential for increased safety by separating out left turns at Division Street. Despite the small degradation in ramp terminal capacity, the overall effect on the Parkway corridor strategy from this project would be negligible. Overall, this project scored well enough to be recommended for implementation, pending further design refinement.

Colorado Avenue Projects

Reconstructing the Colorado Avenue interchange into a diamond configuration would relieve some congestion and safety issues but would be a very expensive and impactful project. Major capacity expansion would be required for a diamond configuration because the major movements at this interchange (the northbound to westbound and eastbound to northbound movements) that currently do not conflict today would conflict under a diamond configuration. Additional turn lanes and ramp widening would be needed to make this alternative work. The ROW impacts and capital costs of this project to provide similar performance to much cheaper alternatives lead to a recommendation not to implement a full interchange re-build at Colorado.

Constructing a traffic signal with westbound right turn lane or roundabout at the northbound ramp terminal could address the safety and capacity problems at a significantly lower cost than reconstructing the interchange in a diamond configuration. Overall, this traffic signal project scored well enough to be recommended for implementation, pending further design refinement.

However, additional improvements at the southbound ramp terminal would still be required, which may involve realigning/reconfiguring the southbound ramps intersection with the Colorado/Arizona couplet. A future project at this location should include consideration of the Aune Extension and the Sisemore Extension, as well as the future circulation impacts identified in the Core Area Plan.

SOUTH STUDY AREA

Reed Market Road

The congestion that occurs along Reed Market Road and spills back onto the Parkway cannot be addressed by simply re-building the interchange to add capacity. In fact, the key issues can likely be addressed through some circulation simplifications and traffic control upgrades at the northbound ramps, combined with access management along Reed Market and improvements at the Reed Market/Bond and Reed Market/3rd Street intersections.

Constructing dedicated left-turn lanes would partially address the safety and congestion issues at the Reed Market/ 3rd Street intersection, but the operational problems will still be significant. A more comprehensive solution will need to be found through further study that encompasses a broader set of issues such as area connectivity, property access, and pedestrian crossing opportunities, while identifying set of solutions that can be implemented on Reed Market Road from Bond Street to 3rd Street. Based on its performance against the evaluation criteria, the signal/roundabout at the northbound ramps is recommended for further consideration as part of a potential solution in this Reed Market Corridor study.

Powers Road

An interchange would perform better from a mobility standpoint and would maintain needed street connectivity in this area. Both alternatives would address a major bottleneck and safety issues on the Parkway, but the overcrossing would divert traffic to surrounding streets and neighborhoods which would create other congestion and safety problems. Therefore, the interchange project is recommended for implementation. The full recommendation for Powers Road will be included in Technical Memorandum #8.

Murphy Road

The recommended design for the remaining ramps at the Murphy Road interchange will be included in Technical Memorandum #8.

China Hat Road

The China Hat Overcrossing scored very well against the project evaluation criteria, but the frontage road from Murphy Road to Ponderosa Street would need to be constructed to maximize the benefits associated with this alternative. When coupled with the frontage road, the China Hat Overcrossing relieves some of the demand from Parrell Road, the Murphy Road and 3rd Street roundabout, and some key collector routes on the local system. The project reduces crashes, improves travel time reliability, and provides a new multimodal low-stress Parkway crossing. Overall, this project performed well against the evaluation criteria, achieving many of the project goals, and is recommended for implementation.

The supplemental frontage road from Ponderosa Street south to Baker Road/Knott Road provides little benefit to the Parkway corridor, other than creating an option for a new parallel low-stress bikeway. It would benefit local connectivity as the area develops, but conflicts with the railroad would need to be resolved.

Baker Road/Knott Road

Construction of either traffic signals or roundabouts at the interchange ramp terminals would address the needs of this interchange. Design challenges created by existing grades, the nearby railroad, and surrounding property access locations warrant a more detailed investigation to determine the appropriate solution. This could be accomplished through an Interchange Area Management Plan (IAMP). Overall, the roundabouts appear to perform slightly better against the goals, mainly due to the anticipation of fewer emissions from vehicle delay and lower severity crashes. However, the full grade related impacts of constructing roundabouts at this location were not assessed in this project and could drive up the cost of this option when detailed in the IAMP.

1.0 INTRODUCTION

The previous step of this planning process conducted the first level screening evaluation for a large range of alternative solutions that were identified to address operational and safety deficiencies for the corridor. The first level screening applied a simplified, qualitative version of the project evaluation criteria that respond to the goals and objectives[2] that guide this planning process. The outcomes of the first level screening identified two bundles of projects for further consideration, as documented in Technical Memorandum #6.[3]

The next step of this process, the "Level 2 evaluation," applied a more comprehensive assessment of potential benefits and trade-offs associated with the alternatives using a combination of qualitative and quantitative analysis and evaluation criteria. The Level 2 evaluation and the findings are the subject of this memorandum. Preliminary results will be reviewed with the Project Management Team, the BMPO Policy Board and TAC, the Sounding Board and on-line open houses. This memorandum will then be revised to address stakeholder input and projects will be further prioritized for implementation as part of the Investment Strategy.

LEVEL 2 EVALUATION PROCESS

Project goals, objectives and evaluation criteria were previously defined in the Methodology Memorandum.[4] Many of the evaluation criteria presented in that memo are quantitative and required a more detailed analysis than was conducted during Level 1 screening. The goals, objectives and evaluation criteria applied for Level 2 screening are summarized in Table 1 below. Note that while the evaluation criteria are mostly focused on the performance, some network and local system measures were also considered and provide input into project implementation recommendations.

Table 1: Level 2 Screening Evaluation Criteria

Goal	Objectives	Evaluation Criteria (Level 2)	Evaluation Method
1. Improve safety for all modes	Reduce the frequency and severity of crashes for all modes with an emphasis on severe and fatal injuries	Reduction in crash frequency (all modes)	HSM Part C / TOPS BC / Crash Modification Factors (CMF)
		Reduction in crash severity (all modes)	HSM Part C / TOPS BC / CMF
2. Support economic development throughout the region and state	Support efficient movement of people, goods and services, and recreational traffic to, within and through the City of Bend	Travel Time Reliability measures on the Bend Parkway (planning time index)	HERS-ST / TOPS BC
		Percent through traffic on congested segments (modeled demand/capacity ratio $\geq$ 1.0) of the Bend Parkway	Travel Demand Model
	Develop strategies to accommodate planned growth through provision of transportation options now, and into the future	Degree to which the alternative enhances travel for multiple modes (qualitative assessment)	Qualitative Assessment
3. Manage transportation mobility into the future	Evaluate the ability to achieve ODOT volume/capacity (V/C) targets and develop alternative	Ability to meet ODOT v/c targets	Synchro/Vistro/ HCS Analysis

[2] US 97 Parkway Plan Phase 2: Methodology Memorandum, January 4, 2019
[3] US 97 Parkway Plan Phase 2: Technical Memorandum #6 First Level Alternatives Evaluation, July 9, 2019
[4] US 97 Parkway Plan Phase 2: Technical Memorandum #4 Future Conditions, November 9, 2018

Goal	Objectives	Evaluation Criteria (Level 2)	Evaluation Method
	mobility measures and targets, where appropriate		
	Assess impacts on local system	Ability to meet Bend mobility standards (v/c ratios and LOS)	Synchro/Vistro
4. Consider accessibility to key destinations now and in the future	Evaluate and assess reliable travel times between key destinations during peak periods	Travel Time Reliability measures (planning time index) for specific routes during PM peak hour	HERS-ST / TOPS BC
		Peak Hour VMT by street classification	Travel Demand Model
5. Facilitate the use of multimodal travel options	Enhance transit, bicycle and pedestrian facilities along, parallel to, and across, US 97	Number of bike and pedestrian crossing locations on the Bend Parkway with low Level of Traffic Stress (LTS 2 or lower)	Bike/Ped LTS Analysis
		Miles of north-south bike and pedestrian facilities with low Level of Traffic Stress within 0.25 miles of the Bend Parkway	Bike/Ped LTS Analysis
	Look for transportation demand management opportunities	Does the alternative allow for transportation demand management strategies?	Qualitative Assessment
6. Enhance the environment	Reduce emissions through reduction of vehicular delay, improved connections in the local system, and the use of alternative modes	Total PM peak hour vehicle delay (vehicle hours)	Synchro/Vistro Analysis
		Total PM peak hour vehicle miles traveled (regional measure)	Travel Demand Model
	Minimize right of way impacts	Approximate degree of right of way impacts (order of magnitude costs)	Conceptual Layout/ Qualitative Assessment
	Design projects to avoid, mitigate and minimize impacts	Not applicable (design criteria; applies to all projects)	N/A
7. Identify cost effective solutions	Prioritize low cost, high benefit solutions	Total cost	Unit Cost/Planning Level Cost Estimates
		Reduction in delay and crashes	Synchro/Vistro Analysis & HSM Part C/ TOPS BC
	Prioritize solutions that that leverage existing planned projects and programs	Does alternative leverage existing planned projects and programs?	Yes/No Assessment
8. Develop an implementation plan	Consider available funding sources and existing planned project and programs	Can the alternative be separated into reasonably fundable and constructible phases?	Qualitative Assessment
	Recommend potential future funding sources	Not applicable (funding sources to be recommended in implementation plan)	Qualitative Assessment
	Include partner commitments to short term actions	Does the alternative have local agency support?	Is included in an adopted or in-process plan demonstrating local support. However, local agencies will need to confirm support through this process.

Based on input from the Technical Advisory Committee each goal was weighted equally, except for safety, which was weighted twice as high. Within each goal, performance measures were scored equally.

The results of the evaluation were organized into scoring bins to simplify comparing outcomes across goal areas. Each candidate project was scored to assess its positive, negative, or neutral impacts relative

to the Future No-Build alternative, unless otherwise indicated. A five-step scoring system was used by assigning a value of +2, +1, 0, -1 or -2, according to the scale presented in Table 2.

Table 2: Level 2 Evaluation Scoring Scale

Evaluation Score	Score = 2	Score = 1	Score = 0	Score = -1	Score = -2
Level of support for goals and objectives	Strongly supports	Moderately supports	No significant change	Moderately conflicts	Strongly conflicts

Groups of similar projects or projects that address the same problem, were identified in Technical Memorandum #6. Within each group projects were scored against the No-Build and compared to each another. For most of the quantitative measures, the range of values reported were analyzed to determine the averages within the project groups for the positive range, and for negative range. Outcomes that exceeded the averages, either positive or negative, were assigned the maximum score, either a +2 or a -2. Outcomes that were numerically below average were assigned either a +1 or a -1. Where no change was expected, a value of 0 was assigned. The exception is Goal 1 (Safety), which was weighted double per direction from the BMPO Policy Board (+4, +2, 0, -2, -4). For example, if all projects with a positive safety impact create on average a 20% reduction in crashes, a project with a 10% reduction in crashes would score a +2, while project with a 30% reduction in crashes would score a +4.

While the final recommended project list is expected to include a comprehensive set of improvements for the entire US 97 corridor, the results of the Level 2 evaluation were organized according to the following geographic and topical areas to facilitate comparisons between competing alternatives and those that could potentially be complementary.

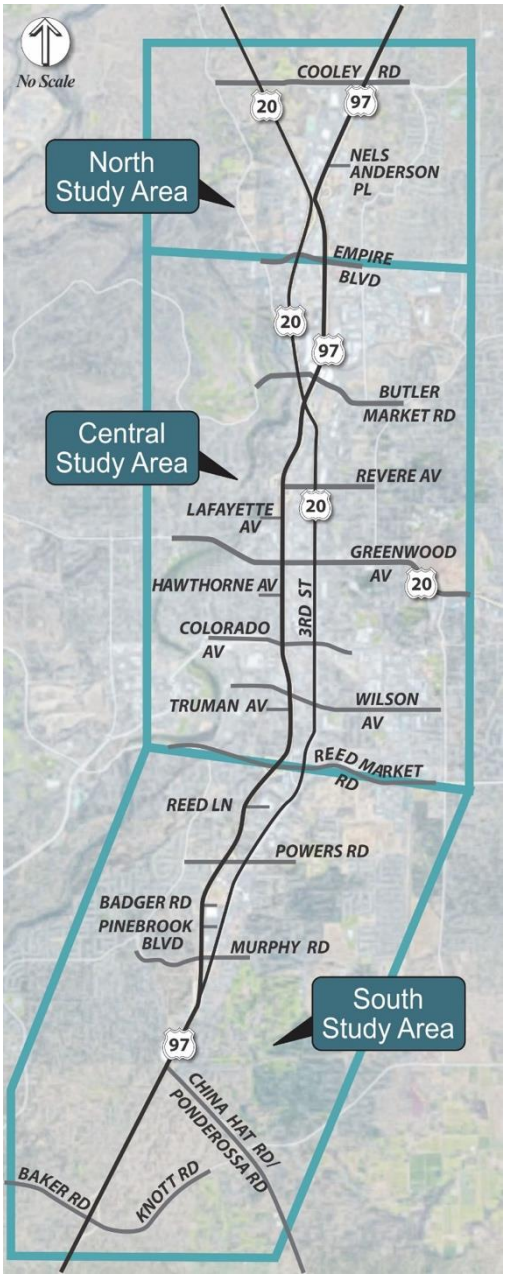
- **Corridor-Wide Projects** – These projects were applied throughout the length of the corridor and include ramp metering, right-in/right-out (RIRO) intersection closures, upgrading ramps to current design standards, and enhanced active transportation projects. Includes TSMO projects as well, a set of strategies with the potential to improve the safety and efficiency of existing infrastructure instead of building new facilities to add capacity.
- **North Study Area** – Includes the Preferred Alternative from US 97 Bend North Corridor Final Environmental Impact Statement (FEIS).
- **Central Study Area** – Includes projects along the US 97 mainline, and at the interchanges with Butler Market Road, Revere Avenue, and Colorado Avenue.
- **South Study Area** – Includes projects at the interchanges with Reed Market Road, Powers Road, China Hat Road and at Baker Road/Knott Road.

2.0 LEVEL 2 PROJECT EVALUATION

Using the Level 2 screening criteria, as described in the previous section, projects were evaluated and ranked to highlight the best performing solutions. The proposed priorities will be reviewed and discussed by the PMT, TAC, Policy and Sounding Board. Once the draft priorities are revised and finalized based on that input, they will be further prioritized for implementation in the Investment Strategy.

Projects within each group were scored against the No-Build and compared to each another. The projects outcomes are reported for the overall corridor, and by north, central and south subareas (see Figure 1). The narrative in the following sections describes the most significant changes for each evaluation case relative to the future No-Build scenario. For cases where there was no significant change for a given criterion, they are so noted.

Figure 1: Study Areas



The documentation of the analysis behind the findings and results included in this document is summarized as follows:

- Appendix 1 – Tables containing the numeric performance measure or description of qualitative assumptions behind each score for each project
- Appendix 2 – Summarizes the analysis results, broken down by project bundles (A and B, as outlined in Technical Memorandum #6, and C, which includes the ramp meter and RIRO Closure projects only)
- Appendix 3 – Includes all the outputs from the analysis tools (HCM reports, Vissim documentation and results, HSM outputs, forecasted traffic volumes, travel time reliability outputs, etc.)

CORRIDOR WIDE PROJECTS

The first category of projects was applied throughout the US 97 corridor. These projects include:

- Ramp metering
- Ramp closure and modifications at right-in, right-out (RIRO) locations
- Ramp upgrades to current design standards
- Enhanced active transportation projects.

Corridor Wide Evaluation results are listed in Table 3 on the following page. The major differences between the proposed category and the Future No-Build scenario are highlighted in the following sections. More specific performance of individual locations and project types is also presented in the following sections.

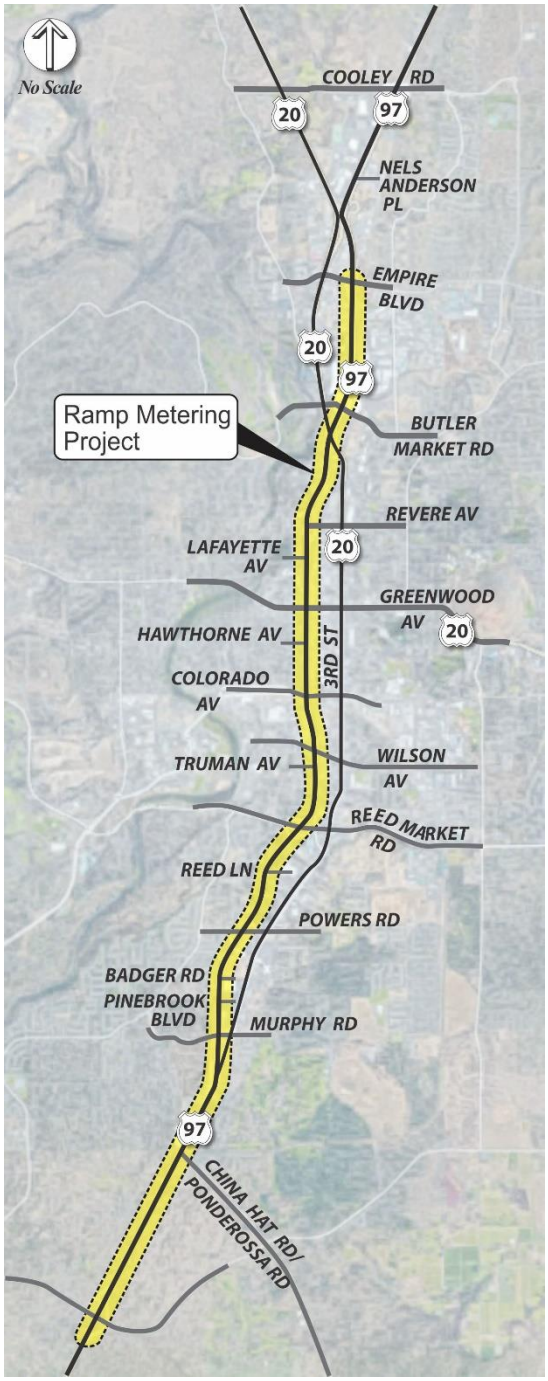
Table 3: Evaluation Results for Corridor-wide Projects

Goal	Evaluation Criteria (Level 2)	Evaluation Rating			
		Ramp Metering	Right-in/ Right-out Closures	Ramps Improved to Standard Lengths	Active Transportation Improvements
1 – Safety (x2)	Reduction in crash frequency (all modes)	2	4	2	2
	Reduction in crash severity (all modes)	0	4	0	4
2 - Economic	Travel Time Reliability on the Bend Pkwy	1	1	0	0
	Percent through traffic on congested segments	2	1	0	0
	Degree to which the alternative enhances travel for multiple modes	0	0	0	2
3 - Mobility	Ability to meet ODOT v/c targets	2	1	1	0
	Ability to meet Bend mobility standards (v/c ratios and LOS)	-2	-1	0	0
4 -Accessibility	Travel Time Reliability for specific routes	-1	-1	0	0
	Peak Hour VMT by street classification	1	-1	0	0
5 - Multimodal	Number of bike and pedestrian crossing locations on the Bend Parkway with low Level of Traffic Stress (LTS 2 or lower)	0	0	0	2
	Miles of north-south bike and pedestrian facilities with low Level of Traffic Stress within 0.25 miles of the Bend Parkway	-1	0	0	0
	Does the alternative allow for TDM strategies?	2	1	0	1
6 - Environment	Total PM peak hour vehicle delay (veh-hrs)	1	2	0	0
	Total PM peak hour vehicle miles traveled (regional measure)	1	-1	0	0
	Approximate degree of right of way impacts (order of magnitude costs)	1	1	0	0
7 - Cost	Total cost	1	2	2	1
	Reduction in delay and crashes	1	2	1	1
	Does alternative leverage existing planned projects and programs?	0	0	0	0
8 - Implementation	Can the alternative be divided into fundable and constructible phases?	0	1	1	2
	Does the alternative have local agency support?	1	1	0	1
Evaluation Total		12	17	7	16

Ramp Metering ($100,000 - $250,000 per location)

The first corridor project set would apply metering traffic signals for all on-ramps to the US 97 Bend Parkway between the Empire Boulevard and the Baker Road-Knott Road interchanges (Figure 2). At on-ramps that currently fail to meet acceleration length standards (Colorado northbound, Revere Avenue northbound, and Division Street northbound), ramp meters were tested in locations far enough up the ramp that vehicles stopped at a ramp meter could still achieve existing ramp design speeds prior to entering the acceleration lanes.

Figure 3: Ramp Metering Project



For the purposes of this study, the following key assumptions were included in the analysis:

- Ramp meters were assumed to be run for the entire peak hour period. This assumption led to significant peak hour trip diversion onto local facilities and reduced overall on/off ramp demand compared to No-Build Conditions, likely overestimating the project benefits at ramp terminal intersections and the negative impacts on the local system.
- Ramp meters on the on-ramps with low speed curves prior to acceleration lanes (Revere Avenue Southbound On-Ramp and Colorado Avenue Southbound On-Ramp) were located in advance of the ramp curvature to ensure existing conditions vehicle speeds entering the acceleration merge lanes.
- Mainline speed-based ramp metering was also tested, but under average weekday volume conditions the ramp meters were seldom triggered by slowing on the mainline. All these assumptions would be the subject of further evaluation through concept design.

All these assumptions would be subject to further evaluation during as part of the implementation plan and concept of operations for ramp meters along the Parkway. In addition, it is important to note that existing operations on the Parkway do not indicate a short term need for ramp meters, with all merge location operating below capacity and no crash history indicating excessive merging.

The **key differences** compared to the Future No-Build scenario are described below for each goal area. Refer to Table 3 for a listing of performance scores.

Goal #1: Safety

- Potential for significant reduction in future crash frequency reduction as merge conflicts increase

Goal #2: Economic

- Moderate improvement to travel time reliability on Parkway due to reduced volume on the Parkway mainline
- Depending on the ramp meter implementation strategy, the percent local trips (beginning and ending in Bend) on the Parkway could significantly decrease, particularly south of the Revere Avenue interchange. However, it is important to note that ramp meters are not likely needed for at least 10-15 years south of Revere Avenue, with the exception of the Colorado Avenue Interchange.

Goal #3: Mobility

- Note that the mobility findings are based off a scenario where the ramp meters were assumed to be run throughout the entire peak hour. This assumption provides a worst-case trip diversion to the local system as well as a likely best-case operational condition on the Parkway. The most likely ramp metering strategies would result in more balance between the Parkway and the local system.
- The demand on the highest volume Parkway ramps would likely decrease, with local to local trips shifting off the Parkway. This could potentially improve operations at some of the ramp terminal intersections.
- A ramp metering strategy would likely target merge locations where the demand exceeds the capacity, reducing both crash risk and Parkway queuing. Based on forecasted future demand, the following locations could experience the greatest benefits:
    - SB Division Street On-Ramp – has a Future (2040) No-Build v/c of 1.24
    - NB 3rd Street On-ramp – has a Future (2040) No-Build v/c 1.20
- While only a partial means to achieving mobility targets across the Parkway system, the ramp meters could significantly improve operations at several key bottleneck locations, particularly on the Parkway mainline, resulting in a high mobility score
- With some local trips moving off the Parkway, the City system would experience increased demand, particularly on 3rd Street (from Empire Boulevard to Murphy Road) and Division Street. Note that upgrading the signals on 3rd Street to accommodate timing coordination could help to mitigate this impact. The signals on the ODOT portion of 3rd Street are currently being updated and coordinated as part of the US 20 Empire to Greenwood project. The seven signals south of Greenwood Avenue would need to be upgraded through a separate project. The cost to upgrade each signal could vary from $25,000 to more than $100,000 per location, depending on the range of improvements necessary.
- The on-ramp volumes were analyzed to determine which locations would need dual lane ramp meters. Table 4 summarizes the range of forecasted year 2040 volumes (from average weekday to 30HV, and ranged across all analyzed No-Build and Build conditions) at each on-ramp and includes recommendations for locations of dual lane meters.

Table 4: Ramp Meter Configuration Recommendations

On-Ramp	Volume Range	Recommended Ramp Meter Configuration
Empire Ave. SB	870 – 1,235	Multi-Lane Metering
Division St./3rd St. SB	440 - 825	Single Lane Metering
Revere Ave. SB	430 - 530	Single Lane Metering
Colorado Ave. SB	430 - 490	Single Lane Metering
Reed Market Rd. SB	135 - 460	Single Lane Metering
Powers Rd. SB	50 - 235	Single Lane Metering
Murphy Rd. SB	580 - 845	Single Lane Metering
Murphy Rd. NB	160 - 425	Single Lane Metering
Powers Rd. NB	290 - 500	Single Lane Metering
Reed Market Rd. (EB Reed Market)	220 - 730	Single Lane Metering
Reed Market Rd. (Division)	545 - 845	Single Lane Metering
Colorado Ave. NB	1,035 – 1,500	Multi-Lane Metering
Revere Ave. NB	330 - 445	Single Lane Metering
3rd St. NB	475 - 550	Single Lane Metering
Butler Market Rd. NB	240 - 310	Single Lane Metering

- Under average weekday conditions in the ramp metering scenario analyzed, queues from the ramp meters could be contained within the existing ramps, except at the following locations, where multi-lane meters should be considered:
    - Empire Boulevard Southbound On-Ramp
    - Colorado Avenue Northbound On-Ramp

  The microsimulation analysis indicated queue spillback issues onto the local system with single lane metering at the Empire Boulevard Southbound On-Ramp and the Colorado Avenue Northbound On-Ramp (see recommendations in Table 4), but did not identify any other significant issues with ramp meter queues spilling back into ramp terminal intersections.

Goal #4: Accessibility

- Could increase demand on low reliability key routes in the City, particularly 3rd Street
- Could increases VMT on City streets

Goal #5: Multimodal

- Provides a system tool that could support a variety of transportation demand management strategies

Goal #6: Environment

- Potential to decrease net vehicle delay, depending on metering strategy implemented by mitigating system bottlenecks (ramp terminals and merge/diverge locations). However, delay benefits to the Parkway would have to be weighed against the delay impacts to the local system. A more detailed dynamic analysis would be needed to assess the full net delay benefits or impacts.

- Overall minor but measurable VMT reductions potential across the MPO, as ramp meters could force out-of-direction local trips taking advantage of the Parkway capacity to shift back onto slower but more direct local routes
- Relatively low ROW impact

Goal #7: Cost Effective

- Total cost is $100-300k per location assuming no significant ramp improvements. Costs could increase at certain locations (particularly Colorado Avenue Northbound and Empire Boulevard Southbound) after further concept design.
- Monetary benefits from both reductions in vehicle delay and crashes
- Leverages other projects such as RIRO closures/modifications to more effectively manage the Parkway

Goal #8: Implementation

- Included as a stand-alone project in City TSP during the Scenario Evaluation, and is now captured in a placeholder project to implement findings from the Parkway Study
- For most effective implementation, at a minimum would need to complete RIRO closures and modifications project
- Ramp meters are not typically recommended for freeway segments shorter than five miles. Therefore, phasing could be challenging, although ramp meters could be installed by direction (i.e. southbound, then northbound) as future demand dictates.

The ramp metering project presents tremendous potential as part of the solution for managing future congestion and operations on the Parkway. However, the minimum warrants for ramp meters are only met at a few locations on the Parkway under present conditions, and with no crash history or Parkway mainline capacity issues identified today, would not provide any significant benefit if implemented as a short-term solution. In addition, the following projects would need to be implemented first to allow for effective ramp metering strategies:

- RIRO Closures/Modifications
- Ramps Improved to Standard Lengths

Further, most of the benefits of ramp meters would be negated if interchange ramp terminals queue onto the Parkway. In particular, if the Powers Road intersection retains its current at-grade configurations, queue impacts stemming from this location would render ramp meters ineffective. Therefore, ramp meters are **Recommended for a Long-Term Implementation Plan**, with the first step being developing a concept of operations to identify the ramp metering strategies that best balance the system, and the next steps being implementation of the RIRO Closures/Modifications and Ramps Improved to Standard Lengths, along with some grade separation at Powers Road.

Right-In/Right-Out Closures and Modifications ($50,000 - $250,000 per location)

A separate analysis of right-in/right-out (RIRO) closures and ramp modifications (Figure 3) was made to determine the RIRO scenario for more detailed evaluation. The analysis reported[5] in April 2019 (included in Appendix 2) considered the following options:

- Closure of Lafayette Avenue
- Closure of Hawthorne Avenue
- Conversion of Lafayette Avenue to right-in only
- Conversion of Hawthorne Avenue to right-in only
- Closure of Nels Anderson Place, Truman Avenue and Reed Lane
- Closure of all intersections listed above

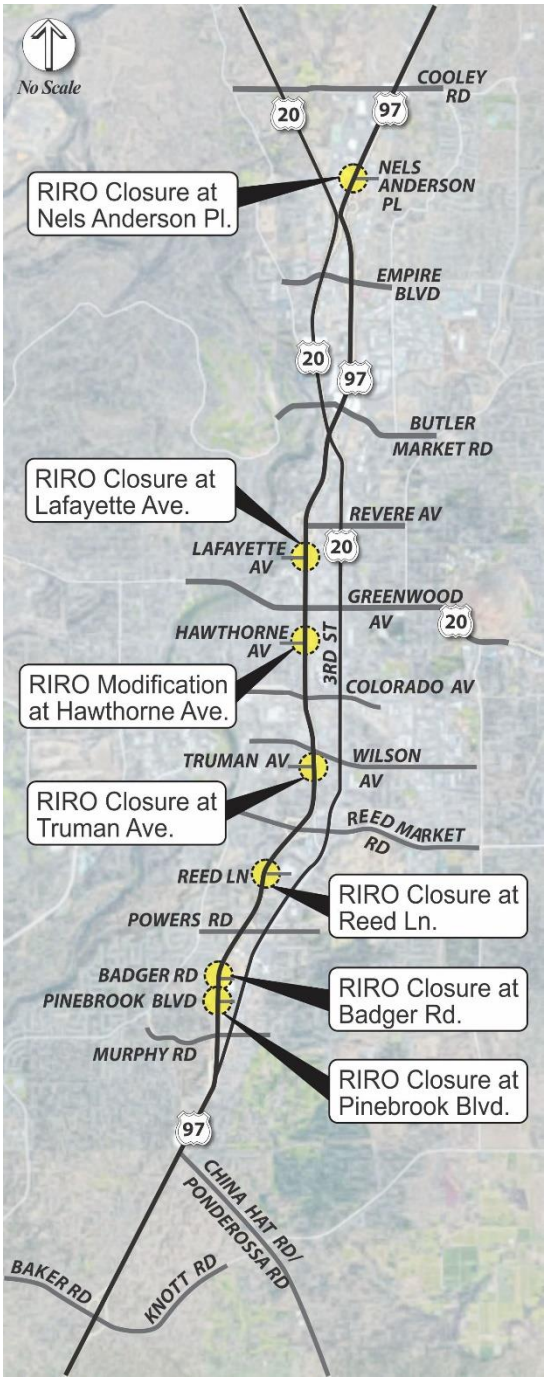
The closure of the Pinebrook Boulevard and Badger Road RIRO access to US 97 was assumed as part of the No-Build analysis.

The analysis findings are attached in Appendix A (RIRO Appendix). Based on these results and feedback from the technical advisory committee, the following RIRO modifications were recommended to advance for Level 2 screening:

1. Nels Anderson Place – full closure
2. Reed Lane – full closure
3. Truman Road – full closure
4. Hawthorne Avenue – close right-out (onto US 97) only, build deceleration lane to standard
5. Lafayette Avenue – full closure

Note that for the RIRO at Nels Anderson Place, findings from the on-going North Corridor work, in particular related to converting US 97 to a business route at Nels Anderson Place, will supersede the recommendations of the Parkway Study for this location.

Figure 5: RIRO Ramp Closure Project



The **key performance differences** compared to the Future No-Build scenario are described below for each goal area. Refer to Table 3 for a listing of performance scores.

[5] US 97 Parkway Plan Phase 2: Technical Memorandum - RIRO Closures/Modifications Alternatives Analysis, April 22, 2019

Goal #1: Safety

- Major reduction in the number (-79%) and severity (-77%) of crashes when right-in and right-out access to the Parkway is closed

Goal #2: Economic

- Improves reliability of segments along the Parkway where RIRO access is modified or closed (improves travel time reliability by 3%), with the largest improvement occurring on the segment between Hawthorne Ave and Colorado Ave
- Net decrease in percent through traffic on roadway segments where the demand exceeds the capacity on the Parkway

Goal #3: Mobility

- Major reduction of v/c along the Parkway by removal of multiple over-capacity, at-grade intersections, offset by increased demand on some ramps, particularly the southbound ramps at the Colorado interchange and the three of the four ramps at the Revere Avenue interchange. The Reed Market interchange and Powers Road intersection are largely unaffected by the RIRO closures and modifications. Also, the ramp demand impacts of the ramp metering project when coupled with the RIRO closure lead to either no change or decreased demand on all ramps between Empire and Murphy.
- The impacts of the RIRO modifications are mainly experienced at the following intersections:
    - 3rd St and Olney Ave
    - Wall St and Portland Ave
    - Wall St and Franklin Ave
    - Bond St and Franklin Ave
    - 3rd St and Franklin Ave
    - 3rd St and Greenwood Ave
    - Bond St at Arizona Ave
    - 3rd St and Wilson Ave
    - 3rd St and Reed Market Rd

  Note that all these intersections excepting Wall St and Franklin Ave are at or above a v/c of 1.0 under future No-Build conditions. The Wall St and Franklin Ave intersection degrades from a v/c of 0.98 to a v/c of 1.03 with the RIRO closures/modifications.

- Resolves queuing issues on Truman, Reed Lane, Hawthorne, and Lafayette. These queue mitigations will particularly benefit Lafayette Avenue, reducing the risk of queuing back to Wall Street, and on Hawthorne Avenue, reducing the risk of neighborhood cut-through traffic.

Goal #4: Accessibility

- Increased demand on key routes within the City flagged as low reliability through the ongoing Bend TSP update, particularly 3rd Street
- Mixed results with VMT, which increases peak hour VMT on the City system, and decreases peak hour VMT on the Parkway

Goal #5: Multimodal

- Partial closure of Hawthorne may allow for a ped/bike overcrossing at Hawthorne, which is included in the City TSP

Goal #6: Environment

- Increases PM Peak hour VMT and delay on city facilities, while decreasing these measures on or accessing the Parkway
- Small net increase in system delay due to reduced access to the Parkway
- ROW impacts are minimal. Extending the right-off deceleration lane at Hawthorne Avenue will not likely require ROW acquisitions, but the ped/bike overcrossing at this location (as planned by the City TSP) may require additional ROW, or ultimately require a full closure at this location as well.

Goal #7: Cost Effective

- Partial closure of Hawthorne is consistent with desire for business access to downtown and consistent with TSP planned ped/bike overcrossing at Hawthorne Ave
- Total cost is $50-250k per location
- Small negative benefit from net system delay increases, positive benefit from crash reductions

Goal #8: Implementation

- Identified as a project in conjunction with ramp meters during the Scenario Evaluation in the City's TSP update
- Closures can be phased but would be needed prior to ramp metering in order to ensure their effectiveness as a traffic management tool.

While the RIRO closure scenario is the ultimate desired solution, particularly to support the effectiveness of ramp meters, the closures do not need to happen all at the same time. A phased approach would be more appropriate, with a focus on the high crash and low volume locations first. The highest crash locations are the Lafayette Avenue and Hawthorne Avenue (which is also the highest volume location) accesses, while the lowest volume locations are the west legs of the Badger Road and Pinebrook Boulevard accesses. Based on overall performance scored against the project goals, this project is **Recommended for Phased Implementation.**

Ramps Improved to Standard Lengths ($1,000,000 - $5,000,000)

Acceleration and deceleration lanes on US 97 provide drivers with an opportunity to adjust their speeds to match the traffic stream while entering or exiting the mainline facility. Locations were identified in Existing Conditions where geometric conditions represented a safety risk due to substandard acceleration/deceleration lane lengths.

There are a variety of approaches available to minimize the costs and ROW impacts of improving ramp acceleration and deceleration lanes and tapers. Removal of RIRO accesses would eliminate some of the most problematic substandard locations. The existing median also provides an opportunity for widening in certain locations to avoid ROW impacts. Removal of the bike lanes – in conjunction with implementation of parallel low-stress routes – could also help standardize some of the ramp tapers on

the corridor. These options may considerably lower the cost of upgrading the deficient locations and may be considered in more detail during concept design.

Based on the ramp deficiencies identified in prior work and assuming the closure of all RIRO access with the exception of the RI at Hawthorne Avenue, the ramps in Tables 5 and 6 are either recommended for improvement to standards, (Tier 1) or not recommended for further improvement due to feasibility constraints (Tier 2).

Table 5: Exit Ramp Recommendations

Exit Location	Existing Deceleration Lane Length (ft)	ODOT HDM Minimum Deceleration Lane Length (ft)[A]		Considerations for Designing to HDM Standards (45 mph)	Feasible?	Tier
		55 mph Design Speed	45 mph Design Speed			
SB US 97 to Hawthorne Ave	225	**320**	215	Meets Standard	N/A (Yes)	Tier 1
SB US 97 to Reed Market Rd	225	**235**	220	Meets Standard	N/A (Yes)	Tier 1
SB US 97 to Powers Rd	50	**320**	**215**	Minimal ROW acquisition; Potential widening impacts to existing sound wall; Would require widening at the Powers Rd/US 97 intersection; May require reconfiguration of SB ramp	Yes	Tier 2
NB US 97 to China Hat Rd	125	**320**	**215**	Minimal ROW acquisition	Yes	Tier 2
NB US 97 to Powers Rd	50	**320**	**215**	Potential widening impacts to existing buildings and sound wall; Would require widening at the Powers Rd/US 97 intersection; May require reconfiguration of SB ramp	No	Tier 2

[A] **Red bold** text indicates that the measured deceleration length is less than the standard.

Note that the China Hat Road northbound deceleration lane is placed in Tier 2 as the China Hat Overcrossing would remove this access location. Likewise, the Powers Road southbound deceleration lane was placed in Tier 2, as the ultimate design at Powers Road may completely change these locations.

Table 6: Entrance Ramp Recommendations

Entrance Location	Existing Acceleration Lane Length (ft)	ODOT HDM Minimum Acceleration Lane Length (ft) [A,B,C]	Considerations for Designing to HDM Standards	Feasible?	Tier
Powers Rd to SB US 97	< 50	**960**	Moderate ROW acquisition; Potential widening impacts to existing sound wall; Impacts could be minimized with new interchange concept	Yes	Tier 2
China Hat Rd to NB US 97	< 50	**960**	Minimal ROW acquisition	Yes	Tier 2
Powers Rd to NB US 97	< 50	**960**	Minimal ROW acquisition; Would require closure of at-grade vehicle and pedestrian access at Reed Ln	Yes	Tier 2
Division St to NB US 97	425	**540**	Utility relocation; Widening impacts to existing sound wall; Potential circulation impacts to adjacent local street network (McKinley Ave/ Roosevelt Ave)	No	Tier 2
Colorado Ave to NB US 97	225	**540**	May require widening bridge over Franklin Avenue, adjacent to railroad bridge; Limits pedestrian and bicyclist access to Franklin Avenue from Parkway. Note: Realigning curvature of NB ramp could allow for sufficient acceleration length	No	Tier 2
Revere Ave to NB US 97	250	**540**	May require retaining wall; minimal ROW acquisition	Yes	Tier 1

[A] **Red bold** text indicates that the measured acceleration lane length is less than the acceleration lane length standard.
[B] Assumes a 55-mph design speed (960' standard acceleration lane length for at-grade intersections and 540' for interchanges).
[C] At-grade acceleration lanes are justified if there are more than 10 veh/hr turning right AND 1) the intersection does not meet OHP v/c mobility target OR 2) the intersection has a high percentage (10%) of heavy vehicles turning right onto the highway OR 3) the intersection has a history of crashes attributed to vehicles turning right entering the highway. For more details, see ODOT HDM Chapter 8. Note that all the RIRO entrances to the Parkway included in this table meet the volume and ODOT v/c mobility target criteria.

Note that the China Hat Road northbound acceleration lane is placed in Tier 2 as the China Hat Overcrossing would remove this access location. Likewise, the Powers Road acceleration lanes (both directions) were placed in Tier 2, as the ultimate design at Powers Road may completely change these locations.

Goals that applied to this class of improvements were reviewed below. All other goals were not applicable.

Goal #1: Safety

- Crash frequency reduction by 11% if ramp acceleration lanes were increased to standard. The tool used for the analysis did not quantity safety benefits for deceleration lanes, however, they are expected to improve safety for exiting vehicles.

Goal #6: Environment

- As discussed previously, the ROW impact for these improvements could vary widely, depending on the design strategies employed, ranging from worst case bridge widening to best case construction contained within the existing cross section.

Goal #7: Cost

- Total Cost: $1-5M per location

Goal #8: Implementation

- Could be helpful if implemented with the ramp metering project, depending on ultimate designs for ramp meter locations.

The acceleration lane improvements could be phased with corresponding ramp meter implementation, potentially allowing for more ramp meter queue storage on the ramps and allowing for more aggressive (lower) ramp meter rates to better manage system throughput. Based on overall performance scored against the project goals, this project is **Recommended for Phased Implementation.**

Active Transportation Improvements

ODOT and the City of Bend have agreed that the preferred approach to providing low-stress active transportation facilities in the Parkway corridor is to develop parallel routes using City streets and paths supplemented with enhanced crossings along US 97 to improve connectivity. The identification of parallel low-stress routes is expected to be a joint City/ODOT effort to be completed at a later date, and in coordination with the broader low-stress network being developed as part of Bend's Transportation System Plan update.

Because the need for enhanced active transportation crossings of the Parkway has already been established, the evaluation of the crossings shown in Table 3 was completed to indicate their relative value compared to other improvements for meeting the Parkway Plan goals and objectives. Providing frequent low-stress active transportation crossings of US 97 is a strategy that scores very well against the project goals, and could easily be implemented in phases (e.g., one crossing at a time). Therefore, this set of projects is **Recommended for Phased Implementation.**

A Bicycle and Pedestrian Working Group comprised of ODOT and City of Bend staff has provided supplemental analysis focused on the need for more high-quality crossing opportunities along US 97 for people walking and biking. This analysis included factors such as the current quality of crossings (e.g., level of traffic stress), distance between crossing opportunities, potential demand resulting from adjacent land uses, crash history, and alignment with the City's low-stress network. The results of the

analysis included a list of existing and potential future crossing locations with a combination of quantitative and qualitative (e.g., high, medium, low) scores for each factor considered.

The project team converted all scores to quantitative values to support further refinement and evaluation of the crossing locations using the ActiveTrans Priority Tool.[6] The many factors scored by the Bicycle and Pedestrian Working Group were aggregated into the following six categories (no new factors were considered):

1. Constraints – accounted for impacts to adjacent properties, feasibility, and cost
2. Safety – accounted for history of vehicle and pedestrian/bicycle crashes
3. Existing Conditions – accounted for presence of walking and biking facilities, distance between crossing opportunities, and existing crossing types
4. Demand – accounted for potential and measured walking and biking activity
5. Connectivity – accounted for connections to the City's low-stress network, ability to cross 3rd Street, presence of railroads, and improved access to key destinations
6. Equity – considered total disposable personal income data in the vicinity

Most categories were weighted equally, but safety was weighted nearly twice as high as the others, which was similar to the approach applied to the project evaluation criteria for other improvements.

The resulting scores were discussed with the Bicycle and Pedestrian Working Group, resulting in refinement of the prioritization of crossing enhancement locations. Table 7 shows the results of this analysis, documenting locations of the highest priority crossing enhancements related to both existing and new crossing locations. Tier 1 locations are considered higher priority and Tier 2 projects, while still important, are considered lower priority. To improve safety and comfort of users, all crossings are assumed to be grade-separated (i.e., they would cross over or under US 97) in the future. The full list of crossings that were evaluated and their resulting scores are provided in Appendix 2.

Note the current proposed strategy in the draft City TSP update is to consider the Franklin Avenue, Greenwood Avenue, and Hawthorne Avenue crossings as one group of projects. The TSP advisory committee has recommended a study be completed to determine specific improvements and cost for each crossing. Funding for two of the crossings would be included in the short-term project list, and the third crossing would be included in the mid-term project list.

[6] http://www.pedbikeinfo.org/topics/tools_apt.cfm; NCHRP Report 803 Pedestrian and Bicycle Transportation Along Existing Roads – ActiveTrans Priority Tool Guidebook, Transportation Research Board, Washington DC, 2015.

Table 7: Priority Locations for Improving Existing and Creating New US 97 Pedestrian & Bicycle Crossings

Study Area	Crossing Investment Locations	Tier 1 Priority	Tier 2 Priority	Improve Existing or Create New Crossing?*
North	Cooley Rd	X		Improve existing (at-grade signal)
	Robal Rd		X	Improve existing (at-grade signal)
	Empire Ave		X	Improve existing (overcrossing unsignalized/signalized)
Central	Butler Market Rd	X		Improve existing (overcrossing unsignalized)
	Revere Ave		X	Improve existing (overcrossing signalized)
	Olney Ave	X		Improve existing (undercrossing)
	Greenwood Ave	X		Improve existing (undercrossing)
	Hawthorne Ave	X		Create new crossing
	Franklin Ave	X		Improve existing (undercrossing)
	Aune Rd		X	Improve existing (undercrossing)
	Wilson Ave		X	Improve existing (overcrossing)
	Reed Market Rd		X	Improve existing (overcrossing unsignalized/signalized)
South	Canal/ Garfield Ave	X		Improve existing (undercrossing)
	Badger Rd/ Pinebrook Blvd	X		Improve existing (at-grade RRFB)
	Powers Rd		X	Improve existing (at-grade signal)
	Murphy Rd	X		Improve existing (overcrossing)
	China Hat Rd	X		Create new crossing
	Baker Rd/Knott Rd	X		Improve existing (overcrossing unsignalized)

* All pedestrian and bicycle crossings of the US 97 Parkway are assumed to be grade-separated in the future (i.e., overcrossings or undercrossings).

Transportation Systems Management and Operations Projects

Transportation System Management and Operations (TSMO) Projects include a set of strategies that focus on operational improvements and maintenance that have the potential to restore or possibly increase the performance of existing facilities. These projects generally do not conflict with one another and multiple strategies may be included. Evaluation scores for each of the TSMO strategies are shown in Table 8, with more detailed descriptions of the findings included below.

In general, the TSMO strategies score very well against the goals related to environmental enhancement (Goal 6), cost-effectiveness (Goal 7), and implementation (Goal 8). Most have little if any right-of-way impacts and can achieve modest improvements in travel safety and efficiency that help reduce congestion-related emissions at significantly less cost than many of the other types of projects being considered.

Figure 4: TSMO Projects

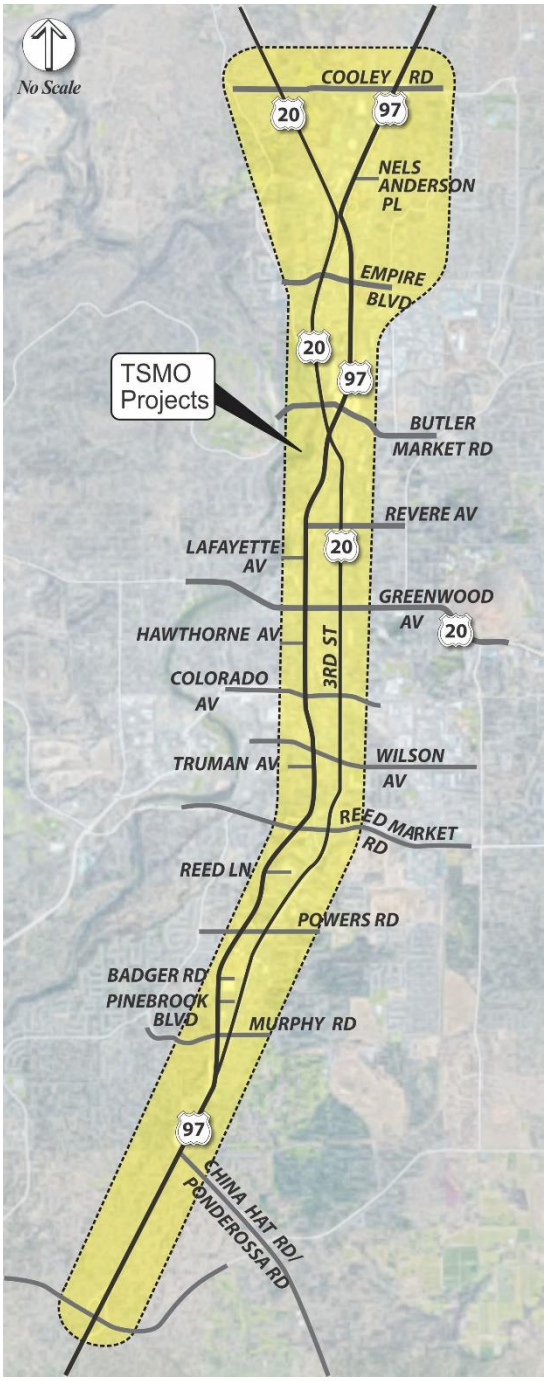


Table 8: Evaluation Results for TSMO Projects

Goal	Evaluation Criteria (Level 2)	Evaluation Rating								
		Shoulders Built to Standard	Weather Warning System	Variable Speed Signs	Incident Mgmt.	Enhanced Signal Operations at Ramp Terminals	Transit Signal Priority	Freight Signal Priority	Travel Info. Signing	Roadside Traveler Info. Dissemination
1 – Safety (x2)	Reduction in crash frequency (all modes)	2	2	2	2	2	0	0	0	0
	Reduction in crash severity (all modes)	0	0	0	0	2	0	0	0	0
2 - Economic	Travel Time Reliability measures on the Bend Parkway (planning time index)	1	2	0	2	0	0	0	0	0
	Percent through traffic on congested segments (modeled demand/capacity ratio $\geq$ 1.0) of the Bend Parkway	0	0	0	0	0	0	0	0	0
	Degree to which the alternative enhances travel for multiple modes (qualitative assessment)	0	0	0	0	0	1	1	0	0
3 - Mobility	Ability to meet ODOT v/c targets	0	0	0	0	0	0	0	0	0
	Ability to meet Bend mobility standards (v/c ratios and LOS)	0	0	0	0	0	0	0	0	0
4 -Accessibility	Travel Time Reliability measures (planning time index) for specific routes during PM peak hour	0	0	0	0	0	0	0	0	0
	Peak Hour VMT by street classification	0	0	0	0	0	0	0	0	0
5 - Multimodal	Number of bike and pedestrian crossing locations on the Bend Parkway with low Level of Traffic Stress (LTS 2 or lower)	0	0	0	0	0	0	0	0	0
	Miles of north-south bike and pedestrian facilities with low Level of Traffic Stress within 0.25 miles of the Bend Parkway	0	0	0	0	0	0	0	0	0
	Does the alternative allow for transportation demand management strategies?	0	0	0	0	0	1	0	1	0
6 - Environment	Total PM peak hour vehicle delay (vehicle hours)	1	2	1	2	0	0	0	0	1
	Total PM peak hour vehicle miles traveled (regional measure)	0	0	0	0	0	0	0	0	0
	Approximate degree of right of way impacts (order of magnitude costs)	1	2	2	2	2	2	2	2	2
7 - Cost	Total cost	1	2	2	2	2	2	2	2	2
	Reduction in delay and crashes (based on estimated monetization of savings in delay and crash costs)	2	2	2	2	1	0	0	0	0
	Does alternative leverage existing planned projects and programs?	0	0	1	1	0	0	0	0	0
8 - Implementation	Can the alternative be separated into reasonably fundable and constructible phases?	2	2	2	2	2	2	2	2	2
	Does the alternative have local agency support?	0	1	1	1	1	1	1	1	1
Evaluation Total		10	15	13	16	12	9	8	8	8

Shoulders Built to Standard Widths ($2,000,000 - $10,000,000): provide space for law enforcement activity, disabled vehicles to pull over, bicycle travel, passage around incidents, opportunities for improved freight operations, potential transit use, and partial storage for snow removal. Standard width shoulders for the Parkway would be eight feet wide for the outer/right shoulder and four feet wide for the inner/left shoulder.

Widening the Parkway shoulders is one of the higher scoring TSMO strategies and supports several project goals. Based on research from other shoulder widening projects, it is estimated that this strategy could reduce crashes on the Parkway by 5-15%.[7] Wider shoulders would also support faster clearance of incidents, which can reduce the amount of non-recurring congestion and improve travel time reliability. HERS-ST modeling of the Parkway corridor found that shoulder widening could reduce incident-based delay by nearly 40%, which would result in a reduction in overall delay of 8%. Eight-foot wide shoulders would slightly reduce the level of stress felt by people biking by providing a small buffer between them and high-speed traffic, but the overall level of stress experienced would still be considered high and not desirable. This strategy may require a greater cost for implementation than many other TSMO strategies, but it can also be constructed in smaller phases to better align with available funding.

While not reflected in the scoring or cost assumed, widened shoulders on the Parkway could also accommodate future hard shoulder running for transit if designed properly. However, this would require widening beyond the standard 8 feet to 12 feet or more.

Based on overall performance scored against the project goals, this project is **Recommended for Implementation.**

Weather Warning System ($5,000 - $450,000 per sign): includes a variety of applications that activate warnings regarding weather (e.g., roadway flooding, fog, snow, or ice) to inform drivers of potentially hazardous conditions. Weather warning systems are often tied to variable speed signs.

The anticipated crash reduction potential of a weather warning system alone is relatively low based on experience from other applications. However, Bend has seen significant increases in crashes during the months of November and December with half of those related to wet or icy road conditions and has experienced severe storms that resulted in multiple fatalities. Therefore, the benefit realized on the Parkway may be greater than typical applications, justifying a higher score than shown in Table 8. Furthermore, a weather warning system could be bundled with other TSMO strategies like variable speed signs and roadside traveler information dissemination that can share infrastructure, making them all more cost-effective.

By preventing crashes during weather events, this strategy would also reduce incident-related delay and improve travel time reliability. Those benefits would largely be limited to the months of November through March when most crashes related to wet or icy road conditions occur, but there is the potential to save hundreds of person-hours per event.[8]

[7] https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Appendix.pdf

[8] Per TOPS-BC analysis, tool developed by Federal Highway Administration.

Based on overall performance scored against the project goals, this project is **Recommended for Implementation.**

Variable Speed Signs ($500,000 - $1,500,000 per sign): used to manage congested corridors, and/or events caused by incidents or weather by displaying advisory speeds according to the conditions ahead.

Applications of variable speed signs have led to crash reductions ranging from 8-29%.[9,10] The overall crash reduction potential for the Parkway is conservatively assumed to be on the lower end of that range since the extent and duration of recurring congestion are relatively small under existing conditions. However, variable speed signs could also be used to improve safety during weather events and in advance of incidents and work zones, resulting in a higher score than shown in Table 8.

Improvements in travel time reliability have been realized following some applications of variable speed systems, but it is unknown if those improvements were directly related to this strategy because variable speed systems are often bundled with other TSMO strategies such as traveler information, ramp metering, and incident management. However, if they are effective at reducing crashes, they should also lead to a reduction in incident-related delay and improvements in travel time reliability.

Based on overall performance scored against the project goals, this project is **Recommended for Implementation.**

Incident Management ($50,000 - $500,000 per year): coordination of responses to clear incidents that impact safe and efficient travel. Strategies include: dedicated incident response programs and strategies, incident response vehicles, and staged/dry-run towing.

Incident management programs can be among the most effective TSMO strategies for reducing crashes and incident-related delay. The ability to respond to incidents and clear them quickly is a key factor in the effectiveness of an incident management program, which can be enhanced through improved inter-agency coordination, having complete detection/surveillance coverage, and increasing the size of the responder fleet. Based on past corridor conditions and experience with other programs, a comprehensive incident management program could reduce crashes by about 3% and could save more than 13,000 hours of vehicle-delay per year.[11] ODOT has an existing incident management program in place, but improvements to current practice could help achieve the maximum benefit at a relatively low cost. Specific actions may be identified as part of the ongoing Deschutes County ITS Plan development, but enhancements could include funding more full-time responders (one of the existing responder positions in District 10 is not permanently funded), improving inter-agency coordination/communication, and expanding surveillance and detection ability. In addition, if paired with the Roadside Traveler Information Dissemination strategy, the ability to inform drivers of incident locations would also be improved.

[9] Evaluating Safety Effects of Variable Speed Limit System using Empirical Bayesian Before-After Analysis, Pu et al, 2017.
[10] Evaluation of Variable Speed Limits on I-270/I-255 in St. Louis, Bham et al., 2010.
[11] Per TOPS-BC analysis, tool developed by Federal Highway Administration.

Based on overall performance scored against the project goals, this project is **Recommended for Implementation** as an expansion of current practice**.**

Enhanced Traffic Signal Operations at Ramp Terminals ($50,000 - $100,000 per terminal): includes improving existing signals through re-timing/optimization, adaptive systems, or better/increased detection. Enhanced traffic signal operations could be combined with geometric and lane utilization improvements to be fully effective. Many of these improvements could be realized through the upcoming ODOT ATC conversion plan. Furthermore, upgrading ramp signals to new technology helps to future-proof the network for potential future Connected and Autonomous Vehicle (CAV) applications.

Enhancing traffic signal operations at ramp terminals scored relatively well, primarily because it is a low-cost and easy to implement strategy that can have significant safety benefits where used to prevent off-ramp queues from encroaching upon the area of the ramp needed to decelerate from a stop from mainline speeds. In addition, it has the potential to slightly improve travel time reliability and peak period delay but compared to the other strategies being considered the degree of improvement in these areas may be minimal. This may be one of the lowest cost strategies, making it a cost-effective option for near-term implementation.

Based on overall performance scored against the project goals, this project is **Recommended for Implementation.**

Traffic Signal Priority for Transit at Signalized Intersections on US 97 ($8,000 - $35,000 per signal): provides extra green time to reduce delay and/or improve safety for transit.

Transit signal priority scores fairly low against the evaluation criteria, primary because the benefits are focused only on transit travel. Also, there are only three traffic signals on the Parkway mainline (Cooley Road, Robal Road, and Powers Road) and the long-term plan is to remove them in favor of grade-separated facilities. Enhancing transit travel time reliability should be an important part of a comprehensive travel demand management strategy for the region and transit signal priority systems could play a key role in that. Because the opportunities on the Parkway mainline may be limited, it may be more beneficial to consider applications along routes that cross the Parkway. However, if it is determined that removal of traffic signals on the Parkway may not occur for some time, the low cost of this strategy may make it an attractive interim improvement, especially in the Cooley Road to Robal Road segment.

Based on overall performance scored against the project goals, this project is **Recommended for Near-term and Interim Implementation** but may have minimal benefits in the long term as signals are removed from the Parkway.

Traffic Signal Priority for Freight at Signalized Intersections on US 97 ($8,000 - $35,000 per signal): provides extra green time at traffic signals for freight to reduce delay and/or improve safety.

Similar to traffic signal priority for transit, traffic signal priority for freight scores fairly low against the evaluation criteria because the benefits are focused only on freight travel and there are limited opportunities on the Parkway mainline. However, if it is determined that removal of traffic signals on

the Parkway may not occur for some time, the low cost of this strategy may make it an attractive interim improvement, especially in the Cooley Road to Robal Road segment.

Based on overall performance scored against the project goals, this project is **Recommended for Near-term and Interim Implementation**, but may have minimal benefits in the long term as signals are removed from the Parkway.

Traveler Information Signing ($2,000 - $30,000): static signing that guides travelers along a certain path.

This strategy supports only a limited number of goal areas and scores fairly low against the evaluation criteria but is also very inexpensive and relatively easy to implement. The primary area of interest for improved guide signing is in the north end of the corridor, from Robal Road to Division Street, where communicating the options for routing to the Parkway could be improved. Therefore, despite the low evaluation score, this strategy is still **Recommended for Near-term Implementation** at that particular location.

Roadside Traveler Information Dissemination ($50,000 - $500,000 per sign): uses variable message signs (VMS) on roadways or highway advisory radio to disseminate traveler information. This system could also be used to help guide travelers during special events such as festivals or concerts.

This strategy scores moderately well against the evaluation criteria compared to other TSMO strategies but would be most cost-effective if bundled with other strategies such as variable speed signs and weather warning systems that can share infrastructure. Based on experience from other applications, roadside traveler information may reduce delay on the Parkway by 3-7%. The safety benefits resulting from this strategy alone are unproven, though having the ability to warn motorists of incidents ahead could reduce the occurrence of secondary crashes, resulting in a higher crash reduction score than shown in Table 8.

Based on overall performance scored against the project goals, this project is **Recommended for Implementation Only if Bundled with Strategies such as Variable Speed Signs and Weather Warning Systems that can Share Infrastructure.**

North Study Area

Under future conditions, the forecasted demands in the north portion of the US 97 corridor will have significant operational and safety issues. The US 97 Bend North Corridor study is assessing some coordinated projects to address queueing and operational issues around Empire Boulevard, Robal Road, and Cooley Road. The project analyzed for the Parkway Study is the full FEIS, which to date is only partially funded. The on-going North Corridor Study will identify the funded interim phases of the full FEIS Preferred Option, and therefore that analysis will provide different results than those presented for the North Study Area in this study. This project was identified as its own group as it will affect only the north portion of the corridor and is compatible with all other projects.

The **key performance differences** compared to the Future No-Build scenario are described below for each goal area for this package of improvements in the North Study Area. Note that many of the performance measures focus primarily on the area from Empire Boulevard to the south, keying in on the

larger system impacts from the Preferred Alternative from US 97 Bend North Corridor FEIS project ($150,000,000 - $250,000,000). Refer to Table 9 for a listing of performance scores.

Table 9: Evaluation Results for the North Study Area

Goal	Evaluation Criteria (Level 2)	Evaluation Rating
		North Corridor FEIS Improvements
1 – Safety (x2)	Reduction in crash frequency (all modes)	4
	Reduction in crash severity (all modes)	4
2 - Economic	Travel Time Reliability measures on the Bend Parkway (planning time index)	2
	Percent through traffic on congested segments (modeled demand/capacity ratio $\geq$ 1.0) of the Bend Parkway	2
	Degree to which the alternative enhances travel for multiple modes (qualitative assessment)	1
3 - Mobility	Ability to meet ODOT v/c targets	2
	Ability to meet Bend mobility standards (v/c ratios and LOS)	0
4 -Accessibility	Travel Time Reliability measures (planning time index) for specific routes during PM peak hour	-1
	Peak Hour VMT by street classification	-1
5 - Multimodal	Number of bike and pedestrian crossing locations on the Bend Parkway with low Level of Traffic Stress (LTS 2 or lower)	2
	Miles of north-south bike and pedestrian facilities with low Level of Traffic Stress within 0.25 miles of the Bend Parkway	2
	Does the alternative allow for transportation demand management strategies?	0
6 - Environment	Total PM peak hour vehicle delay (vehicle hours)	2
	Total PM peak hour vehicle miles traveled (regional measure)	0
	Approximate degree of right of way impacts (order of magnitude costs)	-2
7 - Cost	Total cost	-2
	Reduction in delay and crashes	2
	Does alternative leverage existing planned projects and programs?	1
8 - Implementation	Can the alternative be separated into reasonably fundable and constructible phases?	1
	Does the alternative have local agency support?	1
Evaluation Total		20

Goal 1: Safety

- Major reduction in crashes associated with closure of the at-grade intersections at Cooley Road and at Robal Road on US 97 and removing the interchange with US 20
- Major reduction in both crash frequency (-70%) and fatal and injury crashes (-77%)

Goal 2: Economic

- Enhances freight, transit, motor vehicle by reducing congestion on North Parkway; enhances ped/bike with the addition of multi-use paths along 3rd Street and US 20
- Major reduction of through traffic on the entire North Parkway section (100 percent reduction in through traffic on congested segment due to the elimination of congested segments)
- Large improvement in travel time reliability from Robal Road to old US 20 interchange (worst segment on the Parkway sees improvement in PTI index from 3.1 to 1.0)
- Overall major improvement in trip reliability (average of 44% reduction in variability)

Goal 3: Mobility

- Significant mobility benefits north of Empire Boulevard, not captured in this analysis but indicated in the FEIS
- Empire Boulevard and US 97 ramp terminal intersection improve significantly over No-Build (which assumes some improvements on Empire Boulevard as well), but still remain over capacity under peak seasonal conditions.
- Significant mobility benefits to city streets north of the US 97/US 20 interchange, not captured in this analysis but indicated in the FEIS.
- The FEIS project shifts demand from southbound US 97 to southbound US 20 (3rd Street) between the US 97 and US 20 interchange and Revere Avenue. This leads to degraded operations on US 20 (3rd Street) at O.B. Riley Road (v/c increase from 0.91 to 1.10), Butler Market Road (v/c from 1.24 to 1.49), and Division Street (v/c from 1.34 to 1.48).

Goal 4: Accessibility

- Slight increase in VMT on Parkway without corresponding decrease on City system
- Would improve reliability on North 3rd Street with new alignment of US 97

Goal 5: Multimodal

- Multi-use paths added along North 3rd Street, paralleling the new US 97 alignment.
- Includes grade separated crossing of the Parkway at Cooley

Goal #6: Environment

- PM peak hour delay decreases, mainly due to improvement in the Cooley Road-Robal Road area
- Significant ROW impacts, with the project requiring acquisitions
- Slight increase in VMT on Parkway/North 3rd Street without corresponding decrease on City system, due to increase in lane miles for Parkway/North 3rd Street

Goal #7: Cost Effective

- $300 M total cost
- Cost benefit both from delay savings and crash reductions

Goal #8: Implementation

- Projects are included in City's ongoing Transportation System Plan Update and as an aspirational project in the MPO Metropolitan Transportation Plan. Also, recently received INFRA grant will fund significant first phase of the project, coupled with ODOT funds from HB 2017.
- Can be constructed in phases as funding continues to become available

Based on overall performance scored against the project goals, this project is **Recommended for Implementation.**

CENTRAL STUDY AREA

The projects located within the Central area of the US 97 Parkway include a series of proposed solutions that address specific operational and safety issues along the mainline and at three interchanges. Rather than treat them as a package of projects as was done for the North Area, these projects were evaluated separately to identify their specific benefits and impacts. In several cases, this performance analysis informed the decision process about the preferred traffic control solution at interchange ramp terminals.

The specific projects evaluated in the Central Study Area include:

- US 97 Mainline Projects (also a component of the US 97 North Corridor FEIS Preferred Alternative)
    - Auxiliary lanes in the southbound direction between Empire Boulevard and Butler Market Road
    - Auxiliary lane in the northbound direction from 3rd Street to Empire Boulevard
- Butler Market Road Projects
    - Southbound frontage road connection to Division Street
    - Southbound off-ramp terminal traffic control (signal or roundabout)
    - Southbound off-ramp with channelized two-stage left turn
    - Butler Market/4th Street traffic control (signal or roundabout)
- Revere Avenue Project
    - Lane re-channelization
- Colorado Ave Projects:
    - Diamond interchange
    - Northbound Ramp terminal traffic control (traffic signal or roundabout)

The **key performance differences** compared to the Future No-Build scenario are described below for each group of projects noted above in the Central Study Area. For goal areas that were benefited or impacted by these projects, the findings are noted below. Refer to Table 10 for a listing of performance scores for each case.

Table 10: Evaluation Results for the Central Study Area

Goal	Evaluation Criteria (Level 2)	Evaluation Rating									
		US 97 Mainline Projects		Butler Market Rd. Projects					Revere Ave. Projects	Colorado Ave. Projects	
		Southbound Auxiliary Lane from Empire Blvd. to Butler Market Rd.	Northbound Auxiliary Lane from 3rd St. to Empire Blvd.	Southbound Frontage Rd. to Interchange	Southbound Off-ramp Traffic Signal or Roundabout	Southbound Off-ramp Formalized Two-Stage Left Turn	Butler Market/ 4th St. Traffic Signal	Butler Market/ 4th St. Roundabout	Lane Channelization	Diamond Interchange	Northbound Ramps Traffic Signal or Roundabout
1 – Safety (x2)	Reduction in crash frequency (all modes)	2	2	2	2	0	2	4	2	2	2
	Reduction in crash severity (all modes)	2	2	2	2	0	4	4	0	4	4
2 - Economic	Travel Time Reliability measures on the Bend Parkway (planning time index)	1	1	1	1	0	0	0	0	0	0
	Percent through traffic on congested segments (modeled demand/capacity ratio $\geq$ 1.0) of the Bend Parkway	2	2	0	0	0	0	0	0	0	0
	Degree to which the alternative enhances travel for multiple modes (qualitative assessment)	0	0	1	0	0	0	0	2	0	0
3 - Mobility	Ability to meet ODOT v/c targets	2	2	1	2	0	0	0	-1	2	2
	Ability to meet Bend mobility standards (v/c ratios and LOS)	0	0	0	0	0	2	2	0	0	0
4 -Accessibility	Travel Time Reliability measures (planning time index) for specific routes during PM peak hour	0	0	0	0	0	1	1	0	1	1
	Peak Hour VMT by street classification	0	0	0	0	0	0	0	0	0	0
5 - Multimodal	Number of bike and pedestrian crossing locations on the Bend Parkway with low Level of Traffic Stress (LTS 2 or lower)	0	0	1	1	0	0	0	0	2	2
	Miles of north-south bike and pedestrian facilities with low Level of Traffic Stress within 0.25 miles of the Bend Parkway	0	0	1	0	0	0	0	0	0	0
	Does the alternative allow for transportation demand management strategies?	0	0	0	0	0	0	0	0	0	0
6 - Environment	Total PM peak hour vehicle delay (vehicle hours)	1	1	1	2	0	2	2	1	2	2
	Total PM peak hour vehicle miles traveled (regional measure)	0	0	0	0	0	0	0	0	0	0
	Approximate degree of right of way impacts (order of magnitude costs)	1	1	0	1	2	-1	-1	2	-2	0
7 - Cost	Total cost	2	2	1	2	2	2	2	2	-2	2
	Reduction in delay and crashes	1	1	1	1	0	1	1	0	2	1
	Does alternative leverage existing planned projects and programs?	1	1	0	0	0	0	0	1	-1	0
8 - Implementation	Can the alternative be separated into reasonably fundable and constructible phases?	1	1	1	1	1	1	1	1	-2	1
	Does the alternative have local agency support?	1	1	1	1	0	0	1	1	0	1
Evaluation Total		17	17	14	16	5	14	17	11	8	18

US 97 Mainline Projects

The results of the two auxiliary lane projects ($1,000,000 - $3,000,000) had very similar performance outcomes, so the results are combined below and in Table 10.

Goal 1: Safety

- The frequency of crashes decrease in this area with the addition of the auxiliary lanes. Crashes increase overall due to the volume increases caused by the FEIS project, but the auxiliary lanes will provide safety benefits to mitigate this issue.

Goal 2: Economic

- Construction of auxiliary lanes on the freeway significantly reduces the share of local trips on mainline through lanes.
- Provides major reductions in peak hour vehicle delays (Goal 6) and makes moderate improvements to reliability

Goal 3: Mobility

- Ramp diverge northbound at Empire Boulevard significantly improves (1.27 in No-Build to 0.82).
- Likely similar improvement for SB auxiliary lane
- Major reduction in segment demand to capacity ratio to below capacity

Goal 7: Cost Effective

- Total cost $1-2M for Southbound lane, $1-3M for Northbound lane
- Both auxiliary lanes are included in the larger FEIS project

Goal 8: Implementation

- Identified as project in TSP, included in the Parkway Study findings project

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for Implementation.**

Butler Market Road Projects

The Butler Market Road projects address localized operational and safety needs within this interchange area, and we found that each project tends to respond to only a few performance goals. Therefore, these results were organized by project rather than by goal area.

Southbound Frontage Road from Interchange to US 20 ($7,250,000) – This new frontage road concept extends the southbound off-ramp to connect directly to US 20 (Business 97), as shown in Figure 5. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Moderate safety benefits, with decreases in both frequency (-18%) and severity (-19%)

Goal 2: Economic

- The corresponding redesign of the ramp terminals, particularly at Division Street/3rd Street, provides an opportunity to upgrade traffic controls and moderately improve Parkway crossing access for multimodal travelers

Goal 3: Mobility

- The traffic demand for the westbound left turn at the US 20 and Butler Market Road intersection is dramatically reduced (shifted to the new frontage road), improving operations at this intersection by v/c ratio increment of approximately 0.1, and eliminating most of the westbound queue spillback issues between 3rd Street and the US 97 SB Ramp terminal on Butler Market Road.

Goal 5: Multimodal

- Potential new north-south low stress connection added between Butler Market Road (and SB Off-Ramp Path) and Division Street

Goal #6: Environment

- Decreases PM peak hour delay, both on the Parkway and the local system

Goal 7: Cost Effective

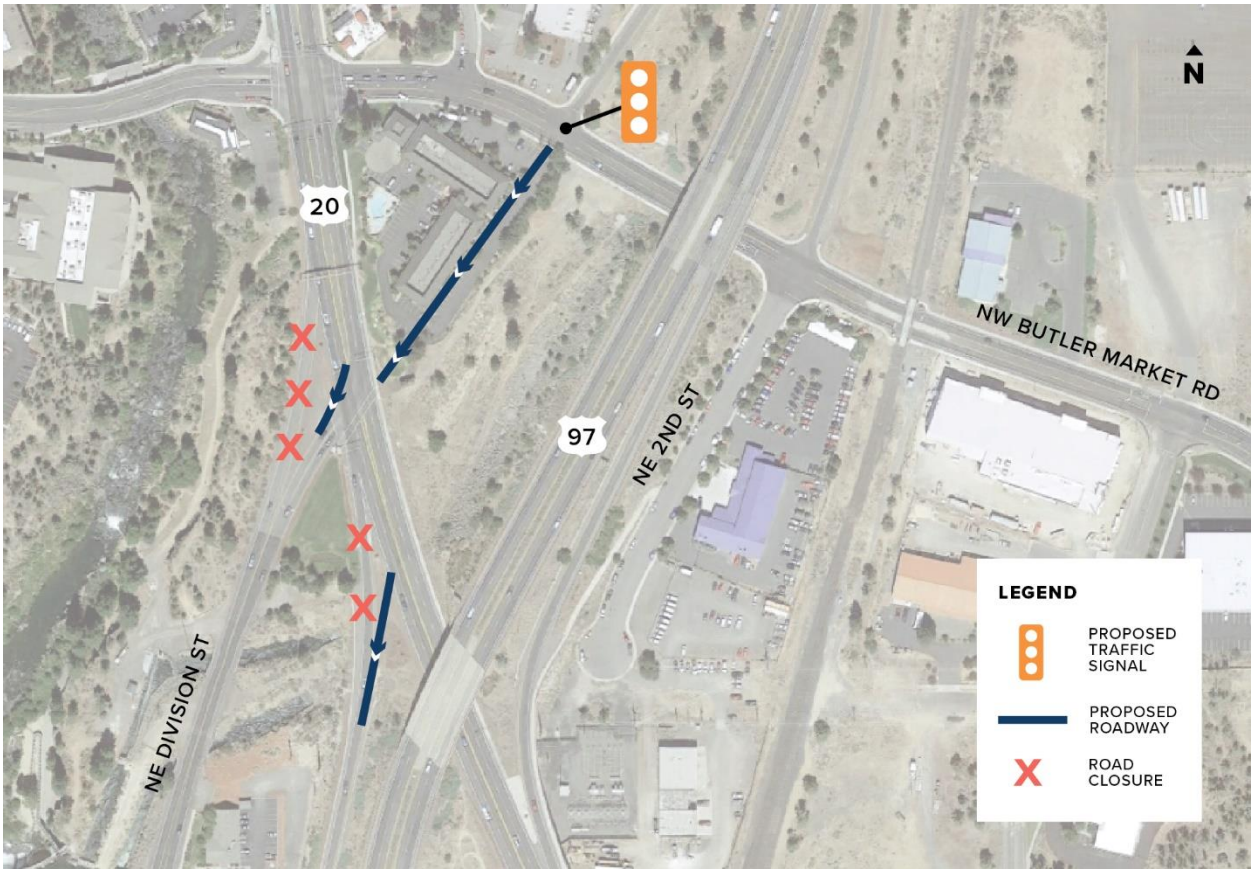
- The estimated cost of $7.2 million is moderate given the benefits

Goal 8: Implementation

- A similar version of this project is under consideration in the ongoing City's Transportation Safety Action Plan

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for Implementation.** This project is also recommended for further analysis as a potential two-way connection (if combined with a roundabout at the US 97 Southbound Off-ramp to Butler Market Road) during concept design.

Figure 5: Butler Market Road Southbound Frontage Road Concept (Map data ©2018 Google Earth)



Southbound Off-Ramp Terminal Signal/Roundabout ($1,100,000) – The options considered at the off-ramp terminal with Butler Market Road included either a traffic signal or a roundabout. In terms of system performance measures, the traffic signal and the roundabout had very similar outcomes and were significant improvements compared to the existing ramp stop control. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Moderate safety benefits (reduction of 20% in frequency and severity)

Goal 3: Mobility

- Reduced congestion from the Future No-Build both as a stand-alone project or if combined with the frontage connection

Goal #5: Multimodal

- Provides a more safe and accessible service for multimodal users

Goal #6: Environment

- Reduces overall vehicle delays

Goal 7: Cost Effective

- The estimated cost of $1.1 million is moderate given the benefits

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for Implementation.** While both a signal or a roundabout could potentially work at this location, timing a signal to operate effectively with US 20 and Butler Market Road could become infeasible. Therefore, a roundabout solution is strongly recommended for consideration at this location.

Southbound Off-Ramp Terminal Channelized Two-Stage Left Turn ($765,000) – The channelized two-stage left turn design provides a safer and more convenient option for vehicle exiting the freeway to make left turns onto Butler Market Road. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal #7: Cost Effective

- Total cost is $765,000, which is less than the signal or roundabout

Note that it would not be feasible to construct both the frontage road extension and the two-stage left-turn channelization. Based on overall performance scored against the project goals and conflict with a performing project (southbound frontage road), this project is **Not Recommended for Implementation.**

Traffic Control Options at Butler Market Road and 4th Street ($500,000 - $2,500,000) – This intersection is within the influence area of the interchange and its performance can impact operations at the ramp terminals. Under future No-Build conditions, eastbound queue spillback along Butler Market Road from this intersection leads to increased queueing on the US 97 southbound off-ramp. The two traffic control options considered here are a traffic signal or a roundabout. Today, this location has all-way stop controls. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 3: Mobility

- Both the roundabout and the traffic signal provide performance within the City's mobility standards with an improvement of two letter grades for Level of Service

Goal #6: Environment

- Significantly reduces delays

Goal #7: Cost Effective

- Overall operational delays for autos and trucks are less for the roundabout option, leading to better economic benefits

The other factor to consider is how the adjacent intersections at the US 97 Southbound Off-Ramp interacts with the choice for traffic control at 4th Street. Generally, it is recommended to implement compatible control concepts, which would mean either both traffic signals or both roundabouts. Given the foregoing results, either set of options provide good performance within the horizon year of this plan. Based on overall performance scored against the project goals and having no conflicts with other

high performing projects, this project is **Supported by the Parkway Study for Implementation through the TSP.**

Revere Avenue Projects

To improve bicycle and pedestrian facilities on Revere Avenue, a lane re-channelization project is proposed from 4th Street to Wall Street, to reallocate the right-of-way width. The lane re-channelization will allow for better sidewalks and buffered bike lanes within the existing right of way. Furthermore, the project would also include the following elements which have the potential to improve safety and operations:

- Dedicated left turn lanes at Division Street and Revere Avenue
- The ability to separate left turn phases at Division Street and Revere Avenue during railroad closures to the east

The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 5: Multimodal

- Provides benefits for multimodal travelers

Goal #6: Environment

- Increases delay at the northbound ramps/Division street due to the lane reduction
- Slightly decreases delay at the southbound ramps/Wall St

Goal #7: Cost Effective

- Relatively low total cost of $500k to $2 million

Goal #8: Implementation

- Consistent with the City's Low Stress Bicycle Network

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Supported by the Parkway Study for Implementation through the TSP.**

Colorado Avenue Projects

The US 97 northbound and southbound ramps at Colorado Avenue will not provide enough capacity to serve the forecasted demand. In addition, the northbound ramp intersection at Colorado Avenue was flagged for safety issues. The projects proposed to address these needs include:

- Upgrade traffic controls at US 97 northbound ramps and Colorado Avenue
- Reconstruct the Colorado Avenue interchange to a diamond configuration.

The Colorado Avenue Projects were evaluated to identify benefits and impacts compared to the future No-Build scenario for this location. The findings are listed in Table 10 and discussion briefly below.

Upgraded Traffic Controls for US 97 Northbound Ramps at Colorado Avenue ($500,000 - $1,500,000) – This project was also assumed to include an westbound right turn lane, based off preliminary

operational analysis. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Replacement of existing TWSC congested intersection with signal or roundabout control decreases crashes

Goal 3: Mobility

- Ramp v/c of 0.84 (meets ODOT Mobility Targets)

Goal #6: Environment

- Reduces vehicle delays to less than 30 seconds per vehicle at the ramp terminal intersection

Goal #7: Cost Effective

- Relatively low cost of $2.5 million
- Cost estimate increase over prior analysis is due to the need for an westbound right turn lane at the intersection to provide sufficient capacity under future conditions, also adding some potential (although still minimal) ROW impacts

Goal #8: Implementation

- This project is included in the City's TSP
- Consideration would need to be given to the nearby relatively inactive rail spur lines crossing Scott Avenue. However, this is not a fatal flaw to this project.

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for Implementation.**

Diamond Interchange at Colorado Avenue ($20,600,000) – The existing interchange is a half cloverleaf design which has traffic signal controls at the SB ramp terminals and stop controls at the NB ramp terminal. At the northbound ramp terminal intersection, the highest vehicle demands are for the northbound to westbound and eastbound to northbound movements during the PM peak. These movements do not conflict under the existing interchange configuration but would conflict under a diamond configuration. Therefore, the diamond interchange design requires dual eastbound left turn lanes, and partial two-lane widening on the northbound on-ramp.

The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Replacement of existing TWSC congested intersection with signal or roundabout control decreases crashes

Goal 3: Mobility

- Improves operations significantly at the southbound ramp terminal intersection, thereby reducing the v/c from 1.05 to 0.78 (meets ODOT Mobility Targets)

- Improves operations significantly at the northbound ramp terminal intersection, reducing the v/c to 0.74 (meets ODOT Mobility Targets)

Goal #6: Environment

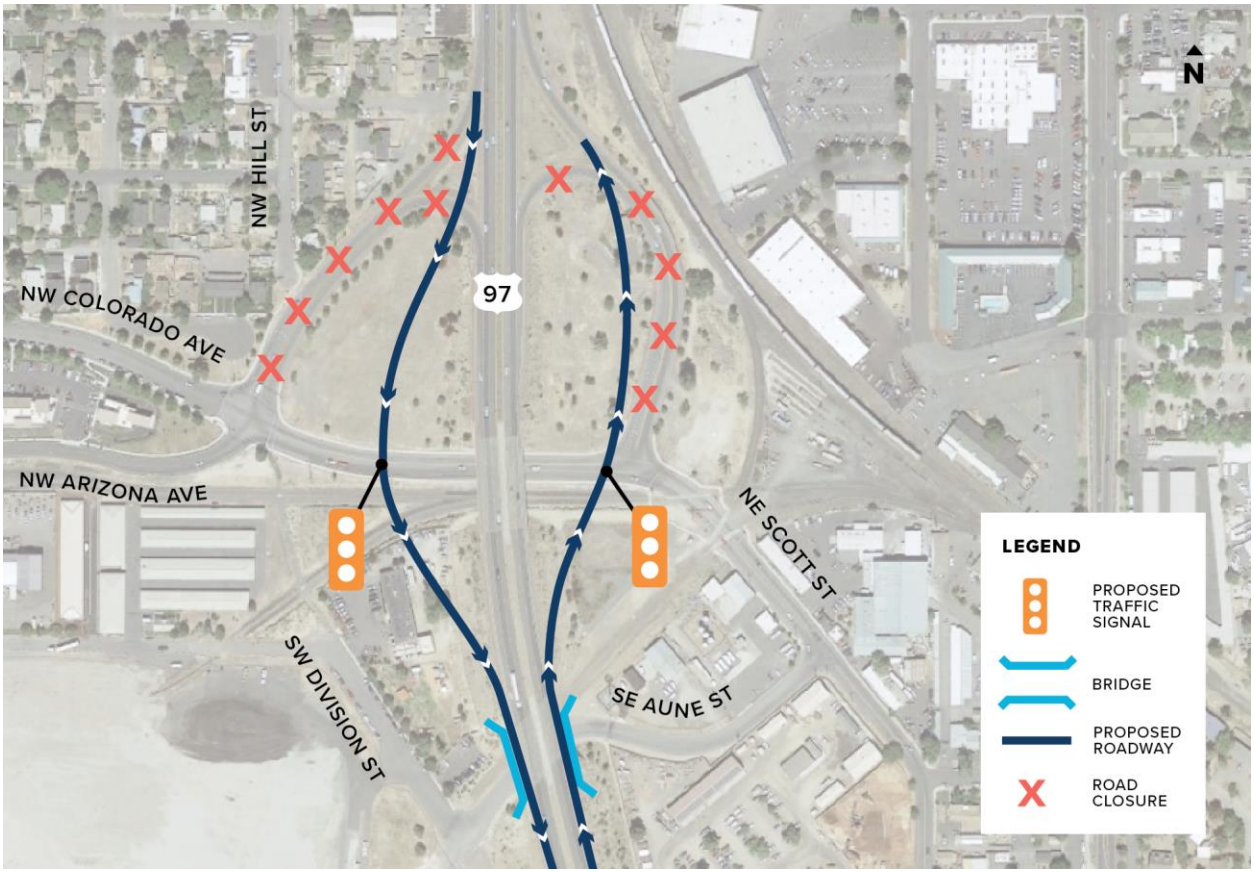
- Significantly reduces delay at ramp terminal intersections
- Significant ROW impacts

Goal #7: Cost Effective

- High capital cost
- Difficult to phase
- Ramps would conflict with Aune Extension under consideration in TSP and Core Area Plan

The Aune Extension and Sisemore Extension would both provide better connectivity in and around the Colorado interchange. A lower cost solution is likely feasible which would leverage the connectivity benefits of these two projects, and potentially shift the southbound ramp terminal away from the Colorado/Arizona couplet. Therefore, based on overall performance scored against the project goals, high costs, ROW impacts, and availability of lower impact solutions a full Colorado interchange rebuild project is **Not Recommended for Implementation.** However, a more detailed study of improvement options for the southbound ramp terminal intersection in coordination with the outcomes of the TSP and Core Area plan is recommended for further consideration.

Figure 6: Colorado Avenue Diamond Interchange Concept (Map data ©2018 Google Earth)



SOUTH STUDY AREA

The projects located within the South area of the US 97 Parkway consist of a variety of solutions including grade separations, improvements to existing interchanges, and frontage road treatments. As with the Central area, these projects were evaluated separately to identify their specific benefits and impacts.

The specific projects evaluated in the Central Study Area include:

- Reed Market Road Projects
    - Dedicated Left-Turn Lanes at the Reed Market Road and 3rd Street intersection
    - Widen the Northbound Off-Ramp
    - Signal (or Roundabout) at the Northbound Off-Ramp
    - New Single-Point Urban Interchange
- Powers/Murphy Road Projects
    - Powers Overcrossing
    - Powers Interchange
    - Murphy Loop Ramp Interchange with frontage system (No-Build assumption)
    - Murphy Tight Diamond Interchange
    - Murphy Frontage Roads
- China Hat Road Projects
    - Overcrossing
    - Frontage Road (Ponderosa to Baker)
- Baker Road/Knott Road Projects:
    - Traffic signals at ramp terminals
    - Roundabouts at ramp terminals

The **key performance differences** compared to the Future No-Build scenario are described below for each group of projects noted above in the South Study Area. For goal areas that were benefited or negatively impacted by these projects, the findings are noted below. Refer to Table 11 for a listing of performance scores for each case.

Figure 7: Reed Market Road Projects

Table 11: Evaluation Results for the South Study Area

Goal	Evaluation Criteria (Level 2)	Evaluation Rating									
		Reed Market Rd. Projects				Powers Rd. Projects		China Hat Rd. Projects		Baker Rd./ Knott Rd. Projects	
		Reed Market Rd./ 3rd St. Dedicated Left Turn Lanes	Northbound Ramps Traffic Signal or Roundabout	Single-Point Urban Interchange	Widen Northbound Off-ramp	Overcrossing	Interchange	Overcrossing	Frontage Road	Traffic Signals at Ramp Terminals	Roundabouts at Ramp Terminals
1 – Safety (x2)	Reduction in crash frequency (all modes)	2	2	2	2	4	2	4	0	2	2
	Reduction in crash severity (all modes)	2	0	0	0	4	2	4	0	4	2
2 - Economic	Travel Time Reliability measures on the Bend Parkway (planning time index)	0	1	1	1	2	2	1	0	0	0
	Percent through traffic on congested segments (modeled demand/capacity ratio $\geq$ 1.0) of the Bend Parkway	0	0	0	0	1	1	0	0	0	0
	Degree to which the alternative enhances travel for multiple modes (qualitative assessment)	0	0	0	0	1	1	2	0	0	0
3 - Mobility	Ability to meet ODOT v/c targets	0	1	2	0	-1	2	1	0	2	2
	Ability to meet Bend mobility standards (v/c ratios and LOS)	1	0	0	0	-2	0	1	0	0	0
4 -Accessibility	Travel Time Reliability measures (planning time index) for specific routes during PM peak hour	1	0	0	0	-1	1	0	0	0	0
	Peak Hour VMT by street classification	0	0	0	0	-1	0	2	0	0	0
5 - Multimodal	Number of bike and pedestrian crossing locations on the Bend Parkway with low Level of Traffic Stress (LTS 2 or lower)	0	2	0	0	2	1	2	0	2	2
	Miles of north-south bike and pedestrian facilities with low Level of Traffic Stress within 0.25 miles of the Bend Parkway	0	0	0	0	0	0	0	2	0	0
	Does the alternative allow for transportation demand management strategies?	0	0	0	0	0	0	0	0	0	0
6 - Environment	Total PM peak hour vehicle delay (vehicle hours)	1	1	2	0	0	2	1	0	1	2
	Total PM peak hour vehicle miles traveled (regional measure)	0	0	0	0	-1	0	0	0	0	0
	Approximate degree of right of way impacts (order of magnitude costs)	-1	1	-1	-1	0	-1	-1	-2	0	0
7 - Cost	Total cost	2	2	-2	2	1	-2	0	1	2	2
	Reduction in delay and crashes	1	1	1	1	1	2	1	0	1	2
	Does alternative leverage existing planned projects and programs?	1	0	0	0	0	0	1	1	0	0
8 - Implementation	Can the alternative be separated into reasonably fundable and constructible phases?	1	1	-2	1	0	0	-1	1	1	1
	Does the alternative have local agency support?	1	1	1	1	0	1	1	1	0	0
Evaluation Total		12	13	4	7	10	14	19	4	15	15

Reed Market Road Projects

The Reed Market Road projects tend to respond to only a few goals each because they are intended to address localized operational and safety needs within this greater interchange area. Therefore, these results were organized by project rather than by goal area.

Dedicated Left-Turn Lanes at Reed Market Road and 3rd Street ($5 Million) – While not on the actual Parkway system**, the traffic operations at the Reed Market and 3rd Street intersection have a significant impact on the Parkway ramp terminals on Reed Market** road due to queue spillback. This intersection is also influenced by many other projects included in this study, namely:

- RIRO Closures/Modifications – results in a negative operational impact (v/c ratio of the intersection increases from 1.53 to 1.57)
- Ramp Meters – results in a positive operational impact (v/c ratio of the intersection decreases back to the No-Build condition)
- Powers Road Overcrossing – results in a negative operational impact due to a diversion of traffic and an increased demand at the northbound left-turn movement

This project allows for more efficient intersection operation by removing the split phasing. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Reduces crash by up to 10% with protected turn left turn lanes

Goal 3: Mobility

- Reduces v/c from 1.52 to 1.31
- Reduces queue spillback impacts to the Reed Market interchange, but spillback issue still exists

Goal 4: Accessibility

- Improves travel time reliability on key east-west City route by reducing queuing on Reed Market

Goal #8: Implementation

- Included in Bend CIP 5-year project list with $5,000,000 allocation

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Supported by the Parkway Study for Implementation through the TSP.** However, a more comprehensive solution for this location may be identified as part of a Reed Market Corridor Study.

Widen Northbound Off-Ramp ($2.4 Million) – This option provides additional storage for a movement that suffers from excessive queuing under future No-Build conditions. The ramp meter project shifts some of the demand away from this ramp, providing some initial relief. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Minor reduction in crashes (<4%)

Goal 2: Economic

- Benefits travel time reliability on the northbound Parkway mainline by decreasing the risk of ramp terminal queue spillback

Goal #6: Environment

- ROW impacts are relatively large for a project of this size, likely requiring noise and retaining wall relocations

Based on overall performance scored against the project goals, due mainly limited to negligible operational benefits combined with significant ROW impacts, this project is **Not Recommended for Implementation.**

Signal (or Roundabout) at Northbound Off-Ramp ($700k-$2 Million) – This project addresses the existing capacity need at this location. In addition, the ramp meter project shifts some of the demand away from this intersection. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Provides marginal safety benefits
- Potential for much larger safety benefits from a more comprehensive project addressing restricted left turns and adjacent access treatments in the Reed Market Road corridor

Goal 3: Mobility

- v/c ratio reduced to 0.89, improving operations but not fully meeting the ODOT Mobility Target
- Intersection still impacted by left turns onto northbound Division Street and eastbound queue spillback from Reed Market and 3rd Street

Goal 5: Multimodal

- Provides designated crossings for pedestrians and bicyclists

Goal #7: Cost Effective

- Relatively low cost
- Significant reduction in delay

Goal #8: Implementation

- Project placeholder in Bend TSP for improvement at this interchange

While this project may provide benefit on its own merit, more benefits could be realized by a comprehensive set of projects on Reed Market from Bond to 3rd that includes current CIP projects at Bond/Reed Market and 3rd/Reed Market, access management, control, and turn restrictions at the interchange, and pedestrian/bicycle crossing improvements. Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for Further Consideration**, to be included with an additional **Recommendation to study the Reed Market Corridor from Bond Street to 3rd Street for a coordinated solution**.

Single-Point Urban Interchange ($38.4 Million) – The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Significantly reduces crashes

Goal 3: Mobility

- Meets ODOT Mobility Targets at the interchange (v/c of 0.74)
- Does not solve the issues at Reed Market/3rd, leading to queuing on the ramps and reducing the benefits of the capacity enhancement to the interchange

Goal 5: Multimodal

- Reduces north-south pedestrian and bicycle crossing opportunities on Reed Market

Goal #6: Environment

- Some ROW impacts
- Reductions in delay

Goal #7: Cost Effective

- High cost

Goal #8: Implementation

- Would likely have to be constructed in a single phase
- Included as a placeholder project in on-going TSP project list

Based on overall performance scored against the project goals and having conflicts with other high performing projects, this project is **Not Recommended for Implementation.**

Figure 8: Reed Market Road SPUI Concept (Map data ©2018 Google Earth)

Powers/Murphy Road Projects

The Powers/Murphy Road projects address localized operational, access, and safety needs at the current at-grade Powers Road intersection with US 97 and at the Murphy Road half interchange. The interaction between the grade separation options at Powers Road and the Murphy Road interchange is analyzed in greater detail in Technical Memorandum #8. The Murphy Road tight diamond interchange concept was analyzed for traffic operations and local travel distribution impacts and evaluated and scored to the level of the other options presented in this memorandum, along with the proposed frontage road system along US 97 near Murphy Road.

Powers Overcrossing ($8.0 Million) – The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Decreases crashes by eliminating conflicts

Goal 2: Economic

- Significantly improves travel time reliability on the southern portion of the Parkway by reducing access south of Reed Market Road and removing queuing impacts caused by the existing Powers Road at-grade intersection

Goal 3: Mobility

- Eliminates the capacity constraints at the existing Powers Road and US 97 intersection
- Shifts significant volume north to the Reed Market Road interchange and south to the Murphy Road interchange, impacting traffic operations at key Parkway intersections (Reed Market Road interchange ramp terminals) and key local intersections (Reed Market Road and 3rd Street, Murphy Road and 3rd Street)

Goal 4: Accessibility

- Traffic demand shifted to Reed Market Road worsens travel times on a corridor flagged as already unreliable in the Bend TSP
- Increases traffic demand on lower classification streets south of Reed Market
- Would likely increase or create neighborhood cut-through traffic issues, particularly in the Silver Lake Road area

Goal 5: Multimodal

- Provides a low-stress bicycle and pedestrian crossing of the Parkway

Goal #6: Environment

- Minor ROW Impacts

Goal #7: Cost

- The negative impacts to vehicle delay at Murphy and Reed Market offset some of the benefits from safety improvements

Goal #8: Implementation

- The ongoing Bend TSP and MTP both identify an interchange at this location rather than an overcrossing

Based on overall performance scored against the project goals and having conflicts with other high performing projects (Powers Interchange), this project is **Not Recommended for Implementation.** However, this concept could be considered as a near term phase to the Powers Road Diamond Interchange concept, but only if the Murphy Interchange provides full access.

Powers Interchange ($24.7 Million) – This option could include either traffic signals or roundabouts at the ramp terminals, likely dictated by right-of-way availability. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 1: Safety

- Provides safety enhancement over existing at-grade configuration

Goal 2: Economic

- Manages queues within the interchange ramps, improving travel time reliability

Goal 3: Mobility

- Meets ODOT mobility targets at the ramp terminals

- Manages queues within the interchange ramps

Goal 5: Multimodal

- Provides low-stress bicycle and pedestrian access across the Parkway

Goal #6: Environment

- Has some ROW impacts

Goal #7: Cost Effective

- High cost project

Goal #8: Implementation

- Could potentially be phased with an overcrossing first, ramps later
- Included on both the ongoing Bend TSP and MTP project lists

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for Implementation.** Note that the full right-of-way, cost, and constructability of this interchange are analyzed in more detail along with the Overcrossing option in Technical Memorandum #8.

Murphy Tight Diamond vs Loop Ramps and Murphy Frontage System – The preferred alternative build-out of the Murphy Road interchange was selected in the South Parkway Refinement Plan, but the ultimate construction of the first two ramps (northbound off, southbound on) precluded some key components of the remaining concept. The loop ramp and a tight diamond concepts are investigated in more detail in Technical Memorandum #8, including assessment of traffic impacts and feasibility as well as interaction with other improvements (overcrossing versus interchange) at Powers Road to both understand the ultimate project at each location and the traffic triggers between the two for proper construction phasing in Technical Memorandum #8. The evaluation ratings for each Murphy Road concept, including the frontage roads, are included in Technical Memorandum #8.

China Hat Road Projects

The China Hat Road Projects address two separate but interacting issues related to future development access to the Parkway between Baker Road/Knott Road and Murphy Road.

China Hat Overcrossing ($12.5 Million) – This option includes closing the RIROs at China Hat Road/Ponderosa Street and US 97 and replacing them with an overcrossing. Under No-Build conditions, the demand from future developments in the "Thumb" area overwhelm the China Hat Road RIRO intersection, and more traffic uses the Parrell Road collector connection to get to 3rd Street. The success of this project would be highly dependent on the completion of a frontage road from Murphy Road to Ponderosa Street, which is an assumed No-Build project but may be in question as part of the Murphy Road tight diamond option. The key performance characteristics of this project were evaluated against the goals are summarized as follows:

Goal 1: Safety

- Reduces crash by eliminating RIRO access at China Hat/Ponderosa/US 97

Goal 2: Economic

- Improves travel time reliability south of Murphy

Goal 3: Mobility

- Benefits the operations at the Murphy Road and 3rd Street roundabout
- When coupled with the frontage road from Murphy Road to Ponderosa Street, relieves some of the demand from Parrell Road
- Note that an intersection control improvement to the Parrell/China Hat intersection (likely a roundabout) would likely be needed as part of this project (which is assumed to rebuild this intersection anyway).

Goal 4: Accessibility

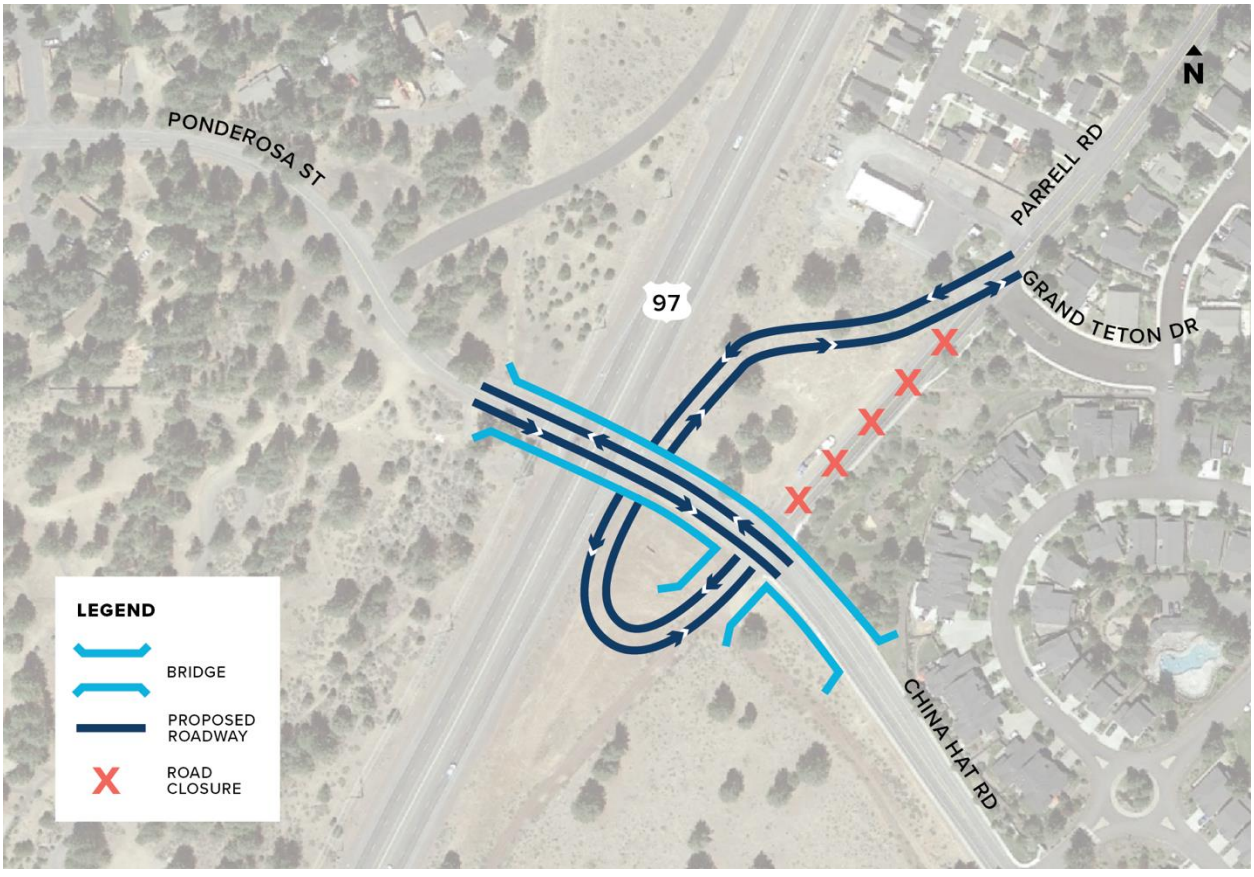
- When coupled with the frontage road from Murphy Road to Ponderosa Street in particular, this project relieves some of the demand from Parrell Road

Goal 5: Multimodal

- Provides new multimodal crossing of US 97

Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for Implementation.**

Figure 9: China Hat Road Overcrossing Concept (Map data ©2018 Google Earth)



Frontage Road from Ponderosa to Baker ($5-10 Million) – This option would provide better connectivity between new developments to the west and either the Baker Road/Knott Road or Murphy Road interchanges. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 3: Mobility

- Minimal operational impact

Goal 5: Multimodal

- Provides opportunity for new north-south Low Street bike/ped facility

Goal #6: Environment

- High ROW impacts

Goal #7: Cost Effective

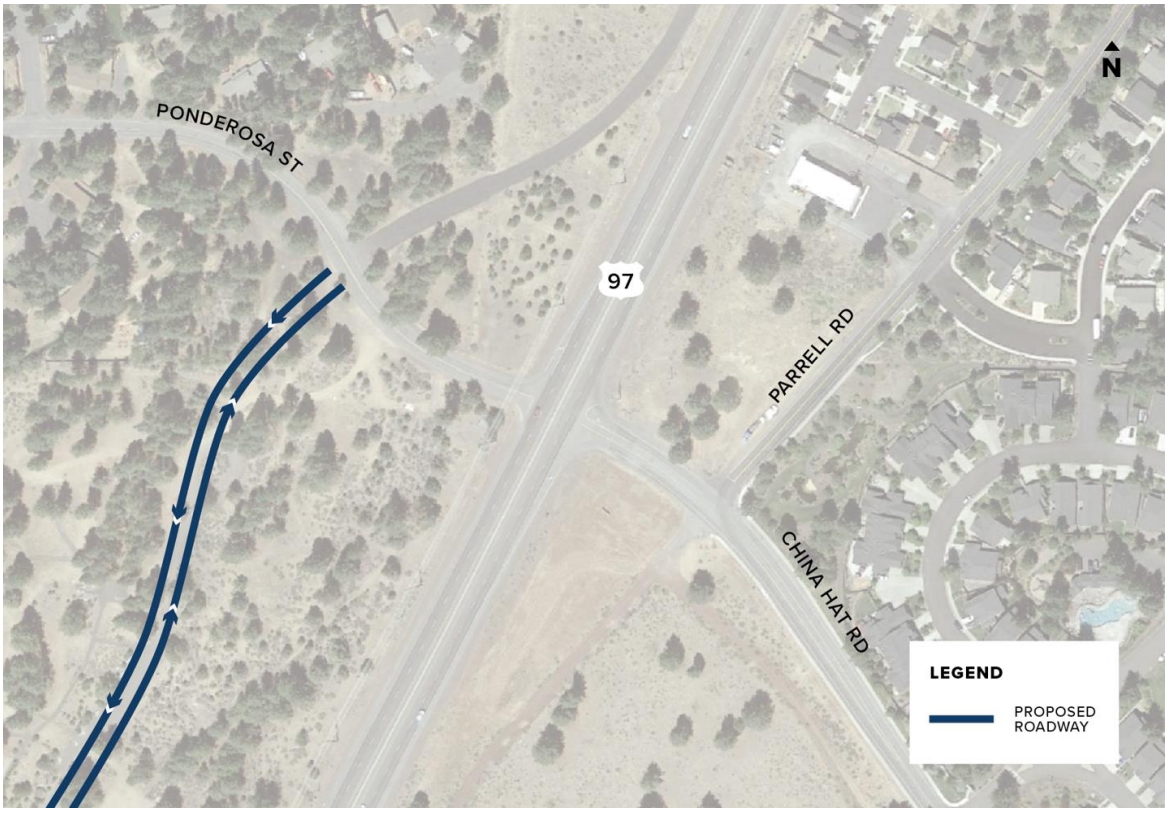
- High cost

Goal #8: Implementation

- Conflicts with heavy rail lines

Based on overall performance scored against the project goals this project is **Not Recommended for Implementation.**

Figure 10: Frontage Road from Ponderosa Street to Baker Road Concept (Map data ©2018 Google Earth)



Baker Road/Knott Road Projects ($1-5 Million)

The Baker Road/Knott Road options consider either signals or roundabouts at the existing two-way stop-controlled ramp terminals. The key performance characteristics of this project evaluated against the goals are summarized as follows:

Goal 3: Mobility

- Meets ODOT Mobility targets (both signal and roundabout)

Goal #6: Environment

- Roundabouts outperform the signal option due to decreased delay

Design challenges created by existing grades, the nearby railroad, and surrounding property access locations warrant a more detailed investigation to determine the appropriate solution, which could occur through an Interchange Area Management Plan (IAMP). Based on overall performance scored against the project goals and having no conflicts with other high performing projects, this project is **Recommended for further consideration in an IAMP.**

3.0 OTHER CONSIDERATIONS

CONNECTED/AUTONOMOUS VEHICLE DISCUSSION

The introduction of connected and autonomous vehicles (CAV) for general public use brings great promise for safer and more efficient transportation alternatives than is available today. There are two interesting facets of this technology that may have implications for the US 97 Bend Parkway corridor. The first is how CAV vehicles will perform in a mixed vehicle environment. Today, the behavior of drivers using their own vehicles is well understood and researched. The tools that were applied for this study as it relates to travel choices, vehicle speeds, and roadway carrying capacity benefits from decades of research and real-world observations. However, the interaction of CAVs and non-CAVs is a very new development and requires new ways of thinking about how real people interact with connected vehicle information systems.

The second aspect of CAV as they are introduced to the general public is how it may lead to more fundamental changes in travel demand choices than are traditionally estimated for long-range planning. As an example, the next evolution of the Transportation Network Carriers (TNCs), like Uber and Lyft, will be based on autonomous vehicles operations, which may sharply reduce travel costs and influence travel choices and vehicle ownership.

The intersection of new CAV technology with human driving behavior is a complex area of study. There remain many questions about how the general public will respond to technology-based information in their own vehicles and how they might interact with non-AV drivers in the adjacent travel lanes. Early theoretical predictions claimed major upgrades in throughput with CAV technology, as much as double existing capacity. A recent study[12] by Texas Transportation Institute (TTI) of the I-35 Corridor in Austin, however, showed much different results. TTI's model simulations of that 12-mile highly congested urban freeway corridor evaluated freeway throughput per lane, volumes and overall travel speeds related to increasing proportions of CAVs in the vehicle mix. The authors demonstrated a major degradation of mobility, in terms of throughput, speeds and safety as CAV was added to the vehicle mix due to interactions between CAV and non-CAV. In fact, the higher the CAV share, the lower the travel speeds and freeway throughput, and greater the travel times became, which is a counter-intuitive outcome.

One of the major performance factors in the mixed vehicle environment is associated with the friction created between CAVs and non-CAVs in the pursuit of traffic harmonization. When a CAV communicates to other CAVs of upcoming traffic, the CAVs respond accordingly but the non-CAVs may or may not. This tends to exacerbate the existing bottlenecks and be more problematic because of increased lane changing as non CAVs navigate around CAVs that are obeying the rules of the road. These types of behaviors not only impact congestion but tend to degrade the expected safety benefits of traffic harmonization.

[12] Impacts Of Connected Vehicles In A Complex, Congested Urban Freeway Setting Using Multi-Resolution Modeling Methods, International Journal of Transportation Science and Technology**,** Volume 8, Issue 1, March 2019,

The other aspect of the CAV that is relevant to the US 97 Parkway is a broader effect on community travel choices and auto ownership. As the CAV market penetration rises, the availability of Transport as a Service (TaaS) may introduce a fundamental shift in how current transport choices are made. As the cost of drivers is removed from the business equation, the concept is that TNC type activities will grow exponentially by offering transportation at a fraction of the current cost per trip. Early estimates by the ReThinkX research group[13] are that TaaS will offer vastly lower cost transport alternatives, as much as four to ten time cheaper per mile than buying a new car and two to four times cheaper than operating an existing vehicle. In addition, they predicted that switching from internal combustion engine vehicles to all electric powered for TaaS could dramatically increase vehicle-utilization rates, which could reduce the total number of vehicles on the system.

If these predictions are realized in the greater Bend area, this will fundamentally change how people travel around the city, including how they use the Bend Parkway. Behavioral issues such as love of driving, fear of new technology or habit may pose initial barriers to consumer uptake. The side effects of this type of change are much high VMT per vehicle (at least 10x more than individually owned cars), lower auto ownership, and lower travel costs. Reductions in auto ownership and usage will drive down gas tax revenues for local agencies. The same study cited above estimated that TaaS will provide 95% of passenger miles traveled within 10 years of widespread regulatory approval of AVs. Overall, the travel behavior trends for AV fleet penetration vary widely across different studies, and for the purposes of the Bend Parkway, are not well enough understood to provide input into future performance measures and recommended designs.

ODOT is working towards providing infrastructure to support this type of technology with upgraded traffic signal controllers and smarter detection. Region 4 currently has the fewest upgraded intersections to support this technology. The cost to begin implementing this is approximately:

- Upgraded Controller = $2,500 per intersection
- Upgraded Detection = $30,000 per intersection
- Where needed, Communication Upgrades = $10,000 per intersection

This effort would go with improving ramp terminal signal operations which is a recommended alternative. Working towards CAV is recommended for implementation.

[13] RethinkX, Rethinking Transportation Choices 2020-2030, 2017. https://bit.ly/2AeAxJR

4.0 CONCLUSION

This section provides a summary the projects recommended for investment prioritization based on the Level 2 evaluation. Table 12 provides the complete list of recommended, broken down by area. It is anticipated that the results will be discussed with project stakeholders, leading to a refinement of this list of projects into a final list of recommended projects.

Table 12: Recommended Improvement Projects for the US 97 Corridor

Project Category	Projects Recommended for Implementation[1]
Corridor-Wide Projects	Ramp Meters
	Close All RIRO Except RI (exit from Parkway) at Hawthorne Ave
	Ramps improved to standard lengths
	Active transportation improvements (Crossings)
	Shoulders built to standard
	Weather warning system
	Variable speed signs
	Incident management
	Enhanced signal operations at ramp terminals
	Traveler information signing
	Roadside Traveler Information Dissemination (only if bundled with other strategies)
North Study Area	FEIS projects
Central Study Area	Auxiliary lane Empire Blvd to Butler Market Rd SB
	Auxiliary lane 3rd St to Empire Blvd NB
	Butler Market SB frontage road to interchange
	Butler Market Roundabout (or signal) at SB off ramp
	Butler Market Roundabout (or signal) at 4th Ave (Through the TSP)
	Revere Avenue Lane Reconfiguration (Through the TSP)
	Colorado Avenue Signal (or roundabout) at NB ramp
	Colorado Avenue Improvement to SB ramp intersection pending TSP and Core Area Plan connectivity recommendations
South Study Area	Reed Market Refinement Study from Bond Street to 3rd Street
	Dedicated left turn lane Reed Market Rd and 3rd St (Through the TSP)
	Powers Road Interchange
	China Hat Overcrossing (pending Murphy to Ponderosa Frontage Road)
	IAMP at Baker Rd/Knott Rd interchange
	Murphy Tight Diamond Interchange (See Technical Memorandum #8)
	North Frontage Road (See Technical Memorandum #8)
	South Frontage Road (See Technical Memorandum #8)

[1]These projects will be further prioritized for short, medium, and long term in the investment strategy

APPENDICES

VOLUME 1

Project Evaluation Ratings

VOLUME 2

Technical Analysis Summary

Active Transportation Prioritization

Right-in/Right-out Analysis

VOLUME 3

Volume Forecasts by Project Bundle

Bicycle and Pedestrian Level of Traffic Stress by Project Bundle

HSM Analysis by Project Bundle

ISATe Analysis by Project Bundle

HCM Outputs by Project Bundle

Vissim Build Model Results Report

Vissim Model Detailed Analysis Results