

Refinement Plan

U.S. 97 Bend to Lava Butte

June 23, 2017

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Acronyms

AADT	annual average daily traffic
APM	Analysis Procedures Manual
GIS	geographic information systems
LOS	Level-of-service
LTS	Level of Traffic Stress
MP	milepost
MUP	multiuse path
NB	northbound
ODOT	Oregon Department of Transportation
ODFW	Oregon Department of Fish and Wildlife
OHP	Oregon Highway Plan
OTP	Oregon Transportation Plan
ROW	right-of-way
SB	southbound
STIP	Statewide Transportation Improvement Project
TAC	Technical Advisory Committee
UGB	Urban Growth Boundary
USFS	United States Forest Service
WB	westbound

Executive Summary

The Lava Butte Refinement Plan was developed by Oregon Department of Transportation (ODOT) to address the safety and operations on U.S. 97 between Baker Road and Lava Butte and the missing connections between the trail systems of the Bend Parks and Recreation District and Deschutes National Forest.

Deschutes County is one of the fastest growing regions in the nation. Much of the growth is due to tourism and active recreation. As the region continues to grow, there is a desire and need for a multiuse path (MUP) to parallel U.S. 97 and connect to the larger active transportation network and trail system. The improvement recommendation is to provide a comfortable non-motorized multiuse path connection from Baker Road to Lava Lands Visitor Center along the U.S. 97 corridor.

The study identified access improvements to meet existing traffic demand as well as the additional traffic generated by the High Desert Museum (HDM) access. The plan also includes an understanding of access improvements that will be needed over the 20-year planning horizon for safe and efficient travel in the corridor. Safety improvements needed specifically related to the High Desert Museum Access are also identified.

Three alternatives were analyzed to compare the benefits of varying multiuse path alignments; as well as three additional concepts to improve vehicle access and safety at the HDM entrance. Based on the planning level analysis, it was recognized that road and trail improvements along U.S. 97 would benefit from a grade-separated undercrossing at the HDM entrance. This plan recommends a partial interchange to eliminate left turns into and out of the HDM, providing a safer direct access point from U.S. 97.

1 Introduction

U.S. 97 is a critical part of the state's transportation system and is the main north-south transportation corridor in Central Oregon. Deschutes County and the City of Bend continue to experience population growth and economic development, affecting access, safety and highway operations along this important corridor. According to the US Census, between 2015 and 2016 the Bend-Redmond Metropolitan area had a population increase of 4.9%.¹ The Oregon Department of Transportation (ODOT) is investigating transportation improvements along U.S. 97 from Baker Road to Cottonwood Road through this plan to improve mobility, access and safety for all modes of transportation.

The changes in Deschutes County and the City of Bend have resulted in additional demands on the transportation infrastructure from a variety of uses – freight, residential and commercial development, industrial activity, tourism, and active recreation. The project area serves as an interface between the City of Bend's southern urban fringe and recreational opportunities provided by the Deschutes National Forest, specifically the Newberry Crater National Monument, the associated Lava Lands Visitor Center, and the private, nonprofit High Desert Museum. The project area also has significant potential to provide bicycle, pedestrian, and transit connections between the trail systems of the Bend Parks and Recreation District and Deschutes National Forest. The growing transportation demand on U.S. 97 is compounded by the affordable housing problem in Central Oregon and the increased commuter demand as a result.

The *U.S. 97: Bend to Lava Butte Refinement Plan* (Plan) provides an assessment of the U.S. 97 transportation system performance within the project area for the 20-year planning period. It addresses all transportation modes and identifies deficiencies and support for a variety of enhancements to respond to shifts in the demand for transportation options.

1.1 Project Area

The project area includes U.S. 97 from the Baker Road interchange (northbound off-ramp and southbound on-ramp) south to Lava Lands Visitors Center and includes the entrance to the High Desert Museum and the intersection of North Paulina Road and U.S. 97. The project area is shown in Figure 1. The project goal is to improve function and safety, while emphasizing bicycle and pedestrian travel with a multiuse trail along U.S. 97 and connections to adjacent trail systems.

¹ https://www.census.gov/newsroom/press-releases/2017/cb17-81-population-estimates-subcounty.html

Figure 1. Project Area



1.2 Plan Components

The Plan consists of the following:

- Multiuse trail options connecting Baker Road Interchange area to Lava Lands
 Visitors Center
- Multimodal options for pedestrian, bicyclists, and vehicles at Baker Road Interchange
- Traffic and safety analysis for trail crossings under U.S. 97 and along access points

The following plans and policies were reviewed and will be considered during the development of corridor improvements within the project area:

- Oregon Transportation Plan (OTP)
- Oregon Highway Plan (OHP)
- Statewide Transportation Improvement Program (STIP)
- Division 51 (Oregon Administrative Rules 731-051)
- Oregon Bicycle and Pedestrian Plan
- Americans with Disabilities Act
- Oregon Bike (and Pedestrian) Bill (ORS 366.514)
- Deschutes National Forest Alternative Transportation Study
- City of Bend Transportation System Plan
- Deschutes County Transportation System Plan

Each plan will be reviewed for relevant guidance toward establishing a framework for considering improvements to the Bend to Lava Butte corridor.

1.3 Public Involvement Summary

As part of the Plan, ODOT hosted open houses for property owners and local residents on December 20, 2016 and February 8, 2017 at the Region 4 Headquarters (63055 N. Highway 97, Bldg. K, Bend, Oregon). The open houses provided the public an opportunity to learn about the project and offer input to ODOT. Open houses delivered informal project information, and the project team was available to discuss the project and answer questions. Approximately, 45 members of the public attended the two open houses. In addition to these meetings, an online open house was available via ODOT's website from January 25 to February 28, 2017 and allowed people to provide input. Approximately 30 comments were gathered online and at the open house.

Themes discussed at the open houses included:

- Use of the U.S. 97 corridor, as well as access to the High Desert Museum and Lava Lands Visitor Center
- Corridor concerns related to safe travel, recreational access and mobility

 Trail access to the High Desert Museum, Lava Lands Visitor Center, and other recreational destinations in the area, as well as what trail concept(s) corridor users would like to see

ODOT carefully considered open house input when identifying the Plan recommendation.

Public input was gathered via two online surveys, the first corresponding with the December 20, 2016 open house, and the second corresponding with the February 8, 2017 open house and the online open house. There were 20 respondents to the first survey and 10 to the second. Results are summarized below.

The first survey asked questions about the respondents' use of the corridor: where they lived, where they traveled to and from, and whether and how they accessed the High Desert Museum and Lava Lands Visitor Center. The majority of respondents did not live or work in the corridor but did visit the Lava Lands Visitor Center, High Desert Museum, or other recreational destinations in area. The majority of respondents (16 of 20) traveled to those destinations by car or truck; 6 also indicated they travel to those locations by bike. The survey also inquired about specific corridor concerns and suggestions. Responses included:

- Concerns about the Baker Road interchange area (traffic flow, safety, visibility)
- Corridor safety (lack of median barrier and turn lanes, unsafe speeds, bike safety, winter driving)
- The desire for an off-road path to provide reliable and safe bike/pedestrian access to the Lava Butte Visitor Center and High Desert Museum

The second survey also included questions about whether the respondents lived or worked in the corridor and how they typically used the corridor. Similar to the first survey, most respondents did not live or work in the corridor; the majority (9 of 10 respondents) used the corridor for recreational travel; 4 respondents also used the corridor for commuting or other trips. Private vehicle was the primary travel mode among responses, followed by biking and walking. Corridor challenges mentioned by respondents included safety, traffic volumes, and trail location.

The survey also asked several questions about trail options, access to the High Desert Museum, transit, and the Baker Road Interchange. Nine of the ten respondents said the presented trail options provided needed connectivity for bikes and pedestrians, and specific comments on the trail options were provided. Most respondents said they would not consider using public transit to visit Lava Butte, Lava Lands Visitor Center or the High Desert Museum. Potential incentives for transit usage suggested by respondents included frequent, low-cost service from Bend and La Pine. Specific suggestions for Baker Road interchanges included improving visibility/sight distances and addressing high levels of bike traffic.

The concerns and suggestions offered through the in-person and online open houses and survey responses were considered in the Plan recommendations.

2 Goals, Objectives, and Evaluation Criteria

The following criteria support the Plan by summarizing project objectives and evaluation criteria that will be used to inform key decisions. The five key decisions the Plan focuses on include:

- 1. Is there a desire and need for a multiuse path (MUP) to parallel U.S. 97 and how can it connect to the larger active transportation network and trail system?
- 2. Which transit improvements are possible and desired to better serve corridor recreational travel?
- 3. Which access improvements are needed over the 20-year planning horizon for safe and efficient travel in the corridor?
- 4. Does the corridor adequately serve the needs of the travelling public?
- 5. Are safety improvements needed in response to existing corridor conditions?

2.1 Project Decision Making and Public Engagement

The project team utilized a decision-making process that involves a variety of ODOT and agency stakeholders. The Technical Advisory Committee (TAC) included participation from the United States Forest Service (USFS), Oregon Department of Fish and Wildlife (ODFW), Central Oregon Intergovernmental Council, Bend Parks and Recreational District, Bend Metropolitan Planning Organization, Deschutes County, and City of Bend. The TAC's purpose was to ensure consistency across plans and policies among the various levels of government.

In addition to the TAC, the project team conducted outreach to key stakeholders who may be impacted by the Plan's outcome. Targeted outreach in the project area included outreach to the High Desert Museum, the Country Store on Baker Road, Cascades East Transit, the few property owners along the corridor, and the USFS, which operates the Lava Lands Visitor Center and manages land along U.S. 97. This targeted outreach was implemented to develop a deep understanding of the stakeholders' needs in the corridor so the Plan outcomes are in alignment with those needs.

Based on early coordination and feedback from project stakeholders, the following goals, objectives, and evaluation criteria were developed to help the project team achieve the desired Plan outcome for ODOT and the community surrounding U.S. 97. These evaluation criteria will be utilized by evaluating alternatives via the performance measures listed in Table 1.

2.2 Goal

The Plan's goal is to improve mobility, access, safety and active transportation use along U.S. 97 from the Baker Road interchange to Cottonwood Road, including access to Lava Lands Visitor Center and High Desert Museum.

2.3 Objectives and Evaluation Criteria

Plan Objectives include:

Access

• Providing safe and convenient access to recreational destinations, such as improved or protected access to High Desert Museum and Lava Lands Visitor Center

Mobility

- Maintain or improve operations on U.S. 97
- Meet OHP intersection mobility targets
- Accommodate for planned growth in travel

Safety

- Provide facilities that will reduce the severity of collisions on the corridor
- Provide facilities that will reduce the number of collisions on the corridor

Active Transportation

- Provide a comfortable non-motorized connection from Baker Road to Lava Lands Visitor Center along U.S. 97 corridor for users of all skill levels
- Provide safe bicycle access to the High Desert Museum from Bend and Sunriver
- Complete regional connections between city, county, ODOT, and USFS facilities. "US 97: Multi-use Trail Planning Study" is included in the draft 2018-2021 STIP.

Table 1. Goals, Objectives, Evaluation Criteria, and Performance Measures

Goal: To improve mobility, access, safety and active transportation use along U.S. 97 from the Baker Road interchange to the Lava Lands Visitor Center.

Objective	Evaluation Criteria	Performance Measure
Access	Provide safe and convenient access to recreational destinations	Improved or protected access to High Desert Museum and Lava Lands Visitor Center
	Maintain or improve operations on U.S. 97	Highway Capacity Software analysis of ramps from Baker Road, segment analysis based on future volumes
Mobility	Provide opportunity for transit service to reduce reliance on private vehicles	Is service being provided or potentially viable?
	Meet OFF mobility targets at intersections	Synchio analysis at intersections
	Accommodate planned growth in travel	Growth factors on volumes compared to capacity
Safety	Provide facilities that will reduce the severity of collisions on the corridor	Predictive Highway Safety Manual

Table 1. Goals, Objectives, Evaluation Criteria, and Performance Measures

Goal: To improve mobility, access, safety and active transportation use along U.S. 97 from the Baker Road interchange to the Lava Lands Visitor Center.						
Objective	Evaluation Criteria	Performance Measure				
	Provide facilities that will reduce the number of collisions on the corridor	Predictive Highway Safety Manual				
	Provide comfortable connection from Baker Road to the Lava Lands Visitor Center along U.S. 97 for users of all skill levels	Use Level of Traffic Stress (LTS) assessment from Analysis Procedures Manual (APM)				
Active Transportation	Provide safe bicycle and pedestrian access to the High Desert Museum from Bend and Sunriver	Use LTS assessment from APM				
	Complete regional connections between city, county, ODOT,USFS facilities and Bend Park & Recreation District	Number of connections currently completed				

2.4 Conclusion

The objectives and evaluation criteria informed the five major corridor decisions listed in Section 2 for this project. The project team applied these criteria when examining Plan alternatives, and the resulting metrics were vetted through the TAC and public engagement process to promote collaboration on the corridor's direction with stakeholders. The final outcomes of this process are documented in the Plan and will be adopted by the Oregon Transportation Commission as an amendment to the OHP.

3 Existing Conditions

3.1 Traffic Volumes and Operations Analysis

Traffic volume data pertaining to the project area were compiled from existing agency and USFS traffic counting sources prior to obtaining new traffic counts. Any new turning movement counts were consistent with ODOT *Analysis Procedures Manual* (APM) requirements; including a 15-minute breakdown of pedestrians, bicyclists, passenger vehicles, and heavy vehicles.

3.2 Existing Conditions Analysis

3.2.1 Intersection Operations Analysis

Traffic operational analysis was completed using Highway Capacity Software 2010 and Synchro 8.0 to implement the analysis methods in the 2010 *Highway Capacity Manual* (2010) and was consistent with APM analysis procedures. All operational analysis, regardless of the jurisdiction, included the following measures of effectiveness:

- Volume-to-capacity ratio (v/c ratio)
- Level-of-service (LOS)
- Average delay (sec/veh)

- 95th percentile queue lengths
- Turning movement volumes

All volumes on state facilities were seasonally adjusted to the 30th highest hour (30HV) using the on-site automatic traffic recorder method consistent with the APM; for the on-site automatic traffic recorder method, the Lava Butte automatic traffic recorder (#09-003) was used. The Lava Butte automatic traffic recorder is located on U.S. 97 at milepost (MP) 142.41, 0.17 miles south of China Hat Road.

All traffic analysis focused on the PM peak period conditions unless otherwise agreed upon with ODOT.

3.2.2 Non-Automobile Transportation Analysis and Multimodal Opportunity GIS Maps

An analysis of primary non-motorized transportation routes (collector and arterial roadways only) was performed using available geographic information systems (GIS) data, field observations, online mapping, and the ODOT video log. A bicycle level traffic stress analysis was performed using the rural methodology dependent on average daily traffic (ADT) and shoulder width.

The non-automobile transportation analysis included:

- Availability of sidewalks and bicycle lanes
- General condition of existing sidewalks and bicycle lanes
- Gaps in primary routes
- Bicycle level of traffic stress
- High-risk crossing locations

Based on this information, bicycle and pedestrian facility and multimodal opportunity (GIS) maps were developed. Special emphasis was placed on the identification of bicycle and pedestrian facility co-location, gaps in connectivity, bicycle level of traffic stress, including connectivity to City of Bend, USFS trail, and Bend Park & Recreation District paths, bicycle, and pedestrian facilities, and potential opportunity sites that support a better integrated multimodal network.

3.2.3 Crash Analysis

A minimum of 5 years of crash data was reviewed and analyzed for potential crash patterns. An overall assessment of crash types, severities, and trends was completed for all users (e.g. vehicles, pedestrians, bicyclists). The Safety Priority Index System was referenced to determine if any top 5 or 10 percent sites exist within the project area. ADT volumes developed for the traffic analysis were used in the crash analysis calculations.

Intersection crash rates were calculated and compared to the published intersection 90th percentile crash rates. The Highway Safety Manual Part B Critical Crash Rate and Excess Proportion of a Specific Crash Type screening methods was used to identify any safety focus locations. Crash patterns were identified and countermeasures documented for any intersections with crash rates that exceed the critical crash rate, the 90th percentile crash rate, or have a positive excess proportion.

Segment crash rates were calculated and compared to Table II in the ODOT Statewide Crash Rate Book to identify study segments with more crashes than other similar Oregon facilities.

3.2.4 Traffic Volumes

ODOT provided traffic count data for U.S. 97, the Baker Road interchange ramps, the High Desert Museum entrance, and the Lava Lands entrance. The project team developed existing (2016) traffic volumes by following the ODOT *Analysis Procedures Manual*. Existing traffic volumes indicated a peak summer period, which was used for the analysis. While the PM peak hour (5 to 6 p.m.) was used for the overall corridor analysis, the traffic volumes into and out of the High Desert Museum were low during this time period, as the museum closes at 5 p.m. during summer hours. Because of this, a more refined analysis was used to evaluate that intersection (as described in the next paragraph). ODOT traffic data indicated that the 2015 annual average daily traffic (AADT) on U.S. 97 within the project area was 14,500 vehicles, with approximately 13 percent consisting of heavy vehicles (trucks, buses, and recreational vehicles).

To evaluate traffic operations at the High Desert Museum entrance intersection on U.S. 97, the project team developed traffic volumes for the museum's peak operating hours. This included peak hours for traffic entering the museum (10 to 11 a.m.) and exiting the museum (3 to 4 p.m.). The project team used traffic counts from the museum's "Free Day" in March 2013 to evaluate the worst-case scenario. Visitor counts provided by the High Desert Museum showed approximately 1,600 visitors on the "Free Day" in March 2013, compared to just over 700 visitors on a typical summer day. Vehicle occupancy ranged from 1.5 to 2.5 persons per vehicle, with a higher occupancy observed on the "Free Day," based on the traffic counts obtained during these time periods. The museum traffic counts also indicated the majority of visitors originate from the north during the morning peak and depart to the north toward Bend during the afternoon peak (approximately 80 percent).

Museum traffic is higher when admission is free, and March 2013 data was the most recent available. A marginal growth rate of 1.0 percent per year was used to develop 2016 museum volumes, while a rate of 2.6 percent per year was used for U.S. 97 and the Baker Road interchange. Existing (2016) PM peak design hour traffic volumes within the project area are shown in Figure 2 (including those volumes for the museum) and peak museum hours (based on the worst-case scenario) are shown in Figure 3.

3.2.5 Operations Analysis

The existing conditions traffic analysis was performed for U.S. 97, the Baker Road southbound on-ramp, the Baker Road northbound off-ramp, and the entrance to the High Desert Museum. In addition to the standard measure of operations (volume-to-capacity [v/c] ratio), the LOS scale from A (best) to F (worst) has also been calculated. The results of this analysis for the U.S. 97 segment and Baker Road ramps are shown in Table 2.



Figure 2. Existing (2016) Design Hour Traffic Volumes



Figure 3. Existing (2016) Peak High Desert Museum Traffic Volumes

Table 2. U.S. 97 Segment Operations Analysis

Description of Segment Location	Segment Type	Traffic Density ¹	LOS	V/C Ratio			
U.S. 97 Southbound	U.S. 97 Southbound (SB)						
U.S. 97 Merge from Baker Road Interchange	Merge	10.2	В	0.27			
U.S. 97 between Baker Road and High Desert Museum	Basic	9.1	А	0.24			
U.S. 97 south of High Desert Museum	Basic	9.1	А	0.24			
U.S. 97 Northbound (NB)							
U.S. 97 Diverge to Baker Road Interchange	Diverge	9.4	А	0.15			
U.S. 97 between Baker Road and High Desert Museum	Basic	6.6	А	0.17			
U.S. 97 south of High Desert Museum	Basic	6.4	А	0.17			

¹ Density = passengers cars per mile per lane (pc/mi/ln).

Source: HDR analysis of ODOT data

During the PM peak hour, the U.S. 97 corridor operates at LOS B or better, and the v/c ratios are all less than 0.30. This finding includes the Baker Road southbound on-ramp merge and the Baker Road northbound off-ramp diverge.

The existing conditions analysis results for the U.S. 97 and High Desert Museum entrance intersection are provided in Table 3 and include the v/c ratio, average delay, LOS, and 95th percentile queue length for the southbound left-turn movement into the museum and the stop controlled left- and right-turn movements exiting the museum onto U.S. 97.

Time Period	Movement	Volume	V/C Ratio	Average Delay (Sec/Veh)	LOS	95th Percentile Queue (Vehicle)	95th Percentile Queue (Feet)
Peak museum entry	SB Left	133	0.18	10.5	В	4	100
(10 – 11 a.m.)	WB Left	1	0.01	39.7	Е	3	75
	WB Right	7	0.01	11.2	В	2	50
Peak museum exit	SB Left	14	0.02	9.5	А	2	50
(3 – 4 p.m.)	WB Left	24	0.17	33.7	D	3	75
	WB Right	129	0.24	12.9	В	7	175
U.S. 97 PM peak	SB Left	8	0.01	9.1	А	2	50
(5 – 6 p.m.)	WB Left	8	0.05	28.2	D	3	75
	WB Right	25	0.04	10.9	В	2	50

Table 3. High Desert Museum Entrance Intersection Operations Analysis

Source: HDR analysis of ODOT data

Note: 95th Percentile Queue (feet) assumes 25 feet per vehicle. WB=westbound

As shown, all turning movements into and out of the High Desert Museum operate at LOS E or better, although it should be noted the LOS E movement during the AM peak (westbound left turn) shows just one vehicle in the entire hour. In addition, the v/c ratios are less than 0.25 for all movements. When the majority of traffic exits the museum during the afternoon peak hour, the 95th percentile queue lengths peak at approximately seven vehicles.

3.3 Land Use

To develop an understanding of the project area, a land-use inventory was prepared. Existing land use, as identified by zoning, is shown in Figure 4. Existing land uses in the project area consist of mostly rural residential and prime forest land.

Figure 4. Zoning Map



3.4 Transit

Transit service on U.S. 97 in the study area exists from RIDE play with Cascades East Transit. RIDE play from Cascades East Transit includes seasonal shuttles that connect people to many Central Oregon recreational opportunities. This transit service on U.S. 97 is demand response (i.e. not on a regular schedule), where passenger services are scheduled in advance. Route 30 also travels between LaPine and Bend with a stop in Deschutes River Woods.

In 2015, the Lava Butte shuttle was added to the RIDE play recreational and seasonal bus service. The Lava Butte shuttle offers riders the chance to ride up to the summit of Lava Butte and experience a view of the Cascade Mountain Range. The Lava Butte shuttle costs riders \$2.00 and rides down from the summit are free. The current service has outpaced projections and currently returns more revenue than is spent operating the service.

3.5 Nonmotorized Transportation

The Deschutes National Forest is a destination for millions of visitors annually. Many tourist or recreational destinations exist throughout the Deschutes National Forest, but those destinations lack sufficient nonmotorized trail connections between them to effectively connect them. There is a 5.5-mile paved path connecting Sunriver, Benham East Trailhead, and Lava Lands Visitor Center. Figure 5 displays the paved multiuse trail connections from SW Bend to major destinations. The trail has been popular since it opened in 2014; creating a greater need for a shuttle between Lava Lands, High Desert Museum, and the City of Bend. The existing 6-mile gap between Baker Road and the Lava Lands Visitor Center could be closed via a multi-use trail connection. The *Deschutes National Forest Alternative Transportation Study* has recommended this action. The project team did not obtain trail usage counts for this study as no formal connection currently exists. Several informal connections are currently utilized along the corridor, suggesting latent demand exists for the connection. The existing and planned recreational routes near the project area are shown in Figure 5.





3.6 Stress Analysis

ODOT's Bicycle Level of Traffic Stress (LTS) methodology assesses street segments, intersections, and intersection approaches for the level of stress incurred by bicyclists

utilizing ODOT facilities.² The stated methodology assesses street segments, intersections, and intersection approaches for the level of stress incurred by bicyclists riding there. LTS is scored on a scale of 1 to 4, with 4 being the most stressful. The segment assessment is based on roadway and traffic characteristics including:

- Number of lanes
- Traffic speed
- Presence and width of on-street parking
- Presence and width of bike lanes
- Volume of ADT

Separated bike lanes and nonmotorized, shared use path segments are automatically scored LTS 1.

The core idea of this methodology is that one factor (speed, traffic volume, type of bicycle facility, etc.) can sway how a bicyclist experiences stress on the facility roadway. For example, a street with a bike lane may rate more stressful than one without if the bike lane street has higher speed traffic or a higher volumes of traffic. Generally, LTS 1 and 2 streets are considered "low stress."

Ratings are generally based on an assumed user who is an "interested but concerned" bicyclist. This person may ride a bicycle more often if there were places to ride with greater separation from traffic, or on routes with shared/separated bicycle facilities with low-speed, low-volume traffic.

The original LTS methodology was developed to assess streets in an urban context. Recognizing that many roadway miles in the state are in rural areas, ODOT modified this method for application on rural roadways. The APM includes guidance on assessing the level of stress for rural roads, as shown in Table 4.

 Table 4. Exhibit 14-11 Rural Segment Criteria with Posted Speeds 45 mph or

 Greater

Daily Volume	Paved Shoulder Width						
(vpd)	0 – <2 ft	2 - <4 ft	4 - <6 ft	≥ 6 ft			
<400	LTS 2	LTS 2	LTS 2	LTS 2			
400 - 1500	LTS 3	LTS 2	LTS 2	LTS 2			
$1500 - 7000^4$	LTS 4	LTS 3	LTS 2	LTS 2			
> 7000	LTS 4	LTS 4	LTS 3	LTS 3			

3.6.1 Existing Study Area Corridor LTS

Based upon LTS criteria for a rural roadway presented above, U.S. 97 rates LTS 3³. In this scoring, the presence of a 6-foot shoulder makes the road more comfortable for bicycling, regardless of adjacent high-speed traffic.

² Maaza C. Mekuria, Ph.D., P.E., PTOE, Peter G. Furth, Ph.D. and Hilary Nixon, Ph.D. Low-Stress Bicycling and Network Connectivity. 2012. Available at: http://transweb.sjsu.edu/project/1005.html

³ Scoring is based on criteria of 15,100 ADT and the presence of a 6-foot shoulder.

However, U.S. 97's LTS characterization may not be appropriate for the anticipated user group of this facility. While some users of a connection between Bend and Lava Butte would be experienced bicyclists completing the entire 30-mile loop ride, it is anticipated that many would be tourists visiting either the Lava Butte site or High Desert Museum. Generally, more people are willing to ride a bike while on vacation than in their daily lives. This means that riders will be less experienced and may also be child bicyclists who would not be comfortable or safe on a highway shoulder. The APM guidance gives some leeway in scoring streets with the LTS methodology, and based on the anticipated users of a Bend-Lava Butte connection, U.S. 97 should score LTS 4, the highest stress level.

The ODOT APM also provides a methodology for assessing Pedestrian Level of Traffic Stress. While it is not anticipated many pedestrians (walker, joggers, etc.) would use the entire length of the corridor because of distance, they may use a portion. The lack of sidewalk along U.S. 97 rates it an automatic Pedestrian Level of Traffic Stress 4, or highest stress.

The provision of a shared use path for both bicyclists and pedestrians along the study area corridor would allow people walking and biking to travel in a low-stress environment. The lack of exposure to high-speed traffic significantly decreases user's level of stress. Furthermore, minimizing the number of crossings with vehicle roads may improve bicyclist and pedestrian comfort and improve safety.

3.7 Crash Analysis

The project team analyzed crash history for U.S. 97 as a roadway segment, as well as two key intersections in the project area. These intersections are the High Desert Museum entrance (MP 145.05) and the Lava Lands Visitor Center entrance (MP 149.48). Because the rates are calculated differently, results for segment crash analysis and intersection crash analysis are presented separately. In each case, rates are compared to the statewide average.

3.7.1 Segment Crash History

The analyzed U.S. 97 segment extends from MP 143.45 to MP 149.57 and was examined between 2011 and 2015 (5 years total). Segment crash rate is calculated based on AADT, as follows:

 $Crashes/MVM = \frac{AADT \ x \ 365 \ x \ Crashes \ x \ Segment \ Length \ in \ Miles}{1,000,000}$

The crash summary and rate calculations for the project area are shown in Table 5.

Table 5. U.S. 97 Segment Crash Analysis, 2011-2015		
Key Measure		
Segment length (miles)	6.12	
Total number of crashes	103	
Crashes by severity (percent)		
Fatal	1	
Serious injury	5	
Moderate injury	24	
Minor injury	20	
Noninjury	50	
AADT (5 Year Average)	15,100	
Vehicle miles (in millions)	169	
Segment crash rate (crashes per million vehicle-miles)	0.61	
Statewide average for "Other Freeways/Expressways (2010-2014)	0.87	
Segment fatal and serious injury crash rate (crashes per 100 million vehicle-miles)	3.56	
Statewide average for "Other Freeways/Expressways (2014 only)	1.49	

0044 0045

Source: HDR Analysis of ODOT crash data

The traffic volume and crash totals for this segment of U.S. 97 translate to a 5-year average segment crash rate of 0.61, which is lower than the statewide average for segments of this type (0.87). The statewide average had not been updated for 2015 at the time of this comparison, so the two rates represent overlapping 5-year periods.

This segment's 5-year fatal and serious injury crash rate was 3.56 (based on 6 fatal and serious injury crashes), which is more than double the 2014 statewide average for segments of this type (1.49). A safety improvement project was recently completed (summer 2016) within the project area that installed median barrier on U.S. 97 between Baker Road and Lava Butte that will reduce serious cross-over crashes.

3.7.2 Intersection Crash History

The project team examined intersection crashes for the two busiest intersections in the corridor: the High Desert Museum intersection (MP 145.05) and the Lava Butte Visitor Center intersection (MP 149.48). The crash information for these intersections is shown in Table 6.

Table 6. U.S. 97 Intersection Crash Analysis, 2011-2015						
	Intersection					
Key Measure	High Desert Museum	Lava Butte Visitor Center				
Crashes within 250 feet of the intersection	9	3				
Estimated traffic (million entering vehicles)	28.3	28.0				
Intersection crash rate (crashes per million entering vehicles)	0.318	0.107				
Statewide 90th percentile intersection crash rate for rural three-leg stop-controlled intersections*	0.475	0.475				

* Statewide rate reported in the Analysis Procedures Manual as of June 2011 (latest available at the time of this publication) Source: HDR Analysis of ODOT crash data

The crash rates for the High Desert Museum and Lava Lands Visitor Center intersections are both lower than the statewide 90th percentile crash rate for similar intersections. No fatal or serious injury crashes occurred at either intersection during the study period.

3.8 Access Management

As U.S. 97 is a limited access facility, there are not many approaches. The approaches consist primarily of USFS forest access roads. Changes to these highway access points would require coordination with the USFS and potentially an environmental process if the modification resulted in an administrative change of use of the forest road. The High Desert Museum is the only private approach in the corridor project area and has channelization for turning movements at the intersection (see Figure 6). The Deschutes River Woods community immediately to the West of U.S. 97 has a gated approach that is only used for emergency egress situations. U.S. 97's nine highway access points in the project area are shown in Figure 11.

Figure 6. High Desert Museum Approach Looking South

4 Future Conditions

4.1 Traffic Volumes and Operational Analysis

4.1.1 Future Volume Development

Future year traffic volumes were developed for the project area consistent with APM procedures. For U.S. 97, the 2035 Future Highway Volume Table was used to develop traffic volumes for the 20-year planning horizon (2036). Growth factors for non-state facilities were calculated using available historical traffic volumes and a Level 1 trending forecast.

4.1.2 No-Build Analysis

Traffic operational analysis for the future year no-build scenario follows *Highway Capacity Manual* 2010 procedures and were performed using Highway Capacity Software 2010 for the U.S. 97 highway segments and Synchro 8.0 for project area intersections. Based on the future year no-build analysis, projected transportation system deficiencies were identified and a predictive safety analysis performed. The operational and predictive safety analysis was consistent with APM analysis procedures. The analysis additionally assessed the approximate year or triggering event for the deficiency to occur.

4.2 Alternatives Analysis

Alternatives developed for the Plan were analyzed using the 20-year planning horizon traffic volumes and analysis procedures discussed in the Future Volume Development section. Volume-to-capacity ratio and LOS metrics were determined for each alternative in an evaluation matrix.

4.2.1 Future Traffic Volumes

ODOT provided traffic count data for U.S. 97, the Baker Road interchange ramps, the High Desert Museum entrance, and the Lava Lands entrance. The project team developed future year traffic volumes for the project area consistent with the ODOT APM procedures, using the previously developed existing year design hour traffic volumes. For U.S. 97, the 2035 Future Highway Volume Table was used to develop traffic volumes for the 20-year planning horizon (2036). An annual growth rate of 2.6 percent per year was used for U.S. 97 and the Baker Road interchange ramps. A marginal growth rate of 1.0 percent per year was used to develop 2036 museum volumes. Future (2036) PM peak design hour traffic volumes within the project area are shown in Figure 7, and peak museum hours are shown in Figure 8.

ODOT traffic data indicated a 2036 (AADT) of 24,800 vehicles on U.S. 97 within the project area, with approximately 13 percent consisting of heavy vehicles (trucks, buses, and recreational vehicles).



Figure 7. Future (2036) Design Hour Traffic Volumes



Figure 8. Future (2036) Peak High Desert Museum Traffic Volumes

4.2.2 Operational Standards

Operational standards used were guided by Table 6 of the 1999 OHP, *Republished* with *all Amendments (May 2015)*. The volume-to-capacity (v/c) ratio is a standard measure of operations and is used in the OHP and the ODOT *Highway Design Manual*. U.S. 97, within the project area (south of Baker Road), is categorized as a Freight Route on a statewide highway and is outside of the UGB. The following OHP mobility targets were used for the future no-build operational analysis:

- U.S. 97 0.70 v/c ratio
- Local roads 0.75 v/c ratio

4.2.3 No-Build Operations Analysis

The future no-build conditions traffic analysis was performed for U.S. 97, the Baker Road southbound on-ramp, the Baker Road northbound off-ramp, and the entrance to the High Desert Museum. In addition to the standard measure of operations (v/c ratio), the LOS scale from A (best) to F (worst) has also been provided. The results of this analysis for the U.S. 97 segment and Baker Road ramps are shown in Table 7.

Description of Segment Location	Segment Type	Traffic Density ¹	LOS	V/C Ratio	
U.S. 97 SE	3				
U.S. 97 merge from Baker Road interchange	Merge	14.8	В	0.40	
U.S. 97 between Baker Road and High Desert Museum	Basic	13.5	В	0.35	
U.S. 97 south of High Desert Museum	Basic	13.5	В	0.35	
U.S. 97 NB					
U.S. 97 diverge to Baker Road interchange	Diverge	13.1	В	0.22	
U.S. 97 between Baker Road and High Desert Museum	Basic	9.8	А	0.26	
U.S. 97 south of High Desert Museum	Basic	9.5	A	0.25	

Table 7. U.S. 97 Segment Future No-Build (2036) Design Hour Operations Analysis

¹ Density = passengers cars per mile per lane (pc/mi/ln).

Source: HDR analysis of ODOT data

During the PM peak hour, the U.S. 97 corridor operates at LOS B or better, and the v/c ratios are well below the OHP mobility target of 0.70. This finding includes the Baker Road southbound on-ramp merge, as well as the Baker Road northbound off-ramp diverge.

The future conditions no-build analysis results for the U.S. 97 and High Desert Museum entrance intersection are provided in Table 8 and include the v/c ratio, average delay, LOS, and 95th percentile queue length for the southbound left-turn movement into the High Desert Museum, as well as the stop controlled left- and right-turn movements exiting the museum onto U.S. 97.

Table 8. High Desert Museum Entrance Intersection Future (2036) Operations Analysis

Time Period	Movement	Volume	V/C Ratio	Average Delay (Sec/Veh)	LOS	95th Percentile Queue (Vehicle)	95th Percentile Queue (Feet)
	SB left	159	0.31	14.5	В	6	150
Peak museum entry	WB left	1	0.04	122.4	F	3	75
(10 – 11 a.m.)	WB right	9	0.02	13.7	В	2	50
Peak museum exit (3 – 4 p.m.)	SB left	17	0.03	11.7	В	3	75
	WB left	28	0.58	141.7	F	4	100
	WB right	154	0.39	18.6	С	11	275
U.S. 97 PM peak (5 – 6 p.m.)	SB left	10	0.02	10.7	В	2	50
	WB left	10	0.17	71.2	F	3	75
	WB right	30	0.07	12.9	В	3	75

Source: HDR analysis of ODOT data

Note: 95th Percentile Queue (feet) assumes 25 feet per vehicle.

As shown, most turning movements into and out of the High Desert Museum are operating below the OHP v/c ratio threshold, indicating an acceptable LOS. However, the westbound left-turning movements exiting the High Desert Museum are operating at LOS F in all three peak periods, with delays exceeding two minutes in the morning and

afternoon peak hours. When the majority of traffic is exiting the museum during the afternoon peak hour, the 95th percentile queue lengths are fairly significant.

By 2038, the westbound left turn exiting the museum to southbound U.S. 97 during the afternoon peak period (3 - 4 p.m.) will have a v/c ratio of 0.75, exceeding the OHP mobility threshold of 0.70 While the volume is relatively low, delays will approach four minutes and traffic will effectively not be able to head south on U.S. 97 without incurring substantial delays.

4.3 Predictive Crash Analysis

The project team analyzed the existing crash history for U.S. 97, the High Desert Museum intersection, and the Lava Lands Visitor Center intersection between 2011 and 2015 (5 years total) and compared rates to the statewide average. The traffic volume and crash totals for this segment of U.S. 97 translated to a 5-year average segment crash rate of 0.61, which is lower than the statewide average for segments of this type (0.87). The fatal and serious injury crash rate was 3.56, which is more than double the statewide average for segments of this type (1.49). The crash rates for the High Desert Museum and Lava Lands Visitor Center intersections were 0.318 and 0.107, respectively, which are lower than the statewide 90th percentile crash rate for similar intersections (0.475).

For the future no-build condition, the *Highway Safety Manual* predictive crash analysis methodology was used to estimate the percent increase in crash frequency based on existing and future traffic volumes. Predictive methods are based on geometric and operational characteristics and do not require observed crash data to derive quantitative safety evaluations. *Highway Safety Manual* predictive crash models for the existing (2016) and future year no-build (2036) condition were developed for U.S. 97, the High Desert Museum intersection, and the Lava Lands Visitor Center intersection. The predictive crash models for U.S. 97 include the entire segment as divided with a median barrier consistent with the safety improvement project that was recently completed (summer 2016) within the project area. That project installed a median barrier on U.S. 97 between Baker Road and Lava Butte, with the exception of in front of the High Desert Museum entrance to allow for turn movements.

By comparing the results of the predictive crash analysis for existing and future year no-build conditions, the estimated percent increase in crash frequency was 2.7 percent per year for U.S. 97 and approximately 3.5 percent per year for the Lava Lands Visitor Center intersection. The predicted annual percent increase in crash frequency on U.S. 97 coincides with the background annual growth in traffic at 2.6 percent. While the crash frequency on U.S. 97 is predicted to increase at a similar rate as the background growth in traffic, the installation of median barrier will reduce serious cross-over crashes.

4.3.1 High Desert Museum Access

The project team analyzed the predictive crash analysis for U.S. 97 at the High Desert Museum intersection. The crash severity and frequency would decrease if access to and from the museum were converted to a grade-separated access (i.e.,undercrossing), or if the access to U.S. 97 was closed entirely and access to the museum was provided via a frontage road. The greatest safety benefit of these modifications comes from eliminating the southbound left turns to and from the High Desert Museum. This would eliminate the potential for high-speed left-turning crashes to and from the highway.

As shown in Table 6, the crash rate (2011-2015) at this intersection is 0.318. The ODOT Analysis Procedures Manual (APM) reports the statewide 90th percentile average crash rate for comparable rural three-legged stop controlled intersections is 0.475 (published in 2011, based on data from 2003-2007). According to the APM, intersections with a crash rate greater than the 90th percentile crash rate for similar facilities are flagged for additional detailed analysis. As such, under current conditions the intersection does not trigger additional investigation for safety enhancements.

Because observed crash data and a state calibration factor are available, the Empirical Bayes (EB) method, documented in the Highway Safety Manual (HSM) (Part C, Appendix A)), is applicable to the existing and forecast conditions in this study. Using the EB method, it is possible to estimate the expected average crash frequency at the site, which can be compared to predicted average crash frequency to estimate the potential for safety improvement under existing conditions as shown in Table 9.

Table 9, the expected average crash frequency at the access is 0.18 crashes per year. The predicted average crash frequency is 0.16 crashes per year. The difference between the EB expected average crash frequency and the predicted average crash frequency is the excess expected average crashes. In this case, the excess expected average crashes are small (0.02), so there are slightly more crashes than predicted at this intersection, however, the number is relatively small and no additional site investigation is required under current conditions.

Future expected average crashes were also estimated using the HSM procedure for forecasting expected average crashes. Under existing conditions the expected average number of crashes per year is 0.18 – approximately 1 crash every 5.5 years. If nothing is done at the intersection, it is forecast that the number of crashes at the intersection will grow by approximately 71 percent to 0.299 expected average crashes per year. The crash frequency could change from approximately 1 crash every 5.5 years to 1 crash every 3 years.

The Federal Highway Administration (FHWA) Crash Modification Factor Clearinghouse (CMF) provides a CMF for converting a three-legged intersection to a grade-separated intersection (0.84). The CMF is for all crashes, all severities, in undefined road types, and does not define whether the intersection is originally stop-controlled or signalized. As such, this CMF only provides an approximation of the benefits of closing U.S. 97 access to and from the High Desert Museum. Applying this CMF shows that there could be an approximate 16-percent reduction in forecast expected average crashes per year to 0.251 expected average crashes per year. With an undercrossing, the crash frequency could decrease from approximately 1 crash every 3 years, to one crash every 4 years, summarized in Table 9.

U.S. 97/High Desert Museum Access	2015 (crashes per year)	2036 (crashes per year)
Predicted Average Crashes Per Year	0.16	NA
Expected Average Crashes Per Year	0.18	0.30
Expected Average Crashes Assuming Grade-Separated Intersection (CMF = 0.84)	1 crash every 5.5 years	1 crash every 3 years

Table 9. Existing and Forecast Expected Average Crashes

4.4 Land and Population

Located between the Cascade Mountains and the high desert plateaus, Deschutes County is an outdoor recreation destination and attracts visitors for major tourist activities, such as golf, skiing, biking, and hiking. From 2000 to 2010, the county's population grew by 3.2 percent, making it one of the fastest growing metropolitan regions in the nation. The current population is approximately 170,600 and is projected to grow to 249,000 by 2035. A population increase of 1.9 percent average annual growth rate is shown in Graph 1.



Graph 1. Projected Population Growth for Deschutes County by UGB

Much of the projected growth is expected to take place in Bend, as shown in Graph 1. The Bend UGB expansion was approved by the Oregon Department of Land Conservation and Development on November 14, 2016. No appeals were filed by December 5, 2016, and the decision is now final and acknowledged. The preferred scenario will provide an additional 245 acres south of China Hat Road and east of U.S. 97, known as "the thumb," and 57 acres in the "southwest" parcel, located south of China Hat Road and west of U.S. 97. These two expansion areas are part of the overall UGB expansion, which is less than 0.5 mile north of the project area, as shown in Figure 9. The proposed zoning for the additional land use consists of commercial, residential, mixed employment, and light industrial. These additional parcels are projected to provide an additional 506 housing units and 1,653 new jobs⁴.

⁴ Table 22, Bend Urbanization Report (August 2016)





4.5 Future System Conditions

This section of the Plan documents the long-term (2036) projected future traffic conditions along the project area and identifies corridor operations based upon an assumption of continued traffic growth and reasonable project area build-out.

The planned infrastructure improvements assume no major transportation improvements to the roadway network with the exception of STIP-funded projects.

A summary of the planned transportation infrastructure improvements within the project area is provided in the following section, along with an assessment of forecast project area traffic growth rates. Traffic operation impacts, as a result of the anticipated traffic growth, are also identified along the roadways and intersections located within the project area.

4.5.1 Planned Transportation Improvements

ODOT identified U.S. 97 from Baker Road to Lava Butte for a refinement plan, which could include a new MUP connection from Baker Road to the Lava Lands Visitor Center. Although there are no identified roadway improvements along U.S. 97 in the refinement plan project area, the "Lava Lands Regional Trail Concept" has been discussed by ODOT and the United States Forest Service. The Lava Lands Regional Trail Concept is comprised of several priority projects identified in the DNFATS, including E1-1 (Paved Multi-Use Trail Connections from SW Bend to Major Destinations), A-3 (Improved Crossings of Cascade Lakes Highway), and D-2 (Bend to Sunriver Path along Conklin Rd/FS41 corridor). The purpose of the Lava Lands Regional Trail Concept is to:

- Complete the Haul Trail, connecting the City of Bend to the Cascade Lakes Welcome Station, by constructing a new Cascade Lakes Scenic Byway undercrossing at Rimrock Trailhead, paving existing Haul Trail gaps (Welcome Station undercrossing to Mammoth Drive), and reconstructing failing trail segments (Mt. Washington Drive to SW Shevlin-Hixon Drive).
- Construct a paved MUP along the study corridor that connects the City of Bend with the Lava Lands Visitor Center in the Newberry National Volcanic Monument, Benham East Day Use recreation area, and the Sunriver community. The proposed path will be Americans with Disability Act-compliant and extend from Baker/Knott Road on the south end of Bend to Lava Lands Visitor Center near the northern Cottonwood Road underpass.
- Provide nonmotorized connections between Cascade Lakes Welcome Station and Sunriver by constructing bicycle facilities along the Conklin Road (NFSR 41) corridor, improving connections to trailheads.
- ODOT will be constructing a variable speed limit project on U.S. 97 to advise drivers on appropriate speeds for the current weather and travel conditions in the study area.
- Improve City of Bend pedestrian and bicycle routes to complete connections between the future U.S. 97 MUP and Haul Trail at SW Reed Market Road.

4.6 Access Management

ODOT's Access Management Program's purpose is to manage the permitting process for proposed access points adjacent to state highways, as well as the process for modifying, relocating, and closing accesses as part of construction projects using the State's Division 51 (Oregon Administrative Rules Chapter 734, Division 51) standards and regulations. The future conditions access management standards followed the procedures outlined in Appendix B.

U.S. 97 is a limited access facility through the project area. The approaches consist primarily of USFS forest access roads. Changes to these access points would require coordination with the USFS and potentially an environmental assessment if the modifications resulted in an administrative change of use of the forest road. No changes to the weigh station approaches are anticipated during this planning horizon (see Figure 10) U.S. 97's nine access points in the project area are shown in Figure 11.



Figure 10. Weigh Station Approach on Southbound US 97



Figure 11. Access Points along U.S. 97

For statewide highways, the rural expressway spacing standard for at-grade intersections is 1 mile (5,280 feet). The spacing standard between an at-grade intersection and interchange ramp in a rural setting is 2 miles. The project area of U.S. 97 is separated by a barrier facility, with the exception of the High Desert Museum entrance; therefore entrances along the opposite direction will not affect the standard access spacing. All intersections and interchanges along the study section of U.S. 97 meet the OHP spacing standard, with the exception of the northbound spacing between the High Desert Museum entrance and FS Road 1801, as well as between FS Road 1801 and the northbound off-ramp at the Baker Road interchange, as shown in Table 10. Currently, no accesses are considered for future closure.

NB							
Roadway Owner	Route (from)	Route (to)	Spacing (Feet)	Minimum Standard Spacing (Feet)			
Deschutes National Forest	Paulina Rd (NB)	Weigh Station pull out	11,208	5,280 ¹			
	Weigh Station pull out	High Desert Museum Entrance (NB)	6,174	5,280 ¹			
Private	High Desert Museum Entrance (NB)	Deschutes National Forest Service Road (NB) FS1801	5,230	5,280 ¹			
Deschutes National Forest	Deschutes National Forest Service Road (NB) FS1801	Baker Road Interchange NB off-ramp	2,133	10,560 ²			
		SB					
Roadway Owner	Route (from)	Route (to)	Spacing (Feet)	Minimum Standard Spacing (Feet)			
Deschutes County	Frank Pennock Lane (SB)	Deschutes National Forest Service Road (SB)	7,172	5,280 ¹			
Deschutes National Forest	Deschutes National Forest Service Road (SB)	Crawford Rd (Lava Lands Entrance)	7,055	5,280 ¹			

Table 10. Access Points and Distances

¹ Distance (feet) between at-grade intersections, OHP, Table 14

² Between at-grade and nearest interchange ramp (C), OHP, Table 19

5 U.S. 97 Bend to Lava Butte Facility Plan

The U.S. 97 Bend to Lava Butte Refinement Plan was developed to provide safe and convenient access to recreational destinations, improve traffic operations along U.S. 97, and provide facilities that will reduce the number and severity of collisions while providing a safe and comfortable bicycle and pedestrian connection from Baker Road Interchange to Lava Lands Visitor Center. Chapter 5 represents the Facility Plan that can be formally adopted by the Oregon Transportation Commission. Section 5.1 considers proposed multiuse pathway concepts and 5.2 discusses trail design consideration and 5.3 evaluates access improvements to the HDM.

5.1 Proposed Multiuse Path Concepts

A significant gap in the regional trail network exists within the project area. The *Deschutes National Forest Alternative Transportation Study* identified an opportunity for an MUP to connect southwest Bend to southern destinations. Closing the 6-mile trail gap will accommodate access to destinations within the project area and provide additional multimodal options for growing demand in bicycle and pedestrian travel.

Three unique MUP concepts were developed using a combination of stakeholder and public input, project goals and objectives, and the existing trail network within proximity of the project area corridor. The three MUP concepts are illustrated in Figure 12 and described in detail below. Opportunities and challenges for each concept are described in Table 11 using a combination of study goals, objectives, and assumptions developed for each concept.

Concept A: The proposed MUP in Concept A aligns entirely on the west side of U.S. 97 from Baker Road to Crawford Road (NF-9702). The alignment would sit within close proximity of an existing Burlington Northern and Santa Fe railroad line on the northern portion of the study corridor. Portions of the proposed alignment would utilize a network of existing unpaved, dirt trails that currently exist on the west side of U.S. 97. The proposed MUP alignment would not directly serve the High Desert Museum unless the potential grade separation would be built at the same time but the alignment would provide direct access to the Lava Land Visitor Center. The MUP would also directly connect to existing and proposed trails at Baker Road and Crawford Road, closing a significant gap in the trail network.

Concept B: This proposed MUP concept aligns entirely on the east side of U.S. 97 from Baker Road to Crawford Road (NF-9702). The northern portion of the Concept B would be within close proximity of U.S. 97 but traverses to the east to utilize Scale House Road south of the High Desert Museum. Portions of the proposed alignment would utilize a network of existing unpaved, dirt trails that currently exist on the east side of U.S. 97. Concept B would provide direct access to the High Desert Museum and Lava Land Visitor Center. The MUP may utilize the Cottonwood Road undercrossing to access the Lava Lands Visitor Center on the west side of U.S. 97. The MUP would also directly connect to existing and proposed trails at Baker Road and Crawford Road, closing a significant gap in the trail network. **Concept C:** This proposed MUP concept would run partially on the west side and partially on the east side of U.S. 97 from Baker Road to Crawford Road (NF-9702). The northern portion of would be within close proximity to an existing Burlington Northern and Santa Fe railroad line. To provide direct access to the High Desert Museum on the east side of U.S. 97, a grade-separated undercrossing within proximity of the High Desert Museum would be needed, connecting to the MUP on the east side of U.S. 97. Portions of the proposed alignment may utilize a network of existing unpaved, dirt trails that currently exist on the both sides of U.S. 97. The proposed MUP alignment would provide direct access to the High Desert Museum and the Lava Land Visitor Center. The MUP would potentially utilize the Cottonwood Road undercrossing with U.S. 97 to access the Lava Lands Visitor Center on the west side of U.S. 97. The MUP would also directly connect to existing and proposed trails at Baker Road and Crawford Road, closing a significant gap in the trail network.



Figure 12. Proposed MUP Concepts

Table 11. Initial Assessment of MUP Concepts

	Concept A – Westside Alignment		Concept B – Eastside Alignment		Concept C – Hybrid Alignment with Undercrossing		
Objective	Opportunities	Challenges	Opportunities	Challenges	Opportunities	Challenges	
Access	 Provides direct and improved access to the Lava Lands Visitors Center Provides direct connection to the existing trail network at Baker Road and Crawford Road 	 Limited access to the High Desert Museum Protected facility may impact rail right-of-way (ROW) 	 Provide safe and convenient access to High Desert Museum and Lava Lands Visitors Center Provides indirect connection via Baker Road 	None at this time	 Provide safe and convenient access to High Desert Museum and Laval Lands Visitors Center Assumes an exclusive undercrossing to provide access to the High Desert Museum Provides indirect connection via Baker Road 	 Protected facility may impact rail ROW 	
Mobility	 Concept will not impact intersection or highway operations Concept will accommodate growth in travel demand for regional trail network 	None at this time	 Concept will not impact intersection or highway operations Concept will accommodate growth in travel demand for regional trail network 	 None at this time 	 Concept will not impact intersection or highway operations Concept will accommodate growth in travel demand for regional trail network 	None at this time	
Safety	 Improves safety by removing active transportation modes from U.S. 97 corridor May reduce the severity and number of collisions on the corridor by establishing exclusive facility 	 May result in additional modal conflicts at locations where the proposed facility intersects with roads 	 Improves safety by removing active transportation modes from U.S. 97 corridor May reduce the severity and number of collisions on the corridor by establishing exclusive facility 	 May introduce additional modal conflicts at the trail connection located at the U.S. 97/Crawford Road interchange May introduce additional modal conflicts along Scale House Road 	 Improves safety by removing active transportation modes from U.S. 97 corridor May reduce the severity and number of collisions on the corridor by establishing exclusive facility Assumes an exclusive undercrossing to provide access to the High Desert Museum 	 May result in additional modal conflicts at the trail connection located at the U.S. 97/Crawford Road interchange 	
Active Transportation	 Introduces comfortable, lower stress active transportation connection Trail design is more direct than other concepts Provides direct connection to the existing trail network 	Limited access to the High Desert Museum	 Introduces comfortable, lower stress active transportation connection Provides comfortable access to High Desert Museum Provides direct connection to the existing trail network 	 Results in out of direction movement between U.S. 97 and Lava Land Visitor Center Trail design is less direct than other concepts 	 Introduces comfortable, lower stress active transportation connection Provides comfortable access to High Desert Museum Provides direct connection to the existing trail network 	Portions of trail meander and are not as direct as other concepts	

5.2 MUP Design Considerations

5.2.1 MUP Design

While the typical minimum recommended width of a MUP is 10 feet, 11-foot-wide pathways are needed to enable a bicyclist to pass another path user going the same direction, at the same time a path user is approaching from the opposite direction, as shown in Figure 13. Functionally, this is identical to a rural highway with a three-lane cross section with two travel lanes in one direction and the third lane going in the opposite direction. If the anticipated number of users at peak usage times exceeds 100 per hour, a wider cross-section should be considered. This ability to ride side-by-side is important for an area like Lava Butte, where many users are likely to be visitors.

If there are areas where environmental barriers (e.g., large boulder, tree that needs to be maintained) are present, it is possible to narrow the pathway to 8 feet in short segments, but these areas should be limited.

Additional space must be provided on both sides of the path between the pathway edge and any fixed vertical objects, such as trees, benches, lights. Three feet of clearance is recommended, with 2 feet an acceptable minimum. A detailed summary of MUP considerations is in Appendix A.

Figure 13. MUP Width and Clearance



(Credit: Federal Highway Administration, Achieving Multimodal Networks).

5.2.2 Surface Material

The MUP is intended to be a hard surface, paved path. This will allow use by all modes, including those in wheeled mobility devices. Designers may consider soft shoulder along one or both sides for runners who often prefer graded, unpaved surfaces to hard surfaces. In some other trail contexts, soft shoulders are also used by equestrians, but it is not anticipated that this trail will serve that user group. The paved surface should include subgrade and base preparation, which contribute to better user experience, facility longevity, and lesser maintenance costs over time.

5.2.3 Grade

Shared MUPs should provide a reasonable grade for all pathway users: pedestrians, bicyclists, users of wheeled mobility devices, in-line skaters, and others. The recommended maximum grade for a pathway is 5 percent. This is likely not an issue along U.S. 97, except at the north access point from Baker Road and at the recommended undercrossing. Grades of less than 0.5 percent should be avoided, as they are not efficient in conveying surface drainage. Cross slope should be approximately 1 percent to aid in drainage. This is recommended instead of providing a trail cross-section with a center crown.

5.2.4 Pavement Markings

A striped center line is not generally recommended for the pathway. It may be desirable to provide one near the spur trail undercrossing to the High Desert Museum to encourage predictable riding/walking/rolling behavior at this possible conflict point. Additionally, if there are trail curves and nighttime or low-light use is anticipated, designers may include edge lines to further delineate the path surface from surrounding unpaved areas.

5.2.5 Undercrossing

Guidance is provided on undercrossing dimensions in ODOT's 2012 *Bicycle and Pedestrian Design Guide*. It calls for a standard recommended height of 10 feet, with a minimum 8 feet. At 8 feet, many trail users feel confined, so the taller height is desirable.

The guide also calls for a width minimum of 14 feet. However, if the MUP is designed at 11 feet wide, it would be desirable to have a 15-foot-wide undercrossing, thus matching the total width of path pavement, plus 2 feet of clearance on either side from objects.

Additionally, the undercrossing should be designed such that users can see through to the other end. This provides both perception of and actual safety with respect to potential crash conflicts between users and feelings of personal safety.

To maintain a grade of 5 percent or less, a minimum of approximately 260 feet of approach is needed to access an undercrossing when the MUP is at the same elevation as the roadway being crossed. It appears the potential undercrossing location to access the High Desert Museum has adequate space between the edge of pavement of U.S. 97 and the rail line to its west to accommodate such an approach. Designers will

need to be conscious of the height of the trail with respect to the roadway surface when choosing the location of an undercrossing.

5.2.6 At-grade Roadway Crossings

There are two potential at-grade roadway crossings along this trail alignment. Both crossings are unpaved and low volume. The northern crossing is access-restricted for emergency vehicles only. At both locations, the paved trail should be continuous across the roadway. This gives trail users a consistent experience and provides visual and physical notice to drivers to expect crossing pedestrians and bicyclists. Trail crossing signage should also be provided for drivers along with "No Motor Vehicles" (Manual on Uniform Traffic Control Devices R5-3) signs restricting access to the trail. This signage, and possibly splitting the pathway on approach to the crossing, is the recommended approach for restricting motor vehicles rather than bollards. Both the American Association of State Highway and Transportation Officials *Guide to the Development of Bicycle Facilities* and the ODOT *Bicycle and Pedestrian Design Guide* discourage the use of bollards as they pose a collision danger to trail users.

It is likely that pathway users will outnumber automobile users of either cross street, so pathway traffic should be given priority and users not required to stop or yield at these crossings.

5.3 Improved HDM Vehicle Access Concepts

The U.S. 97 Bend to Lava Butte Refinement Plan was developed to identify safe and convenient access to recreational destinations, improve traffic operations along U.S. 97, and provide facilities that will reduce the number and severity of collisions, while providing a safe and comfortable bicycle and pedestrian connection from the Baker Road Interchange to HDM. Three unique HDM vehicular access concepts were developed using a combination of project goals, objectives, and the availability of feasible access opportunities to reach the HDM. The three HDM concepts are illustrated in Figure 14 and described in detail below.

Concept A (frontage alignment): This proposed HDM access concept would develop a two-way frontage road entirely on the east side of U.S. 97 from the Baker Road/Knott Road Interchange to the HDM entrance. The proposed frontage access would align within close proximity to the existing U.S. 97 corridor and serve as a frontage road immediately to the east. Portions of the proposed frontage road would utilize the existing Scale House Road near the interchange, then break away to run alongside U.S. 97. The alignment would provide direct access to the HDM to or from Knott Road without crossing U.S. 97.

Concept B (undercrossing/frontage alignment): This proposed HDM access improvement concept would construct a two-way frontage road entirely on the west side of U.S. 97 from the Baker Road/Knott Road Interchange to the HDM entrance. The proposed access would align within close proximity to the existing U.S. 97 corridor and serve as a frontage road immediately to the west. This concept would access the HDM with a grade-separated undercrossing within proximity of the HDM. Concept B would provide direct access to the HDM to or from the Baker Road/Knott Road Interchange.

Concept C (undercrossing/ U.S. 97 alignment): This proposed HDM access concept utilizes U.S. 97 from the Baker Road/Knott Road Interchange to the HDM entrance. This concept improves access to the HDM with a partial interchange for southbound movements (via a grade-separated undercrossing) within proximity of the HDM. Concept C would provide direct access to the HDM to or from U.S. 97 for southbound vehicle movements via ramps, thereby eliminating at-grade left turns into and out of the HDM. Northbound movements would access the facility with right in/right out deceleration and acceleration lanes. The multiuse path (MUP) would be located on the west side of U.S. 97 and also be able to use the undercrossing to access the HDM entrance.



Figure 14.HDM Access Concepts

A typical cross-section for Concepts A and B are displayed in Figure 15. Both concepts assume a frontage road that accommodates both vehicles and bikes. This may rate at a higher level of stress for bicycles according to ODOT's Bicycle Level of Traffic Stress (LTS) methodology as compared to a separated, non-motorized MUP that is assumed in Concept C.





Concept C provides a separate MUP path off U.S. 97 as identified in the U.S. 97: Bend to Lava Butte Refinement Plan that would run along the west side of the highway as shown in Figure 16.



Figure 16. Proposed MUP Trail

(Credit: Federal Highway Administration, Achieving Multimodal Networks).

Concepts B and C would utilize the undercrossing and provide direct access to the museum while not requiring rerouting volumes onto the Baker Road/Knott Road Interchange. They both reduce conflicting movements, therefore making them two of the safest concepts. An example of the undercrossing is shown in Figure 17Figure 17.

Figure 17. Potential Undercrossing Layout



Table 12. Initial Asses	ssment of High Dese	rt Museum Access	s Concepts
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Objective	ve Concept A – Frontage Alignment		Concept B – Under	Concept B – Undercrossing Alignment		Concept C – U.S. 97/Undercrossing Alignment		
Access	 Provides improved access to HDM on the east side of U.S. 97 	 Concept is less direct and limits the convenience of access Would require advanced signing on U.S. 97 	 Assumes an exclusive undercrossing to provide improved access to the HDM using the existing access location to HDM from the Baker Road interchange. Eliminates any out of direction movements to reach the HDM 	 Likely to affect access or circulation for businesses near the interchange. Would require advanced signing on U.S. 97 	 Assumes an exclusive undercrossing to provide improved access to the HDM using the existing access location to HDM from the Baker Road interchange. Eliminates any out of direction movements to reach the HDM 	None at this time		
Mobility	 Concept will improve highway operations by removing conflicting turning movements at the existing HDM access 	Concept will likely impact intersection operations at Scale House Rd/Baker Rd intersection and Baker Rd/US 97 interchange	 Concept will accommodate growth in traffic volumes 	Concept may complicate operations at the Baker Road interchange	 Concept will accommodate growth in traffic volumes Concept will limit impacts to the existing Baker Road interchange 	None at this time		
Traffic Ops	 Concept improves traffic operations on U.S. 97 due to slightly lower volumes and less potential weaving/merging on highway segment 	 Concept will increase volumes on other roads and intersections in proximity to the Baker Road interchange 	 Providing an exclusive undercrossing will improve traffic operations on U.S. 97 by removing conflicting turning movements to access the HDM Concept improves traffic operations on U.S. 97 due to slightly lower volumes and less potential weaving/merging on highway segment 	• None at this time	 Providing an exclusive undercrossing will improve traffic operations on U.S. 97 by removing conflicting turning movements to access the HDM 	Concept could increase volumes weaving or merging onto U.S. 97.		
Safety	• May reduce the severity and number of collisions on the corridor by removing conflicting movements and volumes from the U.S. 97 corridor	 May result in additional modal conflicts at intersection locations along Knott Rd. due to additional turning movements 	 Improves safety by removing additional conflict points on U.S. 97 May reduce the severity and number of collisions on the corridor by establishing exclusive facility Assumes an exclusive undercrossing to provide access to the HDM 	 Could impact crash rates near Baker Road interchange ramp terminals 	 Improves safety by removing conflict points on US 97 May reduce the severity and number of collisions on the corridor by establishing exclusive facility Assumes an exclusive undercrossing to provide access to the HDM 	None at this time		
Right of Way	• Utilize portion of the existing Scale House Rd right of way (ROW)	Concept will require additional ROW and will have more impacts than other concepts	None at this time	 Concept may not accommodate space for potential undercrossing or multi-use path without conflicting with rail ROW Concept will require additional ROW and have more impacts than other concepts 	Concept will require the least amount of additional ROW than other concepts			
Cost	 None at this time 	 May be moderately costly as it requires a new road Cost ranges from \$4.5 to \$5.25 million 	None at this time	 May be most costly because it requires undercrossing improvements Cost ranges from \$8.25 to \$9.0 million 	• May be less costly than other concepts because the road already exists, but would require improvements	Cost ranging from \$2.25 to \$3.75 million for undercrossing		

Based on the qualitative assessment described in Table 12, Concepts B and C result in more opportunities with the fewest constraints. These concepts provide the most direct access to the HDM and the safest route both for vehicles and bicyclists shown in Figure 18.



Figure 18. Concepts C and D - Direct Route

Both concepts provide an exclusive undercrossing, will improve traffic operations on U.S. 97, and provide for future volume growth. They will also improve traffic operations by providing an exclusive undercrossing on U.S. 97. Concept C would improve safety by removing additional conflict points on U.S. 97 and may reduce the severity and number of collisions by establishing an exclusive undercrossing by removing conflicting turning movements (shown in Figure 19).



Figure 19. Concepts B and C – removes conflicting movements

Concept B would be more expensive because it would require a new frontage road, while Concept C would utilize the existing U.S. 97 corridor. Concept B would provide a frontage road with a bike lane on the roadway, while Concept C provides a safe and protected MUP off of the roadway. Concept B would also have the greatest likelihood of railroad ROW conflicts.

Concept C would be the most cost-effective concept and require the least amount of additional ROW. This concept would be less costly than other concepts because the road already exists. The estimated cost for this concept is between \$2.25 and \$3.75 million.

5.4 Refinement Plan Recommendations

The Plan includes a set of initial recommendations based on a combination of analysis, public input, and a thorough understanding of project area challenges and opportunities. The plan includes the following three recommendations:

- 1. MUP: Confirm the need and explore design considerations for an MUP within the project area.
 - a. Conduct land survey work along proposed concept alignments to determine design opportunities and constraints.
 - b. Conduct a ROW assessment along the proposed concept alignments to identify potential ROW impacts.
 - c. Conduct environmental reconnaissance to identify potential environmental impacts of a preferred MUP concept. Mitigation for habitat loss as per ODFW's Habitat Mitigation Policy may be required (OAR 635-415).
 - d. Conduct a formal evaluation of the three MUP concepts using the information gathered in steps a through c above, and use the evaluation measures presented in Table 11 to identify a preferred concept alternative.
 - e. The final alignment location may require Deschutes County land use actions depending on the exact location of and ownership of land underneath the alignment. OAR 660-034-035 also has requirements for parks on forest lands as County zoning is mute on stand-alone trail on land outside public right of way.

Surveying the proposed concept alignments should identify topographic and other physical features, existing roads, access points, and utilities that are design constraints or opportunities for each alignment. ROW should identify private- and government-owned (non-ODOT) properties potentially affected by each alignment. Environmental reconnaissance should review existing environmental data to identify sensitive features potentially impacted by concept alternatives.

Following assessment steps above, the evaluation criteria (see Table 11) may be refined and applied to provide qualitative and, if possible, quantitative assessments of the benefits and drawbacks of each alignment to confirm the need and inform the selection of a preferred alignment.

- 2. U.S. 97 Undercrossing at the HDM access: Evaluate a potential grade-separated undercrossing to connect a potential MUP on both sides of U.S. 97 to provide access to the High Desert Museum.
 - a. Conduct a comprehensive design evaluation to assess the feasibility of a grade-separated undercrossing of U.S. 97. Undercrossing options that could serve either active transportation users only or potentially provide long-term access to the High Desert Museum for all modes, including automobiles and larger vehicles, should be developed and evaluated.
 - b. Monitor on-going ODOT safety and traffic data for increases in serious injury or fatal collisions on the corridor. The segment is currently performing better from a safety perspective than many other segments of U.S. 97, however with increased traffic on U.S. 97 and the High Desert Museum that could change. Access to the High Desert Museum (Figure 20) currently performs adequately and should be monitored regularly for changes in crash type and severity. Similarly, the intersection is currently meeting ODOT standards (.70) for this type of intersection. However, that threshold is projected to be met in 2038, two years beyond the planning horizon of this plan (2036). If growth projections exceed the assumed growth, the need would be justified by policy earlier.



Figure 20. At-grade Intersection at the High Desert Museum

- c. Assessments of site location, constraints, and design concepts sufficient to understand comparative engineering and cost implications (at a conceptual level) should be developed to support a recommendation on an undercrossing alternative.
- d. The future Federal Lands Access Program (FLAP) funding can be used to assess the many cost, impact, and user trade-offs inherent in the environmental and design process.

- e. Evaluation of the options shows Option D: U.S.97/Undercrossing Alignment best meets project objectives and evaluation criteria for the HDM access concepts shown in Table 12. The evaluation can be expanded as greater level of detail of costs and potential impacts is known.
- 3. Baker Road Interchange Area Management Plan (IAMP): Complete an IAMP at the Baker Road interchange.
 - a. The purpose of this Plan was to assess the function of the U.S. 97 corridor between Baker Road and Lava Lands Visitor Center. The study did not conduct a detailed analysis of the Baker Road interchange. The project team received public comments expressing the desire to improve traffic operations and safety at the interchange. The UGB expansion approved in 2016, in conjunction with the potential addition of a trailhead near Baker Road, suggests a future IAMP would help resolve potential transportation conflicts within the interchange. The UGB expansion approved in 2016, in conjunction with the potential addition of a trailhead near Baker Road, suggests a future Interchange Area Management Plan would help resolve potential transportation conflicts within the interchange and identify opportunities to better connect US97 MUP alignments with the local bicycle and pedestrian network.
 - b. This IAMP should also conduct a thorough assessment of land use projections associated with the UGB expansion to determine the likelihood of any resulting impacts to modal operations within the project area and any necessary local transportation system improvements that could help protect the state's interchange investment. The Baker Road interchange area (Figure 21) is expected to change with traffic and land use growth.
 - c. The Deschutes County TSP (2012) also suggested further assessment of the current at-grade rail conflict on Baker Road immediately west of the U.S. 97 SB exit and entrance ramps

Figure 21. Baker Road Interchange Area



Appendix A. Shared Use Path Considerations Memo

Appendix B. Plans and Policies Memo

Appendix C. Qualitative Assessment Memo

Appendix D. Division 415 Fish and Wildlife Habitat Mitigation Policy Appendix E. Technical Memo Deschutes County Comprehensive Plan

Appendix F. Open House Responses