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TECHNICAL MEMORANDUM 2

DATE: May 22, 2023

TO: Project Team

FROM: Eileen Chai, EIT; Kayla Fleskes-Lane, PE; John Bosket, PE | DKS Associates
Rory Renfro | HDR

SUBJECT: US 20 Bend Facility Plan:
Existing Transportation System Conditions

Project #22140-000

This memorandum summarizes existing transportation system conditions for a segment of the US 20 corridor in Bend, Oregon from NE 3rd Street to Powell Butte Highway. This summary is based on field observations collected on October 13, 2022, and analysis of data describing traffic operations, safety, and walking, biking, and transit conditions. A summary of the key findings from this memorandum is provided below, with further information included in the subsequent sections.

The information provided in this memorandum, in combination with *Technical Memorandum #4: Future Conditions Technical Memorandum,* will help provide a baseline understanding of the "No-Build" condition and will be used to identify deficiencies and inform the development of solutions.

SUMMARY OF KEY FINDINGS

EXISTING TRANSPORTATION FACILITIES

- US 20 is a major east-west highway in Oregon, extending from Newport to Ontario. It is classified as a Statewide Highway and is part of the National Highway System. The corridor is also a designated truck, freight, high clearance, and freight reduction review route. In the Bend area, it serves as one of the primary east-west connections across the city.
- The study area extends along US 20 from NE 3rd Street to Powell Butte Highway, approximately 4.3 miles in length.
- Speed limits range from 25 miles per hour to 55 miles per hour.
- Along the study corridor, the typical width of roadway ranges from 45 feet to 75 feet. In general, travel lanes along US 20 are 11 to 12 feet.
- The narrower roadway section west of NE 11th Street features sidewalks that are generally older, narrower, and in worse condition compared to the newer eastern portion.

- Striped, curb-tight bike lanes are present east of NE 11th Street and range between five and seven feet in width. West of NE 11th Street, the bike lanes are between four and six feet in width and are not differently colored.
- East of NE 11th Street, active transportation facilities are wider, and sidewalks intermittently buffered by landscaped buffers. In addition, the bike lane features an earthen toned asphalt that delineates the bike lane from the adjacent general-purpose lanes. The purpose of the earthen tone is to provide additional visual distinction between the bike lane and the motor vehicle travel lanes.
- Outside the Bend urban area, the corridor drops sidewalks and bike lanes and instead features paved shoulders that range between four and six feet wide and graveled shoulders that are between four and 10 feet wide.
- Cascades East Transit (CET) operates fixed route transit service within Bend's urbanized area. CET's Route 7 bus utilizes US 20 within the study area and runs between NE 3rd Street and NE 27th Street along the corridor.

TRAFFIC VOLUMES

- The collected Average Daily Traffic (ADT) volumes along the US 20 study corridor range from nearly 11,000 vehicles per day to 24,000 vehicles per day
- During a typical weekday, traffic peaks sharply in the morning around 7:00 a.m., decreases until around 9:00 a.m., then gradually increases and peaks again at around 4:30 p.m.
- Evening peak traffic volumes are generally 40 percent higher than those in the morning peak.
- Segment 2 (Ne 15th Street to NE Providence Drive) experiences the greatest traffic volumes (around 24,000 vehicles per day), while segment 3 (NE Providence Drive to Powell Butte Highway) experiences the lowest (around 11,000 vehicles per day).

CORRIDOR OPERATIONS ANALYSIS

- Most of the study intersections are able to meet the adopted mobility targets, indicating that congestion is not a major factor for most of the corridor.
  - The signalized intersections of US 20/NE 3rd Street and US 20/NE 8th Street were not able to meet mobility targets. This indicates there is a significant amount of congestion at these study intersections during the peak hour and some form of mitigation may be needed.
  - The stop-controlled north approach of US 20/Dean Swift Road was not able to meet mobility targets, indicating that drivers might be willing to accept shorter gaps in traffic than normal (compared to the Highway Capacity Manual default values) in response to long delays, which could lead to unsafe conditions.
- Using data from Regional Integrated Transportation Information System (RITIS), congestion was determined to occur over multiple hours (rather than a single peak hour) at NE 3rd Street, NE 8th Street, NE Purcell Street, NE 27th Street, and Hamby Road/Ward Road.
- Field observations were conducted in October 2022. Long vehicle queues were observed at NE 3rd Street, NE 8th Street and NE 27th Street. Based on the seasonal peaking of traffic in Bend, traffic operations and queueing under peak summer (30th highest hour) conditions are generally worse than what was observed in October.

ACTIVE TRANSPORTATION

- There are nine marked pedestrian crossing opportunities in the study area, eight of which are within the urban area of Bend.
- The average distance between marked crossings is 1,550 feet within the Bend urban area.
- The average distance between a transit stop and the nearest marked pedestrian crossings is 112 feet and bus stop pairs are predominately associated with marked crossings except between NE 15th Street and NE Purcell Boulevard.
- The City of Bend maintains an extensive bicycle network throughout the urbanized area, including parallel low stress bicycle routes along portions of the local streets. US 20 is identified as part of the low stress bicycle network between NE 11th Street and Larkspur Trail.
- Pedestrian and bicycle facilities along the corridor are high stress (level of traffic stress 3 or 4).
- ODOT's Blueprint for Urban Design (BUD) provides guidance on prioritizing modes within each of the land use contexts. The proposed context for the corridor includes Urban Mix, Commercial, Residential Corridor and Rural Community.

SAFETY ANALYSIS

- Over five-year period from 2016 to 2022, there were 392 crashes within the US 20 study corridor.
- There were three crashes resulting in fatalities and 15 crashes resulting in serious injury reported from 2016-2020. The three fatal injury crashes were classified as intersection crashes and occurred outside the Bend urban area, where vehicle speeds are generally higher. Of the 15 serious injuries crashes, three occurred within Segment 1, seven occurred within Segment 2, and five occurred within Segment 3.
- US 20/Hamby Road had more fatal/serious injury crashes than any other intersection within the study area, however, the crash data was collected prior to the installation of a roundabout at this intersection.
- Crash types vary within the study area, but the majority involved rear-end (33 percent), turning movement (31 percent), and angle (18 percent) collisions.
- During the study period, 24 crashes (six percent) involved people walking and biking, with eight crashes involving a person walking and 16 crashes involving a person biking.
- Two intersections were flagged as safety focus areas in the critical crash rate analysis:
  - US 20/ NE 27th Street: There were 63 reported crashes at this intersection with the majority of the crashes involving rear-end (50 percent) or turning (25 percent) collisions. Contributing factors for many of the crashes were due to drivers failing to avoid vehicle ahead (33 percent) and not yielding the right-of-way (20 percent).
  - US 20/Hamby Road: There were 36 reported crashes at this intersection with the majority of crashes involving angle (56 percent) or turning (30 percent) collisions. However, as mentioned previously, this crash data was collected prior to the installation of a roundabout at this intersection.
- Rear-end, turning, and angle collisions are the most commonly overrepresented crash type at study intersections.
  - At NE 3rd Street, Dean Swift Road, and Erickson Road/Torkelson Road, more rear-end collisions were observed than expected. At NE 4th Street, NE 8th Street, and NE Benson Way, more turning collisions were observed than expected.
- Three segments were flagged as safety focus areas in the segment critical crash rate analysis:

- 3rd Street to 4th Street: There were 10 reported crashes that occurred along the segment. Out of the 10 crashes, 80 percent involved rear-end collisions and 63 percent of the rear-end crashes were due to drivers failing to avoid the vehicle ahead. Note that all 10 crashes were closer to 3rd Street.
- 8th Street to 12th Street: 34 crashes were reported along the segment. Most of the crashes involved rear-end (29 percent), turning (26 percent), or angle (24 percent) collisions. Many of the crashes were due to drivers not yielding the right-of-way (44 percent) and failing to avoid the vehicle ahead (15 percent). It should be noted that most of the crashes occurred west of 12th Street before the median protection.
- Windy Knolls Drive to 27th Street: 13 crashes were reported along the segment, with the majority involving turning (38 percent), rear-end (31 percent), or sideswipe (23 percent) collisions. Of the total crashes, 46 percent were attributed to drivers not yielding the right-of-way.

- Six locations were flagged in the top 10 percent of Safety Priority Index System (SPIS) sites in the state: NE 8th Street, NE 15th Street, NE Dean Swift Road, NE Purcell Boulevard, NE 27th Street and Hamby Road.

STUDY AREA

The US 20 Bend Facility Plan study area extends from NE 3rd Street to Powell Butte Highway (mile point 0.51 to 4.79), as shown in Figure 1. This study will analyze operations at 13 study intersections, including five signal-controlled intersections, one roundabout, and seven two-way stop-controlled (TWSC) intersections. The study corridor will be segmentized into three parts for analysis purposes based on the geographic characteristics as following:

- Segment 1: NE 3rd Street to NE 15th Street
- Segment 2: NE 15th Street to NE Providence Drive (East of NE Benson Way)
- Segment 3: NE Providence Drive to Powell Butte Highway

EXISTING STREET NETWORK

US 20 is a major east-west highway in Oregon, extending from Newport to Ontario. It is classified as a Statewide Highway and is part of the National Highway System. The corridor is also a designated truck, freight, high clearance, and freight reduction review route. In the Bend area, it serves as one of the primary east-west connections across the city. Table 1 lists classifications and characteristics of US 20 and other significant roadways in the study area.

In general, travel lanes along US 20 are 11-12 feet wide. Between NE 3rd Street and NE 11th Street, there is a painted two-way left turn lane (TWLTL), with the exception of raised medians at enhanced pedestrian crossings near NE 6th Street and NE 11th Street. Between NE 11th Street and NE Azure Street (east of NE 15th Street), there are limited access points, and the corridor includes raised medians. There are no raised medians east of Azure Street except approaching the roundabout at Hamby Road.

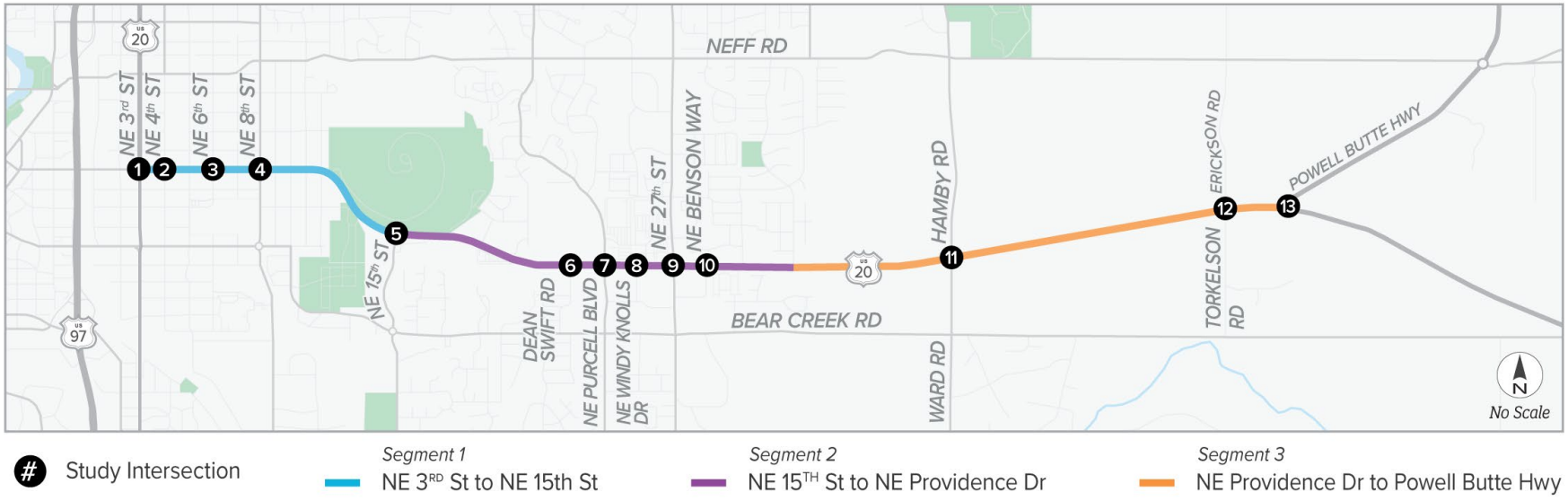

FIGURE 1. STUDY AREA

TABLE 1. STUDY AREA ROADWAY CLASSIFICATIONS AND CHARACTERISTICS

STREET	FUNCTIONAL CLASS[A]	NUMBER OF LANES[B]	POSTED SPEED (MPH)	AADT[C]
US 20	State Highway	4 (2 east of Dalton St)	25 (3rd St to 5th St) 35 (5th St to Providence Dr) 45 (Providence Drive to Hamby Rd) 55 (east of Hamby Rd)	Segment 1: 20,000-30,000 Segment 2: 15,000-20,000 Segment 3: 10,000-15,000
3RD ST	State Highway (N) Major Arterial (S)	4	35	20,000-30,000
4TH ST	Urban Collector	2	25	3,000-6,250
8TH ST	Urban Minor Arterial	2	25 (N)/35 (S)	10,000-15,000
15TH ST	Urban Minor Arterial	2	NP	NA
DEAN SWIFT RD	Local Street	2	NP	NA
PURCELL BLVD	Urban Collector	2	NP	5,000-10,000
27TH ST	Urban Major Arterial	4	35	15,000-20,000
BENSON WAY	Local Street	2	NP	NA
HAMBY RD	Rural Arterial	2	NP	2,500-5,000 1,000-2,500
ERICKSON RD/ TORKELSON RD	Rural Collector	2	NP	NA
POWELL BUTTE HWY	Rural Arterial	2	NP	NA

[A, B, C] Data obtained from ODOT Transgis: https;//gis.odot.state.or.us/transgis/
NP = Speed limit not posted
NA = Information not available

Table 2 lists additional geometric characteristics along the US 20 study corridor. Along the corridor, typical width of the roadway (measured from curb to curb) were obtained as follow:

- Segment 1: The typical roadway width from NE 3rd Street to NE 11th Street is about 65 feet. A raised median was installed from NE 11th Street to NE 15th Street, reducing the curb-to-curb width to approximately 30 feet.
- Segment 2: The median continues from NE 15th Street to NE Azure Drive, reducing the curb-to-curb width to approximately 30 feet. The typical roadway width from NE Azure Drive to NE Providence Drive is nearly 75 feet.
- Segment 3: The typical roadway width along Segment 3 is approximately 45 feet. Approaching the roundabout at Hamby Road/Ward Road, the curb-to-curb width is reduced to approximately 25 feet.

TABLE 2. US 20 ROADWAY GEOMETRY

CROSS STREET	NUMBER OF LANES	SHOULDER TYPE; WIDTH	LANE WIDTH (FT)	MEDIAN TYPE/ WIDTH (FT)
3RD ST – 15TH ST	4	Paved; Left=5ft; Right=5ft	12	3rd St to 8th St: 12ft Painted median lane 15th St: 8ft Barrier
15TH ST – DEAN SWIFT RD	4	Paved; Left=5ft; Right=5ft	12	West of Azure Dr: 8ft Barrier Dean Swift Rd: 12 ft Painted median lane
DEAN SWIFT RD – PURCELL BLVD	4	Paved; Left=6ft; Right=6ft	12	12 ft TWLTL
PURCELL BLVD – WINDY KNOLLS DR	4	Paved; Left=6ft; Right=6ft	11-12	12 ft TWLTL
WINDY KNOLLS DR – BENSON WAY	4	Paved; Left=6ft; Right=6ft	11-12	12 ft TWLTL
BENSON WAY – HAMBY RD (WEST)	2	Paved; Left=6ft; Right=6ft	11-12	NA
HAMBY RD (EAST) – ERICKSON RD/ TORKELSON RD	2	Paved/Gravel; Left=8ft; Right=8ft	12	NA
ERICKSON RD/ TORKELSON RD – POWELL BUTTE HWY	2	Paved/Gravel; Left=9ft; Right=9ft	12	NA

Source: Google map and ODOT Transgis: https;//gis.odot.state.or.us/transgis/

[A] A roundabout was constructed in 2022.

TRAFFIC COUNTS

Turning movement counts were collected on Thursday, October 13th, 2022, during evening peak hours from 4:00 p.m. to 6:00 p.m., including the movements of vehicles, pedestrians, and bicyclists at all study intersections. Average Daily Traffic (ADT) volumes and travel speeds were collected on Thursday October 13th and Thursday October 27th, 2022. Raw traffic counts are included in Appendix A and Appendix B.

The collected ADT volumes along the US 20 study corridor range from nearly 11,000 vehicles per day to 24,000 vehicles per day. Specifically, ADT volumes and 85th percentile speeds recorded for the three segments are:

- Segment 1 (east of NE 6th Street): 22,300 vehicles per day; 34 miles per hour
- Segment 2 (west of Dean Swift Road): 23,800 vehicles per day; 40 miles per hour
- Segment 3 (east of NE Providence Drive): 10,800 vehicles per day; 54 miles per hour

The 85th percentile speeds in Segment 2 and Segment 3 are higher than the posted speed limit (5 miles per hour and 11 miles per hour, respectively). This contributes to higher stress for people walking and biking (discussed in more detail in the *Active Transportation and Transit* section below on page 17).

Figure 2 shows hourly changes in traffic volumes on US 20, based on the 24-hour counts collected in October 2022 for the three segments mentioned above.

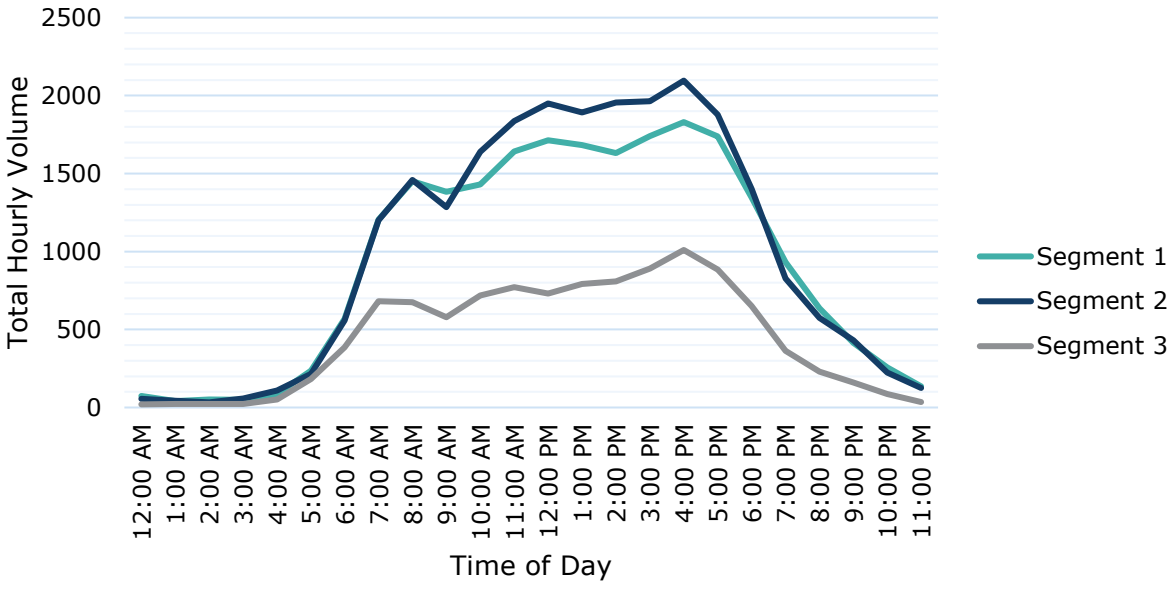

FIGURE 2. AVERAGE WEEKDAY TRAFFIC VOLUME PROFILE BY STUDY SEGMENTS

As shown in Figure 2, traffic peaks sharply in the morning around 7:00 a.m., decreases slightly until around 9:00 a.m., then gradually increases and peaks again between 4:00 p.m. and 5:00 p.m. Evening peak traffic volumes are significantly higher (37 percent) than

those in the morning peak. The peak hour of traffic in the more urban area of the corridor west of the US 20/Hamby Road roundabout generally occurs between 4:30 p.m. to 5:30 p.m., while the peak hour of traffic for the roundabout and intersections to the east occurs from 4:10 p.m. to 5:10 p.m.

Given peak seasonal traffic in Bend typically occurs in the summer and the traffic counts were collected in October, seasonal adjustments were made to the counts to represent the 30th highest annual hour traffic volumes (30HV) for analysis. The collected counts were seasonal factored by 1.14 based on methodology included in the ODOT Analysis Procedures Manual (APM) to obtain the 30HV, as detailed in the *Technical Memorandum #1: Appendix A – Methodology Memorandum*. Figure 3 summarizes existing lane configurations, traffic controls, and the seasonally factored weekday p.m. peak hour turning movement traffic volumes for each study intersection.

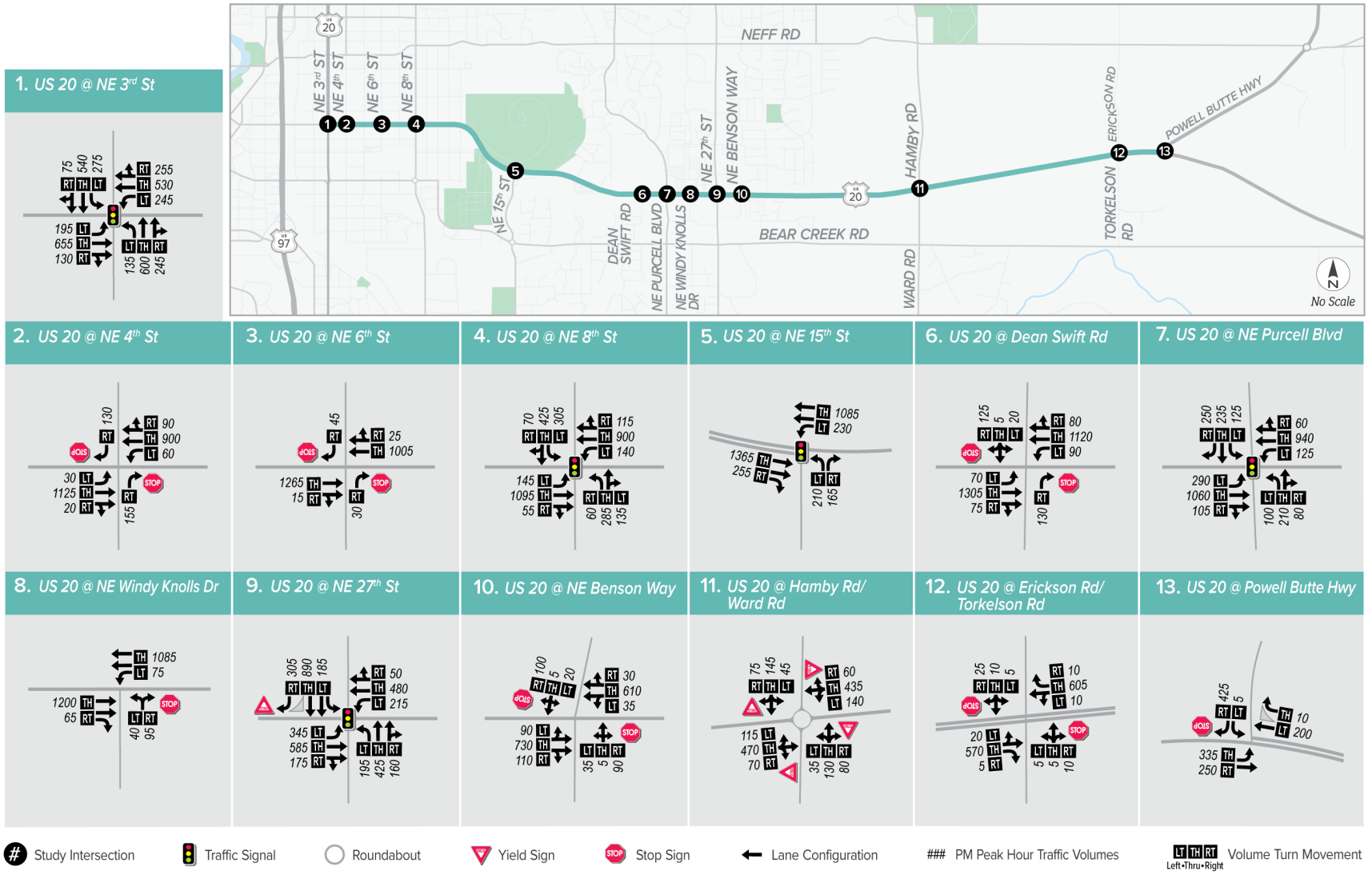

FIGURE 3. EXISTING PM PEAK HOUR (30HV) TRAFFIC VOLUMES

TRAFFIC OPERATIONS

Intersection operations were analyzed using Synchro and Sidra software and the Highway Capacity Manual 6th Edition (HCM 6) methodologies to assess the level of congestion experienced. Performance measures used for this analysis include volume-to-capacity (V/C) ratios, level of services (LOS), and seconds of control delay. Table 3 summarizes the results of this analysis, with each intersection's performance compared to the adopted mobility target[1]. HCM reports are included in Appendix C.

Most of the study intersections are able to meet the adopted mobility targets, indicating that congestion is not a major factor for most of the corridor. US 20/NE 3rd Street, US 20/NE 8th Street, and the stop-controlled north approach of US 20/Dean Swift Road were not able to meet mobility targets. This indicates there is a significant amount of congestion at these study intersections during the peak hour and some form of mitigation may be needed. While the average delay for drivers leaving the north approach of Dean Swift Road is very high, queue lengths observed in the field were not very long. This suggests that drivers might be willing to accept shorter gaps in traffic than normal (compared to the Highway Capacity Manual default values) in response to long delays, which could lead to unsafe conditions.

[1] Mobility targets for ODOT facilities obtained from the 1999 Oregon Highway Plan.

TABLE 3. EXISTING (2022) 30HV INTERSECTION OPERATIONS ANALYSIS SUMMARY

INTERSECTION	CONTROL	MOBILITY TARGET[A] (V/C)	V/C	LOS	DELAY (SEC)
US 20 & 3RD ST	Signalized	0.85	**0.89**	E	68
US 20 & 4TH ST	TWSC	0.85/0.95	0.31/0.38	B/C	12/18
US 20 & 6TH ST	TWSC	0.85/0.95	0.40/0.08	A/C	0/15
US 20 & 8TH ST	Signalized	0.85	**0.98**	E	75
US 20 & 15TH ST	Signalized	0.85	0.71	B	16
US 20 & DEAN SWIFT RD	TWSC	0.85/0.95	0.38/**>2.0**	C/F	15/**>300**
US 20 & PURCELL BLVD	Signalized	0.85	0.82	D	45
US 20 & WINDY KNOLLS DR	TWSC	0.85/0.95	0.34/0.52	B/D	13/32
US 20 & 27TH ST	Signalized	0.85	0.83	D	52
US 20 & BENSON WAY	TWSC	0.85/0.95	0.20/0.83	B/F	10/86
US 20 & HAMBY RD	Roundabout	0.85	0.75	C	15
US 20 & ERICKSON RD/ TORKELSON RD	TWSC	0.70/0.75	0.39/0.11	A/D	9/26
US 20 & POWELL BUTTE HWY	TWSC	0.70/0.75	0.27/0.57	A/D	9/34

Bold and Red indicated failure to meet mobility target (under 30HV operations); TWSC = two-way stop-control

[A] For TWSC intersections, mobility target and results reported as major street/minor street

As a complementary source of information describing traffic operations in the corridor, operating speeds from the Regional Integrated Transportation Information System (RITIS) were obtained to help identify congestion areas. The plots from RITIS are included in Appendix D. The operating speeds obtained from RITIS were averaged per hour for July 2022[2] for every Tuesday, Wednesday, and Thursday, and the speeds compared against the speeds collected from tube count to validate the collected data. Table 4 below presents the 24-hour average speed along the study corridor.

[2] July is the corresponding 30HV period.

TABLE 4. OPERATING SPEED COMPARISON BETWEEN RITIS DATA AND COLLECTED DATA

LOCATION	MEAN SPEED (MILES PER HOUR)		DIFFERENCE
	TUBE COUNT	RITIS	
SEGMENT 1 (EAST OF 6TH ST)	30	30	0%
SEGMENT 2 (WEST OF DEAN SWIFT RD)	35	32	9%
SEGMENT 3 (EAST OF PROVIDENCE DR)	48	49	2%

As shown in the table, differences between both data sets were low (less than 10 percent). Therefore, RITIS congestion[3] scan was then used to help identify areas of congestion over the course of the day, as shown in Appendix D.

Key areas with multiple hours of congestion (rather than a single peak hour) include:

- Eastbound approaching NE 8th Street between 10 a.m. and 6 p.m.
- Eastbound approaching NE 27th Street between 8 a.m. and 6 p.m.
- Westbound approaching NE 3rd Street between 11 a.m. and 5 p.m.
- Westbound approaching NE 27th Street between 11 a.m. and 6 p.m.

VEHICLE QUEUING ANALYSIS

Vehicle queue lengths on intersection approaches in the study area were simulated using SimTraffic. Notable 95th percentile queues that are near (within 50 feet) or beyond the storage capacity are summarized in Table 5. Queuing results for all study intersections within the study area are included in the SimTraffic reports in Appendix C.

TABLE 5. EXISTING (2022) 30 HV INTERSECTION VEHICLE QUEUEING

INTERSECTION	MOVEMENT	95TH PERCENTILE QUEUE (FT)	APPROXIMATE AVAILABLE STORAGE (FT)[A]
US 20 & 3RD ST	EBL	**200**	150
	EBTR	**1025**	300
	WBL	**375**	175 (TWLTL)
	WBTR	**1025**	400
	NBL	**400**	125 (TWLTL)

[3] Congestion is calculated using speed divided by free flow speed. Slight congestion: 75%-85%; Moderate congestion: 65%-75%; Heavy congestion: less than 65%

	NBTR	**1600**	325
	SBL	**375**	175 (TWLTL)
	SBTR	**550**	300
US 20 & 6TH ST	EBT/EBTR	**550**	450
US 20 & 8TH ST	EBL	**425**	125 (TWLTL)
	EBTR	**975**	400
	WBL	**350**	125 (TWLTL)
	WBTR	**600**	275
	NBL	**300**	175
	NBTR	**1700**	300
	SBL	**450**	150 (TWLTL)
	SBTR	**1700**	325
US 20 & 15TH ST	EBR	**300**	200
	WBL	300	350
	NBL	225	225
US 20 & DEAN SWIFT RD	WBL	75	100 (TWLTL)
US 20 & PURCELL BLVD	EBL	**350**	150 (TWLTL)
	WBL	**350**	100 (TWLTL)
	WBTR	**700**	525
US 20 & 27TH ST	EBL	**350**	150 (TWLTL)
	EBTR	**450**	375
	WBL	350	400
	NBL	**300**	275
	SBL	**425**	200
	SBT	**>1200**	425
	SBR	**350**	200
US 20 & POWELL BUTTE HWY	SBR	**125**	100

Bold and red queue exceeds approximate available storage, TWLTL=Two Way Left Turn Lane

[A] Available storage reported as approximate turn bay length or approximate distance to the nearest intersection/railroad crossing.

As shown in Table 5, there are significant queues throughout the study corridor during peak summer (30HV) conditions, including:

- **Segment 1:** Significant queues occur at NE 3rd Street and NE 8th Street during 30HV conditions, spilling back to adjacent intersections on all approaches. Both streets serve as major north-south commuter routes through Bend.
- **Segment 2:** At NE Purcell Boulevard, westbound queues extend beyond NE Windy Knolls Drive but do not extend to 27th Street. At NE 27th Street, long southbound queues extend through the next nearest signal and beyond Forum Drive.
- **Segment 3:** Limited queuing occurs in this segment, with southbound right turns occasionally backing up beyond the striped storage.

The section below describes the queueing observed in the field in more detail. It should be noted the results listed in the table above are likely to show longer queues than what was observed in the field as the traffic volumes used in analysis were seasonally factored to represent 30HV conditions.

In addition to queueing results, travel times along the US 20 corridor were obtained from SimTraffic and compared against data from RITIS to validate the analysis results. The travel times for each of the segments are within 60 seconds or less of the travel times observed in the RITIS data.

TABLE 6. TRAVEL TIME RESULTS

SEGMENT	TRAVEL TIME (MINUTES)					
	EASTBOUND			WESTBOUND		
	MODEL	RITIS	DIFFERENCE (SEC)	MODEL	RITIS	DIFFERENCE (SEC)
1	3.4	2.8	36	3.3	3.2	18
2	3.3	2.5	48	3.3	2.6	42
3	3.5	2.5	60	3.0	2.5	30

FIELD OBSERVATIONS AND OPERATIONS SUMMARY

A detailed description of field observations conducted in October 2022, and a summary of intersection operations is included in the following sections.

SEGMENT 1

At NE 3rd Street, excessive queuing was observed on all approaches during the evening peak hour. On the northbound and southbound approaches, queues spilled back into other intersections, but most vehicles were able to clear the intersection within a single signal cycle. For the eastbound approach, the left turn lane storage length is not able to serve the protected left turn movement efficiently as access to the left turn lane is restricted by a raised median and queue spillback from the through movement. For the westbound

approach, queues also spilled back beyond NE 4th Street, and it was observed that some drivers used the gas station property on the northeast corner of the intersection to bypass the queue.

At NE 4th Street, both northbound and southbound approaches are limited right turns out only. The queue from NE 3rd Street extends through NE 4th Street on the westbound approach. Northbound traffic was generally not affected by the congestion at NE 3rd Street; however, the westbound queue tends to block the intersection and affected the southbound movement. Also, a few (less than five) northbound and southbound through and left movements were observed from the collected counts, which would have been illegal movements.

From NE 5th Street to NE 7th Street, limited queueing was observed. However, this area may be more heavily influenced by traffic peaks associated with the start and end of school, as Bend Senior High School is located nearby south of NE Franklin Avenue. At NE 6th Street, a rectangular rapid-flashing beacon (RRFB) crossing was recently constructed with the northbound and southbound approaches physically restricted to right-in, right-out access only. At NE 8th Street, queues were observed spilling back and blocking NE 7th Street and driveways in between on the eastbound approach, and NE 9th Street and a driveway in between on the westbound approach. Most vehicles on the northbound and southbound approaches were able to be served within a single signal cycle.

At NE 15th Street, westbound and eastbound approaches experience high traffic volumes. Queues were observed but were able to clear within a single signal cycle. The southwest corner has public works and police facilities. Vehicles exiting the facilities and leaving through NE 15th Street were observed during the evening peak hour.

SEGMENT 2

At Dean Swift Road, the northbound approach is restricted for right-out access only by a pork chop island. However, drivers illegally travelling across US 20 to the business on the north side of US 20 were observed. The observed northbound left and through movements might result in some queueing on that approach. The other approaches operated well under capacity during the observation period. Also, two pedestrian crossings were observed near the transit stop at unmarked crosswalks.

At NE Purcell Boulevard, minimal queues were observed at the intersection. The westbound through movement was progressed from NE 27th Street and the queue spilled back to NE Windy Knolls Drive. Also, some unserved queues were observed on the northbound approach. At NE Windy Knolls Drive, some two-stage southbound "through" movements (a right turn followed by an immediate left turn to Windy Knolls Drive) from Mick's Drive were observed. In addition, Mick's Drive provides access to a major shopping mall and many eastbound left turn movements into Mick's Drive were observed during the peak hour (despite an apparent attempt to design this for right turn in access only). The queues from the eastbound left turn movements to Mick's Drive were also observed to block the access to the eastbound left turn storage at NE 27th Street.

At NE 27th Street, minimal queueing was observed on the westbound and eastbound approaches, which appeared to have abundant green time. In addition, some left turn sneakers[4] were observed on the westbound approach. Queueing was minimal for northbound through movements but left turn movements were not fully served in a single signal cycle (around five vehicles generally remained in the queue). On the southbound approach, through movements were queued back through the upstream signal at NE 27th Street/NE Bellevue Drive. Also, southbound through traffic was occasionally disrupted by vehicles slowing to turn right into the gas station on the southwest corner of NE 27th Street. At NE Benson Way, minimal queues were observed, mainly because of the low traffic volume.

SEGMENT 3

At the US 20/Hamby Road roundabout, Erickson Road/ Torkelson Road, and Powell Butte Highway, field observations were obtained before the peak hour. Observed traffic volumes were significantly lower in this portion of the study area and limited delay and queueing was observed.

ACTIVE TRANSPORTATION AND TRANSIT

This section details the existing active transportation and transit facilities and conditions along US 20 within the study area.

CORRIDOR DESCRIPTION AND INVENTORY

US 20 through the study area is approximately 4.3 miles in length, 1.2 miles of which are within an urban context, 1.6 miles within a suburban context and 1.8 miles within a rural context. The western portion of the corridor traverses an established and more traditional grid-based development pattern providing opportunities for parallel routes and relatively high intersection densities. The sidewalk network in this portion of the corridor is predominately complete, with only one parcel between NE 9th Street and NE 10th Street missing sidewalk frontage. The western portion of the corridor features a narrower ROW compared to the segment east of NE 11th Street, which is characterized with more recent development and roadway improvements.

The narrower section of US 20 west of NE 11th Street features sidewalks that are generally older, narrower, and in poorer condition compared to the eastern portion. Conventional, curb-tight bike lanes with red surface application exist east of NE 11th Street and range between five and seven feet in width. West of NE 11th Street, the conventional bike lanes are between four and six feet in width and do not include a colored surface application. Bike

[4] Sneakers are defined as drivers who complete left turns during the clearance and change interval at the end of a permitted phase.

lanes along US 20 remain to the right of combined through/ right-turn lanes (RTL) when approaching intersections. When an exclusive RTL is present at an intersection, the bike lane is positioned to the left of the RTL to reduce turning conflicts.

East of NE 11th Street, active transportation facilities are generally wider, and sidewalks intermittently buffered by landscaped buffers. East of NE 11th Street, the bike lane features an earthen toned asphalt that delineates the bike lane from the adjacent general-purpose lanes. Once the corridor transitions to a rural context east of NE Dalton Street, sidewalks and bike lanes transition to paved shoulders that range between four and six feet wide and graveled shoulders that are between four and 10 feet wide. Figure 4 depicts existing active transportation and transit facilities along US20 and within the surrounding network that connects and crosses the corridor.

The City of Bend has identified key walking and bicycling routes that connect important destinations and offer critical east-west and north-south cross-town travel for people walking and biking. Also, the City proposed bicycle low stress network that allows people biking to comfortably and safely access their destinations. Figures 5 and 6 show the key walking and bicycling routes and low stress bicycling network across the city. While US 20 within the study area is not a key walking and bicycling route, key walking and bicycling routes run parallel to the study corridor on Bear Creek Road and Neff Road. In addition, US 20 is identified as part of the bicycle low stress network between NE 11th Street and Larkspur Trail.

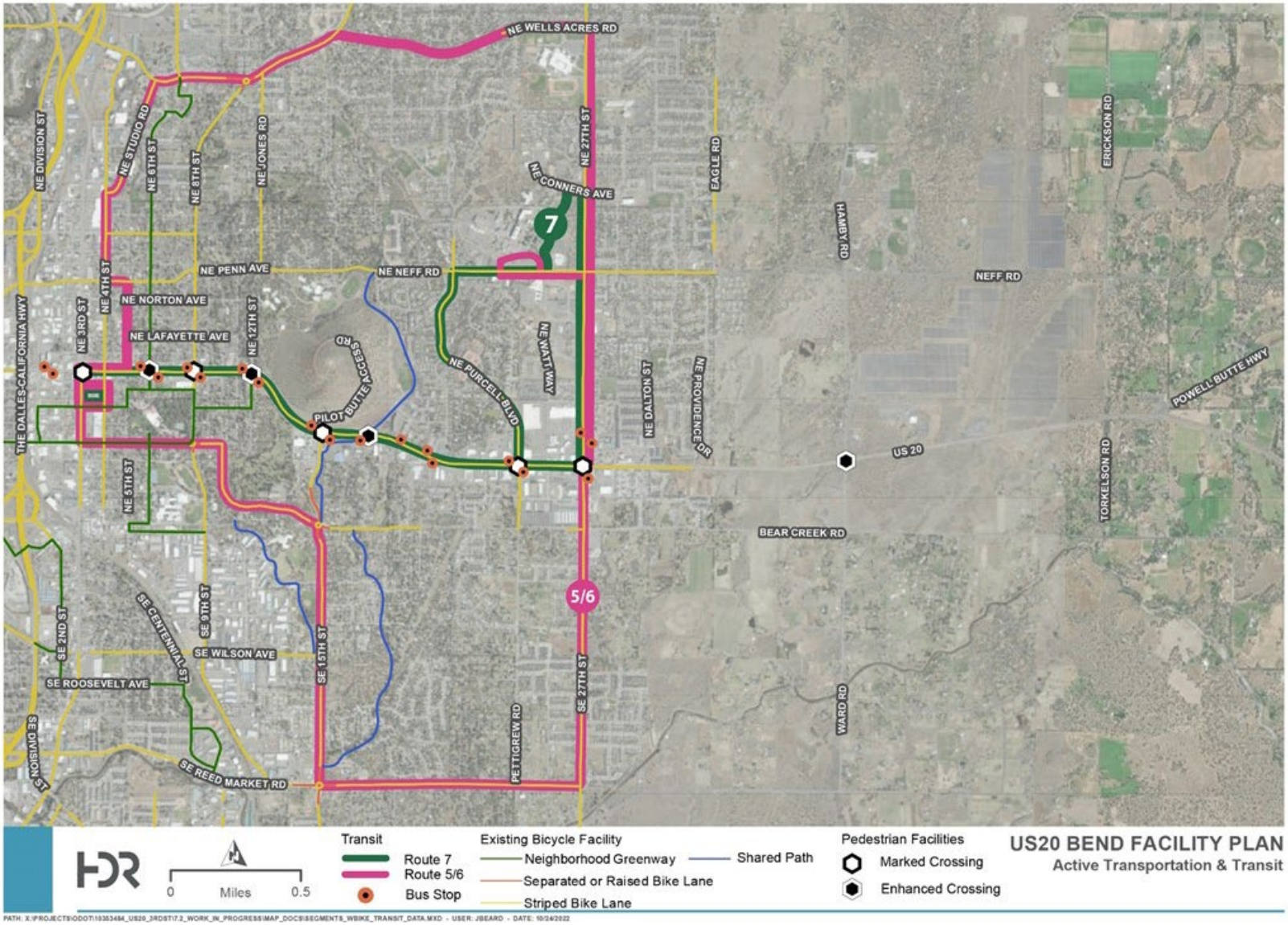

FIGURE 4. ACTIVE TRANSPORTATION AND TRANSIT FACILITIES

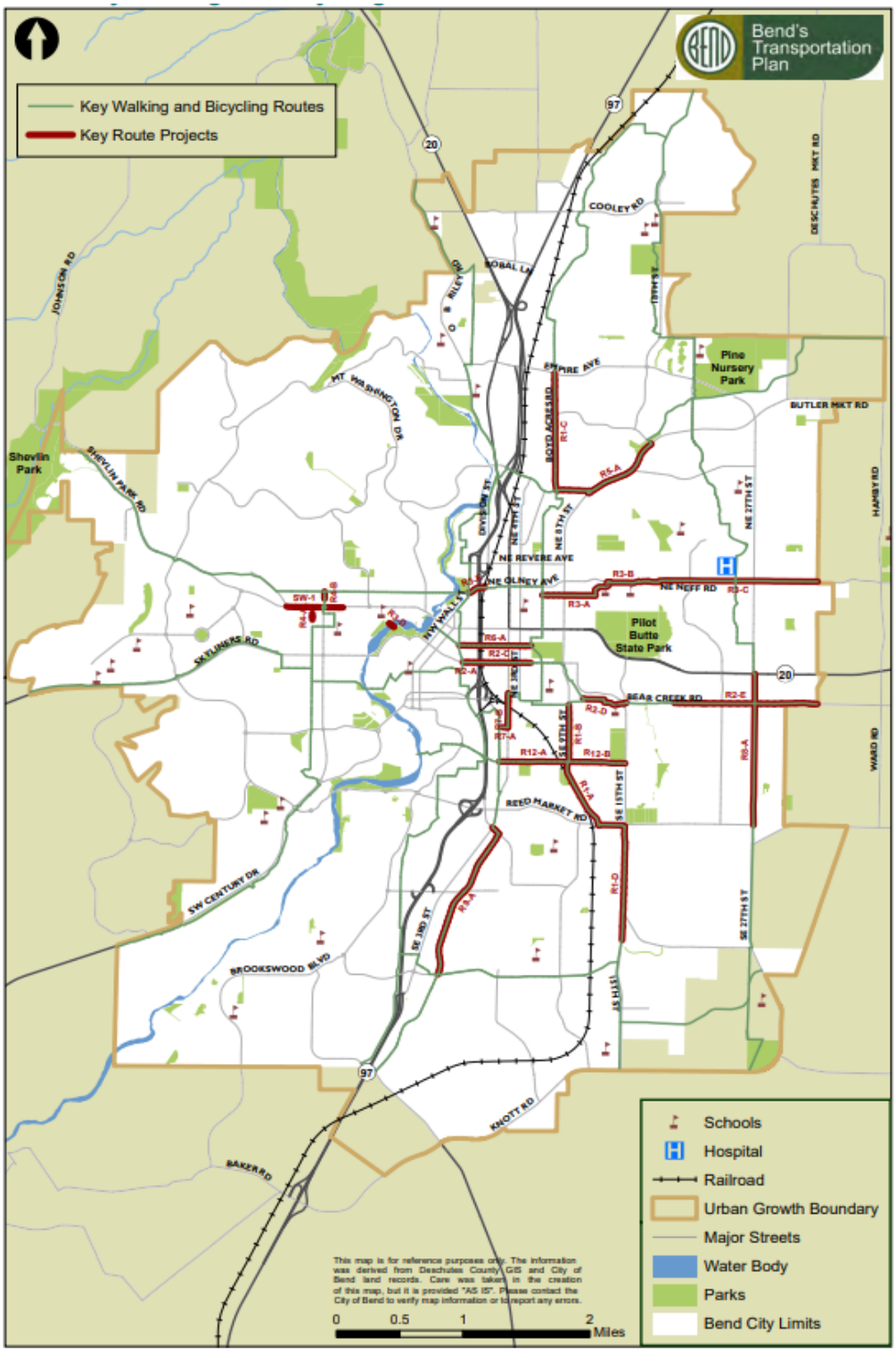

FIGURE 5. CITY OF BEND KEY WALKING AND BICYCLING ROUTES

Source: City of Bend Transportation System Plan

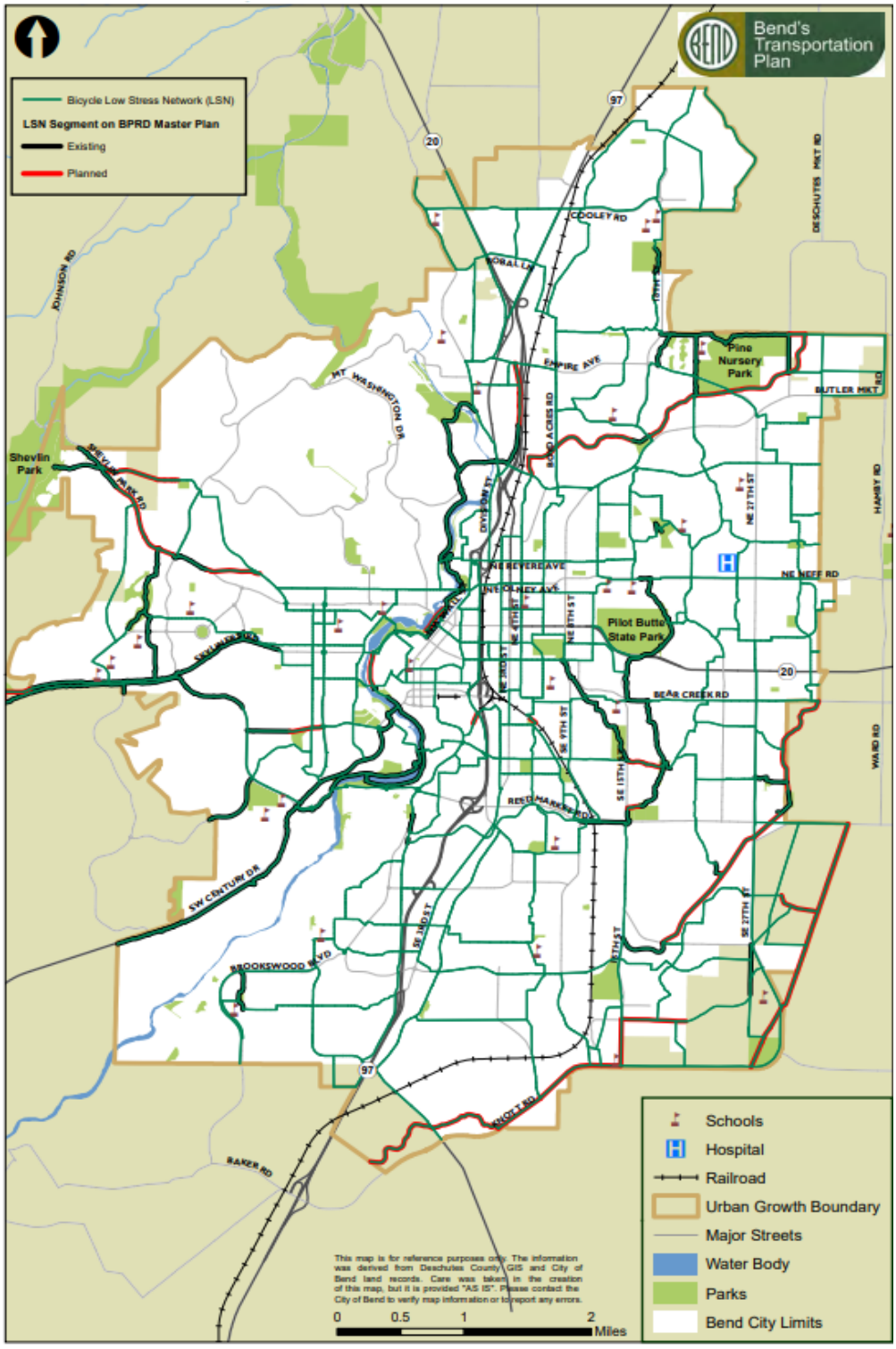

FIGURE 6. CITY OF BEND BICYCLE LOW STRESS NETWORK

Source: City of Bend Transportation System Plan

PEDESTRIAN CROSSING OPPORTUNITIES

Nine marked pedestrian crossings exist along US20 within the study area, eight of which are within the urban area of Bend. Table 7 shows the inventory of marked crossings and associated information.

TABLE 7. CROSSING OPPORTUNITIES

CROSS STREET	CROSSING TYPE	DISTANCE TO LAST CROSSING (FEET)[A]	DISTANCE TO NEXT CROSSING (FEET)[B]	DISTANCE TO NEAREST TRANSIT STOP (FEET)
NE 3RD STREET	Transverse Crosswalk, Signalized	2,044	1,300	440
NE 6TH STREET	High-Visibility Continental Crosswalk, Median, RRFB[C]	1,300	840	20
NE 8TH STREET	Transverse Crosswalk, Signalized	840	1,125	35
NE 12TH STREET	High-Visibility Continental Crosswalk, Median, RRFB	1,125	1,900	120
NE 15TH STREET	Transverse Crosswalk, signalized	1,900	520	40
LARKSPUR TRAIL	Grade-Separated Undercrossing	520	3,450	160
NE PURCELL BOULEVARD	Transverse Crosswalk, Signalized	3,450	1,210	45
NE 27TH STREET	Transverse Crosswalk, Signalized	1,210	5,080	40
HAMBY ROAD	High-Visibility Continental Crosswalk	5,080	N/A	5,055

[A] Distance, in feet, to the nearest marked pedestrian crossing to the west
[B] Distance, in feet, to the nearest marked pedestrian crossing to the east
[C] RRFB = Rectangular Rapid Flashing Beacon

The average distance between marked crossings is approximately 1,550 feet for the corridor's entirety, with the average crossing spacing distance for Segment 1 of approximately1,330 feet, and the average crossing spacing distance for Segment 2 of 1,770 feet. Segment 3's only marked crossings existing within the roundabout at Hamby Road, nearly one mile east of the nearest

marked crossing. The roundabout features high-visibility crossings with medians on each leg. Potential out-of-direction travel for people accessing marked crossings is relatively minimal within Segment 1, where the longest distance a person needs to travel to a marked crossing is approximately 650 feet (about 1.5 blocks). Longer distances between marked crossings in Segment 2 necessitates more out-of-direction travel for people walking, with the longest gap between marked crossings measuring 3,450 feet, thereby requiring a person to potentially walk up to 1,750 feet to access a marked crossing.

TRANSIT SERVICE AND ACCESS

Cascade East Transit (CET) operates fixed route transit service within Bend's urbanized area. CET's Route 7 bus utilizes US 20 within the study area and runs between NE 3rd Street and NE 27th Street. Route 7 connects Bend's eastern neighborhoods adjacent to US20 with the rest of the city through the Hawthorne Station transit center located two blocks south of US20 at the corner of NE 4th Street and NE Hawthorne Avenue. Route 7 operates from 8:00 am to 5:30 pm, Monday through Saturday, with 60-minute headways. As shown in Table 8, most bus stops along the corridor include minimal passenger infrastructure (typically a sign and a small concrete waiting area) and lack features such as shelters and seating. The presence of minimal transit stop infrastructure can present challenges for riders particularly in inclement weather. As most transit stops lack bus pullouts, buses obstruct the adjacent bike lane while serving a stop.

Within the urbanized portion of US 20, marked pedestrian crossings are associated with transit stops, providing direct access to CET service along the corridor. Within the segment of US 20 served by fixed-route transit, the average distance between a transit stop and the nearest marked pedestrian is approximately 112 feet while the longest distance is approximately 1,680 feet for the stop located at Azure Drive. Bus stop pairs are predominately associated with marked crossings in relatively close proximity, except for the segment of US 20 between NE 15th Street and NE Purcell Boulevard.

TABLE 8. EXISTING TRANSIT STOPS ALONG US 20

TRANSIT STOP LOCATION	STUDY AREA SEGMENT	DIRECTION	NEAREST MARKED CROSSING	DISTANCE TO CROSSING (FEET)	AMENITIES
US 20 AT NE 6TH STREET	1	EB	NE 6th Street	20	Signage
US 20 AT NE 9TH STREET	1	EB	NE 8th Street	200	Signage
US 20 AT NE 12TH STREET	1	EB	NE 12th Street	120	Signage
US 20 AT NE 15TH STREET	2	EB	NE 15th Street	50	Signage
US 20 AT LARKSPUR TRAIL	2	EB	Larkspur Trail	160	Signage
US 20 AT NE AZURE DRIVE	2	EB	NE Purcell Boulevard	1,680	Signage
US 20 AT NE PURCELL BOULEVARD	2	EB	NE Purcell Boulevard	45	Signage
US 20 AT NE PURCELL BOULEVARD	2	WB	NE Purcell Boulevard	45	Signage
US 20 AT NE AZURE DRIVE	2	WB	NE Purcell Boulevard	1,800	Signage
US 20 AT NE ARNETT WAY	2	WB	Larkspur Trail	1,090	Signage
US 20 AT NE 15TH STREET	1	WB	NE 15th Street	40	Signage
US 20 AT NE 12TH STREET	1	WB	NE 12th Street	120	Signage
US 20 AT NE 8TH STREET	1	WB	NE 8th Street	35	Signage
US 20 AT NE 6TH STREET	1	WB	NE 6th Street	20	Signage

ADJACENT MULTIMODAL NETWORK

The City of Bend maintains an extensive bicycle network throughout the urbanized area. The neighborhoods adjacent to Segment 1 of US 20 feature a traditional grid-based street network that allows multiple parallel and perpendicular streets designated as On Street Bicycle Facilities in Bend's Transportation System Plan (TSP). Parallel bicycle routes within half a mile of the US 20 corridor include the Hawthorne/Irving Neighborhood Greenway, bicycle lanes along Franklin/10th/Bear Creek and bicycle lanes along Olney/Neff. Outside of Bend, Alfalfa Market Road and Powell Butte Highway are designated County Bikeways by Deschutes County. The roads

feature paved shoulders that vary in width and condition and any signage marking the roads as bikeways is not obviously visible.

Bicycle facilities that cross the US 20 corridor are shown in Table 9.

TABLE 9. LOCAL BICYCLE NETWORK CROSSING US 20

CROSS STREET	SEGMENT	BICYCLE FACILITY	US 20 CROSSING PROVISIONS
NE 4TH STREET	1	Shared Street	None
NE 6TH STREET	1	Shared Street	Signage, Median, Turning restrictions, RRFB
NE 8TH STREET	1	Bicycle Lane	Signalized intersection
NE 12TH STREET	1	Shared Street	Signage, Median, Turning restrictions, RRFB
NE 15TH STREET	2	Bicycle Lane	Signalized intersection
LARKSPUR TRAIL	2	Multi-use Path	Undercrossing
NE PURCELL BOULEVARD	2	Bicycle Lane	Signalized intersection
NE 27TH STREET	2	Bicycle Lane	Signalized intersection
POWELL BUTTE HIGHWAY	3	Paved Shoulder	None

MULTIMODAL LEVEL OF SERVICE

This section describes the existing Multimodal Level of Service along US 20 using ODOT's Level of Traffic Stress (LTS) methodology. LTS measures the relative stress an active transportation user may experience based on adjacent traffic and roadway characteristics. This measure quantifies the perceived safety a person experiences when in close proximity to vehicles, considering spacing distance or speed. Roadways with higher travel speeds, more lanes of traffic, higher volumes and less space between vehicles and active users typically feel more stressful for people walking or biking.

LTS ratings are measured "1" through "4" for both Pedestrian Level of Stress (PLTS) and Bicycle Level of Stress (BLTS), with "1" representing the most comfortable environment for active transportation users, and "4" representing the most stressful conditions. Each rating definition is summarized below from ODOT's Analysis Procedures Manual (APM):

- **LTS 1** – Represents little to no traffic stress and requires little attention to the traffic situation. This is suitable for all users including children 10 years or younger, groups of people and people using a wheeled mobility device (WhMD). Pedestrians feel safe and comfortable and are able to use a sidewalk or shared path. Motor vehicles are either buffered from pedestrians or travel at low speeds. For bicyclists, traffic speeds are low, and intersections are easily crossed by children and adults. Typical locations include residential local streets and separated bike paths/cycle tracks.
- **LTS 2** – Represents little traffic stress but requires more attention to the traffic situation than young children may be capable of. This would be suitable for children over 10, teens and adults. All users should be able to use the facility, but some factors may limit people using WhMDs. Sidewalk conditions should be good with limited areas of fair condition. Roadways may have higher speeds and/or higher volumes. Most users are willing to use this facility. For bicyclists, traffic speeds are slightly higher, but speed differentials are still low, and roadways can be up to three lanes wide for both directions. Intersections are not difficult to cross for most teenagers and adults. Typical locations include collector-level streets with bike lanes or a central business district.
- **LTS 3** – Represents moderate stress and is suitable for adults. An able-bodied adult would feel uncomfortable but safe using the pedestrian facilities. This includes higher speed roadways with smaller buffers. Small areas in the facility may be impassable for a person using a WhMD and/or requires the user to travel on the shoulder/bike lane/street. Some users are willing to use this facility. For bicyclists, intersections are still perceived safe for most adults with typical locations including low-speed arterials with bike lanes or moderate speed non-multilane roadways.
- **LTS 4** – Represents high traffic stress. Only able-bodied adults with limited route choices would use the pedestrian and bicycle facilities. Traffic speeds are moderate to high with narrow or no pedestrian facilities provided. Typical locations include high-speed, multilane roadways with narrow sidewalks and buffers. This also includes facilities with no sidewalk. This could include evident trails next to roads or 'cut through' trails. For bicyclists, intersections can be complex, wide, and or high volume/speed that can be perceived as unsafe by adults and are difficult to cross. Typical locations include high-speed or multilane roadways with narrow or no bike lanes.

The ODOT APM designates target LTS ratings. For bicycles, BLTS 2 is often the target that generally appeals to most potential riders. Near schools, BLTS 1 is desirable for elementary schools while BLTS 2 may be acceptable for roadways in vicinity for middle and high schools. For

pedestrians, PLTS 2 is generally the minimum target for pedestrian routes. Roadways within a quarter-mile of schools should use a target PLTS 1 for elementary schools and PLTS 2 for middle and high schools. Roadways near medical facilities should also have a target of PLTS 1.

Tables 10 and 11 and Figure 7 below present the existing LTS analysis results for the segments and study intersections along US20. The segments within Bend score LTS 3 primarily due the minimal separation between motorized and nonmotorized users, while the rural segment scores an LTS 4 due to the lack of active transportation facilities. PTLS scores for the study area intersections vary, with the majority scoring PLTS 2 or 3. All of the rural intersections score PLTS 4 except for the roundabout at Hamby Road, which scores a PLTS 1. West of NE Purcell Boulevard, the study area intersections along US 20 all score BLTS 1 while to the east, intersection BLTS scores degrade as speeds and crossing distances both increase.

TABLE 10. EXISTING US 20 PEDESTRIAN AND BICYCLE LTS RESULTS – SEGMENT

	STUDY AREA SEGMENT	PLTS	BLTS
1	3rd Street to 15th Street	3	3
2	15th Street to Providence Drive	3	3
3	Providence Drive to Powell Butte Highway	4	4

TABLE 11. EXISTING US 20 PEDESTRIAN AND BICYCLE LTS RESULTS – INTERSECTIONS

INTERSECTION	OVERALL PLTS	MAJOR STREET PLTS	MINOR STREET PLTS	OVERALL BLTS	MAJOR STREET BLTS	MINOR STREET BLTS
NE 3RD STREET	2	2	2	1	1	1
NE 4TH STREET	3	3	2	1	1	1
NE 6TH STREET	3	3	1	1	1	1
NE 8TH STREET	3	3	3	1	1	1
NE 15TH STREET	2	2	2	1	1	1
NE PURCELL BOULEVARD	3	2	3	1	1	1
NE WINDY KNOLLS DRIVE	4	4	2	3	3	1
NE 27TH STREET	2	1	2	1	1	1
NE BENSON WAY	4	4	2	3	3	1
HAMBY ROAD	1	1	1	2	2	2
ERICKSON ROAD	4	4	4	4	4	4
POWELL BUTTE HIGHWAY	4	4	4	4	4	4

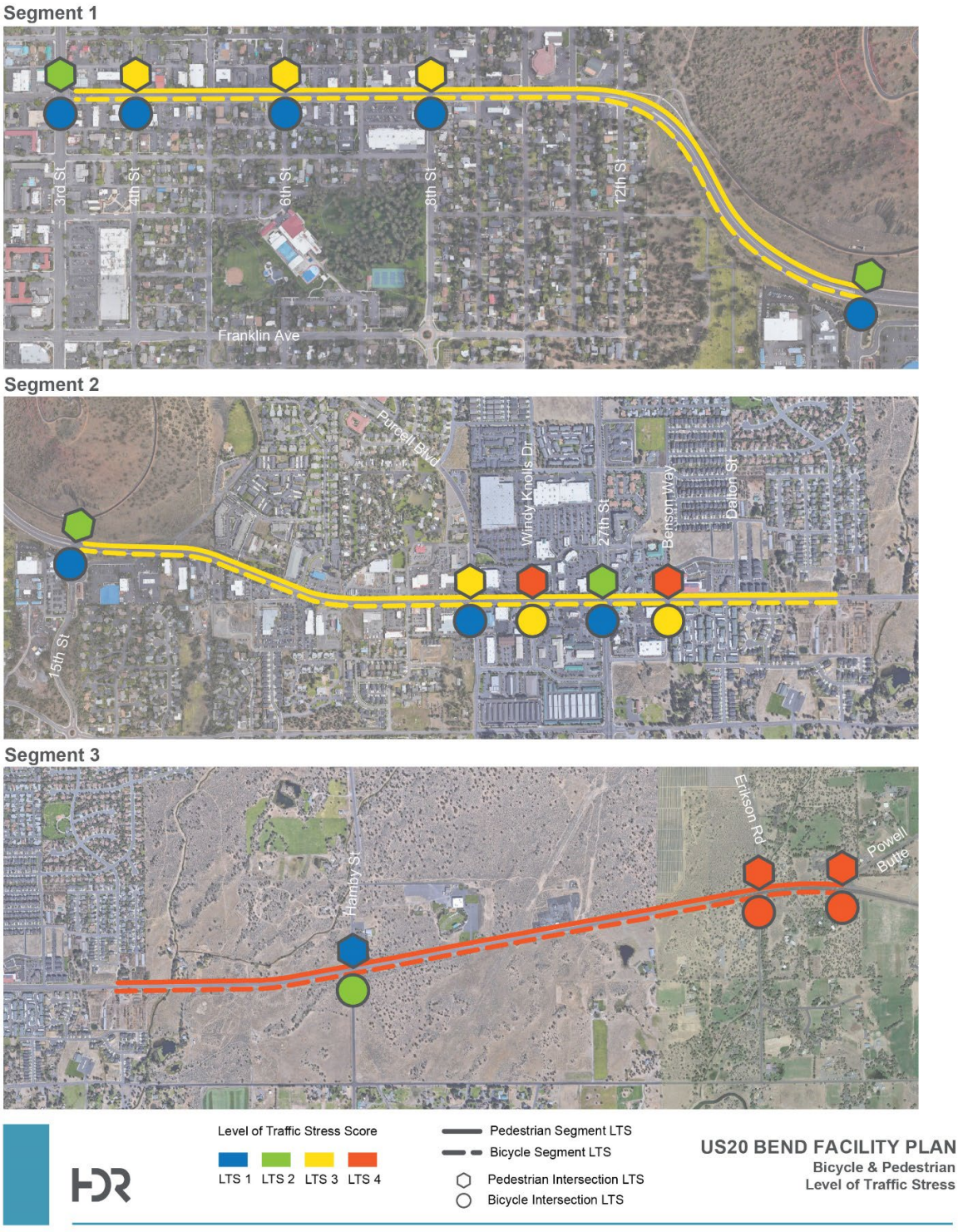

FIGURE 7. SEGMENT AND INTERSECTION EXISTING PEDESTRIAN AND BICYCLE LTS ALONG US 20

BLUEPRINT FOR URBAN DESIGN (BUD) GENERAL GUIDANCE FOR ACTIVE TRANSPORTATION

US 20 traverses several land use contexts that should be taken into consideration when selecting and designing for active transportation and transit access along the corridor. ODOT's Blueprint for Urban Design (BUD) provides guidance on prioritizing modes within each of the land use contexts found within Table 2-3 of the BUD (shown in Table 12). Within the Urban Mix land use context, facilities for pedestrians and bicyclists should be prioritized over other modes of travel. In the Commercial and Residential Corridor context, walking and bicycling modes constitute a medium priority, meaning they are considered, but trade-offs to accommodate other users are more easily allowed.

TABLE 12. BUD MODAL PRIORITIES BY LAND USE CONTEXT

LAND USE CONTEXT	MOTORIST	FREIGHT	TRANSIT	BICYCLIST	PEDESTRIAN
TRADITIONAL DOWNTOWN/CBD	Low	Low	High	High	High
URBAN MIX	Medium	Low	High	High	High
COMMERCIAL CORRIDOR	High	High	High	Medium	Medium
RESIDENTIAL CORRIDOR	Medium	Medium	Low	Medium	Medium
SUBURBAN FRINGE	High	High	Varies	Low	Low
RURAL COMMUNITY	Medium	Medium	Varies	High	High

High: Highest level facility should be considered and prioritized over other modal treatments.

Medium: Design elements should be considered: trade-offs may exist based on desired outcomes and user needs.

Low: Incorporate design elements as space permits.

Source: Blueprint for Urban Design

Table 13 below describes the recommended application of active transportation facilities for each of the land use contexts established for US 20 within the study area. West of 12th Street, the recommended target speed is below 30 miles per hour and the roadway should feature separated bicycle facilities, space for pedestrians and transit stops and optional medians to enhance pedestrian crossing opportunities. Between NE 12th Street and NE Benson Way, target speeds are 30-35 miles per hour while the roadway should feature separated bicycle facilities, continuous buffered sidewalks and medians primarily for access management.

TABLE 13. BUD ACTIVE TRANSPORTATION FACILITY RECOMMENDATIONS FOR US 20

LAND USE CONTEXT	SECTION	TARGET SPEED (MPH)	BICYCLE FACILITY	SIDEWALK	MEDIAN	CROSSING SPACING (FEET)
URBAN MIX	3rd St to 12th St	25-30	Consider Separated Facility	Space for sidewalk cafes or transit shelters	Optional, use for pedestrian crossing refuge	250-550
COMMERCIAL CORRIDOR	12th St to Benson Wy	30-35	Consider Separated Facility	Continuous and buffered sidewalk	Typical, use for safety/ operations management	500-1,000
RESIDENTIAL CORRIDOR	Benson Wy to Providence Dr	30-35	Consider Separated Facility	Continuous and buffered sidewalk	Optional, use for pedestrian crossing refuge	500-1,000
RURAL COMMUNITY	Providence Dr to Powell Butte Hwy	25-35	Consider Separated Facility	Continuous and buffered sidewalk	Optional, use for pedestrian crossing refuge	250-750

SAFETY ANALYSIS

Crash data from the most recent five-year period available (2016-2020) was obtained from ODOT's Crash Analysis and Reporting unit for study intersections and segments. Critical crash rates were calculated and used to flag intersections and segments within the study area. If an intersection or segment was flagged as a safety focus area, details on location, crash type, severity and other crash characteristics were used to identify crash patterns and discuss potential countermeasures.

CRASH TRENDS

Tables 14 and 15 present the intersection and segment crashes within the study area by severity from 2016 to 2020. Over the five-year period analyzed, there were 392 crashes within the US 20 study corridor. Of these, 292 (74 percent) were occurred at the study intersections and 100 were segment crashes between the intersections. Three fatal injury crashes were recorded, with all crashes classified as intersection crashes and located within Segment 3, outside the Bend urban area. US 20/Hamby Road had more fatal/serious injury crashes than any other intersection within

the study area. However, this data was collected prior to the implementation of a roundabout. ODOT recently implemented a roundabout to mitigate this problem.

TABLE 14. INTERSECTION CRASHES BY SEVERITY (2016-2020)

INTERSECTION	PDO[A]	POSSIBLE INJURY	MINOR INJURY	SERIOUS INJURY	FATAL INJURY	TOTAL
US 20 & 3RD ST	26	13	8	1	0	48
US 20 & 4TH ST	5	1	2	0	0	8
US 20 & 6TH ST	1	2	2	0	0	5
US 20 & 8TH ST	18	14	9	2	0	43
US 20 & 15TH ST	8	5	1	2	0	16
US 20 & DEAN SWIFT RD	4	11	2	2	0	19
US 20 & PURCELL BLVD	13	5	1	1	0	20
US 20 & WINDY KNOLLS DR	4	3	1	0	0	8
US 20 & 27TH ST	28	28	6	1	0	63
US 20 & BENSON WAY	5	4	1	0	0	10
US 20 & HAMBY RD[B]	8	10	13	3	2	36
US 20 & ERICKSON RD/ TORKELSON RD	3	5	2	1	0	11
US 20 & POWELL BUTTE HWY	2	1	1	0	1	5
TOTAL	**125**	**102**	**49**	**13**	**3**	**292**

[A] Property Damage Only (PDO)

[B] Data collected prior to the construction of roundabout.

TABLE 15. SEGMENT CRASHES BY SEVERITY (2016-2022)

SEGMENT	PDO[A]	POSSIBLE INJURY	MINOR INJURY	SERIOUS INJURY	FATAL INJURY	TOTAL
3RD ST – 4TH ST	1	1	0	0	0	2
4TH ST – 6TH ST	4	1	2	0	0	7
6TH ST – 8TH ST	3	3	0	0	0	6
8TH ST – 15TH ST	14	15	3	0	0	32
15TH ST – DEAN SWIFT RD	5	10	7	1	0	23
DEAN SWIFT RD – PURCELL BLVD	3	0	0	0	0	3
PURCELL BLVD – WINDY KNOLLS DR	1	2	0	0	0	3
WINDY KNOLLS DR – 27TH ST	4	2	0	0	0	6
27TH ST – BENSON WY	1	0	0	0	0	1
BENSON WY – HAMBY RD	6	2	2	1	0	11
HAMBY RD – ERICKSON RD/ TORKELSON RD[B]	4	1	0	0	0	5
ERICKSON RD/ TORKELSON RD – POWELL BUTTE HWY	1	0	0	0	0	1
TOTAL	**47**	**37**	**14**	**2**	**0**	**100**

[A] Property Damage Only (PDO)

[B] Data collected prior to the construction of roundabout.

Figure 8 shows the overall crash severities within the study area, combining the findings in Tables 14 and 15 for intersections and segments. Most crashes along the corridor resulted in property damage only or possible injuries.

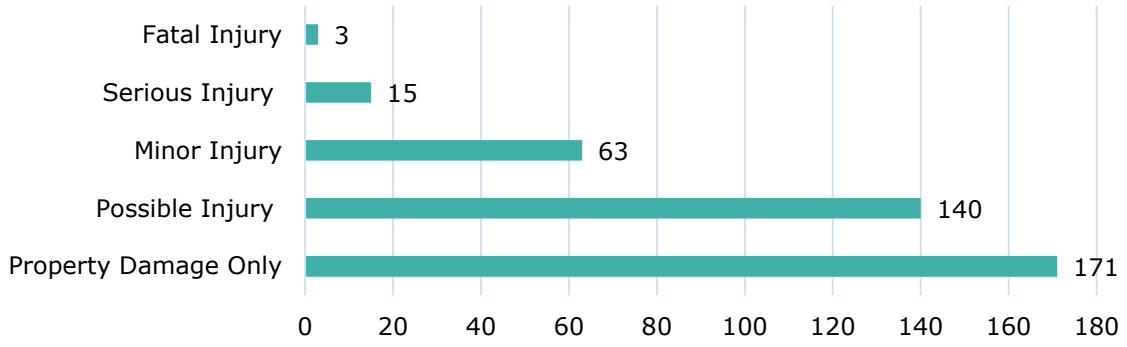

FIGURE 8. CRASH SEVERITIES WITHIN THE STUDY AREA (2016-2020)

Crashes around the study area with fatal and serious injuries are mapped in Figure 7. Note that Figure 9 shows fatal and serious injuries crashes outside of the study corridor but the discussion below focuses only on the crashes along the US 20 study corridor. There were three crashes resulting in fatalities and 15 crashes resulting in serious injury reported from 2016-2020 along US 20. The three fatal crashes along the study corridor occurred at:

- US 20/Powell Butte Highway in 2020
- US 20/Hamby Road in 2017 and 2018, prior to the construction of the roundabout

Of the three fatal crashes:

- All three fatal crashes occurred during daytime.
- Two of the crashes happened under clear conditions and one happened under rainy condition.
- As previously mentioned, all three crashes occurred outside the Bend urban area, where speeds are generally higher.
- The causes of the crashes were due to drivers not yielding the right-of-way or failing to avoid a non-motorist.

Of the 15 serious injuries crashes:

- Three occurred along Segment 1. All crashes happened under clear, daylit conditions. The crashes were due to drivers who did not yield the right-of-way and reckless driving. One crash was involved people biking at NE 8th Street.
- Seven occurred along Segment 2. All crashes occurred under clear, daylit conditions Causes of the crashes include careless driving, drivers did not yield the right-of-way, and drivers disregarding traffic signal.
- Five occurred along Segment 3. Three of the crashes occurred at US 20/Hamby Road, prior to the construction of roundabout. Three crashes occurred during daytime and two occurred during nighttime. One crash occurred under cloudy conditions and the rest occurred under clear conditions. Causes of the crashes were due to improper driving behavior, drivers not yielding the right-of-way, drivers not paying attention, and failure to avoid non-motorists.
- Two of the crashes involved alcohol, two crashes were related to distracted drivers and none of the crashes were related to speeding.

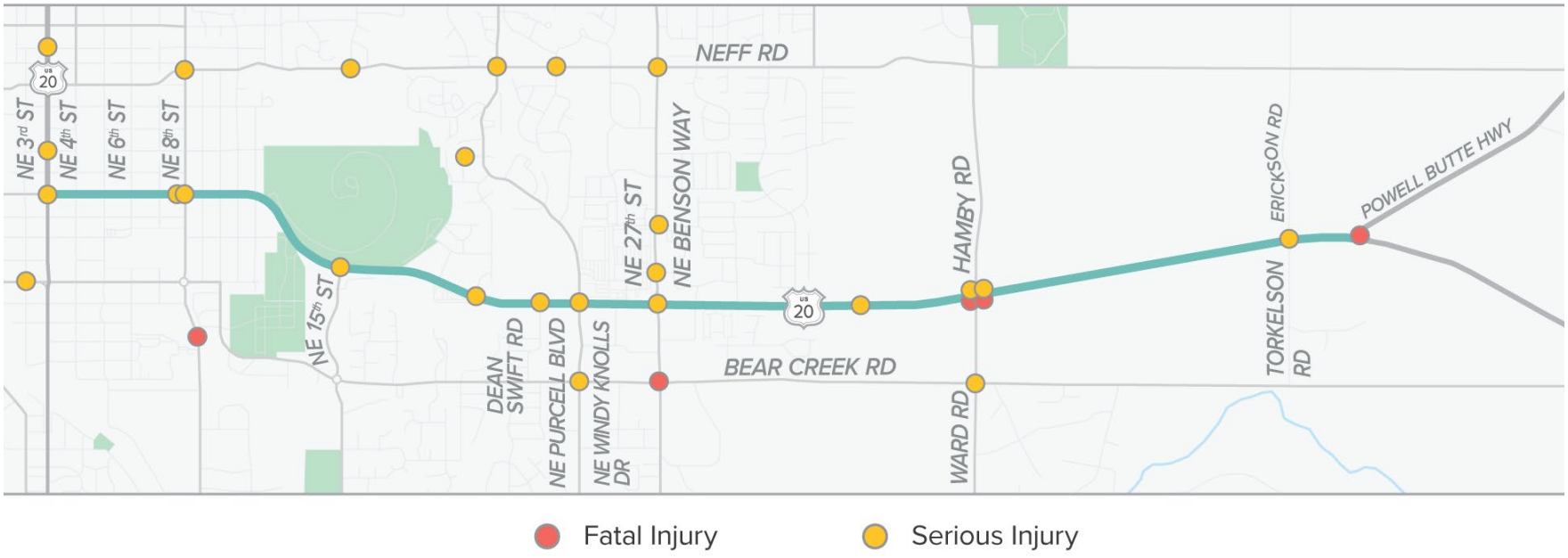

FIGURE 9. FATAL AND SERIOUS INJURIES CRASHES WITHIN THE STUDY AREA (2016-2020)

Crash types vary within the study area, but the majority involved rear-end (33 percent), turning movement (31 percent), and angle (18 percent) collisions, as shown in Figure 10.

- Almost 80 percent of the turning movement crashes were due to driver failing to yield the right-of-way. The remaining turning crashes were mainly due to the driver disregarding traffic signal, performing an improper turn, and passing a stop sign.
- Over half of the angle crashes were cause by the driver failing to yield the right-of-way. The rest of the angle crashes were caused by drivers disregarding traffic signal and passing stop sign.

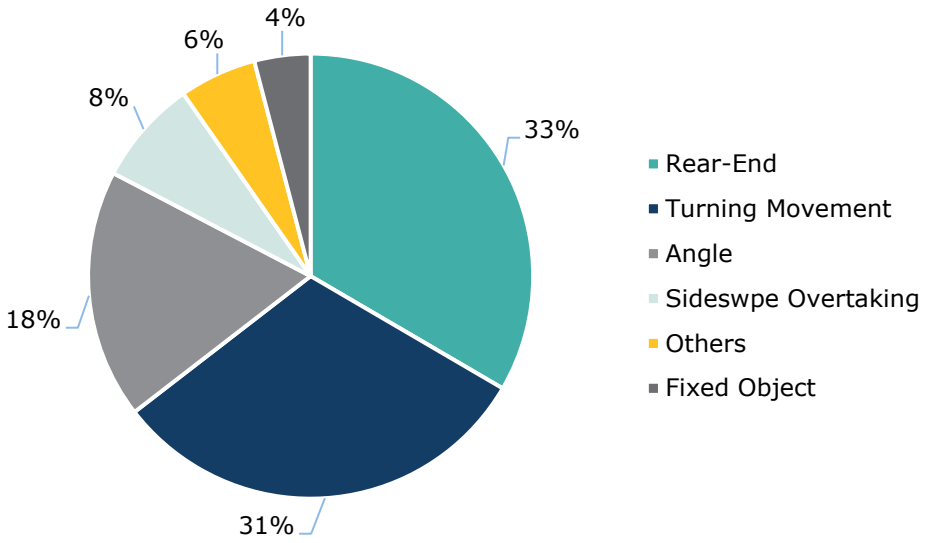

FIGURE 10. CRASH TYPES WITHIN THE STUDY AREA (2016-2020)

Of the 392 crashes, 80 percent of the crashes occurred during daylight condition while five percent (19 crashes) occurred during nighttime. Of the nighttime crashes, 10 percent occurred along Segment 1, 26 percent occurred along Segment 2, and 63 percent occurred along Segment 3.

Pedestrian crashes occurred throughout the US 20 study corridor, both at study intersections and along segments, as show in Figure 11. During the study period, there were 24 crashes (six percent) involving people walking and biking, with eight crashes where a person walking was involved and 16 crashes where a person biking was involved.

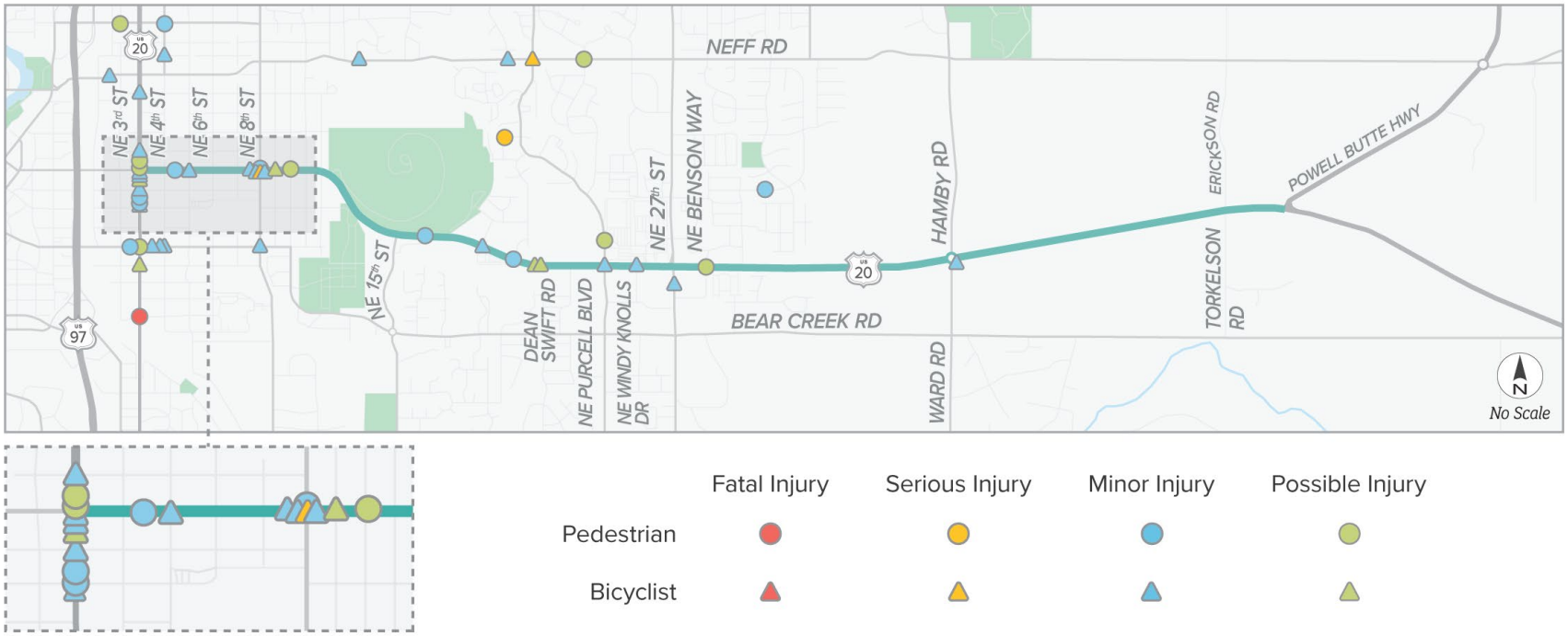

FIGURE 11. PEDESTRIAN AND BICYCLE CRASHES WITHIN THE STUDY AREA (2016-2020)

Of the eight reported pedestrian crashes on the study corridor:

- All the pedestrian crashes occurred within the Bend urban area, with five occurring along Segment 1 and three occurring along Segment 2.
- Along Segment 1, two crashes occurred at signalized intersections with marked crosswalks (NE 3rd Street and NE 8th Street) and three crashes occurred midblock and unmarked crossings (between NE 4th Street and NE 5th Street, north of NE 3rd Street, and between NE 10th Street and NE 11th Street).
- Along Segment 2, two crashes occurred at unsignalized intersection without marked crosswalks (NE Azure Drive and NE Benson Way) and one crash occurred at road segment east of NE 15th Street.
- Four of the crashes resulted in possible injuries and four resulted in minor injuries.
- Three of the crashes were due to driver not yielding the right-of-way with the other contributing factors including driver disregarding a traffic signal indication, non-motorist illegally in the roadway, and other improper driving behavior.
- Six of the pedestrian crashes occurred during clear conditions, one during rainy condition and one during cloudy condition.
- Time of day and lighting conditions varied across pedestrian crashes, with five crashes occurring during daylight, two occurring at dawn, and one occurring at night.

Of the 16 bicycle crashes:

- 10 bicycle crashes occurred along Segment 1, five crashes occurred along Segment 2, and one occurred along Segment 3. The one crash within Segment 3 occurred at Hamby Road, prior to the construction of roundabout.
- 11 crashes were flagged as intersection crashes, with six occurring at intersections with marked crosswalks and five occurring at intersections without marked crosswalk.
- Five crashes occurred around NE 8th Street, where it should be noted NE 8th Street is an access to Bend Swim Club, Juniper Park, and Bend Senior Highschool on the south.
- 11 crashes (69 percent) resulted in minor injury, four crashes (25 percent) resulted in possible injury, and one crash resulted in serious injury. The serious injury crash occurred at NE 8th Street.
- Nine crashes (56 percent) were due to drivers that did not yield the right-of-way, two crashes were due to a non-motorist illegally in the roadway, two crashes were due to driver disregarding a traffic signal indication. Other contributing factors include careless driving, driver failed to avoid non-motorist, and other improper driving behavior.
- Most of the bicycle crashes occurred during clear conditions, where three of the crashes occurred during cloudy conditions, one occurred during smoky, and one occurred during snowy conditions.
- Time of the day and lighting condition varied across the crashes, with most occurring during daylight and one occurring at night.

CRASH RATE ANALYSIS

Crash rate analysis was completed for each study intersection and segments within the study area, with the results compared to rates observed at similar facilities across the state to identify where the frequency of crashes occurring may be higher than would be expected. Intersections and segments were flagged as safety focus locations if observed crash rates surpassed the accepted rates described below.

INTERSECTION CRITICAL CRASH RATE

The observed crash rate for intersections is a function of the number of crashes and the annual average daily traffic (AADT). Each intersection is grouped into a reference population based on intersection control type and urban or rural area classification. The crash rates (crashes per million entering vehicles) for each intersection were compared to the 90th percentile crash rate[5] which is based on similar intersections throughout the state (obtained from ODOT's Analysis Procedures Manual Exhibit 4-1). Full calculations are provided in Appendix E. Table 16 shows these crash rates for study intersections where crashes were reported. Intersections that had observed crash rates greater than the 90th percentile crash rate were flagged as safety focus areas for further considerations.

The following two intersections were flagged as safety focus areas:

- **US 20/ NE 27th Street:** There were 63 reported crashes at this intersection with the majority of the crashes involving rear-end (50 percent) or turning (25 percent) collisions. Contributing factors for many of the crashes were due to drivers failing to avoid the vehicle ahead (33 percent) and not yielding the right-of-way (20 percent).
- **US 20/Hamby Road:** There were 36 reported crashes at this intersection with the majority of crashes involving angle (56 percent) or turning (30 percent) collisions. However, as mentioned previously, this crash data was collected prior to the installation of the roundabout at the intersection.

[5] A critical crash rate which compares performance to other similar intersections in the study area was not used for this analysis as there were not enough similar study intersections on the corridor to calculate a reference rate.

TABLE 16. INTERSECTION CRASH RATES (2016-2020)

CROSS STREET	FLAGGED AS SAFETY FOCUS AREA	OBSERVED CRASH RATE	90TH PERCENTILE RATE
3RD STREET	-	0.68	0.86
4TH STREET	-	0.17	0.41
6TH STREET[A]	-	0.11	0.41
8TH STREET	-	0.64	0.86
15TH STREET	-	0.27	0.41
DEAN SWIFT ROAD	-	0.35	0.41
PURCELL BOULEVARD	-	0.31	0.86
WINDY KNOLLS DRIVE	-	0.17	0.29
27TH STREET	Yes	**0.88**	0.86
BENSON WAY	-	0.30	0.41
HAMBY ROAD[B]	Yes	**1.08**	1.08
ERICKSON ROAD/ TORKELSON ROAD	-	0.46	1.08
POWELL BUTTE HIGHWAY	-	0.22	0.48

Bold and red observed crash rate meet or exceeds 90th percentile rate

[A] Data collected prior to the construction of raised median and RRFB pedestrian crossing.

[B] Data collected prior to the construction of roundabout.

EXCESS PROPORTION OF SPECIFIC CRASH TYPE ANALYSIS

The excess proportion of specific crash types analysis looks at the proportion of crash types (i.e., rear-end, turning, angle, etc.) for each intersection and compares it with the average for the reference population to determine if certain types of crashes are more prevalent than should be expected. A reference population must contain at least five intersections to be valid. In addition, at least two crashes of the same type are necessary to calculate the excess proportion for that intersection[6].

[6] Analysis Procedures Manual Version 2, Oregon Department of Transportation

Crash types with an excess proportion greater than 0.1 were flagged as a safety focus area. Table 17 presents only the flagged intersections and shows that rear-end, turning, and angle collisions are the most commonly overrepresented crash type at study intersections. At NE 3rd Street, Dean Swift Road, and Erickson Road/ Torkelson Road, more rear-end collisions were observed than expected. At NE 4th Street, NE 8th Street, and NE Benson Way, more turning collisions were observed than expected. More angle collisions were observed at Hamby Road, which corresponds to the critical crash rate discussion above, and it should also be noted that the conditions at Hamby Road was prior to the roundabout implementation.

TABLE 17. SUMMARY OF INTERSECTIONS WITH EXCESS PROPORTION OF SPECIFIC CRASH TYPES (2016-2020)

CROSS STREET	FLAGGED	CRASH TYPE	EXCESS PROPORTION
3RD ST	Yes	Rear	**0.11**
4TH ST	Yes	Turn	**0.24**
8TH ST	Yes	Turn	**0.15**
DEAN SWIFT RD	Yes	Rear	**0.18**
BENSON WY	Yes	Turn	**0.42**
HAMBY RD[A]	Yes	Angle	**0.20**
ERICKSON RD/ TORKELSON RD	Yes	Rear	**0.18**

Note: The excess proportion of specific crash types analysis looks at the proportion of crash types for each intersection and compares it with the average for the reference population to determine if certain types of crashes are more prevalent than should be expected. For example, an excess proportion of 0.11 means that are 11% more observed rear-end crashes than the calculated threshold for four-leg signalized intersections in this population.

[A] Data collected prior to the construction of roundabout.

SEGMENT CRASH RATE ANALYSIS

In addition to individual intersections, crash rates for segments of the US 20 study corridor were analyzed to identify potential problem areas. The average crash rate experienced between 2016 and 2020 was either compared against the critical crash rate or statewide average for similar facilities. Segments were flagged as safety focus areas if their five-year average observed crash rate exceeded the critical crash rate or statewide average rate. Critical crash rate compared performance to other similar segments in the study area and there need to be at least five sites in a reference population for this method to be applicable. Since there are less than five sites available to create a reference population for a rural arterial, the critical crash rate method does not apply to the segments east of NE Benson Way. Therefore, crash rates for segments east of NE Benson Way were compared against the statewide average from the ODOT Crash Book[7] (2016-

[7] 2020 State Highway Crash Rate Tables, Transportation Data Section Crash Analysis and Reporting Unit, May 2022

2020 average from Crash Rate Table II). It should be noted that the crashes included in the segment also accounted for intersection flagged crashes to align with ODOT crash rate calculation methodologies. Also, the segment from 8th Street to 15th Street was separated into two segments \ as the roadway changes near 12th Street with the addition of a raised median from 12th Street to 15th Street.

As shown in Table 18, most of the crash rates along the US 20 corridor were lower than the critical rate and statewide average. Three segments were flagged as safety focus areas:

- **3rd Street to 4th Street**: There were 10 reported crashes that occurred along the segment. Out of the 10 crashes, 80 percent involved rear-end collisions and 63 percent of the rear-end crashes were due to drivers failing to avoid the vehicle ahead. Note that all 10 crashes were closer to 3rd Street.
- **8th Street to 12th Street**: 34 crashes were reported along the segment. Most of the crashes involved rear-end (29 percent), turning (26 percent), or angle (24 percent) collisions. Contributing factors for many of the crashes were due to drivers not yielding the right-of-way (44 percent) and failing to avoid the vehicle ahead (15 percent). It should be noted that the crashes occurred west of 12th Street, before the existing raised median.
- **Windy Knolls Drive to 27th Street:** 13 crashes were reported along the segment, with the majority involving turning (38 percent), rear-end (31 percent), or sideswipe (23 percent) collisions. Of the total crashes, 46 percent were attributed to drivers not yielding the right-of-way.

TABLE 18. SEGMENT CRASH RATES (2016-2020)

FROM (MILE POINT)	TO (MILE POINT)	FLAGGED	AREA TYPE	SEGMENT CRASH RATE	CRITICAL/ STATEWIDE CRASH RATE[A]
3RD ST (0.51)	4th ST (0.6)	Yes	Urban Arterial	**2.79**	2.74
4TH ST (0.6)	6th ST (0.77)	-	Urban Arterial	0.89	2.38
6TH ST (0.77)	8th ST (0.94)	-	Urban Arterial	1.92	2.38
8TH ST (0.94)	12th ST (1.16)	Yes	Urban Arterial	**3.45**	2.23
12TH ST (1.16)[A]	15TH ST (1.55)	-	Urban Arterial	0.34	2.04
15TH ST (1.55)	DEAN SWIFT RD (2.18)	-	Urban Arterial	1.24	1.93
DEAN SWIFT RD (2.18)	PURCELL BLVD (2.29)	-	Urban Arterial	2.03	2.55
PURCELL BLVD (2.29)	WINDY KNOLLS DR (2.4)	-	Urban Arterial	1.37	2.73
WINDY KNOLLS DR (2.4)	27th ST (2.55)	Yes	Urban Arterial	**2.60**	2.54
27TH ST (2.55)	BENSON WY (2.65)	-	Urban Arterial	1.48	2.95
BENSON WY (2.65)	HAMBY RD (3.53)	-	Rural Arterial	0.46	0.74[A]
HAMBY ROAD (3.53)	ERICKSON RD/ Torkelson Rd (4.57)	-	Rural Arterial	0.32	0.74[A]
ERICKSON RD/ TORKELSON RD (4.57)	POWELL BUTTE HWY (4.79)	-	Rural Arterial	0.22	0.74[A]

Bold and red segment crash rate exceeds critical statewide crash rate

[A] Marked intersections refer to statewide crash rate from Oregon Crash book where unmarked intersections refer to critical crash rate based on segments within study area.

STATEWIDE AVERAGE CRASH RATE (ODOT CRASH BOOK) SAFETY PRIORITY INDEX SYSTEM

The Safety Priority Index System (SPIS) provides another method for identifying crash hot spots. This method considers the rate, frequency, and severity of crashes to produce a rating, with the highest rated sites statewide (often those with ratings within the top 10 percent) being considered for potential safety improvements.

The 2018, 2019, and 2020 SPIS ratings for US 20 within the study area were obtained from ODOT to screen for locations with SPIS rating among the state's top 10 percent. Table 19 presents the locations that were identified among the top 10 percent of SPIS sites. Among the six flagged locations, NE 8th Street was rated within the top 10 percent for all three years. NE 15th Street and Dean Swift Road were rated for two years, while NE Purcell Boulevard and NE 27th Street rated for one year. Hamby Road also rated within the top 10 percent for three years, however, this was prior to the roundabout construction.

TABLE 19. STUDY LOCATIONS WITH TOP 10TH PERCENTILE SPIS SITES IN 2018, 2019, AND 2020

LOCATION	SAFETY PRIORITY INDEX SYSTEM (SPIS) YEAR		
	2018	2019	2020
8TH ST	X	X	X
15TH ST	X	X	
DEAN SWIFT RD		X	X
PURCELL BLVD	X		
27TH ST		X	
HAMBY RD[A]	X	X	X

[A] Data collected prior to the construction of roundabout.

SUMMARY OF FINDINGS AND POTENTIAL SAFETY COUNTERMEASURES

Based on the crash analysis documented above, Table 20 summarizes the several areas throughout the study corridor were flagged as safety focus areas.

TABLE 20. SUMMARY OF STUDY LOCATIONS FLAGGED IN SAFETY EVALUATION

LOCATION	CRITICAL CRASH RATE	SPIS	EXCESS PROPORTION	OTHER KEY FINDINGS
INTERSECTION				
NE 3RD STREET			X	Excess proportion of rear-end crashes. Included two pedestrian crashes.
NE 4TH STREET			X	Excess proportion of turning movement crashes
NE 8TH STREET		X	X	Excess proportion of turning movement crashes. Intersection with highest number of pedestrian and bicycle crashes along the corridor.
NE 15TH STREET		X		
DEAN SWIFT ROAD		X	X	Excess proportion of rear-end crashes
BENSON WAY			X	Excess proportion of turning movement crashes
PURCELL BLVD		X		
27TH STREET	X	X		
HAMBY ROAD[A]	X	X	X	Included two fatal injury crashes. Excess proportion of angle crashes.
POWELL BUTTE HIGHWAY				Included one fatal injury crash
SEGMENT				
SEGMENT 1 (EAST OF 6TH ST)	X	X		SPIS at NE 9th Street Exceeds critical crash rate between 3rd Street and 4th Street
SEGMENT 2 (WEST OF DEAN SWIFT RD)	X			Exceeds critical crash rate west of NE 12th Street (no raised median)
SEGMENT 3 (EAST OF PROVIDENCE DR)				

[A] Data collected prior to the construction of roundabout.

Through this project, safety improvements will be evaluated at the study intersections and along the corridor. Potential safety countermeasures that many reduce the likelihood of crashes regarding the types and their associated reduction factors[8] are documented in the below sections. The feasibility of these countermeasures will be further refined through the alternatives evaluation process for this project.

[8] Crash Reduction Factor List, ODOT.

SAFETY COUNTERMEASURES FOR PEOPLE WALKING AND BIKING

Six percent of the total crashes along US 20 involved people walking and biking, with hotspots near 8th Street and 3rd Street. To help improve safety for people walking and biking, potential safety countermeasures include:

- Provide intersection lighting at unsignalized intersections
  - Reduces the potential for nighttime crashes for people walking and biking by 42 percent
- Install sidewalk
  - Installing sidewalk can reduce pedestrian crashes by 20 percent
  - In particular, install sidewalk east of NE Benson Way as development continues to occur
- Install enhanced biking facilities along and across US 20
  - Installing cycle tracks, buffered bike lanes and/or bicycle signals can reduce bicycle crashes by 45 to 59 percent.
  - In addition, installing buffered bike lanes along the corridor could also result in narrowed travel lanes, potentially reducing vehicle speeds.
- Install two-stage crossings or activated pedestrian beacons at unsignalized intersections
  - Can reduce pedestrian and bicycle crashes by 10 percent
  - This treatment should especially be considered within Segment 2, where there are limited enhanced crossing opportunities.
- Install urban leading pedestrian or bicycle interval at signalized intersections
  - Can reduce pedestrian and bicycle crashes by 37 percent

ADDITIONAL SAFETY COUNTERMEASURES

As noted in Table 20, several locations were flagged as safety focus areas. Rear-end and turning collisions were reported the most among the stated intersections, except at Hamby Road, where angle collisions were the most prevalent crash type prior to the roundabout construction.

Potential safety countermeasures to improve safety along the corridor could include:

- Install an urban traffic signal at NE 4th Street[9] – Could reduce angle crashes (which are generally higher-severity crashes) by 77 percent but increase rear-end crashes (which are generally lower-severity) by 58 percent
- Reduce driveway density – Could reduce crashes between 25 and 31 percent. Access is generally well controlled along Segment 2 and 3 but could be reduced along Segment 1. It should be noted this countermeasure will be challenging to apply.
- Install offset (buffered) right turn lane
  - Can reduce angle and turning crash reduction by 69 percent
  - Could be considered at NE 3rd Street for westbound movement and NE 15th Street for northbound movement where there are higher right turn volumes.

[9] Recommendation from the 2020 ODOT SPIS Investigation Report

- Restrict left turning and crossing movements by making NE Dean Swift Road[10] right-in, right-out access only. This can be accomplished by installing a pork chop island on the north leg and/or installing raised median in the center turn lane.
- Install adaptive signal timing of urban traffic signals at urban signalized intersections – can reduce crashes by 17 percent.
- Speed management
  - Installing street trees where the speed limit is less than 35 miles per hour can reduce crashes by 10 percent.
  - Narrow travel lane width to reduce vehicle speeds[11].
- Install transverse rumble strips on stop-controlled approaches at rural unsignalized intersections along Segment 3 can reduce crashes by 25 percent.
- Install lighting in Segment 3 – Can reduce nighttime related crashes by 38 percent for intersections and 28 percent for roadway segments.

Signing and marking improvements at rural intersections (e.g., stop ahead signs, stop ahead pavement markings, larger signs, raised splitter installation, warning or regulatory signs) – Can reduce crashes by 20 to 30 percent.

[10] Recommendation from the 2020 ODOT SPIS Investigation Report

[11] Mitigation for Design Exception Strategies, Chapter 3, Federal Highway Administration, June 2007, https://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3_lanewidth.cfm