



City of Bend

G.O. Bond Reed Market Intersection Evaluation Report



Prepared for
City of Bend

Prepared by

DKS

In coordination with
HDR Inc.

July 2012



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July 27, 2012

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Subject: G.O. Bond Reed Market Intersection Evaluation Report

Dear Stephanie:

DKS Associates is pleased to submit the final G.O. Bond Reed Market Intersection Evaluation Report. This final report reflects comments and revisions collected from project team and City staff review.

It has been a pleasure to work with you on this challenging evaluation that sets the stage for designing improvements to the Reed Market Corridor.

Sincerely,
DKS Associates

Chris Maciejewski, PE, PTOE
Senior Project Manager

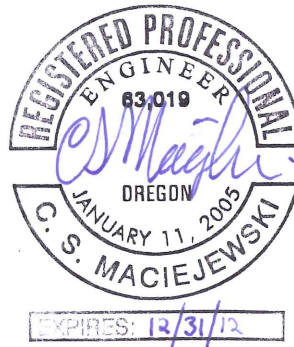


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CHAPTER 1 - INTRODUCTION

The purpose of this report is to document the transportation analysis conducted along the Reed Market Corridor from the unsignalized intersection at American Lane to the signalized intersection at SE 15th Street, as well as their respective influence areas. The project study area is shown in Figure 1. The primary study intersections include SE Reed Market Rd/American Lane, SE Reed Market Rd/SE 9th Street, and SE Reed Market Road/SE 15th Street.

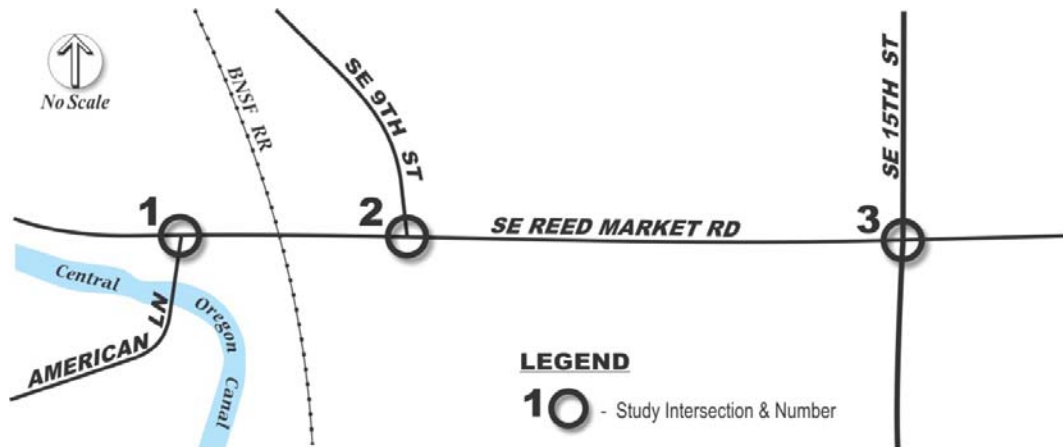


Figure 1: SE Reed Market Road Corridor Study Area

The purpose of this analysis is to determine the recommended lane configuration and intersection traffic control that would accommodate future year 2030 traffic demand, develop construction phasing options for the ultimate design, and highlight important design parameters to incorporate in the roadway design process. The analysis performed and documented in this report follows the City of Bend's *Roundabout Evaluation and Design Guidelines*.¹ The guidelines outlined in the *Tier 1 Intersection Form Selection Criteria* as well as some criteria from the *Tier 2 Intersection Form Selection Criteria* were used to determine the optimal solution for intersection traffic control at the intersection of SE Reed Market Road/SE 15th Street, while also keeping in mind that the City maintains a "roundabouts first" approach to intersection treatments.

This report includes the following chapters:

- Background Document Review
- System Context/Existing Conditions
- Concept Development and Screening
- American Lane & SE 9th Street Refined Evaluation
- SE 15th Street Refined Evaluation
- Corridor Design Recommendations Summary

¹ City of Bend Roundabout Evaluation and Design Guidelines, Kittelson & Associates, Inc., April 2010.

CHAPTER 2 - BACKGROUND DOCUMENT REVIEW

The Reed Market Corridor has been studied several times in the past seven years in an effort to identify roadway modernization improvements resulting in a corridor that moves people efficiently and safely, is attractive, meets community needs and expectations, and is economically feasible to construct and maintain. Paramterix, Inc. was the lead consultant for the studies and they were supported by Otak, Inc., Heritage Research Associates, Kleinfelder Associates, TW Environmental, and Universal Field Services. Several documents were produced as a part of the studies, including the *Reed Market Corridor Study Existing Conditions Technical Report*², *Reed Market Corridor Study Future Baseline Traffic Conditions Technical Report*³, and the *Reed Market Study Corridor Summary Report*.⁴

In addition to the above mentioned documents, Otak, Inc. prepared the *Reed Market Road 9th Street to Newberry Drive 30 Percent Design Summary*,⁵ which took the original background review and analysis and began to develop design documents for improvements along the corridor. A brief summary of the relevant portions of each of these documents is provided in the following sections.

Reed Market Corridor Study Existing Conditions Technical Report, June 2005

This document served to characterize the unique transportation issues and the general environment of the existing Reed Market Corridor from SW Silver Lane Boulevard to SE 27th Street. The document reviewed the existing land use, natural environment, transportation facilities, transportation service levels, and deficiencies along SE Reed Market Road for autos, freight, bicycles, pedestrians, transit, and rail. Key deficiencies that were identified include:

- Operations exceeding LOS D at the signalized intersections of SE Reed Market Road with SE 3rd Street and SE 15th Street.
- Operations at most unsignalized intersections along the SE Reed Market Road corridor operate poorly during the PM peak hour with the intersections of SW Silver Lake Boulevard, Bend Parkway (east ramp terminal), SW Division Street, American Lane, and SE 9th Street all operating below the LOS standard.
- Intersection crash rates exceeding the common 1.0 per million entering vehicles threshold included SE Reed Market Road at Division Street, SE 3rd Street, and SE 27th Street.
- Segment crash rates also exceeded the 1.0 threshold for million vehicle miles traveled from Bend Parkway to SE 27th Street.

² *Reed Market Corridor Study Existing Conditions Technical Report*. Paramterix, Inc., June 2005.

³ *Reed Market Corridor Study Future Baseline Traffic Conditions Technical Report*. Paramterix, Inc., October 2005.

⁴ *Reed Market Corridor Study Summary Report*. Paramterix, Inc., June 2006.

⁵ *Reed Market Road 9th Street to Newberry Drive 30 Percent Design Summary*. Otak, Inc., August 2008.

- Gaps exist in both the bike lane and sidewalk network along the study corridor.
- The at grade crossing with the Burlington Northern Santa Fe railroad causes unpredictable delays for commuters as well as for emergency response providers.

Additional intersection specific background information was given for the intersections of SE Reed Market Road and American Lane, SE 9th Street, and SE 15th Street, which are summarized below.

SE Reed Market Road at American Lane

The SE Reed Market Road/American Lane intersection is a stop-controlled T-intersection on the American Lane approach. The uncontrolled eastbound Reed Market Road approach has a shared through-right turn lane and the uncontrolled westbound approach has a through and a left turn lane. The American Lane approach (northbound) consists of a single lane for left and right turning traffic. Vehicle queuing on the single-lane approach of American Lane periodically extends several hundred feet south of Reed Market Road during the PM peak hour. It was reported that the northbound movement during the 2005 PM peak hour had a control delay of greater than two minutes per vehicle, a V/C ratio well above 1.0, and a LOS F. The westbound left turn movement (also critical) experienced a control delay of 12.9 seconds/vehicle, a V/C ratio of 0.40, and a LOS B. Additionally, an intersection crash history was provided that showed from 2001-2003 the intersection had a crash rate of 0.30 per million entering vehicles, which is well below the common threshold of 1.0 that is used to identify a higher than typical crash rate.

SE Reed Market Road at SE 9th Street

The SE Reed Market Road/SE 9th Street intersection is a stop-controlled T-intersection on the SE 9th Street approach. The eastbound SE Reed Market Road uncontrolled approach has a left turn lane and a through lane and the westbound uncontrolled approach has a shared through-right turn lane. The SE 9th Street approach (southbound) has a left turn lane and a right turn lane. At this intersection excessive queuing occurs on the southbound approach during the PM peak. The southbound left turn movement in the 2005 PM peak experienced a control delay of greater than two minutes per vehicle, a V/C ratio of 0.75, and a LOS F. The southbound right movement was reported to have a control delay of 49.0 seconds/vehicle, a V/C of 0.81, and a LOS E. The intersection crash rate for this study intersection from 2001-2003 was reported at 0.06 per million entering vehicles, which is well below the common threshold of 1.0 that is used to identify a higher than typical crash rate.

SE Reed Market Road at SE 15th Street

SE 15th Street is a two-lane minor arterial that runs north-south and connects SE Reed Market Road to US 20. Around the year 2000, a traffic signal was installed at the SE Reed Market Road/SE 15th Street intersection as a temporary improvement, with a permanent solution still to be determined. Based off of 2005 traffic volumes and vehicle queuing it was found that operations (2005 PM Peak Hour) exceed the minimum standard for urban area level of service (LOS) which is D. The operations reported for the intersection of SE Reed Market Road/SE 15th

Street were LOS E, an overall V/C ratio of 0.88, and an average control delay (seconds/vehicle) of 55.1. In addition, an intersection crash history was provided that showed from 2001-2003 the intersection had a crash rate of 0.96 per million entering vehicles, which is close to the common threshold of 1.0 that is used to identify a higher than typical crash rate.

Reed Market Corridor Study Future Baseline Traffic Conditions Technical Report, October 2005

This document reports the anticipated future traffic baseline conditions (without roadway improvements) along SE Reed Market Road between Silver Lake Boulevard and SE 27th Street based on a forecast year of 2030. The report outlines the methodology used to estimate future baseline traffic volumes, since at the time of the study, the Bend urban area did not have a regional travel demand model to serve as a base for developing future travel demand forecasts. The methodology relied on both existing and historic traffic patterns, as well as assumptions for background traffic growth and growth trend assumptions.

Based on the future traffic volume estimations, an operational analysis was performed. The operational output for the three study intersections are reported in the following sections:

SE Reed Market Road at American Lane

At the intersection of SE Reed Market Road/American Lane, the 2030 operational output reported that the westbound left turn lane would have a control delay of 45.8 seconds/vehicle, a V/C ratio of 0.87, and a LOS E. For the northbound movement, the detailed operational measures were not reported as the level of congestion due to excess demand would exceed the methodologies for intersection analysis (i.e., the intersection would be significantly over capacity with average delays of many minutes). The queuing analysis revealed that the westbound left movement would experience delays and queuing (approximately 200 feet in length) as motorist would experience difficulty finding gaps in the opposing traffic stream. Northbound traffic on American Lane would also experience substantial delays and queuing.

SE Reed Market Road at SE 9th Street

The intersection of SE Reed Market Road/SE 9th Street experienced similar queuing problems as American Lane. The southbound turn movements would experience long delays and queuing, with the southbound left turn movement experiencing the longest delays. The operations for the movements would also significantly exceed capacity and average delays would be multiple minutes.

SE Reed Market Road at SE 15th Street

The evaluation found that SE Reed Market Road/SE 15th Street would have extensive delays and queuing. The 2030 operational output reported the SE Reed Market Road/SE 15th Street intersection with a LOS F, an overall V/C ratio of 1.50, and an average control delay above two minutes per vehicle. Extensive queuing would occur on the eastbound, westbound, and southbound approaches (2,000 feet, 1,400 feet, and 1,000 feet respectively). It was also

determined that the eastbound queuing would spill back beyond SE 9th Street and American Lane and that westbound queuing would spill back beyond Newberry Drive.

Reed Market Corridor Study Summary Report, June 2006

This document outlines the two basic corridor design concepts that were studied along Reed Market Road, which include a signalized corridor and a multi-lane roundabout corridor. Both concepts made recommendations to grade separate the Burlington Northern Santa Fe (BNSF) railroad crossing between Paiute Way and SE 9th Street. The ultimate design concept recommended a multi-lane roundabout corridor because it provided the greatest benefit to operations for all modes of traffic, accommodated access management needs, increased capacity, and allowed for some reduction in right-of-way requirements between intersections.

The study intersection of Reed Market Road/SE 15th Street was recommended for a near-term improvement. The improvement called for constructing a multi-lane roundabout, including widening to the west to allow for additional storage during train delays.

Reed Market Road 9th Street to Newberry Drive 30 Percent Design Summary, August 2008

The *Reed Market Road 9th Street to Newberry Drive 30 Percent Design Summary* document took three of the projects recommended for short-term implementation from the Reed Market Corridor Study and carried those concepts into 30 percent design. The first project was to build a multi-lane roundabout at SE Reed Market Road/SE 15th Street, including acquiring right-of-way for the full year 2030 improvement concept. The second project was to widen SE Reed Market Road from east of SE 9th Street to SE 15th Street to three through lanes (two westbound and one eastbound, with a median divider) to allow for additional storage during train delays. The third project was to construct partial improvements between Newberry Drive and Daly Estates Drive, consisting of a two-lane road with left-turn lanes/landscaped medians, bike lanes, shoulders, and a paved path on one side.

As part of the roundabout analysis performed at the study intersection of SE Reed Market/SE 15th Street, a *VISSIM* microsimulation model was developed and used to evaluate operations. In addition, an evaluation using *aaSIDRA* was conducted alongside the *VISSIM* analysis to provide a v/c ratio (which *VISSIM* does not provide). Traffic volumes for the year 2030 were developed from the Bend MPO regional travel demand model Murphy Overcrossing scenario. The assumed roundabout geometry for the analysis was double lane approaches and exits on SE 15th Street, which would transition back to a two-lane roadway north and south of SE Reed Market Road. On SE Reed Market Road, the single through lane in each direction would be widened to double lanes at the approaches to the roundabout at SE 15th Street. The exits along SE Reed Market Road are dual lane as well, which would taper back to a single lane downstream of the intersection. A partial south bound right-turn bypass lane was considered, but it was determined that other future improvements in the area would alleviate the need for this slip lane, so it was not included in the geometry for analysis purposes. The *VISSIM* microsimulation analysis revealed that the roundabout would operate at LOS C or better in 2030 with 95th percentile

queuing of less than 600 feet on all approaches. The *aaSIDRA* analysis forecasted better operations with a LOS B or better, with queuing less than 300 feet and a maximum v/c ratio of 0.83, which meets the City's 1.00 v/c ratio standard. The ultimate geometry and associated storage lengths were then recommended, which include:

SE Reed Market Road/SE 15th Street

North Leg

- Provide 580 feet of two-lane storage for southbound queuing, or extend to the first residential street north of the intersection.
- Provide 300 feet of merge distance and the required taper distance based on roadway speed for traffic exiting the roundabout northbound.

East Leg

- Provide 450 feet of two-lane storage for westbound queuing, or extend the two-lane section into the Newberry Drive intersection.
- Continue the two-lane exit east where the outside drop lane becomes a right-turn only lane onto Newberry Drive.

South Leg

- Provide 270 feet of two-lane storage for northbound queuing, or extend the two-lane section to the north splitter island of the planned SE 9th Street extension roundabout.
- Provide the maximum merge distance possible for southbound traffic exiting the roundabout while providing the required taper distance before the north splitter island of the planned SE 9th Street extension roundabout.

West Leg

- Provide 350 feet of two-lane storage for eastbound queuing, beginning immediately east of the future commercial access street west of the intersection.
- Continue the two-lane exit west, turning the outside drop lane into a right-turn only lane onto SE 9th Street.

At the intersection of SE Reed Market Road/SE 9th Street, four possible design alternatives were developed to solve the congestion and safety issues projected at this intersection. These include:

- Retain full access in anticipation that the railroad overcrossing is constructed before 2030 volumes are reached or the projected problems occur.
- Limit SE 9th Street access to right-in and right-out only.
- Install a traffic signal.
- Acquire right-of-way to provide left-turn storage, refuge lanes, and additional travel lanes.

In regard to Burlington Northern Santa Fe at-grade railroad crossing, it was recommended that the City consider a warning system of signals or special signage at the roundabout so that vehicles entering the roundabout do not fill the circulating roadway when the west exit lanes are blocked, thereby precluding vehicles on other approaches from entering and exiting other legs of the intersection.

CHAPTER 3 - SYSTEM CONTEXT/EXISTING CONDITIONS

The existing study area transportation characteristics are presented in this chapter. Characterizing the corridor is important to determine factors that would contribute to its overall function, user needs, and future success. The existing corridor facility characteristics are discussed in the following sections and include factors related to the motor vehicle system, nearby traffic control, pedestrian system, bicycle system, transit system, emergency response system, land use, access management, and civic gathering spaces. Figure 2 illustrates an overview of the system context.

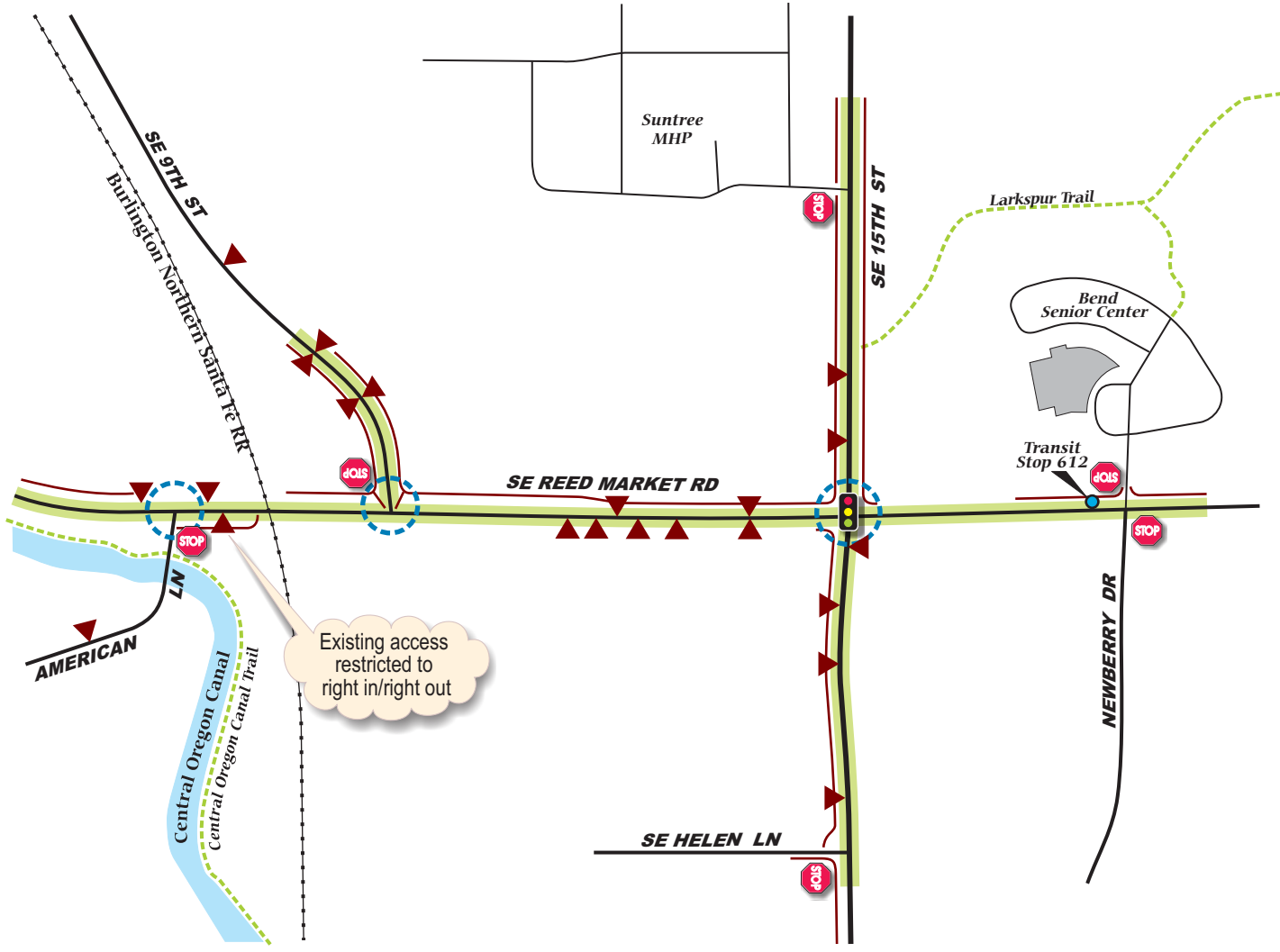
Intersection use is also presented in terms of existing vehicle, pedestrian, and bicyclist volumes. Design vehicles were recommended based off of existing heavy vehicle traffic volumes, surrounding land use types, and roadway designations. Baseline performance in regards to safety is also characterized. Futures volumes were developed and are presented. In addition, intersection operation criteria and existing and future no-build intersection performance are discussed.

Motor Vehicle System








A field inventory was conducted in December 2011 by DKS Associates staff to determine roadway characteristics surrounding the study intersections. SE Reed Market Road, American Lane, SE 9th Street, and SE 15th Street are all under City of Bend jurisdiction. Information collected includes the following:

- Posted Speed Limits
- Intersection Control
- Lane Configurations
- Pedestrian Facilities
- Bicycle Facilities.

A summary of the existing study area roadway characteristics are listed in Table 1.



LEGEND

	- Study Intersection		- Driveway/Access
	- Stop Sign		- Sidewalk
	- Traffic Signal		- Bike Lanes
			- Trail (as indicated)

DKS

Figure 2

Reed Market Corridor
OVERVIEW OF SYSTEM CONTEXT


NO SCALE

Table 1: Existing Study Area Roadway Characteristics

Intersection/ Intersection Leg		Functional Classification ⁶	Posted Speed Limit (mph)	Traffic Control	Number of Lanes	Length of Full Width Turn Lane* (ft)	Bike Lane	Side- walk	Additional Notes
SE Reed Market Rd./American Lane	SE Reed Market Rd. (East Leg)	Major Arterial	35	Uncontrolled	3 (including turn lane)	Left Turn Lane (85)	Yes	South side	Sidewalk on south side extends approximately 230 feet east and then ends.
	American Lane (South Leg)	Major Collector	30	Stop-Controlled	2	n/a	No	No	-
	SE Reed Market Rd. (West Leg)	Major Arterial	35	Uncontrolled	3	TWLTL	Yes	North side	-
SE Reed Market Rd./SE 9 th St.	SE 9 th Street (North Leg)	Minor Arterial	35	Stop-Controlled	3	Left Turn Lane (115)	Yes	Both sides	-
	SE Reed Market Rd. (East Leg)	Major Arterial	35	Uncontrolled	3	TWLTL	Yes	North side	-
	SE Reed Market Rd. (West Leg)	Major Arterial	35	Uncontrolled	3	TWLTL	Yes	North side	-
SE Reed Market Rd./SE 15 th St.	SE 15 th St. (North Leg)	Minor Arterial	40	Traffic Signal	3 (including turn lane)	Left Turn Lane (150)	Yes	Both sides	-
	SE Reed Market Rd. (East Leg)	Major Arterial	40	Traffic Signal	3 (including turn lane)	Left Turn Lane (130)	Yes	None	Sidewalk begins along north side approximately 350 feet east of intersection
	SE 15 th St. (South Leg)	Minor Arterial	40	Traffic Signal	3 (including turn lane)	Left Turn Lane (150)	Yes	West side	-
	SE Reed Market Rd. (West Leg)	Major Arterial	35	Traffic Signal	3 (including turn lane)	Left Turn Lane (100)	Yes	North side	-

*Available length for vehicles to queue before blocking traffic in the adjacent through lane.
TWLTL = Two-way left turn lane

⁶Bend Urban Area Transportation System Plan. Updated 2006-06-21.
<https://scholarsbank.uoregon.edu/xmlui/handle/1794/3223>. Accessed December 13, 2011.

Nearby Traffic Control

Characterizing traffic control along the Reed Market Corridor is important because it helps to understand the overall context of signalized intersections, stop controlled intersections, and the possibility of introducing a roundabout to the corridor. Reference to adjacent intersection control can be seen in Figure 2.

SE Reed Market Road/American Lane

The intersection of SE Reed Market Rd/American Lane is the western most intersection evaluated in this corridor study. The intersection is stop-controlled along American Lane with a single northbound approach lane for vehicles headed eastbound or westbound on SE Reed Market Road. The westbound approach at the study intersection provides both a through lane and westbound left turn lane. The eastbound approach consists of a through lane and a two-way left turn lane.

Adjacent intersections located near SE Reed Market Road/American lane include the side street stop-controlled intersections of Paiute Way to the west, American Lane Loop to the south, and SE 9th Street to the east. Paiute Way is located approximately 550 feet to the west, American Lane Loop is located approximately 500 feet to the southwest, and SE 9th Street is located approximately 550 feet to the east.

SE Reed Market Road/SE 9th Street

The intersection of SE Reed Market Road/SE 9th Street is located just east of American Lane. The intersection is stop-controlled along SE 9th Street and has a southbound left and right turn lane. Along SE Reed Market Road, the cross section is three lanes with a through lane in each direction and a two-way center left turn lane.

Adjacent intersections to SE Reed Market Road/SE 9th Street include the side street stop-controlled American Lane approximately 550 feet to the east, an all-way stop controlled intersection approximately 3,000 feet north at SE Wilson Ave, and the signalized intersection of SE Reed Market Road/SE 15th Street approximately 1,000 feet to the east.

SE Reed Market Road/SE 15th Street

The intersection of SE Reed Market Road/SE 15th St is a signalized intersection. All approaches have three lanes consisting of a through lane in each direction and a left turn lane.

The immediately adjacent intersections along SE Reed Market Road and SE 15th Street are two-way stop controlled along the side street approach. To the north, there is a private roadway on the west side of SE 15th Street approximately 750 feet from the study intersection. In addition, there are two commercial accesses located on the west side at approximately 200 feet and 400 feet north of the intersection. On the south leg of SE 15th Street, SE Helen Lane intersects the roadway on the west side (approximately 780 feet to the south).

To the west, SE 9th Street intersects SE Reed Market Road (approximately 1,000 feet to the west). There are also multiple private accesses to SE Reed Market Road between SE 15th Street and SE 9th Street, as shown in Figure 2. To the east, Newberry Drive intersects SE Reed Market Road (approximately 700 feet to the east). The north leg of Newberry Drive serves as the access to the Bend Senior Center.

Burlington Northern Santa Fe (BNSF) At Grade Rail Crossing

An existing Burlington Northern Santa Fe (BNSF) at-grade railroad crossing is located midblock between American Lane and SE 9th Street (See Figure 2). The at-grade crossing is controlled with gates. The rail line is on the BNSF's trunk line that runs through Deschutes County.⁷ Approximately 10 trains a day cross SE Reed Market Road. In addition, the trains often stop at the railroad-switching yard located just south of SE Reed Market Road. The trains are inconsistent in regard to their length, regularity, and total gate down times. Crossings do occur during peak traffic times and can cause significant vehicle queues along SE Reed Market Road. Gate down time has been observed at times to be between 15-20 minutes, which can cause queue spill back through the extent of the study area.⁸

An advanced railroad warning system was identified as a Deployment Plan Project in the Deschutes County ITS Plan, as project number DC-TM-19A.⁹ The plan identifies that the public via message signs or in-vehicle navigation systems should be provided with advanced information about trains approaching the railroad crossing on SE Reed Market Road between American Lane and SE 9th Street. Deployment of advanced warning devices are proposed to be located at SE Reed Market Road/SE 3rd Street and SE Reed Market Road/SE 15th Street.

After review of the potential corridor improvement concepts, an ITS system to alert drivers in advance of a rail crossing was determined to be possible to implement under any solution using the National ITS Architecture service page for ATMS14-Advanced Railroad Grade Crossings.¹⁰ Therefore, this intersection control evaluation report does not include the ITS system as a selection criteria, but the design of the roadway improvements should consider incorporating the additional infrastructure.

⁷ Appendix D Central Oregon Rail Planning Original Planning Work Assignment and Background. ODOT Central Oregon Rail Plan. June 20, 2007. http://www.oregon.gov/ODOT/HWY/REGION4/Central_Oregon_Rail_Plan/Appendix_D_COACT_Draft_Rail_Planning_Scope.pdf?ga=t. Accessed May 11, 2012.

⁸ Lewis, R. (2011, January 11). Personal interview.

⁹ *Deschutes County ITS Plan*. Prepared for the Oregon Department of Transportation. DKS Associates and IBI Group. June 2011. <http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4575>. Accessed May 3, 2012.

¹⁰ *ATMS14-Advanced Railroad Grade Crossing*. The National ITS Architecture 7.0. <http://www.iteris.com/itsarch/html/mp/mpatms14.htm>. Accessed May 3, 2012.

Pedestrian System

There are some existing sidewalks located along the study corridor, but significant gaps exist as shown in Figure 2. At the intersection of SE Reed Market Road/American Lane, sidewalks are missing on the west leg along the south of SE Reed Market Road and on the east leg along the north side of SE Reed Market Road. Pedestrian facilities for crossing the BNSF railroad also do not exist. Sidewalks are also missing along both sides of American Lane.

Near the intersection of SE Reed Market Road/SE 9th Street, sidewalks are present along the north side of SE 9th Street but are missing along the south side. On SE 9th Street, sidewalks extend approximately 550 feet to the north on the west side and approximately 300 feet on the east side.

At the intersection of SE Reed Market Road/SE 15th Street, sidewalk is missing along the south side of SE Reed Market Road. Along the north side of SE Reed Market Road sidewalk is present to the west of SE 15th Street, but a segment approximately 300 feet long is missing on the north side of SE Reed Market Road just east of the intersection. That missing section would connect the Bend Senior Center to the traffic signal.

On the south leg of SE 15th Street, there is existing sidewalk along the west side that continues to SE Helen Lane and beyond. The north leg of SE 15th Street features sidewalks on both sides of the roadway all the way to SE Bronzewood Avenue and beyond.

There are currently striped crosswalks along all legs of the intersection of SE Reed Market Road/SE 15th Street associated with the traffic signal. These crossings are controlled by pedestrian signals as part of the traffic signal operations. Curb ramps are located on all quadrants but they are currently not ADA compliant.

Bicycle System

Striped bike lanes are present along SE Reed Market Road through the majority of the corridor as can be seen in Figure 2. The existing bike lane terminates at Newberry Drive approximately 700 feet to the east. The City's Transportation System Plan (TSP)¹¹ has identified future bike lanes along Reed Market Road to the east at this location.

Bike lanes do not exist on American Lane, however the location has been identified in the City's TSP as a location for future bike lanes. Bike lanes on SE 9th Street are present approximately 500 feet north of SE Reed Market Road, but are missing further to the north. SE 9th Street is also identified in the City's TSP as a location for future bike lanes. In addition, mention was made in the TSP that the BNSF alignment was identified as a potential opportunity to pursue a Rails with

¹¹ Bend Urban Area Transportation System Plan. Updated 2006-06-21.
<https://scholarsbank.uoregon.edu/xmlui/handle/1794/3223>. Accessed December 13, 2011.

Trails project. The Rails with Trails programs seeks to develop shared use paths and other trails within or adjacent to active railroad and transit right-of-way.¹²

Transit System

Transit services in the City of Bend are provided by Cascades East Transit. Bus route 6 (Bear Creek) travels through the corridor on its route between Hawthorne Station and Worksource Bend.¹³ Service is provided Monday through Friday with headways of approximately 40 minute between 6:00 a.m. and 6:00 p.m. On Saturday the bus runs approximately every hour and twenty minutes between 8:00 a.m. and 4:00 p.m.

There are two bus stops located in the study corridor. Bus stop 612 is located along the north side of Reed Market Road approximately 700 east of SE 15th Street at Newberry Drive. Bus stop 613 is located approximately 1,400 feet to the north along the east side of SE 15th Street at Bronzewood Avenue. Bus stop 612 can be seen in Figure 2; bus stop 613 is just slightly out of the corridor influence area. The bus travels one way through the corridor and runs west along SE Reed Market Road before turning north onto SE 15th Street.

Emergency Response System

There are five Fire and Emergency Medical Staff (EMS) stations that serve the City of Bend. The station that primarily serves the study area is station 303 (South Station)¹⁴, which is located at 61080 Country Club Drive. This station is approximately 2.3 miles south west of the study corridor (via Murphy Road, Brosterhous Road, and American Lane). However, an emergency call to this area could come from any fire station within Bend, as the nearest fire station could be responding to another call when an emergency occurs in the study area. Therefore, the intersection design must accommodate EMS response from all approaches.

The main hospital in town is the St. Charles Medical Center. The medical center is located near the corner of NE Neff Road and NE 27th Street, which is approximately 3.3 miles (via SE 27th Street) northeast of the study corridor.

The Bend Police Department is located on 555 NE 15th Street, which is east of US 97 and just off of US 20 and approximately 1.4 miles north of the study corridor. The Deschutes County Sheriff's office and the Oregon State Police Patrol office are located near the north end of town where US 20 and US 97 converge approximately 6 miles northwest of the study corridor.

¹² Federal Highway Administration. *Rails-with-Trails: Lessons Learned*. August 2002. http://www.fhwa.dot.gov/environment/recreational_trails/publications/rwt/index.cfm. Accessed April 17, 2012.

¹³ Cascade East Transit, Bend Bus Service. *Route 6 Beak Creek*. <http://www.cascadeseasttransit.com/bend-schedule.html>. Accessed December 21, 2011.

¹⁴ City of Bend, *Station Locations*. <http://www.bendoregon.gov/index.aspx?page=335>. Accessed December 21, 2011.

An issue that was noted in several of the background documents was the concern for emergency response times. Due to the unpredictability of the delays associated with the at-grade rail road crossing (railroad crossing gates being down during an emergency), emergency response vehicles will often avoid the corridor altogether even if alternatives routes require greater travel distance. Emergency response time in the vicinity of Reed Market Road average seven to eight minutes (with longer response times during peak travel hours), and the City of Bend would like to reduce response times to four or five minutes.¹⁵ Ultimately a grade separated crossing would resolve this issue, but in the meantime considerations for detecting train activity at the crossing should be investigated to help EMS responders make more educated decisions about their travel routes during emergencies.

Land Use

The existing zoning within the study area is illustrated in Figure 3. A mix of residential, commercial, and industrial zoning exists along the study corridor. Near American Lane and SE 9th Street, light industrial is the primary land use type, while the remainder of the corridor is a mix of residential types with the exception of commercial convenience zoning on the northwest corner of SE Reed Market Road/SE 15th Street. Below are descriptions of the different zoning classifications in the study area:

- **Residential Urban Standard Density (RS):** The Standard Density Residential District is intended to provide opportunities for a wide variety of residential housing types at the most common residential densities in places where community sewer and water services are available. The residential density range in this district is 2.0 to 7.3 dwelling units per gross acre.¹⁶
- **Residential Urban Medium Density (RM):** The Medium Density Residential District is intended to provide primarily for the development of multiple family residential housing in areas where sewer and water service are available. The residential density range in the District is 7.3 to 21.7 units per gross acre shall provide a transitional use area between other residential districts and other less restrictive areas.¹⁷
- **Residential Urban Low Density (RL):** The Low Density Residential District consists of large urban residential lots that are served with a community water system and DEQ permitted community or municipal sewer systems. The residential density range in this district is 1.1 to 2.2 dwelling units per gross acre.¹⁸
- **Commercial Convenience (CC):** The Convenience Commercial District is adjacent and connected to the residential districts(s) it is intended to serve. Convenience Commercial

¹⁵ *Reed Market Corridor Study Existing Conditions Technical Report*. Parametrics, Inc., June 2005.

¹⁶ *Bend Code – Chapter 10-10 Development Code*, Section 2.1.100, <http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006>. Accessed January 24, 2012.

¹⁷ *Ibid.*

¹⁸ *Ibid.*

uses are larger in scale and area than neighborhood commercial uses and provide for frequent shopping and service needs of nearby residents. New Convenience Commercial nodes shall develop as commercial centers rather than a commercial strip and be limited in size up to 5 acres.¹⁹

- **Industrial Light (IL):** This zone is intended to provide for heavier commercial and light industrial uses with easy access to collector and arterial streets.²⁰

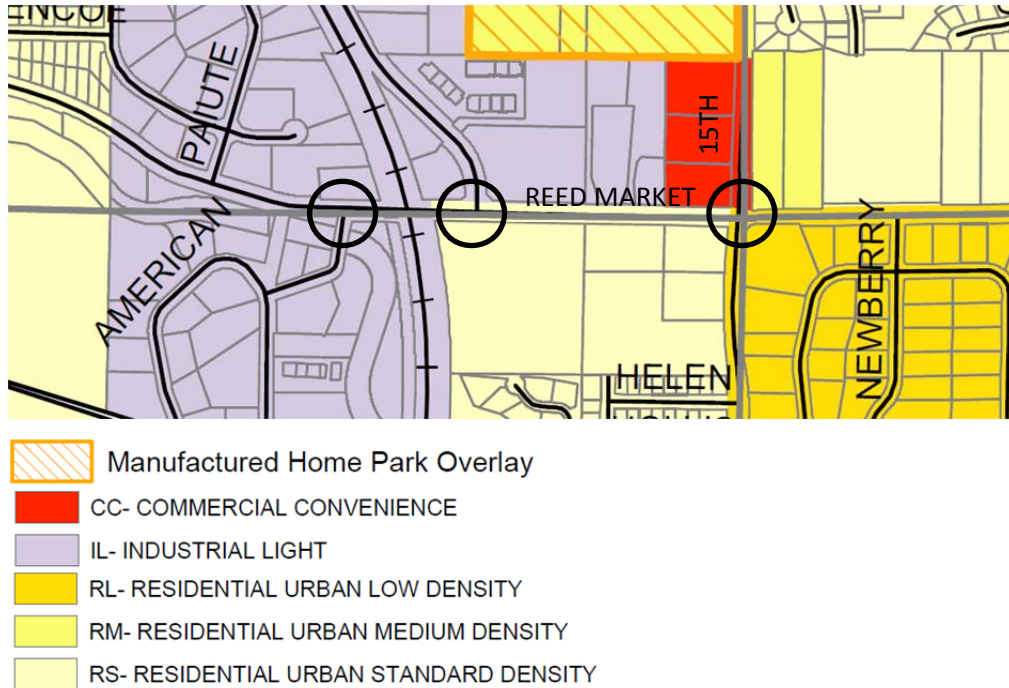


Figure 3: Existing Land Use Zoning

Access Management

With developed commercial, industrial, and residential land uses surrounding the study area, there are multiple existing accesses located along SE Reed Market Road, American Lane, SE 9th Street, and SE 15th Street. Existing access locations within the study area are shown in Figure 2. All existing accesses are full accesses (no turn restrictions) with the exception of the access located on the southeast corner of the SE Reed Market Road/American Lane intersection which is limited to right-in/right-out.

¹⁹ Bend Code – Chapter 10-10 Development Code, Section 2.2.200, <http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006>. Accessed January 24, 2012.

²⁰ Bend Code – Chapter 10-10 Development Code, Section 2.4.200, <http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006>. Accessed January 24, 2012.

The City of Bends Development Code²¹ provides standards with regards to access location, width, and spacing in order to meet operational performance standards and to preserve the functional classification of roadways. The City's code requires:

- All lots and parcels in all zones and all uses shall have one access point
- If a lot or parcel has frontage on two or more streets of different classification, the property shall access the street with the lowest classification.
- An additional access may be allowed when it is demonstrated that the additional access improves on-site circulation, and does not adversely impact the operations of the transportation system.
- The maximum distance achievable between two driveways or a driveway and an intersection shall be provided.
- Driveways shall be located to provide a vehicle in the driveway with an unobstructed view of the roadway for a sufficient distance.

Several accesses are currently located within close proximity to intersections and several parcels currently have multiple accesses. Additionally, there are multiple parcels within the study area that share accesses.

Bend Senior Center and Larkspur Park and Trail

The Bend Senior Center is a community center for gathering and activities for persons at least 50 years old. The center is located east of the SE Reed Market Road/SE 15th Street intersection (See Figure 2). The center is owned and operated by the Bend Park & Recreation District with a focus to promote healthy lifestyles through health, education, recreation, socialization and volunteer opportunities. The center offers a variety of programs, classes, and activities for senior members within the City of Bend.²² As such, safe and efficient infrastructure improvements to and from the senior center should be included where reasonable in the Reed Market Road Corridor project.

Larkspur Park is a companion to the Bend Senior Center and offers traditional neighborhood amenities on a 14.5 acre facility. The park has playgrounds, benches, paver walkways, includes Larkspur Trail (See Figure 2), a restroom, a meadow, a shade shelter, bocce and horseshoe courts, and a picnic shelter among other active areas. Larkspur trail is 1.75 miles in length and begins in the Larkspur Park near the Bend Senior Center.²³ The Larkspur trail travels north from

²¹ ²¹ *Bend Code – Chapter 10-10 Development Code*, Section 3.1.400, <http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006>. Accessed January 24, 2012.

²² *Bend Senior Center*. Bend Park & Recreation District. http://www.bendparksandrec.org/Senior_Center/. Accessed April 18, 2012.

²³ *Park and Trail Directory*. Bend Park & Recreation District. http://www.bendparksandrec.org/Parks_Trails/Park_list/. Accessed April 18, 2012.

the Bend Senior Center and provides access to the Pilot Butte State Park and the Pilot Butte Middle School. Connecting the trail at the Bend Senior Center to the Central Oregon Canal Trail should be an objective of the corridor design. Currently the Central Oregon Canal Trail ends at American Lane and runs along the north side of the Central Oregon Canal.

Intersection Use

This section identifies the users of the transportation system within the study corridor and quantifies the existing motor vehicle, pedestrian, and bicycle use during the AM and PM peak hours. In addition, motor vehicle volumes forecasted for the future year 2030 are provided.

Existing Vehicular Volumes

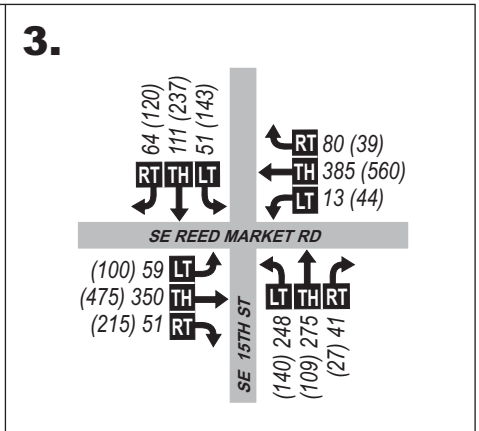
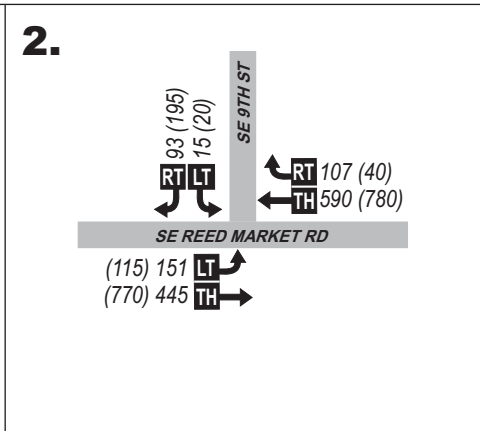
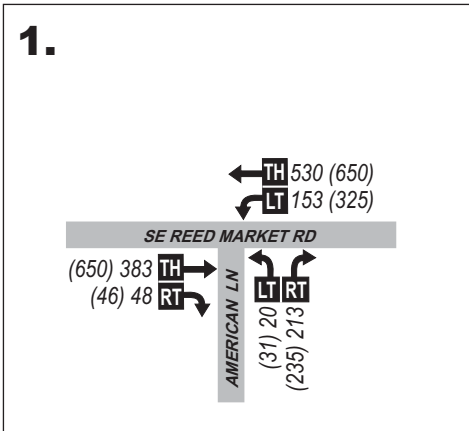
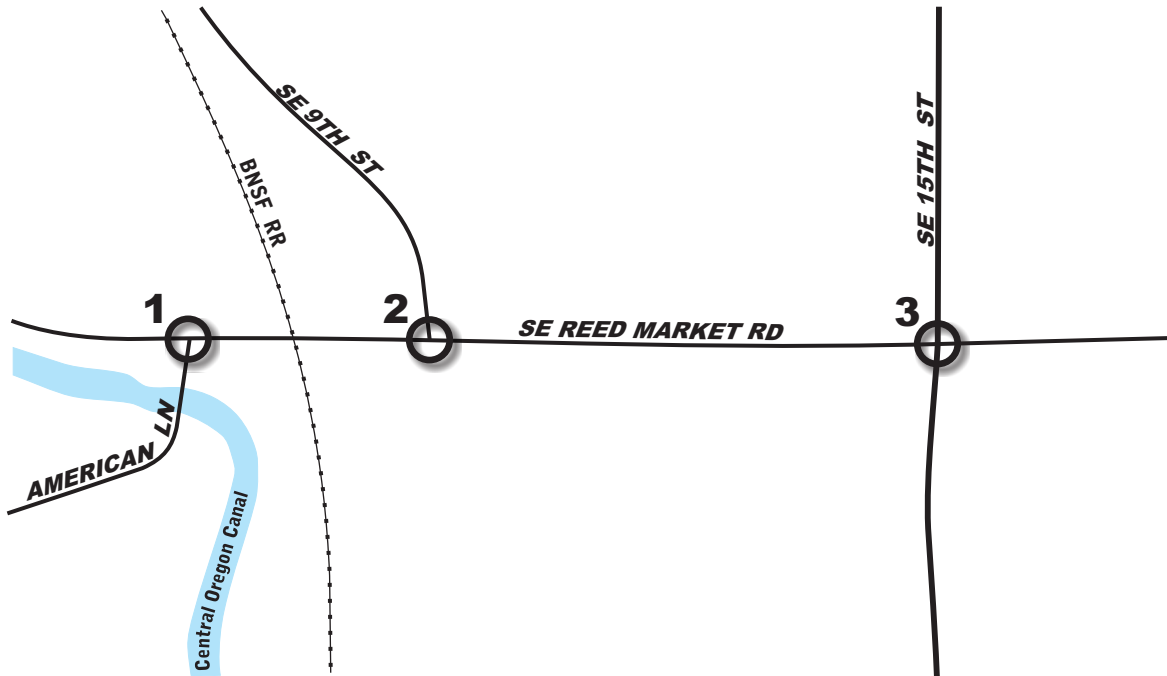
Intersection motor vehicle turn movements were collected at the three study intersections during the AM (7:00-9:00) and PM (4:00-6:00) weekday peak periods and are shown in Figure 4.²⁴ The traffic counts are attached in Appendix A. These peak time periods were selected because this is the time when motor vehicle volumes are typically highest.

Traffic counts at the intersection of SE Reed Market Road/American Lane indicate a total of approximately 1,350 and 1,930 entering vehicles during the AM and PM peak hours, respectively. Volumes are greatest along SE Reed Market Road with about 100 more vehicles traveling westbound rather than eastbound during both peak hours. Along American Lane, volumes do not significantly vary between the AM and PM peak hours.

At the intersection of SE Reed Market Road/SE 9th Street, a total of approximately 1,350 and 1,950 vehicles enter the intersection during the AM and PM peak hours, respectively. During the AM peak hour, westbound traffic is higher than eastbound traffic; however during the PM peak hour, volumes are almost balanced along SE Reed Market Road. Along SE 9th Street, roughly a hundred more vehicles are headed southbound during the PM peak hour compared to the AM peak hour.

Traffic counts at the intersection of SE Reed Market Road/SE 15th Street indicate a total of approximately 1,730 and 2,140 entering vehicles during the AM and PM peak hours, respectively. Volumes are greatest along SE Reed Market Road and are balanced in the eastbound and westbound direction during both peak periods. During the AM peak hour, traffic volumes are highest along NE 15th Street in the northbound travel direction. During the PM peak hour, this peak direction flow reverses to the southbound direction.

²⁴ Intersection turn movement counts, Quality Counts, November 1, 2011, and April 19, 2012.



LEGEND

- 1** - Study Intersection & Number
- AM (PM) - 2011 Peak Hour Traffic Volumes
- ← TH →
← LT →
← RT →
Left • Thru • Right

DKS



No Scale

Figure 4

**Reed Market Corridor
2011 AM/PM PEAK HOUR
TRAFFIC VOLUMES**

American Lane & SE 9th Street Origin-Designation Investigation

Traffic data was collected to determine the number of vehicles traveling in the north-south direction using both American Lane and SE 9th Street, which results in the use of SE Reed Market Road to make the connection with potentially a large number of turning movements. Figure 5 shows the percentages of vehicles making turn movements at the two study intersections. Almost 50 percent of all northbound and southbound travel makes the connection between American Lane and SE 9th Street.

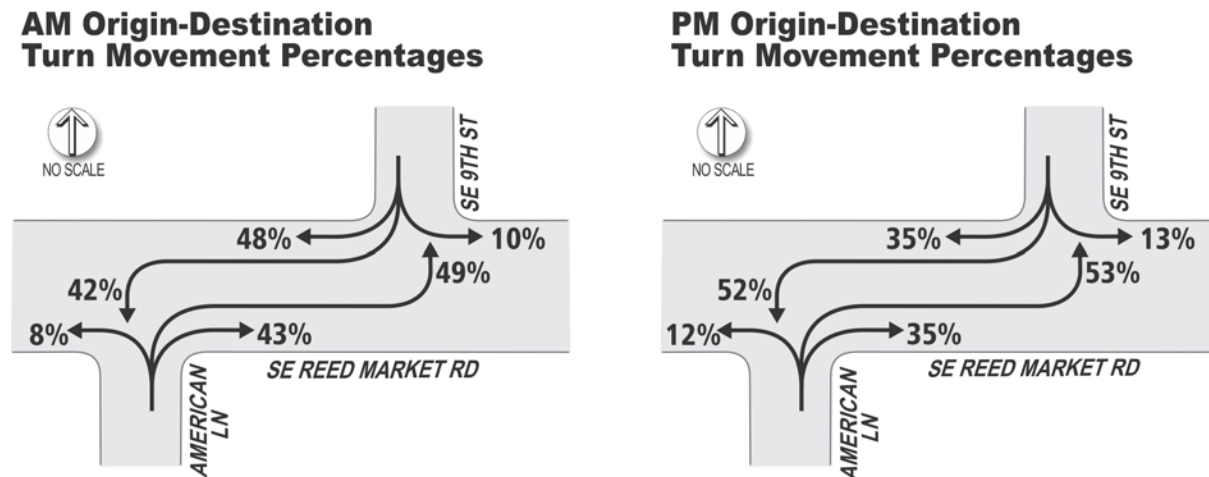


Figure 5: American Lane & SE 9th Street Origin-Destination Percentages

Pedestrian Volumes

Observed pedestrian activity along the study corridor is relatively low, although the time of year of the traffic counts (early November) is not likely to represent peak pedestrian activity. During the AM and PM peak hours, no more than five pedestrians per hour were observed at a study intersection during the AM or PM peak hour. At SE Reed Market Road/American Lane, one pedestrian was counted crossing the south and east leg of the intersection during the AM peak hour. During the PM peak hour two pedestrians were counted crossing the west leg of the study intersection. At SE 9th Street only one pedestrian was observed during the AM peak hour and the pedestrian was traveling along the south side of SE Reed Market Road. During the PM peak hour, no pedestrians were recorded.

At the intersection of SE Reed Market Road/SE 15th Street, no pedestrians were counted at the intersection during the AM peak hour while five were counted during the PM peak hour. Pedestrians counted during the PM hour were observed as crossing SE Reed Market Road on the east and west legs only. The intersection is currently signalized and features protected pedestrian crossing phases with crosswalks located on all four legs of the intersection.

Schools attended by students living along study corridor include Bear Creek Elementary, R.E. Jewell Elementary, Pilot Butte Middle School, High Desert Middle School, and Bend High School. According to the district boundaries, students living along the study corridor would

attend Bear Creek Elementary School, except for those students living on American Lane, which would then attend R.E. Jewell Elementary School.²⁵ Middle school students living north of SE Reed Market Road would attend Pilot Butte Middle School and middle school students living south of SE Reed Market Road would attend High Desert Middle School.²⁶ High school students living along the study corridor would attend Bend High School.²⁷

Students living in residential housing along the north side of SE Reed Market Road would be in the very outer limits of the typical one-mile walking distance boundary to Bear Creek Elementary and Bend High School.

Bicyclist Volumes

At the intersection of SE Reed Market Road/SE American Lane, one bicyclist was observed in the AM peak hour headed westbound through the study intersection. During the PM peak hour, one bicyclist was observed headed eastbound and five cyclist were observed making westbound lefts onto American Lane. Bike lanes are present along SE Reed Market Road.

At the intersection of SE Reed Market Road/SE 9th Street during the AM peak, two bicyclists were observed headed eastbound, and one was observed headed westbound. During the PM peak, two bicyclists each were observed making eastbound lefts, southbound rights, and westbound through movements. Bike lanes exist along all legs of the study intersection.

During the AM peak hour at the intersection of SE Reed Market Road/SE 15th Street, one bicyclist was observed headed westbound, and one was observed making a northbound left. During the PM peak, two bicyclists were observed headed eastbound, one was headed westbound, one was headed northbound, and the last was headed southbound. Bike lanes exist along all legs of the study intersection.

²⁵ *Elementary School Boundary Map 2008*. Bend-La Pine School District.
<http://www.bend.k12.or.us/education/page/download.php?fileinfo=YmxzMdHfZWxlbS5wZGY6Ojovd3d3L3NjaG9vbHMvc2MvYmVuZC9pbWFnZXMvZG9jbWdyLzZMxNV9maWxIXzM3NzdfbW9kXzEyMTcyNzgzNDAucGRm> Updated in 2008. Accessed January 24, 2012.

²⁶ *Middle School Boundaries 2011*. Bend-LaPine School District.
<http://www.bend.k12.or.us/education/page/download.php?fileinfo=TVNfQm91bmRhcmllc18yMDExLnBkZjo6Oi93d3cvc2Nob29scy9zYy9iZW5kL2ltYWdlcy9kb2NtZ3IvNzE0ZmlsZTk1MTUucGRm> Updated in 2011. Accessed January 24, 2012.

²⁷ *High School Boundaries*. Bend-La Pine School District.
<http://www.bend.k12.or.us/education/page/download.php?fileinfo=YmxzMdHfaGlncC5wZGY6Ojovd3d3L3NjaG9vbHMvc2MvYmVuZC9pbWFnZXMvZG9jbWdyLzZMxNV9maWxIXzM3NzdfbW9kXzEyMTcyNzgzNDAucGRm> Updated in 2008. Accessed January 24, 2012.

Special Users

As described in previous sections, the study area is located near the City of Bend Senior Center, schools, and multiple residential and business land use types. The northeast and southwest land parcels on the corner of SE Reed Market Road/SE 15th Street are currently under developed residential land uses. The development of these land parcels may attribute to greater vehicle, bicycle, and pedestrian volumes at this intersection. Based on the variety of land use types, there could be a need for special users to maneuver through the corridor. These special users could be those with physical disabilities, elderly, or school children. The recommended intersection design should account for these potential user types.

Design Vehicles

With any intersection design, a design vehicle needs to be selected that then influences the footprint of the intersection and ensures that a selected vehicle type can navigate safely through an identified approach. Typically this design vehicle is an emergency vehicle (a fire truck), but in the case where larger heavy vehicles are present, those vehicle types will serve as the design vehicle. Capturing the vehicle types using an intersection is done by collecting detailed vehicle classification counts. These counts were collected at the three study intersections to help select the appropriate design vehicle.

SE Reed Market Road/American Lane

SE Reed Market Road is classified as a major arterial and American Lane is classified as a major collector. Both streets are subject to varying vehicle types and are designated as local freight routes.²⁸ Local freight routes are intended to provide freight activity within the City, which complements the existing industrial activities near the study intersection.

To provide more detailed information about the types of vehicles using the study intersection, a detailed vehicle classification study was conducted as part of the AM peak period count (7:00 a.m. – 9:00 a.m.) at the intersection utilizing the Federal Highway Administration’s 13 standard vehicle classes (see Table 2 and Appendix B). This data demonstrated that several tractor-trailer vehicles use the study intersection today along SE Reed Market Road. These vehicles are equivalent to a five-axle double unit truck (WB-67 – Interstate Semitrailer) and smaller.

²⁸ 2007-2030 Metropolitan Transportation Plan, Bend Metropolitan Planning Organization, Figure 11-1, Adopted June 27.

Table 2: Vehicle Classification at SE Reed Market Road/American Lane (AM Peak Period)

Intersection Approach	Vehicle Classification				
	Passenger Car	Single Unit Truck	Tractor/Trailer	Tractor/Multi-Trailer	Low Boy Trailer
Northbound	468	6	0	0	0
Eastbound	761	34	8	0	0
Westbound	1229	40	8	0	1
Total	2458	80	16	0	1

Passenger Car = Vehicle class 1, 2, and 3
 Single Unit Truck = Vehicle class 4, 5, 6, and 7
 Tractor/Trailer = Vehicle class 8, 9, and 10
 Tractor/Multi-Trailer = Vehicle class 11, 12, and 13

The City’s base design vehicle is a WB-50; however, due to the industrial areas and freight routes served by this intersection, the design vehicle recommended along SE Reed Market Road is a WB-67. A double as well as a “lowboy” style trailer should be accommodated for all east-west movements at this intersection. Along American Lane, the recommended design vehicle is a WB-50 and American Lane should be able to accommodate a WB-67 (allowing the truck cab to stay in-lane with the trailer potentially tracking onto the truck apron).

SE 9th Street

A 24-hour vehicle classification count was collected on the north leg of SE 9th Street, however to be consistent with the count taken at SE Reed Market Road/American Lane, just the AM peak hour volumes were evaluated. SE Reed Market Road is classified as a major arterial and SE 9th Street is classified as a minor arterial. SE 9th Street is also classified as a local freight route.²⁹ The local freight route designation means that SE 9th Street is more likely to be used by a variety of larger vehicles accessing the existing industrial activities along the roadway.

To provide more detailed information about the types and frequency of larger vehicles using the intersection, a vehicle classification study was conducted using the Federal Highway Administration’s 13 standard vehicle classes (see Table 3 and Appendix B) during the AM peak period (7:00 a.m. – 9:00 a.m.). The classification found that several tractor-trailers are using SE 9th Street today. These vehicles are equivalent to 5-axle double unit truck (WB-67 - Interstate Semitrailer) and smaller.

²⁹ 2007-2030 Metropolitan Transportation Plan, Bend Metropolitan Planning Organization, Figure 11-1, Adopted June 27.



Table 3: Vehicle Classification at SE Reed Market Road/SE 9th Street (AM Peak Period)

Intersection Approach	Vehicle Classification			
	Passenger Car	Single Unit Truck	Tractor/Trailer	Tractor/Multi-Trailer
Northbound	472	86	4	0
Southbound	251	44	8	0
Total	723	130	12	0

Passenger Car = Vehicle class 1, 2, and 3
Single Unit Truck = Vehicle class 4, 5, 6, and 7
Tractor/Trailer = Vehicle class 8, 9, and 10
Tractor/Multi-Trailer = Vehicle class 11, 12, and 13

As was noted previously, the City’s base design vehicle is a WB-50. However, due to the number of larger vehicles shown in the count using SE 9th Street, the recommended design vehicle is a WB-67 and the approaches should accommodate a double as well as a “lowboy” style trailer. To be consistent with the design of SE Reed Market Road/American Lane, the recommended design vehicle along SE Reed Market Road should also be a WB-67 and the approaches should accommodate a double as well as a “lowboy” style trailer.

SE Reed Market Road/SE 15th Street

SE Reed Market Road is classified as a major arterial while SE 15th Street is classified as a minor arterial. They are, therefore, subject to varying modes of vehicle types. Both SE Reed Market Road and SE 15th Street are designated as future local freight routes³⁰. Local freight routes are intended to provide freight activity within the City. Therefore, this intersection is likely subject to larger vehicles than other areas within the City (e.g., local streets in neighborhoods) that only generally see emergency vehicles, garbage trucks, and school buses.

To provide more detailed information about the types of large vehicles that currently utilize the intersection, a detailed vehicle classification study was conducted as part of the AM peak period count (7:00 a.m. – 9:00 a.m.) at the intersection utilizing the Federal Highway Administration’s 13 standard vehicle classes (see Table 4 and Appendix B). This classification found that several tractor-trailer vehicles use the intersection today. These vehicles are equivalent to 5-axle double unit truck (WB-67 - Interstate Semitrailer) and smaller. The most common larger vehicle type recorded at the study intersection was a class 10 (11 total), which is equivalent to a truck with six or more axles consisting of two units.

³⁰ 2007-2030 Metropolitan Transportation Plan, Bend Metropolitan Planning Organization, Figure 11-1, Adopted June 27.

Table 4: Vehicle Classification at SE Reed Market Road/SE 15th Street (AM Peak Period)

Intersection Approach	Vehicle Classification			
	Passenger Car	Single Unit Truck	Tractor/Trailer	Tractor/Multi-Trailer
Southbound	371	19	7	0
Northbound	911	23	1	0
Eastbound	840	28	10	0
Westbound	885	30	17	0
Total	3007	100	35	0

Passenger Car = Vehicle class 1, 2, and 3

Single Unit Truck = Vehicle class 4, 5, 6, and 7

Tractor/Trailer = Vehicle class 8, 9, and 10

Tractor/Multi-Trailer = Vehicle class 11, 12, and 13

The City's base design vehicle is a WB-50; however, due to the industrial areas and freight routes served by this intersection, the recommended design vehicle is a WB-67 for all movements. In addition, a double as well as a "lowboy" style trailer should be accommodated for all movements at this intersection. Under roundabout control, these "accommodated" vehicles would be allowed to use the apron; however, the apron height should be verified so that a "lowboy" trailer will not get high centered.

Additionally, at roundabout controlled intersections, the City's design guidelines require that emergency vehicles be accommodated at the intersection without the use of truck aprons or mountable curbs.

Baseline Performance

This section summarizes intersection safety, presents future 2030 volumes, and evaluates existing and baseline future year 2030 intersection operations. The purpose is to form a baseline for which future conditions can be compared to.

Safety

To evaluate safety at the existing intersections, the most recent three years of collision records at the three study intersections were obtained from the Oregon Department of Transportation (ODOT) and are attached in the Appendix C.³¹ Using the proportionality of the number of vehicles entering an intersection and the total number of collisions experienced, a collision rate describing the frequency of collisions per million entering vehicles (MEV) was calculated. This collision rate is used to determine if the number of collisions recorded is significant enough to

³¹ ODOT Collision Data for January 1, 2008 through December 31, 2010.

indicate that there may be a safety issue. A collision rate of 1.0 MEV or greater typically warrants further investigation. As listed in Table 5, the collision rate at the three study intersections measured over the previous three years are all below the 1.0 threshold. Being below the 1.0 threshold indicates that a significant safety problem may not exist. More details about the collisions that did occur during the study period are given below.

Table 5: Intersection Collision Summary (2008-2010)

Intersection	Collisions By Year			Total	Collision Severity			Collision Rate ^b
	2008	2009	2010		Fatal	Injury	PDO ^a	
SE Reed Market Rd./American Ln	8	4	1	13	0	6	7	0.66
SE Reed Market Rd./SE 9th St.	5	3	3	11	0	3	8	0.55
SE Reed Market Rd./SE 15 th St.	5	4	6	15	0	5	10	0.69

^aPDO = Property damage only.

^bAverage annual collisions per million entering vehicles (MEV); MEV based on PM Peak Hour Volumes.

At the intersection of SE Reed Market Road/American Lane, 13 collisions occurred between 2008 and 2010. Nine of the 13 collisions occurred because vehicles ran the stop sign or proceeded through the intersection without having the right of way. Most of these collisions occurred with people leaving or entering American Lane and just under half of the collisions resulted in minor or moderate injuries. In addition to the ODOT collision records, the City of Bend provided 2011 (January through November) collision records.³² Within that time period one additional collision occurred at the study intersection during October when a vehicle veered off the road onto the shoulder and hit a fire hydrant.

Eleven total collisions occurred at the intersection of SE Reed Market Road/SE 9th Street from 2008 to 2010. Ten of the eleven collisions were characterized as rear-end collisions. The majority of the injuries resulted in property damage only. In addition to the ODOT collision records, the City of Bend provided 2011 (January through November) collision records.³³ Within that time period, two additional collisions occurred at the study intersection. One collision occurred during March and the other during April and both were rear end collisions where injuries and property damage occurred.

At the intersection of SE Reed Market Road/SE 15th Street, of the 15 collisions that occurred between 2008 and 2010, 12 were classified as rear end. This is a common collision type observed at traffic signal controlled intersections. A majority of these collisions resulted in property damage only. There was one major injury collision reported at the intersection that occurred as a

³² City of Bend Police Department, 2011 Bend Crashes through November 2011.

³³ *Ibid.*

result of an improper turn. The remaining four injury related collisions were either moderate or minor. In addition to the ODOT collision records, the City of Bend provided 2011 (January through November) collision records³⁴. Within this time frame, two additional collisions have occurred at the study intersection. Both collisions were rear end collisions. One of the collisions resulted in injury, while the other collision just resulted in property damage only. The collision records specific to additional City of Bend data can also be found in Appendix C.

Future Volumes

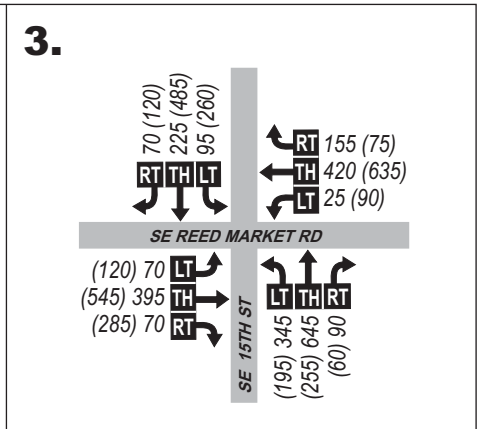
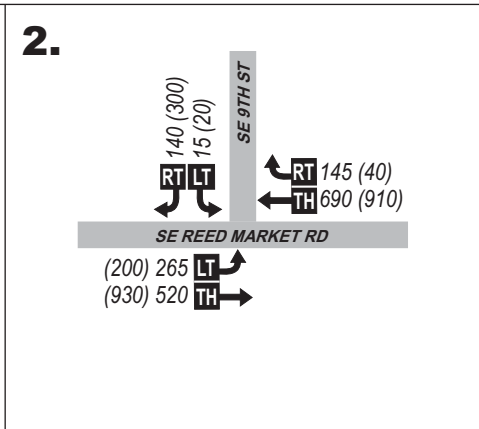
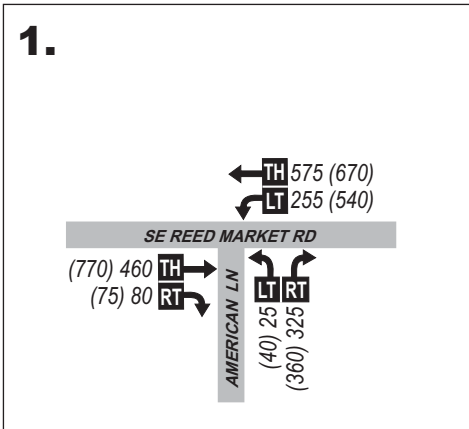
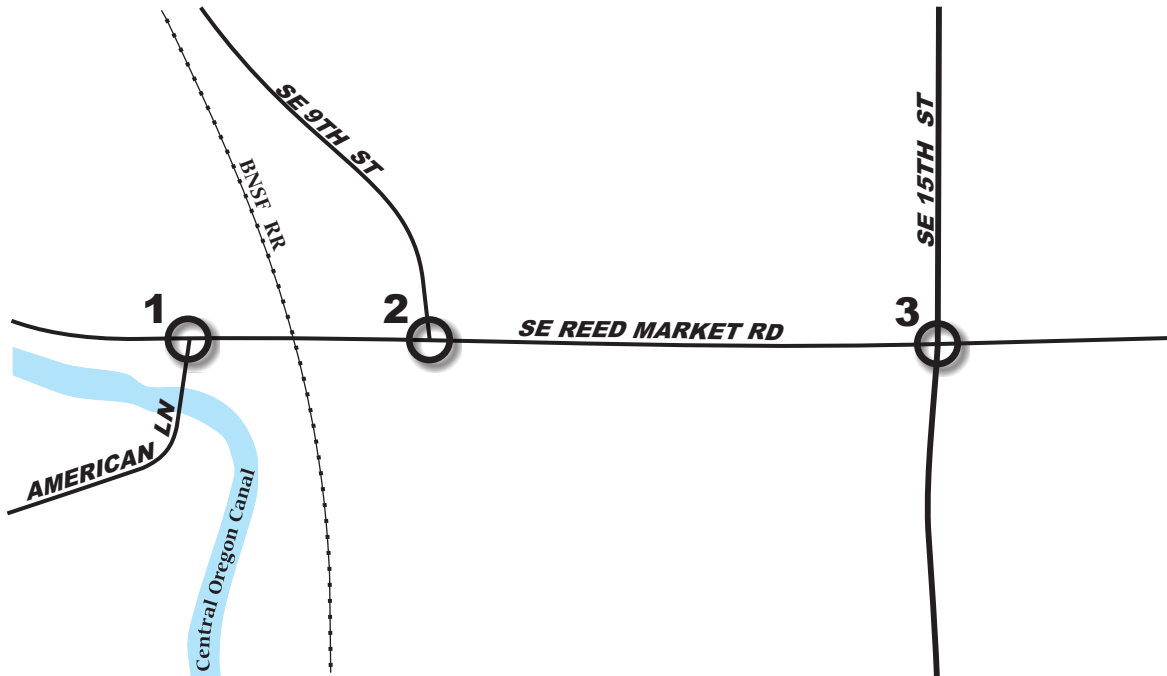
Future motor vehicle traffic demand for the study area was forecasted to the year 2030 to analyze future traffic operations. The future 2030 peak period turn movement volumes were developed using the Bend MPO's regional travel demand model. The scenario used is based on the "Financially Committed" network scenario, which does not include any significant capacity improvement projects near the study area.

In order to test the sensitivity of the planned Murphy Overcrossing Improvements Full-Build Scenario (including an extension east over the railroad and canal to SE 15th Street), the regional travel demand model was used to test the network sensitivity to adding this connection. The comparison found that the forecasted traffic volume growth along the SE Reed Market corridor was not significantly affected with the potential Murphy Road extension.

Traffic forecasts were "post processed" following a methodology consistent with NCHRP Report 255³⁵. The resulting future 2030 AM and PM peak hour turn movement volumes for the intersection are shown in Figure 6. Significant growth is occurring in the north-south direction along with associated turn movements and limited growth is occurring along the east-west Reed Market Corridor. In addition, the O-D pattern between SE 9th Street and American Lane continues to grow significantly. This non-uniform increase in traffic demand over the study area indicates that additional capacity may be needed to serve crossing and turning movements within the study area, but that overall corridor through capacity may not require significant change compared to the existing 3-lane configuration.

³⁴ *Ibid.*

³⁵ *Highway Traffic Data for Urbanized Area Project Planning and Design - National Cooperative Highway Research Program Report 255*, Transportation Research Board, Washington D.C., 1982.



LEGEND

- 1** - Study Intersection & Number
- AM (PM) - 2030 Peak Hour Traffic Volumes
- Left•Thru•Right - Volume Turn Movement

DKS



No Scale

Figure 6

**Reed Market Corridor
2030 AM/PM PEAK HOUR
TRAFFIC VOLUMES**

Intersection Operations

The following sections outline the City of Bend's intersection performance measures and intersection operational standards for various intersection control types.

Measures of Effectiveness

The City of Bend uses four measures of effectiveness (MOEs) to evaluate the operations of an intersection. These measures include the volume to capacity ratio, queuing, level of service, and delay. A combination of these four measures is used to evaluate two-way stop controlled, all-way stop controlled, signalized, and roundabout controlled intersections. A summary of each of the MOEs is given below.

Volume to Capacity Ratio

The volume to capacity ratio is a measure used to represent the level of saturation (i.e., the portion of capacity that is being used). It is given as a decimal typically between 0.00 and 1.00 and is determined by dividing the peak hour traffic volume by the hourly capacity of a given intersection or movement. A lower ratio indicates smoother operations and lower delays. As the ratio approaches 1.00, congestion increases and performance is reduced. If the forecasted ratio is greater than 1.00, the intersection, lane, or movement is oversaturated and usually results in excessive queues and long delays.

Queuing

Queuing reports typically indicate the 95th percentile queue, defined to be the length of queue that is exceeded five percent of the time during the analysis time period. The 95th percentile queue is useful in determining the appropriate length of turn pockets, but is not representative of what an average driver would experience.

Level of Service

The level of service (LOS) is a measure of effectiveness that is similar to a "report card" rating and is based on average vehicle delay. Level of service A, B, and C indicate conditions where traffic moves without significant delays over periods of peak hour travel demand. Level of service D and E are progressively worse operating conditions. Level of service F represents conditions where average vehicle delay has become excessive and demand is near capacity. The average delay value (in seconds) corresponds to each level of service designations.

The unsignalized level of service calculation evaluates each movement separately to identify problems (typically left turns from side streets). The calculation is based on the average total delay per vehicle for stop-controlled movements (typically on the minor side street or left turn movements). Level of service F indicates that there are insufficient gaps of suitable size to allow minor street traffic to safely enter or cross the major street. This is generally evident by long delays and queuing on the minor street.

Delay

The City's operational performance standard for roundabouts is measured against a volume to capacity ratio, but delay is used to compare alternative intersection forms to a roundabout. Typically under the same traffic conditions, a roundabout would result in lower overall delay than traffic signals and all-way stop control, but may result in higher overall delay than a two-way stop controlled intersection.

Agency Intersection Operational Standards

The City of Bend has established operation standards for two-way stop control intersections, all-way stop control intersections, roundabouts, and signalized intersections under the jurisdiction of the City of Bend. Below are the operational standards from the Bend Code – Chapter 10-10 Development Code.³⁶

- Two-Way Stop Control – Approaches with greater than 100 peak hour trips; average delay for the critical lane group is less than or equal to 50 seconds during the Peak Hour;
- All-Way Stop Control – Average delay for the intersection as a whole is less than or equal to 80 seconds during the Peak Hour;
- Roundabout – Volume to capacity ratio for the intersection as a whole is less than or equal to 1.0 during the Peak Hour;
- Signalized Intersection under the jurisdiction of the City of Bend:
 - For intersections that are not constructed to the widths and infrastructure elements of the Bend Urban Transportation System Plan or other approved master plan and not located within or directly adjoining a historic district of Central Business Zone, the volume to capacity ratio for the intersection as a whole is less than or equal to 1.0 during the Peak Hour.
 - For intersections that are not constructed to the widths and infrastructure elements of the Bend Urban Area Transportation System Plan or other approved master plan and are located within or directly adjoining a historic district or Central Business Zone, the volume to capacity ratio for the intersection as a whole is less than or equal to 1.0 during the hour directly preceding and following the Peak Hour.
 - For intersections that are already constructed to the widths and infrastructure elements of the Bend Urban Area Transportation System Plan or other approved master plan, the operation standard shall be a volume-to-capacity ratio less than or equal to the 1.0 for the intersection as a whole during the hour directly preceding and following the Peak Hour.

³⁶ Bend Code – Chapter 10-10 Development Code. Section 4.7.400 Part B.
<http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006> Accessed on December 12, 2011.

Existing Intersection Operations

Intersection traffic operations were analyzed along the study corridor using the Synchro 7TM software, which employs the *2000 Highway Capacity Manual (HCM)*³⁷ methodology for signalized and unsignalized intersections. The following sections summarize existing and future peak hour intersection operations at the study intersection. Table 6 summarizes the AM and PM peak hour intersection operations at intersections along the study corridor. The existing HCM level of service outputs can be found in Appendix D.

Table 6: Existing 2011 Intersection Operating Conditions (AM/PM Peak Hour)

Intersection Operations	Existing 2011					
	AM Peak Hour			PM Peak Hour		
	Delay	LOS	V/C	Delay	LOS	V/C
<i>Unsignalized Intersections</i>						
SE Reed Market Rd./American Ln.	18.3	A/C	0.50	66.0	B/F	0.91
SE Reed Market Rd./SE 9th St.	19.2	B/C	0.06	32.1	B/D	0.63
<i>Signalized Intersections</i>						
SE Reed Market Rd./SE 15 th St.	35.5	D	0.79	47.7	D	0.91
Signalized Intersections	Unsignalized Intersections					
Delay = Average Intersection Delay (sec.)	Delay = Critical Movement Approach Delay (sec.)					
LOS = Intersection Level of Service	LOS = Major Street LOS/Minor Street LOS					
V/C = Intersection Volume-to-Capacity Ratio	V/C = Critical Movement Volume-to-Capacity Ratio					

At the two unsignalized study intersections, the City of Bend standard is the average delay for the critical lane group to be less than or equal to 50 seconds during the peak hour. The intersection at SE Reed Market Road/SE American Lane meets this standard during the AM peak but exceeds the standard during the PM peak by 16 seconds. At the intersection of SE Reed Market Road/SE 9th Street, the City of Bend standards are met for the unsignalized intersection during both the AM and PM peak hours.

The average intersection delays experienced at SE Reed Market Road/SE 15th Street is represented by LOS D conditions during the AM and PM peak hours. This intersection currently meets the City's signalized operational standard during the AM and PM peak hour (v/c <1.0 seconds).

Although the intersection of SE Reed Market Road/SE 15th Street currently meets the City's operational standard, it does experience several long queues, primarily during the PM peak hour.

³⁷ *2000 Highway Capacity Manual*, Transportation Research Board, Washington DC, 2000.

A field visit³⁸ revealed that queues along the eastbound, westbound, and southbound approaches can extend up to twenty vehicles or more on several cycles during the PM peak hour. These movements currently operate near capacity. It was also observed during the field visit that all left turns at the study intersection are operating on minimum recall due to loop detector failure; therefore, this intersection is not operating as efficiently as it could be during peak periods. This could result in longer queues along SE Reed Market Road and SE 15th Street.

One important issue which is not captured in the capacity analysis is the at-grade rail crossing located between the two study intersections. When the crossing closes for a BNSF train, queues extend from the crossing back into both adjacent intersections and potentially all the way to SE Reed Market Road/SE 15th Street.³⁹

Future 2030 No-Build Intersection Operations

Table 7 summarizes the future 2030 “Financially Committed Scenario” AM and PM peak hour intersection operations under existing intersection control and geometry. As listed, each intersection fails to meet City mobility standards due to the increased traffic volumes. At the intersection of SE Reed Market Road/SE 15th Street, operations would degrade to LOS F and a v/c ratio above 1.0 during both peak periods. At the unsignalized intersections, operations would fail during the PM peak period. The HCM operations output for this scenario can be found in Appendix E.

Table 7: Future 2030 Financially Committed Scenario Intersection Operating Conditions (AM/PM Peak Hour)

Intersection Operations	Future 2030 Financially Committed Scenario					
	AM Peak Hour			PM Peak Hour		
	Delay	LOS	V/C	Delay	LOS	V/C
<i>Unsignalized Intersections</i>						
SE Reed Market Rd./American Ln.	40.4	B/E	0.83	>200	D/F	>2.0
SE Reed Market Rd./SE 9th St.	34.5	C/D	0.12	>200	C/F	1.31
<i>Signalized Intersections</i>						
SE Reed Market Rd./SE 15 th St.	166.8	F	1.27	131.0	F	1.26
Signalized Intersections			Unsignalized Intersections			
Delay = Average Intersection Delay (sec.)			Delay = Critical Movement Approach Delay (sec.)			
LOS = Intersection Level of Service			LOS = Major Street LOS/Minor Street LOS			
V/C = Intersection Volume-to-Capacity Ratio			V/C = Critical Movement Volume-to-Capacity Ratio			

³⁸ DKS Field Visit January 11, 2012 and January 12, 2012.

³⁹ Lewis, R, City of Bend. (2011, January 11). Personal interview.

CHAPTER 4 - CONCEPT DEVELOPMENT AND SCREENING

Due to the complex nature of the SE Reed Market corridor (e.g., an active at-grade rail crossing, heavy turn movements, and closely spaced major intersections), a corridor level concept development and screening process was undertaken for the study area to identify alternatives for year 2030 conditions that would warrant refined evaluation with the City of Bend's intersection form evaluation process. The process included an initial concept brainstorming work session with City staff and consultant team members including specialists in traffic, conceptual design, roadway engineering, and rail crossings. From the initial concepts, a preliminary traffic operations and concept screening process completed to identify projects to move into refined evaluation. The following sections describe each of the corridor concepts considered and summarize recommendations for moving concepts into refined evaluation.

Preliminary Corridor Improvement Concepts

Through the initial concept development work session, several key design issues and approaches were discussed that helped shape the various alternatives, including:

- Develop options for both roundabout and traffic signal control
- Develop options that address queuing issues at the at-grade rail crossing
- Avoid alternatives that would impact Central Oregon Irrigation District right of way (i.e., more than the planned realignment of American Lane)
- Consider how the SE 9th Street-SE American Lane travel pattern can be accommodated
- Develop alternatives that can minimize the number of through lanes required, with a goal of identifying a concept that can accommodate a three-lane corridor on SE Reed Market
- Where additional through lanes are needed for capacity, provide continuity as feasible through the study area (accounting for lane utilization imbalances due to lane drops)
- Consider access impacts, including options to provide alternate routes
- Develop options that are safe for all modes of travel

Based on these general guidelines, six preliminary concepts were identified, as described below (full concept layouts are provided in Appendix F):

1. Roundabouts (Superstreet) Configuration

The first alternative developed explored how to provide roundabout control for each of the study intersections. Due to spacing constraints near the railroad (i.e., adequate space to provide safe stopping sight distance for vehicles exiting the roundabout towards the rail crossing), the alternative took the form of a Superstreet that uses medians to restrict turn movements and roundabouts to provide U-turn opportunities. Access to American Lane would be restricted to right-in/right-out with a U-turn opportunity at a new intersection created on SE Reed Market Road west of Paiute Way (an extension of Centennial Boulevard). Access to SE 9th Street would also be restricted to right-in/right-out with a U-turn opportunity at a new intersection created on SE Reed Market Road east

of SE 9th Street. The intersection at SE 15th Street would be a standard multi-lane roundabout. Overall, this concept would result in a four to five lane cross section on SE Reed Market in the study area.

2. Diagonal Roundabout (West) Roundabout (East) Configuration

Concept 2 is similar to Concept 1 at the east end of the corridor with a multi-lane roundabout at SE 15th Street. However, Concept 2 varies significantly at American Lane and SE 9th Street. Instead of providing shifted roundabouts away from the current intersection locations, Concept 2 realigns SE 9th Street and American Lane to provide a new through route that connects the two corridors and intersections SE Reed Market Road at the railroad crossing. This option would reduce the turning movements on SE Reed Market Corridor by directly aligning the key north-south route of American Lane and SE 9th Street. Overall, this concept would result in a four to five lane cross section on SE Reed Market in the study area (with potential to narrow back down to three lanes between the roundabouts).

3. Typical Traffic Signals Configuration

Concept 3 is a series of three traffic signals located at the existing intersections of SE 15th Street, SE 9th Street, and American Lane. The traffic signal at SE Reed Market Road/SE 15th Street would consist of dual left turn lanes for northbound and southbound movements and two through lanes along SE Reed Market Road. The two through lanes would eventually be tapered back into a three-lane cross section east of SE 15th Street. The traffic signals at SE 9th Street and American Lane would also include two through lanes on SE Reed Market Road. The westbound to southbound left turn at American Lane would include dual lanes, which would require two receiving lanes on southbound American Lane. Overall, this concept would result in a four to five lane cross section on SE Reed Market in the study area, except near the railroad crossing where a six lane cross section would be required to accommodate the additional turn lanes at American Lane. This configuration assumes pre-timed signal timing (similar to a tight diamond interchange operation) at the intersections of American Lane and SE 9th Street in order to minimize queuing onto the railroad tracks due to the short distance between the tracks and these two intersections (approximately 250 feet).

4. Diagonal Signal (West) Continuous Flow Intersection (East) Configuration

Concept 4 incorporates the realignment of SE 9th Street and American Lane described in Concept 2, but would include a signalized control at the new intersection on SE Reed Market Road at the railroad crossing. At SE 15th Street, Concept 4 includes a Continuous Flow Intersection (CFI) concept. This type of intersection is unique because the typical left turn lane along the primary roadway is removed from the intersection and located up stream at a separate signalized intersection. Left turn vehicles crossover traffic in opposing lanes and align to the left of the parallel through traffic. The left turning vehicles are then coordinated with the through vehicles so that they do not stop multiple

times at the intersection.⁴⁰ This shift in left turns improves the capacity of the intersection and allows for fewer lanes. Overall, this concept would result in a three lane cross section on SE Reed Market Road.

5. Diagonal Signal (West) Quad Flow Configuration Right-In/Right-Out (East)

Concept 5 includes the diagonal signal concept at SE 9th Street and American Lane described in Concept 4. At SE 15th Street, this concept includes a quad flow concept (similar to the configuration of US 97/Powers Road). As with the Powers Road intersection, Concept 5 would include unsignalized control and right-in/right-out movements at the quad road intersections of SE 15th Street. This configuration would maintain left turns from SE Reed Market Road to SE 15th Street. Due to maintain left turns from SE Reed Market Road, two through lanes eastbound and westbound would be required.

6. Diagonal Signal (West) Quad Flow Configuration (East)

Concept 6 is similar to Concept 5, except that the quad road configuration at SE 15th Street is modified. In this concept, left turn lanes are removed from SE Reed Market Road and routed through the quad roads onto SE 15th Street. This would include adding traffic signals at the quad road intersections with SE 15th Street to provide adequate operation for left turns. Under this concept, SE Reed Market Road would be a three lane corridor.

Feasibility Screening

The project team reviewed each of the six preliminary design concepts to determine if there were any fatal flaws that would warrant removing them from further consideration. Two of the concepts were identified for removal from the alternatives evaluation, including:

- Concept 2 (roundabouts with diagonal alignment of SE 9th Street-American Lane) - further consideration was given to the design of the roundabout across the at-grade railroad crossing. Due to recent discussions with ODOT Rail about their stance on roundabouts at railroad crossings and concerns that they would likely not permit this Concept (in addition to the likely high construction cost), this option was dropped from further consideration.
- Concept 5 (diagonal signal and quad road with right-in/right-out at SE 15th Street) - the operations analysis found that this configuration would not provide adequate capacity for keeping SE Reed Market Road at three lanes. Since the point of this configuration was to reduce lanes, this option was dropped from further consideration.

⁴⁰ *Displaced Left-Turn Intersection*. Federal Highway Administration. October 2009.
<http://www.fhwa.dot.gov/publications/research/safety/09055/09055.pdf> Accessed May 2, 2012.

The remaining four concepts were further screened by qualitatively applying the City's Tier 1 Intersection Form Criteria. This screening, which rates each concept to a minimum desired performance/design adequacy, is shown in Table 8.

Based on the findings of the alternatives screening, the project team identified the following intersection design concepts for refined evaluation:

- American Lane and SE 9th Street - roundabout concepts were found to not be feasible; therefore traffic signal concepts would be explored, including identifying options for potentially reducing the number of required through or turn lanes.
- SE 15th Street - evaluate a multi-lane roundabout and a traffic signal alternative. If a traffic signal alternative is recommended, identifying options to reduce the number of travel lanes such as continuous flow (displaced left turn) if public outreach finds that this type of configuration would be acceptable.

Table 8: Modified Tier 1 Intersection Form Selection Criteria Preliminary Evaluation

Category	General Considerations	Alternatives			
		Concept 1	Concept 3	Concept 4	Concept 6
Safety					
Motor Vehicle Safety	Conflict points (exposure) Severity (speed)	+	✓	✓	✓
Non-Motorized Vehicle Safety	Conflict points (exposure) Severity (speed)	+	✓	✓	-
Traffic Operations					
Peak-Hour Traffic Operations	Volume-to-capacity ratio Average delay LOS	✓	✓	✓	✓
Anticipated Users					
Design Vehicle	Appropriate heavy vehicle Buses Emergency vehicles	✓	✓	✓	✓
Special User Needs	School children Elderly Visually impaired ADA compliance	✓	+	-	✓
System Context					
System Effects	Adjacent traffic control Railroad crossing	✓	✓	+	+
Environmental Impacts	Land use context	✓	✓	✓	✓
Emergency Response	Response time/control delay	✓	+	+	+
Context at Intersection					
Intersection Footprint	Intersection proper (physical & operational influence area)	-	✓	-	-
Intersection Influence Area	Driveway closures or impacts	+	+	-	✓

Scoring Notes:

- + Good
- ✓ Moderate
- Poor

The preliminary rating for each concept resulted in identifying some potential issues with a couple of the concepts.

Concept 6 was discovered to have a significant safety concern for bikes due to the geometry and intersection control that would be in place on SE Reed Market Road near SE 15th Street. Concepts 4 and 6, which include the diagonal alignment of American Lane and SE 9th Street, were determined to have fatal flaws due to cost and property acquisition. Concept 1 was determined to also have significant property impacts with the construction of two new roundabouts that would require road extensions that have not been previously planned (west of American Lane and east of SE 9th Street). In addition, Concept 1 would create significant out of direction travel for north-south traffic. Based on these findings, desirable components of each concept were identified and recommended for further evaluation, as described in the next section.

Recommendations for Further Evaluation of Specific Design Concepts

Based on the findings of the alternatives screening, the project team identified the following intersection design concepts for refined evaluation:

- American Lane and SE 9th Street - roundabout concepts were found to not be feasible; therefore traffic signal concepts should be explored, including identifying options for potentially reducing the number of required through or turn lanes.
- SE 15th Street - evaluate a multi-lane roundabout and a traffic signal alternative. If a traffic signal alternative is recommended, identify options to reduce the number of travel lanes such as continuous flow (displaced left turns) if public outreach finds that this type of configuration would be acceptable.

CHAPTER 5 - AMERICAN LANE & SE 9TH STREET REFINED EVALUATION

As discussed in Chapter 4, it was determined that a traffic signal alternative should be further investigated at both American Lane and SE 9th Street. Because a roundabout alternative was removed from consideration, the evaluation at these intersections does not follow the City's intersection form criteria process. Instead, this chapter evaluates refinements at these intersections to determine a design recommendation. The following sections describe design considerations such as traffic signal warrants, intersection operations, options for reducing the number of travel lanes along Reed Market Road, pedestrian and bicycle treatments, and potential phasing options.

Traffic Signal Warrants

In order to determine if a traffic signal is warranted at the unsignalized intersections of American Lane and SE 9th Street, several traffic signal warrants were evaluated as outlined in the Manual on Uniform Traffic Control Devices (MUTCD)⁴¹ for the years 2011, 2015, 2020, 2025 and 2030. The warrants considered include:

- Peak Hour (Warrant 3)
- Intersection near a Grade Crossing (Warrant 9)

For the purposes of signal warrant analysis, the major street left turn movement was considered the “minor street approach volume” and the opposing through and right turn volume was considered the “major street volume” at both intersections. The major street left turn movement was considered the minor approach at each intersection because the high left turn volumes are more critical than side street approaches with heavy right turn movements (as a portion of the right turns from the minor street approaches are discounted from signal warrant analysis as vehicles experiencing minor delay).

Peak Hour Traffic Signal Warrants

The peak hour traffic signal warrant is intended to be used where the minor street may suffer significant delay due to high volumes along the major street. Under this methodology, the intersection of SE Reed Market Road/American Lane would currently meet the peak hour signal warrant. The intersection of SE Reed Market Road/SE 9th Street does not meet the peak hour signal warrant in the existing or interim forecast years, but would come close to meeting the peak hour signal warrant in the year 2030. The MUTCD worksheet⁴² is included in the Appendix G.

⁴¹ *Manual on Uniform Traffic Control Device*, Part 4, Section 4C.01, FHWA, December 2009.

⁴² *Manual on Uniform Traffic Control Device*, Part 4, Section 4C.01, *Figure 4C-3 Warrant 3 Peak Hour* FHWA, December 2009.

Intersection near a Grade Crossing

The MUTCD has intended for traffic signal Warrant 9, intersections near a grade crossing, to be used at locations where the proximity of an intersection to an at-grade railroad crossing has been identified as a safety concern for vehicles queuing on the tracks. The two criteria that must be met are listed below for this warrant:

- Volumes on MUTCD Figure 4C-9 for the minor street and major street be above the appropriate line for the given distance away from the railroad tracks.
- Distance from the stop or yield line to the railroad tracks equal to or less than 140 feet.

Using the same approach as identified under peak hour warrant of using the major street left turning volume as the “minor street” volume and the opposing major street volume as the “major street,” the volumes for both locations would meet the warrant requirement under the 2011 traffic volumes.

Several trains per day cross SE Reed Market Road and crossing can occur during peak hours. Gates can be down for as long as 10-15 minutes⁴³ when a train is using the switchyard to the south, causing significant delays and queuing. Since traffic volumes and queuing at the study intersections has been shown to increase between the existing conditions and the future 2030 horizon year, queue spillback onto the tracks would be a potential safety concern at this location.

The railroad crossing is currently approximately 250 feet away from both intersections (see Figure 2). While this is further than the 140 feet identified in the MUTCD, it should be noted that 95th percentile westbound left turn queue at the intersection of SE Reed Market Road/American Lane under the 2030 No-Build alternative would 325 feet during the PM peak hour by the year 2030. This would meet the intent of the warrant for the signalization of this intersection.

It should also be noted that the 95th percentile eastbound left turn queue at the intersection of SE Reed Market Road/SE 9th Street would be 200 feet during the PM peak hour by the year 2030 under the No-Build scenario. While this would not exceed the available storage, it would overlap with the westbound left turn queue from the intersection of SE Reed Market Road/American Lane and may present a safety hazard for drivers.

Findings

The peak hour and intersection near grade crossing warrants revealed that a traffic signal would currently be warranted at the intersection of SE Reed Market Road/American Lane. The analysis also revealed that the warrants would not be met under today’s conditions at the intersection of SE Reed Market Road/SE 9th Street, but would come close by the year 2030. Therefore, a traffic

⁴³ Lewis, R. (2011, January 11). Personal interview.

signal could be included at American Lane as part of the first phase of construction, but a traffic signal should not be installed at SE 9th Street until traffic signal warrants are met for delay, safety, or system management reasons.

Design Refinement to Reduce Travel Lanes

Under the future year 2030 full traffic signal design concept presented in Chapter 4, the additional travel lanes along Reed Market Road at both American Lane and SE 9th Street would take up significant amounts of right of way. The signal at SE Reed Market Road/American Lane would feature two through lanes in both directions along SE Reed Market Road, in addition to dual westbound left turn lanes. The dual westbound left turn lanes would require the American Lane approach to be widened to three lanes, two of which would receive the dual westbound lefts, and one lane for the northbound movement. At SE Reed Market Road/SE 9th Street, the signalized intersection geometry would also feature two through lanes in both directions along SE Reed Market Road. Along SE 9th Street, the approach geometry would remain like it is today with two southbound lanes (one for left turns and the other for right turns), and a single northbound receiving lane. Based on the close spacing of these two intersections to the railroad crossing (approximately 250 feet) under existing conditions, pre-timed signal timing similar to a tight diamond interchange configuration was assumed to manage vehicle queuing and minimize the chances of vehicles backing onto the railroad tracks from either American Lane or SE 9th Street.

The geometry and operation described above would require the railroad crossing to be expanded from three lanes to six lanes, doubling the width of the railroad crossing. To reduce the number of lanes on SE Reed Market Road, shifting the alignment of American Lane approximately 250 feet to the west was considered in order to provide additional queue storage for the heavy westbound left turn movement at American Lane in order to prevent queues from spilling back onto the railroad tracks. With this alignment change, the pre-timed signal timing would no longer be needed to manage queuing and operations could be improved with actuated coordinated signal timing. These changes allow a reduction to the future cross section along Reed Market Road to a five lane cross section by eliminating one westbound through lane at American Lane.

To try and further reduce the roadway cross section and improve signal operations and queuing, an intersection design treatment called a Continuous Green “T” (CGT) intersection was evaluated. A CGT intersection allows the main line through traffic to pass through a signalized intersection without stopping (by having left turns from the side street turn into dedicated travel lane). This type of intersection treatment works well when the main line volumes are high and the side street approach has moderate to low left turn volumes and can sometimes result in the

reduction of required through travel lanes.⁴⁴ Sketches of the CGT concepts can be seen in Appendix H. Evaluation of CGT concepts are summarized in the following sub-sections.

Additional Considerations for Continuous Green "T" Concepts

Additional factors that could influence the design of the CGT were evaluated and are discussed below. These factors include bicycle safety, pedestrian safety, phasing, and operational comparison to a typical traffic signal. The following subsections discuss each of these factors.

Bicycle Safety

Bicyclists traveling along Reed Market Road onto the side street (American Lane or SE 9th Street) or vice versa would have to navigate across CGT intersections. These movements are problematic, as bicycles would be forced into a center lane with the left-turning motor vehicle movement and required to merge with high-speed auto traffic. For instance, at the intersection of SE Reed Market Road/SE 9th Street a bicyclist headed eastbound wanting to make a left onto SE 9th Street would need to leave the bike lane and merge across two lanes of traffic to reach the eastbound left turn lane. A cyclist headed southbound on SE 9th Street would need to merge into the southbound left turn lane and then again merge across two lanes of eastbound traffic to reach the bike lane on Reed Market Road. This transition and merge requirement for bicyclists is a fatal flaw for the CGT in the City of Bend.

A modification to the CGT design concept utilizing different signal phasing was identified to improve the bicycle environment. This phasing modification would provide bike signals that would serve bicycles as part of a pedestrian phase for the side-street approach. Further development of the bicycle facilities along SE Reed Market Road should be discussed with City staff to determine the City's vision for this corridor as a bicycle facility (e.g., on-street bike lanes, buffered bike lanes, or off-street trails). Once a clear vision has been developed, further refinement of the above mentioned bicycle design treatments can be further vetted. Discussion on the modified phasing is provided in the Phasing Modification section.

Pedestrian Safety

A CGT intersection configuration does not accommodate pedestrians crossing north-south across SE Reed Market Road. In order to provide a pedestrian phase, a modified phasing as described in the following section would have to be used. Crosswalks and ADA compliant curb ramps should be a part of the ultimate design recommendation.

⁴⁴ *Continuous Green T-Intersections*. U.S. Department of Transportation. Federal Highway Administration. February 2010. http://rspcb.safety.fhwa.dot.gov/noteworthy/pdf/FHWASA09016_intersection7.pdf Accessed May 2, 2012.

Phasing Modification

As was previously discussed in the bicycle and pedestrian safety sections, a true CGT intersection does not adequately accommodate bicyclists and pedestrians. As shown in Figure 7, the through movement would essentially operate as a free movement and would be separated by conflicting side street traffic by a median located along SE Reed Market Road. The side street vehicles would turn into their own travel lane and merge with traffic at some point downstream. To accommodate non-motorized users, alternative signal phasing was identified which introduces a pedestrian phase as can be seen in Figure 7. Under this modified CGT phasing, the through lanes would only have to stop when there is a pedestrian activation. Otherwise the through movement would continuously be served.

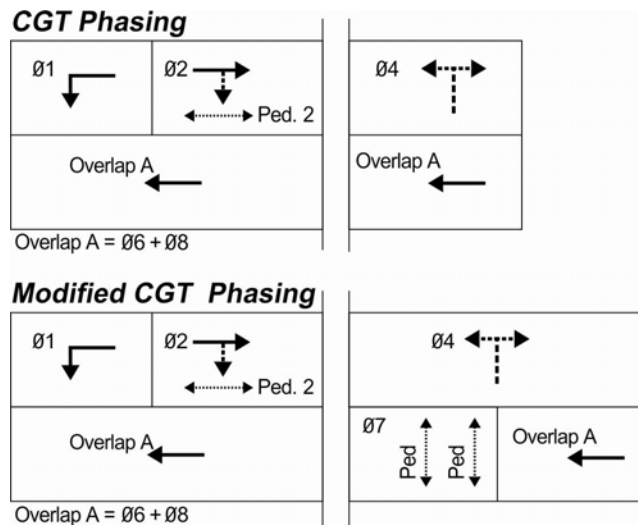


Figure 7: Modified CGT Phasing

With minor signal modifications, bicyclists could also be served during this pedestrian phase with dedicated bike signals.

Operational Comparison with Continuous Green "T" Concept

A HCM and queuing analysis was conducted to evaluate the potential benefits of the modified CGT concept with the pedestrian phase described in the previous section compared to a typical traffic signal (with the American Lane alignment shifted 250 to the west and actuated coordinated signal timing). Traffic signal operations were evaluated using Synchro 7TM and queuing estimates were made using the SimTrafficTM software package. Estimates of 95th percentile queue lengths were determined using an average of five simulation runs of the SimTrafficTM model. Intersection operational output can be found in Appendix I and Appendix J. The results are shown in Table 9 and Table 10.

As listed in Table 9 and Table 10, the overall intersection V/C ratio for both design concepts during the AM and PM peak hours would be below 1.0 and would meet the City's minimum operational standards. The traditional signal and modified CGT would perform very similarly. Therefore, it appears that there would be no significant benefit of the modified CGT concept over a typical traffic signal at the intersections of American Lane and SE 9th Street.

Table 9: 2030 Typical Traffic Signal Operations

Future 2030 Alternatives Comparison American Lane & SE 9 th Street					
Intersection Operations	American Lane & SE Reed Market Road		SE 9 th Street/SE Reed Market Road		
	AM Peak	PM Peak	AM Peak	PM Peak	
Volume/Capacity	0.47	0.69	0.60	0.60	
Intersection Control Delay (sec)	13.8	17.9	11.6	11.1	
Intersection Level of Service	B	B	B	B	
Queuing Results (Average Queue/95 th Percentile Queues)*					
North Leg	L	-	-	50	50
	R	-	-	75	150
East Leg	L	175	325	-	-
	T/R	175	225	250	250
South Leg	L/R	200	325	-	-
West Leg	L	-	-	200	200
	T/R	150	225	50	50

Signalized Intersections

Delay = Average Intersection Delay (sec.)

LOS = Intersection Level of Service

V/C = Intersection Volume-to-Capacity Ratio

L = Left; T = Through; R = Right

*Queue lengths are rounded to the nearest 25 feet.

Table 10: 2030 Modified CGT Traffic Signal Operations

Future 2030 Alternatives Comparison American Lane & SE 9th Street					
Intersection Operations	American Lane & SE Reed Market Road		SE 9 th Street/SE Reed Market Road		
	AM Peak	PM Peak	AM Peak	PM Peak	
Volume/Capacity	0.44	0.81	0.67	0.73	
Intersection Control Delay (sec)	14.8	23.4	18.8	15.5	
Intersection Level of Service	B	C	B	B	
Queuing Results (Average Queue/95 th Percentile Queues)*					
North Leg	L	-	-	50	50
	R	-	-	100	150
East Leg	L	175	350	-	-
	T/R	50	250	250	250
South Leg	L/R	200	300	-	-
West Leg	L	-	-	250	150
	T/R	175	250	50	75

Signalized Intersections

Delay = Average Intersection Delay (sec.)

LOS = Intersection Level of Service

V/C = Intersection Volume-to-Capacity Ratio

L = Left; T = Through; R = Right

*Queue lengths are rounded to the nearest 25 feet.

Design Recommendation

Based on the discussion presented above, it is recommended that traffic signals with traditional phasing (actuated-coordinated timing) be installed at the intersections of SE Reed Market Road/American Lane and SE Reed Market Road/SE 9th Street to accommodate future 2030 traffic volumes. It is also recommended that American Lane be realigned approximately 250 feet west to improve the safety and operations near the railroad crossing.

Construction Phasing

Phasing construction for the 2030 traffic signal build out at American Lane and SE 9th Street would enable the City to achieve improvements to the corridor incrementally without having to completely fund the ultimate corridor configuration at this time. Figure 8 shows the interim design configuration, which would consist of four travel lanes between American Lane and SE 9th Street. As shown, the interim phasing concept includes dual eastbound through lanes. This dual lane configuration is necessary to meet mobility needs at American Lane and it provides continuity and effective lane utilization approaching SE 15th Street. An alternative configuration



was considered that would keep one eastbound through lane on SE Reed Market Road by providing additional capacity at American Lane with dual westbound left-turn lanes. The project team determined that the dual eastbound lane configuration was preferred as it results in less widening of the railroad crossing and avoids the need to provide dual southbound lanes on American Lane south of SE Reed Market Road.

The interim phasing configuration would feature a standard traffic signal at SE Reed Market Road/American Lane and a side street stop controlled intersection at SE Reed Market Road/SE 9th Street (consistent with how it operates today). The SE 9th Street intersection would be unsignalized because it would not meet traffic signal warrants under interim year conditions. With this interim configuration, American Lane would be realigned to the west to accommodate vehicle queuing and improve safety in regards to the railroad crossing.

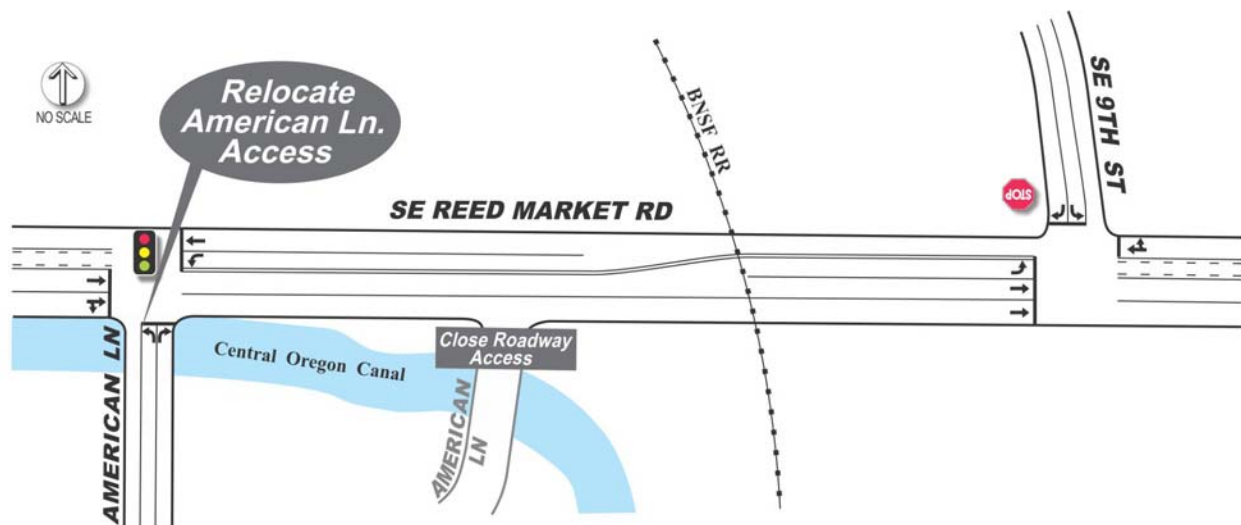


Figure 8: American Lane and SE 9th Street Interim Construction Phasing

Using calculated growth rates that were based on comparing existing (year 2011) traffic volumes and future 2030 volumes, 5-year incremental turn-movement volume sets were developed. The interim year forecasts were then used to evaluate the interim phasing design configuration. Table 11 summarizes the operations of the interim year volumes based on the interim design configuration and HCM output is shown in Appendix K. The interim design configuration would not meet the City’s operational standards through the year 2015. The unsignalized intersection of SE Reed Market Road/SE 9th Street would fail in the PM peak hour by 2015 due to excessive delay along the minor street approach. This intersection should be monitored in the future to determine when traffic signal warrants would be met. It is also recommended that vehicle queuing for the westbound left turn at American Lane be monitored in the future to determine when the additional widening would be warranted to achieve the dual westbound left turn lanes at American Lane (when the queues exceed the available storage length or when cycle failures become problematic). When traffic signal warrants are met at SE 9th Street or when queuing becomes problematic, the transition to traffic signals with traditional phasing (actuated-

coordinated timing) at the intersections of SE Reed Market Road/American Lane and SE Reed Market Road along with dual westbound left turn lanes at American Lane could be done.

Table 11: Future Interim Phasing Operational Results (AM/PM Peak Hour)

	AM Peak Hour			PM Peak Hour		
	Delay	LOS	V/C	Delay	LOS	V/C
Year 2015 Scenario						
*SE Reed Market Rd./American Ln.	8.4	A	0.51	14.3	B	0.70
**SE Reed Market Rd./SE 9th St.	20.3	B/C	0.33	58.6	B/F	0.83
Year 2020 Scenario						
*SE Reed Market Rd./American Ln.	9.4	A	0.53	15.0	B	0.75
**SE Reed Market Rd./SE 9th St.	22.4	B/C	0.35	92.7	B/F	0.98
Year 2025 Scenario						
*SE Reed Market Rd./American Ln.	10.1	B	0.56	18.8	B	0.81
**SE Reed Market Rd./SE 9th St.	25.6	B/D	0.45	150.4	A/F	1.16
*Signalized Intersections			**Unsignalized Intersections			
Delay = Average Intersection Delay (sec.)			Delay = Critical Movement Approach Delay (sec.)			
LOS = Intersection Level of Service			LOS = Major Street LOS/Minor Street LOS			
V/C = Intersection Volume-to-Capacity Ratio			V/C = Critical Movement Volume-to-Capacity Ratio			

Year of Opening Operation

As discussed in the previous section, the signalized intersection of SE Reed Market Road/American Lane would meet the City’s operational standards (V/C < 1.0) through the year 2020 under the interim improvement configuration. The unsignalized intersection of SE Reed Market Lane/SE 9th Street would however fail to meet the City’s operational standards (delay < 50.0) in the year 2015. Under existing traffic volumes both intersections would operate with acceptable delays on all approaches during the year of opening operation. The expected day of opening operational results for the interim configuration is listed in Table 12. Traffic operations and queuing results for year of opening conditions can be found in Appendix L.



Table 12: 2011 Year of Opening Day Operations and Queuing Results (AM/PM Peak Hour)

Opening Day Operations 2011 (AM/PM Peak Hour)					
Traffic Signal Operations		American Lane & SE Reed Market Road (Signalized)		SE 9 th Street/SE Reed Market Road (Unsignalized)	
		AM Peak	PM Peak	AM Peak	PM Peak
Volume/Capacity		0.49	0.72	0.29	0.72
Intersection Control Delay (sec)		8.1	12.8	18.9	43.8
Intersection Level of Service		A	B	B/C	B/E
Queuing Results (95 th Percentile Queues)*					
North Leg	L	-	-	50	50
	R	-	-	75	125
East Leg	L	100	200	-	-
	T/R	100	175	25	25
South Leg	L	50	75	-	-
	R	100	100	-	-
West Leg	L	-	-	100	75
	T/R	100	150	-	-

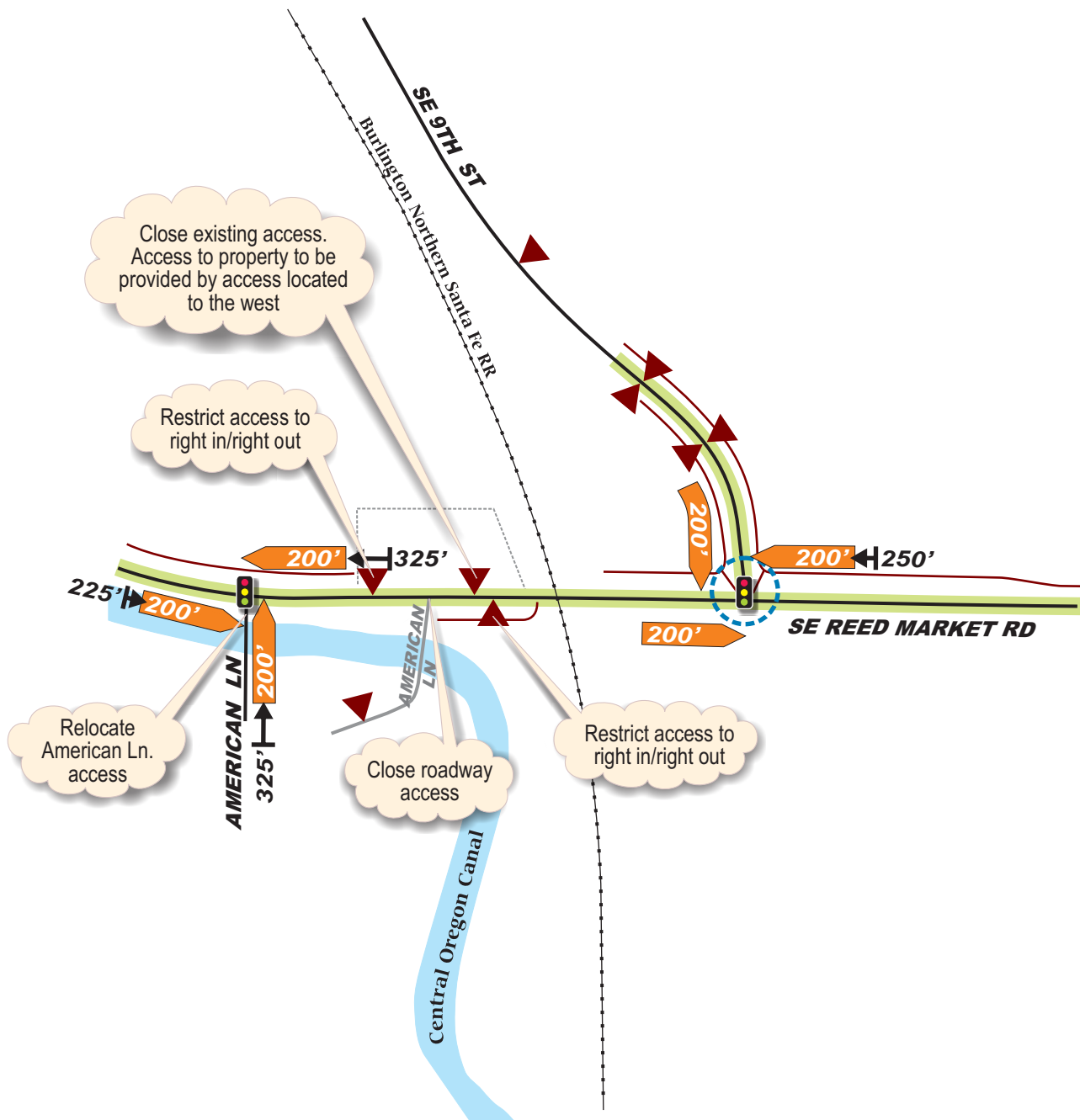
L = Left; T = Through; R = Right

*Queue lengths are rounded to the nearest 25 feet.

Access Management

The design recommendation of realigning American Lane to the west and installing traffic signals at the intersections of SE Reed Market Road at American Lane and SE 9th Street would require geometric modifications along SE Reed Market Road and American Lane. With the design of traffic signals at these intersections and the widening of SE Reed Market Lane, it is recommended that existing access located along the south side of SE Reed Market Road just east of American Lane continue to be restricted to right-in/right-out operation.

The parcel located opposite the existing intersection of SE Reed Market Road/American lane currently features two accesses within the influence area of the railroad crossing at the intersection of SE Reed Market Road/American Lane. It is recommended that access to this parcel be consolidated and limited to right-in/right/out movements. This is noted in Figure 9.



LEGEND

- Study Intersection
- Traffic Signal
- Driveway/Access
- Sidewalk
- Bike Lanes
- 95th Percentile Queue for Left Turn
- 200' Influence Area from Intersection
- Taxlots

DKS

NO SCALE

Figure 9

**Reed Market Corridor/
American Lane & 9th Street
Access Management**

CHAPTER 6 - SE 15TH STREET REFINED EVALUATION

As presented in Chapter 3, the signalized intersection of SE Reed Market Road/SE 15th Street would fail to meet the City's intersection operational standards (excessive vehicle delays and queues) during the AM and PM peak hours in future year 2030 under the existing intersection configuration. An alternatives analysis was conducted in order to determine the most appropriate intersection control configuration to provide efficient operations at this intersection through the year 2030. Based on preliminary analysis and coordination with the project team as discussed in Chapter 4, two intersection control alternatives were selected for future evaluation at this intersection. These two intersection control configurations include a roundabout and a traffic signal which are evaluated in the following sections.

Alternatives Operations Evaluation

Both a roundabout and traffic signal were evaluated using the future 2030 AM and PM peak hour traffic volumes identified in Chapter 3 and shown in Figure 6. The following sections provide a comparison of the peak hour intersection operations and vehicle queuing results for both intersection control alternatives.

Alternative 1 – Roundabout Operations

The first alternative is a roundabout, which was evaluated per the City of Bend guidelines.⁴⁵ In order for the roundabout to meet the City's operational standards during the future year 2030 AM and PM peak hours, a multi-lane roundabout would be required. A conceptual sketch of the multi-lane roundabout is shown in Table 10. As shown the roundabout would feature two entry, circulating, and exit lanes along all approaches.

The AM and PM peak hour roundabout operations and queuing results (using the geometry shown in Figure 10) are listed in

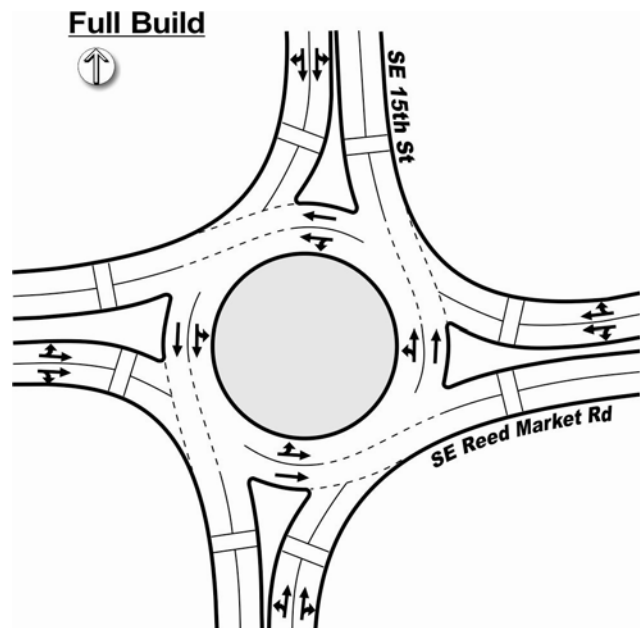


Figure 10: Multi-lane Roundabout

⁴⁵ Roundabout Operation Analysis Guidelines, City of Bend, April 2010.

Table 13 with calculation sheets included in Appendix M. Vehicle queue estimates for this alternative were developed using the VISSIMTM analysis software and compared to 95th percentile queue estimates per the City of Bend roundabout operation analysis guidelines.

Table 13: Alternative 1 – Future 2030 Multi-Lane Roundabout Operations and Queuing Results (AM/PM Peak Hour) – (Using Geometry Shown in Figure 10)

SE Reed Market Road/SE 15 th Street								
Future 2030								
Roundabout Operations	AM Peak				PM Peak			
	North Leg	East Leg	South Leg	West Leg	North Leg	East Leg	South Leg	West Leg
Volume/Capacity	0.33	0.73	0.88	0.30	0.90	0.55	0.56	0.92
Critical Lane Average Delay (sec)	10.7	28.7	35.0	7.6	44.9	14.0	18.1	46.4
Intersection Volume/Capacity**	0.66				0.72			
Intersection Control Delay (sec)	18.4				28.2			
Intersection Level of Service	C				D			
Queuing Results (95 th Percentile Queues)*								
Peak 15 min. flows (ft)	50	175	300	50	275	100	100	300
Peak Hour flows (ft)***	125	150	250	100	375	125	150	225

*Queue lengths are rounded to the nearest 25 feet.

** The intersection v/c ratio was calculated using a weighted average based on the critical lane volumes.

*** 95th percentile queue likely to occur with the peak hour flow rate as determined through microsimulation with VISSIM software, which is the most comparable to the queuing analysis of the signalized control scenario evaluated with Synchro/SimTrafficTM

Although a multi-lane roundabout would be needed to provide acceptable operations during the 2030 AM and PM peak hours, a multi-lane roundabout would not be required to provide acceptable operations under short term growth. In order to determine when the ultimate build out of the multi-lane roundabout would be needed, scaled-down concepts were evaluated in order to develop a phased construction approach based on interim year traffic conditions. This phased construction approach is discussed in the following section.

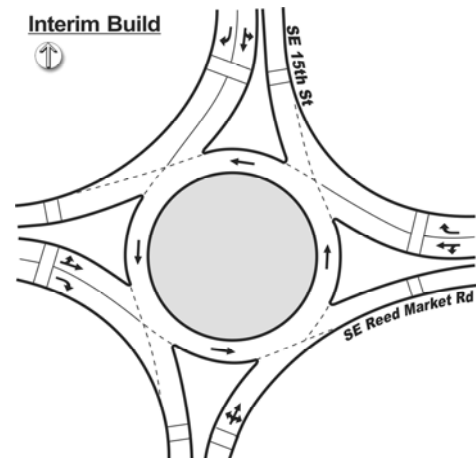


Figure 11: Partial Multi-lane Roundabout

Construction Phasing

Using calculated growth rates that were based on

comparing existing (year 2011) traffic volumes and future forecasted 2030 volumes; 5-year incremental turn-movement volume sets were developed and analyzed. Based on the City of Bend’s roundabout operation analysis guidelines, a single lane roundabout with right turn lanes on the entries for the east, west, and north approaches (partial multi-lane) would be required to meet the City’s peak hour operational standards based on existing 2011 peak hour traffic volumes (See Figure 11). This configuration would accommodate projected volumes to the year 2020 as can be seen in Table 14. Beyond the year 2020, it would be recommended to construct the full multi-lane roundabout as shown in Figure 10, to accommodate the future volumes. The roundabout calculation worksheets for the construction phasing analysis are included in Appendix N.

Table 14: Future Year Roundabout Operations Results (AM/PM Peak Hour)

SE Reed Market Road/SE 15 th Street										
Roundabout Operations	Volume to Capacity									
	AM Peak					PM Peak				
	North Leg	East Leg	South Leg	West Leg	Over-all	North Leg	East Leg	South Leg	West Leg	Over-all
Future 2020										
Single Lane with Three Right Turn Lanes	0.38	0.90	0.93	0.46	0.75	0.91	0.89	0.57	0.87	0.84
Future 2025										
Single Lane with Three Right Turn Lanes	0.45	0.85	1.17	0.50	0.85	1.18	0.94	0.73	1.04	1.00
Multi-Lane	0.25	0.76	0.74	0.28	0.60	0.68	0.88	0.47	0.78	0.76
Future 2030										
Multi-Lane	0.33	0.73	0.88	0.30	0.66	0.90	0.55	0.56	0.92	0.76

Year of Opening Operation

As previously indicated, the interim improvement configuration consisting of a single lane roundabout with right turn lanes along the east, west, and north approaches would operate acceptably up to the year 2020 (V/C less than 1.0). If this configuration is constructed, the intersection would operate acceptably on all approaches during the AM and PM peak hours assuming current 2011 traffic volumes. The expected day of opening operations for the interim roundabout configuration are listed in Table 15. The operations and queuing calculations are included in Appendix O.



Table 15: 2011 Year of Opening Roundabout Operations and Queuing Results (AM/PM Peak Hour) – (Using Geometry Shown in Figure 11)

SE Reed Market Road/SE 15 th Street								
2011 Year of Opening								
Roundabout Operations	AM Peak				PM Peak			
	North Leg	East Leg	South Leg	West Leg	North Leg	East Leg	South Leg	West Leg
Volume/Capacity	0.26	0.69	0.66	0.41	0.62	0.74	0.40	0.70
Critical Lane Average Delay (sec)	8.4	18.1	15.5	7.5	16.7	17.5	10.9	16.6
Intersection Volume/Capacity**	0.56				0.66			
Intersection Control Delay (sec)	13.5				16.2			
Intersection Level of Service	B				C			
Queuing Results (95 th Percentile Queues)*								
Peak 15 min. flows ft)	25	150	150	50	125	200	50	175
Peak Hour flows (ft)***	25	125	125	50	100	150	50	150

*Queue lengths are rounded to the nearest 25 feet.

** The intersection v/c ratio was calculated using a weighted average based on the critical lane volumes.

*** 95th-percentile queue likely to occur with the peak hour flow rates, which is the most comparable to the queuing analysis of the signalized control scenario evaluated with Synchro/SimTrafficTM

Alternative 2 – Traffic Signal Operations

This alternative evaluates traffic signal control at the intersection of SE Reed Market Road/SE 15th Street. For the existing traffic signal to meet the City’s peak hour operational requirements (V/C ratio less than 1.0), additional northbound and southbound left turn lanes would need to be added on SE 15th Street, along with additional eastbound and westbound through lanes along SE Reed Market Road. These additional lanes are illustrated in the conceptual sketch provided in Figure 12. A sketch of the potential traffic signal layout can be seen in Appendix F.

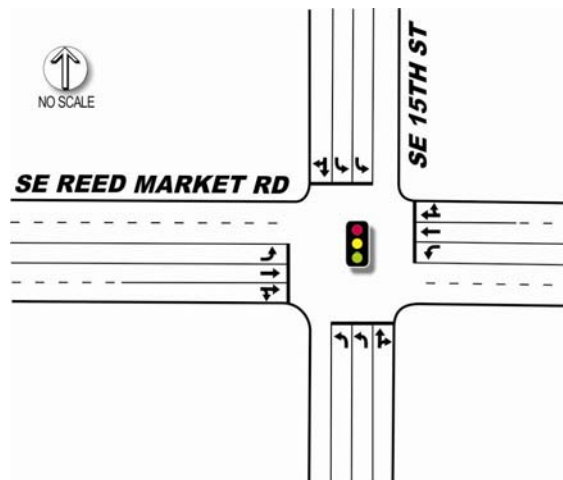


Figure 12: Conceptual Traffic Signal

Traffic signal operations were evaluated using Synchro 7TM and vehicle queuing estimates were made using the SimTrafficTM software package. The evaluation included approximations for lane imbalances that would occur due to the drop lanes on the downstream legs of the intersection.

Estimates of 95th percentile queue lengths were determined using an average of five simulation runs of the SimTrafficTM model.

It was assumed that the traffic signal would operate with protected left-turn phasing on both SE Reed Market Road and SE 15th Street. Intersection operational output can be seen in Table 16 and calculation sheets for this alternative are attached in Appendix P.

The traffic signal under this alternative would operate within the City’s operational standards during both the AM and PM peak hours. This intersection would operate near capacity and would resemble LOS D conditions. Vehicle queues would be greatest along northbound SE 15th Street during the AM peak hour and southbound SE 15th Street during the PM peak (reverse flow).

Table 16: Alternative 2 – Future 2030 Traffic Signal Operations and Queuing Results (AM/PM Peak Hour) - (Using Geometry Shown in Error! Reference source not found.)

SE Reed Market Road/SE 15 th Street			
Traffic Signal Operations	Future 2030		
	AM Peak	PM Peak	
Volume/Capacity	0.93	0.91	
Intersection Control Delay (sec)	45.0	54.3	
Intersection Level of Service	D	D	
Queuing Results (95 th Percentile Queues)*			
North Leg	L	100	350
	T/R	250	1,100
East Leg	L	75	200
	T/R	275	300
South Leg	L	350	150
	T/R	1,925	150
West Leg	L	125	250
	T/R	225	375

L = Left; T = Through; R = Right

*Queue lengths are rounded to the nearest 25 feet.

Similar to the phased construction of the roundabout, the full build out of the traffic signal would not be needed based on short term traffic volumes. In order to determine when the full traffic signal would be needed, a phased construction implementation plan was developed and is discussed in the next section.

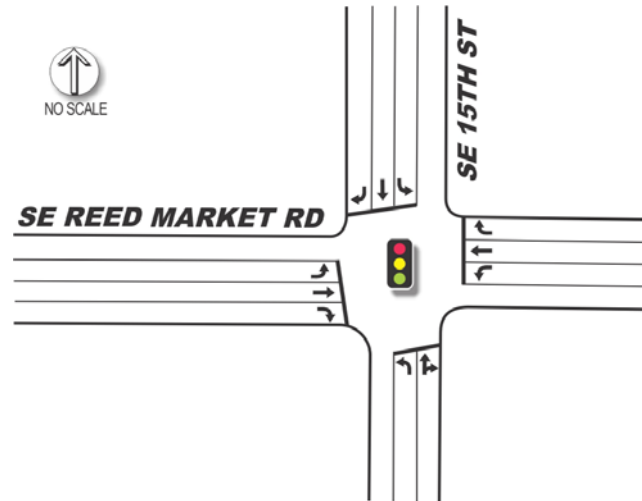


Figure 13: Interim Traffic Signal Phasing

Construction Phasing

Phased construction for the 2030 full signal build out at SE Reed Market Road/SE 15th Street would allow the City to achieve improvements to the corridor without the significant upfront investment to build the ultimate design (such as widening the Reed Market Corridor to five lanes near the intersection). Figure 13 shows the interim design configuration for the traffic signal. As can be seen, an exclusive right turn lane was added to the west leg, north leg and east leg. This is similar to the interim roundabout configuration previously discussed. The south leg would remain as it is today.

Using calculated growth rates that were based on comparing existing (year 2011) traffic volumes and 2030 volumes, 5-year incremental turn-movement volume sets were developed and analyzed. Table 17 summarizes the operations of the interim year volumes based on the interim design configuration and calculations can be found in Appendix Q. As can be seen, the interim design configuration would work through the year 2025 based on the operation output. Significant queuing would still occur in the westbound and southbound through lanes during the peak hours.

Table 17: Future Signal Phasing Operational Results (AM/PM Peak Hour) - (Using Geometry Shown in Figure 13)

Intersection Operations	AM Peak Hour			PM Peak Hour		
	Delay	LOS	V/C	Delay	LOS	V/C
Year 2020 Scenario						
SE Reed Market Rd./SE 15 th St.	34.1	C	0.82	42.8	D	0.86
Year 2025 Scenario						
SE Reed Market Rd./SE 15 th St.	53.1	D	1.01	53.0	D	0.99

Signalized Intersections
 Delay = Average Intersection Delay (sec.)
 LOS = Intersection Level of Service
 V/C = Intersection Volume-to-Capacity Ratio

Year of Opening Operation

As discussed in the previous section, the interim improvement configuration would operate within the City's operational standards (V/C less than 1.0) to the year 2025. If that configuration is constructed, the intersection would operate with minimal delays on all approaches during the year of opening operation.

Table 18 lists the expected day of opening for the interim traffic signal configuration at SE Reed Market Road/SE 15th Street. Traffic operations and queuing calculation can be found in Appendix R.

Table 18: 2011 Year of Opening Day Operations and Queuing Results (AM/PM Peak Hour) - (Using Geometry Shown in Figure 13)

SE Reed Market Road/SE 15 th Street			
Traffic Signal Operations	Opening Day Operations 201		
	AM Peak	PM Peak	
Volume/Capacity	0.64	0.74	
Intersection Control Delay (sec)	30.0	34.3	
Intersection Level of Service	C	C	
Queuing Results (95 th Percentile Queues)*			
North Leg	L	75	175
	T	125	225
	R	50	100
East Leg	L	50	125
	T	275	425
	R	75	75
South Leg	L	250	175
	T/R	275	150
West Leg	L	100	125
	T	250	375
	R	50	125

L = Left; T = Through; R = Right

*Queue lengths are rounded to the nearest 25 feet.

Additional Design Considerations

In addition to the intersection operational analysis for each alternative as presented in the previous section, additional factors could contribute to the decision making process of the preferred alternative as well as influence the design of the selected alternative. These factors include vehicular safety, pedestrian impacts, bicycle impacts, transit impacts, access management, and corridor intersection interactions.

Vehicular Safety

The predictive methodology described in Chapter 12 (Predictive Method for Urban and Suburban Arterials) of the Highway Safety Manual (HSM) was used for crash predication at the intersection of SE Reed Market Road/SE 15th Street under the ultimate configuration. This method allowed for the calculation of the expected crash frequency and severity for the historic (2008 to 2010) for calibration purposes and future (2028 to 2030) time periods for alternative evaluation using the following data inputs and steps:

- **Facility Data** – Motor vehicle and pedestrian volume, intersection geometry and control features, and surrounding land uses were used for this analysis.
- **Safety Performance Functions (SPF)** – Predicted crash frequencies and severities were calculated for both time periods using HSM SPFs to create a statistical “base” crash condition. The SPF developed for this intersection represents the average crash frequency and severity that could be expected for an intersection with similar characteristics. This “base” crash condition was further refined using Empirical Bays’ statistical methods.
- **Empirical Bays** – Empirical Bays Methodology was applied to the SPFs to improve the statistical reliability of the predicted crashes. This methodology relied on local crash data and calibration factors to calculate the expected crash frequency and severity for the intersection.
- **Crash Data** – Crash data and severity were used for this analysis.
- **Local Calibration Factor**⁴⁶ – A local calibration factor of 1.05 was used for this analysis.⁴⁷

HSM methodology described above was applied to develop expected crash frequency and severity for the intersection of SE Reed Market Road/SE 15th Street. Expected crash frequency and severity values were calculated for each intersection control alternative (roundabout and traffic signal).

⁴⁶ Local calibration factors have been developed for the State of Oregon to refine the predictive method and match the predicted number of crashes to the local driving conditions

⁴⁷ Karen Dixon, et al. *Calibrating the Future Highway Safety Manual Predictive Methods for Oregon State Highways*, Table 7.1, February 2012.

Nationwide⁴⁸ and local⁴⁹ Crash Modification Factors⁵⁰ (CMF) were investigated for each option. Both national and local Oregon CMFs are available for the conversion of a signalized intersection to a multi-lane roundabout. The research shows that replacing a traffic signal with a multi-lane roundabout could reduce fatal and injury crashes by as much as 74 percent and property damage only crashes could be reduced by as much as 35 percent.

While there are hundreds of CMFs available for intersection improvements and new ones are being added frequently, none were appropriate for the proposed traffic signal improvements at the study intersection under an urban/suburban environment (e.g., adding capacity with additional through and turn lanes). Since no CMFs were available for the traffic signal alternative, the crash frequency and severity calculated under the future ultimate configuration 2030 scenario have been assumed to be similar to those that would be seen under the existing traffic signal. Table 19 shows the resulting estimated crash frequency and severity under both intersection control alternatives.

Table 19: Expected Crash Frequency, Severity and Rate (2030 Build Scenarios)

Scenarios	TEV (in AADT)	Crash Frequency & Severity			Crash Rate
		Fatal & Injury	PDO	Total	
Alternative 1 (Roundabout)	30,300	2.00	8.08	10.08	0.33
Alternative 2 (Traffic Signal)		7.70	12.43	20.13	0.65

TEV = Total Entering Volume (2030)
 AADT = Average Annual Daily Traffic
 PDO = Property Damage Only
 Crash Rate = Crashes per million entering vehicles

The analysis shows that the expected crashes for the multi-lane roundabout were significantly reduced as a result of the proposed improvement. The roundabout would benefit the safety of the intersection by reducing the total number of crashes, and more importantly, by reducing the fatal

⁴⁸ U.S.DOT, Federal Highway Administration, Crash Modification Factors Clearinghouse website, <http://www.cmfclearinghouse.org/index.cfm>, Accessed April 25, 2012.

⁴⁹ ODOT, Traffic Engineering and Operations Section Updated Crash Reduction Factors website, <http://www.its.pdx.edu/CRF/CRFweb/>, Accessed April 25, 2012.

⁵⁰ Crash Modification Factors are before-after research based factors that represent the ability for an improvement or set of improvements to change the crash frequency or severity of an intersection or roadway. These factors are used to quantify the potential increase or decrease in crashes as a result of improvements.

and injury crashes to less than one per year. The intersection crash rate would also be reduced to a rate lower than what would be expected under today's intersection volumes and configuration.

Assuming that the improvements would be constructed by 2013 and the safety benefits would be realized through the horizon year of the project, 2030 (ultimate configurations), the total number of expected crashes was calculated for each of the scenarios and is displayed in Table 20. As listed, the installation of a roundabout at the intersection of SE Reed Market Road/SE 15th Street would reduce the total number of expected crashes at this location by nearly 50% (50 fewer crashes over the 17 year period). As significant portion of the crash reduction would come in the form of reduced fatal or injury type crashes (18 fewer crashes), which amounts to a significant benefit in terms of savings to the community.

Table 20: Expected Crash Frequency and Severity (2013 to 2030)

Scenario	Total Crashes 2013 to 2030		
	Fatal & Injury	PDO	Total
Roundabout	10	42	52
Traffic Signal	38	65	102

PDO = Property Damage Only

Pedestrian Facilities

Pedestrian access at the SE Reed Market Road/SE 15th Street intersection is missing some important links that would enhance the overall pedestrian experience within the study area. The existing pedestrian network is illustrated in Figure 2. As can be seen, sidewalk is missing along the south side of SE Reed Market Road. A gap is also missing along the north side of SE Reed Market Road just east of the intersection. Along SE 15th Street sidewalk is present except for on the east side of the south leg at the intersection.

The proposed project would improve the existing sidewalk network by filling in any missing gaps on SE Reed Market Road. One of the main connections would be filling in the gap along the north side of SE Reed Market Road which connects the intersection to the Bend Senior Center. Crosswalks would remain on all approaches under both alternatives and all pedestrian ramps at the intersection would be brought up to current ADA accessibility standards.

Under signalization, pedestrian treatments would remain similar to how they are today. Under the roundabout alternative pedestrian treatments outlined in the Manual on Uniform Traffic Control Devices (MUTCD) would be applied to properly sign and mark all pedestrian crossings. In addition, the pedestrian crossings along the multilane approaches at the roundabout could be

signalized or feature pedestrian activated warning devices (Rectangular Rapid Flashing Beacons) to meet the Public Rights-of-Way Accessibility Guidelines.

During the design phase of the intersection, opportunities should be sought to connect the missing link of the Larkspur Trail from the west property line of the Bend Senior Center to the path that runs along the northern side of the COID canal roughly parallel to SE Reed Market Road to a point just east of American Lane where the canal turns south.

Bicycle Facilities

Bicyclists using the existing Reed Market Corridor can use existing bike lanes along both SE Reed Market Road and SE 15th Street. Under the signalization alternative, bicyclists would perform standard maneuvers associated with typical intersection design including traversing across right turn lanes, traveling adjacent to traffic in designated bike lanes, and merging with traffic when executing turns in exclusive turn lanes.

Under roundabout control, a bicyclist traveling through this intersection could select to maneuver through it similar to a vehicle or a pedestrian. Whichever option selected a bicyclist would encounter typical bicycle treatments outlined in the Manual on Uniform Traffic Control Devices (MUTCD).⁵¹

Further development of the bicycle facilities along SE Reed Market Road should be discussed with City staff to determine the City's vision for this corridor as a bicycle facility (e.g., buffered bike lanes, cycle track desired, separated shared-use path). Once a clear vision has been developed, further refinement of the bicycle design treatments can be vetted.

Transit Facilities

The current location of bus stop 612 may have to be relocated depending on the ultimate design of the intersection. The design team should work with Cascade East Transit to evaluate the need to move the bus stop located on the north side of the east leg of SE Reed Market Road/SE 15th Street near the entrance of the Bend Senior Center.

Access Management

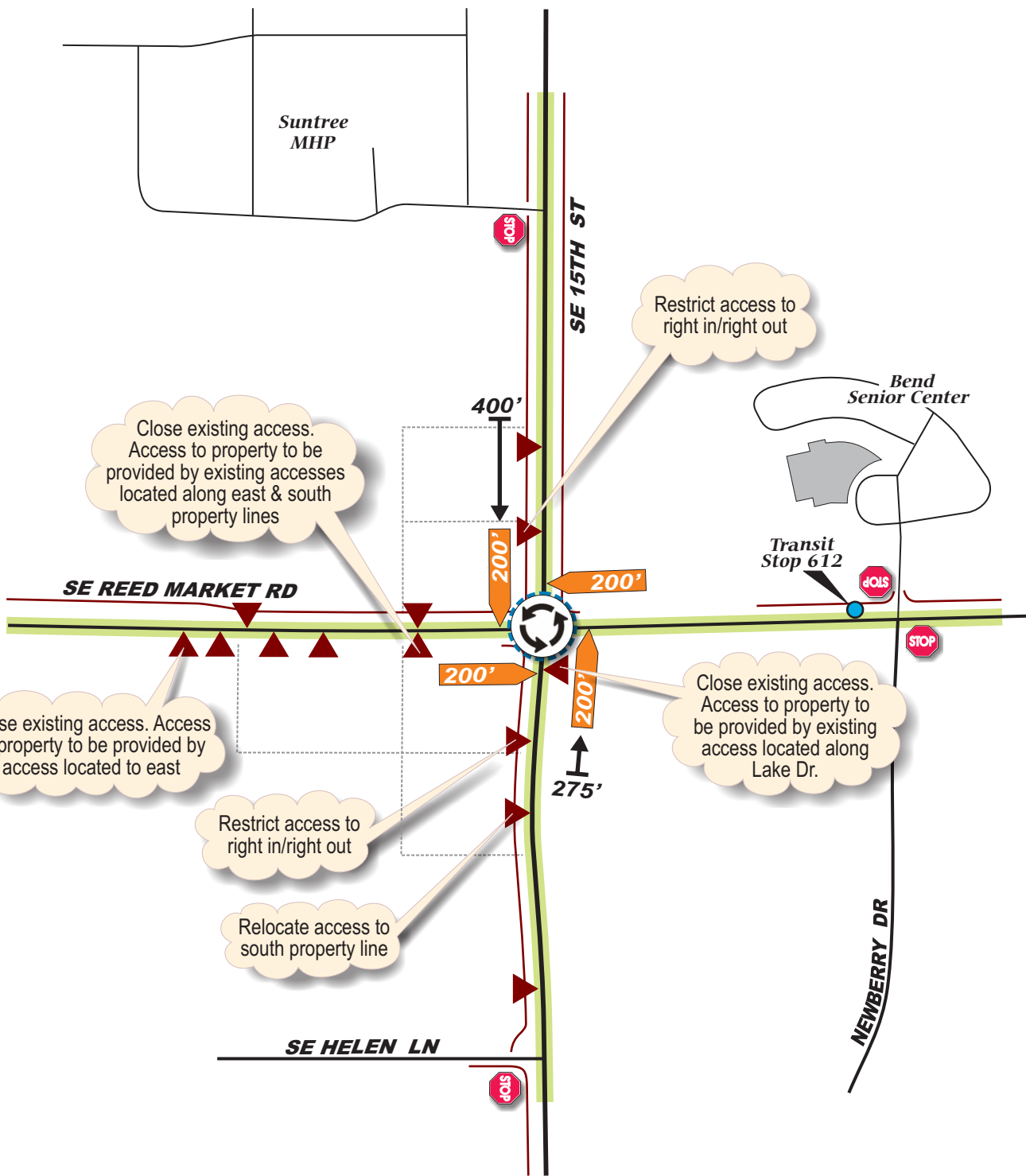
Both the traffic signal and roundabout alternatives would include significant geometric improvements at the intersection of SE Reed Market Road/SE 15th Street. These geometric improvements would impact existing accesses located along SE Reed Market Road and SE 15th Street. This section summarizes the impacts to existing accesses under each alternative and presents access management recommendations to ensure safe and efficient intersection

⁵¹ Part 9 Traffic Control for Bicycle Facilities. Manual on Uniform Traffic Control Devices. US Department of Transportation. Federal Highway Administration. 2009 Edition.










operations. The impacts to existing accesses were determined based on the location to the intersection (influence area), 95th percentile queues, access spacing standards, geometric modifications, and intersection sight distance.

The recommended access modifications surrounding the study intersection for each alternative are shown in Figure 14 and Figure 15. In order to provide efficient operations at the intersection it is recommended that all accesses located within 200 feet of the intersection be restricted to right-in/right out. Additionally, accesses should be located far enough from the intersection as possible to not conflict with queuing at the intersections, particularly the left turns.

The installation of a roundabout would restrict turn movements to right-in/right-out at several accesses near the intersection due to the installation of a splitter island along all approaches. These splitter islands are typically 100 feet in length; although longer islands may be warranted to manage speeds along high speed approaches and to provide positive guidance along approaches where there may be significant realignment. Although these accesses would feature turn movement restrictions, the roundabout would provide the ability to facilitate all turning movements including U-turns.



LEGEND

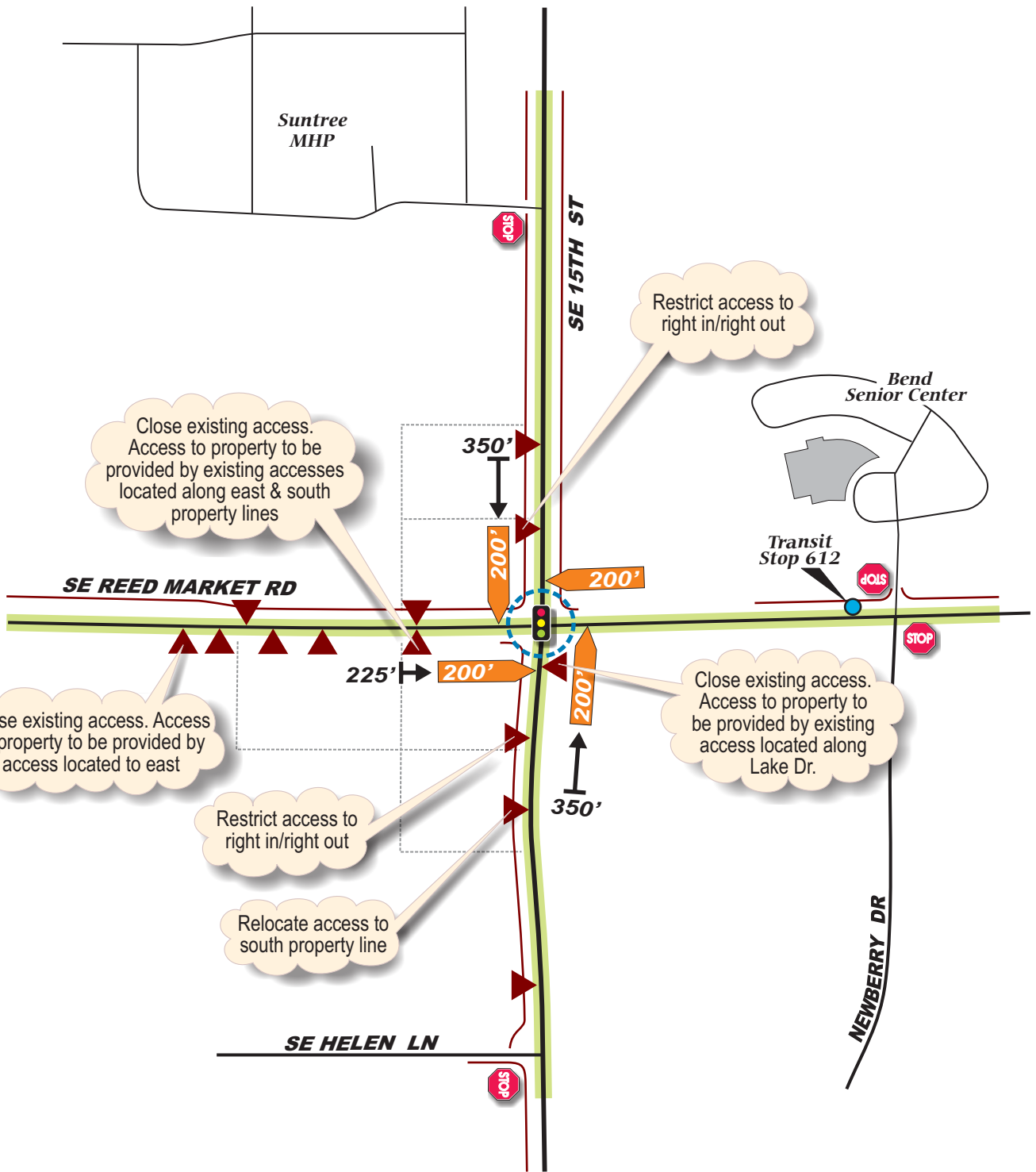
-  - Study Intersection
-  - Stop Sign
-  - Driveway/Access
-  - Sidewalk
-  - Bike Lanes
-  - Roundabout
-  - 95th Percentile Queue for Left Turn
-  - 200' Influence Area from Intersection
-  - Taxlots

DKS

Figure 14

Reed Market Corridor/SE 15th Street Roundabout Access Management Impacts

 NO SCALE



LEGEND	
	- Study Intersection
	- Stop Sign
	- Traffic Signal
	- Driveway/Access
	- Sidewalk
	- Bike Lanes
	- 95th Percentile Queue for Left Turn
	- 200' Influence Area from Intersection
	- Taxlots

DKS **Figure 15**

**Reed Market Corridor/SE 15th Street
Full Signal Buildout
Access Management Impacts**

NO SCALE

Tier 1 and Partial Tier 2 Evaluation

Per the City's Intersection Form Evaluation Framework, the Tier 1 selection criteria was used to compare the roundabout and traffic signal alternatives to determine the preferred intersection control alternative. In addition to the criteria in the Tier 1 criteria, select Tier 2 criteria were added based on their potential to help distinguish between the alternatives. The Tier 2 criteria added to the Tier 1 criteria for the purpose of this analysis are motor vehicle safety as it relates to crash prediction, more emphasis on pedestrians and bicyclists using the facility, and access management. The comparison between the two alternatives is summarized in Table 21. Based on this evaluation; a multi-lane roundabout is the recommended long-term control for this intersection due primarily to safety and operational benefits.

Table 21: Expanded Tier 1 Intersection Form Selection Criteria

Category	Criteria	Evaluation Comments	Conclusion
Safety			
Motor Vehicle Safety	Conflict points (exposure) Severity (speed)	<p>Conflict Points: Traffic signal w/four approaches = 32 Multi-lane Roundabout w/four approaches = 16</p> <p>Posted Speed: SE Reed Market Rd. = 40mph SE 15th St. = 35-40 mph</p> <p>A multi-lane roundabout has fewer motor vehicle conflict points; therefore reducing the exposure to potential accidents. Along with the reduced exposure, the accidents which could occur at a roundabout would be less severe than a traffic signal due to the geometry and lower entry/circulating speeds. This is important considering the higher vehicle speeds along both SE Reed Market Rd. and SE 15th St.</p>	Roundabout
Non-Motorized Vehicle Safety	Conflict points (exposure) Severity (speed)	<p>Pedestrian Conflict Points: Traffic signal w/four approaches = 24 Multi-Lane Roundabout w/four approaches = 16</p> <p>Posted Speed: SE Reed Market Rd. = 40mph SE 15th St. = 35-40 mph</p> <p>A traffic signal would provide a</p>	Neutral

Category	Criteria	Evaluation Comments	Conclusion
		<p>protected pedestrian movement along all legs of the intersection and provide only four locations where vehicles must yield to a pedestrian, assuming a flashing yellow arrow is not used.</p> <p>A multi-lane roundabout would feature eight locations where vehicles must yield to a pedestrian; however it would have fewer pedestrian conflict points thus reducing the overall exposure to potential accidents. A multi-lane roundabout would require pedestrians to cross two travel lanes at a time on all legs of the intersection, which could result in second car-coming conflicts. This would require pedestrians to select larger gaps in the traffic stream while crossing unprotected. These pedestrian issues could be reduced if the multi-lane approaches were signalized or feature pedestrian activated warning devices for pedestrian movements to meet the Public Rights-of-Way Accessibility Guidelines.</p>	
Motor Vehicle Safety (Tier 2)	Crash Prediction	<p>Vehicle Collision Rate: Traffic signal w/four approaches = 0.65/MEV Multi-Lane Roundabout w/four approaches = 0.33/MEV</p> <p>The anticipated number of collisions over the 20 year design life at the intersection would be significantly less at a multi-lane roundabout than a traffic signal (50+ fewer crashes). The severity of vehicle collisions would also be less under a multi-lane roundabout.</p>	Roundabout
Traffic Operations			
Peak-Hour Traffic Operations	Volume-to-capacity ratio Average delay LOS Queue lengths	Both a multi-lane roundabout and traffic signal would meet the City of Bend's operational standards during the AM and PM peak hours. A multi-lane roundabout would yield shorter queues and less delay during the AM	Roundabout



Category	Criteria	Evaluation Comments	Conclusion
		and PM peak hours. A multi-lane roundabout would significantly reduce the delays at the intersection during the AM peak hour compared to a traffic signal.	
Anticipated Users			
Design Vehicle	Appropriate heavy vehicle Buses Emergency vehicles	<p>Both a traffic signal and multi-lane roundabout would be designed using the same design/accommodated vehicle(s).</p> <p>It is assumed that the intersection would be designed for a WB-67 and larger double or triple trailer trucks would be accommodated for all movements. Additionally the truck apron of the roundabout would be designed to accommodate a lowboy trailer.</p> <p>While each of the designs would accommodate emergency vehicles, City staff has received feedback from the fire department that traffic signals are always preferred to roundabouts due to the ability for them to use Opticom to preempt the signal and provide a clear through path.</p>	Traffic Signal
Special User Needs	School children Elderly Visually impaired ADA compliance	<p>Both a traffic signal and multi-lane roundabout would be designed to accommodate the same special user needs at the intersection.</p> <p>With the close proximity of the Bend Senior Center, a multi-lane roundabout may improve the safety for elderly drivers due to the lower operating speeds (which could provide additional perception/reaction time and a reduced number of conflict points). A multi-lane roundabout may, however, pose more difficulty for elderly and visually impaired pedestrians to navigate through.</p> <p>The multi-lane approaches could be signalized or feature pedestrian</p>	Neutral

Category	Criteria	Evaluation Comments	Conclusion
		activated warning devices for pedestrian movements to meet the Public Rights-of-Way Accessibility Guidelines.	
Pedestrians (Tier 2)	Crossing Distances	A roundabout would yield a total of eight crossing locations (two crossings along each leg) while a traffic signal would have a total of four crossings. However with the inclusion of bike lanes as part of the traffic signal and a splitter island as part of the roundabout, it is anticipated that the multi-lane roundabout would provide a shorter overall crossing distance for pedestrians.	Roundabout
Bicyclist (Tier 2)	Adjacent bike facilities Intersection specific considerations	<p>Bike lanes are currently present along both SE Reed Market Road and SE 15th Street. A traffic signal would provide bike lanes along all approaches and bicycles would navigate through the intersection the same as vehicles would. bicyclists would perform standard maneuvers associated with typical intersection design including traversing across right turn lanes, traveling adjacent to traffic in designated bike lanes, and merging with traffic when executing turns in exclusive turn lanes.</p> <p>A roundabout would provide two different options for bicyclists. The bicyclist may travel through the roundabout as a vehicle would or as a pedestrian would. In a multi-lane roundabout a bicyclist would have to circulate in a higher speed inner circle (compared to single lane) and perhaps change lanes if wishing to make a left turn.</p>	Neutral
System Context			
System Effects	Adjacent traffic control Railroad crossing	There are no existing traffic signals or roundabouts located in the near vicinity of the study intersection. There is, however, an active railroad	Traffic Signal

Category	Criteria	Evaluation Comments	Conclusion
		<p>line located approximately 1,330 feet to the west along SE Reed Market Road.</p> <p>Furthermore, the unsignalized intersections at SE Reed Market Road/American Lane and SE Reed Market Road/SE 9th Street would fail to meet the City's operational standard in the future. Per analysis provided in this report, a traffic signal is recommended as the ultimate intersection control at these intersections. These intersections are located approximately 1,575 and 1,020 feet to the west.</p> <p>Neither a traffic signal nor roundabout at SE 15th Street would significantly impact the existing roadway system operations nor the future traffic signals at American Lane and SE 9th Street.</p> <p>If queues from the railroad extended back through the intersection, a traffic signal would be able to recover quicker than a roundabout.</p>	
Environmental Impacts	Land use context	<p>The current land use zoning surrounding the intersection varies, including industrial, commercial, and residential uses. Neither a traffic signal nor roundabout is anticipated to have significant environmental impacts to the surrounding land uses.</p> <p>Due to lower intersection delays and shorter queue lengths during non-peak periods, a roundabout could reduce the number of stops, therefore reducing noise and emissions associated with stop and go driving.</p> <p>A traffic signal may be generally preferred by freight users along this designated freight corridor. However, the roundabout design vehicle has been increased from the City standard WB-50 to a WB-67, which may</p>	Neutral

Category	Criteria	Evaluation Comments	Conclusion
		actually improve turning movements for freight vehicles compared to a traffic signal alternative.	
Emergency Response	Response time/control delay	<p>A traffic signal would be equipped with emergency vehicle preemption along all approaches. In addition, emergency vehicles would be able to use turn lanes and opposing traffic lanes to maneuver through the intersection.</p> <p>A multi-lane roundabout would provide two entry, circular, and exit lanes which would allow drivers to move aside and let emergency vehicles pass. However, this is not as effective as a traffic signal for reducing delays for emergency response vehicles..</p>	Traffic Signal
Access Management (Tier 2)	Facilitates access management Median and U-turn opportunities Driveway connections	The roundabout alternative would restrict accesses located near the intersection to right-in/right-out due to the splitter island. A Traffic signal would have a similar effect due to the need for channelized turn lanes. However, a roundabout would more easily provide U-turn opportunities to maintain all circulation patterns, while a traffic signal would not.	Roundabout
Context at Intersection			
Intersection Footprint	Intersection proper (physical & operational influence area)	<p>Both a traffic signal and multi-lane roundabout would require additional lanes to be added at the intersection along all approaches.</p> <p>A traffic signal would require an additional lane along SE Reed Market Road (5-lane cross-section) while a roundabout would require the inclusion of a splitter island along all approaches and additional lanes on SE 15th Street. The right-of-way impact would therefore be greater for a roundabout than a traffic signal.</p>	Traffic Signal

Category	Criteria	Evaluation Comments	Conclusion
Intersection Influence Area	Driveway closures or impacts	See Tier 2 criteria discussion under Access Management.	Roundabout
Intersection Influence Area (Tier 2)	Approach and segment cross-section	Both a traffic signal and multi-lane roundabout would require additional lanes to be added at the intersection along all approaches. The roadway widening impacts along SE Reed Market Road and SE 15 th Street would be comparable under a traffic signal or roundabout.	Neutral

Design Recommendation

Based on the City’s Intersection Form Evaluation Framework, a multi-lane roundabout would be the recommended intersection control compared to traffic signal control at the intersection of SE Reed Market Road/SE 15th Street for the forecasted future year 2030 conditions. As summarized in Table 21, a multi-lane roundabout would provide safer operations for both vehicles and pedestrians and would result in shorter delays and vehicle queues during the future 2030 AM and PM peak hours.

CHAPTER 7 - CORRIDOR DESIGN RECOMMENDATIONS SUMMARY

Based on analysis presented in this report, the long-term corridor recommendation is to construct traffic signals at the intersections of SE Reed Market Road/American Lane and SE Reed Market Road/SE 9th Street. Furthermore it is recommended that the alignment for American Lane where it crosses the Central Oregon Irrigation District canal be relocated approximately 250 feet west (consistent with the Reed Market Corridor Plan). This would increase the amount of available storage space for vehicles making westbound lefts onto American Lane and conversely for vehicles making eastbound lefts onto SE 9th Street, which is particularly important in relation to the at-grade railroad crossing and the operation/configuration of the signalized intersections.

At SE Reed Market Road/SE 15th Street, a multi-lane roundabout is recommended. A multi-lane roundabout would provide safer operations and would result in shorter delays and vehicle queues during the future 2030 AM and PM peak hours compared to a traffic signal.

A sketch of the recommended future 2030 configuration of the SE Reed Market Road corridor between American Lane and SE 15th Street is provided in Appendix S.

Although the improvements shown in **Error! Reference source not found.** would be necessary to meet City operational standards under the forecasted year 2030 conditions, there is opportunity to phase these improvements over time so that full build out is achieved as warranted. The phasing of improvements may be desired by the City to reduce initial construction costs and right of way impacts, and provide flexibility to adapt to changing development trends and roadway system improvements that could alter the need for the identified full build-out configuration under year 2030 conditions. If the City chooses to design for, and implement, a phased improvement strategy (see Appendix S), the following operational highlights should be considered:

- A traffic signal at SE Reed Market Road/American Lane, combined with two eastbound through lanes from west of American Lane to SE 15th Street, would accommodate future growth through approximately future year 2025 conditions. The queuing for the westbound left turn should be monitored to identify when the dual westbound left turns would be needed.
- The intersection of SE Reed Market Road/SE 9th Street could remain unsignalized until signal warrants are met. This intersection would fail to meet the City's operational standards by the year 2015 if remained unsignalized.
- A single lane roundabout at SE Reed Market/SE 15th Street with additional right-turn lanes on the east, west, and north approaches would accommodate projected volumes to approximately the year 2020. Beyond that time, it would be recommended to construct the full multi-lane roundabout.
- Due to the geometry of the existing corridor, the three lane cross-section along SE Reed Market Road between American Lane and SE 9th Street would need to be widened to accommodate four lanes due to the dual eastbound through lanes.

- The design life of any of these interim options could vary significantly under changes in development patterns and rates or changes to the timing and/or order of constructing roadway improvements in the area.

If a phased implementation strategy is selected by the City, the roundabout footprint at SE Reed Market Road/SE 15th Street (and right-of-way) under interim year scenarios should consider options such as:

- Building for an interim configuration and expanding the roundabout to add lanes in the future when needed;
- Building to accommodate the size of later phases and adding inner lanes in the future; or
- Building to accommodate the size of later phases and using striping to implement reduced lane configurations for interim conditions (restriping to add lanes in the future).

These choices would likely have a significant effect on the design elements of the roundabout, such as drainage and right-of-way. The design team should coordinate with the City to determine the preferred approach.

Under any of the phased or full build-out configurations of the recommended improvements, the following items should be considered during design:

- A design vehicle of a WB-67 should be used as the design vehicle for all intersections. At the roundabout at SE Reed Market/SE 15th Street the design should allow the truck cab to stay in-lane with the trailer potentially tracking onto the inner and/or outer truck apron.
- A double and triple trailer configuration should be accommodated for all intersection approaches. At the roundabout at SE Reed Market/SE 15th Street these trucks may use an inner and/or outer truck apron if necessary.
- The truck apron vertical profile at the roundabout should accommodate a lowboy trailer for all approaches
- Design for emergency response vehicles should be incorporated at all intersections. All traffic signals should be equipped with emergency vehicle pre-emption and the roundabout should allow for an ambulance and a hook/ladder fire truck to stay in-lane for all approaches and exits.
- Sidewalk should be provided along both sides of SE Reed Market Road, American Lane, SE 9th Street, and SE 15th Street within the project limits. Sidewalks and curb ramps should be constructed per ADA requirements all on quadrants of all intersections.
- The potential for installing pedestrian activated signals or rectangular rapid flashing beacons should be considered along all approaches at the multi-lane roundabout at SE Reed Market Road/SE 15th Street (dual entry/exit lanes). This would include installing conduit as part of the street lighting design for future traffic control device installation on each approach.

- Bicyclists should be accommodated along all roadways and intersections to provide system connectivity.
- An advanced warning system which informs the public via message signs should be provided with advanced information about trains approaching the railroad crossing on SE Reed Market Road between American Lane and SE 9th Street. Advance warning devices could be located at SE Reed Market Road/SE 3rd Street and SE Reed Market Road/SE 15th Street.
- Communications infrastructure (conduit) should be provided between the railroad and adjacent traffic signals and train advanced warning system.
- The traffic signals at SE Reed Market Road/American Lane and SE Reed Market/SE 9th Street should feature heavy rail preemption.
- The current location of bus stop 612 may have to be relocated depending on the ultimate design of the intersection. The design team should work with Cascade East Transit to evaluate the need to move the bus stop located on the north side of the east leg of SE Reed Market Road/SE 15th Street near the entrance of the Bend Senior Center.