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TECHNICAL MEMORANDUM 4

DATE: April 28, 2023

TO: Project Team

FROM: Eileen Chai, EIT; Kayla Fleskes, PE; John Bosket, PE | DKS Associates

SUBJECT: US 97 at Reed Market Road Operations and Safety Study Alternatives Development and Evaluation - DRAFT

Project #22129-001

This memorandum describes the development and evaluation of concepts for improving transportation conditions within the US 97 at Reed Market Road study area. Initial concepts were discussed during a concept evaluation workshop with the Technical Advisory Committee (TAC). Based on feedback received during the workshop, the top concepts were further refined and evaluated against the goals and evaluation criteria from *Technical Memorandum #1: Study Background and Goals and Objectives*. This memorandum includes a description of the top concepts and their performance relative to the evaluation criteria.

This memorandum is divided into the following sections:

- **Process for developing and evaluating concepts –** This section describes in more detail how the top concepts were selected at each intersection for further evaluation.
- **Reed Market Road cross section improvements** – This section provides examples for how the cross section of Reed Market Road could be adjusted in the future and discusses how there is a desire for intersection improvements intended for short-term construction to be compatible with the existing cross sections while also maintaining forward compatibility with any potential long-range cross section.
- **Short-term intersection improvements** – Describes the short-term recommendations at two intersections with relatively limited funding available: Reed Market Road/Chamberlain Street and 3rd Street/Brosterhous Road.
- **Alternative evaluation (by intersection) –** This section describes the alternatives and the evaluation findings for each of the five major study intersections. Each alternative was evaluated relative to the six project goals and each intersection discussion includes a documentation of the analysis as well as a summary discussing the key differentiators in qualitative scoring between alternatives.

Following this evaluation, a preferred concept will be selected at each intersection and the entire corridor will be evaluated using microsimulation to verify that the alternatives will function well as a system.

PROCESS FOR DEVELOPING AND EVALUATING CONCEPTS

Based on the needs identified in Technical Memoranda #1-3 and prior planning project recommendations, the project team developed an initial set of concepts at each of the study intersections. These initial concepts were presented to TAC members during a four-hour evaluation workshop held on December 7, 2022. During the workshop, the concepts were discussed and some were qualitatively scored relative to No-Build conditions and against each of the project goals.

After further discussion and consideration of the feedback received during the workshop, the Project Management Team determined that the criteria requiring reasonable alignment with available funding should be considered as "pass/fail" criteria for this project. Therefore, after reevaluating the alternatives using the pass/fail criteria related to cost, the Project Management Team separated the preliminary alternatives into the categories of "Considered and Dismissed" and "Forwarded for Further Refinement and Evaluation." Alternatives in the former category were deemed to either have few merits based on the full range of evaluation criteria or to have costs that would likely exceed current funding expectations. These alternatives were removed from further consideration in this project, while the remaining alternatives were forwarded for further analysis. The results of that analysis are documented in this memorandum.

REED MARKET ROAD CROSS SECTION IMPROVEMENTS

Opportunities to cross US 97 for people walking and biking are limited in the vicinity of the Reed Market Road overcrossing. The current facility does not provide low-stress walking and biking routes with varying buffers along the narrower sidewalk and non-separated bike lanes. Nearest adjacent crossings are at the Wilson Avenue overcrossing located 2,400 feet to the north and at the Central Oregon Historic Canal Trail undercrossing located 1,700 feet to the south. Both of these crossings are designated as part of the low-stress network in the Bend Transportation System Plan (TSP). It should be recognized that the canal trail has limited access points connecting to goods and services. Given the distance between Wilson Avenue and the canal crossing, enhancing the ability to walk and bike across US 97 at Reed Market Road would be beneficial.

While Reed Market Road is not a designated low-stress route, improvements to provide low-stress walking and biking facilities are required by the standard cross sections when the street is reconstructed. Providing low-stress walking and biking facilities would require reconstruction to widen the overpass and the overall cross section. At this time, however, a reconstruction project is neither planned nor funded. Furthermore, formally changing the long-range design of Reed Market Road is not currently identified in the City's TSP project list or in the Draft 2024-2027 Statewide Transportation Improvement Program (STIP). That said, through this planning process, there is a desire for intersection improvements intended for near-term construction to be compatible with the existing cross sections while also maintaining forward compatibility with any potential future cross section changes.

Therefore, Figures 1-4 show examples of long-range cross section designs that may be considered along Reed Market Road in the future. All intersection improvements discussed later in this memorandum should be designed to be compatible with the existing cross section while not precluding a future long-term cross section along Reed Market Road. The example cross sections below show the option of people biking on a multi-use path at sidewalk level. While shown as one-direction bike travel, the facilities could be designed to accommodate two-direction bike travel. Note that any changes in the cross section (such as reducing the travel lane width) at the US 97 interchange require coordination with the Mobility Advisory Committee (MAC).

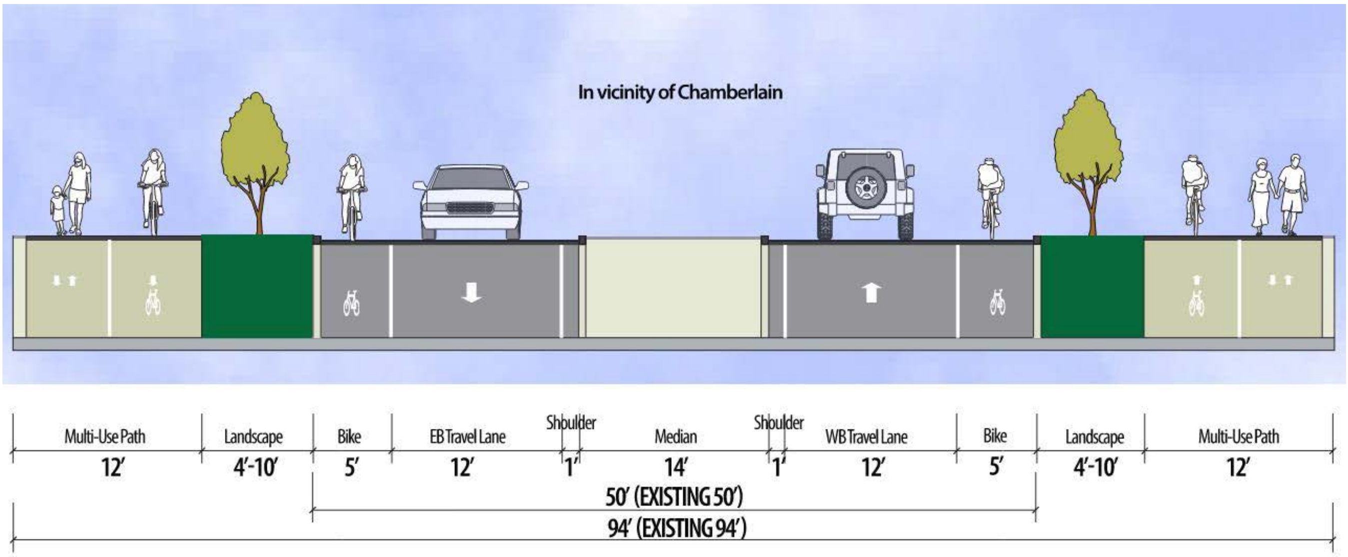

FIGURE 1. POTENTIAL LONG-TERM REED MARKET ROAD CROSS SECTION (IN VICINITY OF CHAMBERLAIN STREET)

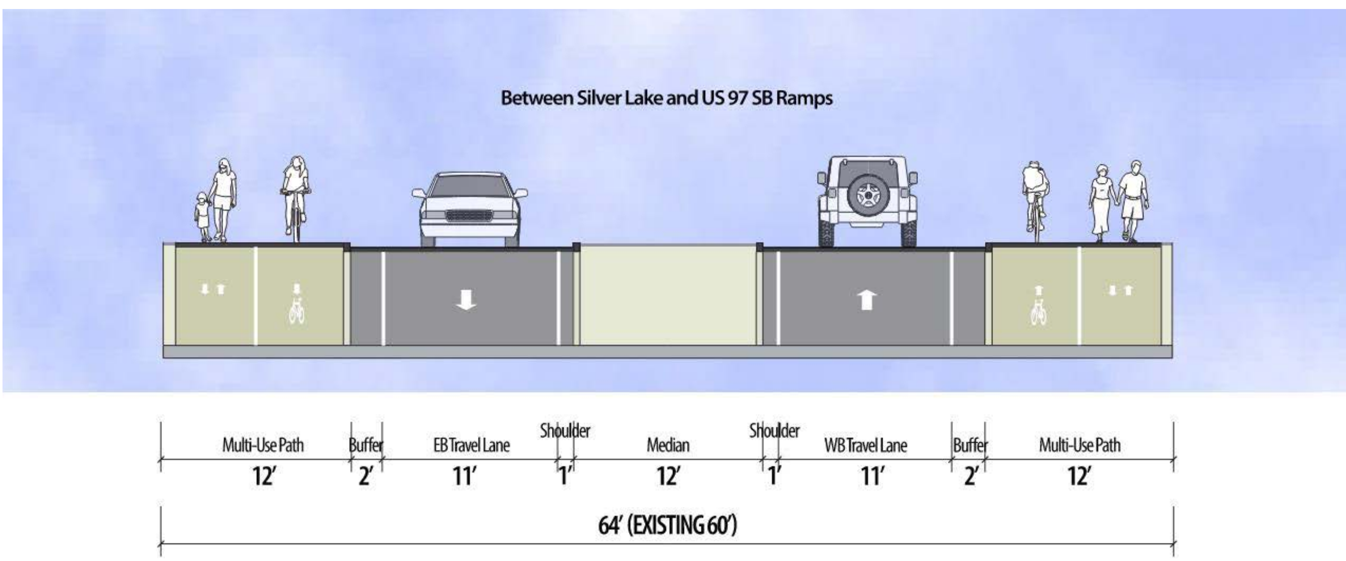

FIGURE 2. POTENTIAL LONG-TERM REED MARKET ROAD CROSS SECTION (BETWEEN SILVER LAKE BOULEVARD AND US 97 SOUTHBOUND RAMPS)

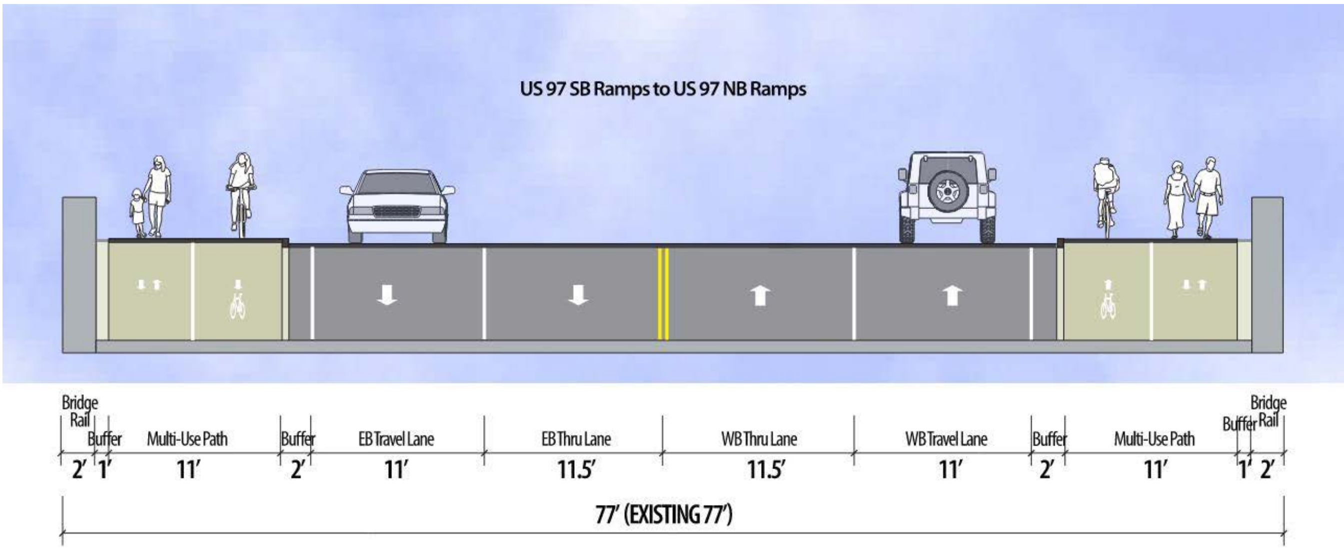

FIGURE 3. POTENTIAL LONG-TERM REED MARKET ROAD CROSS SECTION (US 97 SOUTHBOUND RAMPS TO US 97 NORTHBOUND RAMPS)

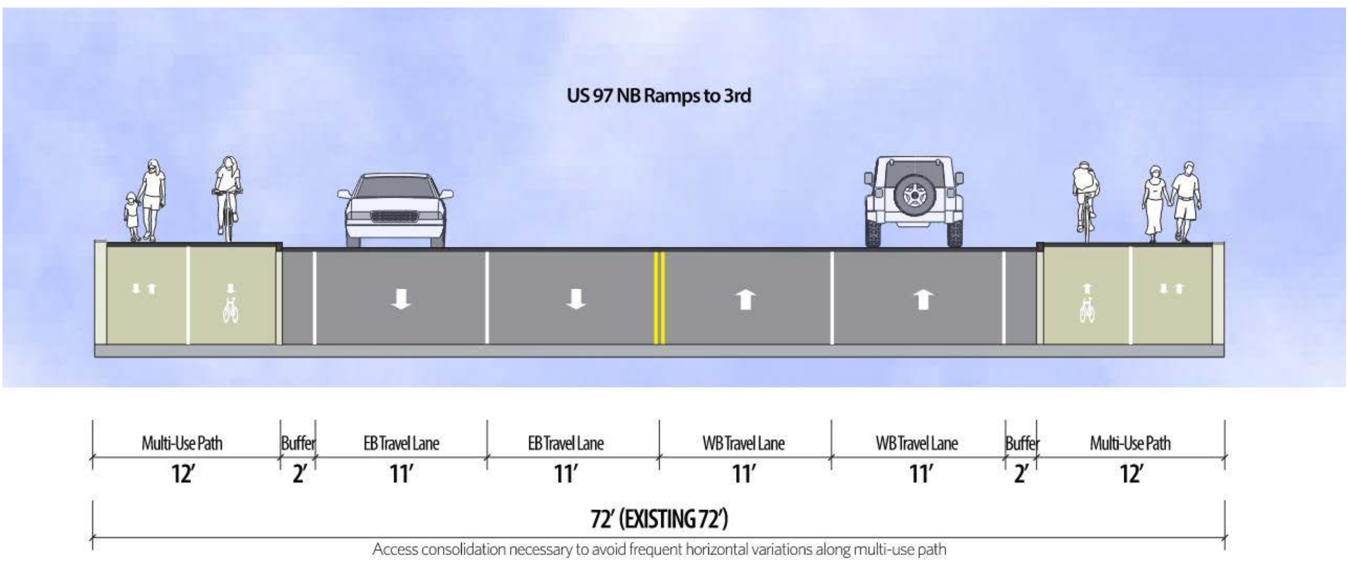

FIGURE 4. POTENTIAL LONG-TERM REED MARKET ROAD CROSS SECTION (US 97 NORTHBOUND RAMPS TO 3RD STREET)

SHORT-TERM INTERSECTION IMPROVEMENTS

Within the study area, two intersections have relatively limited (less than $250,000) funding for improvements: Reed Market Road/Chamberlain Street and 3rd Street/Brosterhous Road. Several short-term enhancements are recommended at these two locations and discussed in more detail below.

REED MARKET ROAD/CHAMBERLAIN STREET IMPROVEMENTS

Chamberlain Street has been identified as a key walking and biking route in the Bend TSP. The City has approximately $250,000 in the Neighborhood Street Safety Program to pave a portion of Chamberlain Street and install crossing enhancements at Reed Market Road. It is recommended that these crossing enhancements include:

- New pedestrian crossing on the east leg.
- Wayfinding signage for people walking and biking.
- Median cutouts for a bicycle crossing and green pavement markings, such as in the example shown in Figure 5.
- Additional pedestrian and bicycle crossing warning signage, such as in the example in Figure 5.
- Possible vegetation removal in the median to improve pedestrian visibility.
- Preserving space for future bus stops along Reed Market Road.
- Adding enhanced lighting at the intersection.

FIGURE 5. EXAMPLE BICYCLE CROSSING THROUGH A MEDIAN IN PORTLAND, OR

Source: Google Streetview, Google Earth

3RD STREET/BROSTERHOUS ROAD

The City is currently conducting a study[1] to evaluate potential short-term and long-term improvement options to enhance safety at this intersection. As a result of that study, several signing, striping, lighting, and signal timing treatments were recommended as short-term improvements that would use existing funding identified in the Bend Capital Improvement Program ($130,000), including:

- Re-striping the eastbound and westbound approaches to move the bike lanes to the left of the right turn lanes (consistent with the signalization at the intersection) and add bicycle conflict striping. The re-striping helps address the lane offset through the intersection.
- Re-striping the eastbound approach to make the right turn lane channelization clearer to drivers.
- Adding signage on the eastbound approach to make the lane channelization clearer to drivers.
- Modifying the striping for the channelized right turns on the northbound and southbound approaches, adding signage, and adding reflectors to the islands.
- Installing lighting at the intersection to enhance nighttime visibility to prevent potential crashes.
- Working with the Central Oregon Irrigation District to install a gate across the canal trail to encourage people walking and biking along the Canal Trail to use the traffic signal to cross Brosterhous Road. People walking and biking along the trail (east leg of the intersection) are more likely to cross Brosterhous Road at the trail instead of using the intersection crossing, which contributes to safety concerns from crossing at an uncontrolled location in close proximity to the signalized intersection.
- Adding a Leading Pedestrian Interval (LPI) to enhance safety for people walking and biking. It should be noted that the signal timing change alone does not address motor vehicle conflicts.
- Implementing eastbound and westbound split phasing to reduce the conflicts between left-turning vehicles and other road users. It should be noted this improvement creates additional intersection delay and requires an upgrade to the signal heads and a structural analysis to determine the feasibility of the existing signal poles and span wire to accommodate the four section signal heads.

While no additional funding has been identified for this intersection, several long-term treatments are discussed in more detail later in the memorandum.

[1] Bend 3rd Street Evaluation and Signal Upgrade; February 2023; DKS Associates.

ALTERNATIVE EVALUATION

The alternatives were compared using the evaluation criteria documented in *Technical Memorandum #1: Study Background and Goals and Objectives* for each of the six project goal areas:

- Goal 1: Increase System Functionality, Quality and Connectivity for All Users
- Goal 2: Ensure Safety for All Users
- Goal 3: Support Economic Development
- Goal 4: Protect Livability and Ensure Equity and Access
- Goal 5: Steward the Environment
- Goal 6: Develop Solutions That Are Cost-Effective and Implementable

Concept figures are included for each alternative in the body of the memorandum as well as in Appendix A. Each of the alternatives was scored relative to evaluation criteria to highlight the assumed level of benefit. These qualitative scores will help guide the discussion of the key opportunities and tradeoffs associated with each alternative and lead to ultimately selecting a preferred alternative. Each evaluation criterion is rated on the qualitative scale listed in Table 1. The following sections describe the evaluation of each of the five major study intersections.

TABLE 1: ALTERNATIVE SCORING SCALE

QUALITATIVE SCORE	PERFORMANCE
	Excellent
	Good
	Fair
	Poor
	Very Poor

REED MARKET ROAD/BROOKSWOOD BOULEVARD

The Reed Market Road/Brookswood Boulevard intersection was analyzed independently based on an analysis completed in 2019-2020 for the City of Bend. The previous study, documented in a February 2020 report, analyzed both the addition of lanes, using the methodologies outlined in the Highway Capacity Manual (HCM), and the existing geometry with a metering signal system for improved system reliability. The metering evaluation was completed using Vissim 11 and was followed up with a field validation study using temporary signals and manual control.

The current evaluation considered two alternatives:

- Alternative 1 - Multilane Roundabout:
  - Under this alternative, left turn lanes were added on the northbound and southbound approaches and right turn lanes were added on the eastbound and westbound approaches. These lane additions were selected based on the findings of the 2019-2020 study and to specifically address peak period patterns during both the AM and PM peak periods. Figure 6 shows the multilane configuration. This alternative maintains the same sidewalk and bike lane with option to exit to the sidewalk or continue in the travel lane. In addition to adding capacity through additional lanes, the geometry shown in Figure 6 also adjusts curb lines to make drivers intended movements more apparent, which may increase gap acceptance for downstream drivers.
- Alternative 2 - Multilane Roundabout with Metering:
  - The second alternative assumed the same geometry and added metering signals to each approach. The metering signals were placed upstream of the lane additions and are intended to operate independently from the roundabout; drivers still must yield at the roundabout during metering operation. The metering signal logic was informed by the previous Vissim study and field evaluation. The metering signals have been made completely dynamic, turning on and off when the metering signals will provide benefit.

EVALUATION METHODOLOGY

For this evaluation, the alternatives have both been evaluated using Vissim. The alternatives evaluation utilized the existing calibrated roundabout model from the 2019 study, with updated geometry for the proposed multilane configuration. The Vissim model was calibrated in 2019 utilizing volume and queueing metrics. The model analyzed the evening peak period, 3 PM to 6 PM. The roundabout was modeled using priority rules for yielding. Full details on the simulation model development and calibration are included in Appendix D.

For this study, 2040 turning movement counts were provided for the PM peak hour and two-hour peak period. Findings from the 2019 study showed that changing volume profiles and routes throughout the peak period are a critical factor to the queueing experienced. Due to this, this study included the same volume profiles and routing profiles from the 2019 study but were scaled to match the provided 2040 peak hour volume data. The scaled volume data was validated to be representative of peak hour conditions.

FIGURE 6. PARTIAL MULTILANE ROUNDABOUT AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

The metering logic is complex and was uniquely developed for this analysis based on past simulation and field test scenarios at this intersection. For this analysis, metering signals were tested in the multilane roundabout alternative; however, the metering signals were placed on the approaches at the single-lane cross section, upstream of where the multilane section develops. Due to this, programming and infrastructure needs for the metering alternative are based on a single lane. The metering signals can operate in one of three modes: off, single-approach, or dual-approach:

- When in the off mode, all signals are dark. The off mode cannot be shorter than two minutes..
- In the single-approach mode, a single approach is metered with periods of green, yellow, and red. Metering signals on all other approaches are dark. The signal will go red if gaps on the metered approach rise beyond a threshold or if it has been green for a set duration. The signal will be green if the adjacent, downstream approach is no longer queued or reaches a set duration.
- During the dual-approach mode, two adjacent approaches are metered. The metering signals on the other two approaches are dark. Both approaches first are held in red, the adjacent,

downstream approach then gets a green indication, then the upstream approach gets a green indication. Green and red activating targets are established similar to the single-approach mode.

Although the evaluation made use of one (single-approach mode) or two (dual-approach mode) metering signals at a time, metering signals are assumed to be placed on each approach to allow operational flexibility through different time periods of the day. There are activating targets in all modes to transition to another mode based on conditions.

The metering logic makes use of several detectors along each approach and in the roundabout. On each approach are a series of four detectors. Detector 0 is at the yield line at the roundabout, Detector 1 is at the stop bar of the metering signal, Detector 3 is just downstream of the ideal max queue (for example south of Columbia Street or west of the ramp terminal), Detector 2 is halfway between Detector 1 and 3.

GOAL 1: INCREASE SYSTEM FUNCTIONALITY, QUALITY AND CONNECTIVITY FOR ALL USERS

OBJECTIVES A AND B (TRAFFIC OPERATIONS)

Objectives A and B of Goal 1 relate to traffic operations, both for US 97 (A) and the local roadway system in the interchange area (B).

Given the location of the Reed Market Road/Brookswood Boulevard intersection, the isolated intersection operations have minimal effect on US 97 mainline. However, metering signals do provide the ability to prioritize certain approaches, which can reduce the occurrence of queues extending from the intersection to the US 97 ramps. This has the potential to reduce the probability of queues causing traffic to back down the ramps to the US 97 mainline. However, the pilot project identified that if the volumes vary significantly over various time periods, it may be difficult to program an approach that consistently reduces queues and improves operation.

For the local roadway network within the study area, the metering signals alternative is shown to improve operations beyond the multilane roundabout alternative. However, metering signals do not completely mitigate congestion. Table 2 shows the average delay through the network for vehicles simulated. Without meters, the average delay is nearly 500 seconds/vehicle. With meters, the delay is improved by about 25 percent to 384 seconds. Table 3 shows the average queue length across the 3-hour period for each approach. With metering, the queues are spread more evenly across each approach. Based on prior analysis, this spreading of the queues has the most potential to benefit US 97 during the AM peak period when queueing can reach the interchange ramps. Similar to queue spreading, delay is also spread. Without metering, the southbound and westbound approaches experience relatively low delay and the northbound approach experiences extremely high delay. With metering, northbound approach delay reduces, while the southbound and westbound movements have an increase in delay.

TABLE 2: MICROSIMULATION DELAY

ALTERNATIVE	TOTAL VEHICLES (ACTIVE + ARRIVED + LATENT)	VEHICLE HOURS OF DELAY (TOTAL DELAY + LATENT DELAY) (HOURS)	AVERAGE DELAY (SECONDS/VEHICLE)
MULTILANE	10,582	1,460	497
MULTILANE METERED	10,571	1,129	384

TABLE 3: MICROSIMULATION AVERAGE QUEUE

ALTERNATIVE	NORTHBOUND	SOUTHBOUND	EASTBOUND	WESTBOUND
DISTANCE AVAILABLE	1,100 feet to SW Hillwood Ct	860 feet to SW Columbia St	1,200 feet to N Alderwood Cir	1,700 feet to US 97 Ramp Terminal
MULTILANE	3,440+ feet (south of Rock Bluff Ln)	25 feet	1,120 feet	200 feet
MULTILANE METERED	2,880 feet (between McClellan Rd and Rock Bluff Ln)	1,660 feet (north of Powerhouse Dr)	565 feet	640 feet

+ QUEUE EXCEEDED MODEL GEOMETRY FOR A LARGE PORTION OF THE PEAK PERIOD

In addition to the Vissim microsimulation analysis, a HCM analysis was conducted for the No Build and multilane build condition. The metered alternative cannot be modeled with HCM methodologies. There are some other key differences between an HCM analysis and a microsimulation analysis. The HCM analysis analyzes a single 15-minute period based on the peak hour volume and a peak hour factor (PHF). The microsimulation analysis was a three-hour analysis with varying demand and routing conditions for each 15-minute period in the three-hour period. Through the field evaluation of the metering, the directionality of traffic flow peaking was observed to have an impact on roundabout operations. An HCM analysis of the roundabout will not fully replicate these traffic flow patterns, particularly for approaches significantly over capacity, and will differ from the Vissim results. The intent of the HCM analysis is to provide a relative assessment of the improvement that could be expected over the No Build scenario by converting the roundabout to a multilane roundabout. Table 4 and Table 5 list the HCM delay, level of service, volume-to-capacity (v/c) ratio and 95th percentile queue lengths and the software reports are included in Appendix B.

Widening for the partial multilane roundabout has significant benefits compared to the No-Build condition.

TABLE 4: HCM DELAY AND LEVEL OF SERVICE

	AVERAGE DELAY BY APPROACH (SEC) [LOS] V/C				
ALTERNATIVE	Northbound	Southbound	Eastbound	Westbound	Intersection
NO-BUILD	339 [F] **1.69**	265 [F] **1.53**	353 [F] **1.72**	296 [F] **1.60**	309 [F] NA
MULTILANE	68 [F] **1.08**	21 [C] 0.80	104 [F] **1.21**	24 [C] 0.80	51 [F] NA

Bold and red indicates approach v/c ratio greater than 1.0.

TABLE 5: HCM 95TH PERCENTILE QUEUE LENGTH

	95TH PERCENTILE QUEUE LENGTH (FEET)			
ALTERNATIVE	Northbound	Southbound	Eastbound	Westbound
NO-BUILD	1,175	1,290	1,175	1,260
MULTILANE	440	205	545	200

Note: 25 feet per vehicle is used to estimate the queue length.

Note: HCM queue results report those vehicles which are in queue for the roundabout itself. Queues extending beyond side streets may be longer due to vehicles which are turning before the roundabout. Queues may also extend onto the side street.

OBJECTIVE C (ACTIVE TRANSPORTATION)

Both proposed alternatives increase the roundabout entries from one lane to two lanes. This increases the number of conflict points and potentially increases speeds on the approaches. However, the roundabout exits remain single lane, which is beneficial for accommodation of pedestrians who are blind or have limited vision (see NCHRP Report 674)[2]. Rectangular rapid flashing beacons (RRFBs) would likely be installed to facilitate pedestrian crossings on the dual entry lanes. Placement of the metering signals relative to the downstream RRFBs would require additional design consideration. During the field evaluation of the metering condition in 2019 there was no noticeable impact on yielding for pedestrians by drivers on the metered or unmetered approaches.

The proposed multilane geometric design continues to allow people bicycling to either use the roundabout traffic lanes or to exit using bicycle ramps and use crosswalks to navigate the intersection.

OBJECTIVE D (TRANSIT)

The alternatives for this intersection have no specific transit improvements other than a reduction in delay for existing or future transit lines on the corridor. While no prioritization was modeled within the metered roundabout alternative, the meters could presumably be used to reduce delay for transit vehicles by providing transit vehicle priority. Further study would be needed to

[2] NCHRP Report 674: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities, National Cooperative Highway Research Program, 2010.

determine the appropriate balance between reducing transit delay and increasing delay and queuing on remaining approaches.

GOAL 1 SCORING SUMMARY

Table 6 shows the overall scoring results under Goal 1 for the improvement alternatives at Reed Market Road/Brookswood Boulevard.

TABLE 6: GOAL 1 SCORING AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. TRAFFIC OPERATIONS (ODOT)	-	-
B. TRAFFIC OPERATIONS (CITY)	^	^
C. ACTIVE TRANSPORTATION	v	v
D. TRANSIT	^	^

GOAL 2: ENSURE SAFETY FOR ALL USERS

Expansion of the roundabout to include multilane approaches will increase the number of conflict points for all users. However, multilane roundabouts still have a better safety performance by reducing the number and severity of crashes compared to other alternatives that would increase capacity, including signalized intersections.

Reduction in queueing leads to increased safety by limiting queues from extending onto the Parkway.

While emergency vehicle preemption was not modeled within the metered roundabout alternative, the meters could presumably be used to reduce delay for emergency vehicles with emergency lights active by providing preemption. Further study would be needed to determine the appropriate balance between emergency vehicle access and queue impacts on the other approaches.

Table 7 shows the scoring results under Goal 2 for the alternatives.

TABLE 7: GOAL 2 SCORING AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. CRASH REDUCTION	I	I
B. SAFETY FOR PEOPLE WALKING AND BIKING	⌄	⌄
C. ODOT'S ACCESS SPACING	-	-

GOAL 3: SUPPORT ECONOMIC DEVELOPMENT

Both alternatives serve to increase capacity of the intersection, reducing queueing impacts on property access points and improving peak hour access to commercial areas. All alternatives are expected to accommodate freight access, with no significant changes from existing conditions.

Table 8 shows the scoring results under Goal 3 for the alternatives.

TABLE 8: GOAL 3 SCORING AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. ACCESS EFFECTIVENESS	I	I
B. TRUCK FREIGHT ACCOMMODATION	I	I

GOAL 4: PROTECT LIVABILITY AND ENSURE EQUITY AND ACCESS

By reducing delay at the intersection, the viability of transit along the Reed Market Road, Brookswood Boulevard, and Bond Street corridors is improved over the existing condition. Furthermore, reduced delay at this intersection supports access from residential areas to commercial uses.

Table 9 shows the scoring results under Goal 4 for the alternatives.

TABLE 9: GOAL 4 SCORING AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. COMPLETE STREET	I	I
B. EQUITY	I	I

GOAL 5: STEWARD THE ENVIRONMENT

By reducing delay at the intersection, both alternatives and especially the metering alternative reduce emissions from idling vehicles. Table 10 shows the scoring results under Goal 5 for the alternatives.

TABLE 10: GOAL 5 SCORING AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. REDUCE EMISSIONS	^	^

GOAL 6: DEVELOP SOLUTIONS THAT ARE COST-EFFECTIVE AND IMPLEMENTABLE

The February 2020 report documented estimated costs for the multilane alternative as well as the option to add metering signals. The 2020 estimated costs as well as adjusted 2023 costs are:

- Multilane Roundabout:
  - 2020 cost estimate = $3,475,000
  - 2023 cost estimate = $3,996,250 (Assumes 15 percent increase due to inflation)
- Addition of Metering Signals
  - 2020 cost estimate = $453,440
  - 2023 cost estimate = $680,160 (Assumes 50 percent increase due to inflation and increased costs for signal equipment)

As shown in Table 11, the expected funding at this intersection is $4.25 million. Therefore, Alternative 1 is expected to fit within the expected funding while Alternative 2 may not. The multilane alternative concept was developed with the intent to generally maintain the inscribed circle diameter footprint to reduce construction impacts and allow for staged construction. Additionally, the alternatives summarized in this analysis allow for phasing with the option to construct the multilane alternative and then add metering when the incremental operational benefits justify the additional cost.

TABLE 11: COST ESTIMATES FOR ALTERNATIVES AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

	ALT 1	ALT 2	EXPECTED FUNDING
TOTAL COST	$4.0 million	$4.7 million	$4.25 million

Table 12 shows the scoring results under Goal 6 for the alternatives.

TABLE 12: GOAL 6 SCORING AT REED MARKET ROAD/BROOKSWOOD BOULEVARD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. LOW-COST, HIGH BENEFIT	^	I
B. LEVERAGE PARTNERSHIPS	^	I
C. CONSTRUCTABLE IN PHASES, MAINTENANCE, DESIGN EXCEPTIONS, TRAFFIC MAINTENANCE DURING CONSTRUCTION	I	^

SUMMARY OF EVALUATION

Table 13 summarizes the scoring for each of the two alternatives across the project goals. Key differentiators in scoring between alternatives include:

- Goal 1: Increase System Functionality, Quality and Connectivity for All Users
  - The Multilane alternative improves operations over the No Build scenario but does not resolve all operational issues.
  - The Multilane with Metering alternative provides additional benefit over the Multilane alternative and allows specific control of where queueing happens and the ability to control queues where other elements of the system could be impacted (e.g., the US 97 ramps).
- Goal 2: Ensure Safety for All Users
  - While both alternatives result in an increased number of conflict points over the existing single-lane roundabout, multilane roundabouts still have a better safety performance than other alternatives that would increase capacity, including signalized intersections.
  - The addition of meters could incorporate emergency vehicle preemption to facilitate emergency response during queued conditions. Further study is required to determine actual impacts.
- Goal 3: Support Economic Development
  - The Multilane alternative increases capacity of the intersection, reducing impacts on property access points and improving peak hour access to commercial areas.

  - The metering condition further improves property access by limiting excessive queue growth on any one approach.
- Goal 4: Protect Livability and Ensure Equity and Access
  - Both alternatives provide increased access to areas served by this intersection.
- Goal 5: Steward the Environment
  - Both alternatives result in emissions reduction by reducing vehicular delay. The metering alternative results in additional delay reduction.
- Goal 6: Develop Solutions that are Cost-Effective and Implementable
  - The Multilane alternative has been developed to minimize impacts during construction. In addition, the lane additions identified in this concept are not dependent on each other and could be phased over time.
  - The addition of meters can be considered once the additional benefit justifies the additional cost.

TABLE 13: REED MARKET ROAD/BROOKSWOOD BOULEVARD ALTERNATIVE PERFORMANCE

	GOAL	ALTERNATIVE 1	ALTERNATIVE 2
GOAL 1	Increase System Functionality, Quality and Connectivity for All Users	^	^
GOAL 2	Ensure Safety for All Users	I	I
GOAL 3	Support Economic Development	I	I
GOAL 4	Protect Livability and Ensure Equity and Access	I	I
GOAL 5	Steward the Environment	^	^
GOAL 6	Develop Solutions That Are Cost-Effective and Implementable	^	I

REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

The Reed Market Road and US 97 southbound ramp terminal is currently signalized and has a southbound left-turn lane and shared left-through-right turn lane. Congestion at the intersection is projected to be slightly worse than the adopted mobility target, with the intersection operating near capacity. In addition, even today, westbound queues from the Reed Market Road/Brookswood Boulevard intersection spill back through the southbound ramp terminal, making the actual level of congestion experienced worse than calculated. If these conditions are not mitigated, the southbound exit ramp queue could spill back into the portion of the ramp needed for safe deceleration and stopping. Other issues to be addressed include conflicts with the westbound right-turn lane drop and the westbound bike lane crossover, and some reported challenges for heavy vehicles attempting to make the westbound right turn to the southbound loop ramp.

Two alternatives to address these concerns at the intersection were evaluated, including:

- Alternative 1: Providing an additional southbound dedicated right-turn lane
- Alternative 2: Extending the US 97 southbound exit ramp

Potential options to improve westbound bicycle comfort level in both alternatives include shifting the bike lane adjacent to the curb, adding a bike ramp to provide an option to cross using the sidewalk or crosswalk, and adding a bike signal at the intersection (adding a bike signal may also require modifications to the signal such as a right-turn overlap with blank-out sign and potentially a bike level-push button). For both alternatives, the analysis assumed that the signal cycle length would be increased and that the signal would be coordinated with a signal at the US 97 Northbound ramp terminal and other signalized intersections within the study area to enhance corridor operations. Figures 7 and 8 show concepts of both alternatives, with zoomable images included in Appendix A.

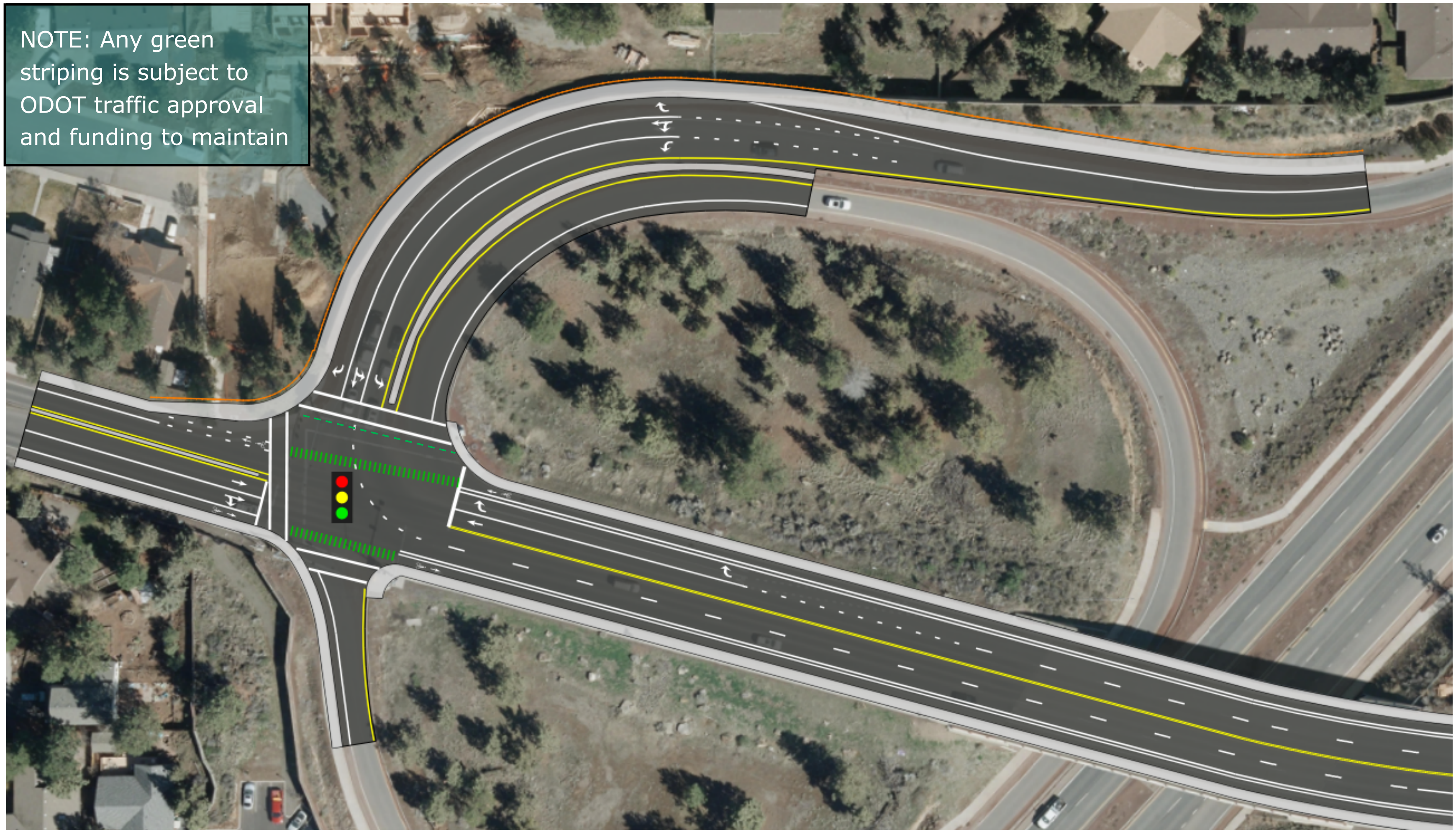

FIGURE 7. ALTERNATIVE 1 AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP

FIGURE 8. ALTERNATIVE 2 AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP

Figure 9 shows how the cross section on Reed Market Road can be modified to add buffered bike lanes within the existing structure while keeping people biking to the right of motor vehicle traffic approaching the southbound ramp terminal intersection. This would reduce the travel lane width to add buffers to the bike lane while maintaining the existing curb-to-curb width. Note that any changes in cross section at the US 97 interchange would need to be coordinated with the MAC.

This would also include a bike signal at the US 97 southbound ramp terminal and restricting westbound right-turn-on-red (RTOR) movements to reduce the risk of right-hook crashes as people biking cross the right turn lane through the intersection. Note: if a bike signal were to be implemented, it would require State Traffic Engineer approval and a blank-out sign with right-turn overlap may be recommended.

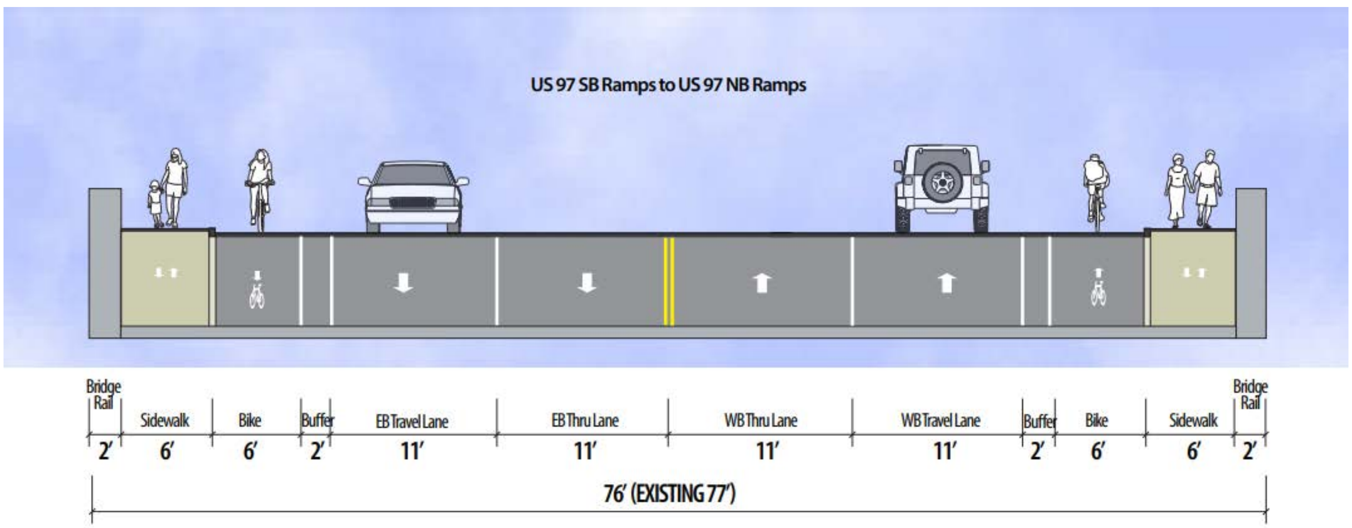

FIGURE 9. REED MARKET ROAD CROSS SECTION TO PROVIDE BUFFERED BIKE LANES (US 97 SOUTHBOUND RAMPS TO US 97 NORTHBOUND RAMPS)

GOAL 1: INCREASE SYSTEM FUNCTIONALITY, QUALITY, AND CONNECTIVITY FOR ALL USERS

OBJECTIVES A AND B (TRAFFIC OPERATIONS)

Table 14 summarizes the results for the two alternatives under future (year 2040) conditions, with the intersection's performance compared to the mobility standard.[3] As shown in the table, none of the alternatives are expected to meet the Highway Design Manual mobility standard, although Alternative 1 is expected to nearly meet the standard and would have a much lower v/c ratio than the No-Build condition. The additional southbound right-turn lane helps to accommodate the heavy southbound right-turn traffic (255 vehicles), reducing delay, queueing on the southbound approach, and providing storage for queue spillback from the Reed Market Road and Brookswood

[3] Intersection operations are reported using Highway Capacity Manual (HCM) 6th Edition methodology and the software reports are included in Appendix B.

Boulevard roundabout. In Alternative 2, extending the deceleration lane can help provide enough safe stopping distance on the ramp to prevent queue spillback onto the US 97 mainline. Due to signal timing changes associated with coordinating signal timing with the northbound ramp terminal (if implemented), the intersection v/c ratio is expected to improve slightly in Alternative 2 compared to the No-Build conditions but would still fail to meet the mobility standard. Both alternatives are expected to mitigate the risk of queue spillback onto mainline US 97. However, it is likely that risk of queue spillback will be significantly mitigated by removing bottlenecks elsewhere on Reed Market Road, indicating that adding the southbound right-turn lane or lengthening the on-ramp may not be needed until later in the 20-year planning horizon.

TABLE 14: FUTURE 2040 DESIGN HOUR TRAFFIC OPERATIONS AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

INTER-SECTION	JURIS-DICTION	ALTER-NATIVE[A]	CONTROL	MOBILITY STANDARD[E]	V/C[B]	LOS[C]	DELAY[D] (SEC)
REED MARKET RD & US 97 SB	ODOT (30HV)	No-Build	Signalized	≤ 0.90	**0.94**	C	26
		Alt 1	Signalized [F]	≤ 0.75	**0.78**	C	25
		Alt 2	Signalized [F]	≤ 0.75	**0.91**	C	30

Bold and red indicate a failure to meet the mobility standard.

30HV=30th highest hour; LOS=level of service; ODOT=Oregon Department of Transportation v/c=volume-to-capacity

[A] Future condition results represent 30HV operations for ODOT intersections and average weekday operations for City intersections, consistent with mobility standards.

[B] v/c ratio reported as the overall intersection v/c ratio at signalized intersections.

[C] LOS reported as the overall intersection LOS for signalized intersections.

[D] Control delay reported for overall intersection delay for signalized intersections.

[E] Oregon Highway Plan mobility targets apply to the no-build condition only. ODOT Highway Design Manual mobility standards apply to new construction. Note that ODOT adopted an alternative mobility target for this intersection as part of the US 97 Parkway Plan, which assumed a 0.90 v/c ratio during 30 HV conditions and ensuring 95th percentile queues do not extend into the portion of the exit ramp needed for deceleration (this applies to the no-build condition only).

[F] Includes westbound right-turn-on-red restriction but does not assume a protected bicycle phase due to HCM 6th edition limitations. The protected bicycle phase was tested with Highway Capacity Manual (HCM) 2000 methodology and did not have a significant impact on overall intersection delay.

OBJECTIVE C (ACTIVE TRANSPORTATION)

The current westbound right-turn lane drop at the southbound ramp terminal crosses the bike lane after a grade change with limited warning to motorists, causing conflicts and safety concerns. Both alternatives could include improvements to bicycle crossing safety to resolve the westbound bicycle conflict issue by shifting the bike lane adjacent to the curb and adding a bike signal at the intersection. However, the alternatives do increase the risk of conflict due to right-hook crashes during the green phase. These accidents could be reduced with the installation of a raised island that moves people biking to a more visible position. Both alternatives are expected to equally enhance the quality of biking facilities travelling through the intersection to cross US 97 and provide an option to use the sidewalk or crosswalk. However, Alternative 1 requires southbound road widening to provide the additional right-turn lane, resulting in a longer crossing distance that increases exposure for people walking and biking. Since this is a signalized intersection, this exposure is minimized, so Alternative 2 scores only slightly better on enhancing facilities for people walking and biking across US 97. It should be noted that both US 97 and Reed Market Road are not designated low-stress bicycle network or key walking and biking routes, therefore the related evaluation criteria were not evaluated.

OBJECTIVE D (TRANSIT)

Route 6 will be modified to serve downtown and the Oregon State University Cascades Campus by travelling along Reed Market Road between 3rd Street and Brookswood Boulevard. Among the two alternatives, Alternative 1 is expected to improve traffic operations at the intersection, reducing delays for future eastbound and westbound traffic by more than 20 percent and improving future transit travel times along Reed Market Road.

GOAL 1 SCORING SUMMARY

Table 15 shows the overall scoring results under Goal 1 for the improvement alternatives at the Reed Market Road/US 97 southbound ramp terminal.

TABLE 15: GOAL 1 SCORING AT THE REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. TRAFFIC OPERATIONS (ODOT)	⇈	I
B. TRAFFIC OPERATIONS (CITY)	N/A	N/A
C. ACTIVE TRANSPORTATION	I	↑
D. TRANSIT	↑	I

GOAL 2: ENSURE SAFETY FOR ALL USERS

Both Alternative 1 and Alternative 2 are expected to help manage the risk of queues spilling back to the US 97 mainline. Alternative 1 has the potential to reduce all types of crashes by four percent[4] by adding a right-turn lane. Both alternatives also place the bike lane adjacent to the curb and include a protected crossing of the intersection with a bike signal and restricting RTOR movements, which could be implemented through the use of a blank-out sign to avoid a full-time RTOR restriction. This improvement reduces conflict points between people biking and vehicles, which significantly minimizes risk factors that could lead to bicycle-related crashes. In addition,

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[4] ODOT Crash Reduction Factor List, 2023, ID: H4.

such an improvement is also expected to help increase physical separation between users by providing a buffer to the current curb tight sidewalk. However, Alternative 1 requires roadway widening on the southbound approach, resulting in longer crossing times and increased exposure for people walking and biking.

ODOT has adopted interchange and access management spacing standards in the Oregon Highway Plan (OHP)[5] that specify the minimum separation required between adjacent interchange ramp tapers and access points along crossroads. The ODOT-adopted access spacing standards require a spacing distance of greater than 5,280 feet (1 mile) along US 97 between adjacent ramp tapers. The current spacing between the Reed Market Road and Colorado Avenue southbound ramp tapers is approximately 3,100 feet, failing to meet the standard. Alternative 1 has no effect on access spacing along US 97, while Alternative 2 is expected to shorten the access spacing slightly by extending the deceleration lane by 200 to 500 feet.

Table 16 shows the scoring results under Goal 2 for the alternatives.

TABLE 16: GOAL 2 SCORING AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. CRASH REDUCTION	⌃	⌃
B. SAFETY FOR PEOPLE WALKING AND BIKING	⌃	⌃⌃
C. ODOT'S ACCESS SPACING	I	⌄

GOAL 3: SUPPORT ECONOMIC DEVELOPMENT

Neither of these alternatives is expected to impact effective access to properties along Reed Market Road, although some additional right-of-way will be needed with Alternative 1. Both alternatives have minimal impacts on facilities accommodating heavy vehicle movements along US 97 and to and from destinations along Reed Market Road. Moving the right-turn lane farther from the curb may provide some minor benefits to freight vehicles making a westbound right turn, although more information is needed about vertical design elements. Note that any changes in cross section at the US 97 interchange would need to be coordinated with the MAC. Scoring results for both alternatives under this goal are presented in Table 17.

[5] 1999 Oregon Highway Plan, as amended May 2015, Oregon Department of Transportation, Appendix C.

TABLE 17: GOAL 3 SCORING AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. ACCESS EFFECTIVENESS	I	I
B. TRUCK FREIGHT ACCOMMODATION	I	I

GOAL 4: PROTECT LIVABILITY AND ENSURE EQUITY AND ACCESS

Table 18 presents the scoring results for alternatives under the goal to protect livability and ensure equity and access.

As discussed under Goal 1 and Goal 2, both alternatives have similar improvements planned to enhance safety for people walking and biking. However, Alternative 1 results in a longer crossing distance that increases exposure of people walking and biking through the intersection, although that exposure is minimized with the traffic signal. Therefore, Alternatives 1 and 2 score similarly on addressing existing barriers for people walking and biking along Reed Market Road. As noted under Goal 1 Objective D, Alternative 1 is expected to improve traffic operations at the intersection, reducing delay for future eastbound and westbound transit along Reed Market Road and potentially better accommodating planned transit service improvements.

Both alternatives are not expected to disproportionately impact properties owned, used, or accessed by historically underrepresented community members relative to other populations.

TABLE 18: GOAL 4 SCORING AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. COMPLETE STREET	^	^
B. EQUITY	I	I

GOAL 5: STEWARD THE ENVIRONMENT

As shown in Table 19, both alternatives score fair on reducing vehicle emissions. Alternative 1 reduces overall vehicle delay better than Alternative 2, including transit delay. However, Alternative 2 better supports access for people walking and biking than Alternative 1. Therefore, both alternatives are expected to have similar impacts on vehicle emissions.

TABLE 19: GOAL 5 SCORING AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. REDUCE EMISSIONS	I	I

GOAL 6: DEVELOP SOLUTIONS THAT ARE COST-EFFECTIVE AND IMPLEMENTABLE

Table 20 lists the planning-level cost estimate of each alternative, with detailed cost estimates included in Appendix C. Alternative 2 is generally more cost-effective than Alternative 1, at approximately half the price, although both alternatives are likely to fit within the expected funding available for the interchange.

TABLE 20: COST ESTIMATE FOR ALTERNATIVES AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

	ALT 1	ALT 2	EXPECTED FUNDING[A]
PLANNING LEVEL COST ESTIMATE	$5.7 million	$2.3 million	$10.25 million (total for interchange)

[A] Future funding estimate provided by ODOT, consistent with the project cost listed in the Bend Transportation System Plan.

Both alternatives are expected to be compatible with other project recommendations from the US 97 Parkway Plan, Bend TSP, and GO Bond. Both alternative designs would need to be constructed in a single phase and are expected to require limited design exceptions. Both are also expected to be able to be reasonably maintained after construction. During construction, Alternative 2 would likely have a larger impact on US 97 mainline traffic but less of an impact on traffic travelling along Reed Market Road. Table 21 lists the scoring of each of the alternatives.

TABLE 21: GOAL 6 SCORING AT REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. LOW-COST, HIGH BENEFIT	^	^^
B. LEVERAGE PARTNERSHIPS	^	^
C. CONSTRUCTABLE IN PHASES, MAINTENANCE, DESIGN EXCEPTIONS, TRAFFIC MAINTENANCE DURING CONSTRUCTION	^	^

SUMMARY OF EVALUATION

Table 22 summarizes the scoring for the two alternatives across the project goals. Key differentiators in scoring between alternatives include:

- Goal 1: Increase System Functionality, Quality, and Connectivity for All Users
  - Alternative 1 significantly reduces the overall intersection v/c ratio by adding a southbound right-turn lane. This results in less queueing on the southbound approach and reduces delay for the eastbound and westbound movements, which may better support a planned transit route travelling along Reed Market Road.
  - Both alternatives equally enhance biking facilities across US 97 by addressing the conflict between people biking and westbound right-turning vehicles. A drawback of Alternative 1 is the longer southbound crossing distance, increasing exposure for people walking and biking.
- Goal 2: Ensure Safety for All Users
  - Both alternatives are expected to have similar reductions in crash frequency and severity, based on crash reduction factors. Both alternatives address the conflict between people biking and westbound right-turning vehicles.
  - In Alternative 1, adding a southbound right-turn lane lengthens the crossing distance, increasing exposure for people walking and biking.
  - Alternative 2 lengthens the deceleration lane length, resulting in less distance between the Reed Market Road and Colorado Avenue southbound interchange ramp tapers, worsening the already deficient access spacing.
- Goal 3: Support Economic Development
  - Neither alternative is expected to impact effective access to properties along Reed Market Road.
  - Both alternatives have minimal impacts on facilities accommodating heavy vehicle movements along US 97 and to and from destinations along Reed Market Road.
- Goal 4: Protect Livability and Ensure Equity and Access
  - Alternative 2 scores better on addressing existing barriers for people walking and biking along Reed Market Road as Alternative 1 results in a longer crossing distance that increases exposure of people walking and biking through the intersection.
  - Alternative 1 is expected to reduce delays for future eastbound and westbound transit along Reed Market Road and potentially better accommodate planned transit service improvements.
  - Both alternatives are not expected to disproportionately impact properties owned, used, or accessed by historically underrepresented community members relative to other populations.
- Goal 5: Steward the Environment
  - Alternative 1 is expected to slightly reduce vehicle delays and emissions but does not perform as well with respect to people walking and biking.
  - Alternative 2 improves conditions for people walking and biking but slightly increases vehicle delay and emissions.
- Goal 6: Develop Solutions that are Cost-Effective and Implementable
  - Alternative 2 is more cost-effective than Alternative 1 but could have slightly larger impacts on traffic during construction.

TABLE 22: REED MARKET ROAD/US 97 SB RAMP TERMINAL ALTERNATIVE PERFORMANCE

	GOAL	ALTERNATIVE 1	ALTERNATIVE 2
GOAL 1	Increase System Functionality, Quality, and Connectivity for All Users	^	I
GOAL 2	Ensure Safety for All Users	^	^
GOAL 3	Support Economic Development	I	I
GOAL 4	Protect Livability and Ensure Equity and Access	^	^
GOAL 5	Steward the Environment	I	I
GOAL 6	Develop Solutions That Are Cost-Effective and Implementable	^	^^

REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

The Reed Market Road/US 97 northbound ramp terminal intersection is currently controlled by a two-way stop. The northbound left-turn movement has limited sight distance and high volumes along Reed Market Road, particularly in the future, resulting in significant delays for northbound left-turning vehicles. Reed Market Road and Division Street, located 150 feet east of the US 97 northbound ramp terminal, are also controlled by a two-way stop and serve as the US 97 northbound entrance ramp but allow for two-way traffic to serve local properties, inconsistent with ODOT's access management and spacing standards and resulting in a shorter than standard acceleration lane[6] onto US 97. Two alternatives to address these concerns at the intersection were evaluated, including:

- Alternative 1:
  - Constructing a traffic signal at the US 97 northbound ramp terminal.
  - Converting the north leg of Division Street to right-in, right-out only (the northbound Division Street entrance ramp would still not meet ODOT's standard for acceleration lane length).
- Alternative 2:
  - Constructing a traffic signal at the US 97 northbound ramp terminal.

[6] Division Street to northbound US 97 ramp has existing acceleration lane length of 425 feet, not meeting the ODOT Highway Design Manual minimum acceleration lane length of 540 feet.

- Separating the northbound entrance ramp from Division Street and aligning the new entrance ramp with the Reed Market Road/US 97 northbound ramp signalized intersection (the new entrance ramp would meet ODOT's standard for acceleration lane length).
- Leaving Division Street north of Reed Market Road in place to provide business access, but converting the approach to Reed Market Road to right-in and right-out movements only.
- Converting the south leg of Division Street to right-in and right-out only.

The signal at the northbound ramp terminal is assumed to be coordinated with other signalized intersections within the study area (i.e., the US 97 southbound ramp and 3rd Street intersections). Note that with the realignment of the new US 97 entrance ramp in Alternative 2, there may be an opportunity to further lengthen the loop ramp (Reed Market Road eastbound right turn onto US 97 northbound) acceleration lane, but that option is not included in the current cost estimate. An alternative that included construction of a roundabout at this intersection was also considered during the preliminary screening phase. However, it was dismissed due to several issues such as the alignment of the existing US 97 overcrossing, topography, and impacts to adjacent development, which would have likely made the cost of construction far greater than available funding for improvements at the interchange. Figures 10 and 11 show concepts of both alternatives, with zoomable images included in Appendix A.

One potential solution in the future to improve safety for people walking and biking is to implement a raised or protected island on both the southeast and southwest corners at the intersection of Division Street and possibly at the US 97 off ramp to the eastbound sidewalk on the east leg. However, the option at the US 97 off ramp may be less feasible due to the grades. In addition, since Brosterhous Road is a designated low-stress network, an option to improve safety is widening the short segment of Division Street from Reed Market Road to Brosterhous Road with a shared use path for people walking and biking to access the signal crossing Reed Market Road at Division Street. This avoids the need to use the Reed Market Road and 3rd Street intersection if the protected intersection design is not selected there.

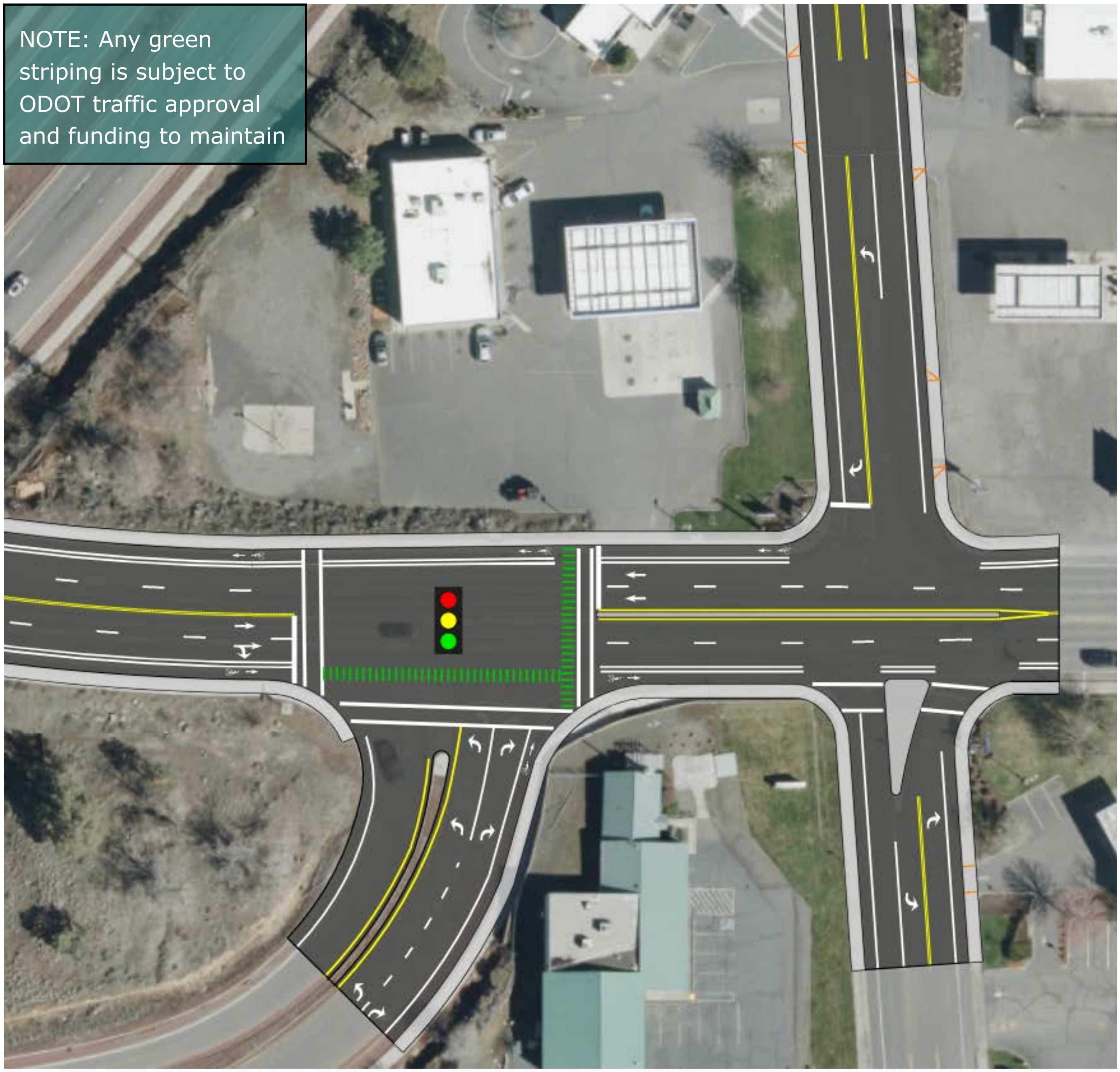

FIGURE 10. ALTERNATIVE 1 AT REED MARKET ROAD/US 97 NORTHBOUND RAMP

FIGURE 11. ALTERNATIVE 2 AT REED MARKET ROAD/US 97 NORTHBOUND RAMP

GOAL 1: INCREASE SYSTEM FUNCTIONALITY, QUALITY, AND CONNECTIVITY FOR ALL USERS

OBJECTIVES A AND B (TRAFFIC OPERATIONS)

Table 23 summarizes the results for the two alternatives under future conditions, with the intersection's performance compared to the applicable mobility standard.[7]

With the addition of a traffic signal, both alternatives are expected to operate significantly better at the US 97 northbound ramp terminal. Both operate with similar levels of delay and the same intersection v/c ratio, meeting the mobility standard. It should be noted that the increased vehicular delay for Alternative 2 at the US 97 northbound ramp terminal is due to delay associated with the westbound right-turn traffic volumes onto US 97 northbound, which occurs at Division Street in Alternative 1. In addition, both alternatives also restricted left turns at Division Street, which was converted to right-in, right-out only. Given the high east-west traffic volumes, restricting left turns helps reduce conflict points and prevents left-turn vehicles from blocking the approaches when waiting for potential gaps.

TABLE 23: FUTURE 2040 DESIGN HOUR TRAFFIC OPERATIONS AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

INTERSECTION	JURIS-DICTION	ALTER-NATIVE[A]	CONTROL	MOBILITY STANDARD[E]	V/C[B]	LOS[C]	DELAY (SEC)[D]
REED MARKET RD & US 97 NB	ODOT (30HV)	No-Build	TWSC	≤ 0.85 (ramp) ≤ 0.85 (Reed Market Rd)	NA/**2.56**	NA/F	NA/>150
		Alt 1	Signalized	≤ 0.75	0.63	A	6
		Alt 2	Signalized	≤ 0.75	0.63	A	9
REED MARKET RD & DIVISION ST	ODOT (30HV)	No-Build	TWSC	≤ 1.00	0.46/0.14	B/C	14/17
		Alt 1	TWSC	≤ 1.00	0.43/0.14	A/C	0/17
		Alt 2	TWSC	≤ 1.00	0.43/0.14	A/C	0/17

Bold and red indicate a failure to meet the mobility target.

30HV=30th highest hour; LOS=level of service; ODOT=Oregon Department of Transportation; TWSC=two-way stop-controlled; v/c=volume-to-capacity

[A] Future condition results represent 30HV operations for ODOT intersections and average weekday operations for City intersections, consistent with mobility targets.

[7] Intersection operations are reported using Highway Capacity Manual 6th Edition methodology and the software reports are included in Appendix B.

[B] v/c ratio reported as the overall intersection v/c ratio at signalized intersections and v/c ratio for major street/minor street at TWSC intersections.

[C] LOS reported as the worst major street LOS/minor street LOS for TWSC intersections and overall intersection LOS for signalized intersections.

[D] Control delay reported for worst case major street/minor street for TWSC intersections and overall intersection delay for signalized intersections.

[E] ODOT Highway Design Manual v/c standards apply to new construction.

OBJECTIVE C (ACTIVE TRANSPORTATION)

In both alternatives, installing a traffic signal provides a new enhanced crossing for people walking and biking across Reed Market Road. In addition, both alternatives implement right-in, right-out only movements at Division Street, which helps to reduce conflict points between intersection users. Both alternatives are expected to improve Reed Market Road and US 97 active transportation crossings.

OBJECTIVE D (TRANSIT)

Both alternatives add a new traffic signal at the US 97 northbound ramp terminal. This slightly increases delay for eastbound and westbound vehicles, including future transit along Reed Market Road, but overall intersection delay is still less than ten seconds, indicating limited impact to transit vehicles. Therefore, both alternatives score fair on the criterion of enhancing transit facilities across US 97.

GOAL 1 SCORING SUMMARY

Table 24 presents the scoring results for the alternatives for each objective under Goal 1.

TABLE 24: GOAL 1 SCORING AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. TRAFFIC OPERATIONS (ODOT)		
B. TRAFFIC OPERATIONS (CITY)		
C. ACTIVE TRANSPORTATION		
D. TRANSIT		

GOAL 2: ENSURE SAFETY FOR ALL USERS

Both alternatives include the installation of a traffic signal, which reduce angle crashes by 67 percent[8] but can also increase rear-end crashes by 143 percent,[9] according to ODOT's crash reduction factors. Despite these conflicting effects, the overall impact is expected to be positive since angle crashes tend to result in higher severity injuries, and about half of the crashes at this location have involved turning movements.

Converting Division Street to right-in, right-out operations restricts left-turn movements and reduces conflict points, with the potential to reduce overall crashes by 45 percent.[10] Both alternatives include the Division Street right-in, right-out turn restrictions, indicating similar effects on reducing the crash frequency and severity based on the crash reduction factor.

With a traffic signal in both alternatives, the northbound left-turn movement will no longer need to wait and find a gap with heavy east-west traffic volumes and limited sight distance. In Alternative 2, the added north leg to access US 97 will enhance safety by consolidating conflicts between people biking westbound and vehicles making a westbound right turn onto US 97 at a traffic signal, where a leading pedestrian interval or leading bicycle interval (LPI/LBI) could be considered. Alternative 2 also mitigates access management conflicts on the entrance-ramp by separating US 97 access from Division Street. This also allows for a lengthening of the acceleration lane to meet ODOT standards.

Table 25 shows the scoring results for both alternatives under the safety evaluation.

TABLE 25: GOAL 2 SCORING AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. CRASH REDUCTION	^	^
B. SAFETY FOR PEOPLE WALKING AND BIKING	^	^^
C. ODOT'S ACCESS SPACING	I	^^

[8] ODOT Crash Reduction Factor List, 2023, ID: H22.

[9] ODOT Crash Reduction Factor List, 2023, ID: H23.

[10] Crash Modification Factors (CMF) Clearinghouse, US DOT Federal Highway Administration, CMF ID 9821. Note: This CMF is based on a study of three-leg intersections.

GOAL 3: SUPPORT ECONOMIC DEVELOPMENT

Table 26 shows the scoring results under the goal of supporting economic development for both alternatives. Both alternatives include the restriction of the Division Street approaches to only right-in and right-out turning movements. While this will improve safety by eliminating closely spaced turning conflicts, it will also reduce the accessibility to some properties from certain directions. Furthermore, Alternative 2 would result in the acquisition of up to two properties. While the removal of businesses is not directly addressed by the evaluation criteria, it is assumed to score negatively in meeting the goal of supporting economic development.

In addition, both alternatives would have no negative impacts on facilities accommodating heavy vehicle movements along US 97 and to and from destinations along Reed Market Road. However, the separation of the US 97 entrance ramp from Division Street that is part of Alternative 2 could make it easier for heavy vehicles to get up to merging speed before entering the Parkway.

TABLE 26: GOAL 3 SCORING AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. ACCESS EFFECTIVENESS		
B. TRUCK FREIGHT ACCOMMODATION		

GOAL 4: PROTECT LIVABILITY AND ENSURE EQUITY AND ACCESS

Alternative 2 scores higher on the evaluation of providing a complete streets approach along the Reed Market Road corridor. As discussed under Goal 1, both alternatives address existing barriers for people walking and biking by enhancing walking and biking facilities, providing an enhanced crossing at US 97 northbound ramp terminal, and reducing left-turn conflicts at Division Street. Alternative 2 further mitigates access management conflicts and supports people walking and biking crossing US 97 by adding a north leg at the US 97 ramp terminal and removing access to US 97 on the north leg of Division Street. Again, both alternatives have minimal impacts on accommodating planned transit service improvements and expansions. Although a traffic signal improves the traffic operation, it also increases intersection delay and affects transit continuous flow.

Neither alternative is expected to disproportionately impact properties owned, used, or accessed by historically underrepresented community members relative to other populations.

Table 27 shows the scoring results under Goal 4.

TABLE 27: GOAL 4 SCORING AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. COMPLETE STREET	I	⌃
B. EQUITY	I	I

GOAL 5: STEWARD THE ENVIRONMENT

As shown in Table 28, both alternatives are expected to perform similarly with respect to stewarding the environment. Both significantly reduced delay at the US 97 northbound ramp terminal (with a similar impact on vehicle emissions) and both have similar benefits to people walking, biking, and taking transit.

TABLE 28: GOAL 5 SCORING AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. REDUCE EMISSIONS	⌃	⌃

GOAL 6: DEVELOP SOLUTIONS THAT ARE COST-EFFECTIVE AND IMPLEMENTABLE

Table 29 lists the planning-level cost estimate for each alternative, with detailed cost estimates included in Appendix C. While the alternatives offer comparable benefits, Alternative 2 provides better safety for all users. However, Alternative 1 is more cost-effective given it costs less than half of Alternative 2 costs. In addition, at approximately $4 million, Alternative 1 better fits within funding expectations.

TABLE 29: COST ESTIMATES FOR ALTERNATIVES AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

	ALT 1	ALT 2	EXPECTED FUNDING
PLANNING LEVEL COST ESTIMATE	$4.0 million	$9.4 million	$10.25 million (total for interchange)

Both alternatives are expected to be compatible with other project recommendations from the US 97 Parkway Plan, Bend TSP, and GO Bond, although Alternative 2 better enhances access onto US 97 by increasing the acceleration lane length. Note that Alternative 1 could function as a first phase of Alternative 2. Both alternatives are expected to require limited design exceptions and are not expected to create maintenance challenges. Table 30 lists the scoring of each of the alternatives.

TABLE 30: GOAL 6 SCORING AT REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. LOW-COST, HIGH BENEFIT	⌃⌃	⌄
B. LEVERAGE PARTNERSHIPS	⌃⌃	⌃
C. CONSTRUCTABLE IN PHASES, MAINTENANCE, DESIGN EXCEPTIONS, TRAFFIC MAINTENANCE DURING CONSTRUCTION	⌃	⌃

SUMMARY OF EVALUATION

Table 31 summarizes the scoring for each of the two alternatives across the project goals. Key differentiators in scoring between alternatives include:

- Goal 1: Increase System Functionality, Quality, and Connectivity for All Users
  - In both alternatives, traffic operations at the Reed Market Road and US 97 northbound ramp terminal are significantly improved by installing a traffic signal. Reed Market Road and Division Street no longer experience westbound and eastbound delay by restricting left-turn movements at the intersection.
  - In both alternatives, installing a traffic signal provides enhanced crossings of Reed Market Road for people walking and biking. Implementing the right-in, right-out treatment at Division Street also helps to reduce conflict points between intersection users.
  - Alternative 2 further supports US 97 crossings by adding a north leg to the intersection of Reed Market Road and US 97 northbound ramp terminal accessing US 97 and removing conflicts from the combined north Division Street and US 97 off ramp.
- Goal 2: Ensure Safety for All Users
  - Both alternatives include a new traffic signal at the US 97 northbound ramp terminal and restrict turning movements to right-in and right-out only at Division Street, similarly reducing crash frequency and severity.
  - Alternative 2 further enhances safety by mitigating access management conflicts on the US 97 northbound entrance ramp by removing US 97 access on north Division Street.

- Goal 3: Support Economic Development
  - Both alternatives include the restriction of the Division Street approaches to only right-in and right-out turning movements. While this would improve safety by eliminating closely spaced turning conflicts, it would also reduce the accessibility to some properties to and from certain directions. Furthermore, Alternative 2 would result in the acquisition of up to two properties.
  - Both alternatives would have no negative impacts on facilities accommodating heavy vehicle movements along US 97 and to and from destinations along Reed Market Road. However, the separation of the US 97 entrance ramp from Division Street that is part of Alternative 2 could make it easier for heavy vehicles to get up to merging speed before entering the Parkway.
- Goal 4: Protect Livability and Ensure Equity and Access
  - Both alternatives address existing barriers for people walking and biking by enhancing walking and biking facilities, providing an enhanced crossing at US 97 northbound ramp terminal, and reducing left-turn conflicts at Division Street.
  - Alternative 2 further mitigates access management conflicts and supports people walking and biking on US 97 by removing US 97 access on north Division Street.
  - Both alternatives have minimal impacts on accommodating planned transit service improvements and expansions.
  - Neither alternative is expected to disproportionately impact properties owned, used, or accessed by historically underrepresented community members relative to other populations.
- Goal 5: Steward the Environment
  - Both alternatives significantly improve traffic operations with less vehicular delays and have similar impacts on enhancing walking and biking facilities.
- Goal 6: Develop Solutions that are Cost-Effective and Implementable
  - Alternative 1 is more cost-effective than Alternative 2 and fits within funding expectations.
  - Alternative 1 could be designed as a first phase of Alternative 2 to improve the acceleration lane length of the US 97 northbound entrance ramp.

TABLE 31: REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET ALTERNATIVE PERFORMANCE

	GOAL	ALTERNATIVE 1	ALTERNATIVE 2
GOAL 1	Increase System Functionality, Quality, and Connectivity for All Users	⌃	⌃
GOAL 2	Ensure Safety for All Users	⌃	⌃⌃
GOAL 3	Support Economic Development	⌄	⌄
GOAL 4	Protect Livability and Ensure Equity and Access	|	⌃
GOAL 5	Steward the Environment	⌃	⌃
GOAL 6	Develop Solutions That Are Cost-Effective and Implementable	⌃⌃	|

REED MARKET ROAD/3RD STREET

The Reed Market Road and 3rd Street intersection is the confluence of two major arterial roadways in Bend and serves high traffic volumes on all approaches. This intersection is very congested today (v/c ratio of 1.05) and is forecast to be even more so in the future (v/c ratio of 1.26 by 2040). A major contributor to this congestion is the lack of separate eastbound and westbound left-turn lanes, which limits signal operations to split phasing. The existing bicycle and walking facilities are high-stress. Three alternatives to address these concerns at the intersection were evaluated, including:

- Alternative 1:
  - (a) Adding eastbound and westbound left-turn lanes
  - (b) Adding eastbound and westbound left-turn lanes and a dedicated southbound right turn lane.
- Alternative 2:
  - (a) Adding the same lanes as Alternative 1(a) and implementing a protected intersection design
  - (b) Adding the same lanes as Alternative 1(b) and implementing a protected intersection design
- Alternative 3:
  - Constructing a dual lane roundabout with northbound and southbound right-turn slip lanes.

Figures 12 to 14 show concepts of all three alternatives,[11] with zoomable images included in Appendix A. Note that all alternatives show the intersection shifted to the northwest to minimize right-of-way costs and impacts. A potential option for accommodating people biking in both Alternatives 1 and 2 is widening sidewalks to allow them to exit and use the crosswalks. In Alternative 3, people biking have the option to exit and use the sidewalk or stay in the lane travelling through the roundabout.

[11] Note: For Alternative 1 and 2, only alternatives with a southbound right-turn lane are shown in the concept drawings.

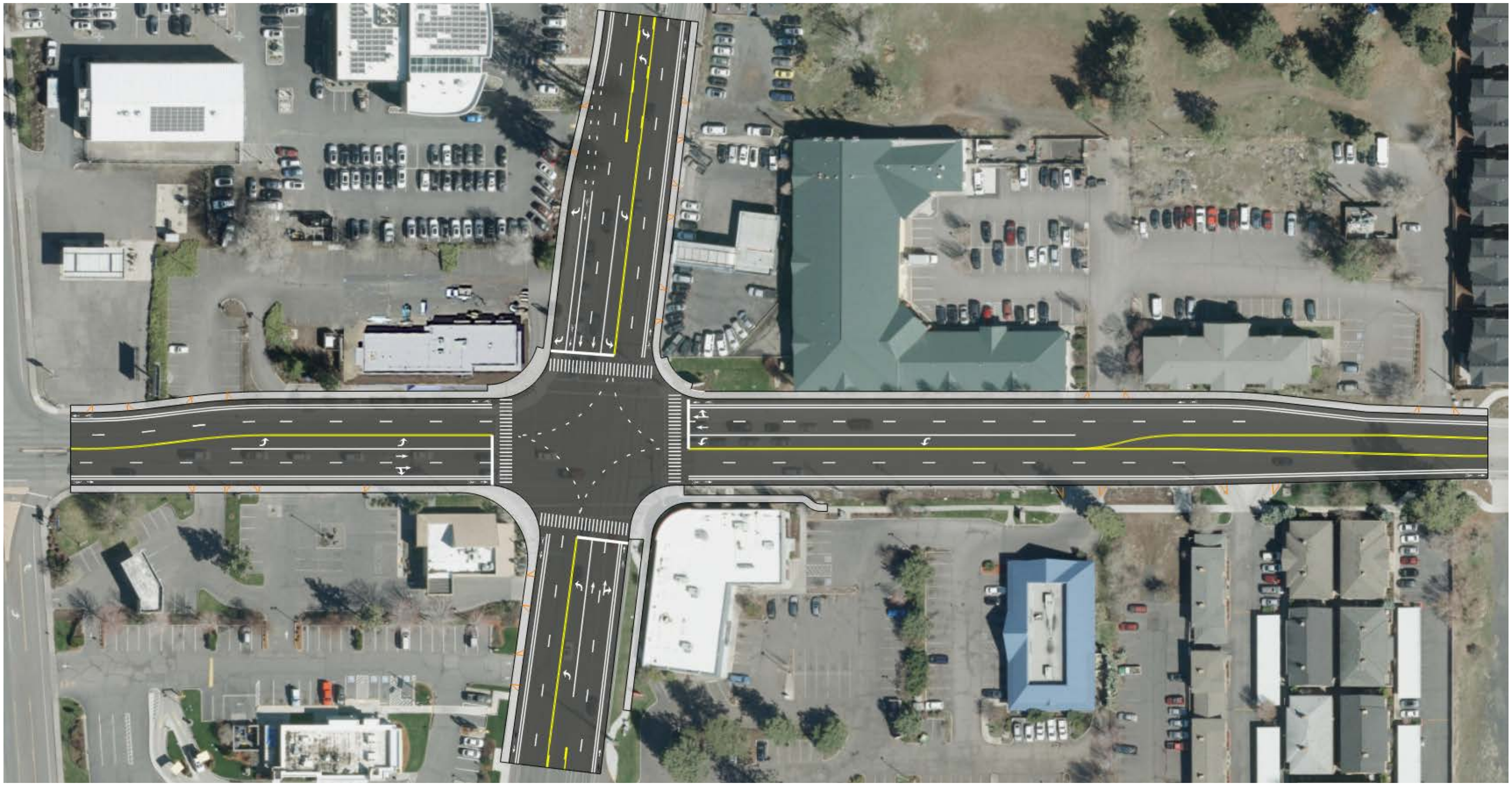

FIGURE 12. ALTERNATIVE 1(B) AT REED MARKET ROAD/3RD STREET

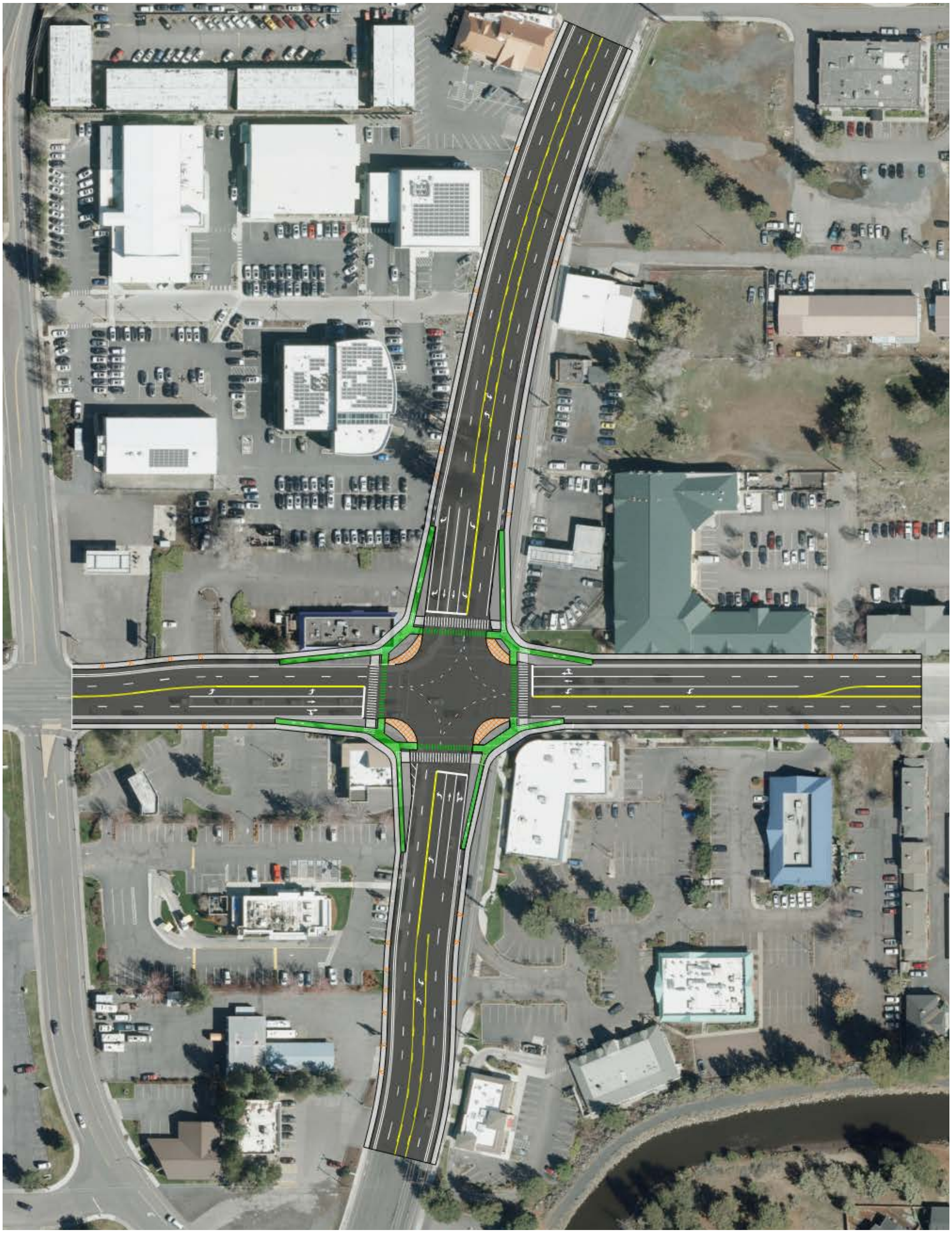

FIGURE 13. ALTERNATIVE 2(B) AT REED MARKET ROAD/3RD STREET

FIGURE 14. ALTERNATIVE 3 AT REED MARKET ROAD/3RD STREET

GOAL 1: INCREASE SYSTEM FUNCTIONALITY, QUALITY, AND CONNECTIVITY FOR ALL USERS

OBJECTIVES A AND B (TRAFFIC OPERATIONS)

Table 32 summarizes the results for the three alternatives under future conditions, with the intersection's performance compared to the mobility standard.[12]

In Alternative 1(a), the overall intersection performance is significantly improved by adding eastbound and westbound left-turn lanes. Adding a southbound right-turn lane (b) results in even better improvements with lower v/c ratio and delay. The mobility standard would easily be met under both conditions.

In Alternative 2, signal timing strategies of leading pedestrian intervals (LPIs)/leading bicycle intervals (LBIs) and RTOR restrictions are assumed in the protected intersection design. LPIs or LBIs give people walking and biking the opportunity to enter the crosswalk approximately five seconds before vehicles are given a green signal indication, while restricting RTOR removes conflicts between motorists and people walking and biking. As a variation of Alternative 1, Alternative 2 also significantly improves the traffic operation in a similar pattern to Alternative 1 with and without a dedicated southbound right-turn lane. However, Alternative 2 results in more intersection delays due to the additional protected phases for people walking and biking. The mobility standard would be met, but with less reserve capacity than under Alternative 1.

In Alternative 3, adding a dual lane roundabout with northbound and southbound right-turn slip lanes increases motor vehicle capacity and improves traffic flow through the intersection but fails to meet the mobility standard. All approaches except the eastbound approach (which operates with a v/c ratio of 0.83) are expected to operate with a v/c ratio greater than 1.00 during the peak hour.

Alternative 1 and 2 significantly improve operations compared to the No-Build condition, can meet the mobility standard, and experience similar delays. Therefore, both alternatives score well on this objective. Although Alternative 3 improves operations, it scores only fair because it fails to meet the mobility standard and would still have insufficient capacity to serve demand. Also, a roundabout is less compatible with interactions with adjacent signalized intersections compared to Alternative 1 and 2.

[12] Intersection operations are reported using Highway Capacity Manual 6th and 2000 Edition methodology and the software reports are included in Appendix B.

TABLE 32: FUTURE 2040 DESIGN HOUR TRAFFIC OPERATIONS AT REED MARKET ROAD/3RD STREET

INTERSECTION	JURIS-DICTION	ALTERNATIVE[A]	CONTROL	MOBILITY STANDARD	V/C[B]	LOS[C]	DELAY (SEC)[D]
REED MARKET RD & 3RD ST	City (AWD)	No-Build	Signalized	≤ 1.00	**1.26**	F	>150
		Alt 1(a)	Signalized	≤ 1.00	0.90	E	61
		Alt 1(b)	Signalized	≤ 1.00	0.88	E	56
		Alt 2(a)[E]	Signalized	≤ 1.00	0.96	F	81
		Alt 2(b)[E]	Signalized	≤ 1.00	0.95	E	68
		Alt 3	Roundabout	≤ 1.00	**1.03 (NB)**	F	103

Bold and red indicate a failure to meet the mobility target.

AWD=average weekday; LOS=level of service; v/c=volume-to-capacity

[A] Future condition results represent 30HV operations for ODOT intersections and average weekday operations for City intersections, consistent with mobility targets.

[B] v/c ratio reported as the overall intersection v/c ratio at signalized intersections and worse case approach v/c at roundabouts.

[C] LOS is reported as the worst-case approach LOS for roundabouts and overall intersection LOS for signalized intersections.

[D] Control delay reported for the worst case approach delay for roundabouts and overall intersection delay for signalized intersections.

[E] Analyzed using Highway Capacity Manual (HCM) 2000 methodology, as leading-pedestrian-interval phasing is not supported in Synchro HCM 6th Edition

OBJECTIVE C (ACTIVE TRANSPORTATION)

3rd Street is identified as a key walking and biking route and is designated as part of the City's low-stress bicycle network, which is intended to serve all ages and abilities of people biking. However, 3rd Street at Reed Market Road is currently a high-stress crossing. Alternative 1 is not compatible with the key walking and biking route framework as adding turn lanes requires road widening, resulting in longer crossing times and increased exposure for people walking and biking. Especially in Alternative 1(b), with an additional southbound right-turn lane, people biking on the southbound bike lane would need to cross the added right-turn lane upstream of the intersection.

Alternative 2 is compatible with the key walking and biking route designation, as protected intersections physically separate people walking and biking away from vehicles, reduce vehicle turning speeds, increase visibility, and improve the level of traffic stress for people walking and biking.

In Alternative 3, adding a dual-lane roundabout is expected to reduce vehicle speeds and provide two-stage crossings for people walking and biking due to the raised splitter island. Dual-lane roundabouts require vehicles in both lanes to yield to people crossing, and even with the installation of a rectangular rapid-flashing beacon, may not be comfortable for all users to cross. Therefore, Alternative 2 scores the highest under the evaluation of active transportation.

OBJECTIVE D (TRANSIT)

Transit Route 6 (Reed Market Road) and Route 1-4 (3rd Street) will be travelling through the intersection of Reed Market Road and 3rd Street. Route 1-4 currently has transit stops close to the intersection (within 250 feet) along 3rd Street. Alternatives 1 and 2 are expected to significantly improve the intersection traffic operations, with less delay for transit vehicles than the No-Build condition. However, Alternative 2 provides a better opportunity for people walking and biking to access nearby transit stops. Alternative 3 is anticipated to improve the operations with less delay for transit but not as significantly as the other two alternatives.

GOAL 1 SCORING SUMMARY

Table 33 shows the scores of all alternatives for Goal 1.

TABLE 33: GOAL 1 SCORING AT REED MARKET ROAD/3RD STREET

OBJECTIVE	PERFORMANCE		
	ALT 1	ALT 2	ALT 3
A. TRAFFIC OPERATIONS (ODOT)	N/A	N/A	N/A
B. TRAFFIC OPERATIONS (CITY)	^	^	I
C. ACTIVE TRANSPORTATION	v	^^	I
D. TRANSIT	^	^^	I

GOAL 2: ENSURE SAFETY FOR ALL USERS

In Alternatives 1 and 2, adding left-turn lanes at the intersection will likely have minimal safety impacts on reducing left-turn crashes since the intersection currently operates with split phasing, which already separates left-turn conflicts between through vehicles and pedestrians. As mentioned previously under the Goal 2 discussion for the Reed Market Road at US 97 Southbound Ramp Terminal area, adding a right-turn lane (Alternatives 1b and 2b) may reduce all crash types by up to four percent. However, adding turn lanes results in longer crossing times and increased exposure for people walking and biking.

In Alternative 2, the protected intersection design keeps people walking and biking physically separated from motor vehicles, provides better visibility of people crossing, and reduces vehicle turning speeds by utilizing raised islands at the intersection corners. It reduces the distance and time that people walking and biking are exposed to conflicts, which results in motorists yielding to people walking and biking over 98 percent of the time and can be more effective than a turn lane with a dedicated bike signal at reducing vehicle-bicycle conflicts at the intersection.[13] In addition, LPIs/LBIs and RTOR restrictions mitigate conflicts with right-turning vehicles, where LPIs/LBIs have the potential to reduce walking and biking related crashes by up to 37 percent,[14] and RTOR could reduce walking and biking related crashes by up to 41 percent.[15]

In Alternative 3, converting a signalized intersection to a roundabout is expected to reduce conflict points at the intersection by up to 75 percent and enhances safety by reducing vehicle speeds entering and through the intersection.[16] Converting a signalized intersection into a double-lane roundabout has the potential to reduce all crashes by up to 19 percent.[17]

As noted above, Alternative 2 generally enhances the safety of people walking and biking better than Alternative 1 or 3 do. None of the alternatives address access spacing along Reed Market Road. Table 34 documents the scoring results under the goal of ensuring safety.

TABLE 34: GOAL 2 SCORING AT REED MARKET ROAD/3RD STREET

OBJECTIVE	PERFORMANCE		
	ALT 1	ALT 2	ALT 3
A. CRASH REDUCTION			
B. SAFETY FOR PEOPLE WALKING AND BIKING			
C. ODOT'S ACCESS SPACING	N/A	N/A	N/A

GOAL 3: SUPPORT ECONOMIC DEVELOPMENT

Table 35 shows the scoring under this goal. While the removal of businesses is not directly addressed by the evaluation criteria, it is assumed to score negatively against the goal of supporting economic development. Alternative 1 is expected to have more limited impact on the right-of-way, likely avoiding impacts to existing structures. Alternative 2 would result in impacts to two buildings on the northwest and southwest corners. Alternatives 1 and 2 have minimal impacts on maintaining effective access to properties along Reed Market Road in a manner that supports the economic development objectives of existing and future businesses. However, in Alternative 3, the dual lane roundabout does require a larger right-of-way, potentially impacting more properties and modifying more access points along 3rd Street and Reed Market Road. For example,

[13] National Association of City Transportation Officials, https://nacto.org/publication/dont-give-up-at-the-intersection/protected-intersections/.

[14] ODOT Crash Reduction Factor List, 2023, ID: BP3.

[15] ODOT Crash Reduction Factor List, 2023, ID: BP25.

[16] ODOT Crash Reduction Factor List, 2023, ID: H19.

[17] Crash Modification Factors Clearinghouse, US DOT Federal Highway Administration, CMF ID 4194.

Alternative 3 could require modifying circulation to the McDonald's property on the southwest corner of the intersection.

All alternatives are designed to accommodate heavy vehicle (WB-67) movements along US 97 and to and from destinations along Reed Market Road.

TABLE 35: GOAL 3 SCORING AT REED MARKET ROAD/3RD STREET

OBJECTIVE	PERFORMANCE		
	ALT 1	ALT 2	ALT 3
A. ACCESS EFFECTIVENESS	I	˅	˅
B. TRUCK FREIGHT ACCOMMODATION	I	I	I

GOAL 4: PROTECT LIVABILITY AND ENSURE EQUITY AND ACCESS

Table 36 shows the scoring for all alternatives under this goal. Alternative 2 scores the highest on the evaluation of incorporating a complete streets approach at Reed Market Road and 3rd Street, for reasons noted in Goal 1 Objective C. No alternatives are expected to disproportionately impact properties owned, used, or accessed by historically underrepresented community members relative to other populations.

TABLE 36: GOAL 4 SCORING AT REED MARKET ROAD/3RD STREET

OBJECTIVE	PERFORMANCE		
	ALT 1	ALT 2	ALT 3
A. COMPLETE STREET	I	⌃⌃	I
B. EQUITY	I	I	I

GOAL 5: STEWARD THE EENVIRONMENT

As shown in Table 37, Alternative 2 performs better than Alternatives 1 and 3 on environmental stewardship in terms of reducing vehicle emissions. All the alternatives significantly reduce delay compared to the No-Build condition, but Alternative 2 best implements the key walking and biking route improvements along 3rd Street to better support walking, biking, and access to transit. The roundabout in Alternative 3 is expected to serve active transportation users slightly better and roundabouts generally reduce emissions throughout the day due to reduced stopping and idling compared to traffic signals.[18]

TABLE 37: GOAL 5 SCORING AT REED MARKET ROAD/3RD STREET

OBJECTIVE	PERFORMANCE		
	ALT 1	ALT 2	ALT 3
A. REDUCE EMISSIONS			

GOAL 6: DEVELOP SOLUTIONS THAT ARE COST-EFFECTIVE AND IMPLEMENTABLE

Table 38 lists the planning level cost estimate for each alternative, with detailed cost estimates included in Appendix C. All alternatives include right-of-way impacts, ranging in assumed costs from $1 million to $4 million dollars, which significantly increases the overall project cost. Note that for Alternatives 1 and 2, the cost estimates shown are for Alternatives 1(b) and 2(b), which include the southbound right turn lane and would therefore be greater than the costs for Alternatives 1(a) and 2(a). During design, if project costs for Alternative 1(b) cannot be reduced to align with the available funding of $5 million, Alternative 1(a) could be chosen instead, which eliminates the southbound right turn lane and would reduce costs while still meeting the mobility standard. Although the southbound right-turn lane could also not be added in Alternative 2(b) (i.e., opting for Alternative 2(a)), the right-of-way costs are still expected to be significant due to the protected intersection design. In addition, all alternatives assume full depth pavement reconstruction, which adds significant cost. There is the potential that Alternative 1 in particular would not require as much pavement reconstruction, as the intersection is not shifted as significantly to the northwest as other alternatives.

TABLE 38: PLANNING LEVEL COST ESTIMATES FOR ALTERNATIVES AT REED MARKET ROAD/3RD STREET

	ALT 1(B)	ALT 2(B)	ALT 3	EXPECTED FUNDING
PLANNING LEVEL COST ESTIMATE	$7.0 million	$10.3 million	$10.8 million	$5 million

Alternative 1 and Alternative 2 are expected to be more compatible with other projects along the corridor, as the surrounding intersections are expected to be controlled by traffic signals. Alternative 1 scores the highest on the criteria of developing a design that is constructable in phases and could be reasonably maintained. All alternatives would likely need to be constructed in

[18] Roundabouts: An Informational Guide, Federal Highway Administration.

a single phase. All alternatives have similar impacts on minimizing the number of potential design exceptions.

Alternatives 1 and 3 create less maintenance challenges after construction, while the protected intersection design in Alternative 2 involves several elements such as pavement markings and raised islands that require regular maintenance and provide more challenges for snow removal. Road widening in Alternatives 1 and 2 can be more easily constructed with regard to the ability to maintain movements of all modes during construction, while Alternative 3 would be more challenging to maintain traffic during construction. Table 39 shows the scoring for all alternatives under Goal 6.

TABLE 39. GOAL 6 SCORING AT REED MARKET ROAD/3RD STREET

OBJECTIVE	PERFORMANCE		
	ALT 1	ALT 2	ALT 3
A. LOW-COST, HIGH BENEFIT	v	vv	vv
B. LEVERAGE PARTNERSHIPS	v	vv	vv
C. CONSTRUCTABLE IN PHASES, MAINTENANCE, DESIGN EXCEPTIONS, TRAFFIC MAINTENANCE DURING CONSTRUCTION	I	I	v

SUMMARY OF EVALUATION

Table 40 summarizes the scoring for each of the three alternatives across the project goals. Key differentiators in scoring between alternatives include:

- Goal 1: Increase System Functionality, Quality, and Connectivity for All Users
  - All alternatives were able to meet the mobility target to a similar degree, with a significant decrease in delays based on the operational results.
  - Alternative 1 requires roadway widening, which results in longer crossing and increased exposure for people walking and biking. Especially in Alternative 1(b), with the additional southbound right-turn lane, people biking southbound must also cross the right-turn lane upstream of the intersection.
  - Alternative 2 provides physical separation, reduces vehicle speeds, improves visibility, and provides LPIs or LBIs and RTOR restrictions to support the implementation of a key walking and biking route on 3rd Street.
  - Alternative 3 provides a two-stage crossing for people walking and biking and reduces vehicles speeds but requires drivers in both lanes of the roundabout to yield to people crossing at the intersection.
- Goal 2: Ensure Safety for All Users

- As noted above, Alternative 2 is expected to best address safety for people walking and biking, followed by Alternative 3. Alternative 1 increases exposure for people walking and biking, with longer crossings.

- Goal 3: Support Economic Development
  - Alternatives 1 and 2 have minimal impacts on maintaining effective access to properties along Reed Market Road in a manner that supports the economic development objectives of existing and future businesses.
  - In Alternative 3, the dual lane roundabout does require a larger right-of-way, potentially impacting more businesses.
  - All alternatives have minimal impacts on facilities accommodating heavy vehicle movements along US 97 and to and from destinations along Reed Market Road
- Goal 4: Protect Livability and Ensure Equity and Access
  - As noted above, Alternative 2 is expected to best address conditions for people walking and biking, followed by Alternative 3.
  - All three alternatives have similar property impacts and are not expected to disproportionally impact properties owned, used, or accessed by historically underrepresented community members relative to other populations.
- Goal 5: Steward the Environment
  - Alternative 1 significantly reduces vehicular delays, but road widening creates a deficiency on supporting walking, biking, and use of transit.
  - Alternative 2 notably reduces vehicular delays, but the delays would be longer than those of Alternative 1 due to the added LPIs or LBIs phasing. However, Alternative 2 supports walking, biking, and the use of transit by reducing speed, providing physical separation and protected phases, and enhancing visibility.
  - Alternative 3 produces less vehicular delays than Alternative 2 while creating a lower speed environment by providing refugee islands to help support walking, biking, and use of transit at the intersection, but not as much as Alternative 2.
- Goal 6: Develop Solutions that are Cost-Effective and Implementable
  - All alternatives are expected to exceed available funding, although there is potential to reduce right-of-way costs in Alternative 1 by not adding the southbound right-turn lane to better align with available funding (i.e., selecting Alternative 1(a)).
  - Alternatives 1 and 2 are more compatible with other projects along the corridor, as the surrounding intersections are expected to remain traffic signals.
  - Alternative 2 is expected to require more maintenance and provide more challenges for snow removal.
  - Alternative 1 and 2 can be more easily constructed with regard to the ability to maintain movements of all modes during construction, while Alternative 3 would be more challenging in maintaining traffic during construction.

TABLE 40: REED MARKET ROAD/3RD STREET ALTERNATIVE PERFORMANCE

	GOAL	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
GOAL 1	Increase System Functionality, Quality, and Connectivity for All Users			
GOAL 2	Ensure Safety for All Users			
GOAL 3	Support Economic Development			
GOAL 4	Protect Livability and Ensure Equity and Access			
GOAL 5	Steward the Environment			
GOAL 6	Develop Solutions That Are Cost-Effective and Implementable			

3RD STREET/BROSTERHOUS ROAD

The 3rd Street and Brosterhous Road intersection currently operates with shared left-through lanes (an atypical configuration) and permissive left turns on the eastbound and westbound approaches, causing delay for through movements and increasing conflicts between motorists and people walking and biking at the intersection. The City is currently conducting a study and has identified short-term improvements (see page 6) that will expend the existing funds budgeted in the City's CIP (approximately $130,000).

Two long-term (i.e., unfunded) alternatives to address these concerns at the intersection were evaluated, including:

- Alternative 1:
  - Converting lane configuration and signal phasing to protected eastbound and westbound left turns.
  - Adding an eastbound dedicated right-turn lane.
  - Adding bike boxes on all approaches.
- Alternative 2:
  - Converting lane configuration and signal phasing to protected eastbound and westbound left turns.
  - Adding an eastbound dedicated right-turn lane.
  - Implementing a protected intersection design.

The intersection is assumed to be coordinated with other signalized intersections within the study area to provide continuous traffic flow at the target speed. A protected intersection design would look similar to that shown in the concept drawing for Alternative 2 at the Reed Market Road/3rd Street intersection.

OBJECTIVES A AND B (TRAFFIC OPERATIONS)

Table 41 summarizes the results for the improvement alternatives under future conditions, with the intersection's performance compared to the mobility standard.[19]

In Alternative 1, converting to protected eastbound and westbound left turns reduces the intersection v/c ratio but slightly increases delays, as the heavy westbound right-turn movement shares a lane with westbound through vehicles and the intersection operates with a longer cycle length due to the protected left-turn phases. The additional eastbound right-turn lane also helps mitigate queueing so that queues do not extend back to Reed Market Road.

In Alternative 2, LPIs/LBIs and RTOR restrictions were assumed. As a result, Alternative 2 experiences more delays than Alternative 1 but is still able to meet the mobility standard. The additional eastbound right-turn lane also helps mitigate queueing so that queues do not extend back to Reed Market Road.

TABLE 41: FUTURE 2040 DESIGN HOUR TRAFFIC OPERATIONS AT 3RD STREET/BROSTERHOUS ROAD

INTERSECTION	JURIS-DICTION	ALTERNATIVE[A]	CONTROL	MOBILITY STANDARD	V/C[B]	LOS[C]	DELAY (SEC)[D]
3RD ST & BROSTERHOUS RD	City (AWD)	No-Build	Signalized	≤ 1.00	0.89	C	21
		Alt 1	Signalized	≤ 1.00	0.75	C	31
		Alt 2	Signalized	≤ 1.00	0.87	D	47

Bold and red indicate a failure to meet the mobility target.

AWD = average weekday, LOS=level of service, v/c=volume-to-capacity.

[A] Future condition results represent 30HV operations for ODOT intersections and average weekday operations for City intersections, consistent with mobility targets.

[B] v/c ratio reported as the overall intersection v/c ratio at signalized intersections.

[C] LOS reported as the overall intersection LOS for signalized intersections.

[D] Control delay reported for the overall intersection delay for signalized intersections.

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[19] Intersection operations are reported using Highway Capacity Manual 6th and2000 methodology and the software reports are included in Appendix B.

OBJECTIVE C (ACTIVE TRANSPORTATION)

3rd Street and a segment of Brosterhous Road (from 3rd Street to Parrell Road) are identified as a key walking and biking route according to the City's TSP. Both 3rd Street and Brosterhous Road are designated as part of the City's low-stress bicycle network and intended to serve all ages and abilities of people biking. Today, walking and biking facilities (primarily sidewalks and on-street bike lanes) are discontinuous and high-stress in the area. Both alternatives improve conditions for people walking and biking, but Alternative 2 better meets the need of a key walking and biking route.

In Alternative 1, the eastbound road widening lengthens the crossing distance and increases exposure for people walking and biking. However, the protected eastbound and westbound left-turn phase reduces eastbound and westbound left-turning conflicts and ensures protected phasing for people walking and biking. In addition, bike boxes provide dedicated space to allow people biking to perform a two-stage left turn, eliminating the need to cross over two lanes of heavy traffic to reach the turn lane.

Alternative 2 is a variation of Alternative 1 that excludes bike boxes but includes a protected intersection design. Alternative 2 significantly enhances the quality of walking and biking facilities by utilizing raised islands at the intersection corners to provide physical separation, providing extra crossing time associated with LPIs or LBIs, reducing vehicle turning speeds, and improving visibility.

OBJECTIVE D (TRANSIT)

Transit Route 1-4 (3rd Street) will be travelling through the intersection of 3rd Street and Brosterhous Road and has transit stops close to the intersection (within 350 feet). Based on the operational results, both alternatives would improve operations but result in higher delays due to the increased cycle length and lane configuration changes. In Alternative 2, the protected intersection design provides better access to transit.

GOAL 1 SCORING SUMMARY

Table 42 shows the scoring results on the objectives under this goal.

TABLE 42: GOAL 1 SCORING AT 3RD STREET/BROSTERHOUS ROAD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. TRAFFIC OPERATIONS (ODOT)	N/A	N/A
B. TRAFFIC OPERATIONS (CITY)		
C. ACTIVE TRANSPORTATION		
D. TRANSIT		

GOAL 2: ENSURE SAFETY FOR ALL USERS

Table 43 presents the scoring results for Goal 2. In both alternatives, the protected left-turn phasing has a potential to reduce left-turning crashes by up to 99 percent[20] while adding a right-turn lane, as previously mentioned under the Reed Market Road/US 97 Southbound Ramp Terminal discussion, has the potential to reduce all crashes by up to four percent. Adding a left-turn bike box improves visibility by placing people biking in motorists' direct line of sight when stopping at the intersection and allows people biking to make a two-stage left turn more easily. Adding a left-turn bike box has the potential of reducing bicycle crashes by up to 35 percent.[21]

Alternative 2 includes the features of LPIs/LBIs and RTOR restrictions that mitigate right-turning conflicts with people walking and biking. As mentioned previously under Reed Market Road and 3rd Street, LPIs/LBIs have the potential to reduce pedestrian-related crashes by up to 19 percent, and RTOR could reduce pedestrian and bicycle crashes by up to 41 percent.

Alternative 1 has minimal impact on designing and building facilities and routes that maximizes safety for people walking and biking, mainly due to the longer crossing distance. The protected left-turn phasing was able to help improve the exposure concerns by providing protected crossing but does not perform as well as the protected intersection design in Alternative 2. In Alternative 2, the protected intersection design significantly minimizes conflicts and risk factors that could lead to crashes by providing physical separation and LPIs/LBIs, restricting RTOR, reducing vehicle turning speeds, and improving visibility.

TABLE 43: GOAL 2 SCORING AT 3RD STREET/BROSTERHOUS ROAD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. CRASH REDUCTION	⇈	⇈
B. SAFETY FOR PEOPLE WALKING AND BIKING	I	⇈
C. ODOT'S ACCESS SPACING	N/A	N/A

GOAL 3: SUPPORT ECONOMIC DEVELOPMENT

Table 44 shows the scoring results for Goal 3. Alternative 1 and 2 are expected to have minimal impacts on property access along Reed Market Road and Division Street/Brosterhous Road. Neither alternative is expected to have a significant impact on accommodating heavy vehicle movements along 3rd Street.

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[20] ODOT Crash Reduction Factor List, 2023, ID: I9.

[21] ODOT Crash Reduction Factor List, 2023, ID: BP7.

TABLE 44: GOAL 3 SCORING AT 3RD STREET/BROSTERHOUS ROAD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. ACCESS EFFECTIVENESS	I	I
B. TRUCK FREIGHT ACCOMMODATION	N/A	N/A

GOAL 4: PROTECT LIVABILITY AND ENSURE EQUITY AND ACCESS

The evaluation criterion of addressing existing barriers for people walking and biking across or along Reed Market Road is not applicable at this intersection and will not be evaluated. Alternative 2 scores better on accommodating planned transit service improvements and expansions by providing better access because of the protected intersection design, as discussed under Goal 1. Both alternatives have minimal impacts on properties owned, used, or accessed by historically underrepresented community members proportionate to those of other populations. Table 45 presents the scoring results for the alternatives.

TABLE 45: GOAL 4 SCORING AT 3RD STREET/BROSTERHOUS ROAD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. COMPLETE STREET	I	^
B. EQUITY	I	I

GOAL 5: STEWARD THE ENVIRONMENT

As shown in Table 46, both alternatives score fair under the criterion of reducing vehicle emissions. The main driver of the ability to reduce vehicle emissions is related to the level of delay in the improvement alternatives, which is discussed in detail under Goal 1. Alternative 1 results in higher vehicle delays (31 seconds compared to 21 seconds) but provides safer crossing opportunities for people walking and biking with the protected eastbound and westbound left-turn movements and better access to transit. Alternative 2 results in even higher delays but the protected intersection design significantly improves safety for people walking and biking, supporting the connections in the local system and the use of alternative travel modes.

TABLE 46: GOAL 5 SCORING AT 3RD STREET/BROSTERHOUS ROAD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. REDUCE EMISSIONS		

GOAL 6: DEVELOP SOLUTIONS THAT ARE COST-EFFECTIVE AND IMPLEMENTABLE

Table 47 shows the scoring results for the alternatives. Both alternatives would require a full rebuild of the intersection, including a new traffic signal. There is no funding allocated for a long-term enhancement at this intersection so neither alternative would be easily implemented. Therefore, both alternatives score poorly on the criteria on prioritizing low-cost and high-benefit solutions, and creating solutions that are compatible with recommendations from prior planning studies.

Both alternatives at 3rd Street and Brosterhous Road would need to be implemented in a single phase and would minimize the number of potential design exceptions. The protected intersection design in Alternative 2 would be more challenging to maintain, particularly with respect to snow removal.

TABLE 47: GOAL 6 SCORING AT 3RD STREET/BROSTERHOUS ROAD

OBJECTIVE	PERFORMANCE	
	ALT 1	ALT 2
A. LOW-COST, HIGH BENEFIT		
B. LEVERAGE PARTNERSHIPS		
C. CONSTRUCTABLE IN PHASES, MAINTENANCE, DESIGN EXCEPTIONS, TRAFFIC MAINTENANCE DURING CONSTRUCTION		

SUMMARY OF EVALUATION

Table 48 summarizes the scoring for each of the two alternatives across the project goals. Key differentiators in scoring between alternatives:

- Goal 1: Increase System Functionality, Quality and Connectivity for All Users
    - Both alternatives are able to meet the mobility target but result in higher delays than the No-Build condition. There is more delay in Alternative 2 due to implementing LPIs/LBIs for people walking and biking.
    - Both alternatives reduce eastbound and westbound left-turning conflicts and ensure protected phasing for people walking and biking by providing protected eastbound and westbound left-turn phases.
    - Alternative 1 requires roadway widening, which lengthens the crossing distance and increases exposure for people walking and biking. However, bike boxes allow people biking to locate themselves in front of vehicles for better visibility.
    - Alternative 2 also requires roadway widening but significantly enhances the quality of walking and biking facilities by utilizing raised islands at the intersection corners to provide physical separation, providing extra crossing time associated with LPIs/LBIs, reducing vehicle turning speeds, and improving visibility.
    - Both alternatives are able to improve operations but result in longer delay due to the increased cycle length.
    - In Alternative 2, the protected intersection design provides better access to transit.
- Goal 2: Ensure Safety for All Users
    - Both alternatives are expected to significantly improve safety by adding protected eastbound and westbound left-turn phases to address a known crash history at this intersection.
    - Alternative 1 has less of an impact on designing and building facilities and routes that maximizes safety for people walking and biking, as it does not provide physical separation between vehicles and people walking and biking.
    - In Alternative 2, the protected intersection design significantly minimizes conflicts and risk factors that could lead to crashes by providing physical separation and LPIs/LBIs, restricting RTOR, reducing vehicle turning speeds, and improving visibility.
- Goal 3: Support Economic Development
    - Both alternatives have minimal impacts on supporting economic development within the study area.
- Goal 4: Protect Livability and Ensure Equity and Access
    - Alternative 2 scores better on accommodating planned transit service improvements and expansions by providing better access to transit.
    - Both alternatives have minimal impacts on properties owned, used, or accessed by historically underrepresented community members proportionate to those of other populations.
- Goal 5: Steward the Environment
    - Alternative 1 results in slightly higher vehicle delay (vehicle emissions) but does enhance facilities for people walking and biking by providing protected eastbound and westbound left-turn phases.

- Alternative 2 generates higher vehicle delays but the protected intersection design significantly improves safety for people walking and biking, supporting the connections in the local system and the use of alternative travel modes.

- Goal 6: Develop Solutions that are Cost-Effective and Implementable
  - Both alternatives would require a full rebuild of the intersection, and given there is no funding allocated for a long-term enhancement at the intersection, would greatly exceed expected funding.
  - The protected intersection design in Alternative 2 would be more challenging to maintain, particularly with respect to snow removal.

TABLE 48: 3RD STREET/BROSTERHOUS ROAD ALTERNATIVE PERFORMANCE

	GOAL	ALTERNATIVE 1	ALTERNATIVE 2
GOAL 1	Increase System Functionality, Quality, and Connectivity for All Users		
GOAL 2	Ensure Safety for All Users		
GOAL 3	Support Economic Development		
GOAL 4	Protect Livability and Ensure Equity and Access		
GOAL 5	Steward the Environment		
GOAL 6	Develop Solutions That Are Cost-Effective and Implementable		

APPENDIX

CONTENTS

APPENDIX A: ALTERNATIVE CONCEPT DRAWINGS

REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL – ALTERNATIVE 1


NOTE: Any green striping is subject to ODOT traffic approval and funding to maintain

REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL – ALTERNATIVE 2

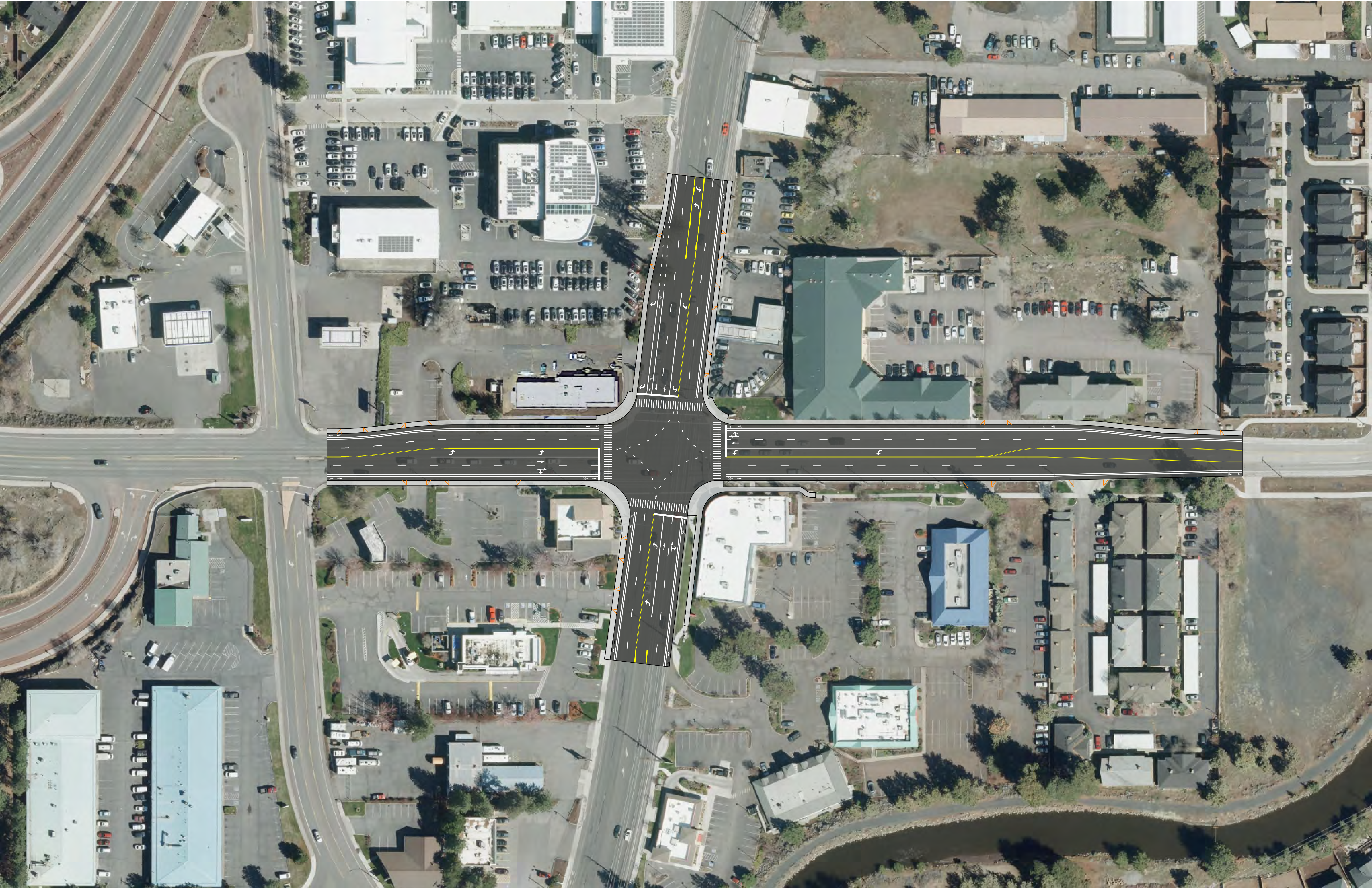
REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET – ALTERNATIVE 1


NOTE: Any green striping is subject to ODOT traffic approval and funding to maintain

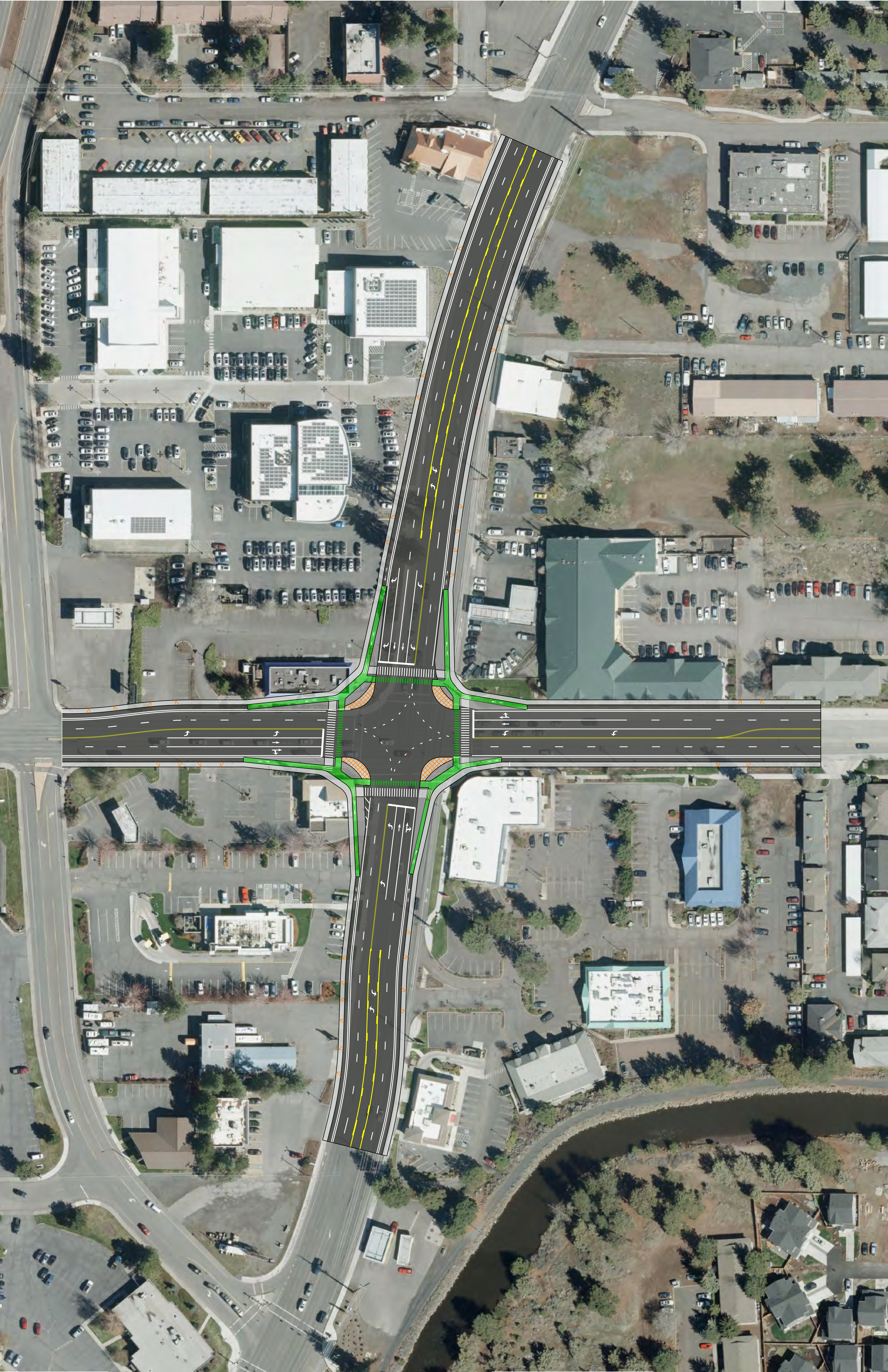
REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET – ALTERNATIVE 2


NOTE: Any green striping is subject to ODOT traffic approval and funding to maintain

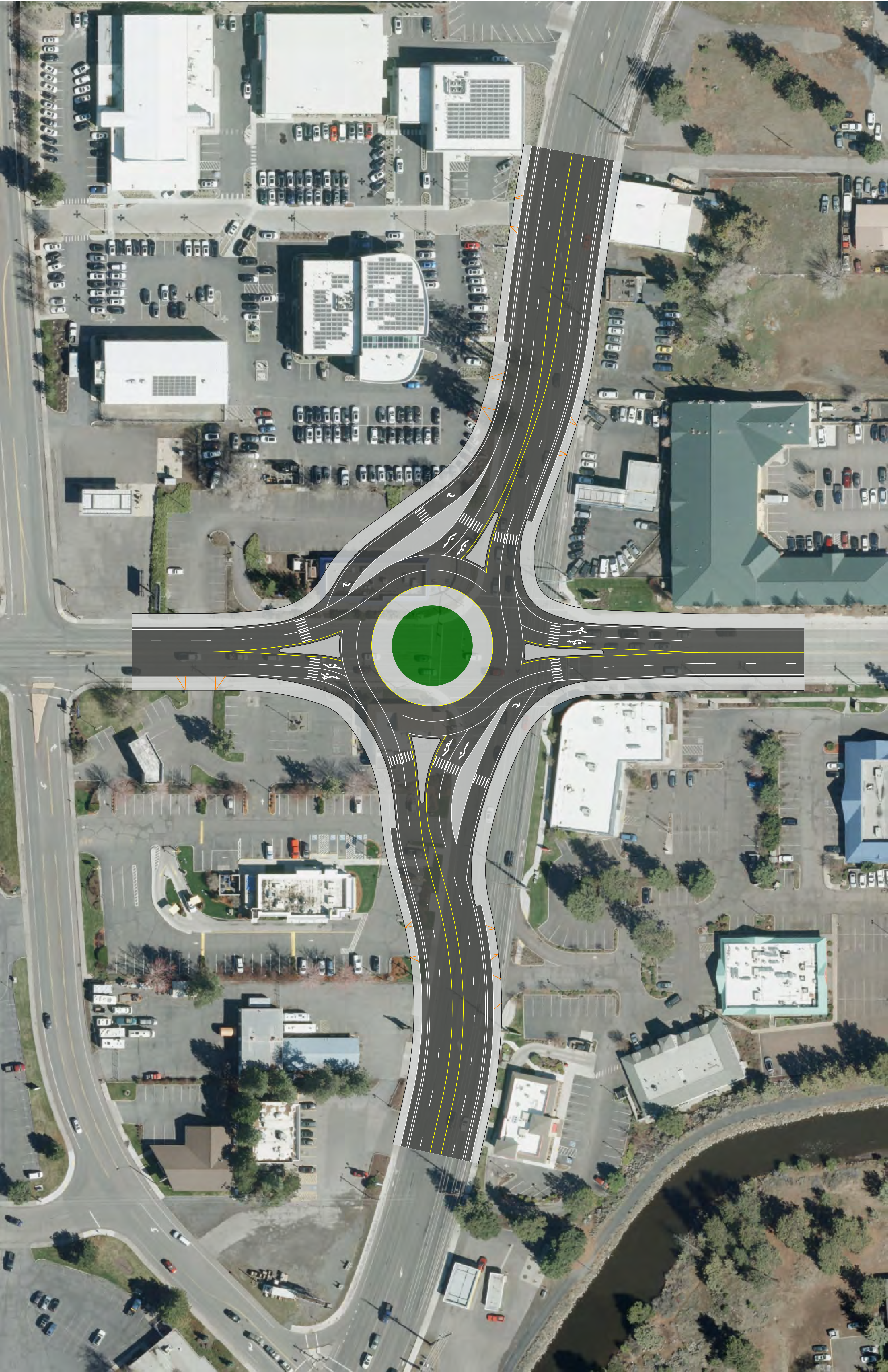
REED MARKET ROAD/3RD STREET -ALTERNATIVE 1



REED MARKET ROAD/3RD STREET -ALTERNATIVE 2



REED MARKET ROAD/3RD STREET -ALTERNATIVE 3



APPENDIX B: SOFTWARE REPORTS

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱			↑↑	↰	↱
Traffic Volume (veh/h)	1285	270	0	860	125	125
Future Volume (veh/h)	1285	270	0	860	125	125
Initial Q (Qb), veh	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		0.98	1.00		1.00	1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach	No			No	No	
Adj Sat Flow, veh/h/ln	1736	1736	0	1750	1750	1723
Adj Flow Rate, veh/h	1367	275	0	915	133	83
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94
Percent Heavy Veh, %	1	1	0	0	0	2
Cap, veh/h	2283	451	0	2776	164	144
Arrive On Green	1.00	1.00	0.00	1.00	0.10	0.10
Sat Flow, veh/h	2821	540	0	3500	1667	1460
Grp Volume(v), veh/h	815	827	0	915	133	83
Grp Sat Flow(s),veh/h/ln	1650	1625	0	1663	1667	1460
Q Serve(g_s), s	0.0	0.0	0.0	0.0	9.4	6.5
Cycle Q Clear(g_c), s	0.0	0.0	0.0	0.0	9.4	6.5
Prop In Lane		0.33	0.00		1.00	1.00
Lane Grp Cap(c), veh/h	1377	1357	0	2776	164	144
V/C Ratio(X)	0.59	0.61	0.00	0.33	0.81	0.58
Avail Cap(c_a), veh/h	1377	1357	0	2776	389	341
HCM Platoon Ratio	2.00	2.00	1.00	2.00	1.00	1.00
Upstream Filter(I)	0.80	0.80	0.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	0.0	0.0	0.0	0.0	53.0	51.7
Incr Delay (d2), s/veh	1.5	1.6	0.0	0.3	7.0	2.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.6	0.6	0.0	0.1	4.2	2.5
Unsig. Movement Delay, s/veh						
LnGrp Delay(d),s/veh	1.5	1.6	0.0	0.3	60.0	54.4
LnGrp LOS	A	A	A	A	E	D
Approach Vol, veh/h	1642			915	216	
Approach Delay, s/veh	1.6			0.3	57.9	
Approach LOS	A			A	E	

Timer - Assigned Phs	2	4	8
Phs Duration (G+Y+Rc), s	15.8	104.2	104.2
Change Period (Y+Rc), s	4.0	4.0	4.0
Max Green Setting (Gmax), s	28.0	84.0	84.0
Max Q Clear Time (g_c+I1), s	11.4	2.0	2.0
Green Ext Time (p_c), s	0.4	18.5	7.1

Intersection Summary	
HCM 6th Ctrl Delay	5.5
HCM 6th LOS	A

Intersection	
Int Delay, s/veh	0.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	760	650	0	820	430	0	0	50	0	0	40
Future Vol, veh/h	0	760	650	0	820	430	0	0	50	0	0	40
Conflicting Peds, #/hr	2	0	2	2	0	2	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	None	-	-	Stop	-	-	None
Storage Length	-	-	-	-	-	-	-	-	0	-	-	0
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	97	97	97	97	97	97	97	97	97	97	97	97
Heavy Vehicles, %	3	1	1	0	1	2	0	0	4	33	0	0
Mvmt Flow	0	784	670	0	845	443	0	0	52	0	0	41

Major/Minor	Major1			Major2			Minor1			Minor2		
Conflicting Flow All	-	0	0	-	-	0	-	-	729	-	-	646
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy	-	-	-	-	-	-	-	-	6.98	-	-	6.9
Critical Hdwy Stg 1	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy Stg 2	-	-	-	-	-	-	-	-	-	-	-	-
Follow-up Hdwy	-	-	-	-	-	-	-	-	3.34	-	-	3.3
Pot Cap-1 Maneuver	0	-	-	0	-	-	0	0	361	0	0	419
Stage 1	0	-	-	0	-	-	0	0	-	0	0	-
Stage 2	0	-	-	0	-	-	0	0	-	0	0	-
Platoon blocked, %		-	-		-	-						
Mov Cap-1 Maneuver	-	-	-	-	-	-	-	-	360	-	-	418
Mov Cap-2 Maneuver	-	-	-	-	-	-	-	-	-	-	-	-
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	0	0	16.7	14.6
HCM LOS			C	B

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBT	WBR	SBLn1
Capacity (veh/h)	360	-	-	-	-	418
HCM Lane V/C Ratio	0.143	-	-	-	-	0.099
HCM Control Delay (s)	16.7	-	-	-	-	14.6
HCM Lane LOS	C	-	-	-	-	B
HCM 95th %tile Q(veh)	0.5	-	-	-	-	0.3

HCM 6th Signalized Intersection Summary
5: SE 3rd St & SW Reed Market Rd 03/21/2023

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	160	555	85	260	600	110	365	780	275	205	850	195
Future Volume (veh/h)	160	555	85	260	600	110	365	780	275	205	850	195
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.97	1.00		0.97	1.00		0.98	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1885	1885	1826	1885	1885	1870	1885	1870	1870	1885	1885	1885
Adj Flow Rate, veh/h	160	555	74	260	600	97	365	780	247	205	850	77
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	1	1	5	1	1	2	1	2	2	1	1	1
Cap, veh/h	192	692	92	254	779	126	403	954	302	245	980	415
Arrive On Green	0.07	0.15	0.14	0.14	0.25	0.25	0.22	0.36	0.35	0.14	0.27	0.27
Sat Flow, veh/h	1795	3165	421	1795	3074	496	1795	2637	835	1795	3582	1565
Grp Volume(v), veh/h	160	313	316	260	349	348	365	525	502	205	850	77
Grp Sat Flow(s),veh/h/ln	1795	1791	1795	1795	1791	1779	1795	1777	1695	1795	1791	1565
Q Serve(g_s), s	10.6	20.3	20.4	17.0	21.7	21.8	23.7	32.2	32.2	13.4	27.1	4.6
Cycle Q Clear(g_c), s	10.6	20.3	20.4	17.0	21.7	21.8	23.7	32.2	32.2	13.4	27.1	4.6
Prop In Lane	1.00		0.23	1.00		0.28	1.00		0.49	1.00		1.00
Lane Grp Cap(c), veh/h	192	391	392	254	454	451	403	643	613	245	980	415
V/C Ratio(X)	0.83	0.80	0.81	1.02	0.77	0.77	0.90	0.82	0.82	0.84	0.87	0.19
Avail Cap(c_a), veh/h	269	463	464	254	454	451	419	643	613	254	980	415
HCM Platoon Ratio	0.67	0.67	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	0.65	0.65	0.65	1.00	1.00	1.00
Uniform Delay (d), s/veh	54.7	48.7	48.8	51.5	41.5	41.7	45.3	34.7	35.0	50.5	41.5	34.1
Incr Delay (d2), s/veh	12.9	7.8	8.1	62.3	7.5	7.8	15.8	7.5	7.8	20.0	10.3	1.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.6	10.3	10.4	12.0	10.5	10.5	12.2	14.9	14.3	7.3	13.2	1.9
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	67.5	56.4	56.9	113.8	49.0	49.5	61.1	42.2	42.8	70.5	51.8	35.1
LnGrp LOS	E	E	E	F	D	D	E	D	D	E	D	D
Approach Vol, veh/h		789			957			1392			1132	
Approach Delay, s/veh		58.9			66.8			47.4			54.1	
Approach LOS		E			E			D			D	

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	31.0	36.8	17.8	34.4	20.4	47.4	22.0	30.2
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	27.0	26.0	18.0	29.0	16.0	37.0	17.0	30.0
Max Q Clear Time (g_c+I1), s	25.7	29.1	12.6	23.8	15.4	34.2	19.0	22.4
Green Ext Time (p_c), s	0.2	0.0	0.3	1.1	0.0	1.7	0.0	1.3

Intersection Summary			
HCM 6th Ctrl Delay			55.6
HCM 6th LOS			E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	85	345	270	55	25	480	30	855	50	230	940	25
Future Volume (veh/h)	85	345	270	55	25	480	30	855	50	230	940	25
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		0.98	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1736	1723	1750	1723	1682	1736	1600	1736	1750	1723	1750	1450
Adj Flow Rate, veh/h	85	345	116	55	25	240	30	855	0	230	940	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	1	2	0	2	5	1	11	1	0	2	0	22
Cap, veh/h	105	399	336	69	28	270	40	1397		258	1844	
Arrive On Green	0.06	0.23	0.23	0.04	0.21	0.21	0.03	0.42	0.00	0.31	1.00	0.00
Sat Flow, veh/h	1654	1723	1454	1641	134	1286	1524	3386	0	1641	3413	0
Grp Volume(v), veh/h	85	345	116	55	0	265	30	855	0	230	940	0
Grp Sat Flow(s),veh/h/ln	1654	1723	1454	1641	0	1420	1524	1650	0	1641	1663	0
Q Serve(g_s), s	6.1	23.1	8.0	4.0	0.0	21.8	2.3	24.2	0.0	16.0	0.0	0.0
Cycle Q Clear(g_c), s	6.1	23.1	8.0	4.0	0.0	21.8	2.3	24.2	0.0	16.0	0.0	0.0
Prop In Lane	1.00		1.00	1.00		0.91	1.00		0.00	1.00		0.00
Lane Grp Cap(c), veh/h	105	399	336	69	0	298	40	1397		258	1844	
V/C Ratio(X)	0.81	0.87	0.34	0.80	0.00	0.89	0.75	0.61		0.89	0.51	
Avail Cap(c_a), veh/h	124	541	457	96	0	423	93	1397		349	1844	
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	0.22	0.22	0.00
Uniform Delay (d), s/veh	55.5	44.3	38.5	57.0	0.0	46.1	58.0	26.9	0.0	40.1	0.0	0.0
Incr Delay (d2), s/veh	27.6	9.8	0.5	26.6	0.0	14.2	18.3	2.0	0.0	4.9	0.2	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.3	10.9	2.9	2.2	0.0	8.8	1.1	9.8	0.0	5.8	0.1	0.0
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	83.1	54.1	39.0	83.6	0.0	60.2	76.4	28.9	0.0	45.0	0.2	0.0
LnGrp LOS	F	D	D	F	A	E	E	C		D	A	
Approach Vol, veh/h		546			320			885			1170	
Approach Delay, s/veh		55.4			64.3			30.5			9.0	
Approach LOS		E			E			C			A	

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	23.4	55.3	11.6	29.7	7.7	71.0	9.0	32.3
Change Period (Y+Rc), s	4.5	4.5	4.0	4.5	4.5	4.5	4.0	4.5
Max Green Setting (Gmax), s	25.5	32.3	9.0	35.7	7.3	50.5	7.0	37.7
Max Q Clear Time (g_c+I1), s	18.0	26.2	8.1	23.8	4.3	2.0	6.0	25.1
Green Ext Time (p_c), s	0.9	4.7	0.0	1.0	0.0	25.2	0.0	1.5

Intersection Summary	
HCM 6th Ctrl Delay	30.3
HCM 6th LOS	C

Notes

Unsignalized Delay for [NBR, SBR] is excluded from calculations of the approach delay and intersection delay.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	160	555	85	260	600	110	365	780	275	205	850	195
Future Volume (veh/h)	160	555	85	260	600	110	365	780	275	205	850	195
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.97	1.00		0.97	1.00		0.98	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1885	1885	1826	1885	1885	1870	1885	1870	1870	1885	1885	1885
Adj Flow Rate, veh/h	160	555	74	260	600	97	365	780	247	205	850	77
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	1	1	5	1	1	2	1	2	2	1	1	1
Cap, veh/h	205	698	93	254	763	123	344	1023	324	209	1037	94
Arrive On Green	0.04	0.07	0.07	0.14	0.25	0.24	0.19	0.39	0.38	0.12	0.31	0.30
Sat Flow, veh/h	1795	3165	421	1795	3074	496	1795	2638	835	1795	3315	300
Grp Volume(v), veh/h	160	313	316	260	349	348	365	525	502	205	459	468
Grp Sat Flow(s),veh/h/ln	1795	1791	1795	1795	1791	1779	1795	1777	1696	1795	1791	1824
Q Serve(g_s), s	10.6	20.6	20.8	17.0	21.8	22.0	23.0	30.8	30.9	13.7	28.4	28.5
Cycle Q Clear(g_c), s	10.6	20.6	20.8	17.0	21.8	22.0	23.0	30.8	30.9	13.7	28.4	28.5
Prop In Lane	1.00		0.23	1.00		0.28	1.00		0.49	1.00		0.16
Lane Grp Cap(c), veh/h	205	395	396	254	445	442	344	689	658	209	560	571
V/C Ratio(X)	0.78	0.79	0.80	1.02	0.78	0.79	1.06	0.76	0.76	0.98	0.82	0.82
Avail Cap(c_a), veh/h	224	463	464	254	493	489	344	689	658	209	560	571
HCM Platoon Ratio	0.33	0.33	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	0.65	0.65	0.65	1.00	1.00	1.00
Uniform Delay (d), s/veh	56.3	52.9	53.0	51.5	42.1	42.3	48.5	31.9	32.2	52.9	38.1	38.2
Incr Delay (d2), s/veh	14.2	7.4	7.7	62.3	7.0	7.3	56.2	5.2	5.4	55.8	12.6	12.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	6.0	10.8	10.9	12.0	10.5	10.5	15.5	13.9	13.4	9.3	14.2	14.4
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	70.5	60.3	60.7	113.8	49.1	49.6	104.7	37.1	37.6	108.7	50.7	50.6
LnGrp LOS	E	E	E	F	D	D	F	D	D	F	D	D
Approach Vol, veh/h		789			957			1392			1132	
Approach Delay, s/veh		62.5			66.9			55.0			61.2	
Approach LOS		E			E			E			E	
Timer - Assigned Phs	1	2	3	4	5	6	7	8				
Phs Duration (G+Y+Rc), s	27.0	41.5	17.7	33.8	18.0	50.5	21.0	30.5				
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0				
Max Green Setting (Gmax), s	22.0	32.0	14.0	32.0	13.0	41.0	16.0	30.0				
Max Q Clear Time (g_c+I1), s	25.0	30.5	12.6	24.0	15.7	32.9	19.0	22.8				
Green Ext Time (p_c), s	0.0	0.9	0.1	1.5	0.0	4.3	0.0	1.3				
Intersection Summary												
HCM 6th Ctrl Delay			60.7									
HCM 6th LOS			E									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	0	885	95	0	855	130	0	0	0	670	0	255
Future Volume (vph)	0	885	95	0	855	130	0	0	0	670	0	255
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)		4.0			4.0	4.0				4.0	4.0	4.0
Lane Util. Factor		0.95			1.00	1.00				0.95	0.95	1.00
Frpb, ped/bikes		1.00			1.00	0.97				1.00	1.00	0.97
Flpb, ped/bikes		1.00			1.00	1.00				1.00	1.00	1.00
Frt		0.99			1.00	0.85				1.00	1.00	0.85
Flt Protected		1.00			1.00	1.00				0.95	0.95	1.00
Satd. Flow (prot)		3236			1750	1449				1564	1564	1449
Flt Permitted		1.00			1.00	1.00				0.95	0.95	1.00
Satd. Flow (perm)		3236			1750	1449				1564	1564	1449
Peak-hour factor, PHF	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Adj. Flow (vph)	0	922	99	0	891	135	0	0	0	698	0	266
RTOR Reduction (vph)	0	6	0	0	0	45	0	0	0	0	0	126
Lane Group Flow (vph)	0	1015	0	0	891	90	0	0	0	349	349	140
Confl. Peds. (#/hr)	2		2	2		2						
Confl. Bikes (#/hr)			2			3						4
Heavy Vehicles (%)	0%	1%	1%	0%	0%	0%	0%	0%	0%	1%	0%	0%
Turn Type		NA			NA	Perm				Perm	NA	Perm
Protected Phases		2			6						4	
Permitted Phases						6				4		4
Actuated Green, G (s)		79.1			79.1	79.1				30.9	30.9	30.9
Effective Green, g (s)		80.1			80.1	80.1				31.9	31.9	31.9
Actuated g/C Ratio		0.67			0.67	0.67				0.27	0.27	0.27
Clearance Time (s)		5.0			5.0	5.0				5.0	5.0	5.0
Vehicle Extension (s)		3.5			4.5	4.5				3.0	3.0	3.0
Lane Grp Cap (vph)		2160			1168	967				415	415	385
v/s Ratio Prot		0.31			c0.51							
v/s Ratio Perm						0.06				c0.22	0.22	0.10
v/c Ratio		0.47			0.76	0.09				0.84	0.84	0.36
Uniform Delay, d1		9.7			13.5	7.1				41.7	41.7	35.8
Progression Factor		1.00			0.77	1.19				1.00	1.00	1.00
Incremental Delay, d2		0.7			4.5	0.2				14.2	14.2	0.6
Delay (s)		10.4			15.0	8.6				55.9	55.9	36.4
Level of Service		B			B	A				E	E	D
Approach Delay (s)		10.4			14.2			0.0			50.5	
Approach LOS		B			B			A			D	

Intersection Summary			
HCM 2000 Control Delay	24.5	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.78		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	8.0
Intersection Capacity Utilization	75.7%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	0	885	95	0	855	130	0	0	0	670	0	255
Future Volume (veh/h)	0	885	95	0	855	130	0	0	0	670	0	255
Initial Q (Qb), veh	0	0	0	0	0	0				0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		0.98				1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00				1.00	1.00	1.00
Work Zone On Approach		No			No						No	
Adj Sat Flow, veh/h/ln	0	1736	1736	0	1750	1750				1736	1750	1750
Adj Flow Rate, veh/h	0	922	90	0	891	135				454	341	211
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96				0.96	0.96	0.96
Percent Heavy Veh, %	0	1	1	0	0	0				1	0	0
Cap, veh/h	0	1699	166	0	981	812				616	373	231
Arrive On Green	0.00	0.56	0.55	0.00	1.00	1.00				0.37	0.37	0.36
Sat Flow, veh/h	0	3116	296	0	1750	1448				1654	1001	619
Grp Volume(v), veh/h	0	502	510	0	891	135				454	0	552
Grp Sat Flow(s),veh/h/ln	0	1650	1675	0	1750	1448				1654	0	1620
Q Serve(g_s), s	0.0	23.1	23.1	0.0	0.0	0.0				28.5	0.0	38.9
Cycle Q Clear(g_c), s	0.0	23.1	23.1	0.0	0.0	0.0				28.5	0.0	38.9
Prop In Lane	0.00		0.18	0.00		1.00				1.00		0.38
Lane Grp Cap(c), veh/h	0	925	939	0	981	812				616	0	604
V/C Ratio(X)	0.00	0.54	0.54	0.00	0.91	0.17				0.74	0.00	0.91
Avail Cap(c_a), veh/h	0	925	939	0	981	812				661	0	648
HCM Platoon Ratio	1.00	1.00	1.00	1.00	2.00	2.00				1.00	1.00	1.00
Upstream Filter(I)	0.00	1.00	1.00	0.00	0.81	0.81				1.00	0.00	1.00
Uniform Delay (d), s/veh	0.0	16.6	16.7	0.0	0.0	0.0				32.6	0.0	36.0
Incr Delay (d2), s/veh	0.0	2.3	2.3	0.0	11.5	0.4				4.0	0.0	17.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0				0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.0	9.2	9.4	0.0	3.1	0.1				12.0	0.0	18.0
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	0.0	18.9	19.0	0.0	11.5	0.4				36.6	0.0	53.0
LnGrp LOS	A	B	B	A	B	A				D	A	D
Approach Vol, veh/h		1012			1026						1006	
Approach Delay, s/veh		18.9			10.0						45.6	
Approach LOS		B			A						D	
Timer - Assigned Phs		2		4		6						
Phs Duration (G+Y+Rc), s		71.3		48.7		71.3						
Change Period (Y+Rc), s		5.0		5.0		5.0						
Max Green Setting (Gmax), s		63.0		47.0		63.0						
Max Q Clear Time (g_c+I1), s		25.1		40.9		2.0						
Green Ext Time (p_c), s		10.7		2.8		20.0						

Intersection Summary		
HCM 6th Ctrl Delay		24.7
HCM 6th LOS		C

Notes

User approved volume balancing among the lanes for turning movement.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	0	1285	270	0	860	350	125	0	125	0	0	0
Future Volume (veh/h)	0	1285	270	0	860	350	125	0	125	0	0	0
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0			
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		1.00	1.00		1.00			
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
Work Zone On Approach		No			No			No				
Adj Sat Flow, veh/h/ln	0	1736	1736	0	1750	1723	1750	0	1723			
Adj Flow Rate, veh/h	0	1367	265	0	915	321	133	0	67			
Peak Hour Factor	0.92	0.94	0.94	0.94	0.94	0.92	0.94	0.92	0.94			
Percent Heavy Veh, %	0	1	1	0	0	2	0	0	2			
Cap, veh/h	0	1904	363	0	1671	584	403	0	353			
Arrive On Green	0.00	0.69	0.69	0.00	0.69	0.69	0.24	0.00	0.24			
Sat Flow, veh/h	0	2839	524	0	2504	844	1667	0	1460			
Grp Volume(v), veh/h	0	810	822	0	628	608	133	0	67			
Grp Sat Flow(s),veh/h/ln	0	1650	1627	0	1663	1598	1667	0	1460			
Q Serve(g_s), s	0.0	35.7	37.8	0.0	22.5	22.7	7.9	0.0	4.4			
Cycle Q Clear(g_c), s	0.0	35.7	37.8	0.0	22.5	22.7	7.9	0.0	4.4			
Prop In Lane	0.00		0.32	0.00		0.53	1.00		1.00			
Lane Grp Cap(c), veh/h	0	1141	1126	0	1150	1105	403	0	353			
V/C Ratio(X)	0.00	0.71	0.73	0.00	0.55	0.55	0.33	0.00	0.19			
Avail Cap(c_a), veh/h	0	1141	1126	0	1150	1105	403	0	353			
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
Upstream Filter(I)	0.00	0.70	0.70	0.00	1.00	1.00	1.00	0.00	1.00			
Uniform Delay (d), s/veh	0.0	11.2	11.5	0.0	9.2	9.2	37.5	0.0	36.2			
Incr Delay (d2), s/veh	0.0	2.6	3.0	0.0	1.9	2.0	2.2	0.0	1.2			
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
%ile BackOfQ(50%),veh/ln	0.0	12.9	13.6	0.0	8.3	8.1	3.5	0.0	1.7			
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	0.0	13.8	14.5	0.0	11.0	11.2	39.7	0.0	37.4			
LnGrp LOS	A	B	B	A	B	B	D	A	D			
Approach Vol, veh/h		1632			1236			200				
Approach Delay, s/veh		14.2			11.1			38.9				
Approach LOS		B			B			D				
Timer - Assigned Phs		2		4				8				
Phs Duration (G+Y+Rc), s		33.0		87.0				87.0				
Change Period (Y+Rc), s		4.0		4.0				4.0				
Max Green Setting (Gmax), s		29.0		83.0				83.0				
Max Q Clear Time (g_c+I1), s		9.9		39.8				24.7				
Green Ext Time (p_c), s		0.4		16.1				10.2				
Intersection Summary												
HCM 6th Ctrl Delay			14.5									
HCM 6th LOS			B									

Intersection	
Int Delay, s/veh	0.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	760	650	0	1170	0	0	0	50	0	0	40
Future Vol, veh/h	0	760	650	0	1170	0	0	0	50	0	0	40
Conflicting Peds, #/hr	2	0	2	2	0	2	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	None	-	-	Stop	-	-	None
Storage Length	-	-	-	-	-	-	-	-	0	-	-	0
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	97	97	97	97	97	97	97	97	97	97	97	97
Heavy Vehicles, %	3	1	1	0	1	2	0	0	4	33	0	0
Mvmt Flow	0	784	670	0	1206	0	0	0	52	0	0	41

Major/Minor	Major1			Major2			Minor1			Minor2		
Conflicting Flow All	-	0	0	-	-	0	-	-	729	-	-	605
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy	-	-	-	-	-	-	-	-	6.98	-	-	6.9
Critical Hdwy Stg 1	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy Stg 2	-	-	-	-	-	-	-	-	-	-	-	-
Follow-up Hdwy	-	-	-	-	-	-	-	-	3.34	-	-	3.3
Pot Cap-1 Maneuver	0	-	-	0	-	-	0	0	361	0	0	446
Stage 1	0	-	-	0	-	-	0	0	-	0	0	-
Stage 2	0	-	-	0	-	-	0	0	-	0	0	-
Platoon blocked, %		-	-		-	-						
Mov Cap-1 Maneuver	-	-	-	-	-	-	-	-	360	-	-	445
Mov Cap-2 Maneuver	-	-	-	-	-	-	-	-	-	-	-	-
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	0	0	16.7	13.9
HCM LOS			C	B

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBT	WBR	SBLn1
Capacity (veh/h)	360	-	-	-	-	445
HCM Lane V/C Ratio	0.143	-	-	-	-	0.093
HCM Control Delay (s)	16.7	-	-	-	-	13.9
HCM Lane LOS	C	-	-	-	-	B
HCM 95th %tile Q(veh)	0.5	-	-	-	-	0.3

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	160	555	85	260	520	190	365	780	275	205	850	195
Future Volume (vph)	160	555	85	260	520	190	365	780	275	205	850	195
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	3.0	2.0		3.0	2.0		3.0	2.0		3.0	2.0	3.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	0.95		1.00	0.95	1.00
Frpb, ped/bikes	1.00	1.00		1.00	1.00		1.00	0.99		1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00
Frt	1.00	0.98		1.00	0.96		1.00	0.96		1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00		0.95	1.00	1.00
Satd. Flow (prot)	1787	3473		1787	3405		1787	3380		1787	3574	1599
Flt Permitted	0.95	1.00		0.95	1.00		0.95	1.00		0.95	1.00	1.00
Satd. Flow (perm)	1787	3473		1787	3405		1787	3380		1787	3574	1599
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	160	555	85	260	520	190	365	780	275	205	850	195
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	160	640	0	260	710	0	365	1055	0	205	850	195
Confl. Peds. (#/hr)	1		8	8		1	6		2	2		6
Confl. Bikes (#/hr)			5			7			12			2
Heavy Vehicles (%)	1%	1%	5%	1%	1%	2%	1%	2%	2%	1%	1%	1%
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	Over
Protected Phases	13	8		7	14		5	12		11	6	13
Permitted Phases												
Actuated Green, G (s)	14.5	32.0		15.0	32.5		22.0	33.6		11.0	26.8	14.5
Effective Green, g (s)	16.5	35.0		17.0	35.5		24.0	36.6		13.0	29.8	16.5
Actuated g/C Ratio	0.14	0.29		0.14	0.30		0.20	0.31		0.11	0.25	0.14
Clearance Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	5.0
Vehicle Extension (s)	2.5	2.5		2.5	2.5		2.5	4.3		2.5	4.3	2.5
Lane Grp Cap (vph)	245	1012		253	1007		357	1030		193	887	219
v/s Ratio Prot	0.09	0.18		c0.15	c0.21		c0.20	c0.31		0.11	0.24	0.12
v/s Ratio Perm												
v/c Ratio	0.65	0.63		1.03	0.71		1.02	1.02		1.06	0.96	0.89
Uniform Delay, d1	49.0	36.9		51.5	37.6		48.0	41.7		53.5	44.5	50.9
Progression Factor	1.12	0.80		1.00	1.00		1.22	0.99		1.00	1.00	1.00
Incremental Delay, d2	4.1	0.8		63.9	4.1		45.4	29.7		82.2	21.6	32.9
Delay (s)	59.2	30.2		115.4	41.7		103.9	71.0		135.7	66.1	83.8
Level of Service	E	C		F	D		F	E		F	E	F
Approach Delay (s)		36.0			61.5			79.5			80.3	
Approach LOS		D			E			E			F	

Intersection Summary			
HCM 2000 Control Delay	67.9	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.95		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	91.2%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑	↱	↰	↱		↰	↑↱		↰	↑↱	
Traffic Volume (vph)	85	345	270	55	25	480	30	855	50	230	940	25
Future Volume (vph)	85	345	270	55	25	480	30	855	50	230	940	25
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	2.5	2.5	2.5	2.5	2.5		2.5	2.5		2.5	2.5	
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00		1.00	0.95		1.00	0.95	
Frpb, ped/bikes	1.00	1.00	1.00	1.00	0.98		1.00	1.00		1.00	1.00	
Flpb, ped/bikes	1.00	1.00	1.00	1.00	1.00		1.00	1.00		1.00	1.00	
Frt	1.00	1.00	0.85	1.00	0.86		1.00	0.99		1.00	1.00	
Flt Protected	0.95	1.00	1.00	0.95	1.00		0.95	1.00		0.95	1.00	
Satd. Flow (prot)	1646	1716	1488	1630	1456		1498	3262		1630	3291	
Flt Permitted	0.95	1.00	1.00	0.95	1.00		0.95	1.00		0.95	1.00	
Satd. Flow (perm)	1646	1716	1488	1630	1456		1498	3262		1630	3291	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	85	345	270	55	25	480	30	855	50	230	940	25
RTOR Reduction (vph)	0	0	0	0	297	0	0	0	0	0	0	0
Lane Group Flow (vph)	85	345	270	55	208	0	30	905	0	230	965	0
Confl. Peds. (#/hr)	3		1	1		3			2	2		
Confl. Bikes (#/hr)			4			3			1			4
Heavy Vehicles (%)	1%	2%	0%	2%	5%	1%	11%	1%	0%	2%	0%	22%
Turn Type	Prot	NA	Over	Prot	NA		Prot	NA		Prot	NA	
Protected Phases	13	8	5	7	14		5	12		11	6	
Permitted Phases												
Actuated Green, G (s)	6.5	28.3	22.8	5.6	23.2		22.8	45.6		18.8	41.6	
Effective Green, g (s)	8.0	30.3	24.8	7.1	25.2		24.8	47.6		20.8	43.6	
Actuated g/C Ratio	0.07	0.25	0.21	0.06	0.21		0.21	0.40		0.17	0.36	
Clearance Time (s)	4.0	4.5	4.5	4.0	4.5		4.5	4.5		4.5	4.5	
Vehicle Extension (s)	3.0	2.5	2.5	3.0	2.5		2.5	4.3		2.5	4.3	
Lane Grp Cap (vph)	109	433	307	96	305		309	1293		282	1195	
v/s Ratio Prot	c0.05	c0.20	c0.18	0.03	0.14		0.02	c0.28		0.14	c0.29	
v/s Ratio Perm												
v/c Ratio	0.78	0.80	0.88	0.57	0.68		0.10	0.70		0.82	0.81	
Uniform Delay, d1	55.1	42.0	46.2	55.0	43.7		38.5	30.2		47.8	34.4	
Progression Factor	1.00	1.00	1.00	1.00	1.00		1.00	1.00		1.06	1.02	
Incremental Delay, d2	28.9	9.5	23.5	8.0	5.6		0.1	3.2		6.6	2.3	
Delay (s)	84.0	51.5	69.6	63.0	49.3		38.6	33.4		57.0	37.3	
Level of Service	F	D	E	E	D		D	C		E	D	
Approach Delay (s)		62.4			50.7			33.6			41.1	
Approach LOS		E			D			C			D	

Intersection Summary			
HCM 2000 Control Delay	45.0	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.84		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	93.6%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	160	555	85	260	520	190	365	780	275	205	850	195
Future Volume (vph)	160	555	85	260	520	190	365	780	275	205	850	195
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	3.0	2.0		3.0	2.0		3.0	2.0		3.0	2.0	
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	0.95		1.00	0.95	
Frpb, ped/bikes	1.00	1.00		1.00	1.00		1.00	0.99		1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Frt	1.00	0.98		1.00	0.96		1.00	0.96		1.00	0.97	
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00		0.95	1.00	
Satd. Flow (prot)	1787	3473		1787	3405		1787	3380		1787	3460	
Flt Permitted	0.95	1.00		0.95	1.00		0.95	1.00		0.95	1.00	
Satd. Flow (perm)	1787	3473		1787	3405		1787	3380		1787	3460	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	160	555	85	260	520	190	365	780	275	205	850	195
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	160	640	0	260	710	0	365	1055	0	205	1045	0
Confl. Peds. (#/hr)	1		8	8		1	6		2	2		6
Confl. Bikes (#/hr)			5			7			12			2
Heavy Vehicles (%)	1%	1%	5%	1%	1%	2%	1%	2%	2%	1%	1%	1%
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	13	8		7	14		5	12		11	6	
Permitted Phases												
Actuated Green, G (s)	11.6	32.0		14.0	34.0		21.0	33.6		12.0	28.8	
Effective Green, g (s)	13.6	35.0		16.0	37.0		23.0	36.6		14.0	31.8	
Actuated g/C Ratio	0.11	0.29		0.13	0.31		0.19	0.31		0.12	0.27	
Clearance Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Vehicle Extension (s)	2.5	2.5		2.5	2.5		2.5	4.3		2.5	4.3	
Lane Grp Cap (vph)	202	1012		238	1049		342	1030		208	916	
v/s Ratio Prot	0.09	0.18		c0.15	c0.21		c0.20	0.31		0.11	c0.30	
v/s Ratio Perm												
v/c Ratio	0.79	0.63		1.09	0.68		1.07	1.02		0.99	1.14	
Uniform Delay, d1	51.8	36.9		52.0	36.3		48.5	41.7		52.9	44.1	
Progression Factor	1.13	0.81		1.00	1.00		1.22	0.95		1.00	1.00	
Incremental Delay, d2	14.1	0.8		85.2	3.5		59.6	29.7		57.8	76.6	
Delay (s)	72.5	30.6		137.2	39.8		118.6	69.3		110.7	120.7	
Level of Service	E	C		F	D		F	E		F	F	
Approach Delay (s)		39.0			65.9			82.0			119.0	
Approach LOS		D			E			F			F	

Intersection Summary			
HCM 2000 Control Delay	81.1	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.96		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	97.6%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

MOVEMENT SUMMARY

Site: 101 [Reed Market Road/3rdSt - Original Vols - Slip Lanes (Site Folder: Post-Workshop Testing)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance														
Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: SE 3rd St														
1	L2	365	1.0	365	1.0	1.033	103.4	LOS F	30.0	218.5	1.00	2.80	6.48	21.3
2	T1	780	12.0	780	12.0	1.033	103.5	LOS F	30.2	233.5	1.00	2.93	6.69	21.7
3	R2	275	2.0	275	2.0	0.379	9.8	LOS A	1.7	12.4	0.65	0.64	0.79	46.3
Approach		1420	7.2	1420	7.2	1.033	85.4	LOS F	30.2	233.5	0.93	2.45	5.50	24.0
East: Reed Market Road														
4	L2	260	1.0	260	1.0	1.012	99.2	LOS F	19.3	136.5	1.00	2.30	5.51	21.9
5	T1	600	1.0	600	1.0	1.012	99.3	LOS F	19.3	136.5	1.00	2.30	5.51	22.1
6	R2	110	2.0	110	2.0	1.012	99.6	LOS F	19.3	136.3	1.00	2.30	5.51	22.1
Approach		970	1.1	970	1.1	1.012	99.3	LOS F	19.3	136.5	1.00	2.30	5.51	22.1
North: SE 3rd St														
7	L2	205	1.0	205	1.0	1.007	92.4	LOS F	21.0	148.0	1.00	2.78	5.58	20.1
8	T1	850	1.0	850	1.0	1.007	92.4	LOS F	21.0	148.0	1.00	2.78	5.58	20.2
9	R2	195	1.0	195	1.0	0.305	9.6	LOS A	1.1	7.7	0.61	0.64	0.68	35.9
Approach		1250	1.0	1250	1.0	1.007	79.5	LOS F	21.0	148.0	0.94	2.44	4.82	21.6
West: Reed Market Road														
10	L2	160	1.0	160	1.0	0.832	42.0	LOS E	5.9	41.9	0.91	1.25	2.07	32.7
11	T1	555	1.0	555	1.0	0.832	42.1	LOS E	5.9	41.9	0.91	1.25	2.07	33.2
12	R2	85	5.0	85	5.0	0.832	43.3	LOS E	5.9	41.7	0.91	1.25	2.08	33.2
Approach		800	1.4	800	1.4	0.832	42.2	LOS E	5.9	41.9	0.91	1.25	2.07	33.1
All Vehicles		4440	3.1	4440	3.1	1.033	79.0	LOS F	30.2	233.5	0.95	2.20	4.69	24.0

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.

Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

HCS Roundabouts Report

General Information		Site Information	
Analyst		Intersection	Reed Market & Bond/Brook...
Agency or Co.		E/W Street Name	Reed Market
Date Performed	3/21/2023	N/S Street Name	Bond/Brookswood
Analysis Year	2040	Analysis Time Period, hrs	0.25
Time Analyzed		Peak Hour Factor	0.92
Project Description	No Build	Jurisdiction	

Volume Adjustments and Site Characteristics

Approach	EB				WB				NB				SB			
Movement	U	L	T	R	U	L	T	R	U	L	T	R	U	L	T	R
Number of Lanes (N)	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
Lane Assignment			LTR				LTR				LTR				LTR	
Volume (V), veh/h	0	65	445	210	0	70	360	425	0	195	470	70	0	395	470	70
Percent Heavy Vehicles, %	5	5	5	5	3	3	3	3	3	3	3	3	2	2	2	2
Flow Rate (v_{PCE}), pc/h	0	74	508	240	0	78	403	476	0	218	526	78	0	438	521	78
Right-Turn Bypass	None				None				None				None			
Conflicting Lanes	1				1				1				1			
Pedestrians Crossing, p/h	0				0				0				0			
Proportion of CAVs	0															

Critical and Follow-Up Headway Adjustment

Approach	EB			WB			NB			SB		
Lane	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass
Critical Headway, s		4.9763			4.9763			4.9763			4.9763	
Follow-Up Headway, s		2.6087			2.6087			2.6087			2.6087	

Flow Computations, Capacity and v/c Ratios

Approach	EB			WB			NB			SB		
Lane	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass
Entry Flow (v_e), pc/h		822			957			822			1037	
Entry Volume, veh/h		783			929			798			1017	
Circulating Flow (v_c), pc/h	1037			818			1020			699		
Exiting Flow (v_{ex}), pc/h	1024			699			1076			839		
Capacity (c_{pce}), pc/h		479			599			488			676	
Capacity (c), veh/h		456			582			473			663	
v/c Ratio (x)		1.72			1.60			1.69			1.53	

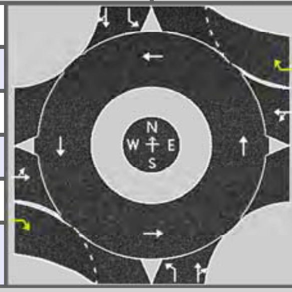
Delay and Level of Service

Approach	EB			WB			NB			SB		
Lane	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass
Lane Control Delay (d), s/veh		352.7			295.6			338.9			265.0	
Lane LOS		F			F			F			F	
95% Queue, veh		47.0			50.4			47.0			51.6	
Approach Delay, s/veh | LOS	352.7	F		295.6	F		338.9	F		265.0	F	
Intersection Delay, s/veh | LOS	309.3						F					

HCS Roundabouts Report

General Information

Analyst	
Agency or Co.	
Date Performed	3/21/2023
Analysis Year	2040
Time Analyzed	
Project Description	Build



Site Information

Intersection	Reed Market & Bond/Brook...
E/W Street Name	Reed Market
N/S Street Name	Bond/Brookswood
Analysis Time Period, hrs	0.25
Peak Hour Factor	0.92
Jurisdiction	

Volume Adjustments and Site Characteristics

Approach	EB				WB				NB				SB			
Movement	U	L	T	R	U	L	T	R	U	L	T	R	U	L	T	R
Number of Lanes (N)	0	0	1	0	0	0	1	0	0	1	1	0	0	1	1	0
Lane Assignment			LT				LT		L		TR		L		TR	
Volume (V), veh/h	0	65	445	210	0	70	360	425	0	195	470	70	0	395	470	70
Percent Heavy Vehicles, %	5	5	5	5	3	3	3	3	3	3	3	3	2	2	2	2
Flow Rate (v_{PCE}), pc/h	0	74	508	240	0	78	403	476	0	218	526	78	0	438	521	78
Right-Turn Bypass	Yielding				Yielding				None				None			
Conflicting Lanes	1				1				1				1			
Pedestrians Crossing, p/h	0				0				0				0			
Proportion of CAVs	0															

Critical and Follow-Up Headway Adjustment

Approach	EB			WB			NB			SB		
Lane	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass
Critical Headway, s		4.9763	4.9763		4.9763	4.9763	4.5436	4.5436		4.5436	4.5436	
Follow-Up Headway, s		2.6087	2.6087		2.6087	2.6087	2.5352	2.5352		2.5352	2.5352	

Flow Computations, Capacity and v/c Ratios

Approach	EB			WB			NB			SB		
Lane	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass
Entry Flow (v_e), pc/h		582	240		481	476	218	604		438	599	
Entry Volume, veh/h		554	229		467	462	212	586		429	587	
Circulating Flow (v_c), pc/h	1037			818			1020			699		
Exiting Flow (v_{ex}), pc/h	1024			699			600			599		
Capacity (c_{pce}), pc/h		479	749		599	748	561	561		752	752	
Capacity (c), veh/h		456	713		582	727	545	545		737	737	
v/c Ratio (x)		1.21	0.32		0.80	0.64	0.39	1.08		0.58	0.80	

Delay and Level of Service

Approach	EB			WB			NB			SB		
Lane	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass	Left	Right	Bypass
Lane Control Delay (d), s/veh		142.7	9.0		30.7	16.4	12.7	87.8		14.4	25.1	
Lane LOS		F	A		D	C	B	F		B	D	
95% Queue, veh		21.8	1.4		7.9	4.6	1.8	17.6		3.8	8.2	
Approach Delay, s/veh | LOS	103.6	F		23.6	C		67.9	F		20.6	C	
Intersection Delay, s/veh | LOS	50.5						F					

APPENDIX C: ALTERNATIVE COST ESTIMATES

REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL – ALTERNATIVE 1

Description of Alternative

Add SB right turn lane at SB ramp terminal. General intersection improvements

Item	Qty	Unit	Unit Cost	Total	Notes
Asphalt	5,584	*TON*	$ 140.00	$ 781,761.75	*Includes asphalt (11 inches)*
Aggregate Base	4,512	*TON*	$ 40.00	$ 180,493.33	*Assume 12"*
Concrete Curb, Standard	2,590	*FOOT*	$ 45.00	$ 116,550.00	*assume mountable/standard the same (same cost)*
Concrete Islands	-	*SQFT*	$ 20.00	$ -	
Concrete Walks	14,758	*SQFT*	$ 18.00	$ 265,644.00	*Includes sidewalk and aggregate base*
Curb Ramps	6	*EACH*	$ 5,000.00	$ 30,000.00	
Sound Wall	5,230	*SQFT*	$ 70.00	$ 366,100.00	*Assume 10' high sound wall*
Signal	1	*EACH*	$ 425,000.00	$ 425,000.00	*assume all new signal equipment*
Subtotal				**$ 2,165,549**	
Permanent Striping/Signing			5%	$ 108,277	*Bicycle markers, arrows, lane striping, pavement bar*
Drainage and Sewers			5%	$ 108,277	
Landscaping			5%	$ 108,277	
Temporary Traffic Control			10%	$ 216,555	
Illumination			10%	$ 216,555	
Erosion Control			2%	$ 43,310.98	
Site Preparation			2%	$ 43,310.98	*Includes pavement removal, clearing and grubbing, removal of obstacles*
Construction Survey Work			2%	$ 43,311	
Construction Subtotal				**$ 3,053,424**	
Design & Construction Management			25%	$ 763,356	
Mobilization			10%	$ 305,342	
ROW	1	*EACH*	$ 50,000	$ 50,000	*Estimate for empty parcel*
Contingency			50%	$ 1,526,712	
Total				**$ 5,698,835**	

$$\left[\frac{11\text{in}}{12in} \times xft^2\right]\left[\frac{1yd^3}{27ft^3}\right]\frac{2.025\text{ tons}}{1yd^3}$$

REED MARKET ROAD/US 97 SOUTHBOUND RAMP TERMINAL – ALTERNATIVE 2

Description of Alternative

Shift SB 97 alignment towards NB 97 to provide room to extend deceleration lane. Install jersey barrier in median of 97.

Item	Qty	Unit	Unit Cost	Total	Notes
Asphalt	4,087	*TON*	$ 140.00	$ 572,138.88	*Includes asphalt (11 inches)*
Aggregate Base	3,302	*TON*	$ 40.00	$ 132,095.56	*Assume 12"*
Concrete Curb, Standard	1,162	*FOOT*	$ 45.00	$ 52,290.00	*assume mountable/standard the same (same cost)*
Concrete Islands	-	*SQFT*	$ 20.00	$ -	
Concrete Walks	2,290	*SQFT*	$ 18.00	$ 41,220.00	*Includes sidewalk and aggregate base*
Barrier	1,162	*FOOT*	$ 60.00	$ 69,720.00	
Signal	-	*EACH*	$ 425,000.00	$ -	*assume all new signal equipment*
Subtotal				**$ 867,464**	
Permanent Striping/Signing			5%	$ 43,373	*Bicycle markers, arrows, lane striping, pavement bar*
Drainage and Sewers			5%	$ 43,373	
Landscaping			5%	$ 43,373	
Temporary Traffic Control			15%	$ 130,120	
Illumination			10%	$ 86,746	
Erosion Control			2%	$ 17,349.29	
Site Preparation			2%	$ 17,349.29	*Includes pavement removal, clearing and grubbing, removal of obstacles*
Construction Survey Work			2%	$ 17,349	
Construction Subtotal				**$ 1,266,498**	
Design & Construction Management			25%	$ 316,625	
Mobilization			10%	$ 126,650	
ROW			0%	$ -	*Assume ROW is owned by ODOT (not impacting soundwall)*
Contingency			50%	$ 633,249	
Total				**$ 2,343,021**	

REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET – ALTERNATIVE 1

Description of Alternative

Signalize the NB 97 Ramp at Reed Market Road

Item	Qty	Unit	Unit Cost	Total	Notes
Asphalt	4,518	*TON*	$ 140.00	$ 632,545.38	*Includes asphalt (11 inches)*
Aggregate Base	3,651	*TON*	$ 40.00	$ 146,042.22	*Assume 12"*
Concrete Curb, Standard	1,922	*FOOT*	$ 45.00	$ 86,490.00	*assume mountable/standard the same (same cost)*
Concrete Islands	603	*SQFT*	$ 20.00	$ 12,060.00	
Concrete Walks	10,785	*SQFT*	$ 18.00	$ 194,130.00	*Includes sidewalk and aggregate base*
Curb Ramps	4	*EACH*	$ 5,000.00	$ 20,000.00	
Signal	1	*EACH*	$ 425,000.00	$ 425,000.00	*assume all new signal equipment*
Subtotal				**$ 1,516,267.60**	
Permanent Striping/Signing			5%	$ 75,813.38	*Bicycle markers, arrows, lane striping, pavement bar*
Drainage and Sewers			5%	$ 75,813.38	
Landscaping			5%	$ 75,813.38	
Temporary Traffic Control			10%	$ 151,626.76	
Illumination			10%	$ 151,626.76	
Erosion Control			2%	$ 30,325.35	
Site Preparation			2%	$ 30,325.35	*Includes pavement removal, clearing and grubbing, removal of obstacles*
Construction Survey Work			2%	$ 30,325.35	
Construction Subtotal				**$ 2,137,937.31**	
Design & Construction Management			25%	$ 534,484.33	
Mobilization			10%	$ 213,793.73	
ROW				$ -	
Contingency			50%	$ 1,068,968.66	
Total				**$ 3,955,184.03**	

REED MARKET ROAD/US 97 NORTHBOUND RAMP TERMINAL/DIVISION STREET – ALTERNATIVE 2

Description of Alternative

Realign the NB ramp from Division to the current NB ramp terminal. Signalize the NB ramp terminal

$$\left[\frac{11\text{in}}{12in} \times xft^2\right]\left[\frac{1yd^3}{27ft^3}\right]\frac{2.025\text{ tons}}{1yd^3}$$

Item	Qty	Unit	Unit Cost	Total	Notes
Aggregate Base	5,273	*TON*	$ 40.00	$ 210,931.11	*Assume 12"*
Full Depth Asphalt	6,526	*TON*	$ 140.00	$ 913,595.38	*Includes asphalt (11 inches)*
Concrete Curb, Standard	1,920	*FOOT*	$ 45.00	$ 86,400.00	*assume mountable/standard the same (same cost)*
Concrete Islands	603	*SQFT*	$ 20.00	$ 12,060.00	
Concrete Walks	10,719	*SQFT*	$ 18.00	$ 192,942.00	*Includes sidewalk and aggregate base*
Curb Ramps	4	*EACH*	$ 5,000.00	$ 20,000.00	
Signal	1	*EACH*	$ 425,000.00	$ 425,000.00	*assume all new signal equipment*
Gas Station Remediation	1	*EACH*	$ 600,000.00	$ 600,000.00	*Includes hazmat, tank removal, testing*
Subtotal				**$ 2,460,928.49**	
Permanent Striping/Signing			5%	$ 123,046.42	*Bicycle markers, arrows, lane striping, pavement bar*
Drainage and Sewers			5%	$ 123,046.42	
Landscaping			5%	$ 123,046.42	
Temporary Traffic Control			10%	$ 246,092.85	
Illumination			10%	$ 246,092.85	
Erosion Control			2%	$ 49,218.57	
Site Preparation			2%	$ 49,218.57	*Includes pavement removal, clearing and grubbing, removal of obstacles*
Construction Survey Work			2%	$ 49,218.57	
Construction Subtotal				**$ 3,469,909.17**	
Design & Construction Management			25%	$ 867,477.29	
ROW	1	*EACH*	$ 3,000,000	$ 3,000,000.00	*Based on Deschutes County DIAL real market value*
Mobilization			10%	$ 346,990.92	
Contingency			50%	$ 1,734,954.58	
Total				**$ 9,419,331.96**	

REED MARKET ROAD/3RD STREET – ALTERNATIVE 1

Description of Alternative

Adds left turn lanes to Reed Market Road at 3rd Street intersection.

Item	Qty	Unit	Unit Cost	Total	Notes
Asphalt	8,022	*TON*	$ 140.00	$ 1,123,025.75	*Includes asphalt (11 inches)*
Aggregate Base	6,482	*TON*	$ 40.00	$ 259,284.44	*Assume 12"*
Concrete Curb, Standard	3,120	*FOOT*	$ 45.00	$ 140,400.00	*assume mountable/standard the same (same cost)*
Concrete Islands	-	*SQFT*	$ 20.00	$ -	
Concrete Walks	17,036	*SQFT*	$ 18.00	$ 306,648.00	*Includes sidewalk and aggregate base*
Curb Ramps	8	*EACH*	$ 5,000.00	$ 40,000.00	
Signal	1	*EACH*	$ 425,000.00	$ 425,000.00	*assume all new signal equipment*
Subtotal				**$ 2,294,358.19**	
Permanent Striping/Signing			5%	$ 114,717.91	*Bicycle markers, arrows, lane striping, pavement bar*
Drainage and Sewers			5%	$ 114,717.91	
Landscaping			5%	$ 114,717.91	
Temporary Traffic Control			10%	$ 229,435.82	
Illumination			10%	$ 229,435.82	
Erosion Control			2%	$ 45,887.16	
Site Preparation			2%	$ 45,887.16	*Includes pavement removal, clearing and grubbing, removal of obstacles*
Construction Survey Work			2%	$ 45,887.16	
Construction Subtotal				**$ 3,235,045.05**	
Design & Construction Management			25%	$ 808,761.26	
Mobilization			10%	$ 323,504.51	
ROW	1	EACH	$ 1,000,000	$ 1,000,000.00	*Estimate scaled from ODOT estimate for Alt 2*
Contingency			50%	$ 1,617,522.53	
Total				**$ 6,984,833.35**	

REED MARKET ROAD/3RD STREET – ALTERNATIVE 2

Description of Alternative

Create protected intersection at Reed Market/3rd Street Intersection. Realign 3rd street to avoid impacts to SE corner of intersection. Add left turn lanes to Reed Market Rd and southbound right turn lane to 3rd Street

Item	Qty	Unit	Unit Cost	Total	Notes
Asphalt	10,142	*TON*	$ 140.00	$ 1,419,812.63	*Includes asphalt (11 inches)*
Aggregate Base	4,512	*TON*	$ 40.00	$ 180,493.33	*Assume 12"*
Concrete Curb, Standard	4,150	*FOOT*	$ 45.00	$ 186,750.00	*assume mountable/standard the same (same cost)*
Concrete Islands	4,349	*SQFT*	$ 20.00	$ 86,980.00	*Assumes islands and truck apron square footage*
Concrete Walks	24,002	*SQFT*	$ 18.00	$ 432,036.00	*Includes sidewalk and aggregate base*
Curb Ramps	8	*EACH*	$ 5,000.00	$ 40,000.00	
Green Bicycle Paint at Intersection	7,008	*SQFT*	$ 2.00	$ 14,016.00	
Signal	1	*EACH*	$ 425,000.00	$ 425,000.00	*assume all new signal equipment*
Subtotal				**$ 2,785,087.96**	
Permanent Striping/Signing			5%	$ 139,254.40	*Bicycle markers, arrows, lane striping, pavement bar*
Drainage and Sewers			5%	$ 139,254.40	
Landscaping			5%	$ 139,254.40	
Temporary Traffic Control			10%	$ 278,508.80	
Illumination			10%	$ 278,508.80	
Erosion Control			2%	$ 55,701.76	
Site Preparation			2%	$ 55,701.76	*Includes pavement removal, clearing and grubbing, removal of obstacles*
Construction Survey Work			2%	$ 55,701.76	
Construction Subtotal				**$ 3,926,974.02**	
Design & Construction Management			25%	$ 981,743.51	
Mobilization			10%	$ 392,697.40	
ROW	1	EACH	$ 3,000,000	$ 3,000,000.00	*Per ODOT ROW estimate*
Contingency			50%	$ 1,963,487.01	
Total				**$ 10,264,901.94**	

REED MARKET ROAD/3RD STREET – ALTERNATIVE 3

Description of Alternative

Convert signalized intersection at 3rd and Reed Market to a 2 lane roundabout with right turn bypass lanes for the northbound and southbound right turns.

Item	Qty	Unit	Unit Cost	Total	Notes
Asphalt	8,012	*TON*	$ 140.00	$ 1,121,639.75	*Includes asphalt (11 inches)*
Aggregate Base	6,474	*TON*	$ 40.00	$ 258,964.44	*Assume 12"*
Concrete Curb, Standard	3,549	*FOOT*	$ 45.00	$ 159,705.00	*assume mountable/standard the same (same cost)*
Concrete Islands	2,765	*SQFT*	$ 20.00	$ 55,300.00	
Concrete Walks	32,678	*SQFT*	$ 18.00	$ 588,204.00	*Includes sidewalk and aggregate base*
Curb Ramps	8	*EACH*	$ 5,000.00	$ 40,000.00	
RRFB	4	*EACH*	$ 75,000.00	$ 300,000.00	
Signal	-	*EACH*	$ 425,000.00	$ -	*assume all new signal equipment*
Subtotal				**$ 2,523,813.19**	
Permanent Striping/Signing			5%	$ 126,190.66	*Bicycle markers, arrows, lane striping, pavement bar*
Drainage and Sewers			5%	$ 126,190.66	
Landscaping			5%	$ 126,190.66	
Temporary Traffic Control			15%	$ 378,571.98	
Illumination			10%	$ 252,381.32	
Erosion Control			2%	$ 50,476.26	
Site Preparation			2%	$ 50,476.26	*Includes pavement removal, clearing and grubbing, removal of obstacles*
Construction Survey Work			2%	$ 50,476.26	
Construction Subtotal				**$ 3,684,767.26**	
Design & Construction Management			25%	$ 921,191.82	
Mobilization			10%	$ 368,476.73	
ROW	1	EACH	$ 4,000,000.00	$ 4,000,000.00	*Per ODOT ROW estimate*
Contingency			50%	$ 1,842,383.63	
Total				**$ 10,816,819.44**	

APPENDIX D: REED MARKET ROAD/BROOKSWOOD BOULEVARD SIMULATION MODEL DEVELOPMENT AND CALIBRATION MEMORANDUM

KITTELSON & ASSOCIATES
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BEND, OR 97702
P 541.312.8300

TECHNICAL MEMORANDUM

Intersection Alternatives Analysis - Reed Market Road & Brookswood Boulevard

Analysis of Roundabout Metering Signal

2019 Existing Conditions – VISSIM Calibration

Date:	November 26, 2019	Project #: 17453
To:	Project File	
From:	Ryan Casburn	

INTRODUCTION

Kittelson & Associates, Inc. (Kittelson) has been retained by the City of Bend to evaluate the operations of the roundabout located at the SW Reed Market Road and Brookswood Boulevard/ SW Bond Street intersection in Bend, Oregon. An alternative to improve operations at the study roundabout include adding metering signals at the approaches. Analysis of this roundabout is being completed in VISSIM version 11.00-07. This memorandum documents the VISSIM calibration process and existing condition results for the evaluation of this roundabout.

STUDY LIMITS & ANALYSIS SCENARIOS

The study limits of this evaluation include the main study intersection of SW Reed Market Road and Brookwood Boulevard/ SW Bond Street and upstream intersections including:

- SW Reed Market Road and Brookswood Boulevard/ SW Bond Street
- Driveway access to Urgent Care complex
- SW Bond Street and Columbia Street

The analysis scenarios include both morning and evening peak periods using existing traffic counts. The larger of the two peak periods (evening) will be used to test several metering alternatives, and the best performing metering alternative will be used for the morning and evening peak period trials. This memo documents the calibration for both peak periods.

The morning peak period analyzed traffic conditions from 7:00 am to 10:00 am. The evening peak period analyzed traffic conditions from 3:00 pm to 6:00 pm.

VOLUME DEVELOPMENT

Intersection turning movement counts (TMCs) were collected at the main study intersection and at Bond Street & Columbia Street on 6/25/2019 from 7:00 am to 10:00 am and from 3:00 pm to 6:00pm. Driveway In/Out counts were collected at the Urgent Care driveway on the same day. These In/Out counts were assigned to directions based on the relative flow of north- and southbound traffic with adjustments made to balance between Columbia Street and Reed Market Road along Bond Street. These volumes were used directly within VISSIM with no further adjustment.

BASE VISSIM MODEL

The base VISSIM model was developed in accordance with guidance provided in the 2011 ODOT Protocol for VISSIM Simulation. VISSIM 11.00-07 was used for this project.

Link Geometry

Standard link-geometry coding practices were used throughout the VISSIM network. Links on the edge of the network were expanded to accommodate expected queueing.

Driver Behavior

The default Wiedemann 74 car following model was used with an adjustment to the number of interaction objects to 10 (default of 4 objects). An adjustment to the number of interaction objects is commonly done with modeling roundabouts due to the larger than normal number of interaction objects (conflict areas, priority rules, reduced speed areas, desired speed decisions, etc.). Increasing this parameter affects how well vehicles in the network can predict other vehicles' movements and react accordingly. In the case of the Reed Market Road and Brookswood Boulevard intersection, there are several interaction objects such as priority rules, desired speed decisions, reduced speed areas, etc. and would benefit from an increase in the number of interaction objects. The same driving behavior will be carried forward into the metering condition models.

Yielding

The stop-controlled intersections of Columbia Street and the Urgent Care driveway was modelled using stop signs and conflict areas to model the appropriate yielding behavior. At the study intersection, priority rules were used to model the appropriate yielding behavior. Due to the slight skew angle of the intersection, conflict areas had difficulty correctly modeling the yielding. Separate priority rules were created for passenger vehicles and trucks to model the increased gaps required for the larger vehicles (trucks). These conditions will remain constant in the metering condition models.

Speeds

All roads within the study limit have a posted speed limit of 25 mph. A speed distribution was created with a linear profile of ± 5 mph of the posted speed limit. Additional speed distributions were created for the roundabout entry radius speed and circulating speed. These also have a linear profile. Desired speed decisions were not explicitly placed at each input link into the model but were instead included in the vehicle compositions of the vehicle inputs. The speed assigned to the vehicle composition at each vehicle input is consistent with the posted speed along the input link. This accomplishes the same as placing the desired speed decisions along the input links without redundant coding in the model. Reduced speed areas were coded along the radii of left-turn and right-turns at the stop-controlled intersections. Reduced speed areas with the roundabout entry radius distribution was placed near the entrance of the roundabout and desired speed decisions were placed just after the reduced speed area with the roundabout circulating speed distribution. Finally, a desired speed decision with the 25 mph posted speed distribution was placed just downstream of the roundabout to return vehicles to their previous speeds. The desired speed distributions can be found in **Table 1**.

Table 1: Desired Speed Distributions

Name	Lower Bound	Upper Bound
25 MPH	20	30
Left Turn	10	20
Right Turn	9	15
Roundabout Entry Radius	15	20
Roundabout Circulating Speed	17	22

Vehicle Inputs

Vehicle inputs and routes were coded in 15-minute increments for the entire three-hour analysis period plus 15-minute warm up and 15-minute cool down periods. Some adjustments from the raw data was made to the routes to correct vehicle calibration.

The North American Default vehicle types were used, but to better represent the vehicle mix in the study area, multiunit trucks percentages were halved.

Pedestrians

Pedestrian crosswalks were analyzed at the roundabout and at the Columbia Street intersection. Bicycles were included in the pedestrian demand.

CALIBRATION

Volume Calibration (GEH Statistic)

Calibration of the model was primarily focused on volumes using the GEH statistic and visual inspection. The GEH statistic was calculated for all study segments, entry and exit volumes, and all turning movement volumes based on the formula below:

$$GEH = \sqrt{\frac{2(m-c)^2}{m+c}}$$

Notes:
m = output traffic volume from the simulation model (vph)
c = input traffic volume (vph)

The two calibration criteria used for the volumes were:

- All intersection turn movements greater than 100 vehicles per hour: GEH <5
- All intersection turn movements: GEH <10

A GEH Statistic was calculated for each hour within the analysis.

Delay

The study intersection was also analyzed for existing conditions in Vistro following the procedures set forth in the Highway Capacity Manual. The delay reported by Vistro was compared for general consistency with the delays reported by VISSIM. Delay from a deterministic approach, such as Vistro is not expected to match VISSIM delays exactly, but general patterns should be consistent. The delay reported from VISSIM occurred in the middle of each analysis (5400-6300 simulation seconds), 8:30-8:45 AM and 4:30-4:45 PM.

Queuing

Queuing measurements were collected by drone on 8/7/2019. Queue measurements at the roundabout and the eastbound movement of Columbia Street are compared to field measurements. Values are reported for the average queue in one 15-minute period which lines up with when the field queue measurements were recorded.

Visual Inspection

The model was visually inspected to check whether the model is accurately replicating field conditions. No major differences were identified between the model and the peak season peak hour conditions at the study intersection.

Number of Runs

For calibration purposes, 10 simulation runs were conducted. Based on these calibration results, the number of runs for the metering scenarios may be increased.

The minimum number of simulation runs was calculated using the formula below provided in Section 6.9 of the ODOT Protocol for VISSIM Simulation. The value reported is rounded up to the next integer

$$N = \left(2 * t_{0.025, N-1} \frac{s}{R} \right)^2$$

R = 95-percent confidence interval for the true mean

$t_{0.025,N-1}$ = Student's t-statistic for two-sided error of 2.5 percent (totals 5 percent) with N-1 degrees of freedom

s = standard deviation of about the mean for selected MOE

N = number of required simulation runs

The key measure of effectiveness (MOE) used for the determination of the minimum number of runs was:

- Overall Node Delay at the study roundabout for each hour

AM CALIBRATION

Volume Calibration (GEH Statistic)

Volume calibration using the GEH calibration criteria for the AM peak period is shown in **Table 2**. All calculated GEH values are shown in Appendix A. **Figure 1** shows a comparison of field and VISSIM volumes. The black line marks where volumes are equal. Points above the line have a higher volume in the VISSIM model; points below the line have a lower volume in the VISSIM model. The yellow line marks where GEH is equal to 5; the red line marks where the GEH equals 10.

Table 2: AM GEH Calibration Criteria Summary

Acceptance Target	Criteria	Number of Measurements	Number unacceptable	Percent acceptable
All Intersection Turn movements greater than 100 vehicles per hour	GEH < 5.0	38	0	100%
All Intersection Turn Movements	GEH < 10.0	82	0	100%

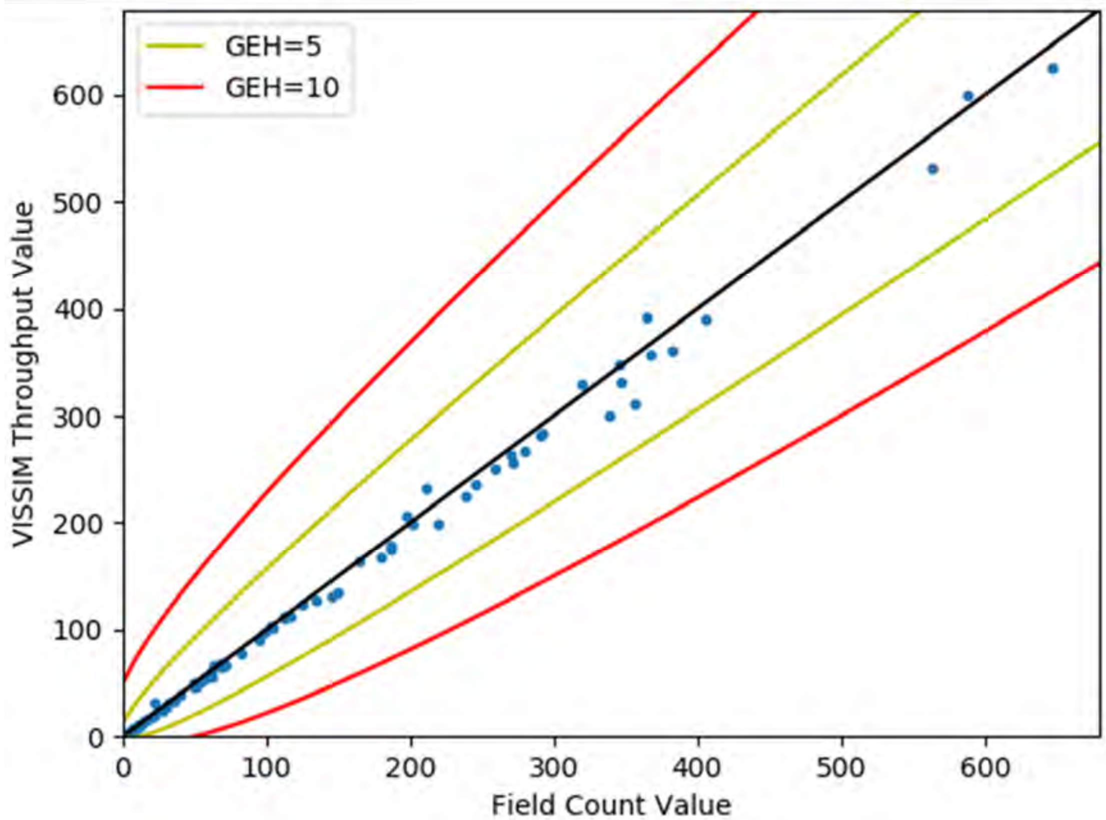

Figure 1: AM GEH Chart

Delay

Delay comparison of Vistro results and VISSIM results are shown in **Table 3**.

Table 3: AM Delay Comparison

Movement	Vistro delay	VISSIM Delay
NB	28.74	52.84
EB	10.37	11.17
SB	12.25	8.39
WB	62.34	248.24

Queuing

Queuing comparison during the AM peak period is shown in **Table 4**. The queues from the model are the average queues during the 15-minute period between 8:00 am and 8:15 am. This time period aligns closely to when the AM queue measurements were recorded.

Table 4: AM Queue Comparison

Movement	Field Measured	VISSIM Queue
NB	1,125	947.6
EB	N/A	147.5
SB	N/A	136.6
WB	1,925	2176.3

Number of Runs Required

The calibration process was conducted with 10 simulation runs (seeds). Based on the overall node delay MOE, the number of runs required was calculated. Based on these values and the values in the PM, the results will be based on 15 simulation runs. While this does not cover all MOEs for all time periods, it covers the majority.

Table 5: Number of Runs Required (AM)

	HOUR 1	HOUR 2	HOUR 3
OVERALL NODE DELAY	10	7	26
SB QUEUE	17	5	27
WB QUEUE	37	14	30

PM CALIBRATION

Volume Calibration (GEH Statistic)

Volume calibration using the GEH calibration criteria for the PM peak period is shown in **Table 2**. All calculated GEH values are shown in Appendix A. **Figure 2** shows a comparison of field and VISSIM volumes. The black line marks where volumes are equal. Points above the line have a higher volume in the VISSIM model; points below the line have a lower volume in the VISSIM model. The yellow line marks where GEH is equal to 5; the red line marks where the GEH equals 10.

Table 6: PM GEH Calibration Criteria Summary

Acceptance Target	Criteria	Number of Measurements	Number unacceptable	Percent acceptable
All Intersection Turn movements greater than 100 vehicles per hour	GEH < 5.0	43	0	100%
All Intersection Turn Movements	GEH < 10.0	81	0	100%

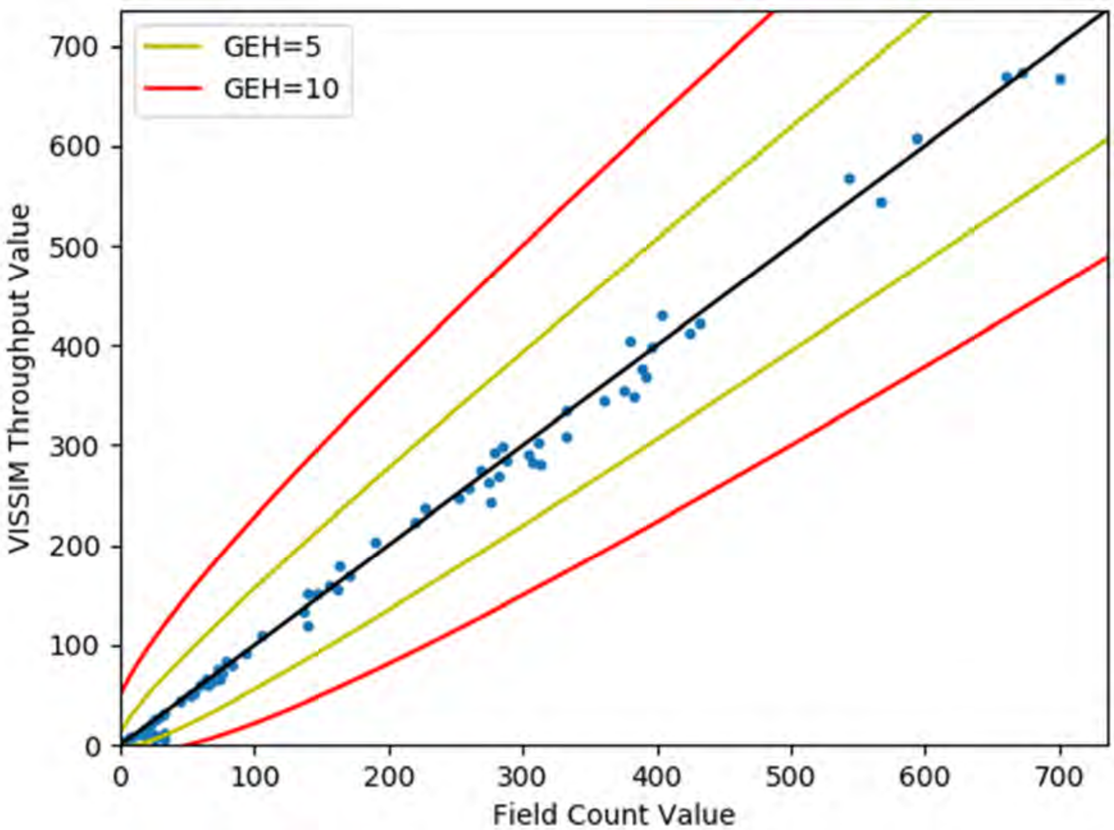

Figure 2: PM GEH Chart

Delay

Delay comparison of SIDRA results and VISSIM results are shown in **Table 7**.

Table 7: PM Delay Comparison

Movement	Vistro delay	VISSIM Delay
NB	26.36	272.23
EB	53.40	165.18
SB	49.58	39.92
WB	18.66	31.41

Queuing

Queuing comparison during the PM peak period is shown in **Table 8** below. The queues from the model are the average queues during the 15-minute period between 5:00 pm and 5:15 pm. This aligns closely to when the PM queue measurements were recorded.

Table 8: PM Queue Comparison

Movement	Field Measured (feet)	VISSIM Queue (feet)
NB	N/A	1222.9
EB	1,325	1779.4
SB	1,900	514.4
WB	1,025	579.1

Number of Runs Required

The calibration process was conducted with 10 simulation runs (seeds). Based on the overall node delay MOE, the number of runs required was calculated and is shown in **Table 9**. Based on these values and the values in the AM, the results will be based on 15 simulation runs. While this does not cover all MOEs for all time periods, it covers the majority.

Table 9: Number of Runs Required (PM)

	HOUR 1	HOUR 2	HOUR 3
OVERALL NODE DELAY	12	32	19
SB QUEUE	6	5	6
WB QUEUE	17	9	55

Appendix A GEH Values per Movement

^ - volume in VISSIM higher than field (only shown for movements with >100 vehicles)

v - volume in VISSIM higher than field (only shown for movements with >100 vehicles)

AM:

Hour -	1	2	3
1-EBL -	1.85	0.21	0.10
1-EBR -	0.37	0.46	0.07v
1-EBT -	0.70v	0.37v	0.12^
1-EBU -	0.43	0.00	0.18
1-NBL -	0.89v	0.49v	0.53^
1-NBR -	0.13	0.51	0.45
1-NBT -	1.15v	0.76v	0.63^
1-NBU -	0.21	0.00	0.21
1-SBL -	0.38	0.24v	1.27v
1-SBR -	0.73	0.42	0.75
1-SBT -	0.41	0.01	1.19v
1-SBU -	0.21	0.60	0.20
1-WBL -	0.50	0.55	0.45
1-WBR -	0.61v	1.37v	0.86v
1-WBT -	0.65v	2.15v	0.83v
1-WBU -	0.06	0.52	0.28
2-EBL -	0.47	0.27	0.02
2-EBR -	0.36	0.28	0.57
2-NBL -	0.05	0.72	0.08
2-NBT -	1.34v	0.85v	0.46^
2-SBR -	0.12	0.50	0.30
2-SBT -	0.89v	0.75v	2.47v
3-EBL -	0.59	0.36	0.01
3-EBR -	0.02	0.05^	0.55v
3-NBL -	0.89v	0.52v	1.36^
3-NBT -	0.50v	0.47v	1.42^
3-SBR -	0.09^	0.20v	0.39
3-SBT -	0.49v	0.10v	0.13v

Node 3 - none
PM:

Hour -	1	2	3
1-EBL -	0.33	0.27	0.20
1-EBR -	0.36v	0.30^	0.50v
1-EBT -	1.13v	0.10^	0.49v
1-EBU -	0.00	0.15	0.30
1-NBL -	1.72v	0.42^	0.98^
1-NBR -	0.82	0.48	0.30
1-NBT -	2.01v	0.80^	0.80^
1-NBU -	0.00	0.00	0.10
1-SBL -	0.87v	1.89v	0.32v
1-SBR -	0.97	0.37	0.09
1-SBT -	1.37v	1.77v	0.56v
1-SBU -	0.00	0.17	0.00
1-WBL -	0.09	0.20	0.29^
1-WBR -	0.63^	0.17^	0.17v
1-WBT -	0.41^	0.22v	0.72v
1-WBU -	0.00	0.49	0.18
2-EBL -	0.11	0.07	0.11
2-EBR -	0.04	0.47	0.17
2-NBL -	3.61	2.02	5.07
2-NBT -	1.01v	1.04^	0.57^
2-SBR -	4.33	3.17	5.81
2-SBT -	0.03^	1.25v	0.37^
3-EBL -	0.47	0.34	0.29
3-EBR -	0.62v	1.33v	0.70v
3-NBL -	0.11v	1.29^	0.89^
3-NBT -	0.17^	1.22^	1.34^
3-SBR -	0.15	0.73	0.38
3-SBT -	0.46v	1.21v	0.53v