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DRAFT MEMORANDUM

DATE: January 21, 2014

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SUBJECT: Bend Central District
Technical Memorandum #5: Multi-Modal Level of Service — P#13162-000-003

The purpose of this memorandum is to build on previous project work that documented existing and future transportation conditions in the Bend Central District. This memo evaluates alternative transportation network options for the district, presenting level of service (LOS) conditions across mode types at designated intersections and segments in the study area. The memo also includes additional guidance regarding safety countermeasures at key locations, design treatment alternatives to support a future multi-modal network, and a discussion of potential future multi-modal demand. The evaluation is intended to help the City of Bend select a preferred transportation network for the Central District.

The Central District is adjacent to Bend's existing downtown core, covering roughly 206 acres and bounded by the Bend Parkway (OR 97) to the west, NE Revere Avenue to the north, NE 4th Street to the east, and the railroad tracks to the south (see Figure 1). The existing transportation network features several major east-west streets that carry traffic to and through the district, but only 3rd Street

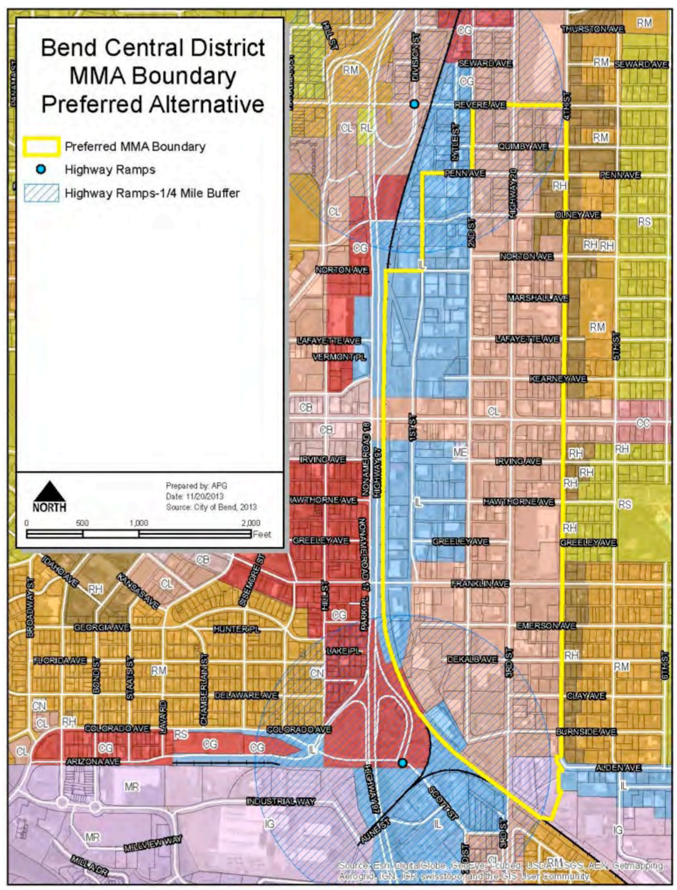

Figure 1: Study Area and Preferred MMA Boundary

provides significant north-south capacity and signals at major cross streets. Future analysis, documented in Technical Memorandum 2, has shown that all signalized intersections on 3rd Street will be operating over capacity in 2030, whether or not land uses are intensified in the district. Previous project work has also documented significant bicycle and pedestrian deficiencies in the district, as well as potential safety issues.

This memo looks at four alternative transportation network improvements, and evaluates them for traffic operations, multimodal LOS, and safety. The four options were first presented in the Bend Central Area Plan (CAP). Three options focus on providing added roadway capacity to the 3rd Street corridor (including parallel roadways), and the fourth is focused on making 3rd Street more multimodal without adding north-south auto capacity in the district. In addition to the four concepts, a no-action alternative is presented. This alternative, like the four "build" alternatives, anticipates more intense land use in the Central District, but leaves infrastructure as it exists today.

The alternatives are as follows:

- No-Build
- 2nd/ 3rd Street Couplet with Enhancements (CAP Option 1)
- Expanded Grid (CAP Option 2)
- 2nd/ 4th Street Couplet with Enhancements (CAP Option 3)
- 3rd Street Boulevard (CAP Option 4)

Summary of Findings

The assessment in this memo showed significant differences in motor vehicle, bicycle, and pedestrian performance among the networks analyzed. The following are key findings from the assessment.

- Motor vehicle LOS analysis shows that several concepts, either grid or couplet, can potentially provide adequate motor vehicle capacity, with intersections operating at LOS D or better. Spreading north-south volume across multiple facilities allows for those facilities, including 3rd Street, to carry fewer motor vehicle lanes, creating opportunities for significant improvements to the bicycle and pedestrian environment.
- For couplet and grid concepts that spread traffic to multiple north-south facilities, design challenges exist at the north end of the study area where multiple facilities must merge back to 3rd Street. North of Revere Avenue, the grid's interface with 4th Street and with Studio Road may require some realignment along with roundabouts or signals. This could impact existing land uses and structures in these areas.

- A new Hawthorne Avenue connection from downtown will be a key low-stress east-west connection that will significantly improve bicycle and pedestrian connectivity through the area. Sidewalks should be completed on Hawthorne through the Central District, along with a bicycle treatment appropriate to the moderate vehicle volumes forecast for Hawthorne.
- 3rd Street is currently signed at 35 mph and likely has even higher prevailing speeds. In alternatives where 3rd Street was modeled with lower speeds, the bicycle LOS benefited significantly from the reduced speeds and some reduced volumes due to routing changes.

Multimodal Level of Service and Intersection Operations

Methodology

For the assessment documented in this memo, all intersection operations and Multimodal Level of Service (MMLOS) analysis was performed within a mesoscopic model environment. The mesoscopic model is a windowed subarea of the Bend Metropolitan Planning Organization (BMPO) travel demand model, enhanced by the project team to include attributes that contribute to Highway Capacity Manual (HCM) analysis. Enhancements include addition of all study area streets, lane geometry, intersection control, and MMLOS inputs (sidewalk widths, buffers, pavement condition, etc.) on a link basis.

The mesoscopic model was calibrated by comparing the base model year (2003) assignment to counts collected at 23 study intersections in and around the study area. Link speeds on the model network were adjusted (by not more than 10 mph) in order to best match the travel patterns and turning movement volumes seen in the counts collected. ODOT staff will be reviewing the model calibration, which could require revisions to the draft analysis conducted to date.

With the base year calibrated, future conditions were analyzed. Future land use assumptions[1] for the Central District were accounted for with a new BMPO model run, performed by ODOT's Transportation Planning Analysis Unit (TPAU) for 2030.[2] Future network alternatives were coded in the mesoscopic model, and then the windowed 2030 trip table, generated from the new BMPO model run, was assigned to each alternative network.

Note that the modified land use and the mesoscopic model approach, which account for intersection congestion and shifts in traffic to alternate routes, can result in intersection operations forecasts that are significantly different from prior studies. This method is a more refined estimate of throughput based on system congestion, as opposed to results directly from the regional travel demand model that are more reflective of corridor demand.

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[1] See Technical Memorandum 4 for detail on future Central District land use assumptions.
[2] See the appendix for plots showing how the motor vehicle traffic assignment for this 2030 land use scenario compares to the base 2030 Metropolitan Transportation Plan (MTP) scenario.

HCM 2000 calculations for intersection operations analysis were performed within the mesoscopic model for study intersections identified for the project. While this method relies upon raw model assigned volumes, it does allow intersection performance to be compared between alternatives and provides a preliminary (i.e., "ballpark") evaluation of the network's ability to serve future demand. Note that full post-processed Synchro analysis of a preferred alternative will be carried out in a later task.

Bicycle and Pedestrian LOS analysis was incorporated within the mesoscopic model environment as well. Analysis of all streets was based on motor vehicle trip table assignments and the varying street cross section characteristics of each network alternative. Note that the methodology used in this memo's assessment did not include the full set of MMLOS variables, but has been modified to include those that can be analyzed within the model environment, such as cross-section elements, traffic volumes, and traffic speeds.[3]

[3] See the appendix to this memorandum for more information on how the Highway Capacity Manual MMLOS calculations were modified.

Future No-Build Assessment

LOS for Autos

With no improvements to 2nd, 3rd, or 4th Streets, north-south travel demand through the Central District would continue to rely on a five-lane 3rd Street, which would provide the only signalized intersections at busy east-west streets such as Revere Avenue, Greenwood Avenue, and Franklin Avenue. This means that high north-south volumes will continue to focus at intersections along 3rd Street rather than being distributed to other north-south streets. HCM analysis shows that high delays (LOS E) will occur at 3rd/Greenwood and 3rd/Franklin, and many unsignalized east-west approaches to 3rd Street will experience LOS F. This condition is characterized by significant delays at intersections, generally with long queues and vehicles waiting multiple signal cycles to proceed through the intersection.

The no-build network also features high delay for side street movements at unsignalized intersections along 3rd Street and Greenwood Avenue. Most of these intersections operate at LOS F for minor movements, indicating the difficulty for vehicles attempting to cross or turn left onto these major streets from local streets. Minor street intersections on Greenwood Avenue generally perform poorly under all alternatives, but many minor street intersections along 3rd Street improve under alternatives where traffic volume is redistributed to 2nd Street and/or 4th Street.

Intersection levels of service in the study area are shown in Figure 2.

LOS for Bicycles

Under no-build conditions, north-south bike lanes continue to be nonexistent in the study area. 3rd Street varies between LOS E and LOS F, and 4th Street varies between LOS A and LOS D. Note that the bike LOS is on a segment level, and does not account for delays for people attempting to ride bikes across busy streets like Greenwood Avenue while traveling low-traffic streets like 4th Street. 2nd Street provides generally good segment LOS, but is not fully connected through the study area. A plot showing bicycle LOS performance is shown in Figure 3.

LOS for Pedestrians

Pedestrian level of service on an unimproved 3rd Street is generally LOS C throughout, while LOS is generally A on 2nd and 4th Streets, with a few exceptions where there are currently sidewalk gaps. As with the bicycle LOS, this analysis was done on a segment basis, and does not consider the delay, comfort, or safety of pedestrians crossing at busy arterials such as Greenwood Avenue. Also, note that the importance of pedestrian LOS may vary by the amount of likely foot traffic, with 3rd Street currently having significantly more destinations that the other north-south streets. Pedestrian LOS through the study area is shown in Figure 4.

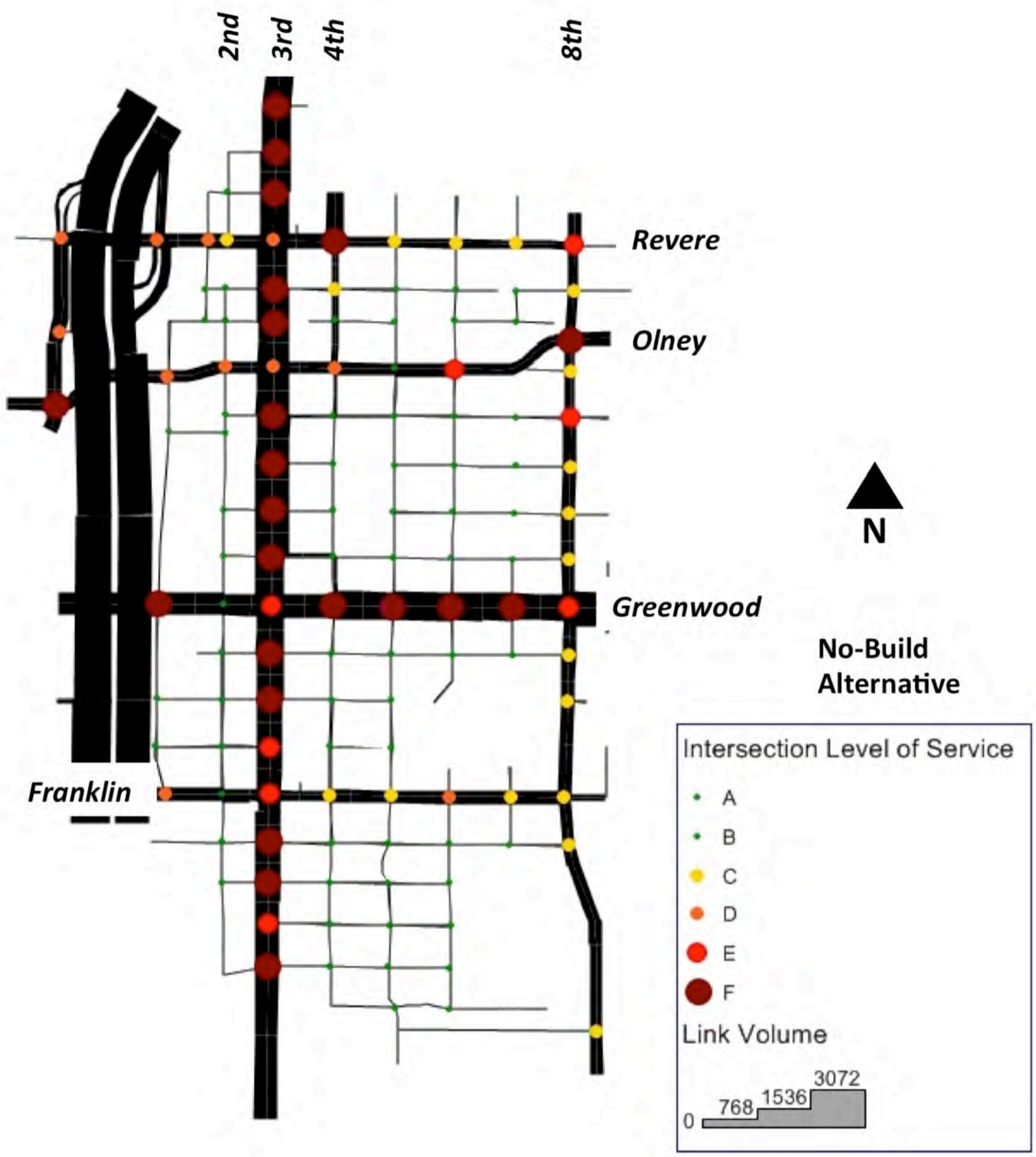

Figure 2: No-Build Intersection LOS

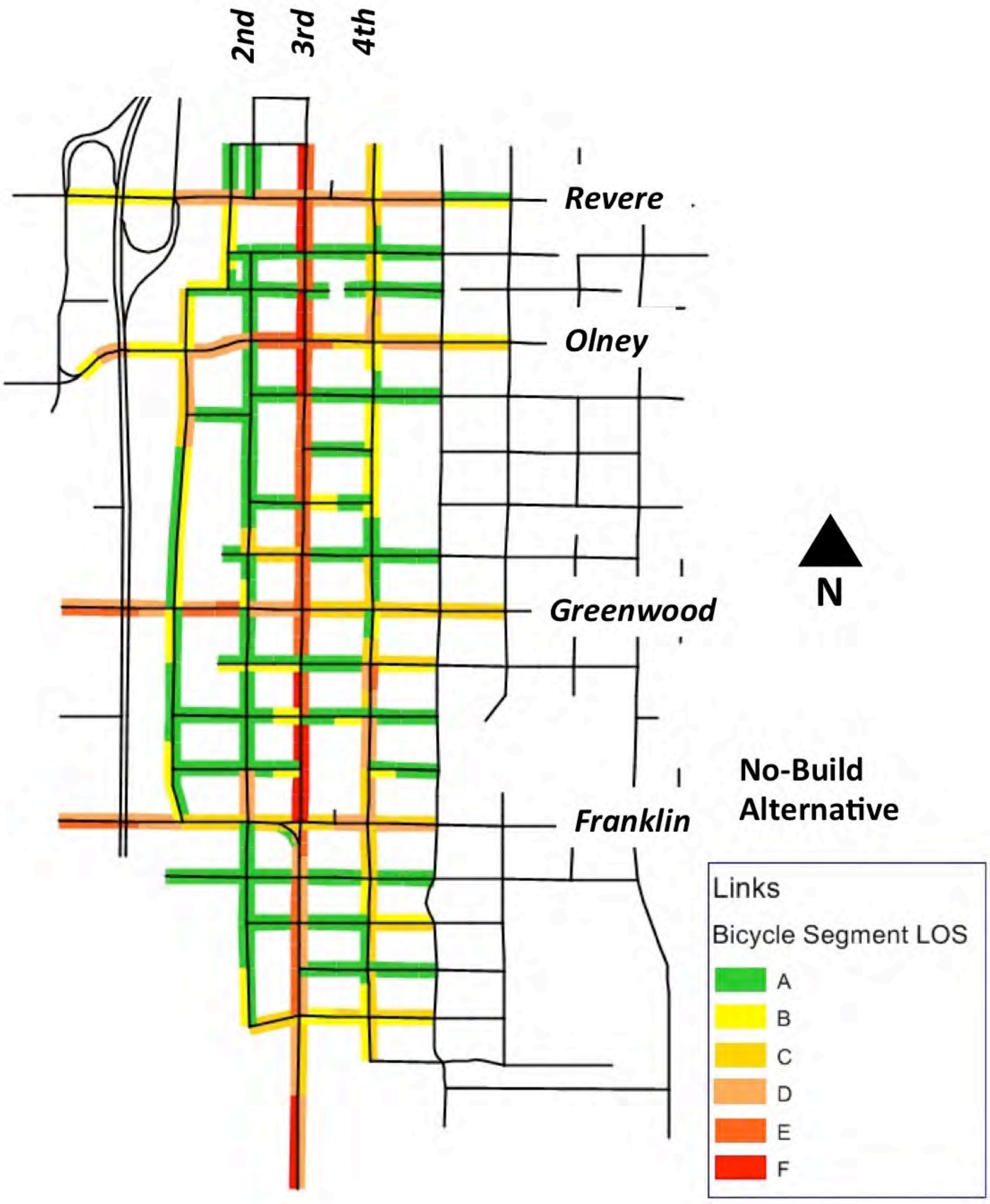

Figure 3: No-Build Bicycle LOS

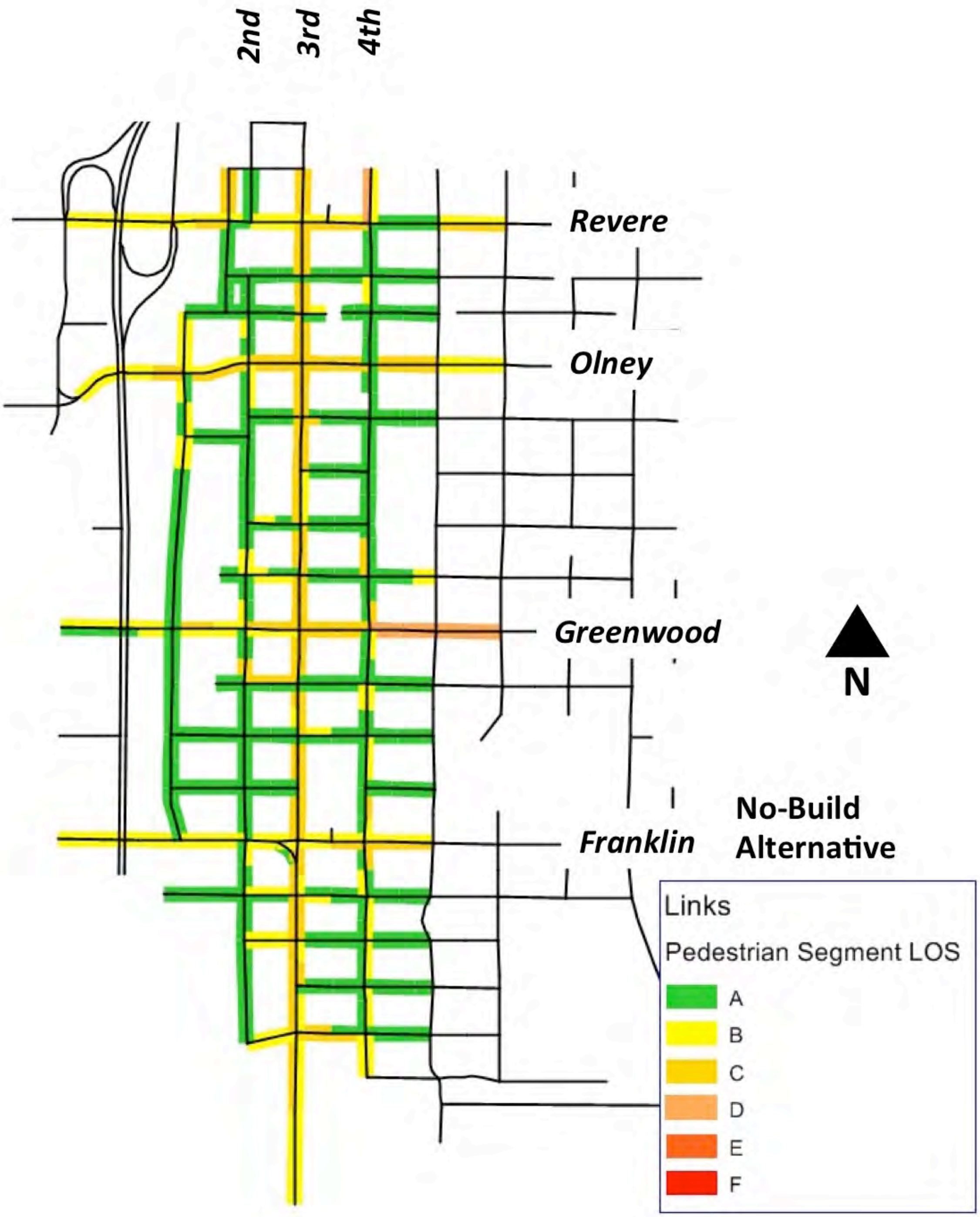

Figure 4: No-Build Pedestrian LOS

Central District Network Alternatives

Four transportation network alternatives were presented in the Central Area Plan (CAP). Three options add north-south roadway capacity while the fourth proposes multimodal improvements without adding auto capacity. The four sections below present intersection, bicycle, and pedestrian LOS findings based on the alternatives' varying network characteristics. Descriptions of the detailed intersection improvements assumed for each scenario are listed in the appendix.

2nd/ 3rd Street Couplet with Enhancements (BCAP Option 1)

Option 1 involves developing a one-way couplet system using 2nd Street as the southbound half of the couplet and converting 3rd Street to the northbound half of the couplet, with each street having two vehicular travel lanes. Both streets would be provided with widened sidewalks and bicycle lanes, narrowed pedestrian crossings of both 2nd and 3rd Streets, management of access to adjacent properties, and potential on-street parking. Some changes could be made to Greenwood and Franklin Avenues at the new 2nd Street intersection approaches.

LOS for Autos

In general, the 2nd/3rd Street couplet operates better than the No-Build option. Signalized intersections that operated at LOS E under no-build conditions, at Greenwood and Franklin Avenues, operate at LOS C under this network alternative. New signalized intersections on 2nd Street operate reasonably well, too, with all providing LOS C or better. Side street delays at stop-controlled 3rd Street intersections operate better under this network as well. Note that this and other couplet network options will likely increase out-of-direction travel to and from land uses along the one-way streets. Vehicle LOS under this alternative is shown in Figure 5.

LOS for Bicycles

Bicycle performance is improved under the 2nd/3rd Street couplet, with conditions on 3rd Street improving to LOS C, while LOS on 2nd Street drops from A to B. Again, it's important to note that this analysis does not account for delays for people attempting to ride bikes across busy streets like Greenwood Avenue. These delays are significantly reduced on 2nd Street with the addition of multiple traffic signals on the corridor. Note that 2nd Street is fully connected through the study area in this network alternative. A plot showing bicycle LOS performance is shown in Figure 6.

LOS for Pedestrians

Pedestrian level of service on a one-way 3rd Street is generally LOS B throughout, improving on the no-build condition due to wider sidewalk and improved buffer from traffic. Performance on 2nd Street is degraded compared to the no-build, generally performing at LOS C due to significantly increased vehicular traffic and minimally wider sidewalks. Pedestrian LOS through the study area is shown in Figure 7.

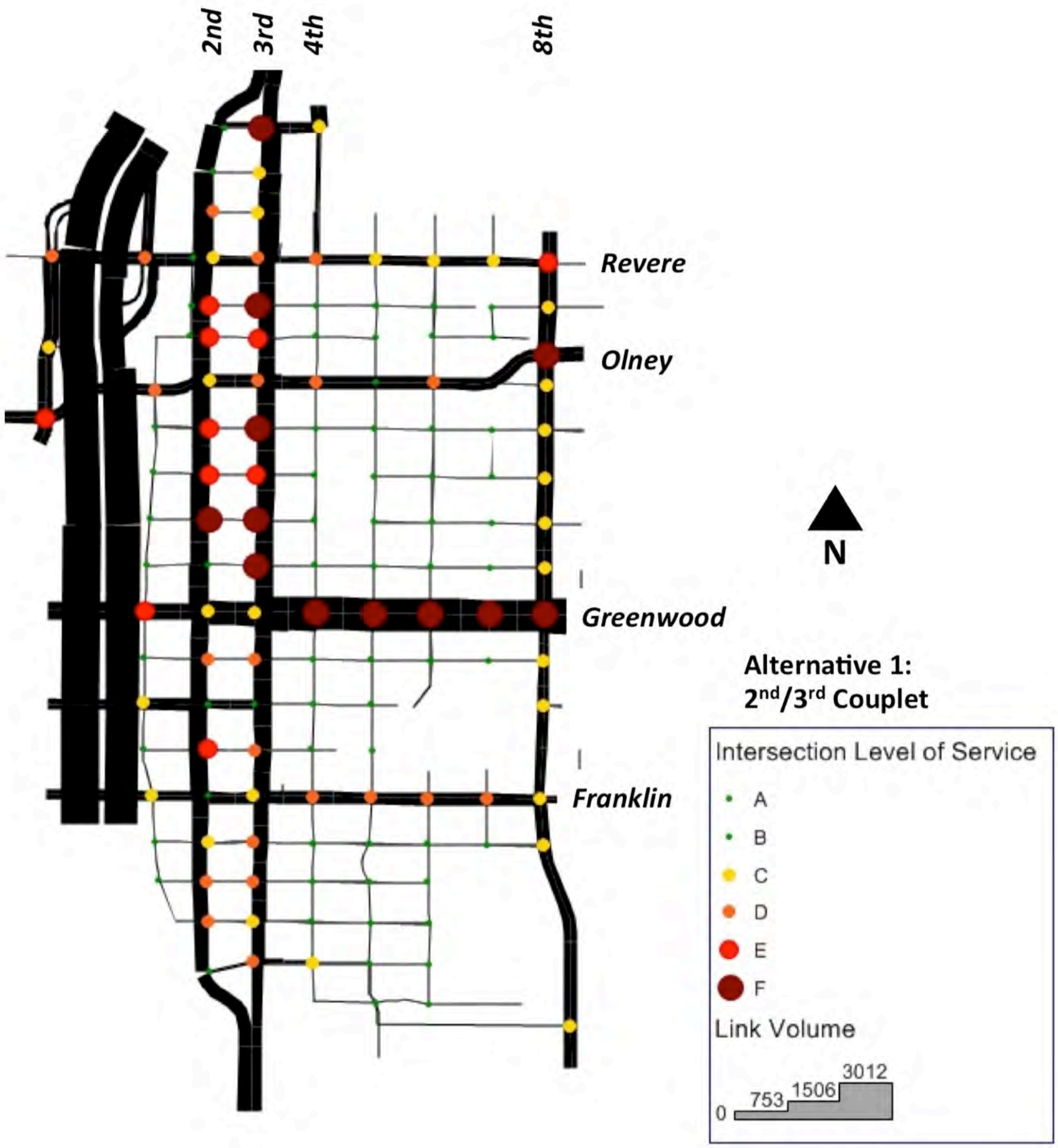

Figure 5: Alternative 1 Intersection LOS

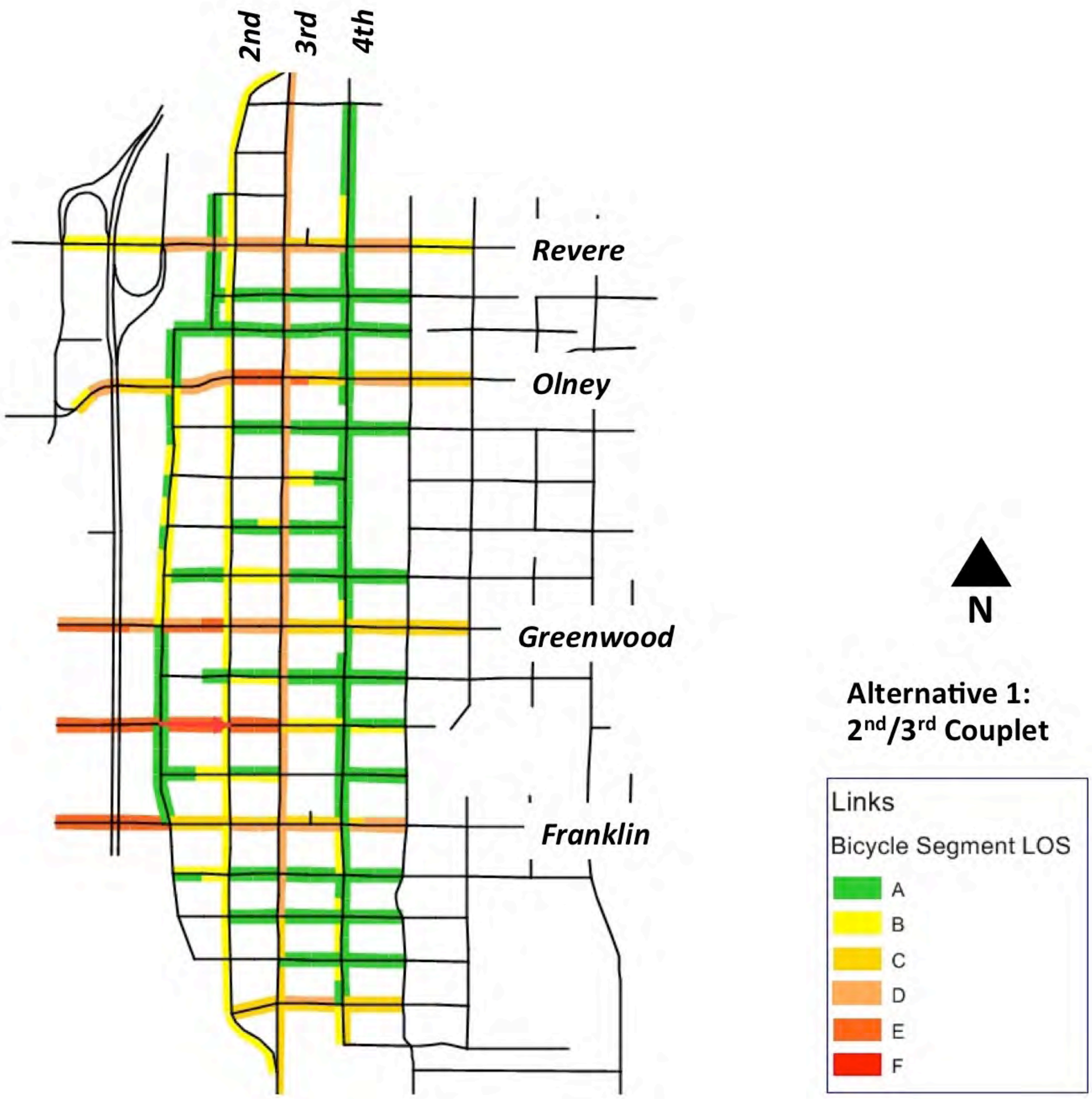

Figure 6: Alternative 1 Bicycle LOS

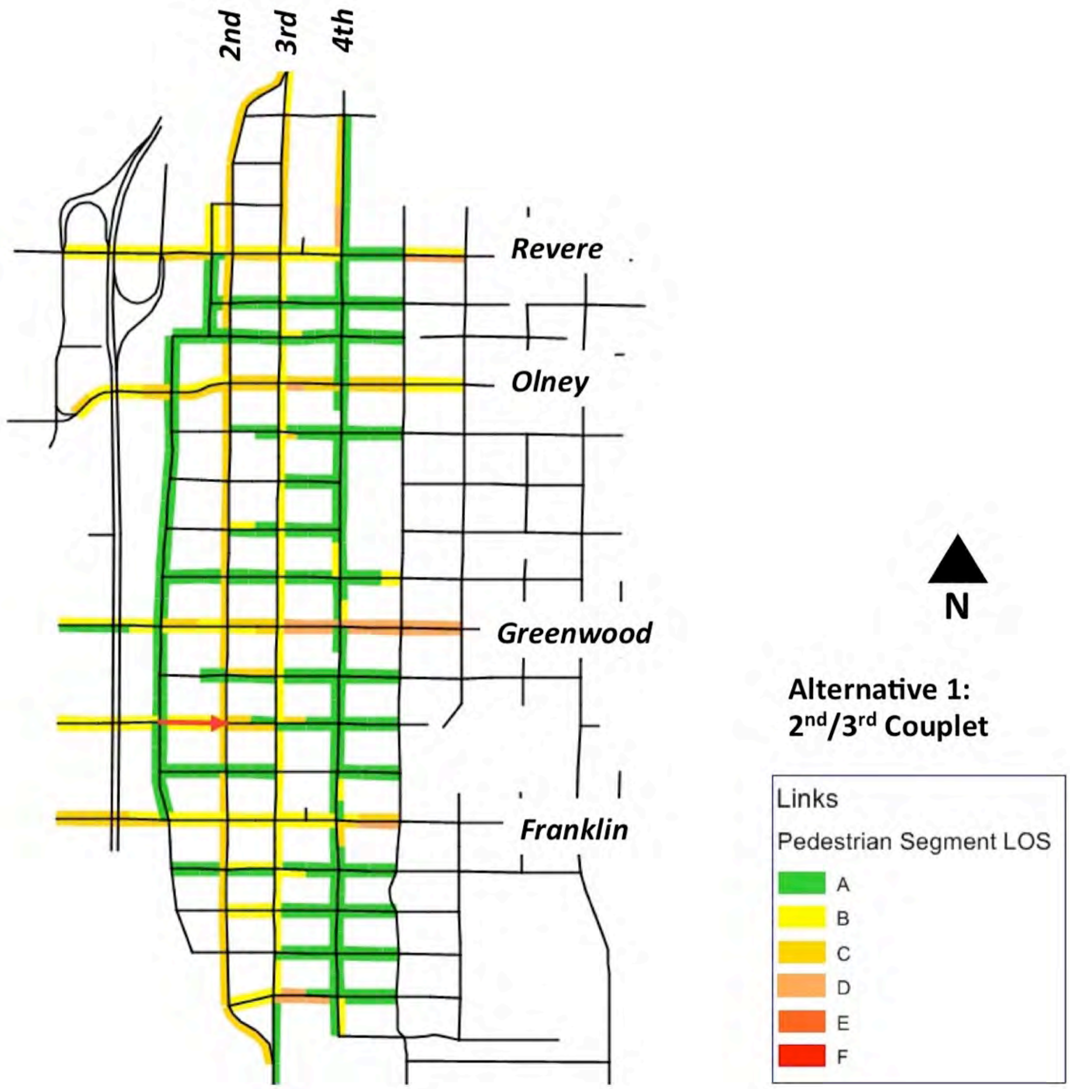

Figure 7: Alternative 1 Pedestrian LOS

Expanded Grid (BCAP Option 2):

This scenario involves the continued use of 3rd Street for two-way traffic operations with development of an expanded grid system throughout the area between roughly Revere Avenue on the north and Burnside Avenue on the south. This expanded grid system could include potential widening on 2nd and 4th Streets with traffic signal control or roundabouts at major intersections. 2nd and 4th Streets would help relieve capacity to 3rd Street by accommodating localized north/south travel demand.

For this analysis, 2nd and 4th Streets are assumed to be two-way streets with one travel lane in each direction with turn pockets and signals at major intersections, but no bicycle or pedestrian improvements. 3rd Street is assumed to be narrowed to a 3-lane cross section. 2nd and 4th Streets are tied back into 3rd Street by two roundabouts north of Revere Avenue, and by a single roundabout south of Burnside Avenue. The model shows that this network is effective at spreading north-south traffic among the three streets: traffic moving between downtown and the corridor tends to use 2nd Street, traffic moving through the corridor tends to use 3rd Street, and traffic moving to and from points east (such as Greenwood Avenue) tends to use 4th Street.

LOS for Autos

The Expanded Grid with a three-lane 3rd Street functions better than the no-build scenario in terms of intersection operations. All signalized intersections on the three-street north-south corridor operate at LOS D or better, and all minor street approaches are at least LOS E.. Intersection levels of service in the study area are shown in Figure 8.

LOS for Bicycles

This alternative included no bike lanes on 2nd Street or 4th Street, instead retaining the existing on-street parking and providing intersection control upgrades at key intersections. Bicycles would share the roadway with vehicles on those streets. The network concept, as analyzed, relies on new bike lanes on 3rd Street to provide north-south movement. As a result, 2nd and 4th Streets perform poorly for bicycles, mostly operating at LOS E. 3rd Street performs at LOS D, as the bike lanes assumed are just five feet wide and nestled between on-street parking and a heavily-used travel lane. Bicycle LOS throughout the study area is shown in Figure 9.

LOS for Pedestrians

Pedestrian level of service throughout all three facilities is generally good, with 3rd Street varying between LOS A and LOS B, and 2nd and 4th Streets mostly varying between LOS B and LOS C. The 3rd Street pedestrian environment benefits significantly from this scenario, with wider sidewalks, a planted buffer, and on-street parking and a bike lane providing additional buffer from traffic. Pedestrian facilities on 2nd and 4th Streets are assumed not to be improved compared to existing facilities. Pedestrian LOS through the study area is shown in Figure 10.

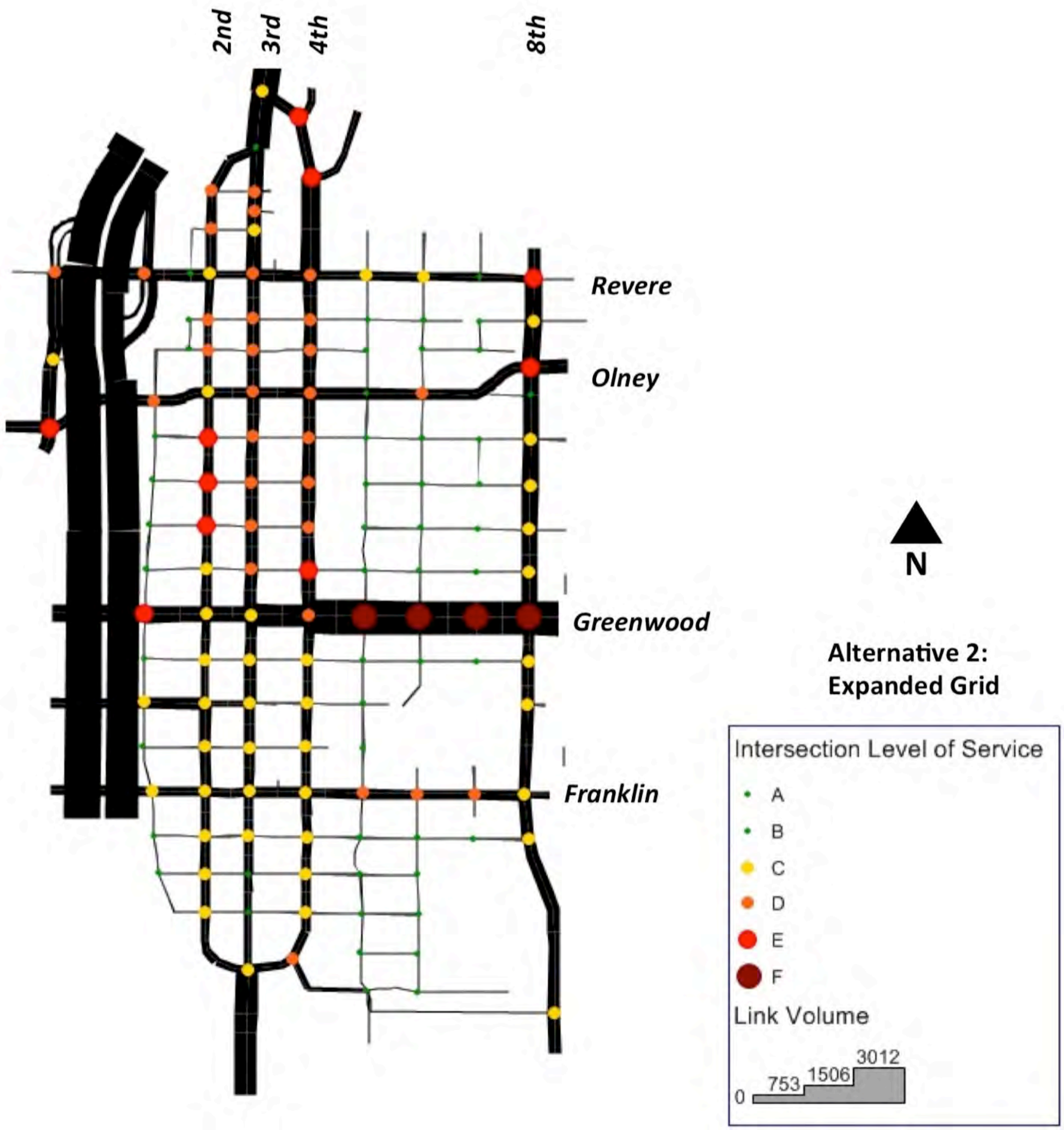

Figure 8: Alternative 2 Intersection LOS

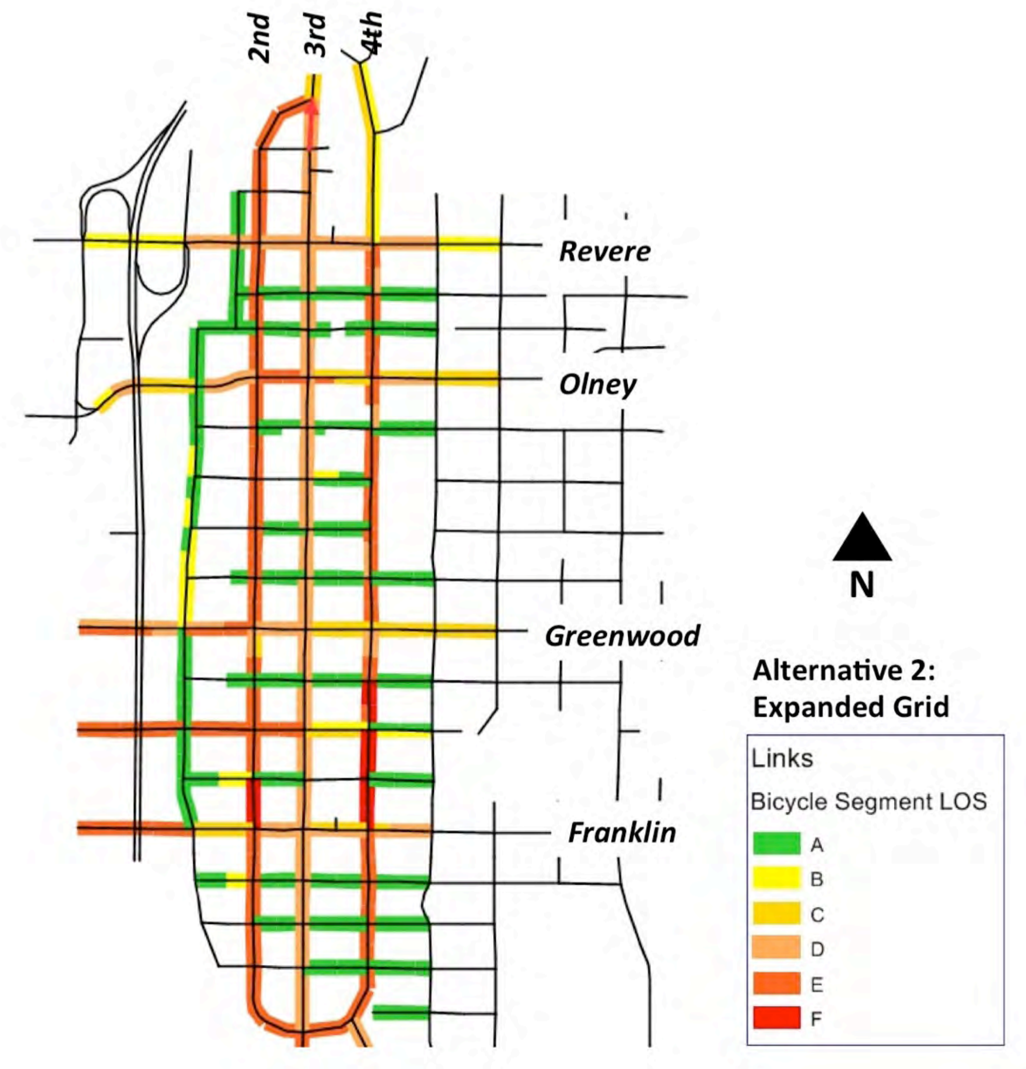

Figure 9: Alternative 2 Bicycle LOS

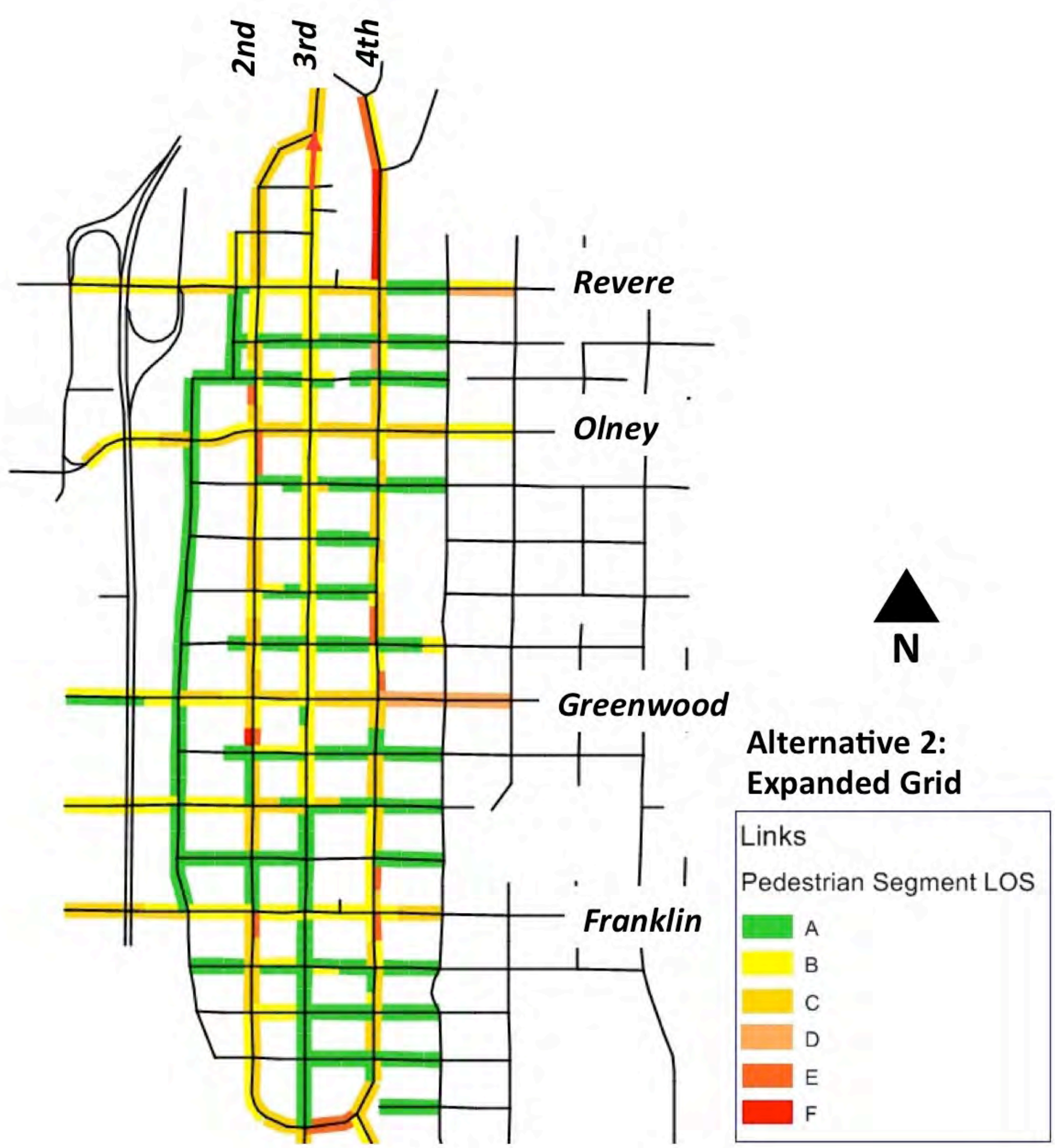

Figure 10: Alternative 2 Pedestrian LOS

2nd / 4th Street Couplet with Enhancements (BCAP Option 3):

Option 3 would entail development of a one-way couplet system using 2nd Street for southbound traffic and 4th Street for northbound traffic, with each street carrying two lanes of traffic. Two-way traffic would be maintained on 3rd Street between the two legs of the couplet, but the existing cross-section could be narrowed to accommodate widened sidewalks, bicycle lanes, and potentially on-street parking. This analysis assumes that 3rd Street is narrowed to three lanes and provides all of these improved multi-modal accommodations. Also, the prevailing speed on 3rd Street is assumed to be 25 mph, as the 2nd/4th Street couplet would be designed to carry heavier traffic loads. Signals would be added at key intersections along 2nd and 4th Streets.

LOS for Autos

Motor vehicle operations are generally improved in this alternative compared to the no-build option. Signalized intersections on the three facilities operate at LOS D or better, with the exception of the new intersection where the 2nd/4th Street couplet joins back up with 3rd Street north of Revere Avenue, near NE Underwood. Some unsignalized approaches to 2nd Street operate at LOS E. Note that this and other couplet network options will likely increase out-of-direction travel to and from land uses along the one-way streets. Intersection levels of service in the study area are shown in Figure 11.

LOS for Bicycles

Similar to the Expanded Grid (Alternative 2), the 2nd/4th Street Couplet includes no bike lanes on 2nd Street or 4th Street, relying instead on 3rd Street to provide the major north-south bike facility. 2nd and 4th Streets retain on-street parking on one side and widened sidewalks on both sides, also providing intersection control upgrades at key intersections. As with the Expanded Grid, 2nd and 4th Streets perform poorly for bicycles, mostly operating at LOS E. 3rd Street, at LOS B, performs better than it does in the Expanded Grid alternative, as traffic speeds and volumes are lower in the model. Bicycle LOS throughout the study area is shown in Figure 12.

LOS for Pedestrians

Pedestrian level of service throughout all three facilities is much improved compared to no-build conditions, with 3rd Street mostly performing at LOS A, and 2nd and 4th Streets mostly varying between LOS B and LOS C. This pedestrian LOS performance is similar to that of the Expanded Grid, with slightly better conditions on 3rd Street due to lower vehicular traffic speeds and volumes. Pedestrian LOS through the study area is shown in Figure 13.

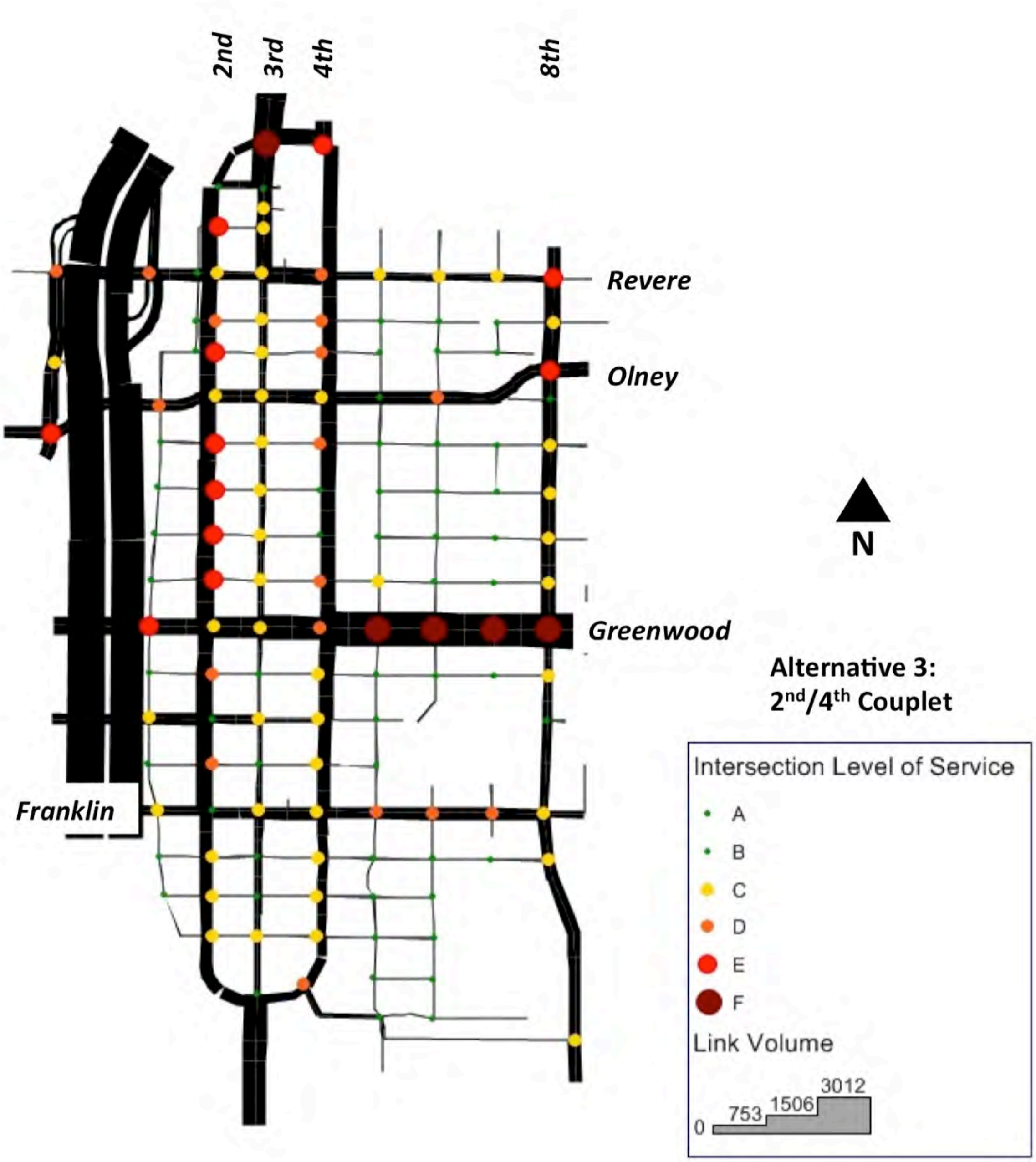

Figure 11: Alternative 3 Intersection LOS

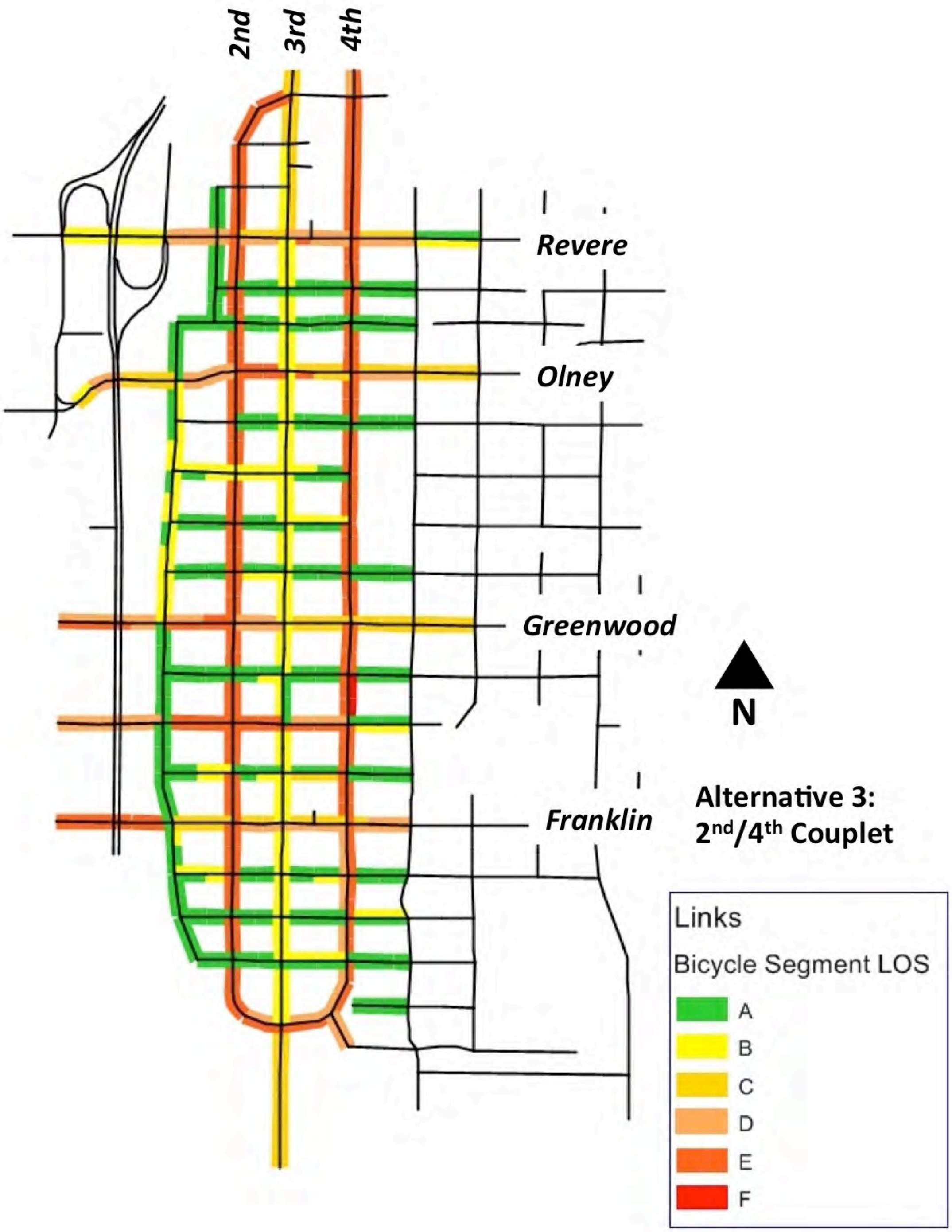

Figure 12: Alternative 3 Bicycle LOS

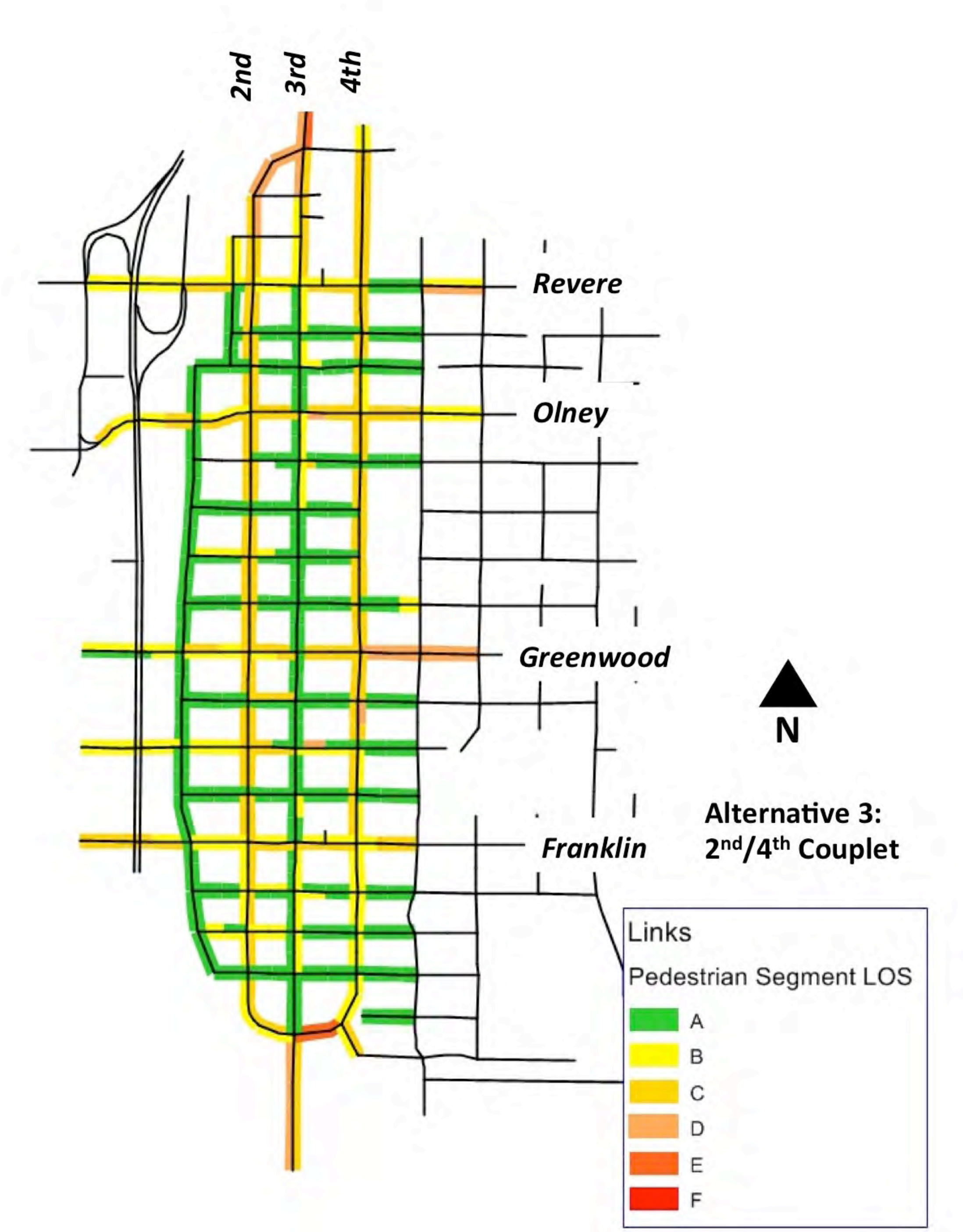

Figure 13: Alternative 3 Pedestrian LOS

3rd Street Boulevard (BCAP Option 4):

A fourth option involves the development of a boulevard along 3rd Street with an emphasis on widening sidewalks, adding enhanced streetscape, and adding bicycle lanes. North/south traffic movement would continue to use this facility with some minor widening and right-of-way acquisition to accommodate the bicycle lanes and sidewalks. Existing lane widths would be reduced to minimize the needed right-of-way. This option maintains similar corridor capacity to the no-build condition, but does add some capacity improvements in the form of turn lanes at intersections such as 3rd/Greenwood and 3rd/Franklin. For the analysis presented here, it is assumed that the street cross section is widened by about ten feet, and travel lanes narrowed, to accommodate new streetscape and bike lanes.

LOS for Autos

While the 3rd Street Boulevard network leaves 2nd and 4th Streets unchanged and offers the same number of travel lanes on 3rd Street, operations at signalized intersections are generally improved over the no-build option. The intersections at 3rd/Revere and 3rd/Olney operate at LOS D, similar to no-build, and the intersections at 3rd/Greenwood and 3rd/Franklin improve to LOS C. This improvement is based on some widening at the intersection with new right turn pockets on some approaches. However, the 3rd Street Boulevard option features high delay for side street movements at unsignalized intersections along 3rd Street and Greenwood Avenue, similar to the no-build scenario. Intersection levels of service in the study area are shown in Figure 14.

LOS for Bicycles

Under the 3rd Street Boulevard alternative, north-south bike lanes are provided, resulting in a significantly improved LOS of B. 2nd and 4th Streets mostly perform at Bike LOS A, but again note that the analysis is provided on a segment level, and does not account for delay and comfort of people riding bikes across busy streets while traveling on low-traffic streets. A plot showing bicycle LOS performance is shown in Figure 15

LOS for Pedestrians

Pedestrian level of service on a 3rd Street boulevard is generally LOS C throughout, while LOS is generally A on 2nd and 4th Streets. As with the bicycle LOS, this analysis was done on a segment basis, and does not consider the delay, comfort, or safety of pedestrians crossing at busy arterials such as Greenwood Avenue. Pedestrian LOS under the Boulevard alternative does not vary significantly from the no-build condition, as the cross-section change provides minimal sidewalk enhancement and no on-street parking to provide a buffer from traffic. Pedestrian LOS through the study area is shown in Figure 16.

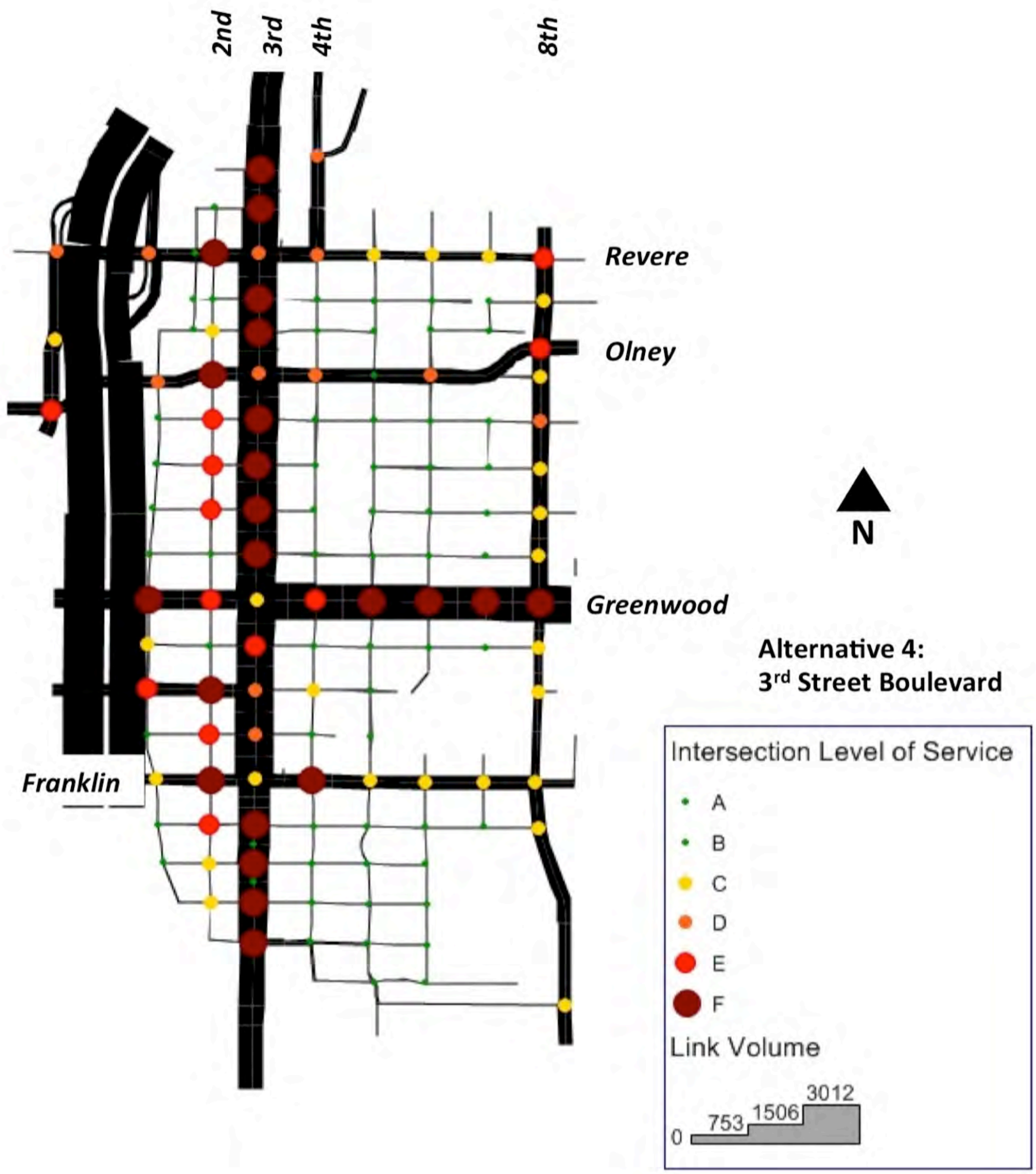

Figure 14: Alternative 4 Intersection LOS

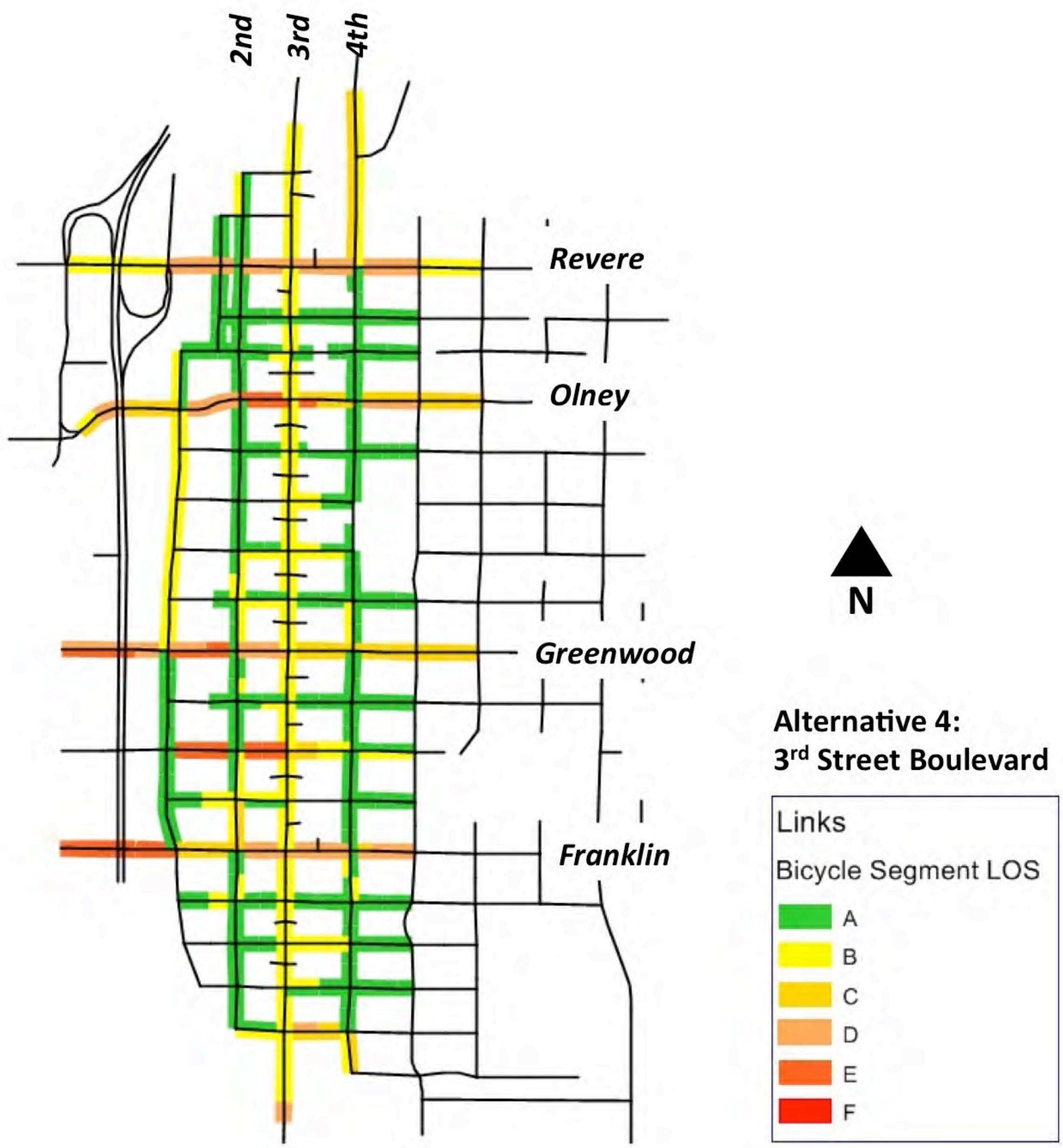

Figure 15: Alternative 4 Bicycle LOS

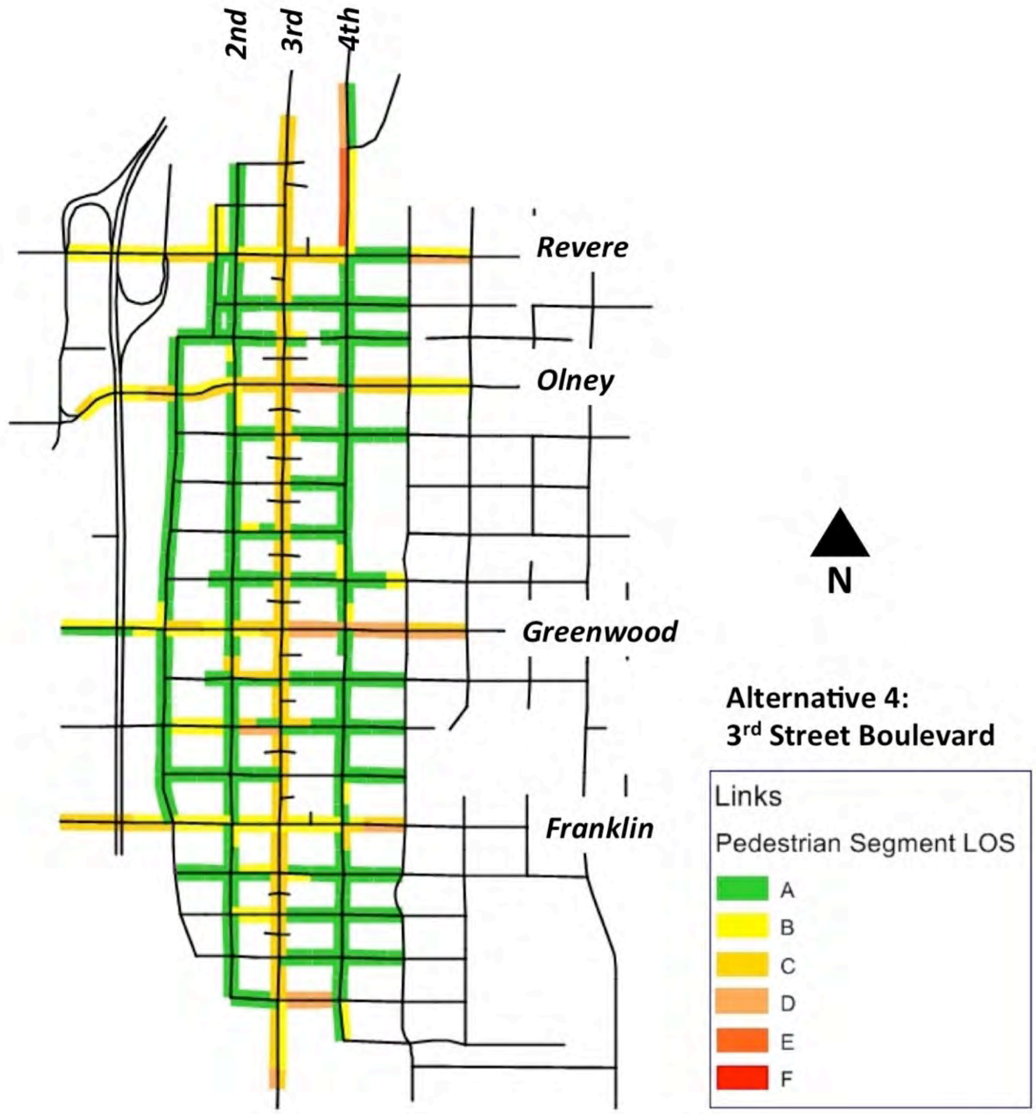

Figure 16: Alternative 4 Pedestrian LOS

Multi-Modal Design Treatment Options

This section builds upon the MMLOS analysis provided in the previous section to provide a qualitative assessment of street and intersection design treatments to improve multiple travel within the Central District. It first summarizes the street design assumptions and MMLOS results presented above for each alternative relative to No-Build conditions. Based on this analysis, this section provides a toolbox of street design features and identifies locations where these improvements could be applied within the district.

Interpretation of MMLOS Results

Figure 17 summarizes the key features of each of the four Central Area Plan alternatives relative to No-Build conditions. Attributes such as motor vehicle speed and the number of vehicle lanes help define the types of design features necessary to establish pedestrian and bicycle travel as attractive and comfortable modes within the District.

Figure 17 Summary of Existing and Assumed Alternative Transportation Networks

	No-Build	Alt. 1: 2nd/3rd Street Couplet	Alt. 2: Expanded Grid	Alt. 3: 2nd/4th Street Couplet	Alt. 4: 3rd Street Boulevard
3rd Street	▪ 4 motor vehicle lanes with center-turn lane ▪ Signed for 35 mph ▪ No bike facilities ▪ Narrow sidewalks with no buffer ▪ No on-street parking	▪ Converted to one-way NB with two motor vehicle lanes ▪ 35 mph assumed ▪ 6-foot bike lane with 3-foot buffer ▪ Widened sidewalks (8-foot) ▪ On-street parking; ▪ Narrowed crossing distance	▪ 3 motor vehicle lanes ▪ 30 mph assumed ▪ 5-foot bike lanes ▪ Widened sidewalks, with planted buffer ▪ On-street parking; ▪ Narrowed crossing distance	▪ 3 motor vehicle lanes ▪ 25 mph speed assumed ▪ Bike lanes ▪ Widened sidewalks ▪ Potential on-street parking	▪ Maintains 4-lane cross-section, but reduces lane widths ▪ 35 mph assumed ▪ Widens right-of-way to add bicycle lanes and widened sidewalks ▪ No on-street parking ▪ Streetscape enhancement
2nd Street	▪ 2 motor vehicle lanes ▪ No bike facilities ▪ Partial sidewalks	▪ Converted to one-way SB (2 lanes) ▪ 35 mph assumed ▪ SB bike lane ▪ Widened sidewalks ▪ SB transit will need to run on either 2nd or 4th	▪ No bike lanes ▪ Potential widening to expand motor vehicle capacity (2 lanes with turn lanes at key locations) ▪ 30 mph assumed ▪ Retains existing on-street parking ▪ Intersection upgrades	▪ No bike lanes ▪ 35 mph assumed ▪ Retain on-street parking on one side ▪ Widened sidewalks on both sides ▪ Intersection upgrades	No change
4th Street	▪ 2 motor vehicle lanes ▪ No bike facilities ▪ Partial sidewalks	▪ No change			

Note: NB = Northbound; SB = Southbound

Figure 18 provides a generalized assessment of the segment-level MMLOS analysis results presented in the previous section for each north-south street. This assessment helps identify the need for street design treatments to improve multimodal travel conditions. Each cell in the table is color-coded to illustrate improvement or degradation relative to No-Build. Each of the alternatives generally improves motor vehicle operations relative to No-Build. Bicycle and pedestrian LOS varies by alternative as follows:

- Alternative 1 improves bicycle and pedestrian LOS on 3rd and 4th but causes some degradation on 2nd (due to increased traffic volumes).
- Alternatives 2 and 3 improve bicycle and pedestrian LOS on 3rd Street, but degrade bicycle and pedestrian LOS significantly on 2nd and 4th Streets.
- Alternative 4 provides the best bicycle LOS on all three streets, but does not improve pedestrian LOS on 3rd Street from No-Build conditions.

Figure 18 Generalized LOS by Mode Relative to No-Build

Mode / Street	No-Build	Alt. 1: 2nd/3rd Street Couplet	Alt. 2: Expanded Grid	Alt. 3: 2nd/4th Street Couplet	Alt. 4: 3rd Street Boulevard
MOTOR VEHICLE					
3rd, 2nd, and 4th Streets	High north-south volumes on 3rd Street, with some diversion to 4th Street	Generally improved relative to No-Build	Generally improved relative to No-Build	Generally improved relative to No-Build	Generally improved relative to No-Build
BICYCLE					
3rd Street	E-F	C	D	B	B
2nd Street	A-B	B	E	E	A
4th Street	A-D	A-B	E	E	A
PEDESTRIAN					
3rd Street	C	B	A-B	A	C
2nd Street	A	C	B-C	B-C	A
4th Street	A-B	A	B-C	B-C	A

Note: Shading indicates change relative to No-Build (green = improvement; red = degradation). Note: To facilitate segment-level comparisons between scenarios, Appendix A presents the bicycle and pedestrian LOS plots for No-Build and each alternative on a single page

Multimodal Design Toolbox

The MMLOS analysis presented above (both generalized results and at the segment level), along with additional assessment of existing multimodal conditions, was used to identify the types of street and intersection design treatments needed to improve safety and comfort for all travel modes in each alternative. Table 1 provides a multimodal design toolbox describing these treatments and where they may be applied on 2nd, 3rd, and 4th Streets as well as east-west streets within the District.

A set of accompanying maps identifies both general and specific locations where these treatments are suggested for application. Figure 19 depicts general improvements in the Central District (regardless of alternative) while Figure 20, Figure 21, Figure 22, and Figure 23 illustrate improvements for alternatives 1, 2, 3, and 4, respectively.

A more detailed discussion of specific elements is provided below. The appendix to this memorandum contains an expanded matrix with photos for each treatment.

Streetscape Improvements

Streetscape improvements can include street trees or other vegetation; pedestrian amenities or furnishings such as benches, pedestrian-oriented lighting or public art; widening of sidewalks; and use of vegetated stormwater facilities within the right of way. Streetscape improvements do more than simply improve the aesthetics of a street; they separate pedestrians from moving vehicles and provide pedestrians with a sense of psychological and visual comfort. An emphasis on 3rd Street is a priority, however 2nd and 4th Streets would also greatly benefit and streetscape improvements are recommended throughout the district.

Access Management

Much of the retail development along 3rd Street has its own driveway, resulting in a multitude of driveways along the corridor. This form of development creates a challenging pedestrian and bicycling environment because each new driveway represents a new conflict point. Managing access will help create a safer and less stressful walking and biking environment.

Traffic calming

Traffic calming elements should be considered for residential east-west streets east of 3rd Street (including 4th Street in some alternatives). These elements include speed humps, mini traffic circles, and lower signed speeds; these features should also be considered in and around the retail corridors. Streetscape improvements, narrowed vehicle travel lanes (maximum of 11-feet), on-street parking, and curb extensions also help slow vehicle travel speeds.

Pedestrian

No-Build Pedestrian level-of-service on 3rd Street is generally LOS C, and LOS C or D on Greenwood and Olney Avenues. Recommended improvements to improve pedestrian conditions and safety along 3rd Street and other streets throughout the district include widening sidewalks, which in many cases lack sufficient clearance for wheelchairs and other mobility devices, and providing accessibility (curb) ramps at all intersections and driveways. Corner curb radii can be tightened at many intersections to prevent excessive turning speeds, expand the pedestrian area, and reduce pedestrian crossing distances (see #28 in the design toolbox – Table 1). Curb bulbouts and pedestrian-scale wayfinding signage are other elements that will help make pedestrians more visible to other road users and ensure a safer and at times faster walking trip.

As described in the previous section, the level-of-service analyses reflect segment-level conditions but do not account for the difficulty of crossing the major arterial streets in the District. Signalized intersection spacing along 3rd Street in the core of the District is over a quarter-mile between Franklin and Greenwood Avenues, and over a third-mile between Greenwood and Olney Avenues. There are no designated crossings west of 3rd Street on Olney, Greenwood, or Franklin Avenues, and signalized intersection spacing on Greenwood Avenue is over 0.4 miles between 3rd and 8th Streets. These distances require lengthy out-of-direction travel to reach a traffic signal and crosswalk, and some users cross at unprotected crossings.

In addition, 3rd Street, Greenwood Avenue (west of 3rd), and Franklin Avenue are current transit streets and Greenwood Avenue east of 3rd Street is a proposed future transit street. Bus riders require crossings to access the stop in the opposite direction. Notwithstanding additional signalization that is included in various alternatives, placing high-visibility pedestrian crossings at intermediate intersections or high-demand mid-block locations between signals would provide safe and convenient crossing locations for pedestrians, bicyclists, and transit riders. Raised crosswalks, Rectangular Rapid Flash Beacons (RRFB), and overhead or in-pavement indicators are examples of treatments that should be used to maximize visibility of these crossings, particularly on wide, higher-speed streets such as 3rd Street and Greenwood Avenue. On wider, multi-lane streets such as 3rd Street in alternatives 2, 3, and 4 and on Greenwood Avenue, a pedestrian refuge island can be provided in conjunction with a street median or turn lanes, reducing the pedestrian crossing distance.

This photo of 3rd Street at Franklin (looking north) illustrates the need for streetscape improvements, access management (fewer driveways), wider sidewalks, and more frequent designated pedestrian crossings.

Source: SERA

Bicycle

Most bicycle improvements are recommended along 3rd Street, but in some alternatives additional improvements on 2nd or 4th are recommended, such as connections from the existing bike network. Basic striped bike lanes provide cyclists with dedicated right-of-way but a minimal degree of separation from other traffic. Depending on adjacent traffic speeds, higher degrees of separation are desirable, such as a buffer between the bike and travel lanes (e.g., Alternative 1). Such separation is desirable in other alternatives as well, particularly those that assume a speed limit of 35 mph. Other infrastructure elements, such as bike boxes and left-turn bike boxes at intersections, improve visibility and alert drivers to the presence of cyclists. This is particularly critical at intersections with high turn movements. Wayfinding and "Share the Road" signage may also help develop a sense of caution among all road users.

Transit

All four alternatives assume improved transit operations and comfort. Bus bulbouts located at bus stops will help improve visibility for both bus drivers and passengers waiting to board and also enhance the attractiveness/comfort of transit use. Pedestrians and other road users will see a clear indication that riding transit is easy, pleasant, and accessible. Shelters should also be provided at moderate-to-high volume stops, including transit and walking information; shelter capacity should be increased at projected high-demand stops.

As described above, pedestrian crossings are needed to provide access between transit stops in either direction, which on 3rd Street are frequently located between signalized intersections; locating stops either at the near or far side of intersections is typically preferred, except where high-demand activity centers are served. Crossings are also needed on Franklin and Greenwood, and along 2nd Street in Alternative 1.

A particular conflict point for transit passengers exists on the eastern half of Hawthorne Avenue (between 3rd and 4th Streets), which serves as an on-street transit center. Passengers cross Hawthorne mid-block to transfer between bus routes, while vehicles may egress the Safeway parking lot eastbound onto Hawthorne and have limited visibility of pedestrians crossing the street between buses. Right-turns onto eastbound Hawthorne could be prohibited at this parking lot egress and one or more raised, high-visibility crossings could be installed across the eastern portion of this block to provide designated crossing locations.

Parking

Attractive walking and shopping districts frequently increase demand for parking. On-street parking not only benefits businesses but serves as an additional buffer for pedestrians. Under some of the alternatives, adding parking may be appropriate on 2nd, 3rd, and/or 4th Streets. Parking spaces can also be converted into bicycle parking corrals.

Signalization

Signal timing on high-use pedestrian and bicycle corridors complements other corridor enhancements. Signal timing can be managed to manage traffic speeds at the target level, particularly on one-way streets. Signals should provide adequate time for pedestrians to cross the street; leading pedestrian and bicycle signals can provide a brief head start at high pedestrian and/or bicycle volume intersections to increase visibility and help prevent turning conflicts. Excessively long traffic signal cycles should be avoided to ensure convenient east-west connections across 2nd, 3rd, and/or 4th Streets. Providing additional signalized intersections would help distribute local traffic away from the major east-west arterials into the broader street network.

Additional Grid Connections

The bicycle and pedestrian level-of-service analyses illustrate the marginal to poor conditions for existing crossings under the BNSF railroad tracks and Bend Parkway on the major east-west streets through the District (see photos below). Given the likely expense and difficulty of improving existing facilities, the City of Bend Transportation System Plan (TSP) and Central Area Plan include a project to develop an under-crossing (or potentially over-crossing) of the tracks and the Bend Parkway at Hawthorne Avenue. Such a crossing could provide a low-volume auto, bicycle, and/or pedestrian connection between downtown and the core of the District.

Franklin east of underpass
Source: SERA

Greenwood, from overpass, looking east
Source: SERA

Table 1 Summary of Multimodal Design Treatments

Type	Map ID	Design Treatment and Brief Description	Alt 1: 2nd/3rd Street Couplet	Alt 2: Expanded Grid	Alt 3: 2nd/4th Street Couplet	Alt 4: 3rd Street Boulevard
	1	**Pedestrian safety islands.** Recommended to limit pedestrian exposure in intersections or crossings with 3+ traffic lanes.	✓	✓ (2nd/3rd)	✓ (3rd)	✓ (3rd)
	2	**Sidewalk expansion.** Provide sidewalk capacity to comfortably meet pedestrian demand.	✓ (2nd/3rd)	✓ (3rd)	✓ (2nd, 3rd, 4th)	✓ (3rd)
	3	**Planted buffer.** Provide separation from motor vehicle traffic.	✓ (2nd/3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)
	4	**Bulbouts/curb extensions.** Visually and physically narrow roadway. Often used in conjunction with on-street parking.	✓ (3rd)	✓ (3rd)	✓ (3rd)	
	5	**Highly visible, mid-block crosswalk.** Meet high demand for pedestrian crossings between intersections.	✓ (2nd/3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)
	6	**Raised crosswalks.** Visually and/or physically emphasize crossing locations.	✓ (2nd/3rd)	✓	✓ (2nd, 4th)	✓ (3rd)
	7	**Accessibility ramps.** Required at all intersections & mid-block crossings.	✓	✓	✓	✓
	8	**Rectangular Rapid Flash Beacon (RRFB).** Increase visibility of high-demand unsignalized ped. crossings of higher-speed, multi-lane roadways, e.g., 3rd, Greenwood, etc.	✓	✓ (3rd)	✓	✓ (3rd)
	9	**Bike lane (no buffer).** Standard bike lane with no additional separation from vehicle travel lanes (appropriate for moderate-volume roadways and vehicle speeds of approx. 25-30 mph).		✓ (Acceptable on 3rd)	✓ (Acceptable on 3rd)	Not desirable on 3rd Street with 35 mph speed
	10	**Buffered bike lane (e.g., Thermoplastic, Planters, Striping).** Provide additional separation/protection for cyclists on higher-volume and/or speed roadways, e.g., ≥ 30 mph.	✓ (Recommended on 2nd/3rd with 35 mph speed)	✓ (Desirable on 3rd with 30 mph speed)	✓ (Desirable on 3rd with 25 mph speed)	✓ (Recommended on 3rd with 35 mph speed)
	11	**Bike corrals.** Serve bike parking demand; often converted from on-street parking and/or implemented in conjunction with curb extensions.	✓ (2nd & 3rd)	✓ (2nd & 3rd)	✓ (3rd)	
	12	**Bike boxes.** Increase visibility of bicyclists at major intersections and/or with high turning movements.	✓ (2nd & 3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)
	13	**Left turn bike boxes.** Facilitate bicycle left-turns without crossing motor vehicle lanes.	✓ (2nd & 3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)

Type	Map ID	Design Treatment and Brief Description	Alt 1: 2nd/3rd Street Couplet	Alt 2: Expanded Grid	Alt 3: 2nd/4th Street Couplet	Alt 4: 3rd Street Boulevard
	14	**Bus bulbouts.** Increase transit stop visibility/comfort/capacity and minimize bus delay.	✓ (2nd & 3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)PP
	15	**"Share the road signs", other bike and pedestrian signage**	✓ (2nd & 3rd)	✓ (2nd & 3rd)	✓ (2nd & 3rd)	✓ (2nd & 3rd)
	16	**Narrow travel lanes.** Reduce motor vehicle speeds.	✓ (2nd & 3rd)	✓ (2nd, 3rd, and 4th)	✓ (2nd, 3rd, and 4th)	✓ (3rd)
	17	**Street narrowing.** Narrow curb-to-curb distance, e.g., to increase right-of-way for sidewalks.				✓ (3rd)
	18	**New signalized intersections and/or additional signalized control or upgrades at key intersections.**	✓ (2nd & 3rd)		✓ (2nd & 4th)	
	19	**Advanced vehicle stop lines.** Increase separation from pedestrian crossings. (Could be coordinated with bike boxes).	✓	✓	✓	✓
	20	**On-street parking.** Support local businesses, calm traffics, and separate pedestrians from vehicle lanes.	✓ (2nd & 3rd)	✓ (3rd)	✓ (2nd, 3rd, and 4th)	✓
	21	**Managed access.** Consolidate driveways to reduce turning movement locations (increases bicycle and pedestrian safety).	✓ (2nd & 3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)
	22	**Stormwater management features.** Filters runoff, calms traffic, beautifies streetscape.	✓ (2nd & 3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)
	23	**General Streetscaping.** Calms traffic and increases pedestrian comfort.	✓ (2nd & 3rd)	✓ (3rd)	✓ (3rd)	✓ (3rd)
	24	**Speed humps.** Reduce vehicles speeds, increases driver awareness. Can be applied 4th Ave in some alternatives and to east-west residential streets.	✓ (4th)	✓ (4th)	✓	✓ (4th)
	25	**Parklets.** Expand restaurant/café seating, create public spaces, add buffer between sidewalk and vehicle lanes.	✓ (2nd & 3rd)	✓ (3rd)	✓ (2nd, 3rd, 4th)	✓ 2nd & 4th (Future Potential)
	26	**Mini roundabout.** Calm/ manage traffic at neighborhood street intersections where volumes do not warrant a stop sign.	✓ (4th)	On 4th Street assuming increased vehicle traffic to the District	On 2nd & 4th Streets (possible)	On 4th Street assuming increased vehicle traffic to the District
	27	**Large roundabouts.** Slow turning vehicle speeds, forcing greater awareness of pedestrians.	✓	✓ (2nd, 4th)	✓	✓

Type	Map ID	Design Treatment and Brief Description	Alt 1: 2nd/3rd Street Couplet	Alt 2: Expanded Grid	Alt 3: 2nd/4th Street Couplet	Alt 4: 3rd Street Boulevard
	28	**Reduce curb radii at intersections.** Reduce turning speeds and shorten pedestrian crossing distances. Examples: 3rd & Franklin, Greenwood, Olney; 4th & Olney, Franklin; 2nd & Greenwood, Olney	✓	✓	✓	✓
	29	**Overpass or underpass.** Provide low-traffic volume over- or under-crossing on Hawthorne of BNSF railroad tracks and Bend Parkway, as an alternative to improvement of Franklin and Greenwood underpasses.	✓	✓	✓	✓

Figure 19 Street and Intersection Treatments Identified for Central Area – General

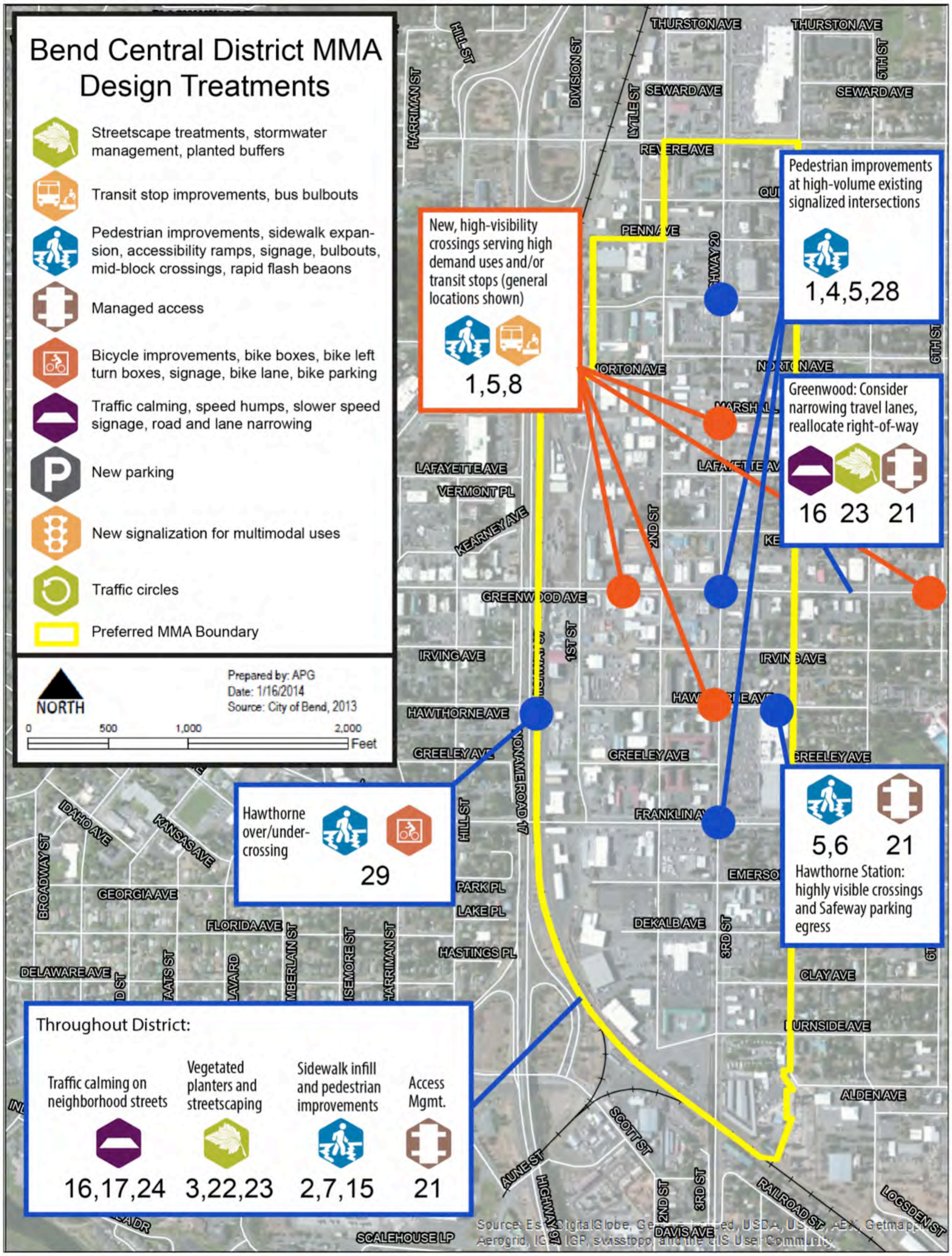

Figure 20 Street and Intersection Treatments Identified for Central Area – Alternative 1

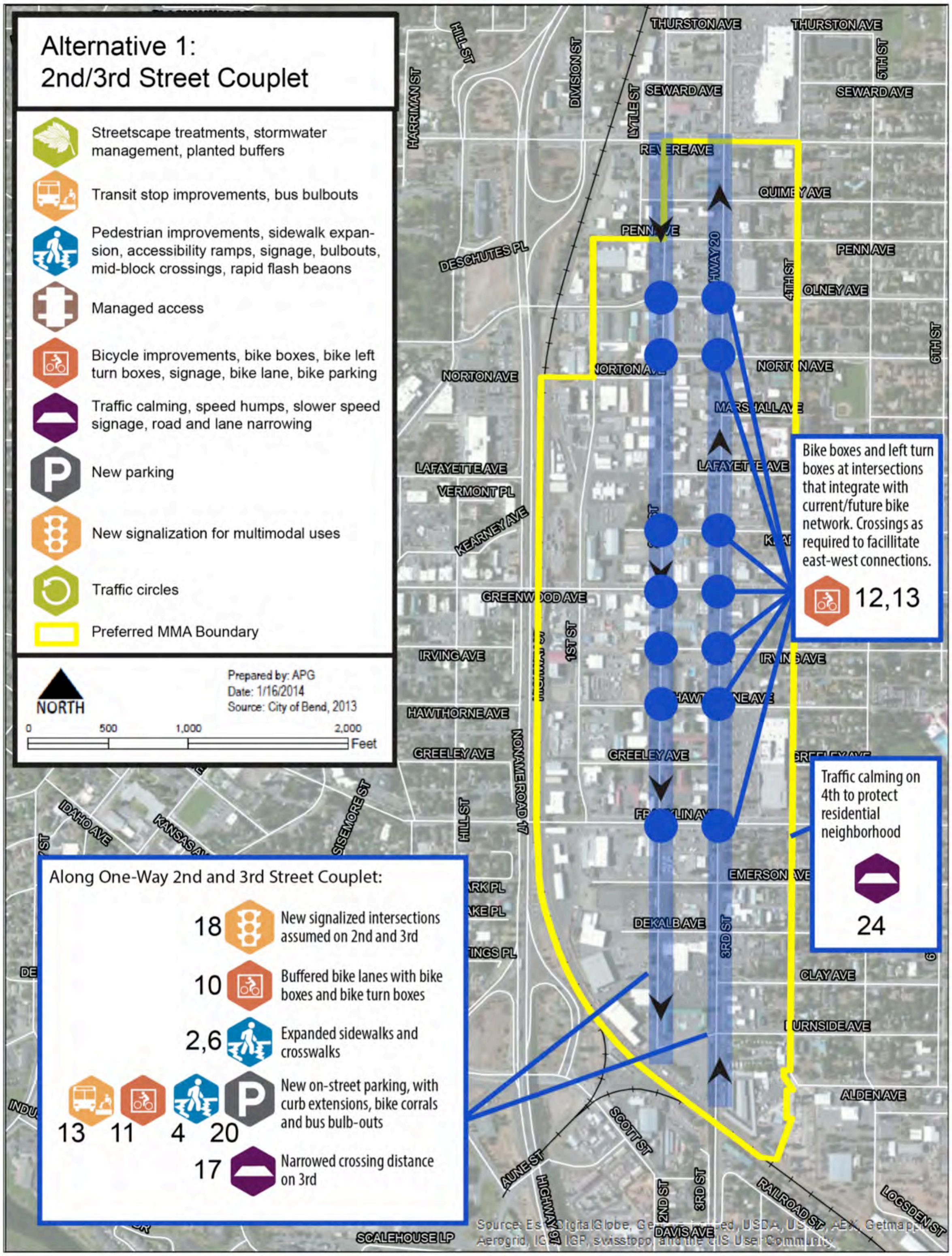

Figure 21 Street and Intersection Treatments Identified for Central Area – Alternative 2

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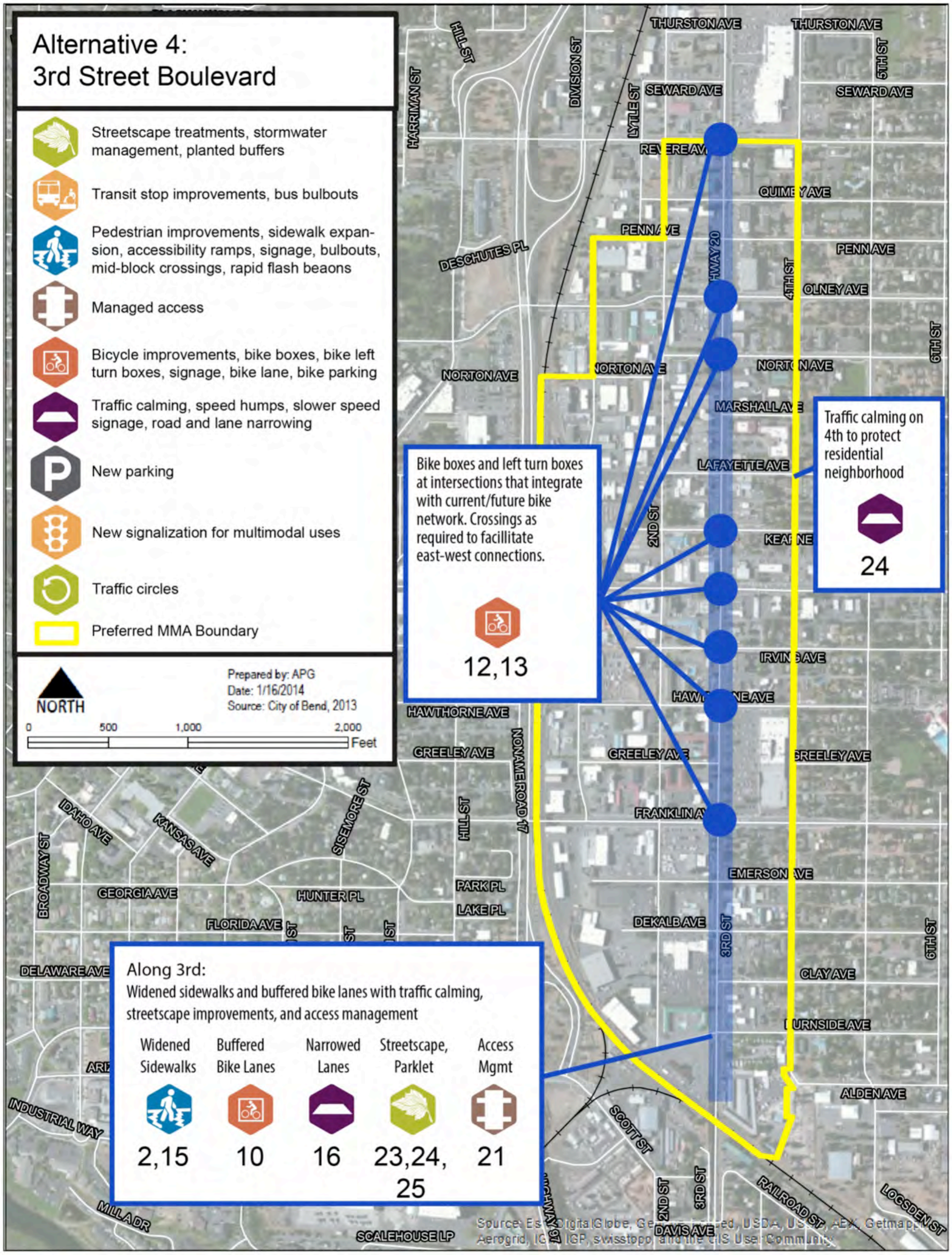
Figure 22 Street and Intersection Treatments Identified for Central Area – Alternative 3

Figure 23 Street and Intersection Treatments Identified for Central Area – Alternative 4



Safety Considerations in the Central District

In Technical Memorandum 1, documenting existing conditions, various safety programs and metrics were analyzed, including:

- City of Bend Multimodal Traffic Safety Program
- Critical crash rates on the Bend Parkway
- 2012 safety priority index system (SPIS) locations along on US 97
- Excess proportion of specific crash types at key intersections in the study area

The memo documented no significant safety issues on the Bend Parkway through the study area. The Parkway segments analyzed were under the statewide average (average rate of 2.56) for that facility's classification of Urban Principal Arterial. The top 10% of SPIS locations for the State of Oregon in 2012 were reviewed, and none were located on US 97.

On 3rd Street, the City's Multimodal Traffic Safety Program documented a combination of design issues and pedestrian and cyclist behaviors that have led to mode conflicts in that area. For example, cyclists are often observed riding on sidewalks where bike lanes don't exist. This creates potential conflicts with pedestrians or bicyclists riding the wrong way.

Another safety concern identified was jaywalking midblock by pedestrians. In a transit survey, 3rd Street was specifically identified as needing more frequent pedestrian crossings. Because buses are infrequent and there are very few signalized or other formal pedestrian crossings on 3rd Street, riders often cross the five-lane road mid-block to catch a bus, creating potential conflicts with other road users. Another safety challenge is the underpasses pedestrians and cyclists use to cross the Bend Parkway. Cyclists tend to share the path rather than take the road, but poor lighting, narrow right of way, and short sight distances can lead to conflicts between the users.

Bend Multimodal Traffic Safety Program Recommendations

In 2012, the City of Bend began its Multimodal Traffic Safety Program to screen and evaluate the transportation system and look at countermeasures to reduce crashes. The following crash trends and countermeasures were identified in the city's 2012-2014 program intersections within the study area. These intersections should be included in consideration of transportation treatments to improve the 3rd Street Corridor.

Trend 1: 3rd Street/ Franklin Avenue

Crash trends indicate that red light running and right turn hooks involving bikes are issues at this intersection. Identified countermeasures include Dutch intersection treatments for bikes and updated signal timing and phasing.

Trend 2: 1st Street/ Greenwood Avenue

Crash trends indicate northbound and eastbound angle crashes. The identified countermeasure is curb extensions on the south side of the intersection.

Trend 3: Revere Avenue/ Division Street/ Bend Parkway NB

Crash tends include incidents involving permitted left turns, rear end crashes in the share left/ through lane, and red light running. Countermeasures include protected-only phasing (and potentially new signal timing) and a road diet to separate left turns and reduce passing maneuvers.

Crash Reduction Analysis for Excess Proportion Locations

To supplement the City's work in its Multimodal Traffic Safety Program, the existing conditions analysis in Technical Memo 1 documented excess proportion of specific crash types analysis at key intersections in the study area. The analysis flagged three intersections and identified potential safety improvements at these three locations. The locations described further in this section, and crash modification factors (CMFs) are used to estimate crash reductions from potential mitigations.

3rd Street/Greenwood Avenue

The intersection of 3rd Street at Greenwood Avenue experienced an excess proportion of turning crashes. Roughly half of these crashes occurred within the intersection, and half on the intersection approaches. Of the eight turning movement collisions recorded between 2008 -2012, three of them occurred within the intersection. The intersection already provides dedicated left turn lanes and protected left turn phasing, so no adjustments are recommended to the signal.

Turning crashes on the intersection approaches can be mitigated with access management, which benefits multiple crash types in addition to turning movement crashes. The CMF available for access management looks at the reduction of access points per mile between existing and future configurations.

To analyze this for the study intersection, access points between the study intersection and its nearest neighboring intersection were tallied and extrapolated to represent a one-mile segment. Then, access points were evaluated for potential closure (i.e. if a business had more than one access point, it was reduced to one) to determine a future scenario. Using these metrics, a CMF of 0.79 was calculated for Greenwood Avenue and 0.81 for 3rd Street. Applying this to the crash types at the study intersection over a five year period shows a potential reduction of two crashes on Greenwood Avenue and one crash on 3rd Street.

Table 2: Crash Modification Estimates for 3rd/Greenwood

Roadway	Existing Driveway Density (driveways/mi)	Proposed Driveway Density (driveways/mi)	CMF	Existing Crash Frequency (Five Year Total)	Mitigated Crash Frequency (Five Year Total)	Net
Greenwood Avenue	63[1]	38[3]	0.79	11	9	-2
3rd Street	57[2]	36[4]	0.81	6	5	-1

Notes
[1] Based on 10 driveways per 0.16 miles
[2] Based on 8 driveways per 0.14 miles
[3] Based on 6 driveways per 0.16 miles
[4] Based on 5 driveways per 0.14 miles
Crashes included in the table only include those that are recorded on the intersection approaches

8th Street/Greenwood Avenue

The excess proportion of specific crash types analysis indicated an overrepresentation of rear-end collisions at the intersection of 8th Street and Greenwood Avenue. Of the 24 crashes recorded between 2008 and 2012, 16 of them were rear-end, with 50% of these occurring on the east leg of the intersection. Of the eight rear-end collisions on the east leg of the study intersection for the five year study period of 2008-2012, two were injury crashes and the other six property damage only crashes. This area transitions from a median divided, limited-access roadway surrounded by undeveloped land to an undivided area with many access points. This change in environment may cause drivers to not anticipate queued vehicles at this signal, resulting in rear-end collisions.

Rear-end collisions on the east leg of this intersection can be mitigated with advanced queue warning systems, helping to alert drivers who may not be aware of the upcoming signal that they should expect to encounter the back of a queue. The CMF available for advanced queue warning applies a single factor for each severity type.

The CMF for advanced queue warning is 0.84 for injury collisions and 1.16 for property damage only (PDO). This indicates that the treatment reduces severe crashes, but increases property damage only crashes. Using these two CMFs, the injury collisions would experience a small reduction (so small it doesn't represent even one less crash per five year period), but PDO collisions would experience an increase of one crash over a five year period.

No CMF is available to allow analysis of advanced signal warning signs.

3rd Street/Revere Avenue

The intersection of 3rd Street at Revere Avenue experienced an excess proportion of rear-end crashes, mostly on the north and south legs of the intersection. Rear-end crashes can occur from driver slowing down to access driveways. Of the 22 crashes recorded from 2008 to 2012, 16 of them were rear-end collisions.

Access management benefits multiple crash types in addition to rear-end crashes. The crash modification factor (CMF) available for access management looks at the reduction of access points per mile between existing to a future configuration. Similar to the 3rd Street/Greenwood Avenue intersection, this location was analyzed by reviewing the access points at this intersection within in the nearest block and extrapolating these values to represent a one-mile segment. Then, access points were evaluated for potential closure (i.e. if one business had more than one access point, it was reduced to one) to determine a future scenario. Using these metrics, a CMF of 0.74 was calculated for Revere Avenue and 0.87 for 3rd Street. Applying this to the crash types at the study intersection over a five year period shows a potential reduction of zero crashes on Revere Avenue and one crash on 3rd Street. Although this does provide some reduction, the benefit is likely not high enough to outweigh the costs associated with reducing access.

Table 3: Crash modification estimates for 3rd/Revere

Roadway	Existing Driveway Density (driveways/mi)	Proposed Driveway Density (driveways/mi)	CMF	Existing Crash Frequency (Five Year Total)	Mitigated Crash Frequency (Five Year Total)	Net
Revere Ave	56[1]	25[3]	0.74	2	2	0
3rd St	29[2]	14[4]	0.87	10	9	-1

Notes
[1] Based on 9 driveways per 0.16 miles
[2] Based on 4 driveways per 0.14 miles
[3] Based on 4 driveways per 0.16 miles
[4] Based on 2 driveways per 0.14 miles
Crashes included in the table only include those that are recorded on the intersection approaches