2019

BOULDER
Low-Stress Walk and Bike Network Plan

The Low-Stress Walk & Bike Network Plan

CITY OF BOULDER

CONTENTS

TABLES

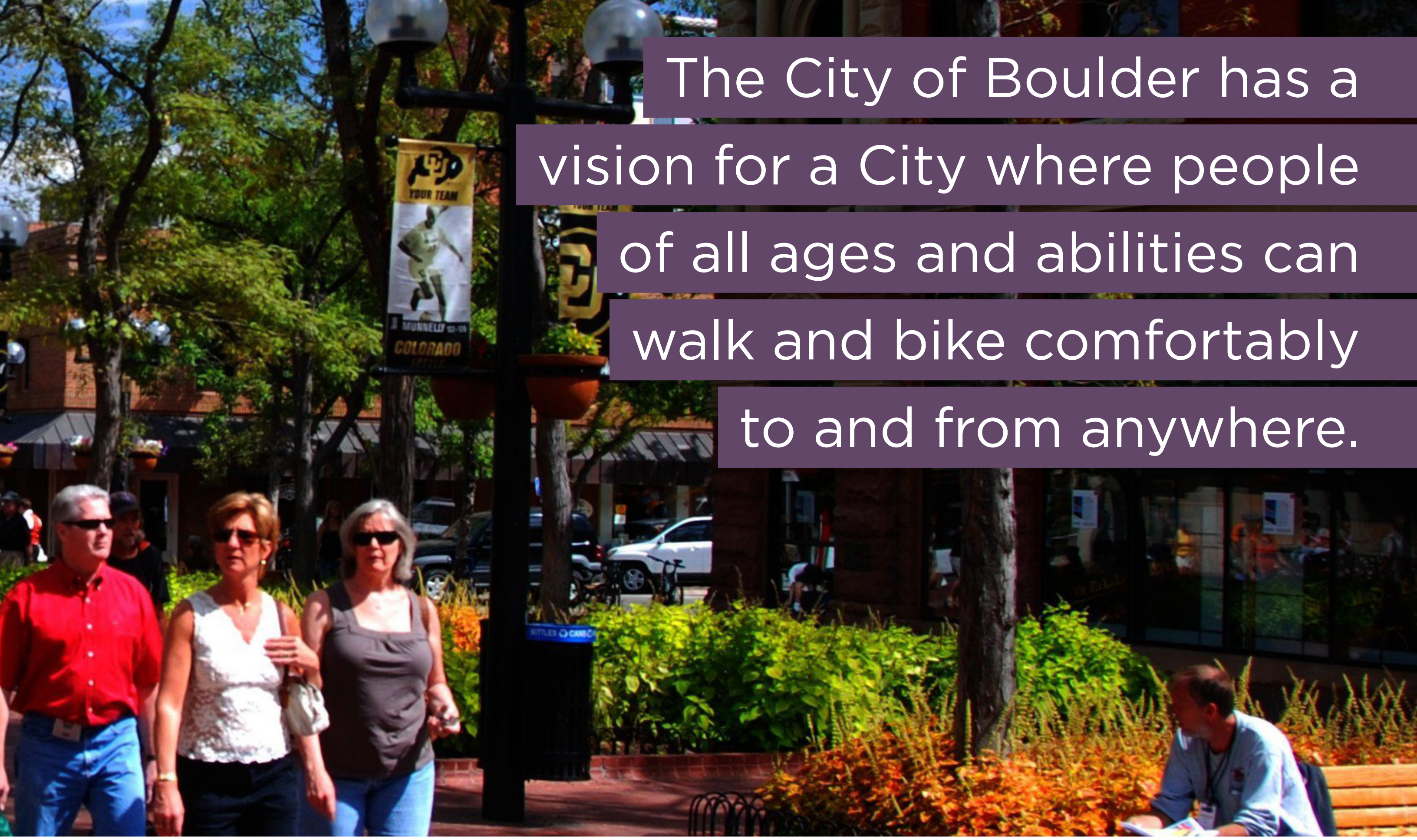
FIGURES

EXECUTIVE SUMMARY

Boulder's vision is to create a network of low-stress facilities to help people of all ages and abilities walk and bike safely and comfortably throughout the community. The City of Boulder understands and has initiated a proactive, comprehensive planning process based on national best practices and community input to turn this vision into a reality. For this reason, the development of the Low-Stress Walk and Bike Network Plan comes at an ideal time as the city updates the 2019 Transportation Master Plan. These plans are inextricably linked and are intended to identify and prioritize key projects that create a connected network of low-stress walk and bike facilities with easy connections to transit.

This plan includes the methods that help assess the comfort of existing pedestrian and bicycle facilities in Boulder and thus serves as a reference for how to identify and prioritize needed improvements to the bicycle and pedestrian environment. The methodologies developed as a part of this plan include national best practices and are also Boulder-specific, designed to recommend projects that are in line with the community's vision and goals.

The Low-Stress Walk Network Plan is shown in **Figure 1** and **Figure 3** and includes both areas and corridors in which to focus future improvements. The areas have been denoted as Pedestrian Improvement Areas (PIAs) and the corridors are called Neighborhood GreenStreets. These have been integrated into the 2019 Pedestrian Plan. Subsequent to plan adoption, each area will be studied in detail and improvements recommended. These could include building new sidewalks, upgrading existing sidewalks and curb ramps to meet ADA requirements, new pedestrian crossings and/or enhancements to existing crossings, lighting, other amenities, and wayfinding. While the structure of each study will be similar, the identified improvements will be specific to each area and developed by working with the community. It is the intent to study and implement improvements in all 13 PIAs by 2030.



The City of Boulder has a vision for a City where people of all ages and abilities can walk and bike comfortably to and from anywhere.

In addition to these areas, Neighborhood GreenStreet corridors have been identified and are described in more detail in the report. Similar to the PIAs, corridors will be studied and improvements identified and implemented by 2030.

The proposed areas and corridors also serve the purpose of increasing the proportion of 15-minute neighborhoods in Boulder. In a 15-minute neighborhood, people can access their basic needs and non-work errands (parks, food, etc.) within 15-minutes via walking. This plan was developed with the guidance of a community-based Pedestrian Advisory Committee.

The Low-Stress Bike Network for on-street and off-street bicycle facilities in Boulder is shown in **Figure 1, 2, and 4.** This plan includes identification of facility type, consisting of Neighborhood GreenStreets, bike lanes (preferably buffered), and vertical separation projects (consisting of separated bike lanes and multi-use paths).

Neighborhood GreenStreets (NGs) benefit both the pedestrian and bicycle network to create a seamless network of low-stress facilities, primarily on residential streets. A Neighborhood GreenStreet is a low-traffic street prioritized for walking and biking where people of all ages and abilities feel safe and comfortable.

The plan for low-stress bike and walk networks are presented together because of the synergy between creating safe environments for both pedestrians and bicyclists. This plan includes methodologies for identifying and prioritizing pedestrian and bicycle projects and final networks of proposed low-stress pedestrian and bicycle projects. This plan also includes a prioritized list of pedestrian and bicycle projects for further study to help the city build these networks in a fiscally responsible way. The top projects in each category are presented in **Figures 3, 4, 5, and 6.** Details on prioritization and cost estimation methods are included in the plan.

Figure 1. Low-Stress Walk and Bike Network Plan

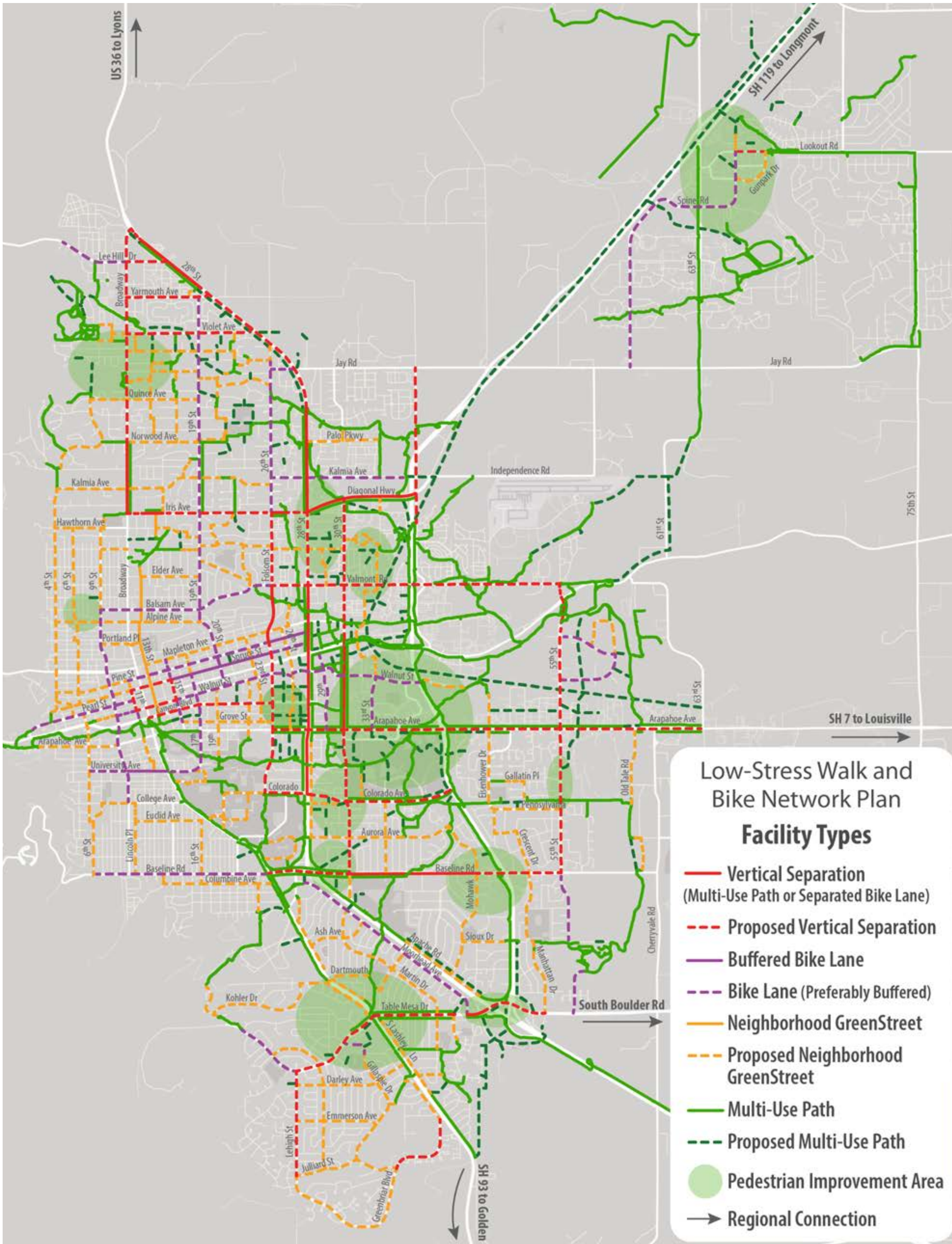


Figure 2. Low-Stress Bike Network Plan: Existing and Proposed Differentiated

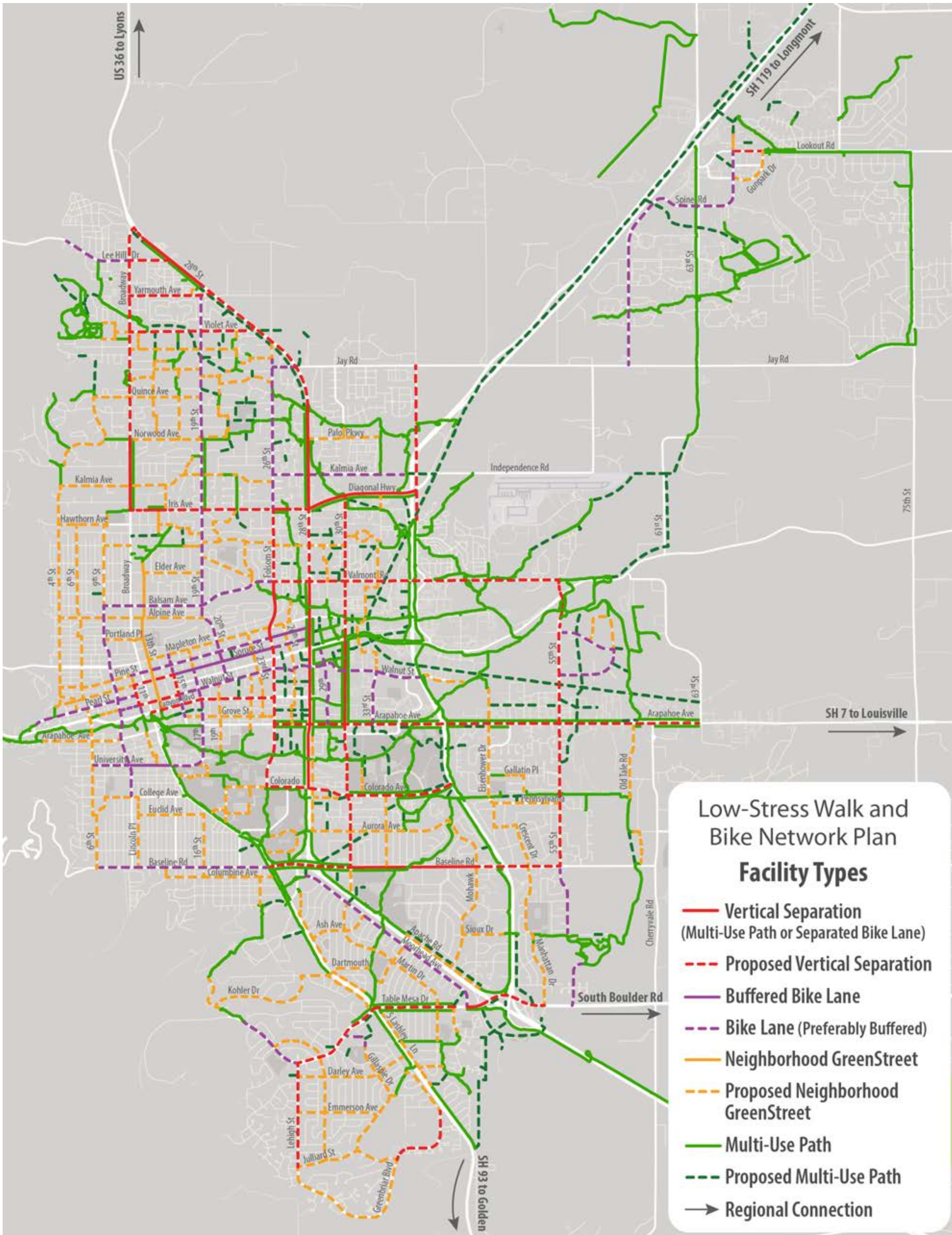


Figure 3. Low-Stress Walk Network Plan

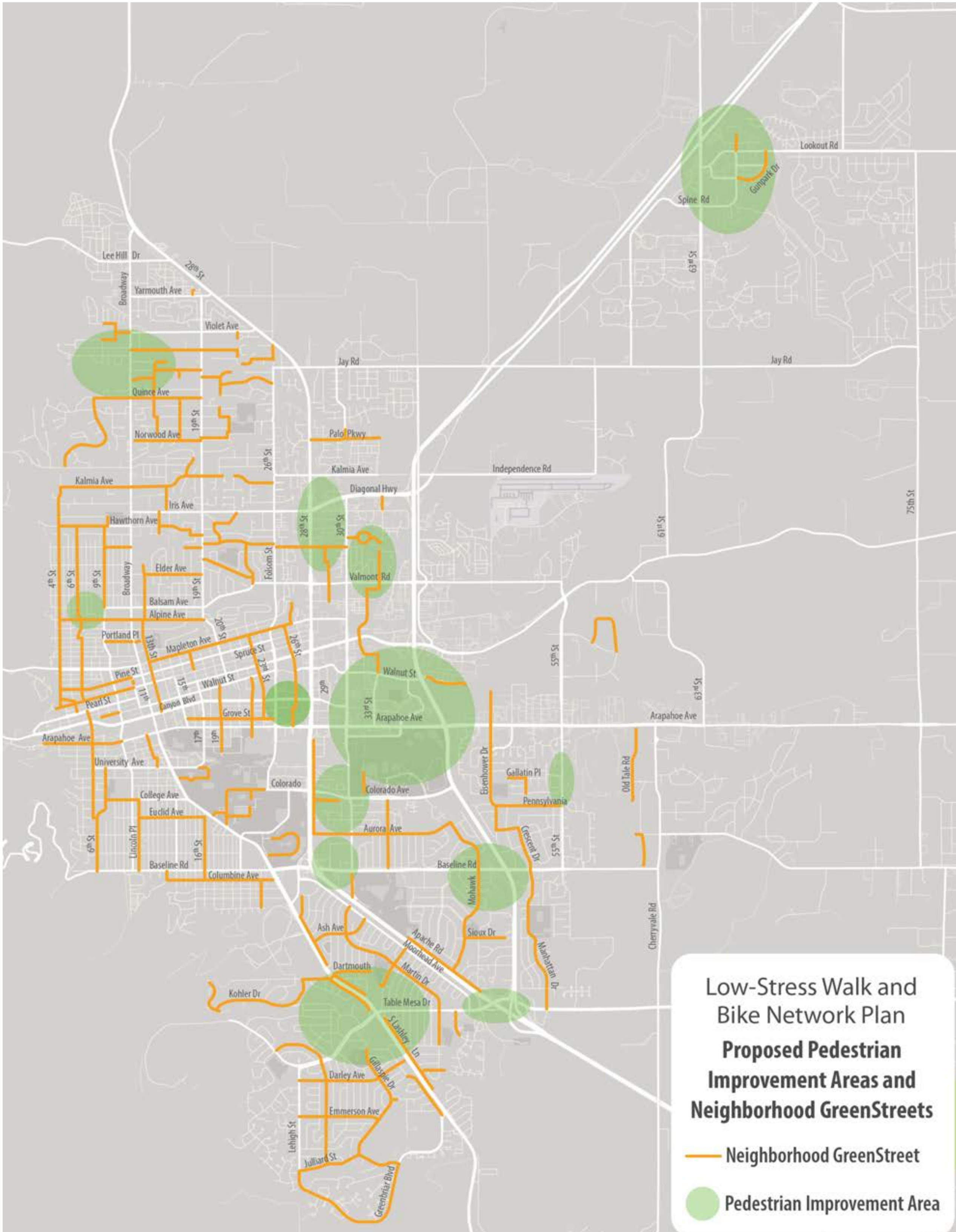


Figure 4. Low-Stress Bike Network Plan: Existing and Proposed Combined

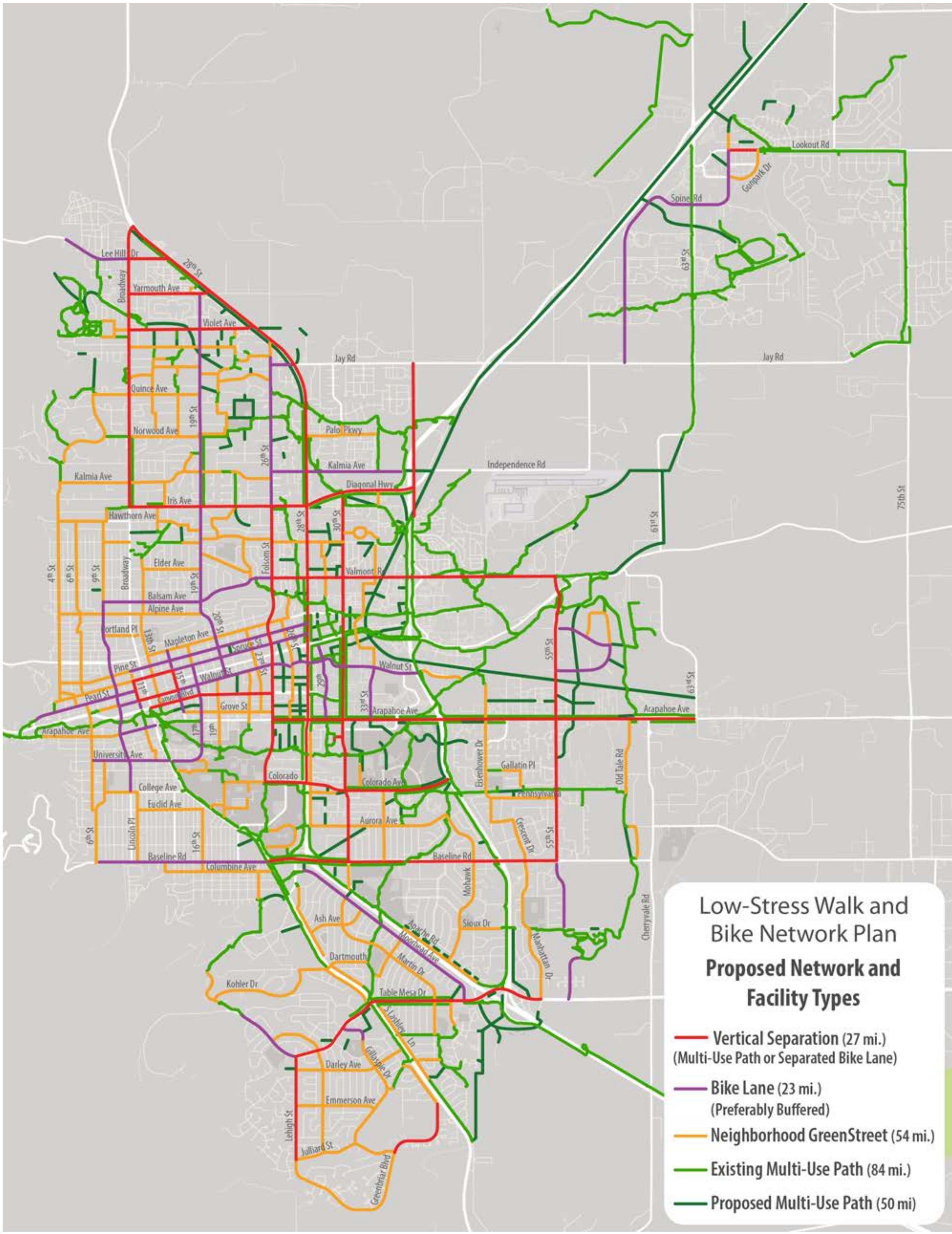


Figure 5. Prioritized Pedestrian Improvement Areas

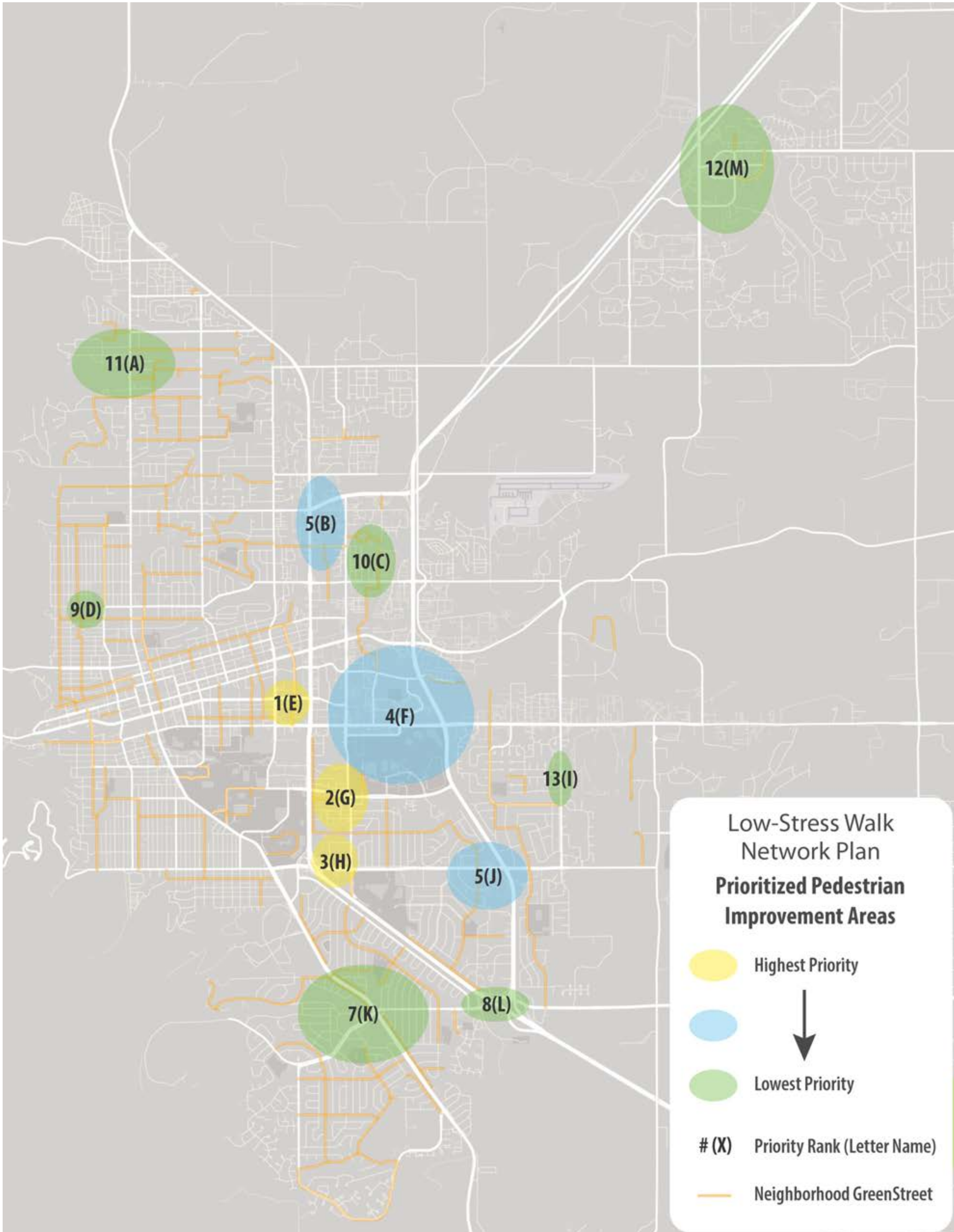


Figure 6. Prioritized Neighborhood GreenStreets

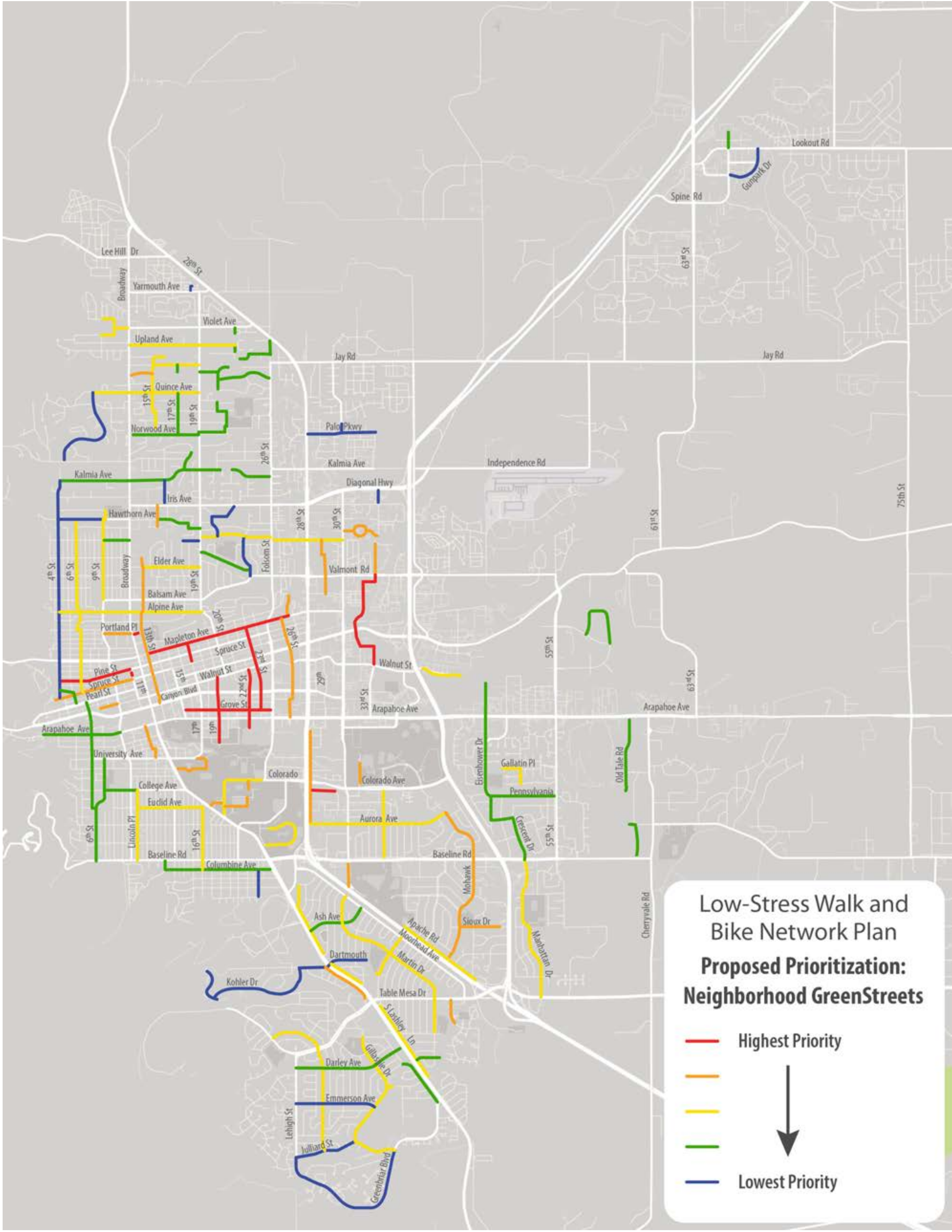


Figure 7. Prioritized Bike Lane Projects (Preferably Buffered)

Figure 8. Prioritized Vertical Separation Projects

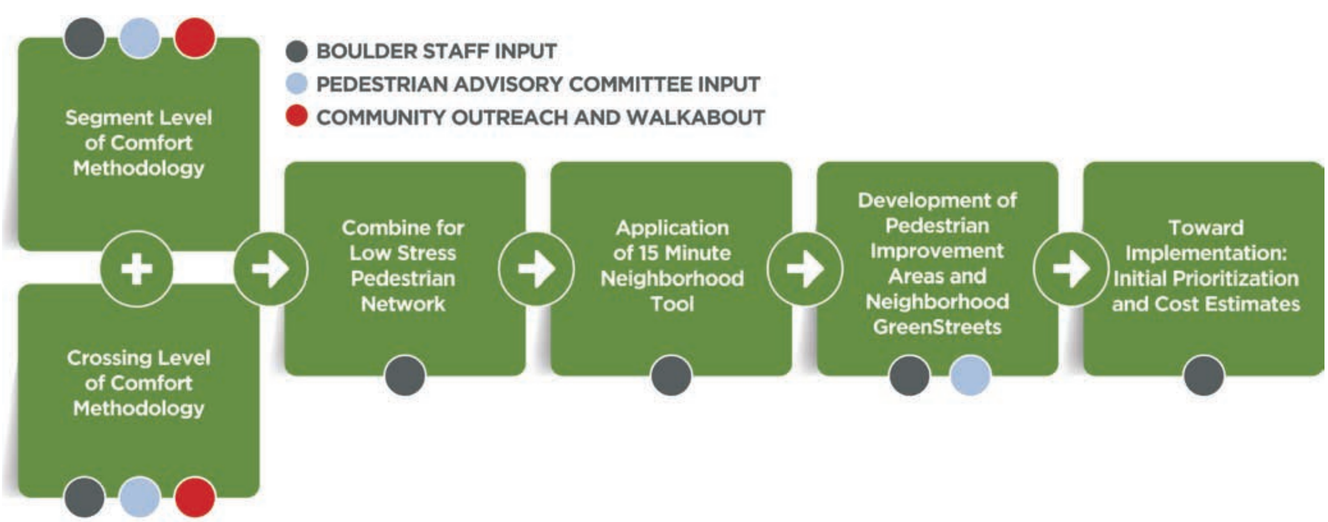
LOW-STRESS WALK NETWORK PLAN

The Low-Stress Walk Network Plan has been integrated into Boulder's 2019 Pedestrian Plan. The plan is intended to guide the city in creating a complete network of low-stress pedestrian facilities to increase the accessibility and safety of walking. This network is guided by the goal of ensuring that all Boulder residents can access their basic needs (food, parks, schools, etc.) within at most a 15-minute walk—known as the 15-minute neighborhood concept.

To complete the pedestrian network in a cost-effective way, the plan prioritizes areas (Pedestrian Improvement Areas (PIAs)) and corridors (Neighborhood GreenStreets (NGs)) in the city in need of additional or enhanced pedestrian facilities with the greatest potential to connect people to the places they want to go, incorporating community feedback throughout. Pedestrian Improvement Areas have destinations that would be within a comfortable 15-minute walk if there were not large crossings, missing sidewalks and other barriers. A Neighborhood GreenStreet is defined as a low-traffic street prioritized for walking and biking where people of all ages and abilities feel safe and comfortable traveling. The implementation of PIAs and NGs is intended to increase the percentage of people who live and work in a 15-minute neighborhood by eliminating the high-stress barriers that keep people from walking and biking. The "Low-Stress Walk Network: Proposed PIAs and NGs" shown in **Figure 3** highlights the recommended project areas and corridors.

The process for developing this plan is outlined in **Figure 9.** The first step of this plan was to understand where pedestrians currently have difficulty walking comfortably because of the high-stress pedestrian environment. Using segment and crossing Level of Traffic Stress (LTS) methodologies, an existing Low-Stress Walk Network was identified. This network was used for analysis with the 15-minute neighborhood tool, to support the identification of areas where there are gaps in low-stress facilities that prevent people from accessing their basic needs in a 15-minute walk. This resulted in identification of PIAs and NGs, that were then prioritized and assigned initial cost estimates to help move toward implementation. The plan was developed with the guidance of a community-based Pedestrian Advisory Committee.

Figure 9. Walk Network Plan Development Process



Pedestrian Level of Traffic Stress

The first part of the process was understanding the existing network. Each sidewalk or identified missing sidewalk segment, as well as each crossing, was classified as Level of Traffic Stress (LTS) 1 to 4. Segments are along streets (such as a block of sidewalk), while crossings indicate places pedestrians are intended to cross a street (such as at an intersection or midblock). LTS levels are defined as shown in **Figure 10.** These scores were developed based on national research and best practices for measures of both bicycle and pedestrian comfort. Mekuria, Furth, and Nixon's development of the original Level of Traffic Stress (2012) provided a framework that was adapted to pedestrian facilities based on the National Association of City Transportation Officials (NACTO) Urban Streets Design Guide and safety research, as well as research from the American Association of State Highway and Transportation Officials (AASHTO). Based on this research, there are a few key inputs readily available at a city-wide level that together can serve as a proxy for pedestrian comfort and perceived safety. The Level of Traffic Stress (LTS) score for pedestrians traveling along and across streets conveys comfort levels using a 1 to 4 scale. Scores of 1 and 2 are considered high comfort (or low-stress) and score of 3 and 4 are considered low comfort (or high-stress).

Figure 10. Defining Pedestrian Level of Traffic Stress

15-Minute Neighborhood Assessment

The low-stress pedestrian methodology was incorporated into an update of the 15-minute neighborhood tool, a tool designed to identify walking access throughout Boulder. Specifically, the 15-minute neighborhood tool calculates how many destinations, such as schools, parks, or grocery stores, can be reached in less than a 15-minute walk in order to better understand how well the low-stress pedestrian network connects people with the places they want to go. This 15-minute neighborhood analysis tool only considers a destination as accessible if it can be reached exclusively on high comfort facilities. This means that there is a continuous low-stress route from place to place without any high-stress crossings or segments. For the purposes of the 15-minute neighborhood tool, the scoring simplifies and consolidates the typical LTS 1 to 4 scoring to classify each segment and crossing as either high comfort (LTS 1 or LTS 2) or low comfort (LTS 3 or LTS 4). Using the segments and crossing methodologies described next, the complete pedestrian network including segments and crossings was designated as either high-stress or low-stress, as shown in **Figure 11.**

Figure 12 and **Figure 13** show the outcomes of the 15-minute neighborhood assessment by presenting the walk access scores throughout the city. Higher scores represent better access. **Figure 12** shows the scores when considering a network of all facilities. **Figure 13** shows the scores when considering a network of just low-stress facilities.

Figure 11. Existing Low-Stress Walk Network

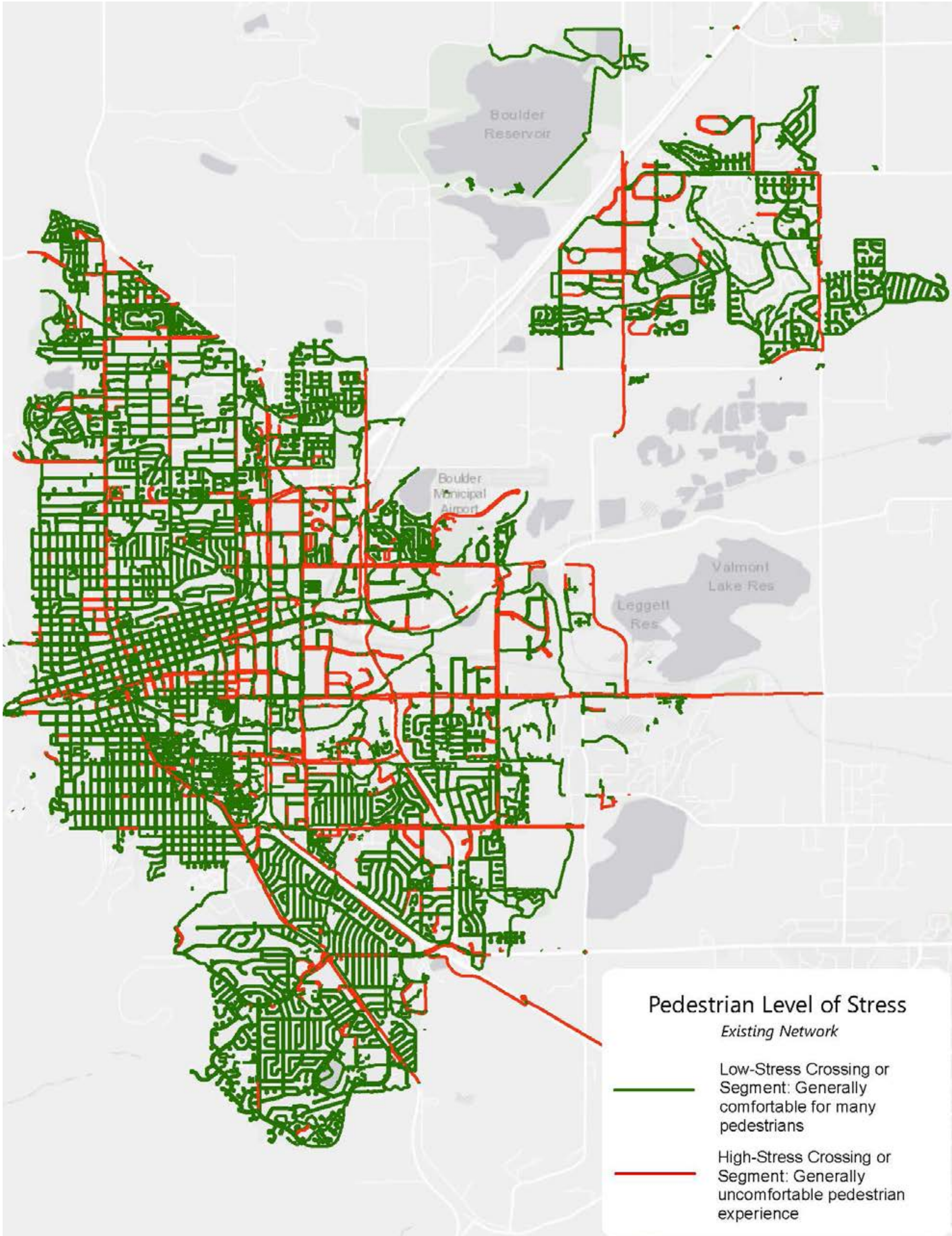


Figure 12. 15-Minute Neighborhood Assessment, All Facilities

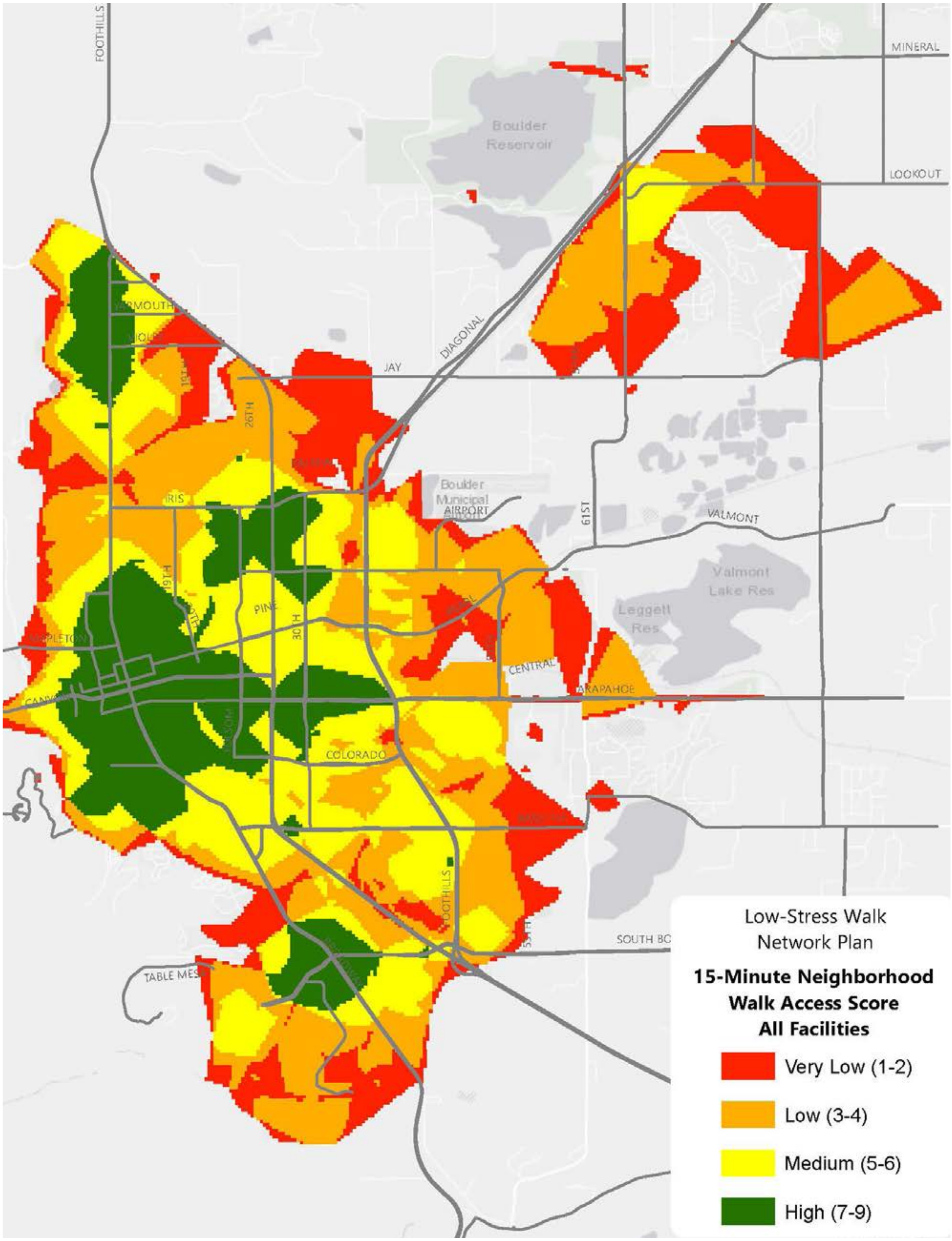
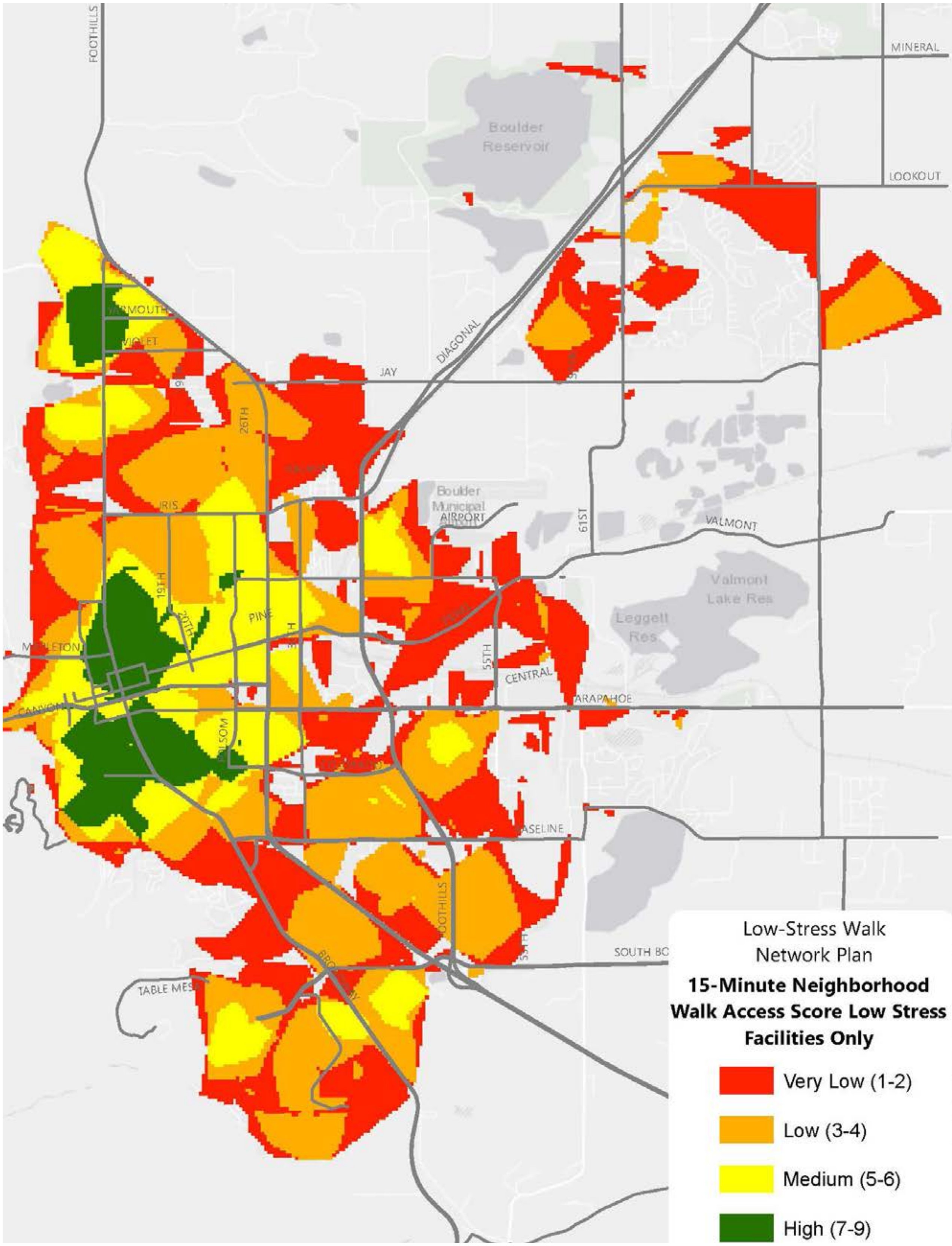


Figure 13. 15-Minute Neighborhood Assessment, Low-Stress Facilities Only



Segment Methodology

The methodology for determining the Level of Traffic Stress for pedestrians along street segments accounts for the **presence of sidewalks and buffers, the number of travel lanes and posted speed limit of the adjacent street,** and **the presence of commercial driveways.** This methodology informed the Level of Traffic Stress for existing pedestrian facilities that served as an input to the 15-minute neighborhood tool, a tool to better understand how well the low-stress pedestrian network connects people with the places they want to go. City-wide results are shown in **Figure 14** and study area results are in **Figure 15.**

The methodology considers the following inputs for each roadway segment being evaluated:

- **Presence of Sidewalk and Type -** Sidewalks are classified as either attached or detached. Attached sidewalks are immediately adjacent to the curb of the adjacent street. Detached sidewalks have a buffer between the sidewalk and the curb of the adjacent street, often landscaping or an amenity zone. If no sidewalk is present, the segment would fall under the mixed traffic criteria, meaning pedestrians walking along the street would be mixed with vehicular and other traffic.

- **Number of Travel Lanes –** The total number of travel lanes on the adjacent street is considered in this methodology for determining the pedestrian Level of Traffic Stress, with more travel lanes correlated to lower comfort. Number of travel lanes is a proxy for traffic volume on a roadway (because traffic volume data was not available for all roadways). Three-lane segments typically include one travel lane in either direction plus a two-way left turn lane. Five lane segments typically include two travel lanes in either direction plus a two-way left turn lane. This methodology does not count the turn lanes at intersections.

  Center Median Adjustments - The presence of a center median changes the user experience of a roadway, providing enough separation so the user is impacted only by the street characteristics of one direction of travel. A more robust discussion on how to consider medians is discussed in the 'future inputs' section, examining the relativity between the median width and the distance between curb faces on either side of the street. For this methodology, three streets were identified with wide enough medians to change the number of lanes criteria to be only the lanes on the near side of the median. For the applicable sections on Colorado Avenue, Table Mesa Drive, and Mapleton Avenue, the number of lanes and corresponding LTS score reflects the number of lanes on just the side of the median closest to the sidewalk.

- **Posted Speed Limit –** The posted speed limit on the adjacent street is considered in this methodology, with higher speeds correlated to higher stress. The posted speed limit serves as a proxy for actual travel speed of vehicles on the roadway.

- **Commercial Driveway Curb Cuts –** The presence of a commercial driveway curb cut

Current Methodology Criteria Influences:

- Attached sidewalks decrease comfort
- Detached sidewalks increase comfort
- Increased number of lanes decreases comfort
- Increased speed decreases comfort
- Presence of commercial driveways decreases comfort

intersecting a sidewalk creates a high-stress score of LTS 3. For any type of sidewalk commercial driveways specifically are included because they typically have a higher frequency of vehicle use and thus a greater chance for potential auto-pedestrian conflicts.

Table 1 shows the criteria for assigning a pedestrian Level of Traffic Stress score for attached sidewalks while **Table 2** shows the criteria for detached sidewalks. The criteria for pedestrians in mixed traffic (where there is no sidewalk) are shown in **Table 3.**

Weakest Link Approach:

If a roadway segment included a detached sidewalk with two travel lanes (LTS 1), a posted speed limit of 30 mph (LTS 2), and no commercial driveways (no effect on LTS), the overall LTS of the segment would be 2 (high comfort). However, if a roadway segment included an attached sidewalk with four travel lanes (LTS 3), a posted speed limit of 30 mph (LTS 2), and no commercial driveways (no effect on LTS), the overall LTS of the segment would be 3 (low comfort).

TABLE 1. CRITERIA FOR ATTACHED SIDEWALKS

Input	Low-Stress		High-Stress	
	1	2	3	4
Number of Travel Lanes	2 to 3 lanes	(no effect)	4 to 5 lanes	6+ lanes
Posted Speed Limit	≤ 25 mph	30 mph	35 mph	≥ 40 mph
Commercial Driveway Inventory	(no effect)	(no effect)	Curb cut intersects sidewalk	(no effect)

TABLE 2. CRITERIA FOR DETACHED SIDEWALKS

Input	Low-Stress		High-Stress	
	1	2	3	4
Number of Travel Lanes	2 to 3 lanes	4 to 5 lanes	(no effect)	6+ lanes
Posted Speed Limit	≤ 25 mph	30-35 mph	40-45 mph	≥ 50 mph
Commercial Driveway Inventory	(no effect)	(no effect)	Curb cut intersects sidewalk	(no effect)

TABLE 3. CRITERIA FOR PEDESTRIANS IN MIXED TRAFFIC

Posted Speed Limit	Number of Travel Lanes		
	2-3 Lanes	4-5 Lanes	6+ Lanes
≤ 25 mph	LTS 2	LTS 3	LTS 4
30 mph	LTS 3	LTS 4	LTS 4
≥ 35 mph	LTS 4	LTS 4	LTS 4

For attached and detached sidewalks, the three inputs (number of travel lanes, posted speed limit, and commercial driveway presence) each received a score of LTS 1 through 4. The overall score for each segment is determined by the highest stress value across all criteria. This calculation approach is referred to as the "weakest link" approach and is common among Level of Traffic Stress methodologies. For example, if a roadway segment included a detached sidewalk with two travel lanes (LTS 1), a posted speed limit of 30 mph (LTS 2), and no commercial driveways (no effect on LTS), the overall LTS of the segment would be 2 (high comfort). However, if a roadway segment included an attached sidewalk with four travel lanes (LTS 3), a posted speed limit of 30 mph (LTS 2), and no commercial driveways (no effect on LTS), the overall LTS of the segment would be 3 (low comfort).

For pedestrians in mixed traffic, the driveways factor is omitted, and Level of Traffic Stress is determined based on the posted speed limit and number of travel lanes. The only low-stress combination for pedestrians in mixed traffic is a scenario with a street 2 to 3 lanes wide and a posted speed limit of 25 mph or less.

Multi-Use Paths and Designated Pedestrian Paths

The existing pedestrian network includes paths categorized as either multi-use or pedestrian paths, which often indicates separation from a street. Due to separation from vehicle conflict, paths are considered high comfort and LTS 1 in this methodology. However, some paths align adjacent to the street, specifically for particular crossings. In those cases, the methodology for attached or detached sidewalks is applied, as shown in **Tables 1 and 2.**

Project Buffer Width Assessment

The methodology included in this plan focuses on the entire city and is limited to a certain extent by the GIS data available for every pedestrian facility in the entire city. One of the characteristics that

TABLE 4. CRITERIA FOR DETACHED SIDEWALKS WITH BUFFER WIDTH

Widths of Buffer	Input	Low-Stress		High-Stress	
		1	2	3	4
< 8 feet	Number of Travel Lanes	2 to 3 lanes	4 to 5 lanes	(no effect)	6+ lanes
	Posted Speed Limit	≤ 25 mph	30-35 mph	40-45 mph	≥ 50 mph
	Driveway Inventory	(no effect)	(no effect)	Curb cut intersects sidewalk	(no effect)
≥ 8 feet	Number of Travel Lanes	2 to 3 lanes	4+ lanes	(no effect)	(no effect)
	Posted Speed Limit	≤ 35 mph	≥ 40 mph	(no effect)	(no effect)
	Driveway Inventory	(no effect)	(no effect)	Curb cut intersects sidewalk	(no effect)

has an influence on comfort that was not available city-wide is the buffer between the sidewalk and the street. In general, the increased separation from vehicles reduces traffic stress (i.e., increases comfort). Although not available city-wide yet, such data is typically available at a corridor or project level, so a methodology was developed to account for this.

Buffer width can consist of on-street or off-street bicycle facilities, on-street parking, or a traditional sidewalk buffer such as landscaping or an amenity zone. City-wide data on buffer presence and width is not available to be able to assess existing sidewalks based on this criteria. For specific study areas, and for more detailed projects where existing and proposed buffer widths are known, the following criteria can be used in calculations and planning for projects, as shown in **Table 4.** If buffer width does become systemically available, it should be used as part of the methodology for detached sidewalks.

Future Segment Methodology Inputs and Updates

The methodology described in the previous section includes the key factors influencing comfort that are currently available at the city-wide level. Through collaboration with City staff, stakeholders, and the public, the following inputs can be considered in future iterations of the methodology as data becomes available:

- **Sidewalk Width –** When comprehensive sidewalk width data becomes available, it should be incorporated into the methodology, with wider sidewalks correlating with lower stress.
- **Traffic Volumes –** Average daily traffic volumes or peak hour volumes should be incorporated into the methodology should this data become available city-wide. Technological advances of Big Data, through companies such as INRIX or StreetLight Data, make this data increasingly available, though unlikely for all local roads to be included in this type of data. Currently, the number of travel lanes serves as a proxy for traffic volumes.
- **Operating Travel Speed -** Currently, posted speed limit serves as a proxy for operating travel speeds. However, actual operating speed data could more accurately reflect the actual conditions and pedestrian experience where there is a discrepancy between posted and operating travel speeds.
- **Buffer Width and Type –** Buffer width for detached sidewalks is currently incorporated into the project-level methodology but not yet used in the automated tool due to a lack of city-wide data. When computing a score manually, buffer width data can be field calculated or calculated from project plans and thus included as an input. With appropriately organized spatial data, the buffer between vehicles and pedestrians can be used as an automated input into the tool to better reflect the pedestrian user experience and comfort levels. This detailed buffer data should

Future Methodology Criteria Influences:

- Increased sidewalk width increases comfort
- Higher traffic volume decreases comfort
- Higher operating travel speed decreases comfort
- Wider buffers increase comfort
- Presence of wide medians increase comfort
- Enhanced pedestrian scale lighting and general luminance increases comfort
- Curb cuts decrease comfort
- High quality sidewalks increases comfort

also take into account the presence, width, and type of buffer such as bicycle facilities, on-street parking, and landscaping, such as street trees.

• **Median Width –** City-wide data on median width would allow for the change in comfort provided by the presence of a wide median to be reflected in the methodology. If the median is wider than the curb to curb width (the combined width of travel lanes between the sidewalk or path and the start of the median), then it is appropriate to consider only the travel lanes between the median and the sidewalk or path as the number of lanes for the given segment. In other words, the presence of a median of qualifying width creates the same experience for pedestrians as walking along a one-way street, and the street characteristics applied to that sidewalk segment should reflect that experience. The current methodology has data manually edited for three locations where this is evident– along segments of Colorado Avenue, Table Mesa Drive, and Mapleton Avenue.

• **General Luminance and Pedestrian-Scale Lighting –** The luminance of an area is influential in pedestrian comfort. The incorporation of both general luminance and pedestrian-scale lighting would allow the Level of Traffic Stress scores to more accurately reflect pedestrian comfort during different times of the day. Incorporating this input would require comprehensive data on the lighting levels along roadways and the effectiveness of pedestrian-scale lighting.

• **Curb Cut Proportion Inventory –** The current methodology accounts for commercial driveway curb cuts. The length of each curb cut is recorded in the data; however, because of the variation in how the sidewalk is segmented, it is difficult to assess and standardize what percent of each block, or other set unit of measurement, is a curb cut. A future iteration of the tool would ideally use this type of metric to assess stress caused by driveways, both commercial and other.

• **Sidewalk Condition –** Data documenting sidewalk condition would include inventory of surfacing issues such as cracks, holes, sidewalk displacement, and surface deterioration, as well as the presence of obstructions. Temporary and permanent obstructions, such as vegetation, perpendicular curbs, and utility poles, can pose navigability and comfort challenges for some pedestrians, particularly those in a wheelchair or using a mobility device. Curb ramp data can also be incorporated into an assessment on the condition of the sidewalk. This would include the presence of curb ramps, but also their quality and usability in terms of surfacing and the slope of the ramp.

Segment Calibration Sites

Calibration sites serve to provide a check of reasonableness, and also to affirm the methodology as helpful for explaining the experiences of people walking in Boulder. To validate the methodology, the LTS outputs along ten different sidewalk segments in the city were calculated in the model and the results reviewed by the PAC and City staff. The calibration segments and results are in **Table 5,** including two multi-use paths adjacent to roadways. Bolded cells show the criteria that resulted in the overall Level of Traffic Stress output, applying the weakest link approach. Additional public input was gathered on the thresholds and methodology as part of a community walkabout on December 13, 2018 for the 30th and Colorado Corridors Study project area. This corridors study extends along Colorado Avenue from Foothills Parkway to Folsom Street and along 30th Street from Baseline Road to Pearl Street, and input on the project as it relates to pedestrian comfort was considered in developing this LTS methodology.

TABLE 5. SEGMENT METHODOLOGY CALIBRATION SITES

Street	Segment	Side of Street	Facility Type	Lanes		Speed Limit		Driveways		Total	
				Number of Lanes	Number of Lanes LTS	Posted Speed Limit	Posted Speed Limit LTS	Presence of Commercial Driveway	Driveway LTS	Low-Stress/ High-Stress Estimate	LTS Output
Manhattan	Between Seminole and Santa Clara	East	Attached Sidewalk	2	1	25	1	No	(no effect)	Low	1
Mapleton	Between 8th and 9th	East	Detached Sidewalk	2	1	25	1	No	(no effect)	Low	1
19th	Between Avocado and Yarmouth	East	Detached Sidewalk	2	1	30	2	No	(no effect)	Low	2
Arapahoe	Between 18th and 19th	South	Detached Sidewalk	3	1	30	2	No	(no effect)	Low	2
Redwood	Between 15th and 17th	South	Mixed Traffic	2	2* given speed limit	25	2* given number of lanes	N/A	N/A	Low	2
30th Street	South of Colorado	East	Attached Sidewalk	4	3	35	3	No	(no effect)	High	3
Broadway	Between Hawthorn and Iris	West	Attached Sidewalk	4	3	35	3	Yes	3	High	3
Colorado	Colorado Avenue North Path, east of 30th	North	Detached Multi-Use Path	2	1	40	3	No	(no effect)	High	3
Broadway	Between Dartmouth and Rayleigh	West	Detached Sidewalk	6	4	40	3	No	(no effect)	High	3
Foothills Parkway	Foothills Parkway Path, north of Arapahoe	East	Detached Multi-Use Path	6	4	45	3	No	(no effect)	High	4
Colorado	Between Bus Stop at 33rd and 35th	South	Attached Sidewalk	4	3	40	4	No	(no effect)	High	4
Violet	Between Broadway and 22nd	South	Mixed Traffic	2	4* given speed limit	35	4* for any number of lanes	N/A	N/A	High	4

Figure 14. Segments Network: Existing Conditions

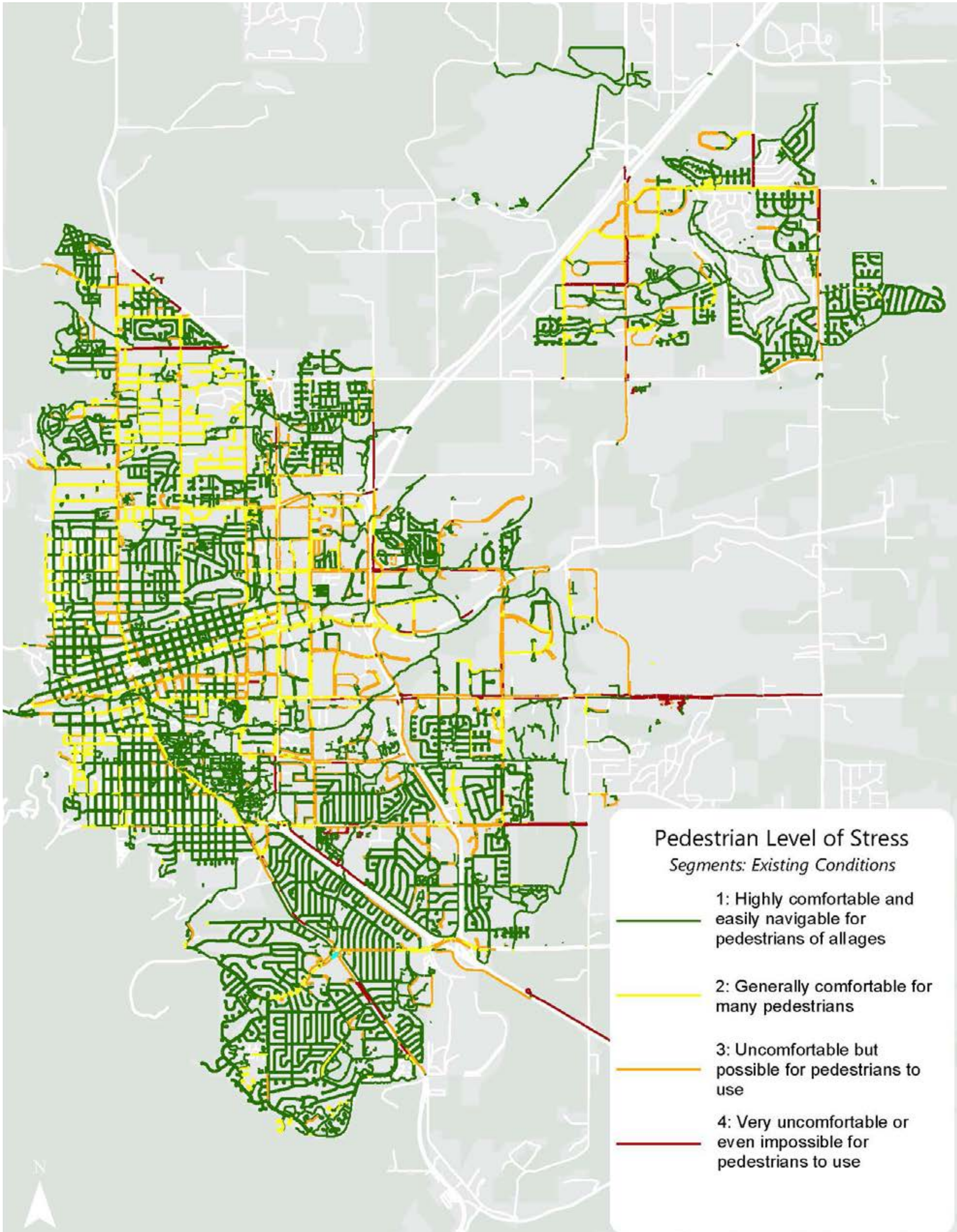
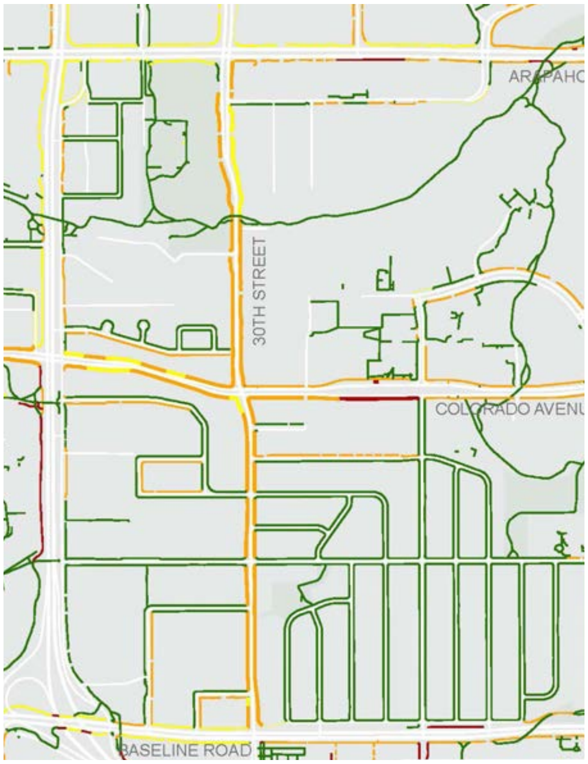
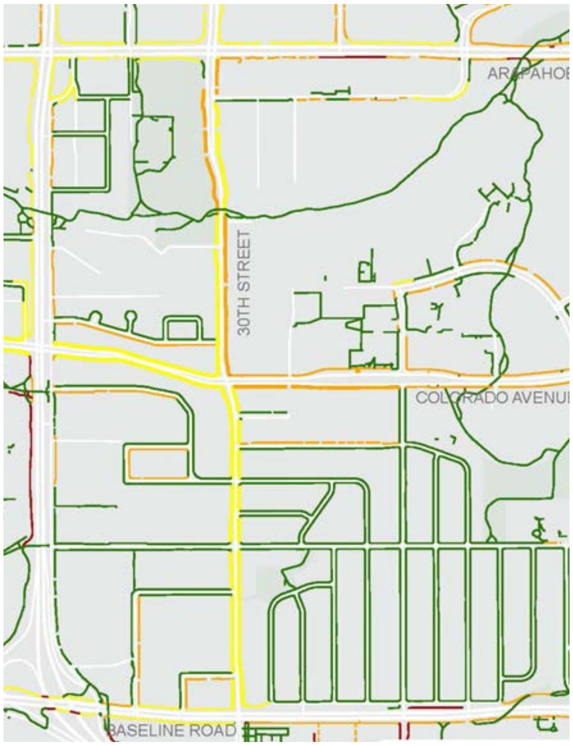


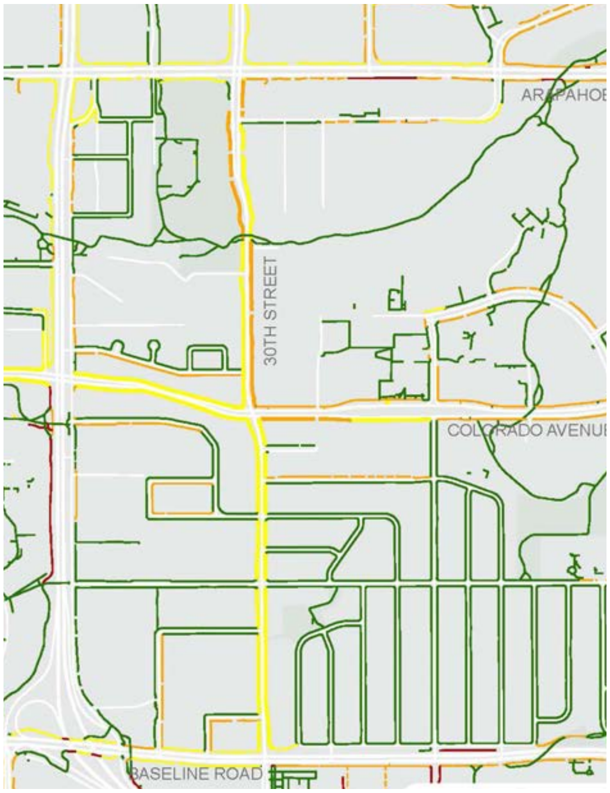
Figure 15. Segments Network: 30th and Colorado Study Area



Existing Conditions



Proposed Conditions - No Buffer Width in Calculations



Proposed Conditions - Buffer Width in Calculations

Crossing Methodology

This section of the plan describes the methodology for determining the Level of Traffic Stress for pedestrians at crossings. This methodology was applied to any legal crossing, marked or unmarked, through a GIS-based tool used to automate a crossing's Level of Traffic Stress. Results are shown in **Figure 17.**

The methodology builds off of the City of Boulder's Pedestrian Crossing Treatment Installation Guidelines (2011) at marked uncontrolled locations and traffic signal standards at marked signalized intersections. The methodology uses the following factors:

- **Intersection control-** Whether traffic at the pedestrian crossing is controlled or uncontrolled. Controlled traffic means the traffic is controlled by either a signal or stop sign. Uncontrolled traffic is traffic that does not approach either of these devices and could be traffic that flows freely through an intersection, or traffic that meets a yield sign or a Rapid Rectangular Flashing Beacon (RRFB).
- **Traffic control device-** If the traffic is controlled, it is controlled by either a signal or stop sign. A traffic signal constitutes a signalized crossing, while a stop sign is considered unsignalized. If the crossing is uncontrolled but an RRFB is present this is considered to reduce pedestrian stress.
- **Marking presence–** Marked crossings have on-street markings to indicate a pedestrian crossing. Unmarked crossings are legal crossing locations that do not have any markings.
- **Intersection posted speed limit-** Speed limit is considered in this methodology as shown in the **Figure 16** and **Table 6.** For unmarked crossings at uncontrolled or unsignalized locations, the highest speed limit of any approach is applied to determine if the crossing has an intersection-wide speed greater or less than 25 miles per hour.
- **Crossing distance-** GIS data currently only includes the number of through lanes a pedestrian must cross to reach the other side of the street. In the future, more comprehensive data regarding medians may allow for crossings to be evaluated as one or two stage crossings. For now, the crossing distance is the entire length of the crossing. To account for higher pedestrian stress when pedestrians cross a further distance than the number of travel lanes would suggest (e.g., due to bike lanes, turn lanes, or parking lanes), a crossing distance value, the "XD value," is considered for marked crossings. The XD value is the ratio of crossing distance to number of lanes. This ratio was multiplied by lane width, assuming 8 foot lane width for residential streets and 11 feet for all other street classifications.

Each crossing can be categorized and evaluated as described. **Figure 16** shows the work flow and **Table 6** includes a lookup table for each of the crossing types.

- **Uncontrolled unmarked crossings-** are low-stress if the crossing distance is 3 lanes or fewer and the highest posted speed limit of any approach is 25 mph or less. This correlates to LTS 2 (high comfort) per the segment methodology for mixed traffic. If the crossing does not meet these criteria, then it is considered LTS 4 (low comfort).
- **Controlled signalized unmarked crossings-** are always LTS 4 (low comfort), under the

assumption that pedestrian crossing markings at a signalized intersection are required to create a low-stress pedestrian environment.

• **Controlled unsignalized unmarked crossings-** are low-stress if the crossing distance is 3 lanes or fewer and the highest posted speed limit of any approach is 35 mph or less. This correlates to LTS 2 (high comfort) per the segment methodology for detached sidewalks. If the crossing does not meet these criteria, then it is considered LTS 4 (low comfort).

• **Uncontrolled marked crossings, Controlled unsignalized marked crossings, Controlled signalized marked crossings -** follow the look up table based on the City's Pedestrian Crossing Treatment Installation Guidelines as shown in **Table 6.**

Figure 16. Crossing Methodology Workflow

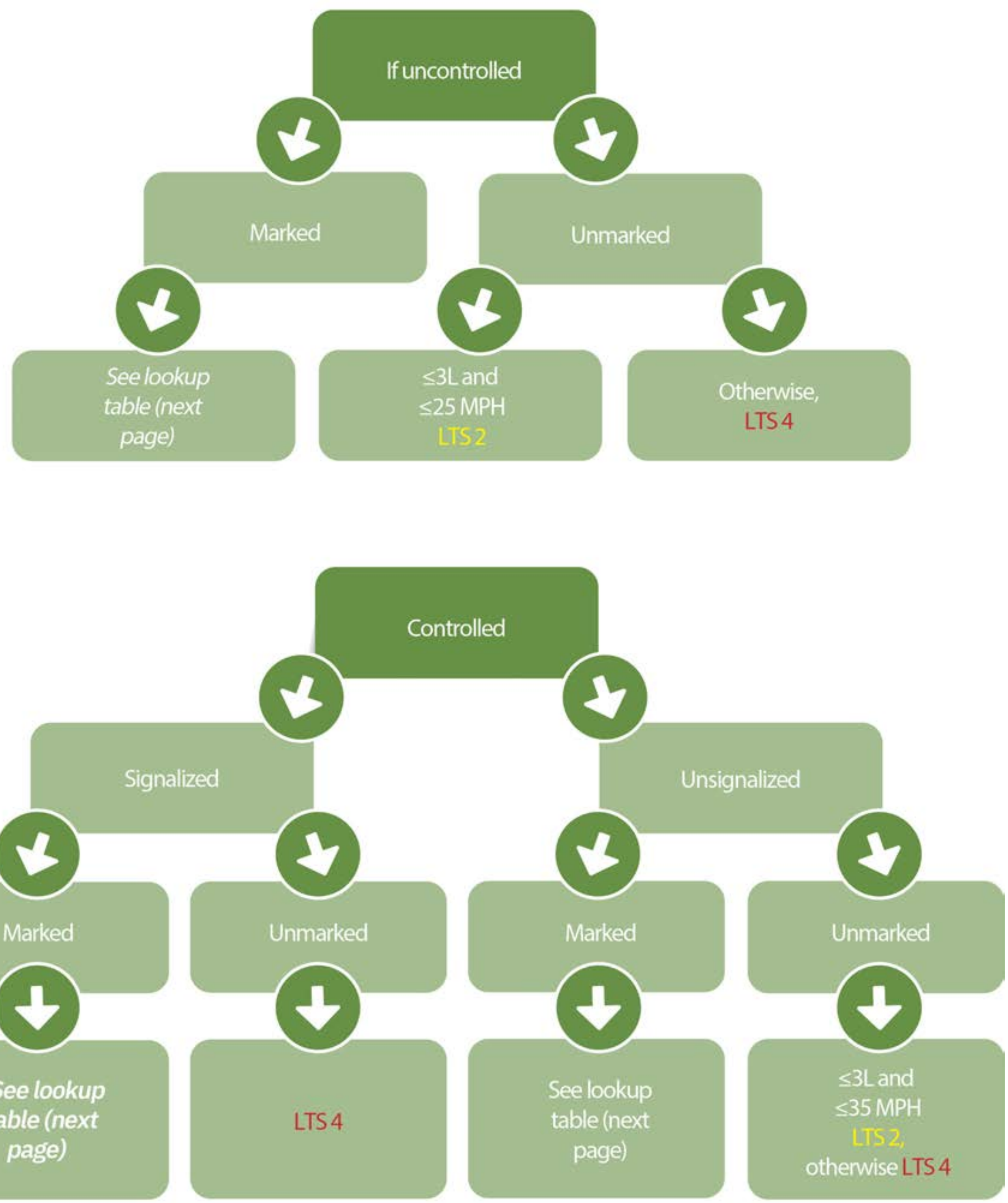


TABLE 6. LTS LOOKUP TABLE FOR MARKED CROSSINGS

Roadway Configuration	≤25 mph	30 mph	35 mph	40 mph	≥45 mph
2L (one way street); XD does not affect	2	2	2 w/ signal/stop, 3 w/ RRFB, 4 w/ out	2 w/ signal/stop, 3 w/ RRFB, 4 w/ out	3 w/ signal/stop, 4 w/out
2L & XD<1.4	1	2	2	2 w/ signal/stop, 3 w/ RRFB, 4 w/ out	3 w/ signal/stop, 4 w/out
2L & XD ≥1.4 [ed. - 3L]	2	2	2 w/ RRFB or signal/stop, 4 w/out	2 w/ signal/stop, 3 w/ RRFB, 4 w/ out	3 w/ signal/stop, 4 w/out
4L & XD<1.4	2 w/ RRFB or signal/stop, 4 w/out	2 w/ RRFB or signal/stop, 4 w/ out	2 w/ signal/stop, 3 w/ RRFB, 4 w/ out	2 w/ signal/stop, 3 w/ RRFB, 4 w/ out	3 w/ signal/stop, 4 w/out
4L & XD ≥1.4 [ed. - 5L]	2 w/ signal/stop, 4 w/out	2 w/ signal/stop, 4 w/out	3 w/ signal/stop, 4 w/out	3 w/ signal/stop, 4 w/out	3 w/ signal/stop, 4 w/out
5L (imbalanced), 6L +; XD does not affect	3 w/ signal/stop, 4 w/out	3 w/ signal/stop, 4 w/out	3 w/ signal/stop, 4 w/out	3 w/ signal/stop, 4 w/out	3 w/ signal/stop, 4 w/out

*Non-Residential XD = crossing distance/(11' x L); where L = number of lanes

*Residential XD = crossing distance/(8' x L); where L = number of lanes

**Crossing speed taken as the maximum speed present at an intersection

Figure 17. Crossing Locations: Existing Conditions

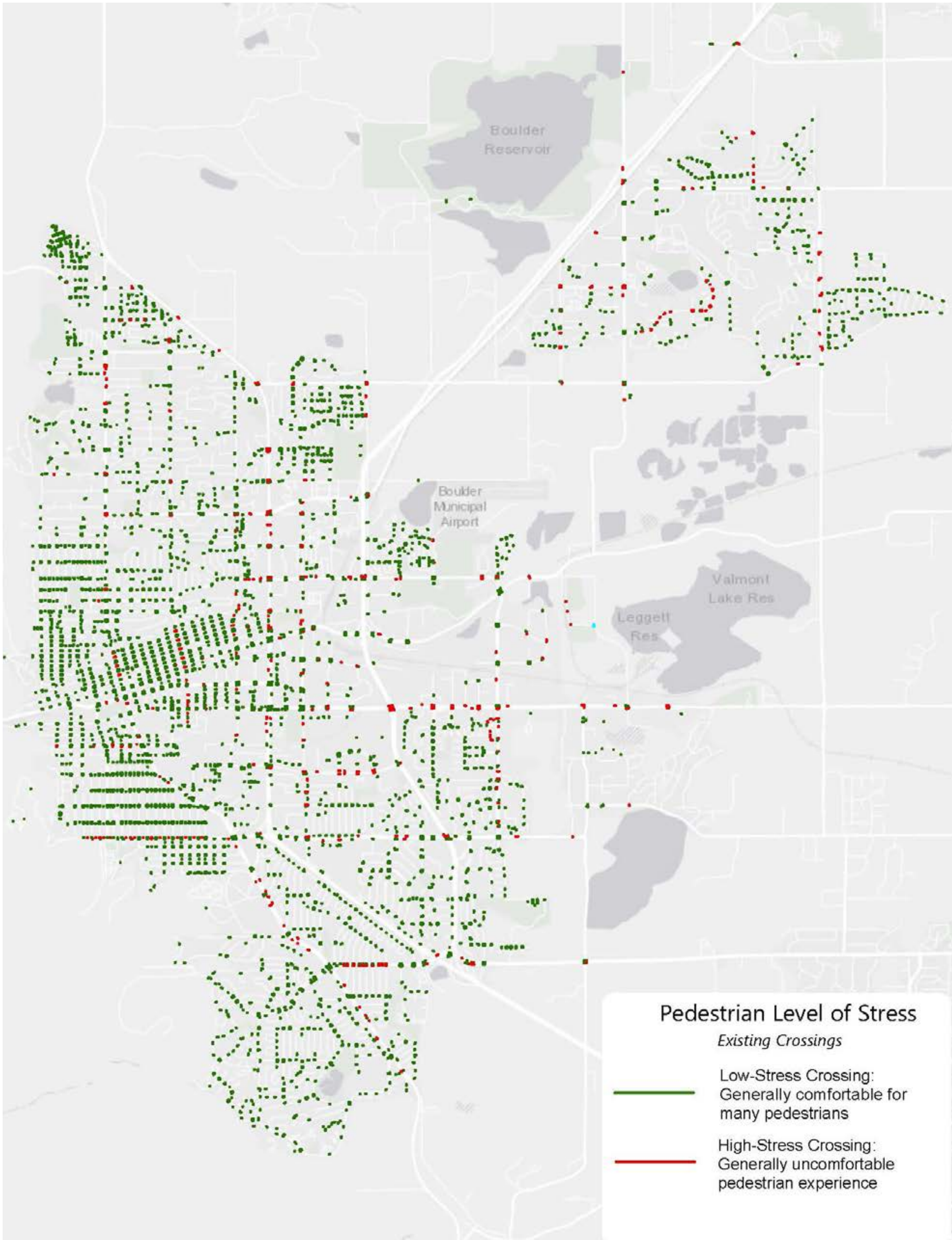
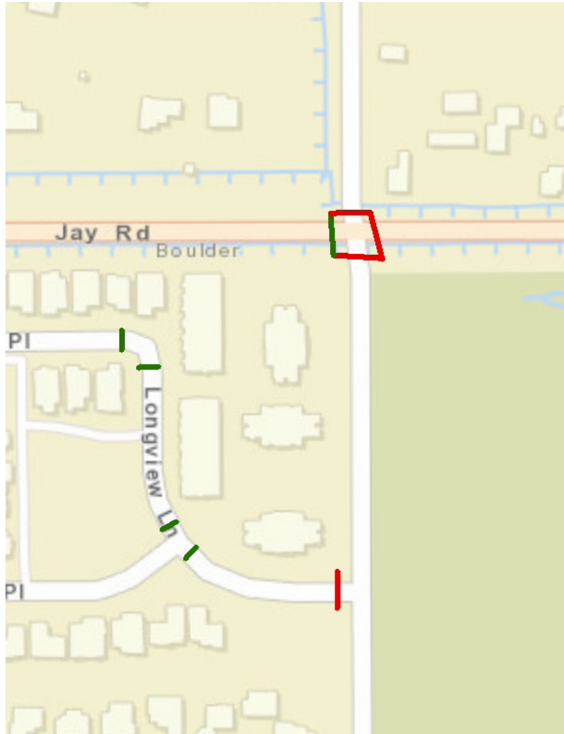


Figure 18. Crossing Locations: Calibration Site Examples

11th Street and Walnut Street



Jay Road and 47th Street

Standford Avenue and Table Mesa Drive

30th Street and Valmont Road

Calibration Sites

The zoomed extents in **Figure 18** highlight a few of the calibration sites used to validate the crossing LTS methodology, comparing the LTS scores of crossings at eleven different intersections to expectations from staff and members of the Pedestrian Advisory Committee (PAC). The calibration crossing locations and results are shown in **Table 7.** The calibration sites include examples from each crossing type—a combination of controlled and uncontrolled, signalized and unsignalized, and marked and unmarked crossings. Instances where the methodology called for the consideration of the number of lanes and the highest intersection approach posted speed limit are noted.

TABLE 7. CROSSING METHODOLOGY CALIBRATION SITES

Street 1	Street 2	Leg	Controlled/ Uncon-trolled	Other Treatments	Through Lanes	XD Value	Max Posted Speed at Inter-section (mph)	Low-stress/ High Stress Estimates
4th	Mapleton	North	Controlled	Stop sign (at intersection)	2	2.6	25	Low
		West	Controlled	Stop sign (at intersection)	2	2.8	25	Low
11th	Canyon	East	Uncontrolled	RRFB	4	1.5	35	High
11th	Walnut	North	Controlled	Signal (at intersection)	2	2.2	20	Low
		West	Controlled	Signal (at intersection)	2	2.2	20	Low
19th	Norwood	South	Uncontrolled	Signing/Striping	2	2.3	30	Low
28th	Pearl	North	Controlled	Signal (at intersection)	4	2.2	35	High
		East	Controlled	Signal (at intersection)	4	2.0	35	High
30th	Valmont	South	Controlled	Signal (at intersection)	4	1.7	35	High
		East	Controlled	Signal (at intersection)	4	1.7	35	High
Arapahoe	Cones-toga	North	Controlled	Signal (at intersection)	2	1.8	45	High
		East	Controlled	Signal (at intersection)	6	1.3	45	High
Broadway (N/S)	Dart-mouth	North	Controlled	Signal (at intersection)	6	1.2	40	High
		East	Controlled	Signal (at intersection)	2	1.5	40	Low
Broadway	Quince	North	Controlled	Signal (at intersection)	2	2.1	35	Low
		East	Controlled	Signal (at intersection)	2	1.5	35	Low
Jay	47th	South	Controlled	Signal (at intersection)	2	2.3	40	High
		West	Controlled	Signal (at intersection)	2	2.2	40	Low
Stanford (N/S)	Table Mesa	North	Controlled	Stop sign (at intersection)	2	2.3	35	Low
		East	Uncontrolled	Signing/Striping	4	2.5	35	High

Future Crossing Methodology Inputs and Updates

Future updates to this methodology can incorporate additional criteria based on data that may become available. Feedback from the public engagement process was useful for identifying these inputs as potential future considerations for city-wide analyses and as additional considerations for projects. Additional assessments in the future or on a project by project basis could consider the following inputs:

- **Traffic Volumes** – Average daily traffic volumes or peak hour volumes should be incorporated into the methodology should this data become available city-wide. Technological advances of Big Data, through companies such as INRIX or StreetLight Data, make this data increasingly available, though unlikely for all local roads to be included in this type of data. Currently, the number of travel lanes serves as a proxy for traffic volumes.

- **Turn Lanes -** Currently, only the number of through lanes at an intersection is consistently available. If data becomes available for the total number of lanes at each crossing, including turn lanes, the methodology should be updated to consider the total number of through and turn lanes. Currently, crossing distance and the number of lanes together serve to approximate turn lanes and other uses within the curb to curb width (e.g., on-street parking, bike lanes, etc.) that influence crossing distance and comfort. Turn lane data would change how an XD value is considered in this methodology.

- **Median Width -** City-wide GIS data on median presence and width would allow the methodology to consider the change in comfort provided by the presence of a wide median. The median width at which the crossing of a roadway is considered two distinct crossings will vary depending on roadway characteristics. The presence of a median of qualifying width allows pedestrians to cross the street comfortably in two stages and wait at the median between crossings. The current methodology does not account for median presence and width, as the data is not sufficient to comprehensively consider its influence on pedestrian comfort.

- **General Luminance and Pedestrian -** The luminance of an area is influential in pedestrian comfort. The incorporation of both general luminance and pedestrian-scale lighting would allow the Level of Traffic Stress scores to more accurately reflect pedestrian comfort during different times of the day. This would require comprehensive GIS data on the lighting levels at crossings and the effectiveness of pedestrian-scale lighting.

- **Sidewalk Condition –** Data documenting the sidewalk condition at each crossing would include an inventory of surfacing issues such as cracks, holes, sidewalk displacement, and surface deterioration, as well as the presence of obstructions. Temporary and permanent obstructions, such as vegetation, perpendicular curbs, and utility poles, can pose navigability and comfort challenges for some pedestrians, particularly those in a wheelchair or using a mobility device. Curb ramp data can also be incorporated into an assessment on the condition of the sidewalk. This would include the presence of curb ramps, as well as their quality, usability, and ADA-compliance.

- **Leading Pedestrian Intervals ("Pedestrian Head Starts") and Signal Timing –** Leading pedestrian intervals (LPIs)—also called "Pedestrian Head Starts"—are treatments at an intersection that give pedestrians a 3 to 7 second head start in advance of the green signal for vehicles. Currently, GIS comprehensive data of the presence of leading pedestrian intervals is limited. In the future, the presence of a leading pedestrian interval can have the potential to reduce the Level of Traffic Stress score by one point, moving some crossings potentially from LTS 3 to LTS 2, and thus changing its designation from low to high comfort.

- **Turning Operations -** Data on if left turns are permissive or protected, and if right turns on red are allowed, could provide additional details about the way signal operations and vehicle turning movements impact pedestrian comfort.

- **Turning Speed and Travel Speed –** In the current methodology, the posted speed limit serves as a proxy for vehicle travel speed on a roadway. If actual travel speed (including turning speed) data becomes comprehensively available, it could be incorporated into the methodology to give a better sense for how pedestrian comfort is influenced by vehicular travel speed in both the through lanes and the turning lanes. Both right and left turning vehicles at intersections with permitted control potentially conflict with crossing pedestrians, thus creating a strong correlation between turning speed and pedestrian comfort.

- **Geometric Design Elements –** Design elements influence the comfort of pedestrians at crossings. Particularly, curb radii as well as any additional vertical and horizontal separation from vehicles at the termini of a crossing influence pedestrian comfort. These features can alter the pedestrian comfort even when other factors, such as posted speed limit, are held constant.

Pedestrian Improvement Area and Neighborhood GreenStreet Implementation

This methodology focuses on identifying areas with the highest potential for improvements to increase walking access (based on key destinations and identification of key gaps). These areas or segments were then identified as Pedestrian Improvement Areas or Neighborhood GreenStreets, as shown in **Figure 3.**

These have been integrated into the 2019 Pedestrian Plan. Subsequent to plan adoption each area will be studied in detail and improvements recommended. These could include building new sidewalk, upgrading existing sidewalks and curb ramps to meet ADA requirements, new pedestrian crossings and/or enhancements to existing crossings, lighting, other amenities, and wayfinding. While the structure of each study will be similar, the identified improvements will be specific to each area and developed working with the community. It is the intent to study and implement improvements in all 13 PIAs by 2030.

In addition to these areas, Neighborhood GreenStreet corridors have been identified and are described in more detail. Similar to the PIAs, corridors will be studied and improvements identified and implemented by 2030.

The proposed areas and corridors also increase the proportion of 15-minute neighborhoods in Boulder. In a 15-minute neighborhood, people can access their basic needs and non-work errands (parks, food, etc.) within 15-minutes via walking. This plan was developed with the guidance of a community-based Pedestrian Advisory Committee.

The next two steps in implementing the Pedestrian Improvement Areas and Neighborhood GreenStreets identified as an outcome of this process are:

1. Prioritization of PIAs and NGs
2. Determination of planning-level costs

Having a list of prioritized projects helps to build projects into budgets and streamlines the implementation process as funding becomes available.

Pedestrian Improvement Area and Neighborhood GreenStreet Prioritization

The Pedestrian Improvement Areas and Neighborhood GreenStreets were prioritized based on four inputs—crashes, key destinations, equity index, population and employment densities. Each input was given a score for each project based on how well the project addresses the input, with higher scores representing that the project is more relevant to the input. The input scores were summed together, and then projects were ranked based on summed scores. The four quantifiable, geospatial inputs were:

• **Crashes-** City of Boulder crash data from 2015 to 2017 was used to prioritize projects. The crash data includes information on crash severity, and specifies when bicyclists or pedestrians are involved. For pedestrian projects, pedestrian-involved, bicyclist-involved, and killed or seriously injured (KSI) crashes were weighted. The highest consideration was given to projects with the most crashes, weighted for pedestrian-involved crashes.

• **Key destinations-** The following key destinations were included based on how many total destinations were within a Pedestrian Improvement Area or within a quarter mile buffer of the Neighborhood GreenStreet. Other destination categories were considered, but these three most consistently lined up with match public input, research on walking and biking destinations, and geospatial city-wide data was available for use at the time of development.

- Parks
- Schools
- High-frequency transit stops - defined as stops along transit routes with 15-minutes or greater frequency

• **Equity Index-** The equity index was developed by the City of Boulder as a separate effort to show the variance in different locations, divided by Census tract, to represent underserved populations. Projects that serve underserved populations have a higher score in this prioritization input. Populations considered as underserved, as defined by the equity index, consist of the following:

- % population with a disability
- % families living below the poverty level
- % households with no vehicle
- % non-white population
- % population under 17 or over 65 years old

•**Population and Employment Density-** The population and employment density within or around a project serves as an input in the prioritization methodology. The higher the density within PIAs and around NGs, the higher the input score these projects received.

Context Sensitive Adjustments

The prioritization inputs described in the previous section provide an initial prioritization of PIAs based on quantifiable, geospatial information. Subsequent to this plan, this prioritization will be reviewed and refined based on qualitative considerations and inputs, such as public input, professional judgment, cost-effectiveness, and the potential to leverage other ongoing projects. The primary reason for adjusting prioritization was to account for potential project synergies, where completing one project will increase the potential benefits of an adjacent project, or where two projects need to be implemented together to fully fill a key gap. Public input will include feedback from the Pedestrian Advisory Committee, as well as related feedback as a part of other ongoing public engagement efforts. Professional judgment includes adding insight about political or engineering efficiencies or barriers to project implementation. **Figure 5** and **Figure 6** show the draft prioritization to be further refined, considering potential project synergies.

Pedestrian Improvement Area and Neighborhood GreenStreet Cost Assessment

Each of the thirteen Pedestrian Improvement Areas and segments of Neighborhood GreenStreets were assigned costs based on expected improvements. **Table 8** includes the list of prioritized PIAs and costs associated with each. For Pedestrian Improvement Areas, a planning-level cost was estimated based on the existing infrastructure in the area. At this point in the process, it is assumed the average cost of a PIA is about $750,000. This is derived from rounding up the average of the estimated costs for the thirteen specific PIAs, to be conservative. For Neighborhood GreenStreets, an estimated cost is dependent on the types of potential improvements necessary for any given GreenStreet. The cost variance for Neighborhood GreenStreets is high given the small scale of some and the varied segmentation, but costs per project can be estimated with further study. The conversation is ongoing about how Neighborhood GreenStreets and Pedestrian Improvement Areas can move the pedestrian environment towards ADA compliance. These costs do not yet include potential costs to bring the pedestrian environment fully up to ADA compliance. The three categories of improvements included in the cost estimates are:

- **Sidewalks-** Sidewalk costs were estimated based on whether upgrades to existing sidewalks were being proposed or new sidewalks were being proposed.
- **Crossing Treatments-** Crossing treatments were assigned based on anticipated number of crossing improvements in three categories: Signals, Rapid Rectangular Flashing Beacons (RRFBs), and Signing and Striping Only Projects. This was derived from existing crossing spacing along a corridor or in an area, and looking at how already approved or underway crossing improvements change crossing spacing, and considering this is as more ideal spacing.
- **Curb Ramps-** The number of needed curb ramp installments or improvements was calculated into the overall cost, based on area curb ramp completion rate estimates. Curb ramp completion rates were developed through the ongoing ADA data collection and improvement efforts.

TABLE 8. COST ESTIMATE FOR EACH PEDESTRIAN IMPROVEMENT AREA			
Priority Rank	**Letter Symbol**	**PIA Name**	**Cost Estimate**
1	E	Village Shopping Center	$1,014,000
2	G	30th & Colorado	$1,088,000
3	H	Williams Village	$888,000
4	F	CU East Campus/ Office Park	$2,152,000
5	B	28th & Diagonal	$828,000
5	J	Foothills & Baseline	$832,000
7	K	Table Mesa	$3,085,000
8	L	Table Mesa Park-n-Ride	$397,000
9	D	North Boulder Park	$230,000
10	C	Orchard Grove	$247,000
11	A	North Broadway	$974,000
12	M	Gunbarrel	$1,334,000
13	I	55th Street	$325,000

Figure 5. Prioritized Pedestrian Improvement Areas

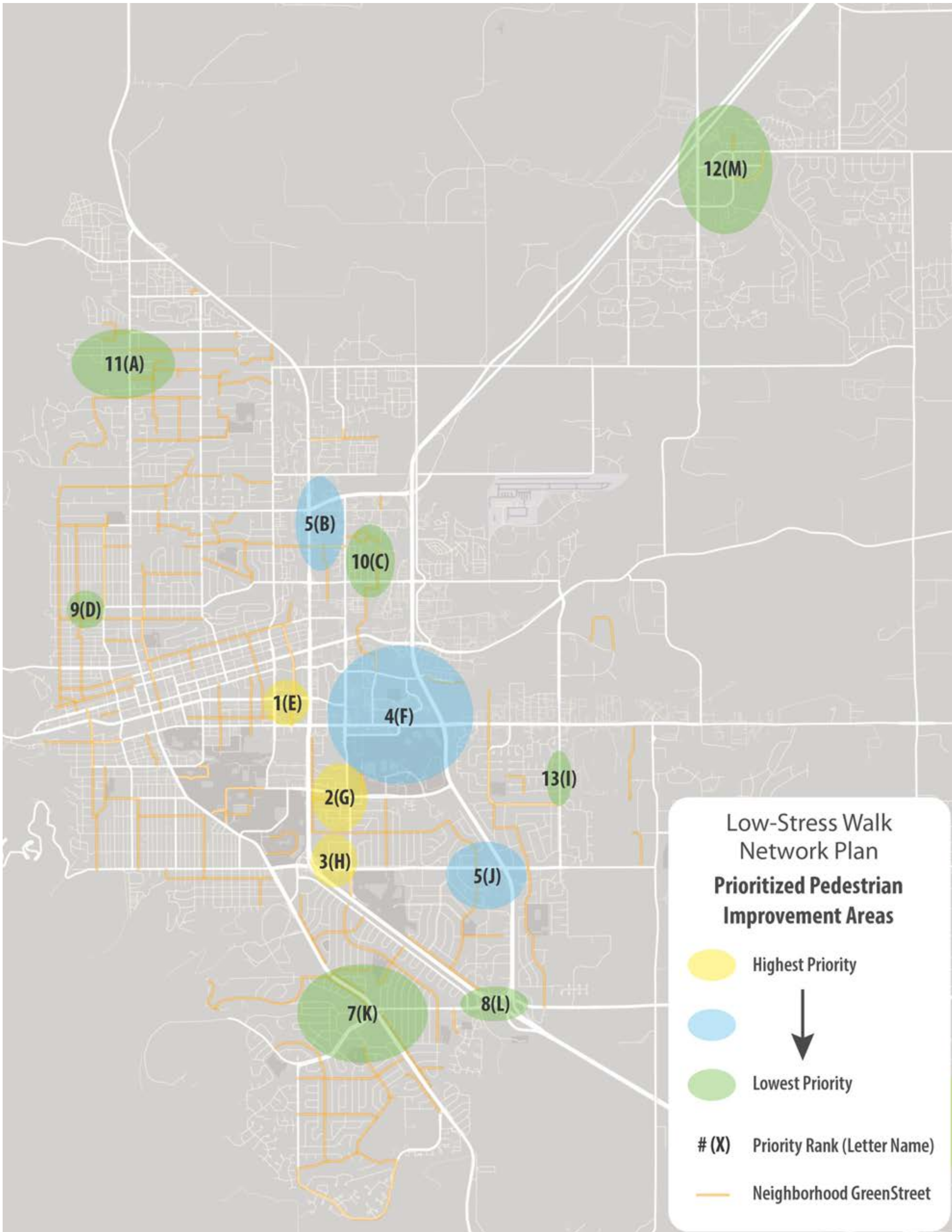


Figure 6. Prioritized Neighborhood GreenStreets

LOW-STRESS BIKE NETWORK PLAN

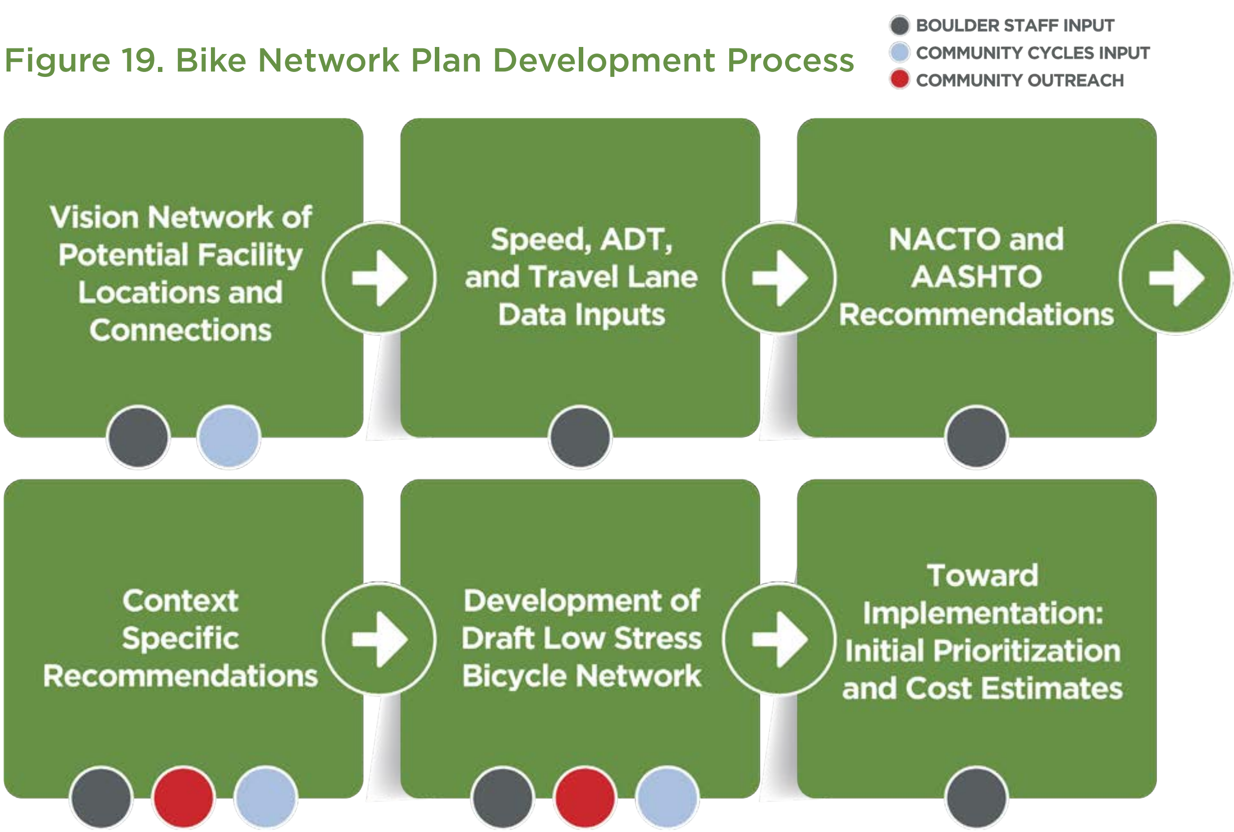
The Low-Stress Bike Network Plan serves as a supplement to the City of Boulder's 2019 Transportation Master Plan. The plan recommends various bike facilities (Neighborhood GreenStreets (NGs), bike lanes (preferably buffered) (BBLs), and vertical separation projects) to make bicycling throughout Boulder comfortable and seamless. Each project has been prioritized with a potential cost range assigned to it, to serve as a first step in the implementation process.

The 2014 Transportation Master Plan (TMP) introduced the concept of a "low-stress" bike network ("Bike 2.0") with a focus on accommodating riders from 8 to 80 years of age—especially women, older adults, and families with children. The idea of developing a network of comfortable facilities for people of all ages and abilities to bike was later expanded to include walking and access to transit.

Although Boulder already has a well-developed network of facilities for people biking relative to many United States cities, it is important to recognize that even one small "high-stress" location can change a person's choice of route or could deter them from choosing to walk or bike at all, especially if children are involved.

In contrast to walking, bicycle trips are typically longer—generally anywhere from under a mile to

Figure 19. Bike Network Plan Development Process



more than five miles round trip. Because of this, the desired bicycle network will be a system of longer East-West and North-South routes that extend across town.

To develop the Bike Vision Network, staff reviewed:

- Characteristics of existing facilities, including comfort level, as determined by the Bicycle Network Analysis within the People for Bike's City Snapshot Program
- User data from a prominent cyclist app (Strava) and the City of Boulder's permanent bike counters
- Locations of transit stops and other key activity centers
- Community comments on where users like/do not like to bike and why

Bike Vision Network

The purpose of creating a Low-Stress Bike Network, shown in **Figure 4**, is to be specific in identifying the types and locations of facilities needed to meet the goal of creating comfortable facilities for people of all ages and abilities to bike throughout Boulder. The process for developing this plan is outlined in **Figure 19**. The initial step to arrive at a Low-Stress Bike Network was the development of a Vision Network, as shown in **Figure 20,** that identifies the network of all streets to include in the network that are recommended to become low-stress facilities for biking.

Facility Type Selection

The next step after the development of the Vision Network was to determine the appropriate facility type for each street in the Vision Network based on national research and local context. As shown in **Figure 2,** there are three primary types of proposed bicycle facilities—Neighborhood GreenStreets (NGs), bike lanes (preferably buffered (BBLs)), and vertical separation projects (multi-use path and/or separated bike lanes). The Low-Stress Bike Network Maps also include proposed multi-use paths. The facility types can be seen in the visual glossary shown in **Figure 21.**

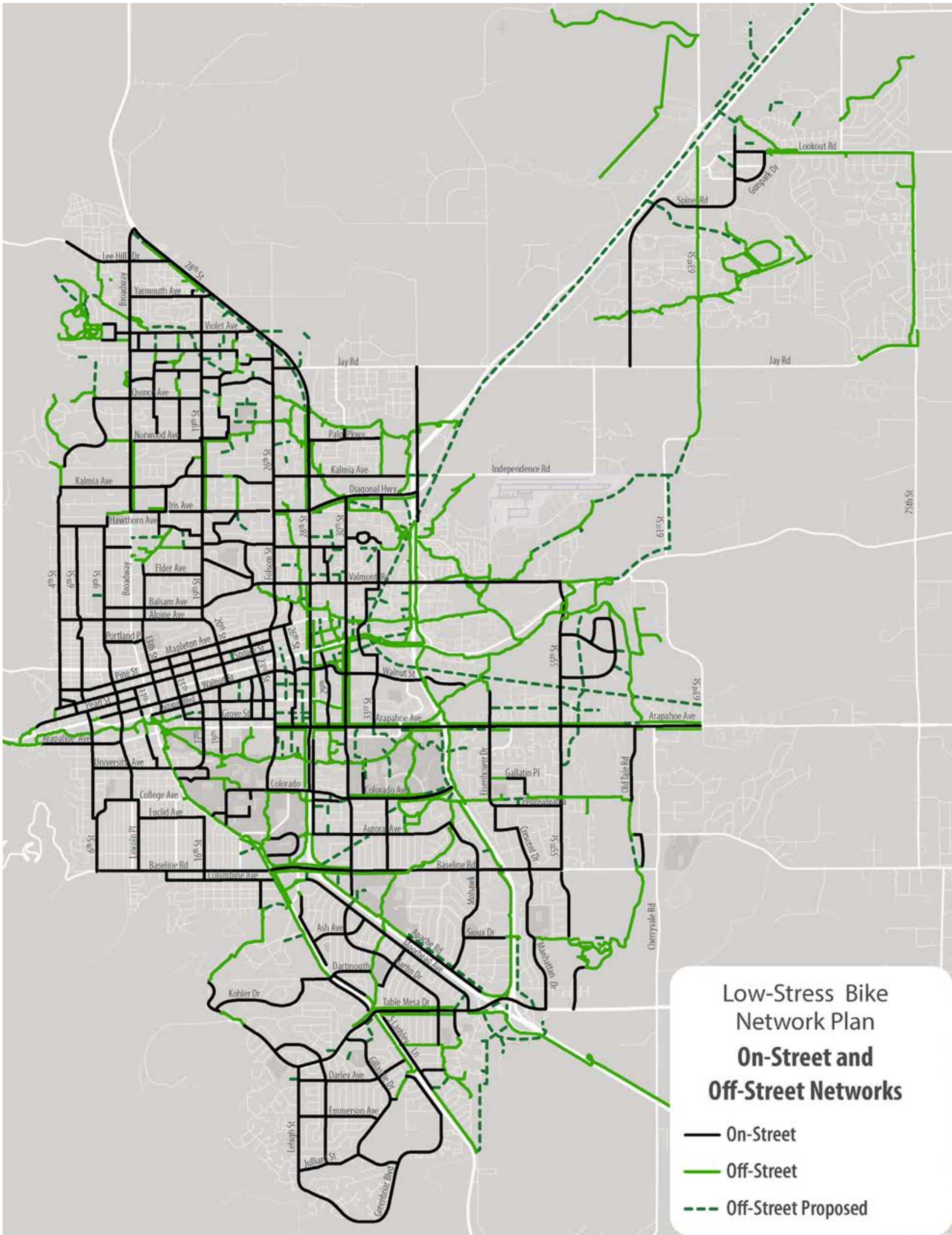
Guidance from the National Association City of Transportation Officials (NACTO) and American Association of State Highway and Transportation Officials (AASHTO) was used to determine the appropriate facility type based on street characteristics. The recommended facility type may change based on changes to average daily traffic and vehicle speed. Data will be collected and studied prior to implementing improvements to ensure the current recommended facility is still relevant. If not, an alternative facility may be more desirable in order to achieve the low stress condition. **Table 9** compares the NACTO and AASHTO recommendation for facility type based on roadway speed, average daily traffic (ADT), and number of travel lanes. This table highlights where the two sources point to different recommendations under the same input assumptions. Posted speed limit and travel lane data were available through city-wide street centerline data. Average daily traffic data was available for some roadways through City of Boulder and Denver Regional Council of Governments (DRCOG). City staff provided ADT estimations for streets where data was not readily available and indicated streets definitively above the 10,000 vehicle per day threshold. **Figure 22** and **Figure 23** show the ADT input sources and the volumes, categorized in line with thresholds provided by national guidance. **Figure 24** and **Figure 25** show the proposed facility types under NACTO and AASHTO guidance, respectively.

TABLE 9. NACTO AND AASHTO FACILITY SELECTION COMPARISON

Speed Limit	ADT	Number of Lanes	NACTO	AASHTO
< 10	<=3000	<=2	NG	NG
< 10	>=3000 and <=6000	<=2	NG	BBL
< 10	>6,000	<=2	NG	PBL
>= 10 and <=20	<=2000	<=2	NG	NG
<= 25	<=1500	<=2	NG	NG
<=25	>=1500 and <=3000	<=2	BBL	NG
<=25	>=3000 and <=6000	<=2	BBL	BBL
<=25	>6,000	<=2	PBL	PBL
<=25	<=3000	>2	PBL	NG
<=25	>=3000 and <=6000	>2	PBL	BBL
<=25	>6,000	>2	PBL	PBL
=30	<=3000	<=2	PBL	BBL
=30	>=3000 and <=6000	<=2	PBL	BBL
=30	<=3000	>2	PBL	BBL
=30	>=3000 and <=6000	>2	PBL	BBL
=30	>6,000	<=2 or >2 (any)	PBL	PBL
>30	<=3000	<=2	PBL	PBL
>30	>=3000 and <=6000	<=2	PBL	PBL
>30	<=3000	>2	PBL	PBL
>30	>=3000 and <=6000	>2	PBL	PBL
>30	>6,000	<=2 or >2 (any)	PBL	PBL

Note: Gray highlight indicates where NACTO and AASHTO facility selection guidelines yield different results.

Figure 20. On-Street and Off-Street Bike Vision Network



Neighborhood GreenStreets

Neighborhood GreenStreets are streets with "low vehicle volumes and speeds, designed to prioritize and improve conditions for walking and bicycling. They are streets where people of all ages and abilities feel safe and comfortable."

To create this condition, the City of Boulder uses the following approach:

- Traffic calming and speed limits – provide neighbors along a GreenStreet corridor an opportunity to lower vehicle speeds to 20 mph through the installation of traffic calming treatments.
- Traffic diversion - should be considered if the street volume per each direction is greater than 2,000 vehicles per day and if it is feasible to divert this traffic to a higher classification street.
- Signing and pavement markings - to provide organizational, safety and wayfinding signs and markings for people walking, bicycling, and driving.
- Intersection design treatments – to prioritize and provide safe and comfortable opportunities for people walking and bicycling to cross busy streets.

Neighborhood GreenStreets, or Neighborhood "Greenways" are employed in many cities around the United States with the essential functions to provide low-cost, quick build, low-stress routes for people primarily bicycling, but also walking. Neighborhood GreenStreets can slightly differ in definition and approach from city to city. Boulder's approach will primarily utilize residential (local) streets without existing bicycle facilities but may also include minor collectors with bike facilities such as bike lanes (preferably buffered) to create longer North-South and East-West Neighborhood GreenStreet corridors. In some cases, sections of multi-use path may be used to connect two sections of a GreenStreet thereby extending the intended corridor.

Bike Lanes (Preferably Buffered)

A bike lane is separated from the general-purpose travel lane or parking lane by a single white line. A buffered bike lane is separated by the general-purpose lane by a pattern of standard cross hatch marks painted onto the roadway. Buffered bike lanes appeal to a wide cross-section of bicyclists, reduce the possibility of a wide bicycle lane being misconstrued as a travel or parking lane, and delineate a space between a parking lane and an adjacent bicycle lane. A buffer area provides a greater separation between the bicycle lane and adjacent travel lanes than is provided by a single normal or wide lane line. In some cases, achieving a buffered bike lane facility depends upon the removal of parking or the acquisition of additional right-of-way due to physically constrained space. These factors will be considered for each project to determine if providing a buffer is feasible. When installing buffered bike lanes, the inclusion of flexible bollards or other type of light protection may be considered to provide added vertical separation between the general-purpose lane and bike lane.

Vertical Separation (Separated Bike Lanes and Multi-use Paths)

Primarily intended for arterial streets with higher average daily vehicle traffic and vehicle speeds, this treatment places vertical elements in the buffer area of a bike lane to further separate bike lanes from motor vehicle traffic, providing comfort and safety to cyclists. Separation types range from simple, painted buffers with flexible delineators, to more substantial separation measures including raised curbs, grade separation, bollards, planters, and parking lanes. These options range in feasibility due to roadway characteristics, available space, and cost. In some cases, it may be possible to provide additional space in areas where pedestrians and bicyclists may interact, such as the parking buffer, or loading zones, or extra bike lane width for cyclists to pass one another.

Multi-use Path

Multi-use or shared–use paths provide low-stress environments for bicycling and walking that are entirely separated from motor vehicle traffic. Systems of shared–use paths in urban and suburban communities serve as the arterials of the bicycle and pedestrian transportation system and an extension of on-street facilities.

FIGURE 21. FACILITY TYPE VISUAL GLOSSARY

Vertical separation projects can include multi-use paths.

Vertical separation projects can include separated bike lanes.

Bike lanes are an on-street facility, a marked space designed for cyclists.

Bike lanes preferably have a marked buffer.

Neighborhood GreenStreets are low-volume streets prioritized for biking, through marking.

Neighborhood GreenStreets are low-volume streets prioritized for biking, through signage.

Figure 22. Average Daily Traffic (ADT) Input Source

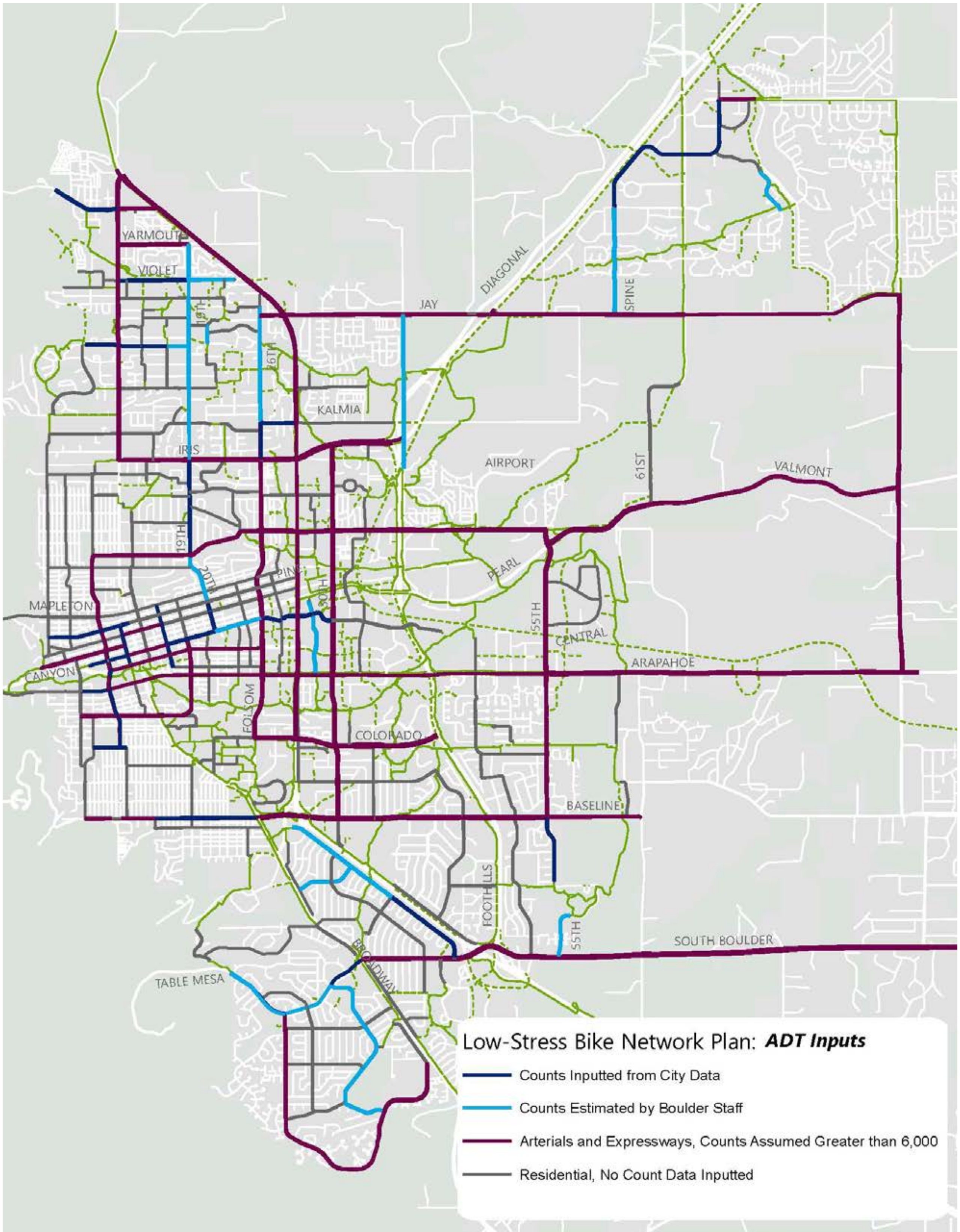


Figure 23. Average Daily Traffic (ADT) Volumes

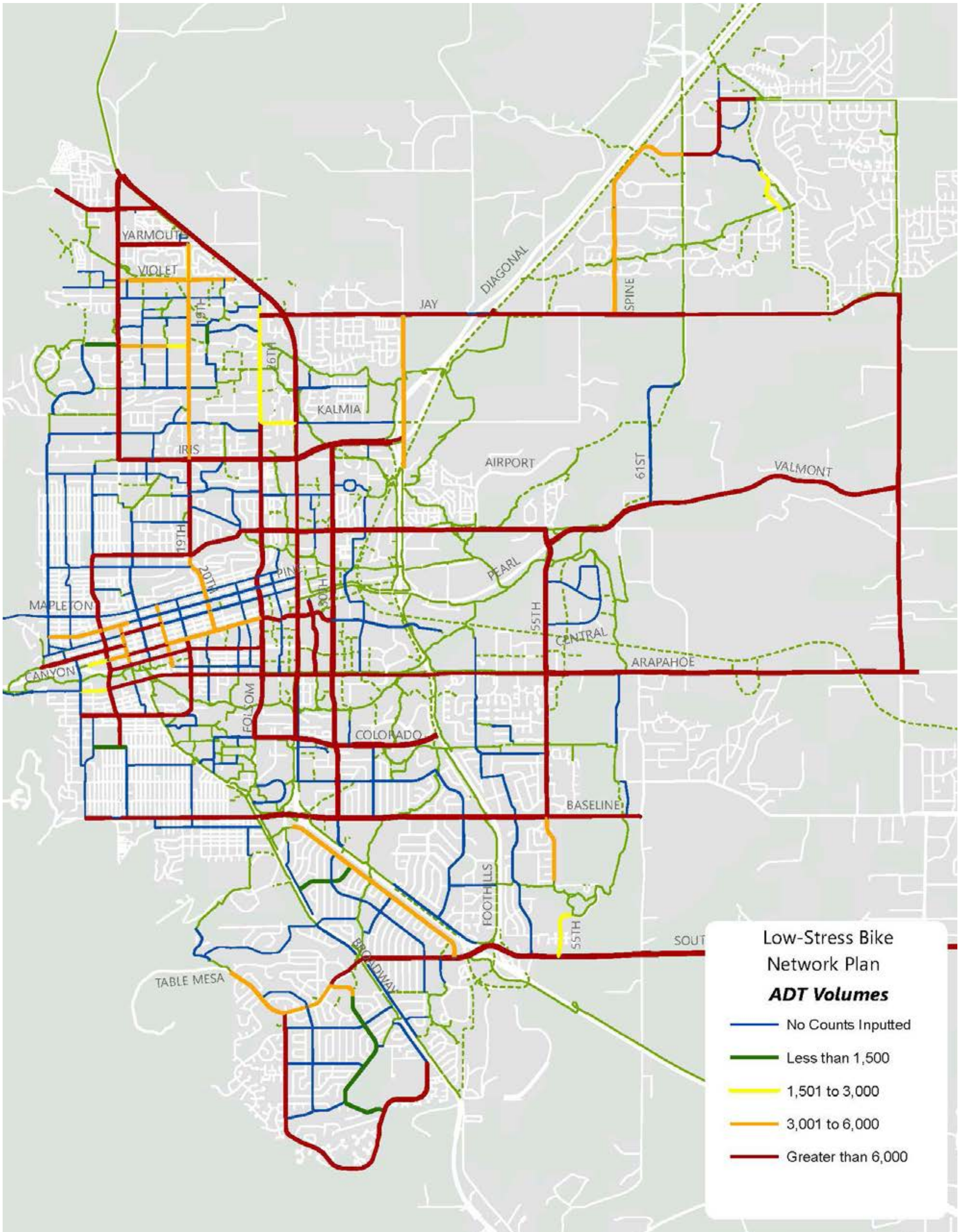


Figure 24. NACTO Facility Type Selection

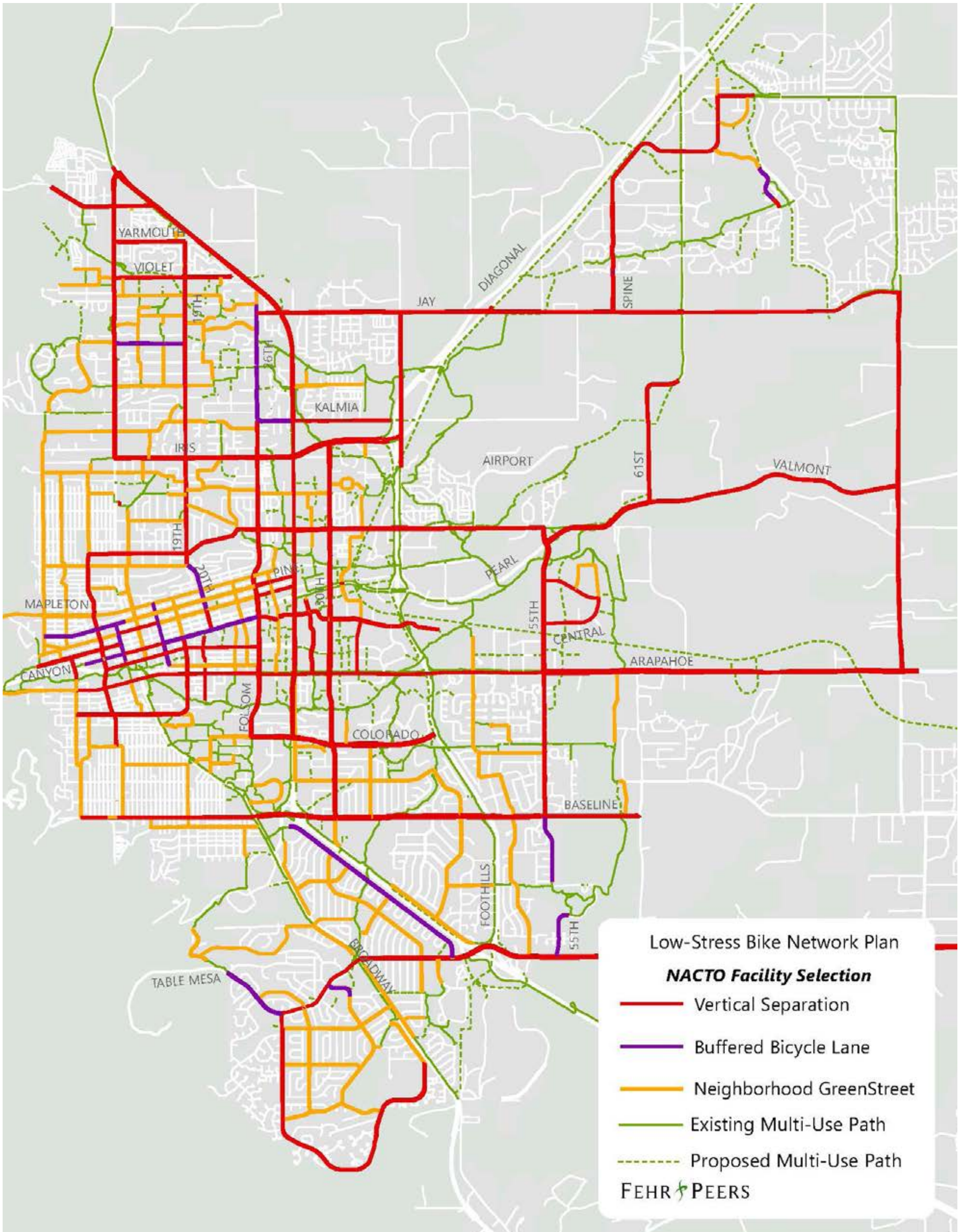
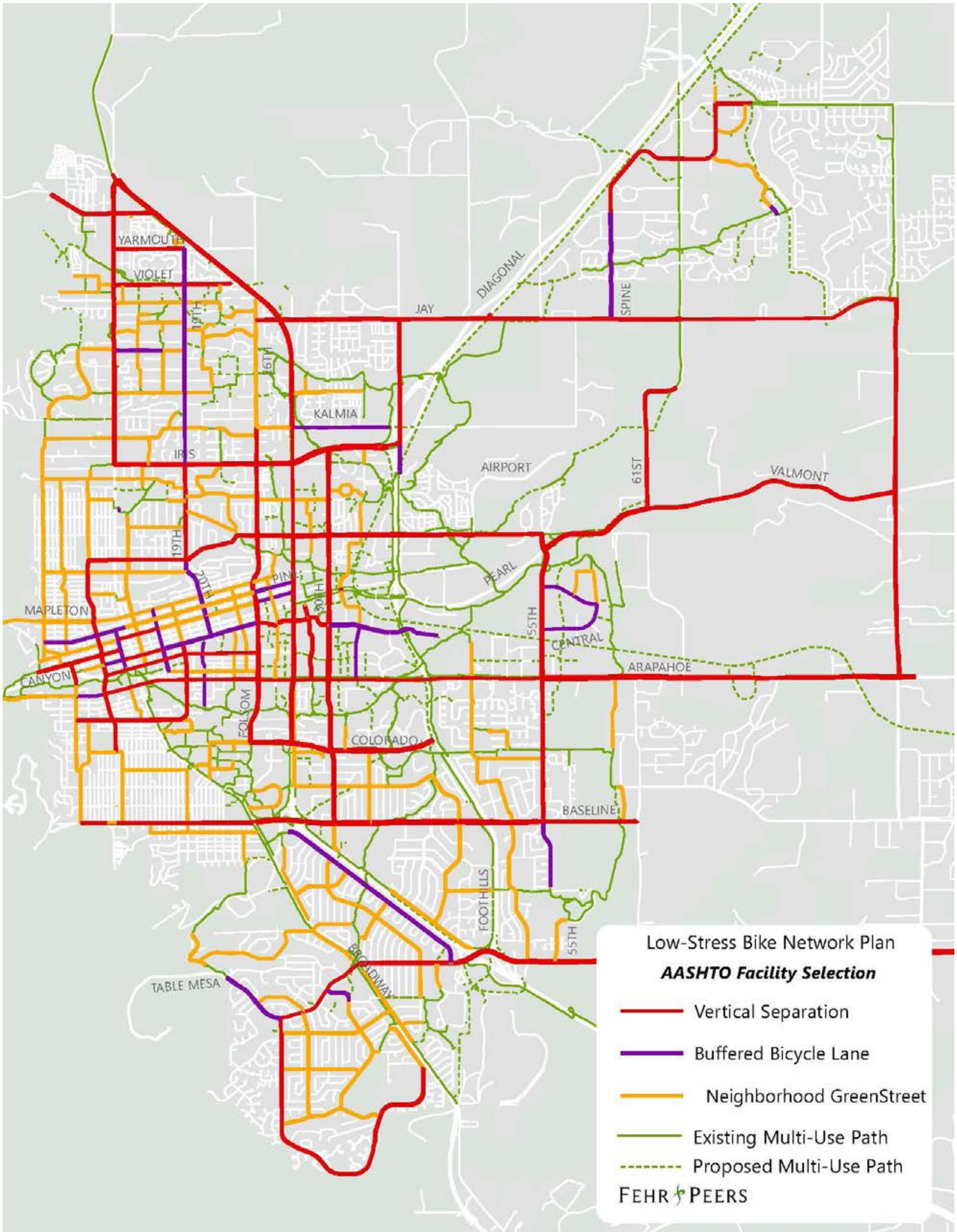


Figure 25. AASHTO Facility Type Selection



Bike Network Implementation

Two key steps in implementing the facilities identified in Bike Vision Network are prioritizing them, and understanding the cost for each.

Bicycle Project Prioritization

The Neighborhood GreenStreets, bike lanes (preferably buffered), and vertical separation projects (focusing on potential separated bike lanes) were prioritized based on four inputs—crashes, key destinations, equity index, population and employment densities. Each input was given a score for each project. Scoring was based on how well the project addresses the input, with higher scores representing that the project is more relevant to the input. The input scores were summed together, and then projects were ranked based on summed scores. The four quantifiable, geospatial inputs were:

- **Crashes-** City of Boulder crash data from 2015 to 2017 was used to prioritize projects. The crash data includes information on crash severity, and specifies when bicyclists or pedestrians are involved. For bicycle projects, pedestrian-involved, bicyclist-involved, and killed or seriously injured (KSI) crashes were weighted. Highest consideration was given to projects with the most crashes, weighted for bicyclist-involved crashes.

- **Key destinations-** The following key destinations were included in the prioritization based on how many were within a quarter mile of the Neighborhood GreenStreet or BBL. Other destination categories were considered, but these three most consistently lined up with match public input, research on walking and biking destinations, and geospatial city-wide data that was available for use at the time of development.
    - Parks
    - Schools
    - High frequency transit stops - defined as stops along transit routes with 15-minutes or greater frequency

- **Equity Index-** The equity index was developed by the City of Boulder as a separate effort to show the variance in different locations, divided by Census tract, to represent underserved populations. Projects that serve underserved populations have a higher score in this prioritization input. Populations considered as underserved, as defined by the equity index, consist of the following:
    - % population with a disability
    - % families living below the poverty level
    - % households with no vehicle
    - % non-white population
    - % population under 17 or over 65 years old

- **Population and Employment Density-** The population and employment density within or around a project serves as an input in the prioritization methodology. The higher the density within or around NGs, BBLs, and vertical separation projects, the higher the input score these projects received.

Context Sensitive Adjustments

The inputs described provide quantifiable, geospatial information to prioritize projects. Qualitative considerations and inputs were used to refine the list of prioritized projects. These include public input, professional judgment, and cost efficiency, considering potential project synergies. The primary reason for adjusting prioritization is to account for potential project synergies, where completing one project will increase the potential benefits of an adjacent project- or where two projects need to be implemented together to fully fill a key gap, or reach a key destination.

Bicycle Project Costs

A cost per mile estimate can be used to understand how to install the proper infrastructure for each bike facility type. The cost per mile comes from a more detailed assessment of cost, often based on a cost per linear foot. This is true for Neighborhood GreenStreets and buffered bike lanes, which accounts for the on-street treatment along streets and at intersections or other crossings. The recently developed 13th Street Neighborhood GreenStreet was helpful to calibrate this approach and to understand the potential elements that make up a Neighborhood GreenStreet. Vertical separation projects have more variance in cost per project, built into the project cost contingency.

The estimated costs per mile are as follows:

- Neighborhood GreenStreet - $50K per mile
- Bike Lanes (Preferably Buffered) - $215K per mile
- Vertical Separation (Separated Bike Lanes or Multi-Use Paths) - $9.5M per mile

Figure 6. Prioritized Neighborhood GreenStreets

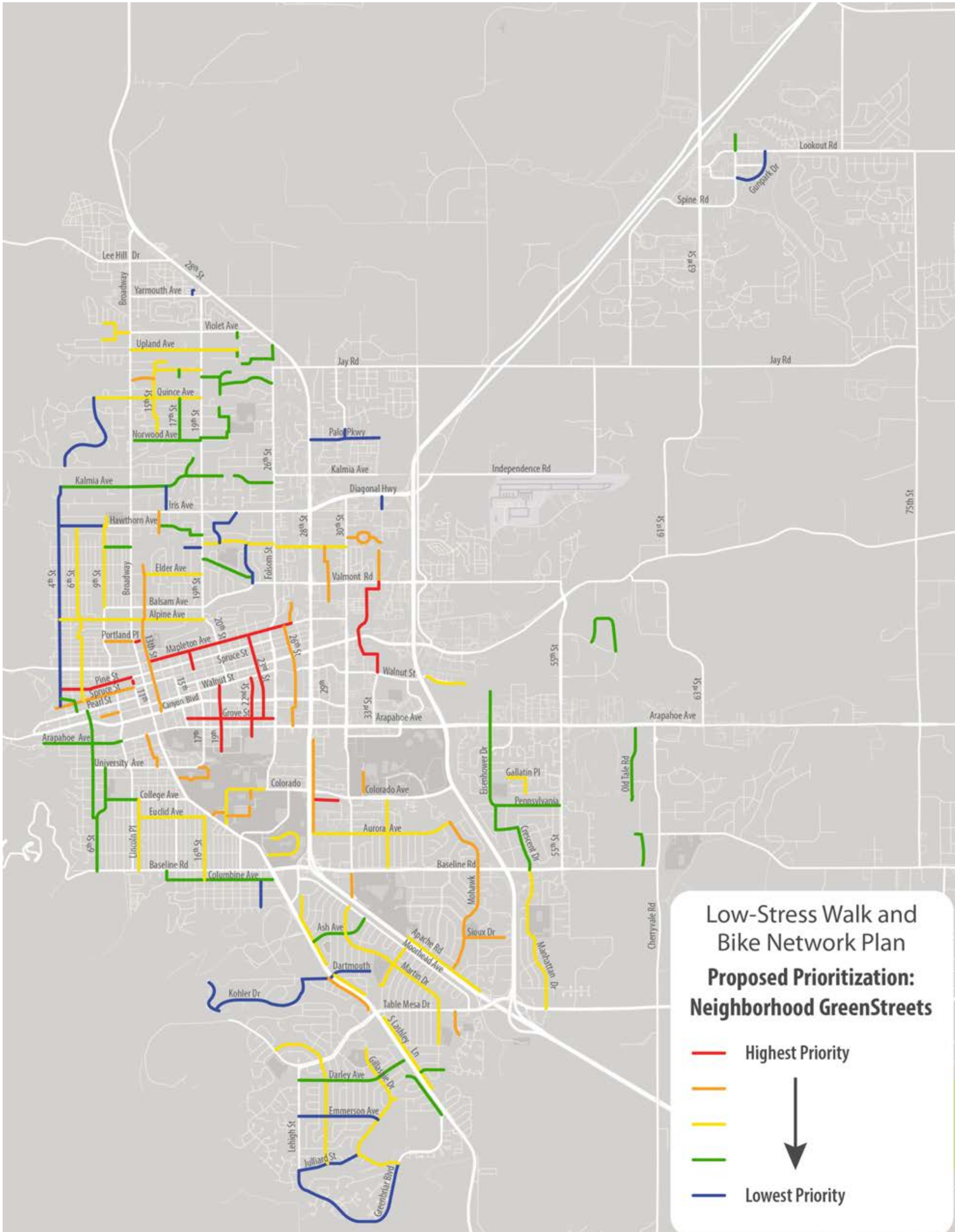


Figure 7. Prioritized Bike Lane Projects (Preferably Buffered)

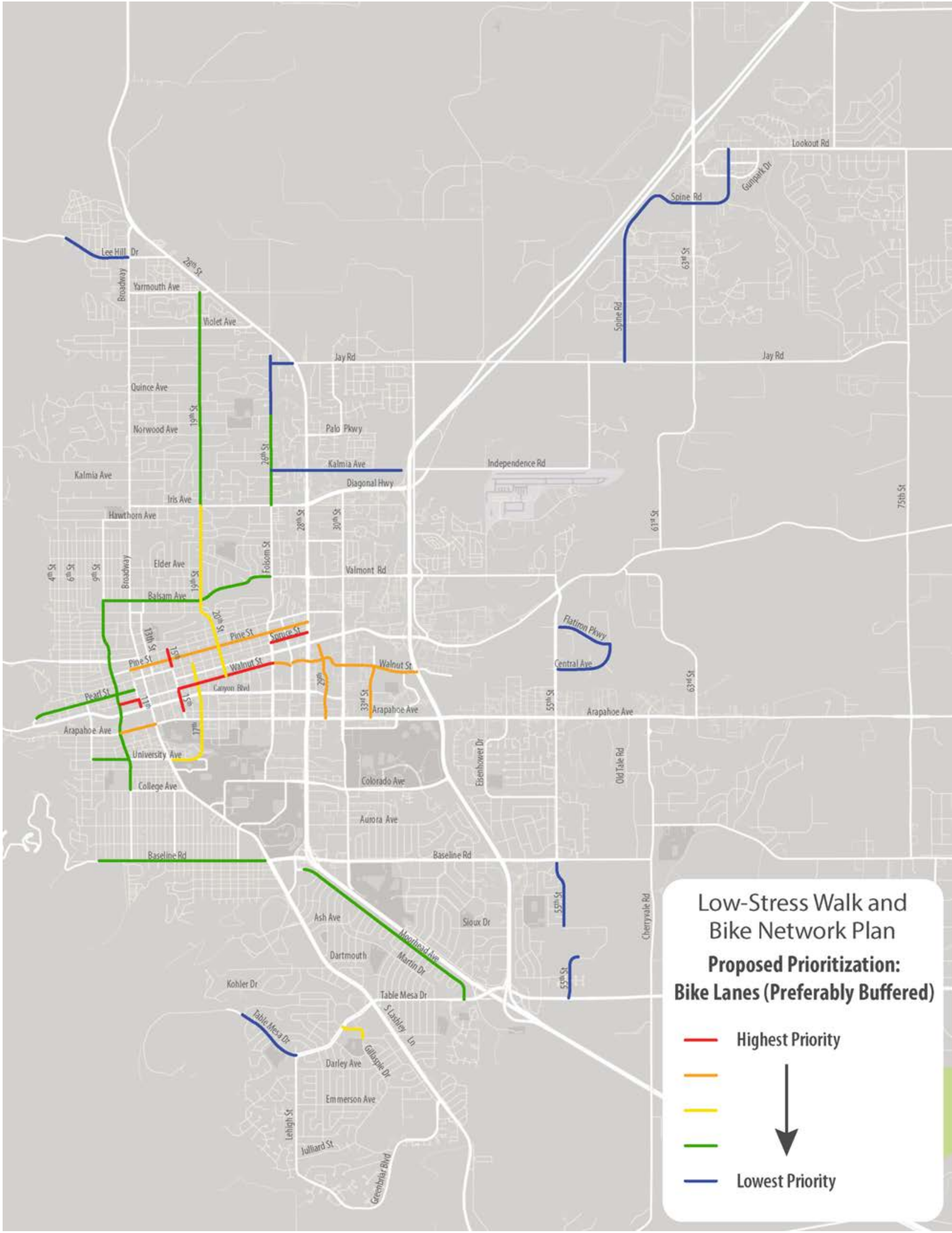


Figure 8. Prioritized Vertical Separation Projects