CITY OF STOCKTON

SYSTEMIC SAFETY ANALYSIS REPORT AND LOCAL ROAD SAFETY PLAN

CITY OF STOCKTON

August 2021

ENGINEER'S SEAL: By signing and stamping this document, Erin M. Ferguson, P.E., attests to this report's technical information and engineering data upon which local agency's recommendations, conclusions, and decisions are made.

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EXECUTIVE SUMMARY

Purpose

The purpose of this report is to provide the City of Stockton and its multidiciplinary safety partners (e.g., police, fire, school district) information and direction on strategies and treatments most likely to improve roadway safety performance within the City.

The effort to conduct the analysis and develop this report is funded by the City's Systemic Safety Analysis Report Program (SSARP) grant funds from Caltrans. The scope of the analysis and contents of this report fulfill the SSARP requirements and were expanded to meet Caltrans' more recent Local Road Safety Plan (LRSP) requirements. Kittelson & Associates, Inc., (Kittelson) developed the content of this report in collaboration with the City and its safety partners.

This report speaks to citywide collision patterns and trends and associated systemic treatments that can be used to address those citywide trends. This report also sets forth a vision and goals specific to roadway safety performance, identifies empahsis areas, suggests multidisciplinary safety strategies for improvements, and presents proposed safety improvements for the highest priority intersections and segments within the City.

This reports establishes a basis for informing roadway safety performance improvements over the next three to five years and also provides a framework the City can use to update its raodway safety performance analysis and produce updated local road safety plans in the future.

Vision and Goals

The City's vision is to continuouolsy improve roadway safety peformance by investing in strategies and improvements that reduce the risk of fatal and injury collisions occuring on public roadways within the City.

The following presents specific goals to help the City achieve its vision.

1. Use data-informed analysis and community needs to identify and prioritize opportunities to reduce collision risk.

Goal 1.1: Establish a regular practice of assessing citywide collision patterns and trends and identifying locations with collision history or characteristics are indicative of collision risk.

Goal 1.2: Reduce the number of fatal and severe injury collisions in emphasis areas by 25% by 2026 and 50% by 2031.

Goal 1.3: Reduce the number of fatal and severe injury collisions across all public City roadways by 25% by 2026 and by 50% by 2031.

Goal 1.4: Implement proven roadway safety performance countermeasures systemically to target emphasis areas.

2. Strengthen partnerships with other agencies and organizations to promote roadway safety

Goal 2.1: Coordinate with the fire department, police department, school district, and County quarterly to exchange information and ideas specific to enhancing roadway safety performance and to plan targeted enforcement and educational strategies to reduce fatal and injury collisions.

Goal 2.2: Apply a safety lens to all roadway projects by considering roadway safety performance in the project development process. By 2023, establish and begin evaluating a methodology for assessing the safety impacts (i.e., quantifying increased risk of collisions) associated with land use development projects.

Goal 2.3: Establish a safety mitigation program by 2025 that is funded by land use development permits. This program could create a steady funding source for implementing countermeasures to mitigate collision risk associated with increased travel demand from land use changes.

Key Findings

Kittelson used reported collision data from January 1, 2015 through July 31, 2020 to inform the findings in this Systemic Safety Analysis Report and Local Road Safety Plan. Highlighted below are key findings from the analysis. Greater detail about the findings as well as recommended strategies and improvements to reduce fatal and injury collisions are presented in later sections of this report.

COLLISION PATTERNS AND TRENDS

- There were 21,271 reported collisions on City streets. Three percent of reported collisions resulted in a fatality (130) or serious injury (400) in the five years of collision data analyzed.
- Among reported located collisions, 90% occurred within 250 feet of an intersection.
- The three most frequent collision types overall include:
  - Broadside (34% of reported collisions);
  - Rear end (24% of reported collisions); and,
  - Sideswipe (17% of reported collisions).
- The three most frequent collision types among fatal and serious injury collisions include:
  - Vehicle-pedestrian (34% of reported fatal and serious injury collisions);
  - Broadside (26% of reported fatal and serious injury collisions); and,
  - Hit object (16% of reported fatal and serious injury collisions).
- Pedestrian violations[1] were the most frequently cited collision factors among fatal and severe collisions (22% of citywide fatal and 18% of citywide severe injury collisions).
- Alcohol, drug use, or impairment is documented in reported collisions:
  - Among reported collisions, 5% (1,113 collisions) involved driving under the influence.
  - Among fatal and serious injury collisions, 16% (87 collisions) involved alcohol.
    - Out of these 87 collisions, 83 were cited for being under the influence of drugs/alcohol and four (4) were cited as impairment not known or not stated.

[1] Pedestrian Violation refers to a pedestrian failure to yield the right-of-way to other vehicles.

HIGH PRIORITY LOCATIONS

Kittelson identified the following 29 intersections (including two ramp terminal intersections under Caltrans' jurisdiction) and 9 roadway segments as high priority locations for roadway safety performance investments based on their collision history and roadway characteristics present.

- **Intersections:**
  - Dr MLK Jr Boulevard at Stanislaus Street
  - Hammer Lane at Lan Ark Drive
  - Dr MLK Jr Boulevard at Harrison Street
  - March Lane at El Dorado Street
  - Hammer Lane at Lorraine Avenue
  - Dr MLK Jr Boulevard at Lincoln Street
  - Harding Way at Commerce Street
  - Hazelton Avenue at Airport Way
  - Dr MLK Jr Boulevard at California Street
  - West Lane at Swain Lane
  - Pershing Avenue at Telegraph Avenue
  - Airport Way at Washington Street
  - Wilson Way at Acacia Street
  - El Dorado Street at Jamestown Street
  - March Lane at Precissi Lane
  - El Dorado Street at Ivy Avenue
  - Wilson Way at Fremont Street
  - Harding Way at Center Street
  - Sierra Nevada Street at Lindsay Street
  - Dr MLK Jr Boulevard at Airport Way
  - I-5 Southbound Ramp at Charter Way
  - March Lane at Quail Lakes Drive/Da Vinci Drive
  - Charter Way at Stockton Street
  - I-5 Southbound Ramp at March Lane
  - Hammer Lane at Holman Road
  - Hammer Lane at Don Avenue/Meadow Avenue
  - Airport Way at Anderson Street
  - Hammer Lane at Lower Sacramento Road
  - El Dorado Street at Iris Avenue

- **Segments:**
  - West Lane from Hammer Lane to Knickerbocker Drive
  - El Dorado Street from Lowell Avenue to South 900' of Clayton Avenue
  - Feather River Drive from Driftwood Place to Fourteen Mile Slough Crossing
  - Pacific Avenue from March Lane to Longview Avenue
  - West Lane from Alpine Avenue to University Avenue
  - Hammer Lane from Lower Sacramento Road to Tam O'Shanter Road
  - Myrtle Street from Filbert Street to I-99
  - Hammer Lane from Lorraine Avenue to Marantha Drive
  - E Mariposa Road from County Line to Austin Road

COLLISION RISK FACTOR FINDINGS

Kitteelson identified the following roadway characteristics as collision risk factors (i.e., roadway characteristics potentially associated with more frequent or severe collisions) based on total reported collisions:

- **Number of legs of the intersection** – As the number of legs of the intersection increases, the collision risk increases.
- **Type of intersection control (i.e., stop control vs. signal control)** – Signalized intersections are associated with an increase in collision risk compared to unsignalized intersections.
- **Maximum posted speed** – As the maximum posted speed (among all legs of the intersection) increases, the collision risk increases (with a maximum posted speed of 40 mph which corresponds to arterials and major collector roadways or when the roadway transitions from urban to rural context).
    - **Frequent collision types and posted speed** – For signalized and unsignalized intersections, collision risk increases for the three most frequent collision types (broadside, rear end, and sideswipe), with maximum posted speed (among the legs of intersection) up to 40 mph. These roadways include arterials and major collectors.
    - **Roadway segments** – As the posted speed on roadway segments increases, collision risk increases.
- **Presence of transit stop** – If a transit stop is present within 300 feet of an intersection, collision risk for total collisions and pedestrian and bicycle collisions increases

INTRODUCTION

Purpose

The purpose of this report is to provide the City of Stockton and its partners information and direction on strategies and treatments most likely to improve roadway safety performance within the City.

The development of this report funded by the City's Systemic Safety Analysis Report Program (SSARP) grant funds from Caltrans. The scope of the analysis and contents of this report fulfill the SSARP requirements and were expanded to also address Caltrans' more recent Local Road Safety Plan requirements. The content of this report was developed in collaboration with the City and its multidisciplinary partners in implementation (e.g., police, fire, school district).

As a result, this report speaks to citywide collision patterns and trends and systemic treatments that can be used to address those citywide trends. The content of this report was also sets forth a vision and goals specific to roadway safety performance, identifies empahsis areas, suggests multidisciplinary safety strategies for improvements, and presents proposed safety improvements for the highest priority intersections and segments within the City.

This reports establishes a basis for informing roadway safety performance improvements over the next three to five years and also provides a framework the City can use to update its roadway safety performance analysis and produce updated local road safety plans in the future.

PROCESS

The content of this report is informed by data analysis as well as input from key agency stakeholders. In developing the content of this report, the City engaged a Project Management Team (PMT) at key milestones to review and provide input into draft results, recommendations and deliverables. The members of the PMT included representatives from the fire department, police department, Stockton Unified School District, and San Joaquin County.

ORGANIZATION

The remainder of this document is organized into the following sections:

- **Vision & Goals:** Presents the City's vision and goals specific to roadway safety performance (reduce the number of severe and fatal collisions).
- **Safety Partners:** Summarizes the partner agencies involved in providing input into this report.

- **Previous Efforts:** Presents the previous efforts the City has undertaken to improve roadway safety performance.
- **Data Analysis Techniques and Results:** Discusses the approach used and findings from detailed collision and data analysis activities.
- **Emphasis Areas:** Presents the City collision focus areas based on priority collision patterns and trends as well as locations to address. This section Includes engineering and non-engineering strategies that can be used to mitigate collision risk, frequency, or severity.
- **Evaluation and Implementation:** Describes performance measures and approaches to gauge progress in improving roadway safety performance. It outlines a process for future updates to this analysis and report.

VISION AND GOALS

Vision

Continuoulsy improve raodway safety performance by investing in strategies and improvements that reduce the risk of fatal and injury collisions occuring on public roadways within the City.

Goals

The following presents specific goals aimed at helping the City achieve its vision.

1. Use data-informed analysis and community needs to identify and prioritize opportunities to reduce the risk of collisions.

Goal 1.1: Establish a regular practice of assessing citywide collision patterns and trends and identifying locations with collision history or characteristics indicative of collision risk.

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Goal 1.4: Implement proven safety countermeasures systemically to target emphasis areas.

2. Strengthen partnership with other agencies and organizations to promote roadway safety

Goal 2.1: Coordinate with the fire department, police department, school district, and County on a quarterly basis to exchange information and ideas specific to roadway safety and to plan targeted enforcement and educational strategies to promote roadway safety.

Goal 2.2: Apply a safety lens to all roadway projects by incorporating safety in the project development process. By 2023, establish and begin evaluating a methodology for assessing the safety impacts (i.e., quantified increased risk of collisions) due to land use development projects.

Goal 2.3: By 2025, establish a safety mitigation program that is funded by land use development permits to create a steady funding source of countermeasures to mitigate collision risk that is created by increased travel demand due to changes in land use.

VISION SAFETY PARTNERS

Agency Partners Engaged

The City assembled and engaged a Project Management Team (PMT) to review and provide input on draft results, recommendations, and deliverables at key milestones. The PMT included representatives from the Stockton Fire Department, Stockton Police Department, Stockton Unified School District, and San Joaquin County.

Input Gathered

Members of the PMT provided input on the following topics over the course of this report's development:

- Existing and past efforts undertaken targeting roadway safety performance improvement including specific projects, treatments, planning efforts, educational related messages, and enforcement.
- Data analysis findings specific to the collision patterns and trends identified across the City and specific locations identified as higher priority for improvements.
- Specific countermeasures for use by the City on a systemic or widespread basis as well as specific safety improvement projects tailored to the highest priority locations.
- Non-engineering strategies identified to complement or support roadway safety performance improvement where engineering countermeasures are less effective at influencing road user behavior.

In addition to the topical areas above, the PMT reviewed and provided comments on draft deliverables throughout the project and met six times to discuss the development steps of the LRSP as well as draft deliverables and recommendations.

EXISTING EFFORTS

Prior to developing a systemic safety analysis report and local road safety plan, the City has addressed roadway safety performance through a number of previous and existing plans, projects, and programs. Those previous efforts are summarized below.

Regional and Local Planning Efforts

There are many planning efforts in City of Stockton and the region as a whole aimed at addressing roadway safety. These efforts range from a general plan to a bicycle master plan. They are discussed below.

SJCOG REGIONAL BICYCLE, PEDESTRIAN, AND SAFE ROUTES TO SCHOOL MASTER PLAN (2012)

This plan serves as a guide to planning, developing, and managing a regional bicycle and pedestrian network. The plan aims to increase commuter walking and bicycling and support active and safe transportation to and from schools. The plan details the existing bicycle, pedestiran, and safe routes to school infrastructure and environment throughout San Joaquin County.

It categorizes bicycle infrastructure based on Caltrans standards of Class I bike path, Class II bike lane, and Class III bike route. Pedestrian infrastructure addressed by this plan includes sidewalks, curb extensions, crosswalks, refuge islands, curb ramps, pathways, signs and traffic signals.

The plan describes Safe Routes to School, which refers to a variety of multidisciplinary programs aimed at promoting walking and biking to school and improving traffic safety around school areas through education, incentives, increases law enforcement, and engineering measures.

The plan’s priorities for pedestrian and bicycle safety are:

- Reduced conflicts with vehicular traffic
- Reduced vehicle speeds along the roadway and approaching the intersection
- Greater attention to the existence of pedestrian crossings
- Opportunities for additional signs in the middle of the road
- Reduced exposure in the roadway for non-motorized users

CITY OF STOCKTON'S GREATER DOWNTOWN ACTIVE TRANSPORTATION PLAN, MATERIAL ON WEBSITE (2020)

This plan identifies and recommends future bicycle and pedestrian facility projects to improve Stockton's growing downtown. Goals of the plan include:

- Enhance safety performance for non-motorized users through improved access to transit, schools, work, and regional trails
- Balance user travel needs in the existing roadway space
- Create connections to and from other areas in the city
- Enhance public health and livability
- Improve air quality
- Support the revitalization of Stockton's core

The draft plan identifies priority intersections and roadway segments that can be improved to fulfill the above goals. Specific improvements at these intersections and segments are prioritized by the following criteria:

- Equity
- Safety
- Connectivity
- Access to Transit
- Population and Employment Density
- Economic Development
- Level of Traffic Stress
- Project Readiness

CITY OF STOCKTON 2040 GENERAL PLAN (2018)

The Stockton's General Plan is the community's overarching policy document that defines a vision for future change and guides the location and character of development. The intent of the General Plan is enhancing the local economy, improving public services and safety, conserving resources, and fostering community well-being.

The City of Stockton 2040 General Plan represents a substantial change in the policy framework for future development in Stockton compared to the prior 2035 General Plan. The fundamental shift is from emphasizing growth in "outfill" areas at the periphery of the City to focusing new construction and redevelopment in existing "infill" neighborhoods.

The sections of the plan that are related to roadway safety considerations are described below:

- **As part of LU Policy 2.5** – Promote Downtown Stockton as a primary transit node that provides multimodal connections to destinations throughout the city and region
- **As part of LU Policy 3.2** – Retain narrower roadways and reallocate the right-of-way space to preserve street trees and mature landscaping. Enhance the pedestrian and bicycle network within and adjacent to residential neighborhoods
- **As part of TR Policy 4.1** – Use level of service (LOS) information to aid the understanding of potential major increases to vehicle delay at key signalized intersections

CITY OF STOCKTON BICYCLE MASTER PLAN (2017)

The Bicycle Master Plan is the result of an extensive, community-driven planning process involving close collaboration between the City and its residents. The City launched this effort to completely rethink how facilities are selected and prioritized for investment. The goals of the Plan are as follows:

- Enhance Citywide Connectivity
- Safety First for All Users
- Mode Shift and Access
- Education and Support Programs

The plan analyzed citywide bicycle collision data to pinpoint high-injury areas for bicyclists and reveal trends affecting bicycylist safety in Stockton. The effort documented the number of bicyclist collisions accounted for eight percent of all reported traffic collisions. This is disproportiantely higher than the City's bicycle modeshare of 0.6 percent of all trips. The plan supplemented these findings with community feedback to make the most thorough treatment recommendations.

Local Guidelines and Previous Roadway Safety Performance Tracking

There are many local guidelines as well as previous roadway safety tracking documents presenting best practices related to roadway safety. These documents are discussed below.

CITY OF STOCKTON TRAFFIC CALMING GUIDELINES (2021)

These guidelines provide a framework for selecting, applying, and designing traffic calming measures in the City. The guidelines are not rigid requirements, but rather a tool used to develop effective traffic calming plans that adequately accommodate motor vehicles, pedestrians, and bicyclists while enhancing the nieghborhood environment. The document is focused on four primary goals: reduced speeding; reduced numbers and/or reduced severity of reported collisions; reduced cut-through traffic where existing levels are significant and where the remedy will not create a problem on other streets; and a better environment for residents and busines owners as indicated by their sense of safety, property values, comfort in using the street, and reduced traffic-related complaints.

The traffic calming plan focuses on changing driver behavior to improve safety performance. The five types of traffic calming measures are:

- Non-physical measures – targeted speed enforcement, radar trailers, speed feedback signs, lane striping, approved markings per current MUTCD, signage, centerline or edgeline Botts dots, high visibility crosswalks
- Narrowing measures – bulb outs, chokers, center island narrowing, pedestrian refuge islands
- Horizontal measures – traffic circles, roundabouts, lateral shifts, chicanes
- Vertical measures – speed humps, speed lumps, speed cushions, split devices, speed tables, raised crosswalks, raised intersections
- Diversion devices –full closures, half closures, median barriers, forced turn islands

These measures, police enforcement,and educational outreach combine to provide a comprehensive approach to traffic calming.

CITY OF STOCKTON PEDESTRIAN SAFETY AND CROSSWALK INSTALLATION GUIDELINES (2021)

These guidelines are aimed at improving pedestrian safety and enhancing pedestrian circulation. This document provides a comprehensive pedestrian safety strategy with a five-pronged approach of engineering, enforcement, encouragement, education and evealution. It also focuses on engineering elements, such as pedestrian crossing treatments and intersection desgins.

The document describes best practices realted to various pedestrian treatments, including pedestrian signals, pedestrian refuge islands, compact intersections, sidewalks, and crosswalks. The document is intended to serve as a reference guide for staff, citizens, and developers when determining the best engineering solutions to pedestrian safety concerns.

The guidelines recommend installing marked crosswalks at approaches (i.e. legs of the intersection) using standard crosswalk markings or high-visibility markings. Where the accident data or observations of conflicts identify a crosswalk of particular concern, special treaments should be considered. There are two situations which are exceptions to this rule, and they are: crossing locations with heavy right- or left-turn volumes that occur during the same signal phase as the conflicting pedestrian movement, and intersections with inadequate sight distance of pedestrians.

CITY DOCUMENTS (2020)

As of August 2020, the City of Stockton and the Stockton Police Department identified and ranked top 10 collision locations at midblock crossings and signalized intersections. The City also shared with Kittelson the comments and complaints about the City's intersections and roadway segements received from residents.

The common themes for resident comments include:

- Uneven/broken sidewalks
- Streetlights not working
- Regulatory signs being knocked down
- Missing one-way and street name signs
- Increased vehicle speeds on some roadway segments

Recent HSIP Applications

In addition to local planning efforts, the City of Stockton has applied for and received Highway Safety Improvement Program (HSIP) funding to implement projects that reduce fatalities and serious injuries on public roads. These projects are identified on the basis of collision experience, collision potential, collision rate, or other data-supported means. Over the past four cycles (7, 8, 9, and 10), Stockton has received $20,736,580 in total. The projects that have been approved for funding are shown in Table 1 below.

Table 1: Recent HSIP Projects

Project Description	Location	HSIP Funds
Install high friction surface treatments (HFST) and variable speed warning signs at certain horizontal curves.	Multiple locations on Manthey Rd., Brookside Rd., Feather River Dr., Bianchi Rd.	$ 759,960
Pedestrian crossing improvements, install high-intensity activated crosswalk (HAWK) pedestrian crossing and install pedestrian crossing at uncontrolled locations (new signs and markings).	Intersection of South Airport Way and East Sonora Street, south of the Crosstown Freeway (SR-4).	$ 373,800
Install Emergency Vehicle Premption.	Intersections of N. Filbert St. / E. Myrtle St. and N. Filbert St. / E. Market St., at the Filbert St. exits of the Crosstown Freeway (SR-4).	$ 266,600
Install guardrail, transition railing and collision cushions, re-striping of the roadway and other improvements.	Along S. Airport Way and Industrial Dr.	$ 253,600
To reduce the travel lanes from four lanes to three (Road Diet), to accommodate a center two-way left turn lane and install new bike lanes.	On North Hunter Street between West Harding Way and East Miner Ave.	$ 404,100
Convert signals from pedestal-mounted to mast arms and provide protected left-turns.	Dr. Martin Luther King, Jr. Blvd. between N. El Dorado St. and S. Aurora St., at the intersections of S. San Joaquin St., California St. and S. Grant St.	$ 1,163,500
Install raised median.	Dr. Martin Luther King, Jr. Blvd. between Bieghle Alley and Mariposa Rd.	$ 370,710
Upgrade the existing guardrails with new guardrails, transition rails and end treatments.	Sixteen (16) locations throughout the City of Stockton.	$ 1,180,900

Project Description	Location	HSIP Funds
Install left turn pockets with left turn phasing, upgrade signals, cabinet & appurtenances, install pedestrian countdown signal heads, and install High Friction Surface Treatment (HFST) through approaches.	Harding Way and Lincoln Street, Harding Way and Pacific Avenue/Madison Street	$ 1,365,840
Install high-visibility crosswalks, pavement markings, ADA ramps, sight triangles and rapid-flashing beacons.	Madison Street and Willow Street, Vine Street, Rose Street, Magnolia Street, Acacia Street, Poplar Street, Flora Street	$ 644,940
Install protected left phasing, lengthen an existing turn pocket and upgrade signal equipment.	North Pershing Avenue and Country Club Boulevard, North Pershing at Rosemarie Lane	$ 721,200
Place 3 speed trailers and 27 speed sentries at curve approaches that experience high rates of collisions.	Various locations on curve approaches throughout the City.	$ 320,000
Install pedestrian hybrid beacons, other crossing improvements, and intersection lighting.	Eight interesctions throughout South Stockton.	$ 5,861,500
Rehabilitate/replace guardrail posts, sections and end sections.	Frontage Road just South of the Stockton Soccer Complex, Lower Sacramento Road South of Bear Creek, and Manthey Road at the curve adjacent to I-5.	$ 374,200
Install reflective thermoplastic edgelines where existing striped edgelines have significantly faded and road departures exist.	Various locations throughout the City.	$ 250,000
Install pedestrian crossings (with enhanced safety features), including high visibility crosswalks and flashing beacons.	Nine (9) intersections in the Weston Ranch subdivision in the southwestern corner of the City of Stockton, just west of the Interstate-5 freeway.	$ 1,034,700
Reduce the travel lanes from four to three (Road Diet), to accommodate a center two-way left turn lane and install new bike lanes.	N. Eldorado St. between Morada Lane and W. Hammer Lane.	$ 530,550

Project Description	Location	HSIP Funds
Install a raised median with pedestrian median fencing to prevent J-walking; Install new sidewalks and ADA compliant curb ramps.	N. El Dorado St. between Essex St. and the Calaveras River Trail (near E. Ingram St.).	$ 664,830
Install raised median curb between the existing median limits at various locations.	Pacific Ave. between Calaveras River Trail and W. Hammer Ln.	$ 969,750
Add left-turn lanes, install left-turn phasing, and improve signal hardware at El Dorado Street intersections; install left-turn phasing and improve signal hardware.	Intersections of El Dorado Street and Robinhood Drive, El Dorado Street and Benjamin Holt Drive, and March Lane and McGaw Street.	$ 714,420
Add designated left-turn lanes to the intersection of Airport Way/Hazelton Avenue, combined with associated signal modifications and upgrades. Add sidewalk to close gaps and improve access for pedestrians on Airport Way along with other improvements.	Airport Way and Hazelton Avenue.	$ 1,427,400
Install sidewalk/pathway (to avoid walking along roadway) and install pedestrian median fencing on Dr. Martin Luther King, Jr. Blvd (E. Charter Way).	Dr. Martin Luther King, Jr. Blvd (E. Charter Way) and S. Aurora St.	$ 600,660
Install Rectangular Rapid Flashing Beacons (RRFBs), signing & pavement marking.	Four crossing locations, including Alpine Avenue at Sutter Street, Pacific Avenue at Elm Street, El Dorado Street at Iris Avenue and Hunter Street at Channel Street.	$ 250,000

DATA ANALYSIS TECHNIQUES AND RESULTS

The following section describes the methods and results for citywide collision patterns and trends; network screening analysis; and systemic evaluation. The focus of the collision patterns and trends analysis is to identify behavioral and roadway patterns associated with injury and fatal collision outcomes.

For the network screening and systemic evaluation analyses, the focus is to identify locations in the City that would benefit the most from transportation safety improvements. Findings from these analyses identify emphasis areas, help establish and measure progress toward goals, and inform the systemic countermeasures and projects described in subsequent sections of this report.

Safety Data Analyzed

This section documents the data assembled for analysis.

COLLISION DATA

Kittelson worked with the City to build a database of the five most recent complete years of reported collisions, representing January 1, 2015 through July 31, 2020. Reported collisions were provided by the City from Crossroads, an internal City-maintained database. Public databases that are typically used for this analysis appear to underrepresent collision frequency. The City also provided a log of fatal collisions with which the project team supplemented the database.

The collision data analyzed do not include collisions that occurred along grade-separated roadways in the City (Highways 4 and 99 and Interstate 5). However, Kittelson retained collisions occurring at or within the influence area of ramp terminal intersections for analysis. Kittelson identified and removed duplicate records by inspecting the recorded time, date, and location. A portion of the entries in the database provided by the City were geolocated with coordinates for spatial analysis. Kittelson used the following methods to geolocate the remaining collisions that had no spatial information.

Where possible, Kittelson:

- Matched collisions with an associated record from the publicly available UC Berkeley Transportation Injury Mapping System (TIMS) database, which includes spatial information for reported injury and fatal collisions.
- Used reference data saved in each collision record for primary and secondary streets, and associated distance and direction from intersection to geocode and manually offset collisions. Locations that were in the intersection influence area were not manually offset to maintain their association with the intersection.

- Geolocated collisions that could not be matched to a TIMS record were geolocated in GIS using the reference data mentioned above.

Of the 15,822 collisions in the database, 13,478 (85%) were successfully geolocated. Kittelson retained collisions that could not be geolocated for the descriptive analysis of citywide trends. However, Kittelson was not able to include them in spatial analysis or in analysis characterizing their association to roadway characteristics.

ROADWAY CHARACTERISTIC DATA

For this analysis effort, Kittelson assembled a spatial database including roadway characteristics and contextual data. The supplementary contextual data included data provided by the City and data collected by Kittelson. These data include:

- **Bus stop locations:** The San Joaquin Regional Transit District provided spatial data on their current bus stops and routes;
- **Posted speed limit:** The City provided the posted speed for public roadways; and
- **Functional classification:** The City provided functional classification information along roadway segments. The classifications included interstates, highways, arterials, collectors, and rural and local roadways.

Traffic volume data were not available during the time of the analysis and thus are not incorporated in the findings. This data has been subsequently archived and can be used for more detailed evaluation in future updates to this document.

Citywide Collision Patterns and Trends

This section presents citywide collision patterns and trends. This analysis focuses on identifying behavioral and roadway patterns associated with injury and fatal collision outcomes. By analyzing reported collisions together, systemic trends across locations can be identified. Findings from this analysis helped inform the countermeasures considerations discussed later in this report.

ALL ROAD USERS

Kittelson analyzed reported collisions across motor vehicles, pedestrians, and bicyclists. Trends and findings are presented based on the following:

- Collision Severity;
- Collision Location;
- Collision Type;
- Primary Collision Factor;
- Time of Day;
- Lighting Conditions; and

- Alcohol and Drug Involvement.

Bicycle and pedestrian collisions are included in the following charts and tables. Specific characteristics unique to bicycle and pedestrian collisions are also discussed in the following sub-sections.

Collision Severity

Kittelson classified collisions by severity based on the most severe outcome associated with the collision, with the following reported severities (in descending order of severity): fatal, serious injury, other visible injury, complaint of pain injury, and property damage only (PDO). Table 2 presents collisions by severity and by the road users involved (e.g., pedestrian, bicyclist, motorvehicle).

Table 2: Road Users Involved and Collision Severity, City of Stockton, January 2015-July 2020

Road User Involved	Fatal		Severe Injury		Other Visible Injury		Complaint of Pain		Property Damage Only		Total	
Vehicle-Vehicle or Vehicle-Other	51	39%	217	54%	1,433	72%	4,744	89%	13,191	98%	19,636	92%
Pedestrian-Involved	51	39%	120	30%	298	15%	298	6%	76	1%	843	4%
Bicyclist-Involved	21	16%	56	14%	252	13%	266	5%	144	1%	739	3%
Pedestrian-and Bicyclist-Involved	0	0%	7	2%	7	0%	11	0%	9	0%	34	0%
Motorcycle-Involved	7	5%	0	0%	7	0%	5	0%	0	0%	19	0%
Grand Total	130	1%	400	2%	1,997	9%	5,324	25%	13,420	63%	21,271	100%

Note: Percentages may not sum to 100% due to rounding.

Source: City of Stockton, UC Berkeley TIMS, 2020.

- Among reported collisions, 530 (3%) resulted in either a fatality or serious injury.
- The share of injuries and fatalities among pedestrian- and bicyclist-involved collisions is higher than among collisions overall.
    - Pedestrians are involved in 4% of collisions and 32% of fatal and severe injury collisions (This percentage is calculated by the number of pedestrian fatal and severe injury collisions divided by total fatal and severe injury collisions).
    - Bicyclists are involved in 3% of collisions and 14% of fatal and severe injury collisions (This percentage is calculated by the number of bicycle fatal and severe injury collisions divided by total fatal and severe injury collisions).

Collision Location

From located collisions, Kittelson further identified the collisions as either intersection or segment collisions. An intersection collision, in this case, is defined as a collision that occurs within 250-feet of an intersection. Reported collisions by location are shown in Figure 1 below.

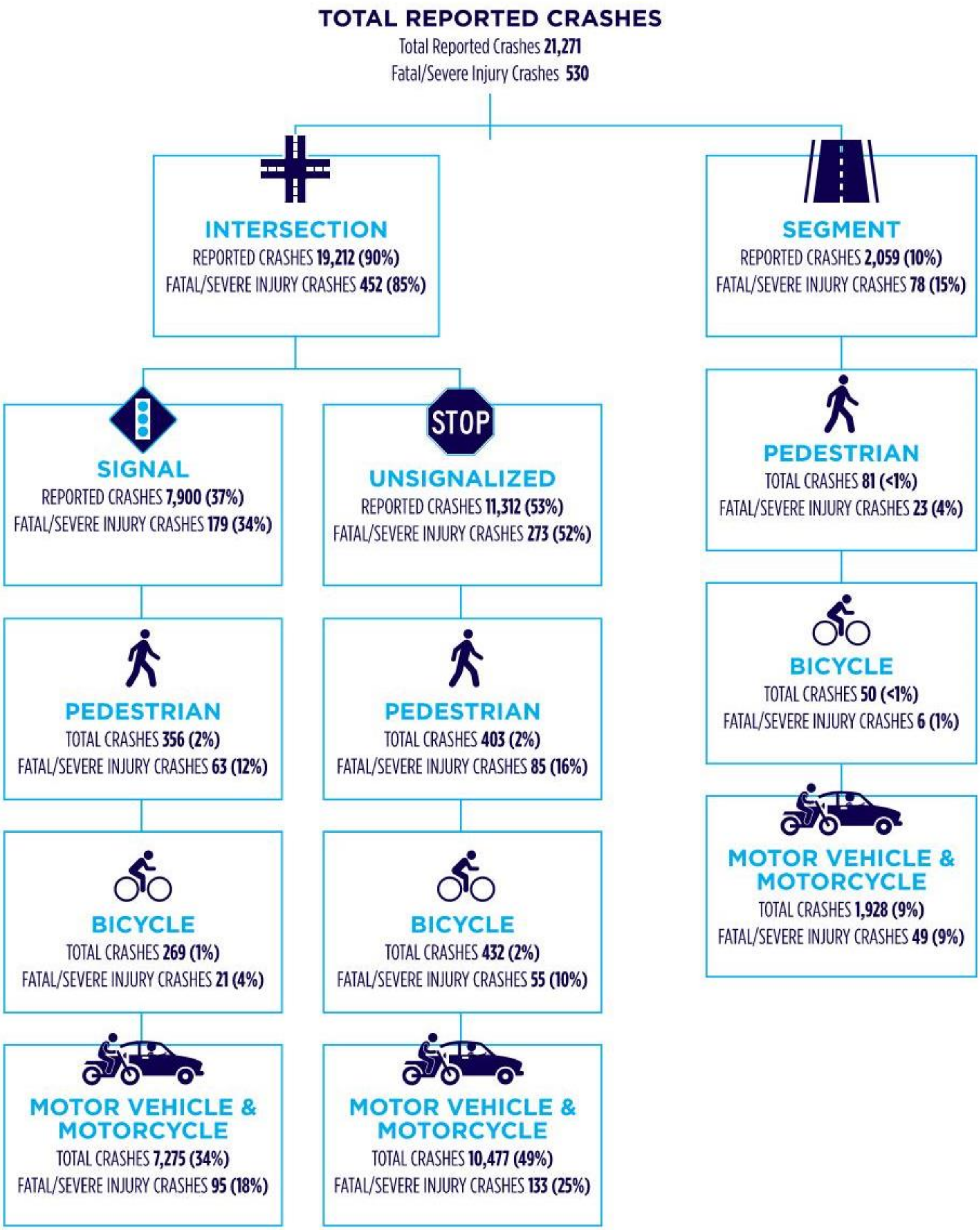
Collisions occurring beyond 250 feet of an intersectionwere defined as a segment collision. The following are key collision location findings:

- Of the located reported collisions, 90% of collisions occurred within 250 feet of an intersection, and 10% occurred at segments.
- Most (85%) reported fatal and severe injury collisions occurred at intersections, and 15% of reported fatal and severe injury collisions occurred at segments.
- Signalized intersections accounted for 37% of total reported collisions and 34% of fatal and severe injury collisions, though these intersections represent 5% of all reported intersections within the City.
- Fatal and severe injury collisions are slightly overrepresented for segment collisions, with segment collisions representing 10% of total reported collisions but 15% of fatal and severe injury collisions.
- Pedestrian fatal and severe injury collisions are overrepresented for intersections, with pedestrian collisions representing 4% of total reported collisions but 12% (signalized) and 16% (unsignalized) of fatal and severe injury collisions.
- Bicycle fatal and severe injury collisions are overrepresented for intersections, with bicycle collisions representing 3% of total reported collisions but 4% (signalized) and 10% (unsignalized) of fatal and severe injury collisions.

These trends are consistent with findings in the California Strategic Highway Safety Plan 2020-2024 (SHSP)[2], released by Caltrans, which outlines 16 Challenge Areas for the state. Three of the challenge areas in SHSP, which are relevant to the discussion here, are: Intersections, Pedestrians, and Bicyclists.

[2] California Strategic Highway Safety Plan 2020-2024, https://dot.ca.gov/programs/safety-programs/shsp. Accessed September 29,2020.

Figure 1: Reported Collisions by Location, City of Stockton, January 2015 - July 2020



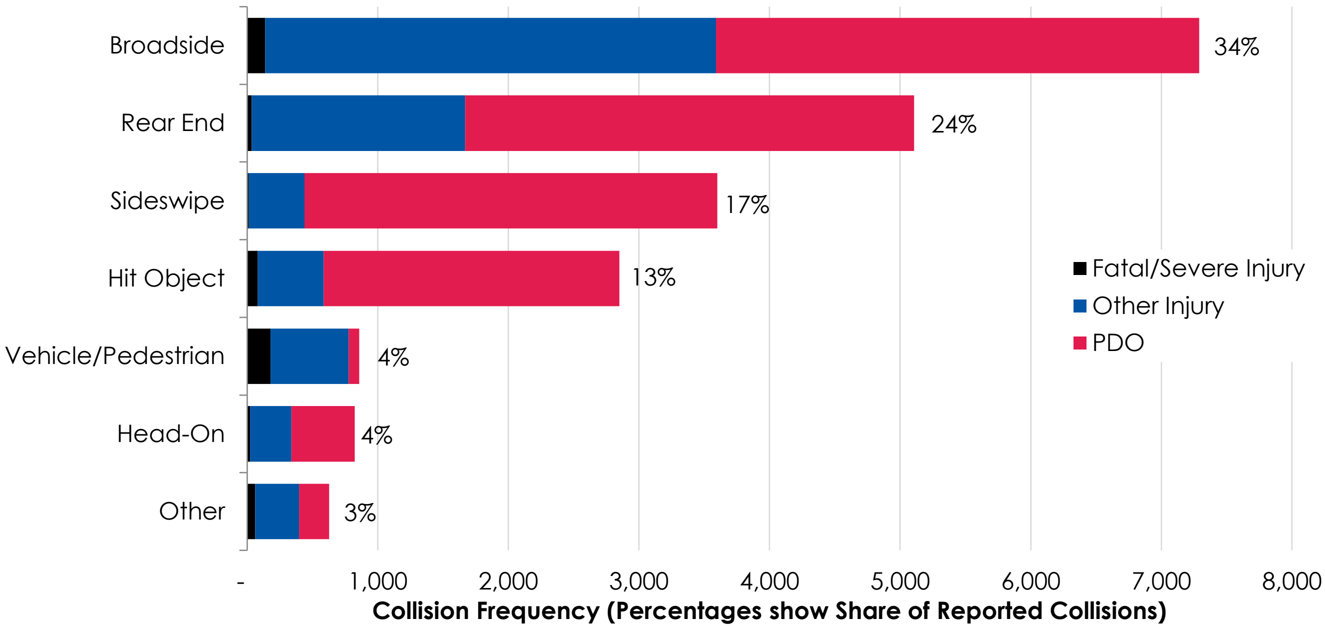
Note: The number of total crashes shown in each box is the total for that given sub-category of all crashes. Unsignalized intersections include those labeled as uncontrolled, two-way stop, all-way stop, yield sign, and other. This data does not include roundabout related collisions. Collisions shown in this figure do not account for those that were coded as N/A or not stated.

Source: City of Stockton, UC Berkeley TIMS, 2020.

Collision Type

Figure 2 presents collisions by reported collision type and severity, arranged in descending order based on the frequency of total collisions.

Figure 2: Reported Collisions by Collision Type and Severity, City of Stockton, January 2015 – July 2020



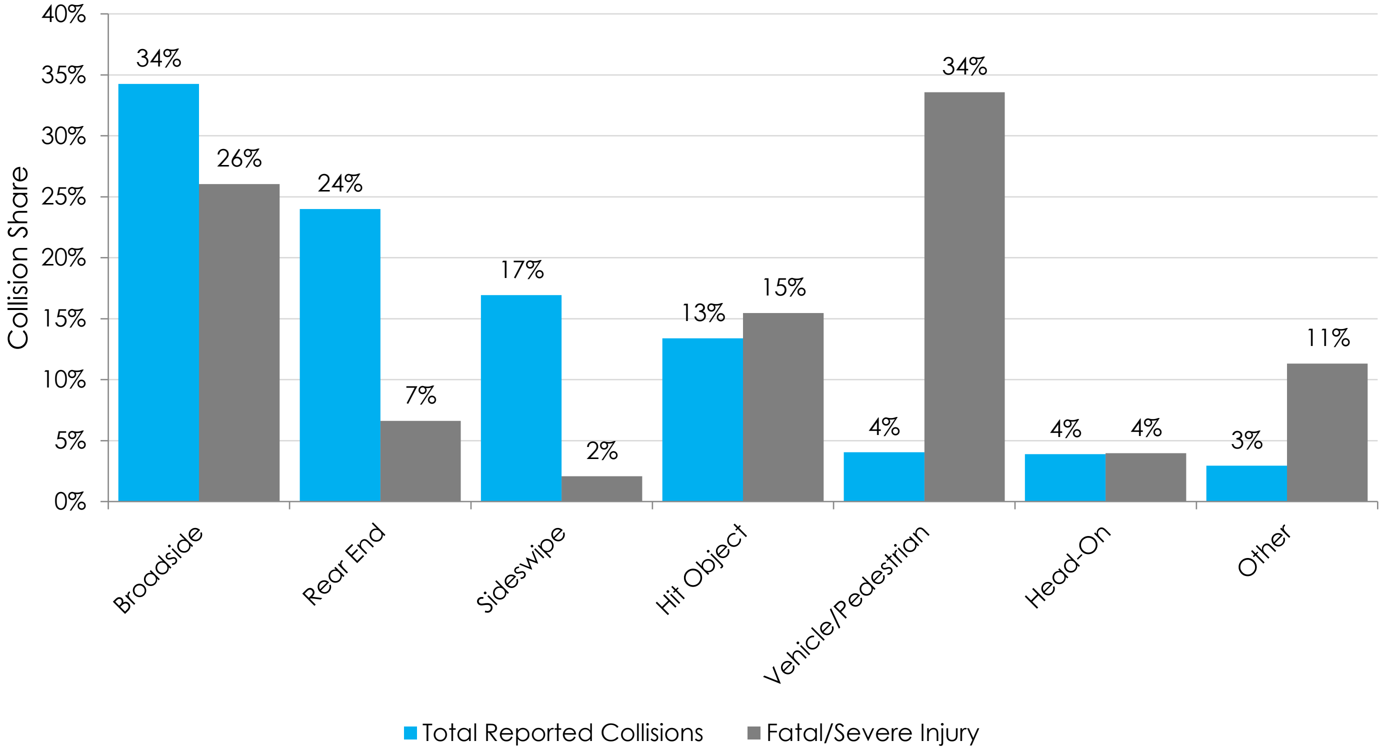
Source: City of Stockton, UC Berkeley TIMS, 2020.

Figure 3 demonstrates that fatal and severe injury collision share does not follow the trend of number of total reported collisions by type.

- The three most frequent collision types were:
  - Broadside (34% of reported collisions);
  - Rear end (24% of reported collisions); and
  - Sideswipe (17% of reported collisions).
- The three most frequent collision types for fatal and severe injury collisions were:
  - Vehicle-pedestrian (34% of reported fatal and severe injury collisions);
  - Broadside (26% of reported fatal and severe injury collisions); and
  - Hit object (15% of reported fatal and severe injury collisions).

These three collision types—vehicle-pedestrian, broadside, and hit object—together account for 75% of fatal and severe injury collisions in the City. Figure 3 compares the proportion of collision types for total reported collisions against fatal and severe injury collisions.

Figure 3: Collision Type for Fatal and Severe Injury Collisions Compared to All Collisions, City of Stockton, January 2015 - July 2020



Source: City of Stockton, UC Berkeley TIMS, 2020.

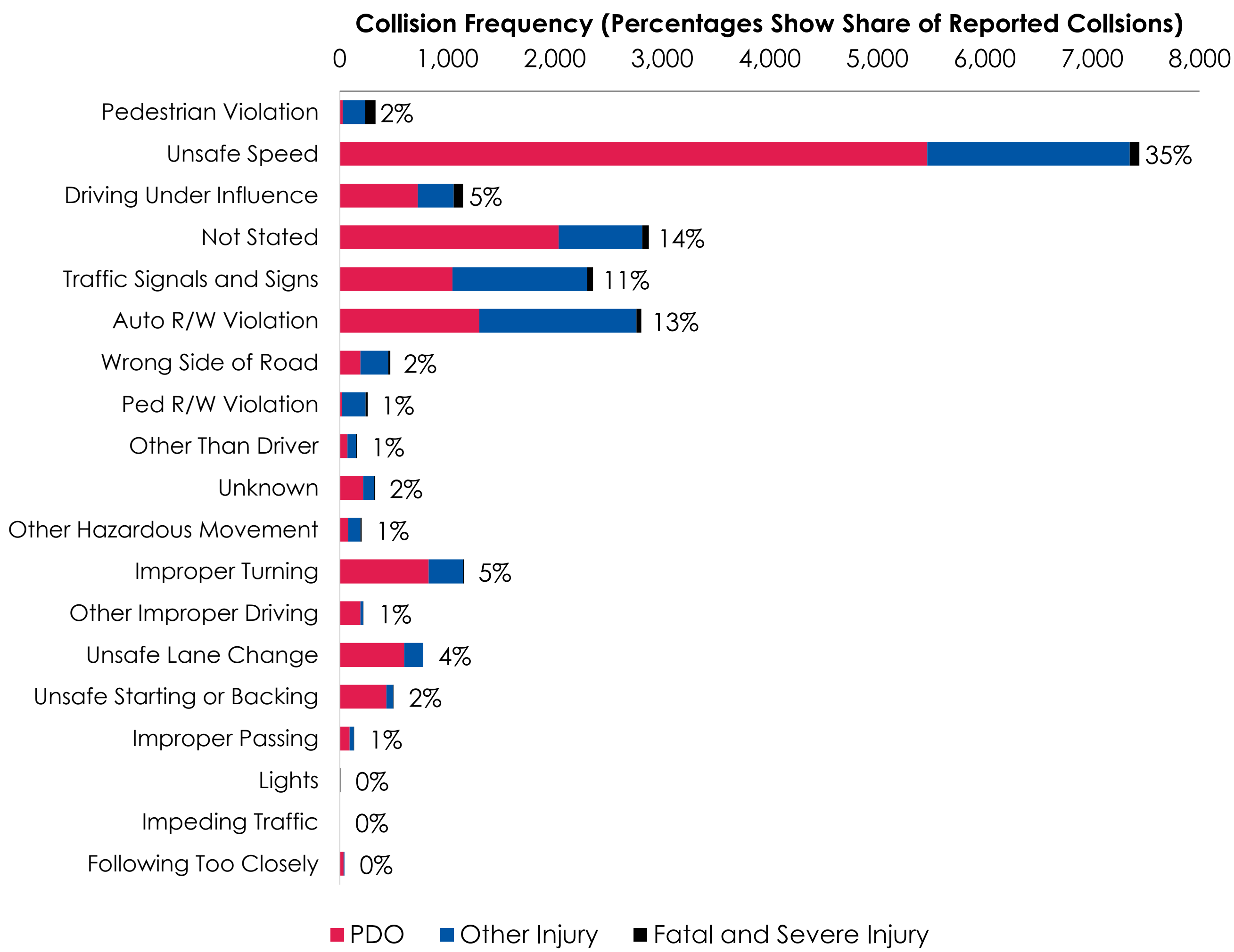
- Vehicle-pedestrian collisions are overrepresented for fatal and severe injury collisions, with a vehicle-pedestrian collision 8.5 times as likely to result in a fatal or severe injury collision compared to their proportion of overall collisions.
- Hit object collisions are also slightly overrepresented, with a hit object collision 1.2 times as likely to result in a fatal or severe injury collision compared to its proportion of reported collisions.
- By comparison, broadside collisions are slightly underrepresented for fatal and severe injury collisions, with these collisions 24% less likely to result in a fatal and severe injury collision compared to the total reported collision proportion.

These key collision types are discussed in more detail in subsequent sections of this report.

Primary Collision Factor

Figure 4 presents reported collisions with cited primary collision factors. The figure is arranged in descending order based on the frequency of ***fatal and severe injury collisions***. While some collision factors occur much more frequently for ***total*** reported collisions or the proportion of ***injury*** collisions (e.g., unsafe speed or traffic signals and signs), others like pedestrian violations or driving under the influence account for large shares of fatal and severe injury collisions.

Figure 4: Collisions by Reported Primary Collision Factor, City of Stockton, January 2015 – July 2020



Source: City of Stockton, UC Berkeley TIMS, 2020.

- Unsafe speed was the most frequently cited collision factor (35% of reported collisions), followed by automobile right-of-way (13%) and traffic signals and signs (11%) violations.
- A total of 16% of reported collisions had unknown or not stated cited primary collision factors.
- Pedestrian violations (99 collisions), unsafe speed (91), and driving under the influence (87) are the collision factors with the highest fatal and severe injury collision frequencies, accounting for 52% of total reported fatal and severe injury collisions.

The three most frequent fatal and severe injury collision factors collision types is analyzed below.

Primary Collision Factor Among Key Collision Types

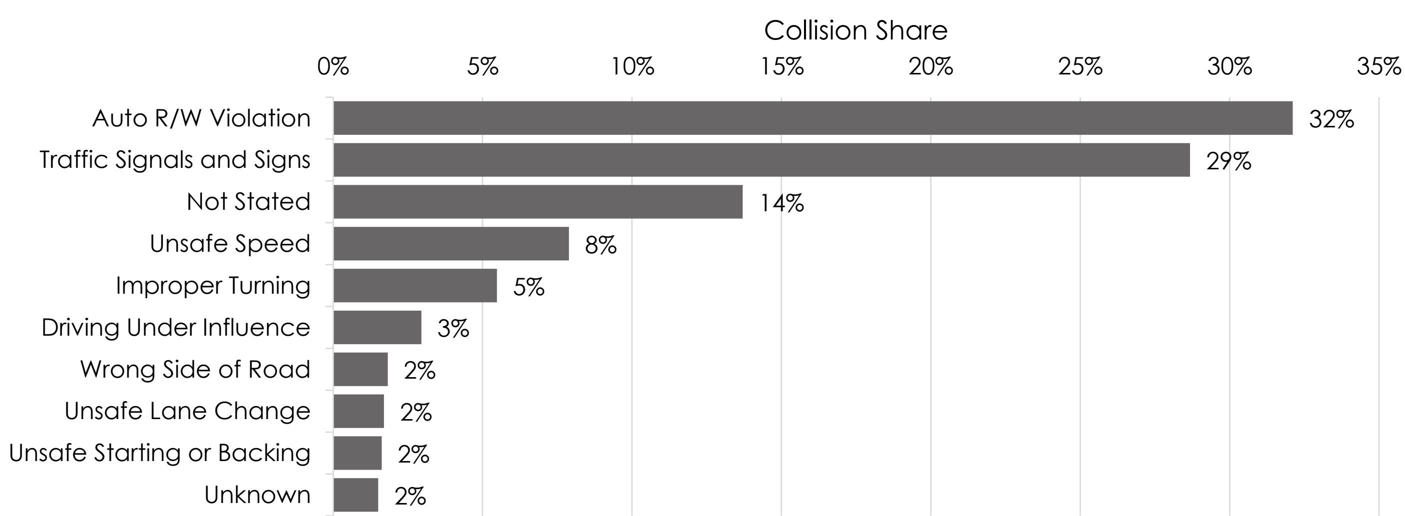
Three collision types—vehicle-pedestrian, broadside, and hit object—account for 75% of fatal and severe injury collisions. Broadside and hit object collisions are analyzed in more detail below; pedestrian collisions are subsequently discussed in the *Pedestrian Collisions* section of this report.

BROADSIDE COLLISIONS

Broadside collisions account for 34% of reported collisions and 26% of fatal and severe injury collisions. Broadside collisions predominately occurred at intersections (95%). To isolate patterns among broadside collisions, Kittelson analyzed the top ten most frequent Primary Collision Factors (PCF). Figure 5 presents this analysis.

- Broadside collisions are most frequently the result of auto right-of-way[4] (32%) and traffic signals and signs[5] (29%) cited primary collision factors. Together, these two factors account for 61% of all broadside collisions.
- All other collision factors—other than those without a stated primary collision factor—account for less than 10%, with unsafe speed (8%) and improper turning (5%) violations as the only other collision factors equal to or above 5% of all broadside collisions.

Figure 5: Top Ten Primary Collision Factors for Broadside Collisions, City of Stockton, January 2015 – July 2020



Source: City of Stockton, UC Berkeley TIMS, 2020.

Note: "Not Stated" indicates that the collision report does not offer a conclusive statement of a collision factor.

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[4] This is a reported PCF that indicated a failure to yield right-of-way to oncoming traffic.

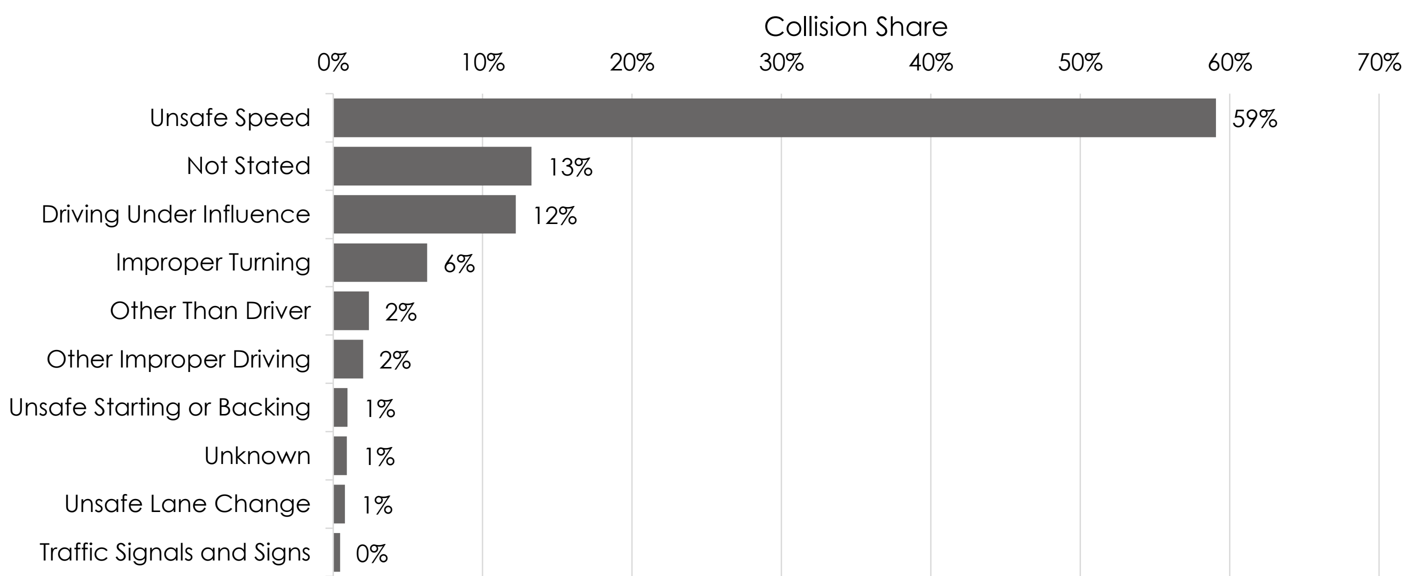
[5] This is a reported PCF that indicated a failure to adhere to traffic control (e.g., running a stop sign).

HIT OBJECT COLLISIONS

Hit object collisions account for 13% of reported collisions and 15% of fatal and severe injury collisions. Among hit object collisions, 86% were at intersections. To isolate patterns among hit object collisions leading to severe outcomes, Kittelson analyzed exclusively fatal and severe injury hit object intersection collisions and organized the results by the most frequent primary collision factors, and cited (CVC) violations. Figure 6 presents this analysis.

- Of those recorded, 71% of intersection-related hit object collisions occurred at unsignalized intersections.
- The most common violation of a fatal and severe injury hit object collision was unsafe speeding (40% of hit object fatal and severe injury collisions) on a highway, followed by driving under the influence (32% of hit object fatal and severe injury collisions).

Figure 6: Top Ten Primary Collision Factors for Hit Object Collisions, City of Stockton, January 2015 – July 2020

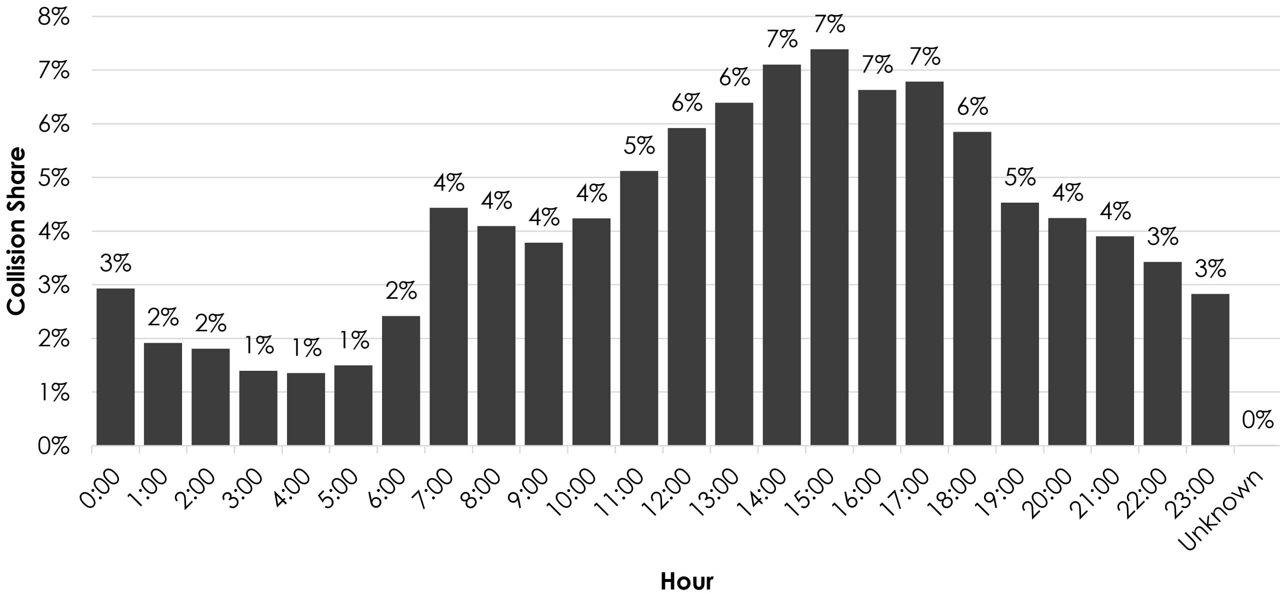


Source: City of Stockton, UC Berkeley TIMS, 2020.

Time of Day

Figure 7 presents reported collisions by time of day (under all weather conditions).

Figure 7: Reported Collisions by Time of Day, City of Stockton, January 2015 – July 2020



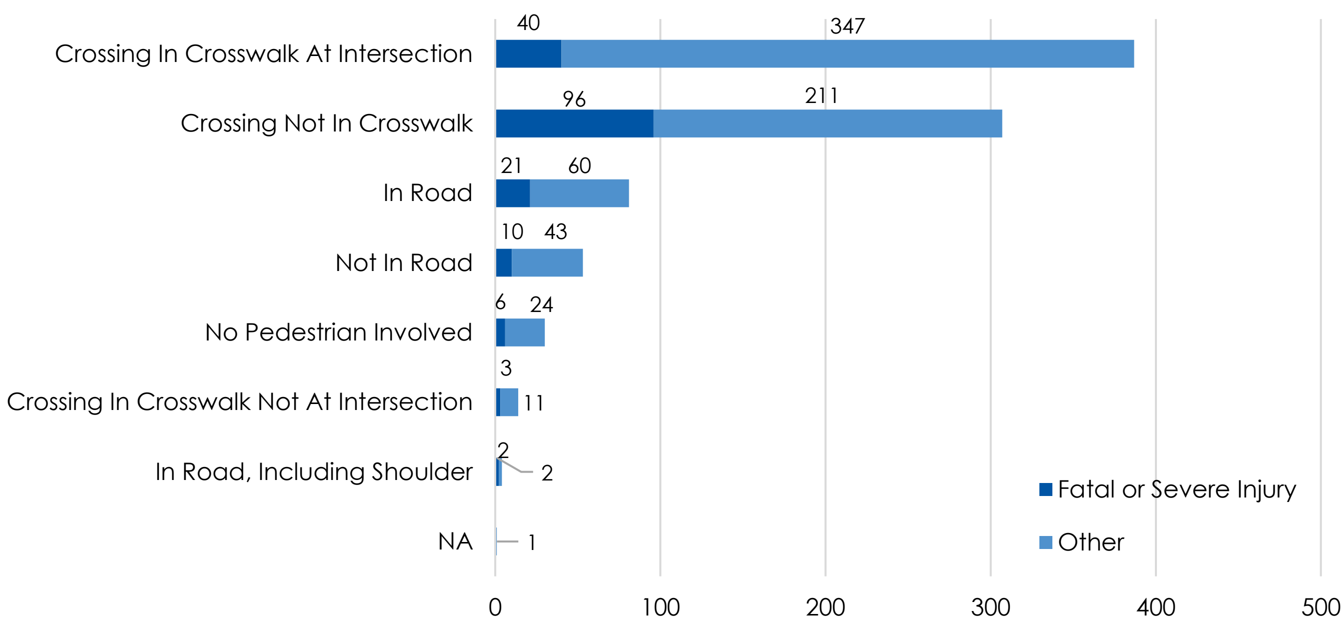
Source: City of Stockton, UC Berkeley TIMS, 2020.

- Collisions peak in the afternoon and early evening, with each hour between noon and 6pm accounting for between 6% and 7% of reported collisions by hour.
- The hour between 3-4pm has the highest frequency of reported collisions.

Pedestrian Collisions

Figure 8 highlights pedestrian-involved collisions by reported pedestrian action preceding a collision and by severity.

Figure 8: Pedestrian Action Preceding Collision by Severity, City of Stockton, January 2015 – July 2020



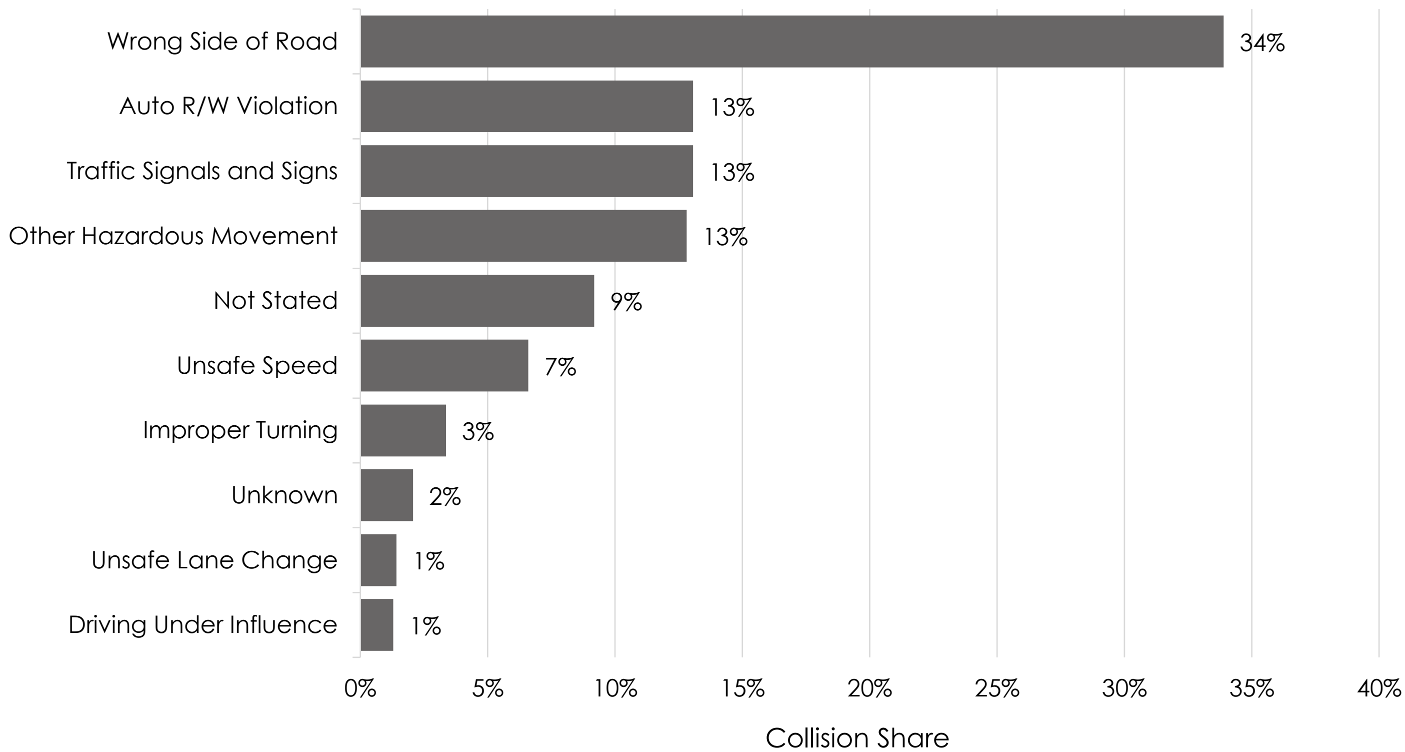
Source: City of Stockton, UC Berkeley TIMS, 2020 . Note: Collision data shown in this figure has been augmented with party level data, which results in more actions shown than the number of collisions.

- Among fatal or severe injury pedestrian collisions, 56% occurred while a pedestrian was crossing a roadway outside a crosswalk. This is disproportionately higher than the share of the same pedestrian action among the total reported pedestrian collisions (37%).
- The second and third most common pedestrian actions preceding a collision included crossing in a crosswalk at an intersection (22%) and pedestrian in roadway midblock (12%). Pedestrians in the roadway account for a slightly higher proportion of fatal and severe pedestrian collisions compared to the share of the same action among total reported pedestrian collisions (9%).
- For pedestrian action – "No Pedestrian Involved", the majority of these collisions (28 out of 30) were classified as pedestrian collisions in the data set, but the two parties reported to be involved were bicyclist and driver. Based on the information available, it is unclear if a pedestrian was involved in each of these collisions, or if the pedestrian was one of the primary parties involved in these collisions.

Bicycle Collisions

Figure 9 highlights bicyclist-involved collisions by the top ten cited primary collision factors. Each of these collision factors led to a minimum of ten bicyclist-involved collisions.

Figure 9: Bicyclist-Involved Collision by Primary Collision Factor, City of Stockton, January 2015 – July 2020



Source: City of Stockton, UC Berkeley TIMS, 2020.

Note: This figure shows bicycle-involved collisions for the top 10 PCFs only.

- Among bicyclist-involved collisions, 34% were cited as involving the wrong side of the road. This may indicate wrong-way or sidewalk riding by bicyclists where bike facilities are not present.
- Traffic signals and signs, automobile right-of-way, and other hazardous movements each accounted for 13% of reported bicyclist-involved collisions.
- Of the total bicyclist-involved collisions, 10 collisions were classified as driving under the influence. However, of the total bicyclist-related collisions, 2% (13) of collisions involved a bicyclist who was under some influence of drug or alcohol, and 11% (74) of collisions involved a bicyclist who was impaired in some way.

Collision Risk Factors

The first analysis examined reported collisions across motor vehicles, pedestrians, and bicyclists. Trends and findings for reported collisions are presented based on the following risk factors:

- Number of intersection legs;
- Intersection control;
- Posted speed; and
- Transit stop presence.

Number of Intersection Legs

Kittelson calculated the Risk Ratio (RR) for signalized and unsignalized intersections using total reported collisions. The results suggest collision risk increases with the number of intersection legs. Table 3 shows the RR values computed for signalized and unsignalized intersections, with varying numbers of intersection legs.

Table 3: Collision Risk Analysis by Number of Intersection Legs, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
3 Leg Signalized	66	1.14%	738	3.84%	3.38
4 Leg Signalized	232	4.00%	6,786	35.32%	8.84
5 or 6 Leg Signalized	6	0.10%	364	1.89%	18.33
3 Leg Unsignalized	3,898	67.16%	5,196	27.05%	0.40
4 Leg Unsignalized	1,588	27.36%	5,884	30.63%	1.12
5 or 6 Leg Unsignalized	14	0.24%	232	1.21%	5.01
Total	**5804**	**100.00%**	**19212**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020. Note: Three signalized intersections within the City are not represented in this table because they were not able to be classified into 3, 4, 5 o 6 leg intersections due to a lack of available information.

- The collision risk increases by 12% for unsignalized intersections with four legs and increases by 401% for unsignalized intersections with more than four intersection legs.
- For unsignalized intersections with three legs, collision risk decreases by 60%, when compared to the other intersection groups.
- For signalized intersections, collision risk increases by 238% for three-legged intersections and increases by 784% for four-legged intersections when compared to other intersection groups.

Intersection Control

Analysis results for the total reported collisions for signalized and unsignalized intersections showed signalized intersections are associated with increased collision risk. Table 4 shows the Risk Ratio (RR) values Kittelson computed for signalized and unsignalized intersections.

Table 4: Collision Risk Analysis by Intersection Control, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
Signalized	307	5.29%	7,900	41.12%	7.78
Unsignalized	5,500	94.71%	11,312	58.88%	0.62
Total	**5,807**	**100.00%**	**19,212**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020.

- The higher collision risk numbers are associated with signalized intersections, where the sample size is relatively small when compared to unsignalized intersections. Signalized intersections account for about 5 percent of all intersections within the City.
- The RR suggests that when considering all intersections, collisions on unsignalized intersections are under-represented by 38% when evaluated on a collision per intersection basis.
- The collision risk increases by 678% for signalized intersections, when compared to unsignalized intersections.

Posted Speed

Kittelson calculated the Risk Ratio (RR) for posted speed using total reported collisions. The results suggest collision risk increases at intersections and roadway segments as posted speed increases.

Posted speed limits are set as per California Vehicle Code (CVC) Section 22349 after conducting engineering and traffic surveys. These speed limits are established by considering prevailing speeds (or 85th percentile speeds), collision history, and highway, traffic, roadside conditions that are not readily apparent to the driver. Drivers do not necessarily travel at posted speeds, and select their speeds based on individual perception of safety, and surrounding land use characteristics.

The sections below present more details on the relative risk for intersections and segments.

INTERSECTIONS

Analysis of the total reported collisions for signalized and unsignalized intersections was based on posted speed. The posted speed criteria is based on the maximum posted speed among all legs of the intersection. The analysis results showed that intersections with a posted speed of 40 mph, based on the maximum speed among all of the intersection approaches, are potentially associated with more frequent occurrences for collisions, as shown in Table 5. This grouping is primarily composed of intersections along arterials and major collectors.

Table 5: Collision Risk Analysis by Posted Speed and Intersection Type, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
Signalized 25mph	134	2.33%	2,801	14.81%	6.37
Signalized 30mph	58	1.01%	1,170	6.19%	6.14
Signalized 40mph	109	1.89%	3,839	20.30%	10.73
Unsignalized 25mph	4,913	85.28%	7,660	40.50%	0.47
Unsignalized 30mph	269	4.67%	1,368	7.23%	1.55
Unsignalized 40mph	278	4.83%	2,074	10.97%	2.27
Total	**5,761**	**100.00%**	**18,912**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020.

- When considering all intersections, collisions at unsignalized intersections with a posted speed of 25 mph, based on the maximum speed among intersection approaches, are under-represented by 53% when evaluated on a collision per intersection basis.
- The collision risk increases by 55% for unsignalized intersections with a 30 mph maximum posted speed limit among intersection legs and 127% for unsignalized intersections with a maximum posted speed limit of 40 mph.
- Similarly, the collision risk increases by 537% and 514% respectively, for signalized intersections with a 25 mph and 30 mph maximum posted speed limit among intersection legs.
- The collision risk is highest for signalized intersections with a maximum posted speed limit of 40 mph among these intersection groups. The collisions are over-represented for this group by 973%, when evaluated on a collision per intersection basis.
- The statistical correlation between collision occurrence and posted speeds does not infer causation. In other words, the relative risk associated with changes in posted speed does not mean that the cause of collisions is associated only with the posted speeds. There are several factors including driver behavior, land use characteristics, and roadway design characteristics that influence drivers' speeds on a roadway.
- This risk ratio analysis is helpful to understand that the locations with higher posted speed limits may justify more emphasis for speed-reduction related countermeasures.

Kittelson calculated the Risk Ratio (RR) for signalized and unsignalized intersections for the three most frequent collision types in the City (broadside, rear end, and sideswipe collisions). Table 6 through Table 8 shows the RR values computed for intersections by posted speed for the most frequent collision types.

Table 6: Collision Risk Analysis by Posted Speed and Broadside Collisions, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
Signalized 25mph	134	2.33%	1,117	16.43%	7.06
Signalized 30mph	58	1.01%	500	7.36%	7.31
Signalized 40mph	109	1.89%	1,318	19.39%	10.25
Unsignalized 25mph	4,913	85.28%	2,564	37.72%	0.44
Unsignalized 30mph	269	4.67%	585	8.61%	1.84
Unsignalized 40mph	278	4.83%	714	10.50%	2.18
Total	**5,761**	**100.00%**	**6,798**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020.

- When considering all intersections, broadside collisions at unsignalized intersections with a posted speed of 25 mph, based on the maximum speed among intersection approaches, are under-represented by 56% when evaluated on a collision per intersection basis.
- The broadside collision risk increases by 84% for unsignalized intersections with a 30 mph maximum posted speed limit among intersection legs and 118% for unsignalized intersections with a maximum posted speed limit of 40 mph.
- The broadside collision risk increases by 606% and 631% respectively, for signalized intersections with a 25 mph and 30 mph maximum posted speed limit among intersection legs.
- The collision risk is highest for signalized intersections with a maximum posted speed limit of 40 mph among these intersection groups. The broadside collisions are over-represented for this group by 925%, when evaluated on a collision per intersection basis.

Table 7: Collision Risk Analysis by Posted Speed and Rear End Collisions, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
Signalized 25mph	134	2.33%	681	15.22%	6.55
Signalized 30mph	58	1.01%	300	6.71%	6.66
Signalized 40mph	109	1.89%	1,242	27.77%	14.68
Unsignalized 25mph	4,913	85.28%	1,461	32.66%	0.38
Unsignalized 30mph	269	4.67%	240	5.37%	1.15
Unsignalized 40mph	278	4.83%	549	12.27%	2.54
Total	**5,761**	**100.00%**	**4,473**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020.

- For unsignalized intersections with a maximum posted speed limit of 25 mph among all intersection approaches, rear end collision risk decreases by 62%, when compared to the other intersection groups with higher posted speed limits on the intersection approaches.
- The rear end collision risk increases by 15% for unsignalized intersections with a 30 mph maximum posted speed limit among intersection legs and 154% for unsignalized intersections with a maximum posted speed limit of 40 mph.
- The rear end collision risk increases by 555%, and 566% respectively, for signalized intersections with a 25 mph and 30 mph maximum posted speed limit among intersection legs.
- The rear end collision risk increases by 1368% for signalized intersections with a 40 mph maximum posted speed limit.

Table 8: Collision Risk Analysis by Posted Speed and Sideswipe Collisions, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
Signalized 25mph	134	2.33%	386	12.21%	5.25
Signalized 30mph	58	1.01%	138	4.36%	4.33
Signalized 40mph	109	1.89%	601	19.01%	10.05
Unsignalized 25mph	4,913	85.28%	1,529	48.36%	0.57
Unsignalized 30mph	269	4.67%	194	6.14%	1.31
Unsignalized 40mph	278	4.83%	314	9.93%	2.06
Total	**5,761**	**100.00%**	**3,162**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020.

- For unsignalized intersections with a maximum posted speed limit of 25 mph among all intersection approaches, sideswipe collision risk decreases by 43%, when compared to the other intersection groups.
- The sideswipe collision risk increases by 31% for unsignalized intersections with a 30 mph maximum posted speed limit among intersection legs and 106% for unsignalized intersections with a maximum posted speed limit of 40 mph.
- The sideswipe collision risk increases by 425%, and 333% respectively, for signalized intersections with a 25 mph and 30 mph maximum posted speed limit among intersection legs.
- The sideswipe collision risk increases by 905% for signalized intersections with a 40 mph maximum posted speed limit.

ROADWAY SEGMENTS

When considering posted speed, roadway segment Risk Ratios (RRs) also show that roadway segments with a posted speed of 40 mph are potentially associated with more frequent occurrences for collisions. Table 9 shows the RR values computed for roadway segments by posted speed for total reported collisions.

Table 9: Collision Risk Analysis by Posted Speed for Roadway Segments, City of Stockton, January 2015 – July 2020

Criteria	Total Length (Feet)	% of Total	Collision Count	% Collision Count	Risk Ratio
Segments 25 mph	17,693,653	80.44%	1,104	53.75%	0.67
Segments 30 mph	2,504,382	11.39%	193	9.40%	0.83
Segments 40 mph	1,023,505	4.65%	702	34.18%	7.34
Segments 45 mph	59,355	0.27%	1	0.05%	0.18
Segments 50 mph	32,784	0.15%	5	0.24%	1.63
Segments 55 mph	681,742	3.10%	49	2.39%	0.77
Total	**21,995,421**	**100.00%**	**2,054**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020.

- The RR suggests that when considering all roadway segments, collisions on roadway segments with a posted speed of 25 mph and 30 mph are under-represented by 33% and 17%, respectively, when evaluated on a collision per length basis.
- The collision risk increases by 63% for roadway segments with a posted speed of 50 mph and decreases by 82% and 23% respectively for roadway segments with a posted speed limit of 45 mph and 55 mph.
- The collision risk is highest for roadway segments with a posted speed of 40 mph among all roadway segments. The collisions are over-represented for this group by 634%, when evaluated on a collision per length basis. Based on a review of these locations, this grouping is primarily composed of roadway segments that are classified as arterials or major collectors.

Transit Stop Presence

The Risk Ratios (RRs) for signalized and unsignalized intersections by transit stop presence for total reported collisions is shown in Table 10. The RRs for pedestrian and bicycle collisions is shown in Table 11. The findings suggest collision risk increases with the presence of a transit stop within 300 feet of an intersection.

Table 10: Collision Risk Analysis by Transit Stop Presence, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
Signalized, stop present	165	2.84%	5,070	26.39%	9.29
Signalized, no stop present	142	2.45%	2,830	14.73%	6.02
Unsignalized, stop present	866	14.91%	3,560	18.53%	1.24
Unsignalized, no stop present	4,634	79.80%	7,752	40.35%	0.51
Total	**5,807**	**100.00%**	**19,212**	**100.00%**	**--**

Source: Kittelson & Associates, Inc., 2020.

- The RR suggests that when considering all intersections, collisions at intersections with transit stops within 300 feet are over-represented by 829% and 24%, respectively, for signalized and unsignalized intersections.
- The collision risk for intersections with no transit stop within 300 feet increases by 502% for signalized intersections and is reduced by 49% for unsignalized intersections when compared to all other intersection groups.

Table 11: Pedestrian and Bicycle Collision Risk by Transit Stop Presence for Unsignalized Intersections, City of Stockton, January 2015 – July 2020

Criteria	Total Intersections	% of Total	Collision Count	% Collision Count	Risk Ratio
3 Leg Unsignalized, no stop present	3,326	57.50%	231	28.00%	0.49
3 Leg Unsignalized, stop present	572	9.89%	146	17.70%	1.79
4 Leg Unsignalized, no stop present	1,298	22.44%	293	35.52%	1.58
4 Leg Unsignalized, stop present	290	5.01%	155	18.79%	3.75
Total	**5,486**	**94.85%**	**825**	**100.00%**	**--**

Note: This table does not include information on unsignalized intersections with more than 4 legs (14 intersections).

Source: Kittelson & Associates, Inc., 2020.

- Pedestrian and bicycle collisions at unsignalized intersections with a transit stop present, are over-represented by 79% and 275% at three-legged and four-legged intersections respectively, on a collision per intersection basis.
- Pedestrian and bicycle collision risk for unsignalized intersections with no transit stops present within 300 feet increases by 58% for four-legged intersections and decreases by 51% for three-legged intersections.

Network Analysis and Systemic Findings

This section describes the network screening and systemic evaluation of the Stockton roadway network. In addition to the network screening, Kittelson also reviewed collision risk at the ten highest-frequency collision locations provided by the City. The findings from this review can be found in Appendix A.

DATA AND NETWORK SCREENING APPROACH

Kittelson identified the intersections and segments with the highest collision severity using the Equivalent Property Data Only (EPDO) network screening performance measure from the AASHTO *Highway Safety Manual (HSM)*. The EPDO calculation was performed for all public intersections and roadway segments. Private roads and grade-separated highways were excluded from the analysis. The EPDO performance measure is described below. Moving forward throughout this document, the EPDO performance measure is referred to as a collision severity score.

The collision severity score assigns weight to individual collisions based on the collision severity and location of the collision (Table 12). Weights, provided by the 2020 *Caltrans' Local Roadway Safety Manual*, are based on the cost of property-damage-only (PDO) collisions, assigning each collision with a score relative to a PDO collision.

Table 12: Collision Weights by Severity and Location Type

Location Type	Collision Severity by Severity				
	Fatal	Severe Injury	Other Visible Injury	Complaint of Pain	Property Damage Only
Signalized Intersection	119.55	119.55	10.70	6.08	1.00
Unsignalized Intersection	190.23	190.23	10.70	6.08	1.00
Roadway	164.66	164.66	10.70	6.08	1.00

Source: Weights derived from Caltrans, *Local Roadway Safety: A manual for California's Local Road Owners* (Version 1.5), 2020.

The weights prioritize fatal and severe injury collisions equally to recognize that a death versus a severe injury is often a function of the individual involved or of emergency response time. Therefore, both outcomes represent locations where the City may want to prioritize improvements. Collision weights vary by location due to the relative costs associated with the collision severity at the location types. Specifically, unsignalized intersections have a higher cost for fatal and severe collisions because fatal and severe collisions at these locations tend to result in more severely injured persons on average.

Intersection Methodology

Kittelson identified signalized and unsignalized intersections in the City road network and then defined collisions as intersection or segment collisions.

An intersection collision is defined as a collision that occurs within 250 feet of the intersection. These collisions were spatially joined and summarized in ArcGIS to show the total number of collisions by severity at each intersection. Where intersections were less than 500 feet from each other, collisions were assigned to the nearest of the two intersections. Collisions occurring more than 250 feet from any intersection were separated to be used in the segment analysis discussed below.

Kittelson calculated the collision severity score for the intersections by multiplying each collision severity total by the associated weight (by intersection type) and summing the results using the following formula:

> **Collision Severity Score** = [Fatal weight] * [# of fatal collisions + severe injury weight] * [# of severe injury collisions + other visible injury weight] * [# of other visible injury collisions + complaint of pain injury weight] * [# of complaint of pain injury weight collisions + PDO collisions]

Kittelson annualized the collision severity score by dividing the score by the years (5.5) of collision data analyzed.

Roadway Segment Methodology

After completing the intersection analysis, Kittelson used the collisions reported more than 250 feet from the nearest intersection to conduct a separate segment analysis.

A Python script in ArcGIS allowed for splitting the Stockton street network into overlapping half-mile segments, incrementing the segments by one-tenth (1/10) of a mile. This methodology helps to identify portions of roadway with the greatest potential for safety improvements.

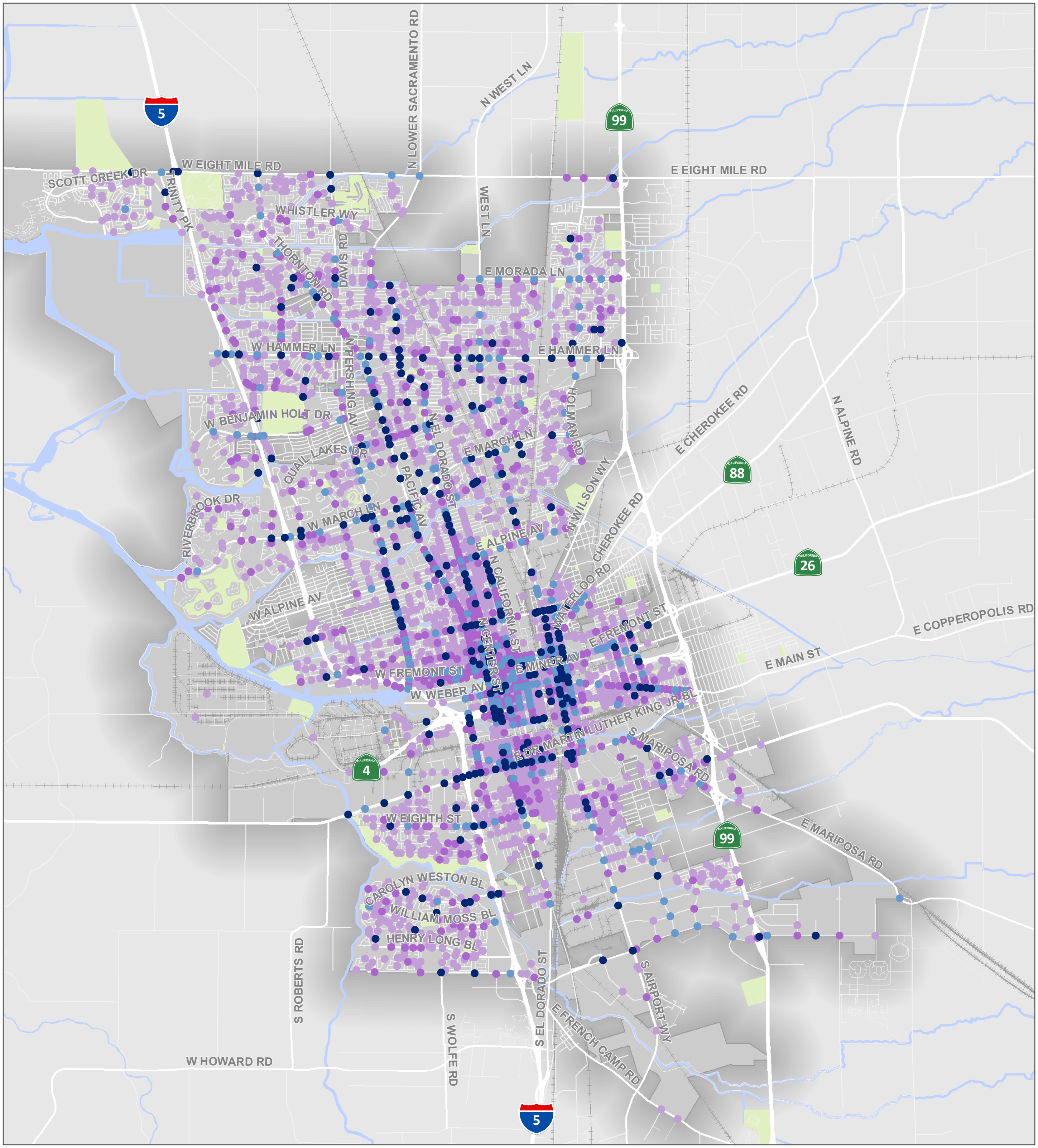
After splitting the network, the Python script spatially joined non-intersection collisions to each segment. Similar to the intersection methodology above, Kittelson summarized collisions by severity, and multimplied the totals by the collision severity weights for roadway segments. The weighted collision severity scores of the collisions were totaled and annualized by the number of years of collision data (5.5) to generate an annualized collision severity score.

NETWORKING SCREENING FINDINGS

Kittelson identified priority intersections and segments using the annualized collision severity scores; the results are presented below.

For intersection locations, the collision severity scores ranged from zero (no reported collisions during the 5.5 years) to 234.64. For the half-mile roadway segments, the collision severity scores ranged from zero to 99.76.

Figure 10 and Figure 11 show the results of the collision severity scoring by percentiles for intersection locations and roadway segments, respectively. Intersections or segments shown as not falling within one of the quartiles indicates there were no reported collisions at that location.



Crash Severity Scoring

- 95 - 100th Percentile (34.95 - 191.59)
- 90 - 94th Percentile (7.74 - 34.95)
- 80 - 89th Percentile (2.20 - 7.74)
- 0 - 79th Percentile (0.18 - 2.20)
- Railroad
- Parks
- City Limits

0 2 Miles

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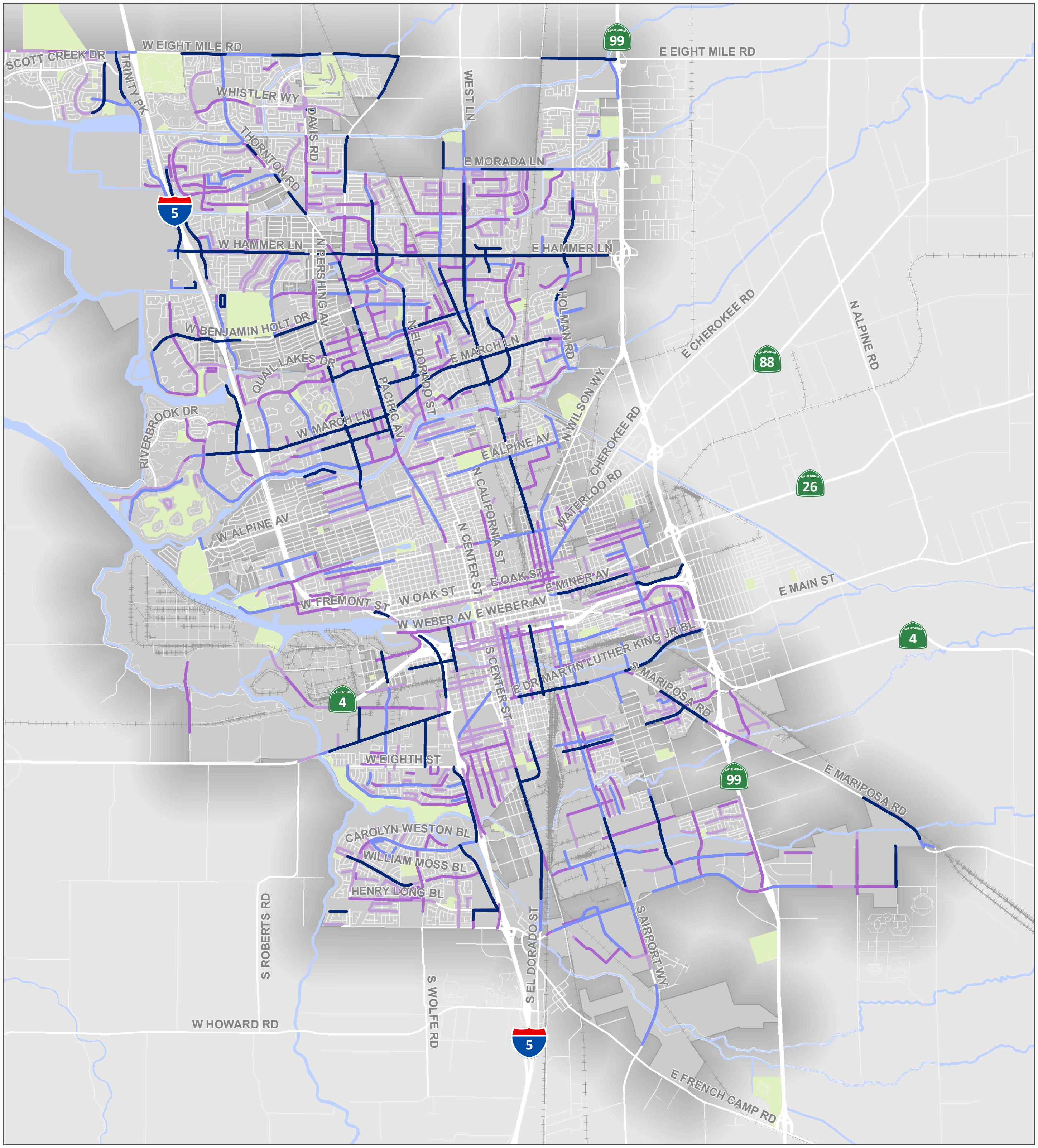
Figure 10

Intersection Screening Crash Severity Scores Stockton SSAR



Crash Severity Scores

- 95 - 100th Percentile 95.55 - 99.76)
- 90 - 94th Percentile (1.65 - 5.55)
- 83 - 89th Percentile (0.36 - 1.65)
- 0 - 82nd Percentile (0.18 - 0.36)
- Railroad
- City Limits
- Parks

0 2 Miles

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Figure 11

Roadway Screening Crash Severity Scores Stockton SSAR

Priority Locations

Kittelson identified priority intersections and segments using the annualized collision severity score for intersections and segments.

The top scoring intersections and segments were reviewed to determine priority locations. Based on natural break points in the collision severity score, the top 29 intersections (including two ramp terminal intersections under Caltrans' jurisdiction) and 9 roadway segments were identified based on the collision severity score, collision types, and collision factors at the locations. This refined list of priority locations is provided in Table 13, Table 14, and Figure 12.

Table 13: Screening Priority Intersection

Intersection	Traffic Control	Annualized Collision Severity Score
Dr MLK Jr Boulevard at Stanislaus Street	Unsignalized	191.59
Hammer Lane at Lan Ark Drive	Signalized	157.53
Dr MLK Jr Boulevard at Harrison Street	Unsignalized	146.34
March Lane at El Dorado Street	Signalized	133.65
Hammer Lane at Lorraine Avenue	Signalized	131.09
Dr MLK Jr Boulevard at Lincoln Street	Signalized	126.27
Harding Way at Commerce Street	Unsignalized	126.26
Hazelton Avenue at Airport Way	Signalized	121.48
Dr MLK Jr Boulevard at California Street	Signalized	120.54
West Lane at Swain Lane	Signalized	118.3
Pershing Avenue at Telegraph Avenue[6]	Unsignalized	115.03
Airport Way at Washington Street	Unsignalized	113.25
Wilson Way at Acacia Street	Unsignalized	112.9
El Dorado Street at Jamestown Street	Unsignalized	112.61
March Lane at Precissi Lane	Signalized	109.33
El Dorado Street at Ivy Avenue	Unsignalized	107.99
Wilson Way at Fremont Street	Signalized	107.12
Harding Way at Center Street	Signalized	106.58
Sierra Nevada Street at Lindsay Street	Unsignalized	104.67

[6] This location is representative of the merging location between Telegraph Avenue and Pershing Avenue rather than a traditional intersection.

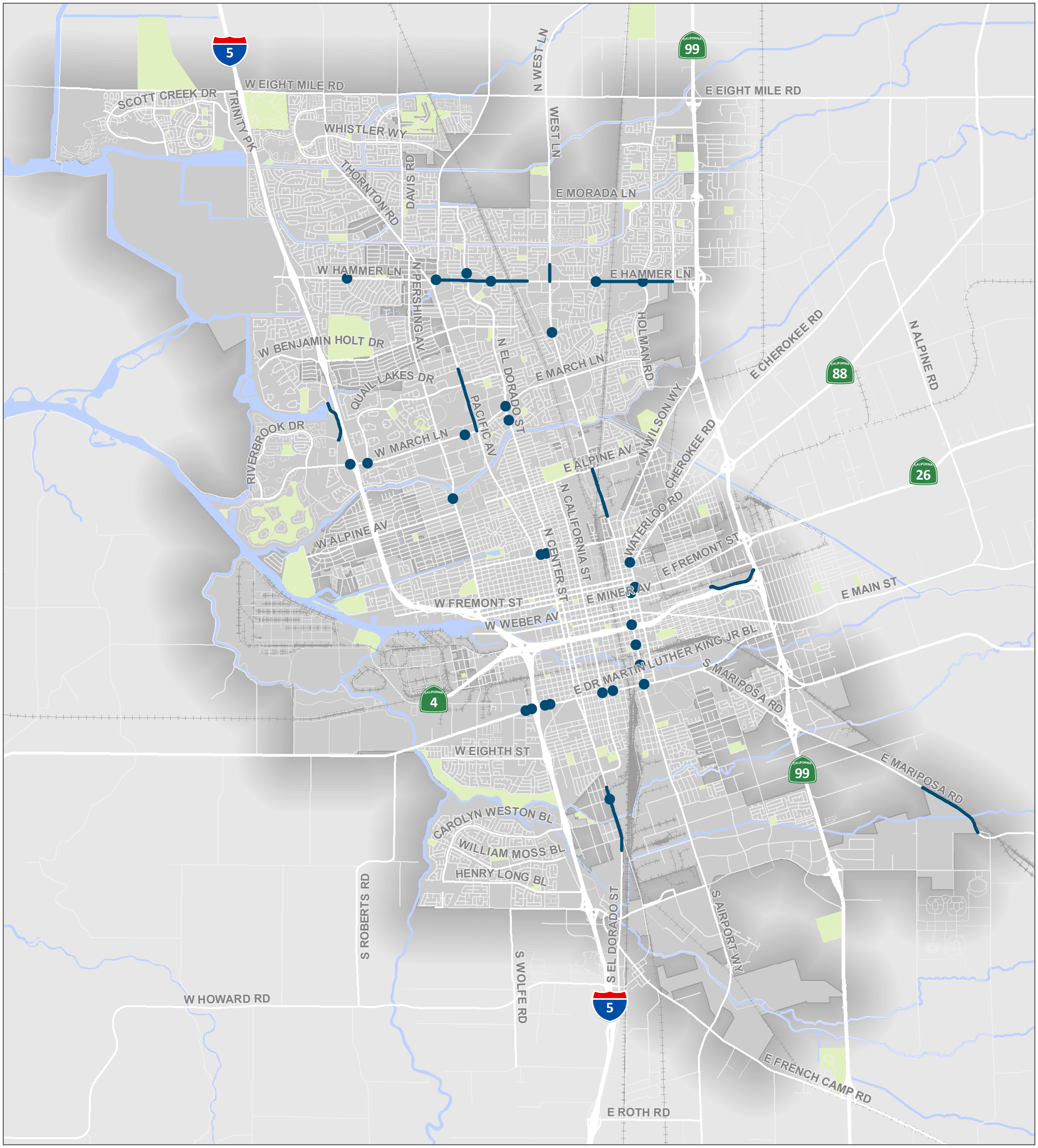
Intersection	Traffic Control	Annualized Collision Severity Score
Dr MLK Jr Boulevard at Airport Way	Signalized	103.71
I-5 Southbound Ramp at Charter Way	Unsignalized	103.05
March Lane at Quail Lakes Drive/Da Vinci Drive	Signalized	95.23
Charter Way at Stockton Street	Unsignalized	94.21
I-5 Southbound Ramp at March Lane	Signalized	93.36
Hammer Lane at Holman Road	Signalized	92.66
Hammer Lane at Don Avenue/Meadow Avenue	Signalized	90.69
Airport Way at Anderson Street	Unsignalized	89.19
Hammer Lane at Lower Sacramento Road	Signalized	88.88
El Dorado Street at Iris Avenue	Unsignalized	87.35

Source: Kittelson & Associates, Inc., 2020.

Table 14: Screening Priority Segments

Location	Functional Classification	Annualized Collision Severity Score
West Lane from Hammer Lane to Knickerbocker Drive	Arterial	69.46
El Dorado Street from Lowell Avenue to South 900' of Clayton Avenue	Arterial	131.45
Feather River Drive from Driftwood Place to Fourteen Mile Slough Crossing	Collector	82.36
Pacific Avenue from March Lane to Longview Avenue	Arterial	90.27
West Lane from Alpine Avenue to University Avenue	Arterial	83.02
Hammer Lane from Lower Sacramento Road to Tam O'Shanter Road	Arterial	148.01
Myrtle Street from Filbert Street to State Route 99	Local Road	75.09
Hammer Lane from Lorraine Avenue to Marantha Drive	Arterial	76.96
E Mariposa Road from County Line to Austin Road	Arterial	62.00

Source: Kittelson & Associates, Inc., 2020.



- Priority Intersections (Crash Severity Score > 87)
- Priority Segments (Crash Severity Score > 62)
- Railroad
- City Limits
- Parks

0 2 Miles

Figure 12

Priority Locations Crash Severity Scores Stockton SSAR

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EMPHASIS AREAS

Engineering Emphasis Areas

Using the analysis described in the preceding section, Kittelson identified five major emphasis areas for the City. Each is discussed in more detail in the sections that follow.

Highest Occuring Collision Type:

1. Broadside collisions (discussed in Highest Occuring Collision Types Section)
2. Rear end collisions (discussed in Highest Occuring Collision Types Section)
3. Sideswipe collisions (discussed in Highest Occuring Collision Types Section)

Roadway/Infrastructure:

4. Arterials and major collector roadways with posted speed limits up to 40 mph (discussed in High-Risk Corridors and Intersections)
5. Transit stops located within 300 feet of unsignalized and signalized intersections

HIGHEST OCCURING COLLISION TYPES

As identified in the previous chapter, the following collision types were most frequent:

- Broadside (34% of reported collisions)
- Rear end (24% of reported collisions)
- Sideswipe (17% of reported collisions)

However, Kittelson with input from the PMT selected the the three most frequent collisions types *among fatal and severe injury collisions* as emphasis areas:

- **Vehicle-pedestrian** (34% of reported fatal and serious injury collisions). Vehicle-pedestrian collisions are overrepresented for fatal and severe injury collisions, with a vehicle-pedestrian collision 8.5 times as likely to result in a fatal or severe injury collision compared to their proportion of overall collisions.
- **Broadside** (26% of reported fatal and serious injury collisions). By comparison, broadside collisions are slightly underrepresented for fatal and severe injury collisions, with these collisions 24% less likely to result in a fatal and severe injury collision compared to the total reported collision proportion.
- **Hit object** (16% of fatal and serious injury collisions). Hit object collisions are also slightly overrepresented, with a hit object collision 1.2 times as likely to result in a fatal or severe injury collision compared to its proportion of reported collisions.

These three collision types account for over 75% of fatal and severe injury collisions in Stockton.

A shared goal across all three collision type emphasis areas is to identify systemic countermeasures and potential capital project locations that are eligible and competitive for grant funding to reduce the frequency and severity of these collision types.

HIGH-RISK CORRIDORS AND INTERSECTIONS

According to the network screening results, the top 38 locations by collision severity score were identified and grouped by control type (Table 15):

- Group A: Signalized Intersections
- Group B: Unsignalized Intersections
- Group C: Roadway Segment Corridors

Through network screening and discussions with the PMT, locations within each group were identified as emphasis locations for the City of Stockton. This section presents opportunities to advance capital projects that improve transportation safety at each of these emphasis area locations.

Table 15. Top High-Risk Intersections & Segment Corridors

Location	Group	Segment/Intersection	Annualized Collision Severity Score
Hammer Lane at Lan Ark Drive	A	Signalized Intersection	157.53
March Lane at El Dorado Street	A	Signalized Intersection	133.65
Hammer Lane at Lorraine Avenue	A	Signalized Intersection	131.09
Dr MLK Jr Boulevard at Lincoln Street	A	Signalized Intersection	126.27
Hazelton Avenue at Airport Way	A	Signalized Intersection	121.48
Dr MLK Jr Boulevard at California Street	A	Signalized Intersection	120.54
West Lane at Swain Lane	A	Signalized Intersection	118.3
March Lane at Precissi Lane	A	Signalized Intersection	109.33
Wilson Way at Fremont Street	A	Signalized Intersection	107.12
Harding Way at Center Street	A	Signalized Intersection	106.58
Dr MLK Jr Boulevard at Airport Way	A	Signalized Intersection	103.71
March Lane at Quail Lakes Drive/Da Vinci Drive	A	Signalized Intersection	95.23
I-5 Southbound Ramp at March Lane	A	Signalized Intersection	93.36
Hammer Lane at Holman Road	A	Signalized Intersection	92.66
Hammer Lane at Don Avenue/Meadow Avenue	A	Signalized Intersection	90.69
Hammer Lane at Lower Sacramento Road	A	Signalized Intersection	88.88
Dr MLK Jr Boulevard at Stanislaus Street	B	Unsignalized Intersection	191.59
Dr MLK Jr Boulevard at Harrison Street	B	Unsignalized Intersection	146.34
Harding Way at Commerce Street	B	Unsignalized Intersection	126.26

Location	Group	Segment/Intersection	Annualized Collision Severity Score
Pershing Avenue at Telegraph Avenue[7]	B	Unsignalized Intersection	115.03
Airport Way at Washington Street	B	Unsignalized Intersection	113.25
Wilson Way at Acacia Street	B	Unsignalized Intersection	112.9
El Dorado Street at Jamestown Street	B	Unsignalized Intersection	112.61
El Dorado Street at Ivy Avenue	B	Unsignalized Intersection	107.99
Sierra Nevada Street at Lindsay Street	B	Unsignalized Intersection	104.67
I-5 Southbound Ramp at Charter Way	B	Unsignalized Intersection	103.05
Charter Way at Stockton Street	B	Unsignalized Intersection	94.21
Airport Way at Anderson Street	B	Unsignalized Intersection	89.19
El Dorado Street at Iris Avenue	B	Unsignalized Intersection	87.35
West Lane from Hammer Lane to Knickerbocker Drive	C	Arterial Segment	69.46
El Dorado Street from Lowell Avenue to South 900' of Clayton Avenue	C	Arterial Segment	131.45
Feather River Drive from Driftwood Place to Fourteen Mile Slough Crossing	C	Collector Segment	82.36
Pacific Avenue from March Lane to Longview Avenue	C	Arterial Segment	90.27
West Lane from Alpine Avenue to University Avenue	C	Arterial Segment	83.02
Hammer Lane from Lower Sacramento Road to Tam O' Shanter Road	C	Arterial Segment	148.01
Myrtle Street from Filbert Street to State Route 99	C	Local Road Segment	75.09
Hammer Lane from Lorraine Avenue to Marantha Drive	C	Arterial Segment	76.96
E Mariposa Road from County Line to Austin Road	C	Arterial Segment	62.00

Note: Bold font indicates the locations that were identified for safety project scopes.

Source: Kittelson & Associates, Inc., 2021.

[7] This location is representative of the merging location between Telegraph Avenue and Pershing Avenue rather than a traditional intersection.

COUNTERMEASURES IDENTIFIED

This section presents the engineering safety countermeasures identified to address the systemic collision trends documented in the previous section.

Kittelson compiled a list of engineering countermeasures with the following considerations:

- **Relevance to Stockton**. Countermeasures included in the Caltrans Local Roadway Safety Manual (and funded by the HSIP program) that appear most relevant for the City of Stockton. For example, pedestrian supportive or urban speed management treatments were prioritized, whereas treatments more applicable to a rural highway (e.g., truck climbing lane) were deemed low priority.
- **HSIP eligibility**. Countermeasures that have been eligible for HSIP funding in previous cycles (note that this may change in future HSIP cycles).
- **Alignment with collision analysis findings**. Countermeasures that most directly relate to the three emphasis area collision types: broadside, hit object, and vehicle-pedestrian collisions.
- **Collision reduction potential, cost, and systemic application potential**. Low-cost countermeasures with: (a) high documented collision reduction potential; and (b) an ability to be applied systemically throughout the City.

With guidance from the PMT, Kittelson identified engineering treatments to address citywide collision patterns and trends. The countermeasure treatments have been grouped into five treatment groups to most directly address the collision patterns and trends for overall collisions and fatal and severe injury collisions. The five treatment groups identified include:

- Pedestrian Crossing Enhancements;
- Bicycle Intersection Treatments;
- Signalized Intersection Treatments;
- Unsignalized Intersection Treatments; and,
- Roadway Segment Treatments.

For each of these treatment groupings, Kittelson identified priority countermeasures and summarized each based on the safety issues addressed, quantitative effectiveness, and implementation considerations.

Pedestrian Crossing Enhancements

Through discussions with the PMT, Kittelson identified Pedestrian Crossing Enhancements as a priority countermeasure for the City because vehicle-pedestrian collisions were identified as one of the most frequent collision types (34%) among fatal and serious injury collisions in the City. In addition, pedestrian violations were the most frequently cited collision factors (19%) among fatal and severe injury collisions. Pedestrian fatal and severe injury collisions are overrepresented for signalized and unsignalized intersections, with pedestrian collisions representing 2% of total reported collisions but 12% (signalized) and 16% (unsignalized) of fatal and severe injury collisions.

Kittelson's review of the City's most frequent collision locations showed common trends regarding pedestrian considerations including: lack of pedestrian scale lighting, long pedestrian crossings, objects in the pedestrian zone, and at least one corner without contemporary pedestrian ramp design at those locations.

Pedestrian crossing enhancements are based on improving the visibility of pedestrians and increasing the awareness of drivers approaching a crossing location. Kittelson identified the following five countermeasures for the City of Stockton:

1. Crosswalk Visibility Enhancements
2. Rectangular Rapid Flashing Beacons (RRFBs)
3. Pedestrian Hybrid Beacon (PHB)
4. Pedestrian Refuge Island
5. Signalized Intersection Treatments

Each individual countermeasure is discussed below including a description of the treatment, purpose, application, considerations, possible systemic application, collision reduction factor, and relative planning-level cost.

The information provided in the sections below is adapted from the Federal Highway Administration (FHWA) *Field Guide for Selecting Countermeasures at Uncontrolled Pedestrian Crossing Locations* (FHWA Field Guide, 2018) and National Cooperative Highway Research Program (NCHRP) *Guidance to Improve Pedestrian and Bicyclist Safety at Intersections* (NCHRP, 2020).

The collision reduction factor noted for each of the countermeasures in this report is from the *Local Roadway Safety Manual* for California's Local Road Owners (LRSM, 2020), unless otherwise noted for countermeasures in the sections below.

CROSSWALK VISIBILITY ENHANCEMENTS

- **Description:** This group of treatments include high-visibility crosswalk markings, improved nighttime lighting, advance or in-street warning signage, curb extensions, and parking restrictions. Figure 13 shows an example pedestrian crossing treatment and Figure 14 shows an example of curb extension.

- **Purpose:** The use of different crosswalk visibility enhancements in combination help indicate preferred locations for pedestrians to cross and increase the visibility of a crossing location. These treatments increase pedestrian and driver awareness and help reinforce drivers' requirement to yield the right-of-way to crossing pedestrians.
- **Application:** Per the FHWA Field Guide, adding advance Yield Here to Pedestrian sign and yield line should be considered for the following roadway combinations of average daily traffic (ADT), number of travel lanes, and posted speed limit conditions:
  - Any ADT + 4 or more lanes (with or without a raised median) + any posted speed limit
  - Any ADT + any number of lanes + ≥ 35 mph posted speed limit

  On roadways with 4 or more lanes and ADT > 9,000 vehicles per day, the risk of pedestrian collisions at an uncontrolled marked crosswalk could increase if marked crosswalks are not combined with other treatments such as pedestrian refuge islands, or hybrid beacons.
- **Considerations:** These treatments may be considered when any of the following factors are observed on site:
  - Drivers not yielding to pedestrians in crosswalks;
  - Inadequate conspicuity/visibility of crosswalk and/or crossing pedestrian;
  - Noted conflicts at crossing locations; or,
  - On-street parking restrictions and curb extensions should be considered for implementation with marked crossings to reduce the risk of pedestrian collisions at uncontrolled crossings.
- **Systemic Application:** Low-cost crosswalk visibility enhancements may easily be integrated into other ongoing maintenance or capital improvement projects. This could include integration into routine restriping or resurfacing activities. Curb extensions and lighting are most likely addressed as capital improvement projects given the increased cost and complexity of these improvements.
- **Collision Reduction Factor:** 25% - 35% depending on treatments selected.
- **Planning-Level Cost:** Varies - $1,000 – 10,000 depending on treatments selected.

Figure 13: Example Pedestrian Crossing

Source: City of Sacramento

Figure 14: Example of Curb Extension

Source: Google Maps

RECTANGULAR RAPID FLASHING BEACONS (RRFBS)

- **Description:** Rectangular rapid flashing beacons (RRFBs) are user-actuated amber Light Emitting Diodes (LEDs) that supplement warning signs to improve awareness and safety at unsignalized intersections or mid-block crosswalks. Figure 15 shows an example RRFB installation.
- **Purpose:** RRFBs have been shown to significantly increase driver yielding behavior at uncontrolled crosswalks, with motorist yielding rates ranging from 34% to over 90% (NCHRP, 2020). This treatment helps reduce pedestrian-vehicle conflicts, increase the visibility of pedestrian crossing locations, and reduces pedestrians trapped in the roadway.
- **Application:** Per the City of Stockton guidance, RRFBs may be considered under the following roadway conditions:
  - ADT ≤ 15,000 + 2 lanes or one lane in each direction with a raised median + ≥ 40 mph posted speed limit
  - ADT 9,000 – 15,000 + one lane in each direction with or without median + ≥ 35 mph posted speed limit
- **Considerations:** This treatment may be considered when the following factors are observed on site:
  - Lack of pedestrian separation from traffic for long crossing distances;
  - Inadequate conspicuity/visibility of crosswalk and/or crossing pedestrian; or,
  - Noted conflicts at crossing locations.
- **Systemic Application:** RRFBs are mostly likely to be integrated as part of larger capital improvement projects or installed as their own capital improvements. This treatment may be better suited as a spot treatment or a treatment package in urban neighborhoods.
- **Collision Reduction Factor:** 35%
- **Planning-Level Cost:** $35,000 - $60,000 per location (depending on whether it is solar powered or AC).

Figure 15: Example of Enhanced Pedestrian Crossing with RRFB

Source: Washington County, Oregon, www.co.washington.or.us/lut/trafficsafety/drivingsafety/rrfb.cfm

PEDESTRIAN HYBRID BEACON (PHB)

- **Description:** A Pedestrian Hybrid Beacon (PHB) is a hybrid beacon used to control traffic and reverts to all dark until a pedestrian activates it via a push button or other form of detection. When activated, the beacon displays a sequence of flashing and solid lights that indicate when vehicles must stop and when pedestrians should cross. Figure 16 shows an example of PHB.
- **Purpose:** PHBs provide active warning to drivers when a pedestrian is in the crosswalk. PHBs have been shown to significantly increase driver yielding behavior at uncontrolled crosswalks, with motorist yielding rates exceeding 90% (FHWA, 2014).
- **Application:** Per the City of Stockton guidance, PHBs may be considered under the following roadway conditions:
  - ADT 9,000 – 15,000 + one lane in each direction without raised median or more lanes + ≥ 40 mph posted speed limit
  - ADT ≥ 15,000 + two or more lanes in each direction + any posted speed limit
  - ADT ≥ 9,000 + one lane in each direction with or without median + ≥ 35 mph posted speed limit
  - Any ADT + any number of lanes + ≥ 40 mph posted speed limit
  - 100 feet from intersection or driveway with a stop or yield control
- **Considerations:** This treatment may be considered when the following factors are observed on site:
  - Long pedestrian delay due to few available gaps in traffic;
  - Drivers not yielding to pedestrians in crosswalks; or,
  - Noted conflicts at crossing locations.
- **Systemic Application:** PHBs are most likely installed as their own capital improvement projects and are usually installed in conjunction with a marked crosswalk and pedestrian countdown signals.
- **Collision Reduction Factor:** 55%
- **Planning-Level Cost:** Varies – $200,000 - $350,000 (includes fiber optic interconnect) depending on the type of signal and overall scope of the project.

Figure 16: Example of Pedestrian Hybrid Beacon

Source: NACTO

PEDESTRIAN REFUGE ISLAND

- **Description:** A pedestrian refuge island is a median with a refuge area that is intended to help protect pedestrians who are crossing the roadway. This treatment is also referred to as a crossing island or pedestrian island. Figure 17 shows an example of the pedestrian refuge island.
- **Purpose:** Refuge island allows the pedestrians to focus on identifying adequate gap in traffic for one direction at a time. This treatment reduces the crossing distance for pedestrians and creates a place for refuge to allow multiple-stage crossings. Refuge island positions pedestrians in the sightline of drivers approaching the intersection.
- **Application:** Per FHWA Field Guide, refuge islands may be considered under the following roadway conditions:
  - Any ADT + 2 or 3 lanes (without a raised median) + any posted speed limit
  - ADT ≥ 9,000 + 4 or more lanes (without a raised median) + any posted speed limit
  - Any ADT + 4 or more lanes (without a raised median) + ≥ 35 mph posted speed limit
- **Considerations:** This treatment may be considered when the following factors are observed on site:
  - Inadequate conspicuity/visibility of the crosswalk and/or crossing pedestrian;
  - Excessive vehicle speed; or,
  - Lack of pedestrian separation from traffic during long crossings.
- **Systemic Application:** Raised concrete medians are most likely installed as their own capital improvement projects and are usually installed in conjunction with a marked crosswalk and warning sign. Interim crossing islands can be implemented systemically using flexible delineators and temporary curbing.
- **Collision Reduction Factor:** 45%
- **Planning-Level Cost:** Varies – $2,000 - $40,000 depending on the type of treatment selected.

Figure 17: Example Pedestrian Refuge Island

Source: NACTO

SIGNALIZED INTERSECTION PEDESTRIAN TREATMENTS

- **Description:** This group of treatments include implementing leading pedestrian interval, prohibit right-turns on red, and implementing Barnes Dance, which improve drivers' awareness of pedestrians at intersections. The detailed explanation for each of the strategies is below:
    - ***Leading Pedestrian Interval (LPI)***: LPIs provide pedestrians a head start when crossing at a signalized intersection. LPIs can be easily programmed into existing signals to give pedestrians the "Walk" signal a minimum of 3 to 7 seconds before motorists are given a green indication. With this head start, pedestrians can better establish their presence in the crosswalk before motorists have priority to turn left at the intersection. LPIs can be provided automatically with each phase or provided only when actuated (actively or passively). Figure 18 shows an example of this treatment.
    - ***No Right-Turn on Red (No RTOR)***: This treatment restricts motorists on turning right during the red light. In California, turning right on red is not a default condition of the existing laws. Drivers in California are advised of this restriction with the posting of "No Turn on Red" signs (static or dynamic), according to the sign specifications in California Manual on Uniform Traffic Control Devices (CA MUTCD). Dynamic signs can be used to restrict right turns during certain times of day or during certain signal phases.
    - ***Barnes Dance***: This treatment also known as 'pedestrian scramble' allows pedestrian movements in all directions simultaneously, including diagonally. This is a traffic signal operation that functions differently than a standard signal operation because it allows for an exclusive pedestrian phase, i.e., all pedestrians to cross in any direction while all vehicles are stopped. Figure 19 shows an example of this treatment.

- **Purpose:** LPIs increase visibility of crossing pedestrians and reduce conflicts between pedestrians and vehicles. This treatment increases the likelihood of motorists yielding to pedestrians. No RTOR eliminates conflicts between turning vehicles and pedestrians during a concurrent walk phase. Barnes Dance reduces conflicts between vehicles and pedestrians and improves pedestrian access and safety.

- **Application:** Per NCHRP guidance document, the following treatments may be considered for application under the following roadway contexts:
    - LPIs and No RTOR treatments may be considered at signalized intersections, specifically at intersections with medium to high motor vehicle turning volumes and pedestrian volumes.
    - Barnes Dance may be considered in dense urban areas at intersections where pedestrian volumes outnumber vehicular volumes.

- **Considerations:** These treatments may be considered when the following factors are observed on site:
    - LPIs may be considered at locations with particularly high elderly populations, high collision history, or at school crosswalks.
    - No RTOR treatment may be considered at intersections with exclusive pedestrian phase, and school crossings.

- Barnes Dance may be implemented along with No RTOR treatment at intersections with high pedestrian volumes.

- **Systemic Application:** LPIs may be better suited as a systemic treatment in areas where there are existing pedestrian signals and high volumes of pedestrians and turning vehicles. No RTOR may be implemented as a systemic treatment, paired with a solution to address higher right-turn on green needs if warranted. Barnes Dance may be better suited as a spot treatment or a treatment package in dense urban neighborhoods with high pedestrian activity.
- **Collision Reduction Factor:** LPI – 60%; No RTOR – 25%; and Barnes Dance – 51% (NCDOT, 2021).
- **Planning-Level Cost:** LPIs - $550 - $6,000, including countdown timer, controller, signal head and software upgrade; No RTOR - $200 - $6,000 depending on the type of sign (electronic vs. others); Barnes Dance – $5,000 - $15,000 depending on signal timing modifications and pavement markings.

Figure 18: Example of Leading Pedestrian Interval

Source: PedBikeInfo

Figure 19: Example of Barnes Dance Intersection

Source: Wall Street of Rockies (http://wallstreetoftherockies.com/the-barnes-dance/)

Bicycle Intersection Treatments

Kittelson, with input from the PMT, identified bike-related treatments at intersections as a priority countermeasure for the City because the share of injuries and fatalities among bicycle collisions is higher than all reported collisions. Bicycle fatal and severe injury collisions are overrepresented for signalized and unsignalized intersections, with bicycle collisions representing 3% of total reported collisions but 4% (signalized) and 10% (unsignalized) of fatal and severe injury collisions. Among bicycle collisions, 34% were cited as involving the wrong side of the road. This may indicate wrong-way or sidewalk riding by bicyclists where bike facilities are not present.

Kittelson's review of the City's most frequent collision locations showed some common trends regarding bicycle considerations including: presence of unprotected bike lanes and missing dedicated bike facilities.

Bike-related treatments at intersections improve the visibility of bicyclists, increase the awareness of drivers approaching the intersections, and increase predictability of bicyclist location. Kittelson identified the following five countermeasures for the City of Stockton:

1. Bike Lanes
2. Bike Lane Extension Through Intersections
3. Bike Signals
4. Bike Boxes
5. Road Diet

Each individual countermeasure is discussed below including a description of the treatment, purpose, application, considerations, possible systemic application, collision reduction factor, and relative planning-level cost. The information provided in the sections below is adapted from the Federal Highway Administration (FHWA) *Bicycle Safety Guide and Countermeasure Selected System* (FHWA BIKESAFE, 2021), NCHRP *Guidance to Improve Pedestrian and Bicyclist Safety at Intersections* (NCHRP, 2020), and National Association of City Transportation Officials (NACTO) *Urban Bikeway Design Guide* (NACTO, 2011).

The collision reduction factor noted for each of the countermeasures in this report is from the *Local Roadway Safety Manual* for California's Local Road Owners (LRSM, 2020), unless otherwise noted for countermeasures in the sections below.

BIKE LANES

- **Description:** This treatment designates a portion of roadway for the preferential or exclusive use of bicyclists through striping, signage, and pavement markings. Bike lanes typically run in the same direction of traffic, though they may be configured in the contra-flow direction on low-traffic corridors for the connectivity of a particular bicycle route. Different types of bike lanes are as follows:
  - ***Conventional Bike Lanes***: These bike lanes designate an exclusive space for bicyclists using pavement markings and signage. These are located adjacent to motor vehicle travel lanes and flow in the same direction as motor vehicle traffic.
  - ***Buffered Bike Lanes***: These bike lanes are conventional bike lanes paired with a designated buffer space separating the bike lane from motor vehicle travel lanes and/or parking lane. Figure 20 shows an example of buffered bike lane at intersection approach.
  - ***Contra-Flow Bike Lanes***: These bike lanes allow bicyclists to ride in the opposite direction of motor vehicle traffic. They convert a one-way street into a two-way street: one direction for motor vehicles and bikes, and other for bikes only.
  - ***Left-Side Bike Lanes***: These bike lanes are conventional bike lanes placed on the left-side of one-way streets or two-way median divided streets.

- **Purpose:** Bike lanes helps bicyclists to ride at their preferred speed without interference from prevailing traffic conditions and facilitates predictable behavior and movements between motorists and bicyclists.

- **Application:** Per the NACTO Guide, the following treatments may be considered for application under the following roadway contexts:
  - Conventional Bike Lanes: ADT ≥ 3,000 + ≥ 25 mph posted speed limit + high transit vehicle volumes
  - Buffered Bike Lanes: ADT ≥ 3,000 + ≥ 35 mph posted speed limit
  - Contra-Flow Bike Lanes: On streets where bicyclists are already riding the wrong way, and on low-speed and low volume streets
  - Left-Side Bike Lanes: ADT ≥ 3,000 + ≥ 35 mph posted speed limit + one-way or median divided streets + frequent transit stops or loading zones on right side of street

- **Considerations:** These treatments may be considered when any of the following factors are observed on site:
  - Presence of sidewalk or wrong-way riding behavior by bicyclists;
  - Limited connectivity and access to bicyclists; or,
  - Presence of right or left-turning conflicts between bicyclists and motor vehicles.

- **Systemic Application:** Low-cost bike lane installations may easily be integrated into other ongoing maintenance or capital improvement projects, provided it involves striping the roadway and minor signing. This could include integration into routine restriping or resurfacing activities. Projects that require roadway widening, right-of-way acquisition and environmental impacts are most likely addressed as capital improvement projects given the increased cost and complexity of these improvements.

- **Collision Reduction Factor:** 35% - 45% depending on treatments selected.
- **Planning-Level Cost:** Varies - $1,000 – $100,000 depending on treatments selected and existing roadway configuration.

Figure 20: Example of Buffered Bike Lane at Intersection Approach

Source: Kittelson & Associates, Inc.

BIKE LANE EXTENSION THROUGH INTERSECTIONS

- **Description:** Bicycle pavement markings through intersections indicate the intended path of bicyclists through an intersection or across a driveway or ramp. They guide bicyclists on a safe and direct path through the intersection and provide clear boundary between paths of bicyclists and motorists. Figure 21 shows an example of bike lane extension through intersections.
- **Purpose:** Bicycle pavement markings helps raise awareness for both bicyclists and motorists to potential conflict areas. This treatment reinforces that the through bicyclists have priority over turning motor vehicles.
- **Application:** Per the NACTO Guide, bicycle pavement markings may be considered for application for the following roadway context:
  - At particularly wide or complex signalized intersections, where the bicycle path may be unclear.
- **Considerations:** This treatment may be considered when any of the following factors are observed on site:
  - Presence of right or left-turning conflicts between bicyclists and motor vehicles; or,
  - Locations with bicycle lanes or separated bike lanes where it is desired to delineate the bicycle crossing.

  Since the effectiveness of markings depends entirely on their visibility, maintaining markings should be a high priority where this treatment is considered.

- **Systemic Application:** Bicycle pavement markings are mostly likely to be integrated as part of larger capital improvement projects along major bike-routes. This treatment may be better suited as a treatment package in urban neighborhoods.
- **Collision Reduction Factor:** 39% (ODOT, 2021).
- **Planning-Level Cost:** Varies - $200 - $5,000 per intersection depending on surface area of markings, materials used, and the color of markings.

Figure 21: Example of Bike Lane Extension Through Intersection

Source: Kittelson and Associates, Inc.

BIKE SIGNALS

- **Description:** A bicycle signal is a traffic signal with a green, yellow, or red display intended to control bicycle movements. The display may include arrows or a bicycle-shaped symbol. These signals indicate a leading or protected phase for bicycle movements. These signals can be activated passively or actively. Active detection requires bicyclists to push the button. Video detection systems can be integrated with bike signals or existing traffic signals to trigger phase changes based on the presence of bicyclists. Bicycle detection may also occur by automated means including loop detectors and microwave. Figure 22 shows the example of bike signal.
- **Purpose:** Bike signals is shown to increase signal compliance and improve safety for bicyclists.
- **Application:** Per the NACTO Guide, bike signals may be considered for application under the following roadway context:
    - At particularly wide or complex signalized intersections, where the bicycle path may be unclear.
- **Considerations:** This treatment may be considered when any of the following factors are observed on site:
    - Presence of intersections where a bicycle facility transitions from a cycle track to a bicycle lane; or,
    - Locations with highly used bicycle route that must cross a major signalized intersection to connect users to the rest of the route.

- **Systemic Application:** Bike signals may be better suited as a spot treatment at intersections that are complicated for bicyclists to navigate, intersect a primary bicycle route, and have high bicycle volumes. This treatment may be better suited as a treatment package in cases where agencies want to create a "green wave" effect by timing bicycle signals along the corridor to allow bicyclists to move through intersections at a consistent speed.
- **Collision Reduction Factor:** 45% (ODOT, 2021).
- **Planning-Level Cost:** Varies - $5,000 - $25,000 depending on the type of detection, and number of signal heads.

Figure 22: Example of Bike Signal

Source: NACTO

BIKE BOXES

- **Description:** A Bike Box is a designated area at the head of a traffic lane at a signalized intersection that provides bicyclists with a safe and visible way to get ahead of queuing traffic during the red signal phase. Figure 23 shows an example of Bike Box at an intersection.
- **Purpose:** Bike boxes increases visibility of bicyclists and helps prevent 'right-hook' (or left-hook) conflicts with turning vehicles at the start of the green indication. In addition to increasing the visibility and predictability of bicyclists, bike boxes provide priority for bicyclists by allowing them to come to the front of the queue.
- **Application:** Per the NACTO Guide, bike boxes may be considered for application under the following roadway context:
    - At signalized intersections with high volumes of bicyclists and/or motor vehicles, especially those with frequent bicyclist left-turns and/or motorist right-turns.
- **Considerations:** This treatment may be considered when any of the following factors are observed on site:
    - Presence of right or left-turning conflicts between bicyclists and motor vehicles;
    - Desire to better accommodate left turning bicycle traffic; or,

- A situation where dominant motor vehicle traffic turns right (e.g., onto a ramp) and bicycle traffic goes straight, at the intersection.

- **Systemic Application:** Bike Boxes are mostly likely to be integrated as part of larger capital improvement projects along major bike-routes. This treatment may be better suited as a treatment package in urban neighborhoods.
- **Collision Reduction Factor:** 35% (ODOT, 2021).
- **Planning-Level Cost:** $5,000 per box, including green thermoplastic, pavement markings and signage.

Figure 23: Example of Bike Box

Source: NACTO

ROAD DIET

- **Description:** Road Diets reduce the number of travel lanes on the roadway and provide space to implement pedestrian and bicyclist related treatments including adding bike lanes, and median crossing islands. The most common road diet configuration involves converting a four-lane roadway into three travel lanes (with one lane in each direction and a two-way center-turn lane), often supplemented with bike lanes. Figure 24 shows an example of road diet, i.e., reconfiguration of the roadway.
- **Purpose:** Road Diets are intended to improve access management, increase pedestrian and bicyclist access, and enhance roadway safety.
- **Application:** Per the NCHRP Guide, road diets may be considered for application for the following contexts:
  - At priority pedestrian and bicycle routes; or,
  - In urban and suburban areas with multilane roadways.

- **Considerations:** This treatment may be considered when any of the following factors are observed on site:
  - Presence of left-turning conflicts between bicyclists and motor vehicles; or
  - Desire to better accommodate pedestrian and bicycle traffic.

- **Systemic Application:** Road Diets are most likely addressed as their own capital improvement projects and are usually installed in conjunction with bicycle lanes and/or a pedestrian refuge island.
- **Collision Reduction Factor:** 30%
- **Planning-Level Cost:** Varies - $20,000 - $40,000 per mile, depending on context and configuration.

Figure 24: Example of Road Diet (Roadway Cross-Section Before and After Reconfiguration).

Source: https://domz60.wordpress.com/2014/08/26/road-diet-bibliography/

Signalized Intersection Treatments

Collisions within the influence area of signalized intersections represent 37% of total reported collisions and 34% of fatal and severe injury collisions. Additionally:

- The relative risk analysis found signalized intersections have seven times the collision risk for total collisions, despite representing 5% of all intersections within the City.
- Additionally, despite representing 5% of all intersections, signalized intersections represent 16 of the 21 highest priority locations identified through the SSAR's intersection screening and all the top ten intersections identified in the City of Stockton's High Incidence Intersection Report.

As a result, given the relatively smaller number of signalized intersection locations and the fact that they account for over a third of all fatal and severe injury collisions – safety treatments at signalized intersections have the potential to provide a considerable postive effect toward reducing overall and severe collisions.

Treatments at signalized intersections improve the visibility of the intersection, reduce the potential for conflicting movements within the intersection, and reduce the number of conflict points within the intersection influence area. Kittelson identified the following four countermeasures treatment groups:

1. Improve Signal Hardware or Timing
2. Provide Protected Left Turn Phase
3. Provide Advanced Dilemma-Zone Detection
4. Install Raised Medians on Approaches

Each individual countermeasure is discussed below including the treatment's description, purpose, application, considerations, possible systemic application, collision reduction factor, and relative planning-level cost. The information is adapted from FHWA Safety documentation, the *Caltrans Local Roadway Safety: A Manual for California's Local Road Owners* (LRSM) (2020), and current research. Kittelson obtained the collision reduction factor noted for each of the countermeasures from the LRSM, unless otherwise noted.

IMPROVE SIGNAL HARDWARE, STRIPING, TIMING, OR LIGHTING

- **Description:** These treatments include hardware and timing improvements to signals to improve the visibility of the intersection or help drivers negotiate the intersection. Treatments may include the following:
  - ***Adding or Upgrading Signal Heads***: Signal heads may be added to provide additional clarity on movements where a signal head communicates movements for multiple travel lanes. Additionally, signal heads may be upgraded to add larger signal heads (i.e., increasing the signal head size from 8 inches to 12 inches), new LED lighting, visors, signal back plates, or retro-reflective tape outlining the back plates to increase the visibility of the intersection. Figure 25 shows a signal with retroreflective marking.
  - ***Installing Raised Pavement Markers and Striping Through the Intersection***: Where signalized intersection footprints are large, skewed, or have multiple turn lanes for a given movement,

raised pavement markers and striping can clarify the preferred travel path through the intersection to help avoid potential conflicts. Figure 26 shows an example of pavement markers delineating turning path of travel.

- ***Converting from Pedestal-Mounted to Mast Arm***: When signals are currently mounted on pedestals in the median or outside shoulder, converting the pedestal-mounted intersections to mast arms can improve visibility of the traffic signal heads.
- ***Improving Signal Timing*** : Signal timing improvements may include adjusting clearance intervals, phasing adjustments, eliminating or restricting certain movements, or coordinating signals along a corridor to reduce the potential for conflicting movements. Vehicle-to-vehicle communication can also be used for improving signal timing and coordination.
- ***Improving Intersection Lighting***: Lighting may be improved at the intersection or at its approaches to make drivers' more aware of the intersection surroundings, enhance drivers' available sight distances, and improve the visibility of non-motorists. In commercial areas or in downtown areas where there is more pedestrian activity, pedestrian scale lighting may be placed over sidewalks to help pedestrians navigate the intersection and be seen by motorists.

- **Purpose:** Signal hardware, striping, timing, and lighting improvements enhance the visibility of the intersection. Signs and signals help approaching drivers perceive the upcoming intersection. These treatments can also improve awareness of, clarify, or restrict movements to avoid potential conflicts.

- **Application:** These treatments may be considered at any signalized intersection, but the following may be considered for specific treatments:
  - Converting to mast arms may be considered where mast arms have the potential to increase visibility of the intersection and signal heads for one or more approach(es).
  - Signal timing improvements may be considered where collision patterns indicate conflicts between movements associated with different signal phases or there are opportunities to rephase the signal to separate conflicting movements.
  - Signal hardware upgrades may be considered where collision patterns indicate visibility of the intersection or signal heads may benefit from enhancements.
  - Striping and marking through the intersections may be considered where intersection footprints are large or skewed, or when multiple turn lanes are present for a movement to provide a clear path of travel for the movement.
  - Intersection lighting improvements may be considered at intersections that have a disproportionate number of night-time collisions and do not currently provide lighting at the intersection or at its approaches.

- **Considerations:** These treatments may be considered when high frequencies of angle, broadside, rear-end, night-time or other conflicting movement collisions are occurring at a signalized intersection.

- **Systemic Application:** Signal hardware, striping, signal timing and lighting improvements are low-cost and best suited to systemic applications. These improvements can easily be packaged together for multiple sites as a low-cost capital improvement or integrated into other ongoing projects to integrate safety treatments. Converting to mast arms is more costly and is more suited to a combined capital improvement project or site-by-site implementation.

- **Collision Reduction Factor:** 10% - 74% depending on treatments selected.
- **Planning-Level Cost:** Varies - $4,000 – $100,000 depending on treatments selected and existing roadway configuration with signal timing, striping, lighting, and low-cost hardware representing the low-end of the cost range and converting to mast arms at the high-end.

Figure 25: Signal with Retroreflective Marking

Source: FHWA

Figure 26: Example of Pavement Markers Delineating Turning Path of Travel

Source: Google Maps

PROVIDE PROTECTED LEFT-TURN PHASE/LANE

- **Description:** This treatment consists of adding a new protected left-turn phase to a signal where left-turns are currently permitted. If no left-turn currently exists, adding a left-turn lane will allow left-turning vehicles to queue separately from through movement traffic. This treatment includes adjustments to signal timing and new signal hardware to provide for the protected movement. Figure 27 shows an example of this treatment.
- **Purpose:** Protected left-tun phasing can help reduce rear-end or sideswipe collisions related to left-turn vehicles conflicts with oncoming traffic or vehicles behind them where permitted left-turns are allowed. This phasing removes the need for left-turning drivers to select in opposing through vehicles.
- **Application:** These treatments may be considered at any signalized intersection where left-turn phases are currently permissive or protected-permissive.
- **Considerations:** These treatments may be considered when high collision frequencies involving left-turning vehicles are occurring at a signalized intersection.
- **Systemic Application:** Adding a protected left-turn phase where a left-turn currently exist may be implemented systemically at signalized intersections. They may be integrated with capital improvements at the signal due to the limited needs for the additional phase (adjusting signal

timing and dedicated left-turn signal heads). Where no left-turn lane currently exists, these improvements are likely to require a site-specific capital improvement.

- **Collision Reduction Factor:** 30% - 55% depending on whether a left-turn lane currently exists or not.
- **Planning-Level Cost:** Varies - $25,000 – $200,000 per approach depending on whether a left-turn lane will need to be constructed and the existing signal hardware at a location.

Figure 27: Example of Protected Left-Turn/Phase

Source: Google Earth

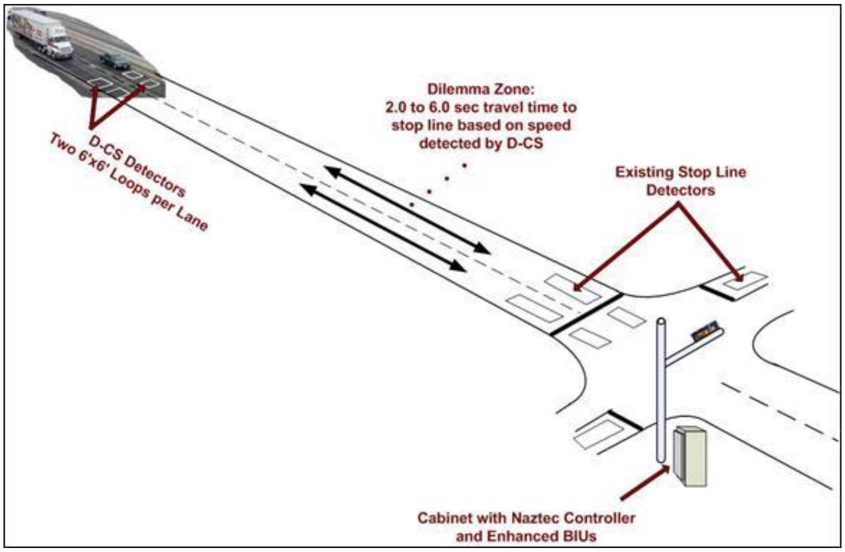
PROVIDE ADVANCED DILEMMA-ZONE DETECTION

- **Description:** This treatment consists of adding new advance detection and signal hardware to detect vehicles that may approach the intersection in the "dilemma zone" of deciding whether to stop or proceed during a yellow phase. The detection system modifies the signal timing to reduce the number of drivers needing to make this decision and the reduce the potential for conflicts due to phase changes. Figure 28 shows an example layout of advanced dilemma zone detection at an intersection.
- **Purpose:** Providing advanced dilemma-zone detection can help reduce conflicts due to late-entering vehicles proceeding through the intersection. It can reduce conflicts arising from hard-stopping vehicles due to the dilemma of whether to proceed or stop during the yellow phase of a signal. Advanced dilemma-zone detection can help reduce the frequency of red-light violations, collisions associated with phase changes and may provide operational benefits.
- **Application:** These treatments may be considered at any signalized intersection. They are most effective for signalized intersections with high-speed approaches.
- **Considerations:** These treatments may be considered when high collision frequencies involve hard-stopping vehicles resulting in rear-end collisions, or there is a collision pattern related to late-entering vehicles or vehicles running red lights.
- **Systemic Application:** Providing dilemma-zone detection can be implemented in combination with other ongoing signal modifications or corridor capital improvements. Video detection systems can allow dilemma-zone detection to be installed systemically> Each intersection will

need to be modified individually to determine the approach settings for detection and desired signal timing modifications.

- **Collision Reduction Factor:** 40%
- **Planning-Level Cost:** $5,000 - $25,000 per approach depending on whether hardware modifications are necessary beyond the detection system.

Figure 28: Example Layout of Dilemma Zone Detection



Source: FHWA

INSTALL RAISED MEDIANS ON APPROACHES

- **Description:** This treatment consists of adding new raised medians on intersection approaches to control and restrict movements from access points on the approach to a signalized intersection. Figure 29 shows an example of raised median near the intersection.
- **Purpose:** Adding raised medians can help reduce conflicts by restricting access-related movements to the roadway on the intersection approaches. The raised medians prohibit left turns into and out of driveways that may be located within the intersection influence area to reduce potential conflicts.
- **Application:** These treatments may be considered at any signalized intersection where driveways are within the intersection influence area and left-turn movements into or out of those access points may lead to potential conflicts.
- **Considerations:** These treatments may be considered when high collision frequencies involve left-turning vehicles on the approach to any intersection. They also apply when there is other evidence of access-related collisions on the intersection approaches. However, implementation of these treatments will need to balance access to businesses where restrictions occurred with safety benefits in commercial and retail areas.
- **Systemic Application:** Raised medians on the intersection approach can be implemented in combination with other ongoing signal modifications or corridor capital improvements.
- **Collision Reduction Factor:** 25%

- **Planning-Level Cost:** $5,000 - $25,000 per approach depending on the type of median installed and other roadway construction needs.

Figure 29: Example of Raised Median

Source: Kittelson & Associates, Inc.

Unsignalized Intersection Treatments

Collisions within the influence area of unsignalized intersections represent 53% of total reported collisions and 52% of fatal and severe injury collisions.

The relative risk of a collision occurring at an unsignalized intersection is lower than signalized forms. However,given 13 of the 29 highest priority locations identified through the SSAR's intersection screening are at unsignalized intersections, these locations represent an opportunity for systemic treatments to reduce severe and fatal collisions.

Unsignalized intersections treatments improve the visibility of the intersection and reduce the potential for conflicting movements within the intersection. Kittelson identified the following four countermeasures:

1. Install or Upgrade Signing and Pavement Markings
2. Improve Sight Distance to Intersection
3. Install Splitter-Islands on the Minor Road Approaches
4. Install Roundabouts

Each individual countermeasure is discussed below including the treatment's description, purpose, application, considerations, possible systemic application, collision reduction factor, and relative planning-level cost. The collision reduction factor noted for each of the countermeasures is from the Caltrans LRSM, unless otherwise noted.

INSTALL OR UPGRADE SIGNING AND PAVEMENT MARKINGS

- **Description:** This treatment consists of adding or upgrading signing and pavement markings at an unsignalized intersection. This can include advance intersection warning signs, STOP AHEAD pavement markings, transverse rumble strips on the approach, stop bars, and upgraded warning or control signs. Figure 30 shows an example of a larger and additional sign installation.
- **Purpose:** Adding or upgrading signing and pavement markings for an uncontrolled intersection can help increase intersection visibility for approaching drivers as well as reducing potential conflicts by clarifying the intersection footprint and intended travel paths.
- **Application:** These treatments may be considered at any unsignalized intersection, especially intersections with high speed, curved, or skewed approaches, or locations with other visibility limitations.
- **Considerations:** These treatments may be considered when high collision frequencies are related to intersection visibility or the intersection footprint is not clearly delineated by striping or pavement markings.
- **Systemic Application:** New or upgraded signs and pavements markings are low-cost treatments that can be implemented systemically and integrated into ongoing maintenance and capital improvement projects.
- **Collision Reduction Factor:** 15-25% depending on the treatments applied.

- **Planning-Level Cost:** $500 - $5,000 per approach depending on the combination of signing and striping implemented.

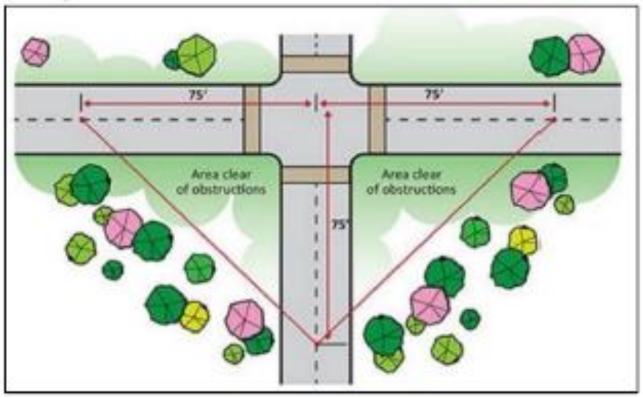
Figure 30: Example of Larger or Additional Signs

Source: South Carolina DOT

IMPROVE SIGHT DISTANCE TO INTERSECTION

- **Description:** This treatment consists of clearing vegetation, roadside objects, on-street parking, fences, buildings, or other objects in the right-of-way. Figure 31 shows an example of a sight triangle to remain clear of obstructions to provide sufficient line of sight.
- **Purpose:** Clearing obstructions within the vicinity of the intersection improves sight distance at the intersection by providing clear sight triangles on the approach or adjacent to the intersection.
- **Application:** These treatments may be considered at any unsignalized intersection where intersection sight distance is limited by on-street parking or other obstacles.
- **Considerations:** These treatments may be considered when high collision frequencies are related to conflicting movements that may be impacted by limited visibility at the intersection. However, sight distance improvements should be balanced with other concerns (such as the loss of on-street parking) to balance competing needs.
- **Systemic Application:** Some obstructions and on-street parking may be removed from the right-of-way at low cost and implemented systemically. Some obstructions such as earthen berms or buildings may require separate capital improvements to implement.
- **Collision Reduction Factor:** 20%
- **Planning-Level Cost:** $200 - $50,000 per approach, depending on the extent/type of obstruction.

Figure 31: Example of Sight Triangle



Source: Chester County Planning Commission

INSTALL SPLITTER-ISLANDS ON THE MINOR STREET APPROACHES

- **Description:** This treatment consists of adding a raised median island at minor street intersection approaches. Figure 32 shows an example of a splitter-island with an additional stop sign.
- **Purpose:** Raised splitter islands create a physical separation between vehicles turning onto the stop-controlled approach and vehicles stopped on that same approach. The splitter island also increases the visibility of the intersection, clarifies movements at the intersection, and provides a space for a secondary stop sign on the approach, if desired.
- **Application:** These treatments may be considered at any unsignalized intersection where conflicts occur between turning and stopped vehicles at an approach, or intersection visibility is limited.
- **Considerations:** These treatments may be considered when high collision frequencies are related to conflicting movements resulting from movements onto or off minor street approaches. Splitter islands should also be designed to accommodate appropriate design vehicles while still being large enough to be visible to drivers and provide a refuge area for crossing pedestrians.
- **Systemic Application:** Due to the need to design splitter islands for the context of each location, this treatment is best implemented as part of a site-specific capital improvement.
- **Collision Reduction Factor:** 40%
- **Planning-Level Cost:** $10,000 per approach

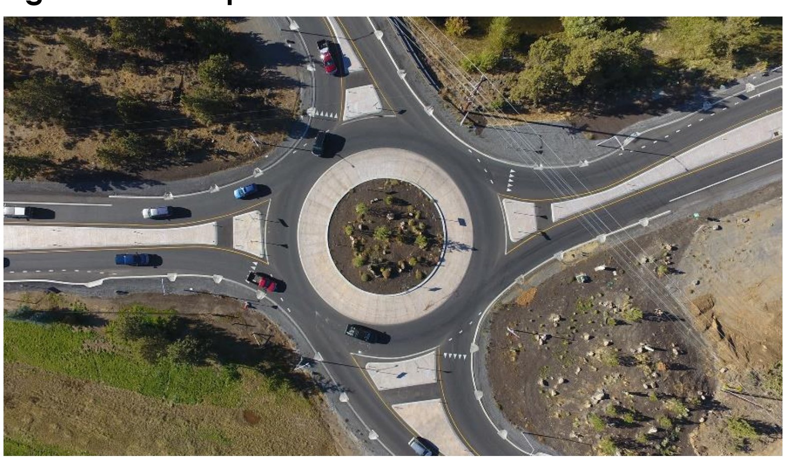
Figure 32: Example of Splitter Island

Source: Mid-Ohio Regional Planning Commission

INSTALL ROUNDABOUTS

- **Description:** This treatment consists of installing a roundabout as intersection traffic control. A roundabout is a circular intersection without traffic signals or stop signs, where drivers travel counterclockwise around a center island. When entering the roundabout, drivers yield to existing traffic, then enter the circulatory roadway and exit in their desired direction. Figure 33 shows an example of a roundabout.
- **Purpose:** Roundabouts are designed to eliminate left turns conflicts by requiring traffic to traverse to the right around a central island. Roundabouts manage intersection vehicular conflicts, reducing severe collisions by eliminating broadside and head-on collisions and helping traffic flow more efficiently.
- **Application:** This treatment may be considered at any intersection with a high frequency of reported collisions, traffic delays, complex geometry (more than four approach roads), frequent left-turns, and/or relatively balanced traffic flows.
- **Considerations:** Roundabouts work well for intersections with low-to-moderate traffic speeds, and lower traffic volumes. Per the NCHRP 672: Roundabout Informational Guide, the typical daily service volumes for four-legged roundabouts are as follows:
  - Up to 15,000 veh/day for a mini-roundabout with desirable entry design speed of 15-20 mph,
  - Up to 25,000 veh/day for a single-lane roundabout with desirable entry design speed of 20-25 mph, and,
  - 25,000 – 45,000 veh/day for a multi-lane roundabout (2-lane entry) with desirable entry design speed of 25-30 mph.
- **Systemic Application:** Because roundabouts are designed for the context of each location, this treatment is best implemented as part of a site-specific capital improvement.
- **Collision Reduction Factor:** 12% - 78%
- **Planning-Level Cost:** $250,000 - $1,000,000 depending on the size, site conditions, and right-of-way acquisition.

Figure 33: Example of Roundabout



Source: Kittelson & Associates, Inc.

Roadway Segment Treatments

Kittelson identified segment related treatments as a priority countermeasure because the share of severe injuries and fatalities among roadway segment collisions (15%) is higher than total reported segment collisions (10%). Roadway segment treatments improve the visibility of the roadway, increase pavement friction, enhance delineation along curves, and manage traffic speeds along the roadway. The following four countermeasure categories were identified:

1. Segment Curve Treatments
2. Delineation Treatments
3. Median Related Treatments
4. Speed Management

Each countermeasure category is discussed below including the treatment's description, purpose, application, considerations, possible systemic application, collision reduction factor, and relative planning-level cost. The collision reduction factor noted for each of the countermeasures in this report from the Caltrans LRSM, unless otherwise noted.

SEGMENT CURVE TREATMENTS

Kittelson identifed segment curve treatments based on a review of the highest-scoring segments from the SSAR's network screening results. Four of the nine highest-priority roadway segments involved curved roadway segments. Curves treatments at these locations can be used to systemically address collisionsat curves throughout the City. Curve treatments improve the visibility of the approach curve and guide road users through the curve. Friction treatments increase driver control through a curve. The following two countermeasures were identified:

1. Install or Upgrade Signs for Horizontal Curves
2. Install High-Friction Surface Treatments (HFST)

Install or Upgrade Signs for Horizontal Curves

- **Description:** This treatment consists of adding new or upgrading existing advisory signs along or on the approach to horizontal curves. This may consist of chevron signs, curve warning signs (including flashing warning beacons), or other advisory signs. Figure 34 shows an example of curve advance warning sign.
- **Purpose:** New or upgraded advisory signs provide drivers with advance warning of the approaching curve and can help them navigate safely through the curve.
- **Application:** These treatments may be considered at any horizontal curve where visibility of the approaching curve is limited or providing guidance through the curve via chevron signs may provide safety benefits.
- **Considerations:** These treatments may be considered when high frequencies of run-off-road collisions related to a horizontal curve are identified. Signing should be in accordance with California MUTCD requirements and may be implemented in phases, as needed.

- **Systemic Application:** Because of the low cost of new or upgraded signs, curve treatments may easily be implemented systemically or integrated with ongoing maintenance or capital improvement projects.
- **Collision Reduction Factor:** 15-40% depending on the treatment(s) selected.
- **Planning-Level Cost:** $4,000 - $20,000 per curve depending on the treatment(s) selected.

Figure 34: Example of Curve Advance Warning Sign

Source: Google Maps

Install High-Friction Surface Treatments (HFST)

- **Description:** This treatment involves applying f high-quality aggregate to the pavement surface using a polymer binder to restore and/or maintain pavement friction. Figure 35 shows an example treatment application.
- **Purpose:** Higher pavement friction helps drivers maintain better control in dry and wet driving conditions.
- **Application:** These treatments may be considered along horizontal curves or intersection approaches where vehicles frequently brake, and pavement surfaces become prematurely polished, thereby reducing the available pavement friction. This friction reduction may contribute to drivers losing control or vehicles skidding when they speed or turn abruptly.
- **Considerations:** These treatments may be considered when high collision frequencies of run-off-road are related to a horizontal curve are identified or frequent hard-braking related collisions occur on intersection approaches.
- **Systemic Application:** These treatments can be relatively low cost and can be implemented in a short timeframe. They are also ongoing maintenance or capital improvement projects.
- **Collision Reduction Factor:** 17-68%.
- **Planning-Level Cost:** $35 per square yard.

Figure 35: Example High-Friction Surface Treatment Application

Source: Utah Department of Transportation

DELINEATION TREATMENTS

Delineation treatments improve roadway visibility and provide visual information about changes in the roadway environment. These treatments are particularly helpful where visibility can become poor due to rain, fog, or dark conditions. Kittelson identified the following two countermeasures:

1. Install Delineators, Reflectors and/or Object Markers
2. Install Edge-Lines and Centerlines

Install Delineators, Reflectors or Object Markers

- **Description:** This treatment consists of adding delineators, reflectors, or object markers on the approach and through a horizontal curve. Figure 36 shows an example of delineators on curved roadway.
- **Purpose:** Delineators, reflectors, and object markers provide drivers with a visual cue of the approaching horizontal curve and help drivers navigate safely through the curve.
- **Application:** These treatments may be considered at any horizontal curve where visibility of the approaching curve is limited or providing guidance through the curve via delineation may provide safety benefits.
- **Considerations:** These treatments may be considered when high frequencies of run-off-road collisions are related to a horizontal curve.
- **Systemic Application:** Because of the low cost of delineators or reflectors, these treatments may easily be implemented systemically or integrated with ongoing maintenance or capital improvement projects.
- **Collision Reduction Factor:** 15% depending on the treatment(s) selected.
- **Planning-Level Cost:** $500 - $2,500 per curve depending on the treatment(s) selected.

Figure 36: Example Delineators on Curved Roadway

Source: FHWA

Install Edge-Lines and Centerlines

- **Description:** This treatment consists of installing or modifying edge-lines or centerlines through a horizontal curve. Figure 37 shows an example of this treatment.
- **Purpose:** New or modified edge-lines or centerlines help clarify and increase the visibility of the edge of the roadway and lane boundaries.
- **Application:** These treatments delineate the appropriate path of travel through the curve. They are intended to help drivers who may depart the roadway or travel lane correct their driving path.
- **Considerations:** These treatments may be considered at locations of high collision frequencies of run-off-road collisions are related to a horizontal curve They may be considered when the roadway is not defined through edge-lines or centerlines (or may benefit from adjustments to the existing striping). Adjustments may be considered when roadways have wide travel lanes that may contribute to higher speeds on the approach to a curve.
- **Systemic Application:** Striping is a low-cost implementation that can easily be implemented systemically or integrated with ongoing maintenance or capital improvement projects. Striping plans for each curve must be developed to account for the individual roadway cross section for each curve.
- **Collision Reduction Factor:** 20% depending on the treatment(s) selected.
- **Planning-Level Cost:** $500 - $5,000 per each direction of travel depending on the extent of the striping needed.

Figure 37: Example of Road with Edge-lines and Centerlines

Source: FHWA

MEDIAN RELATED TREATMENTS

Median treatments for roadways represent one of the most effective means to regulate access and reduce collisions by restricting certain movements. These treatments reallocate the existing roadway cross-section to incorporate a buffer between the opposing travel lanes, reinforces the limits of the travel lane, and physically restrict or control certain movements. Kittelson identified the following three countermeasures:

1. Install Raised Median
2. Install Pedestrian Median Fencing
3. Install Two-Way Left-Turn Lane

Install Raised Median

- **Description:** This treatment consists of adding new raised medians on roadways to control and restrict left-turn and U-turn movements on the roadways except at few designated locations. Figure 38 shows an example of this treatment.
- **Purpose:** Adding raised medians can help reduce conflicts by restricting access-related movements to the roadway. The raised medians prohibit left turns into and out of driveways located along the roadway and within the influence area of an intersection. In addition to preventing left-turns at minor driveways, the raised separates opposing traffic.
- **Application:** These treatments may be considered on roadways with high collision frequencies of head-on, left-turning vehicle, and other access-related collisions that may be affected by the number of vehicles that cross the centerline and by the speed of oncoming vehicles.
- **Considerations:** These treatments may be considered on roadways after verifying there is enough space for wider sidewalks and bike lanes after installing the median. The landscaping in medians should not obstruct the visibility between pedestrians and approaching vehicles. The safety benefits of restricting movements should be balanced with restrictions to business access and its associated impacts on commercial and retail areas.
- **Systemic Application:** Providing raised medians on roadway can be implemented in combination with other ongoing corridor capital improvements.
- **Collision Reduction Factor:** 20-75%

- **Planning-Level Cost:** $15,000 - $30,000 per 100 feet of the roadway, depending on design, site conditions, and whether the median can be added as part of a utility improvement or other capital improvement project.

Figure 38: Example of Raised Median

Source: FHWA

Install Pedestrian Median Fencing

- **Description:** This treatment consists of installing pedestrian fencing within the roadway median. Figure 39 shows an example of this treatment.
- **Purpose:** This treatment is used within the median to discourage pedestrian crossings and guide pedestrians to formal crossing points (i.e., at intersection or designated mid-clock crossings).
- **Application:** These treatments enhance pedestrian safety performance by preventing unwanted pedestrian crossing movements where visibility of pedestrians to drivers is limited.
- **Considerations:** These treatments may be considered on roadway segments with high-pedestrian generators and pedestrian destinations, e.g., transit stops, schools with high pedestrian volumes J-walking across travel lanes at mid-block locations and where they can be directed to the nearest intersection crossing or designated mid-block crossing locations. Pedestrian median fencing must not obstruct drivers' view of pedestrians on the sidewalk or those about to cross the roadway at designated crossings.
- **Systemic Application:** These treatments are mostly likely to be integrated as part of larger capital improvement projects or installed as their own capital improvements. This treatment may be better suited as a spot treatment or a treatment package in urban neighborhoods.
- **Collision Reduction Factor:** 25-40%.
- **Planning-Level Cost:** $1,500 - $5,000 per 100 feet of the roadway, depending on the type of treatment selected.

Figure 39: Example of Pedestrian Median Fencing

Source: Maryland Coast Dispatch (https://mdcoastdispatch.com/2018/05/24/coastal-highway-median-fence-project-wrapping-thursday/)

Install Two-Way Left-Turn Lane

- **Description:** This treatment consists of installing a two-way left-turn lane (TWLTL) on the roadway. Figure 40 shows an example of this treatment.
- **Purpose:** This treatment removes left-turning vehicles from the through lanes and stores those vehicles in the median area until an acceptable gap is available in the opposing traffic.
- **Application:** These treatments provide a buffer between opposing travel directions and separates left-turning traffic from through traffic. TWLTL also helps drivers to begin to accelerate before entering the through traffic lanes.
- **Considerations:** These treatments may be considered on roadways having a high frequency of drivers being rear-ended while attempting to make a left turn across oncoming traffic.
- **Systemic Application:** TWLTL is a low-cost implementation (e.g., it can be as simple as restriping the roadway) that can easily be implemented systemically or integrated with ongoing maintenance or capital improvement projects.
- **Collision Reduction Factor:** 8-50%.
- **Planning-Level Cost:** $500 - $5,000 per each direction of travel depending on the extent of the striping needed. Costs and time to implement could significantly increase if the existing roadway needs to be widened.

Figure 40: Example of TWLTL on Roadway

Source: FHWA

SPEED MANAGEMENT

Kittelson identified speed management as a priority countermeasure f because unsafe speed was the most frequently cited collision factor accounting for 35% of the total reported collisions.

This treatment is intended lower the vehicular speeds, thereby reducing speeding related collisions. Speed management should be addressed comprehensively to encompass all of the factors that may influence travel speeds, including road user/driver behavior, roadway design, surrounding land use context, traffic, roadway conditions, posted speed limits, and enforcement. The following two countermeasures were identified:

1. Install Dynamic Speed Feedback Signs
2. Traffic Calming

Install Dynamic Speed Feedback Signs

- **Description:** This treatment consists of installing dynamic or variable speed feedback signs on the roadway. Figure 41 shows an example of this treatment.
- **Purpose:** Speed feedback signs tell drivers about their speed in relationship to the posted speed limit.
- **Application:** These treatments provide a message to drivers exceeding a certain speed threshold (or posted speed limit). The intent of these treatments is to get drivers attention and provide them with a visual warning that they may be traveling over the recommended speed on the roadway.
- **Considerations:** These treatments may be considered on roadways that have higher incidence of collisions attributed to excessive speeds, and on relatively sharp curves.
- **Systemic Application:** This treatment is a relatively low-cost implementation that can easily be implemented systemically or integrated with capital improvement projects.
- **Collision Reduction Factor:** 0-41%.
- **Planning-Level Cost:** $2,000 - $11,000 per display, depending on whether it is solar powered or AC.

Figure 41: Example of Dynamic Speed Warning Sign

Source: Kittelson and Associates, Inc.

Traffic Calming

Kittelson identified traffic calming as a countermeasure to manage speeds given collisions involving pedestrians and bicyclists accounted for 7% of all reported collisions, and 46% of reported fatal and severe injury collisions.

Traffic calming consistes of mainly physical roadway design measures to slow motor vehicles as they move through urban, commercial, and residential neighborhoods. These treatments also help to improve the safety performance of non-motorized users by reducing the potential for higher speed and associated higher severity conflicts.

The City of Stockton addresses the neighborhood traffic issues, traffic safety and neighborhood livability through a community-based Neighborhood Traffic Management Program (NTMP). The neighborhood traffic calming measures attempt to enhance non-motorized safety performance and preserve neighborhood character and livability. More information on the NTMP can be found on the City's website[8].

VIABLE PROJECT SCOPES AND PRIORITIZED LIST OF SAFETY PROJECTS

Kittelson identified competitive groupings of locations for potential Highway Safety Improvement Program (HSIP) applications and capital improvement projects to reduce the collision risks. A total of 10 locations were advanced into scoping, and several have been grouped by similar characteristics. The project scopes and groupings developed are listed below.

- **Group A: Signalized Intersections**
  - Hammer Lane at Lan Ark Drive
  - Hammer Lane at Lower Sacramento Road
  - March Lane at El Dorado Street
  - Dr. Martin Luther King Jr Boulevard and Lincoln Street
- **Group B: Unsignalized Intersection**
  - N Pershing Avenue at Telegraph Avenue
  - Sierra Nevada Street at Lindsay Street
  - Martin Luther King Jr Boulevard at Stanislaus Street
  - Martin Luther King Jr Boulevard at Harrison Street
- **Group C: Roadway Segment Corridors**
  - Hammer Lane from Lower Sacramento Road to Tam O'Shanter Drive
  - El Dorado Street from Lowell Avenue to Clayton Avenue

[8] NTMP - http://www.stocktongov.com/government/departments/publicWorks/tCalm.html

The scoping structure has been written to support potential use for HSIP grants. This includes:

- A summary of the site, recommended improvements, collision history, and justification of the safety improvements proposed. The collision history shown per location includes all reported collisions specific to the location.
- Planning-level cost estimates and benefit-to-cost ratios derived from HSIP Cycle 10 Guidelines. The planning-level cost estimates include a 30% contingency for construction items and estimates for environmental, PS&E, right-of-way engineering, and construction engineering. Details can be found in Attachment A.

Group A: Signalized Intersections

HAMMER LANE AT LAN ARK DRIVE

The Hammer Lane and Lan Ark Drive intersection has dedicated left turn lanes on all approaches. Hammer Lane is an eight-lane, principal arterial divided by a raised median and Lan Ark Drive is a two-lane, major collector.

This intersection has marked pedestrian crossings across all approaches and an unprotected Class II bike lane along Hammer Lane. Transit stops are located on Hammer Lane in the northwest and southeast corners of the intersection.

Single family and multi-family residential dwellings compose the land use in all four corners of the intersection. Table 16 provides an overview of this intersection's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 16. Collision History (January 2015 to July 2020), Hammer Lane and Lan Ark Drive

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
Hammer Lane at Lan Ark Drive	54	3	3	3	18	27

Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 42:
  - Provide pedestrian-scale intersection lighting to increase intersection visibility and pedestrians at the crossings.
    - This treatment is intended to address nighttime collisions. 21 of the 54 collisions occurred in dark conditions. (S1)
  - Install retroreflective backing on signal heads to improve visibility of the signal indications.
    - This treatment is intended to address right-angle and rear-end collisions. 35 of 54 collisions were either rear-end or broadside collisions. (S2)
  - Provide a protected left turn phase to an existing left turn lane.

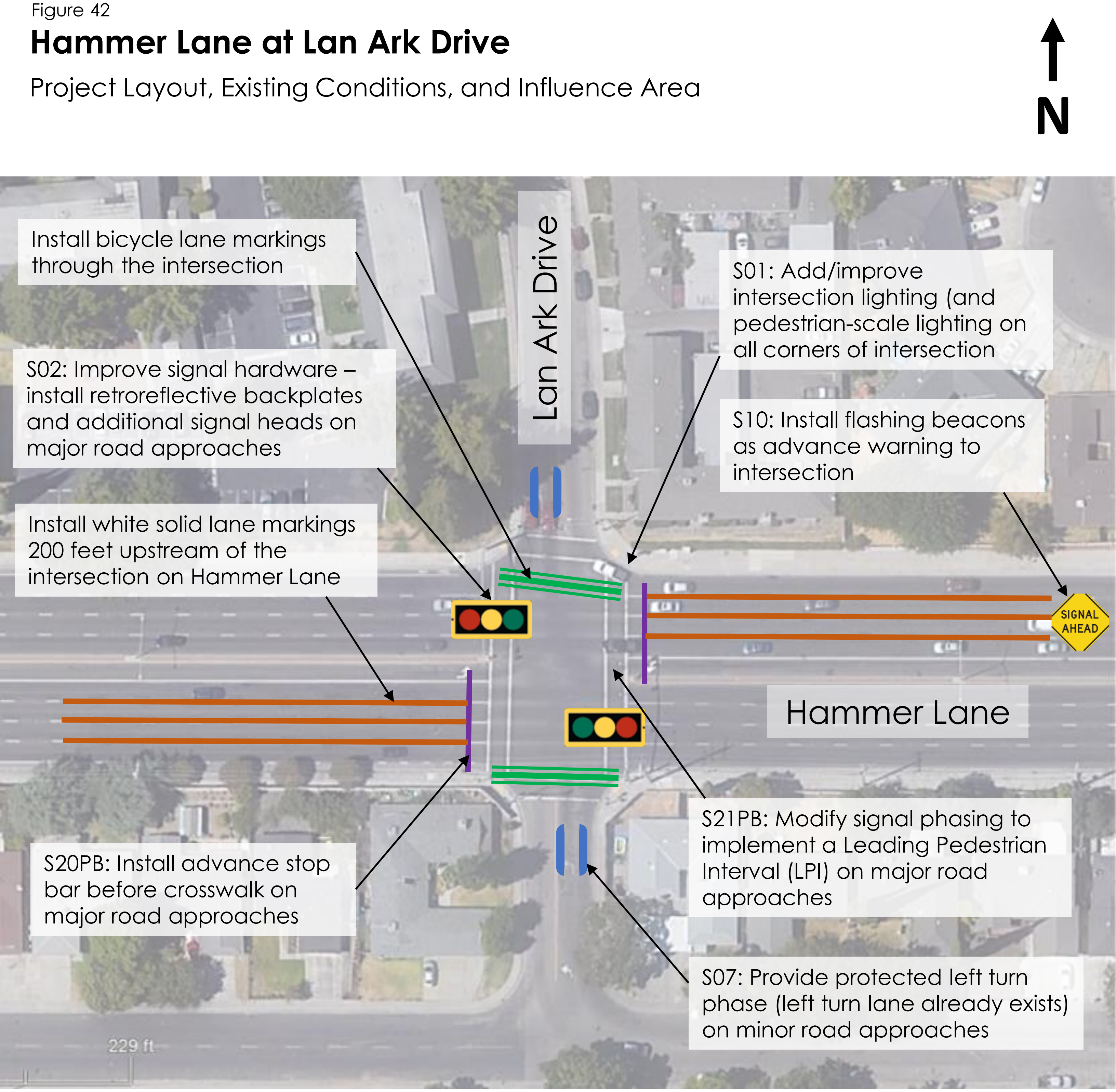
        - This treatment is intended to address rear-end, sideswipe, and broadside collisions. 43 of the 54 collisions were broadside, rear-end or sideswipe collisions. (S7)
    - Install flashing beacons as advance warnings to signalized intersections.
        - This treatment is intended to address rear-end and angle collisions. 35 of 54 collisions were either rear-end or broadside collisions. (S10)
    - Install advanced stop bars on all approaches.
        - This treatment further separate vehicles from crossing pedestrians and provides dedicated space for bicyclists. 5 of 54 collisions involved a pedestrian or bicyclist, including 3 fatal collisions. (S20PB)
    - Modify signal phasing to implement a leading pedestrian interval.
        - This treatment is intended to address pedestrian-involved collisions. 5 of 54 collisions involved a pedestrian or bicyclist, including 3 fatal collisions. (S21PB)
    - Install bike lane markings through the intersection.
        - This treatment would to direct cyclists to the projected bike lane on the intersection's west leg. 3 of the 54 collisions involved cyclists, including 2 fatalities.
    - Install white solid lane markings 200 feet upstream of the intersection on Hammer Lane.
        - This treatment encourages drivers to maintain their lane as they approach the intersection. 8 of the 54 collisions were sideswipe collisions.

- Cost Estimate: $1,040,11
- Planning-Level B/C Ratio: 10.82

Figure 42

Hammer Lane at Lan Ark Drive

Project Layout, Existing Conditions, and Influence Area



Legend

- Improve signal hardware – install retroreflective backplates and additional signal heads
- Provide protected left turn phase
- Install advance warning to intersection
- Install white solid lane markings 200 feet upstream of the intersection
- Install bicycle lane markings through the intersection
- Install advance stop bar before crosswalk

HAMMER LANE AND LOWER SACRAMENTO ROAD

The Hammer Lane and Lower Sacramento Road intersection has dedicated left turn lanes on all approaches. Hammer Lane is an eight-lane, principal arterial divided by a raised median. Dual left turn lanes are present on both of Hammer Lane's approaches. Lower Sacramento Road is a four-lane, principal arterial divided by a raised median. Both approaches on Lower Sacramento have a single, dedicated left turn lane, and the southern approach has a striped, separated right turn lane.

This intersection has marked pedestrian crossings across all approaches. A Class II bike facility is present on the east leg of this intersection and is expected to be continued on the west leg in the future. A Class III Bike Facility is planned along Lower Sacramento Road in the future. Although there is no on-street transit facilities at the intersection of Hammer Lane and Lower Sacramento Road, an off-street transit station is present in the southwest corner.

The remaining three corners of this intersection have commerical or retail land uses, including two shopping centers, restaurants and retail stores. Table 17 provides an overview of this intersection's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 17. Collision History (January 2015 to July 2020), Hammer Lane and Lower Sacramento Road

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
Hammer Lane at Lower Sacramento Road	73	0	2	9	18	44

Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 43:
    - Provide pedestrian-scale intersection lighting to increase intersection visibility and pedestrians at the crossings.
        - This treatment is intended to address nighttime collisions. 25 of the 73 collisions occurred in dark conditions. (S1)
    - Install retroreflective backing on signal heads to improve visibility of the signal indications.
        - This treatment is intended to address right-angle and rear-end collisions. 56 of 73 collisions were either rear-end or broadside collisions. (S2)
    - Install raised pavement markers and striping through signalized intersections.
        - This treatment is intended to address all collision types in wet and night conditions. 25 of the 73 collisions occurred in dark conditions. (S9)
    - Install advanced stop bars on all approaches.
        - This treatment further separates vehicles from crossing pedestrians and provides dedicated space for bicyclists. 14 of 73 collisions involved a pedestrian or bicyclist. (S20PB)

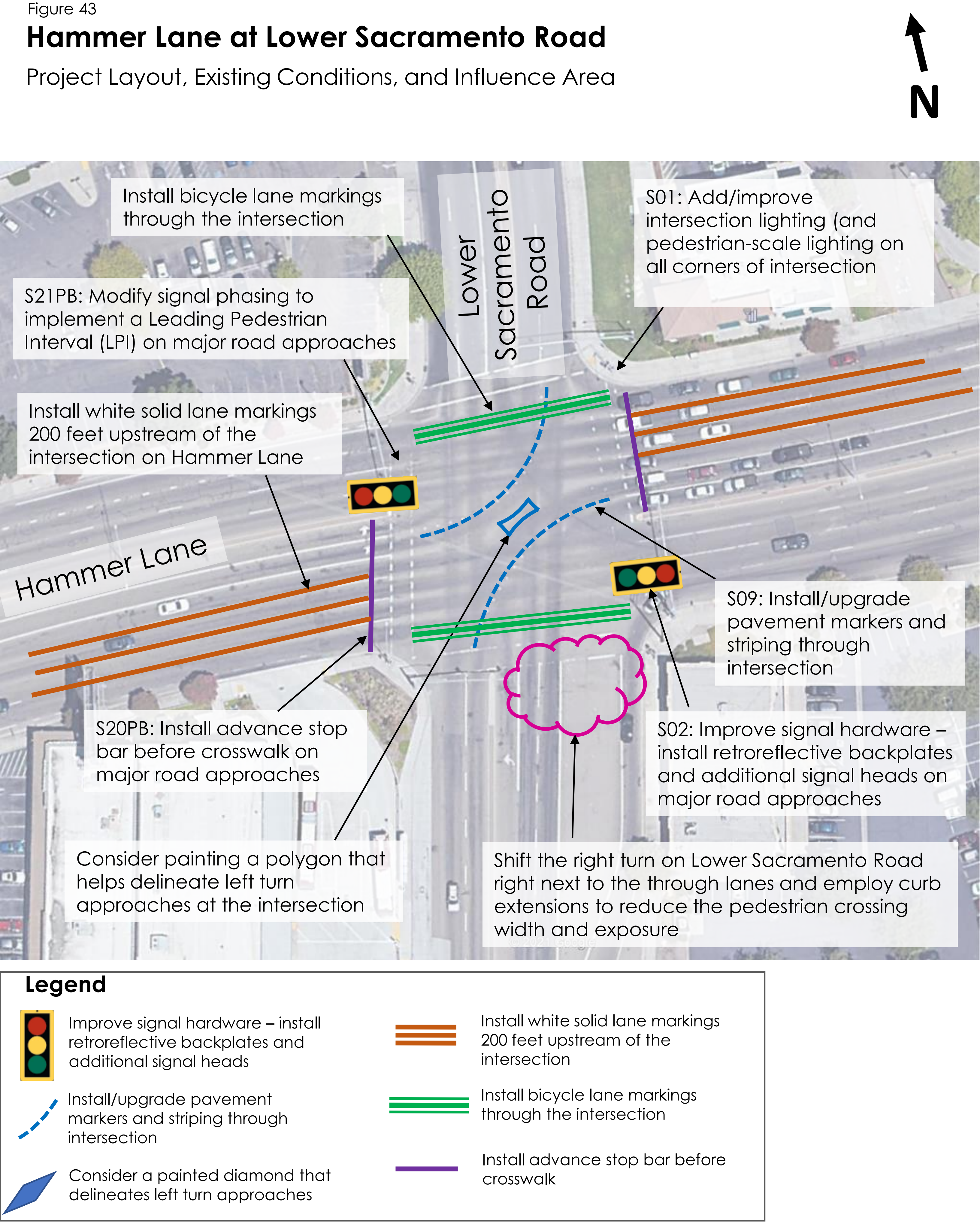
- Modify signal phasing to implement a leading pedestrian interval.
  - This treatment is intended to address pedestrian-involved collisions. 14 of 73 collisions involved a pedestrian or bicyclist. (S21PB)
- Install bike lane markings through the intersection.
  - This treatment directs cyclists to the projected bike lane on the intersection's east and west legs. 4 of the 73 collisions involved cyclists.
- Install white solid lane markings 200 feet upstream of the intersection on Hammer Lane.
  - This treatment encourages drivers to maintain their lane as they approach the intersection. 7 of the 73 collisions were sideswipe collisions.
- Shift the right turn on Lower Sacramento Road right next to the through lanes and add curb extensions.
  - This treatment reduces the pedestrian crossing width and exposure. 10 of the 73 collisions involved pedestrians, including 5 collisions that included pedestrians crossing at the intersections.
- Add a diamond using paint or thermoplastic at the intersection's center.
  - This treatment delineates left turn approaches at the intersection. 27 of 73 collisions were broadside collisions.

- Cost Estimate: $967,400
- Planning-Level B/C Ratio: 4.71

Figure 43

Hammer Lane at Lower Sacramento Road

Project Layout, Existing Conditions, and Influence Area



MARCH LANE AND EL DORADO STREET

The March Lane and El Dorado Street intersection is characterized by skewed approaches. March Lane is a six-lane, principal arterial with dedicated right and left turn lanes and raised medians. Both right turns have pedestrian refuge islands and immediate lane drops as vehicles enter El Dorado Street. El Dorado is also a six-lane, principal arterial with dual left turn lanes on both approaches and raised medians. The northbound approach has a dedicated right turn lane and the southbound approach has a parallel boulevard separated by a raised barrier.

This intersection has pedestrian crossings across all approaches and a separated, Class I Bike Path along March Lane. No transit stops are located within 300’ of this intersection.

Single family and multi-family residental dwellings are present south of March Lane and a religious institution, hotel and pharmacy are located north of March Lane. Table 18 provides an overview of this intersection’s reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 18. Collision History (January 2015 to July 2020), March Lane and El Dorado Street

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
March Lane at El Dorado Street	90	0	4	4	26	56

Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 44:
  - Install retroreflective backing on signal heads to improve visibility of the signal indications.
    - This treatment is intended to address right-angle and rear-end collisions. 57 of 90 collisions were either rear-end or broadside collisions. (S2)
  - Provide Advanced Dilemma-Zone Detection for high-speed approaches.
    - This treatment is intended to address all collision types approaching a signal. 90 collisions occurred approaching the March Lane and El Dorado Street intersection. (S4)
  - Install raised pavement markers and striping through signalized intersections.
    - This treatment is intended to address all collision types in wet and night conditions. 24 of the 90 collisions occurred in dark conditions. (S9)
  - Modify signal phasing to implement a leading pedestrian interval.
    - This treatment is intended to address pedestrian-involved collisions. 6 of 90 collisions involved a pedestrian or bicyclist. (S21PB)
  - Remove channelized right-turn lanes and receiving lanes on March Lane approaches and restrict right turns on red on all approaches.
    - This treatment is intended to address conflicting movements associated with right-turns. 33 of the 90 collisions were sideswipe or broadside collisions.

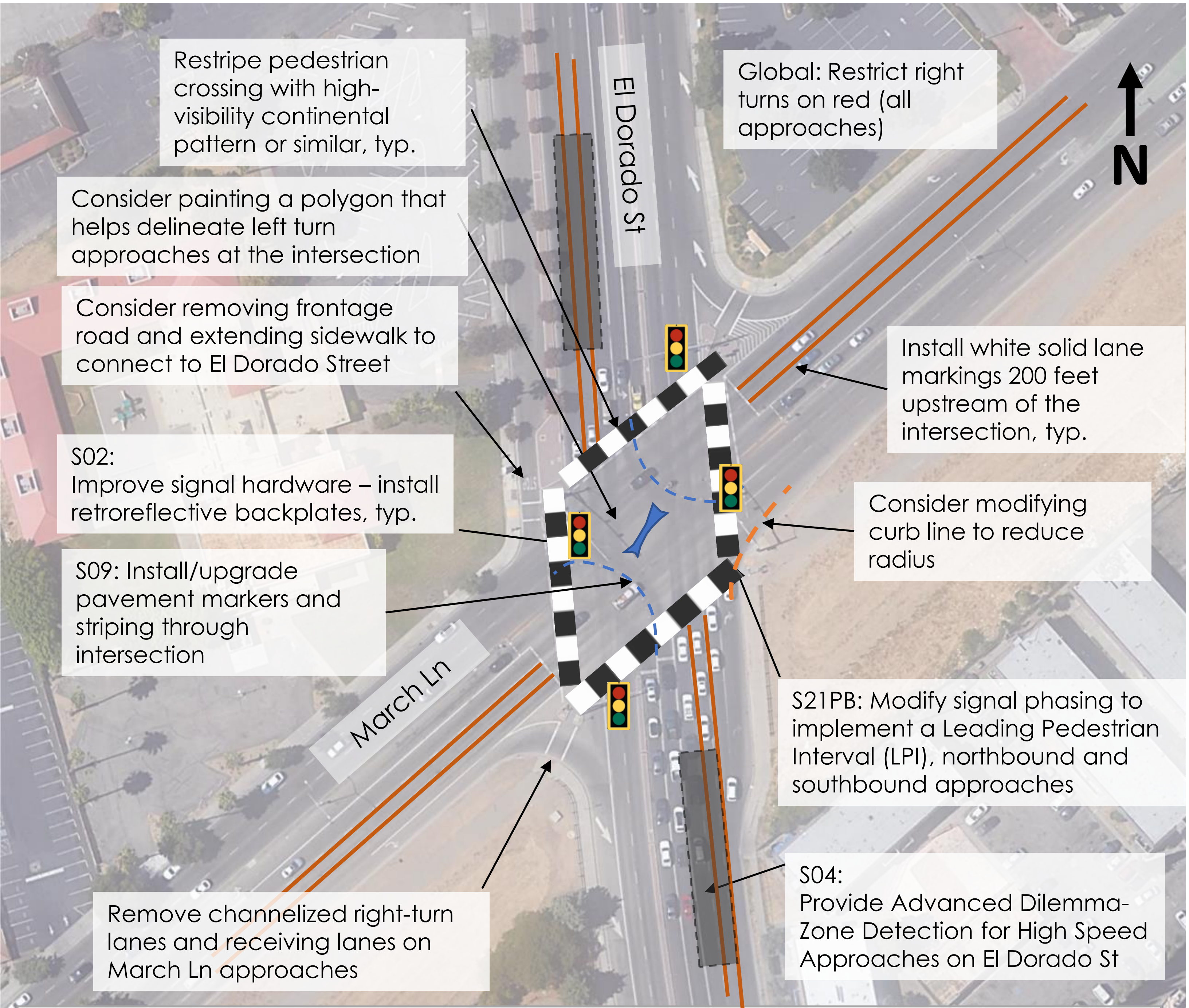
- Restripe pedestrian crossings with high-visibility continental pattern or similar on all approaches.
  - This treatment will encourage pedestrians to cross at designated locations. 6 of the 90 collisions involved a pedestrian or bicyclist.
- Install white solid lane markings 200 feet upstream of the intersection on Hammer Lane
  - This treatment will encourage drivers to maintain their lane as they approach the intersection. 13 of the 90 collisions were sideswipe collisions.
- Consider removing frontage road and extending sidewalk to connect to El Dorado Street.
  - This treatment is intended to reduce conflicts between pedestrians and vehicles. 6 of 90 collisions involved a pedestrian or bicyclist.
- Add a diamond using paint or thermoplastic at the intersection's center
  - This treatment delineates left turn approaches at the intersection. 20 of the 90 collisions were broadside collisions.
- Consider modifying curb line in the southeast corner to reduce radius.
  - This treatment will encourage drivers to maintain their lane as they approach the intersection.

- Cost Estimate: $891,600
- Planning-Level B/C Ratio: 5.16

Figure 44

March Lane and El Dorado Street

Project Layout, Existing Conditions, and Influence Area



Legend

- Install white solid lane markings 200 feet upstream of the intersection
- Consider a painted polygon that delineates left turn approaches
- Improve signal hardware – install retroreflective backplates and additional signal heads
- Install/upgrade pavement markers and striping through intersection
- Install new curb
- Advanced Dilemma-Zone Detection for High-Speed Approaches
- Restripe crosswalks with high-visibility continental pattern or similar

DR. MARTIN LUTHER KING JR BOULEVARD AND LINCOLN STREET

The Dr. Martin Luther King Jr Boulevard and Lincoln Street intersection is impacted by its close proximity to an I-5 ramp to the west. Dr. Martin Luther King Jr Boulevard is a five-lane, principal arterial with a raised median and dedicated left turn lanes on both approaches. The eastbound approach has a dedicated right turn lane. Lincoln Street is a four-lane, major collector with no dedicated turning lanes.

This intersection has marked pedestrian crossings on all approaches. No bike facilities currently exist at this intersection, but a Class III bike facility is planned along Lincoln Street. Transit stops are located along Lincoln Street in the northeast and southwest corners and on Dr. Martin Luther King Jr Boulevard in the northeast corner.

Commericial and retail land uses are located adjacnent to the intersection, but single family dwellings are located to the north and a large school facility is just south of this intersection. Table 19 provides an overview of this intersection's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 19. Collision History (January 2015 to July 2020), Dr. Martin Luther King Jr Boulevard and Lincoln Street

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
Dr. Martin Luther King Jr Boulevard at Lincoln Street	54	3	3	3	18	27

Proposed Project:

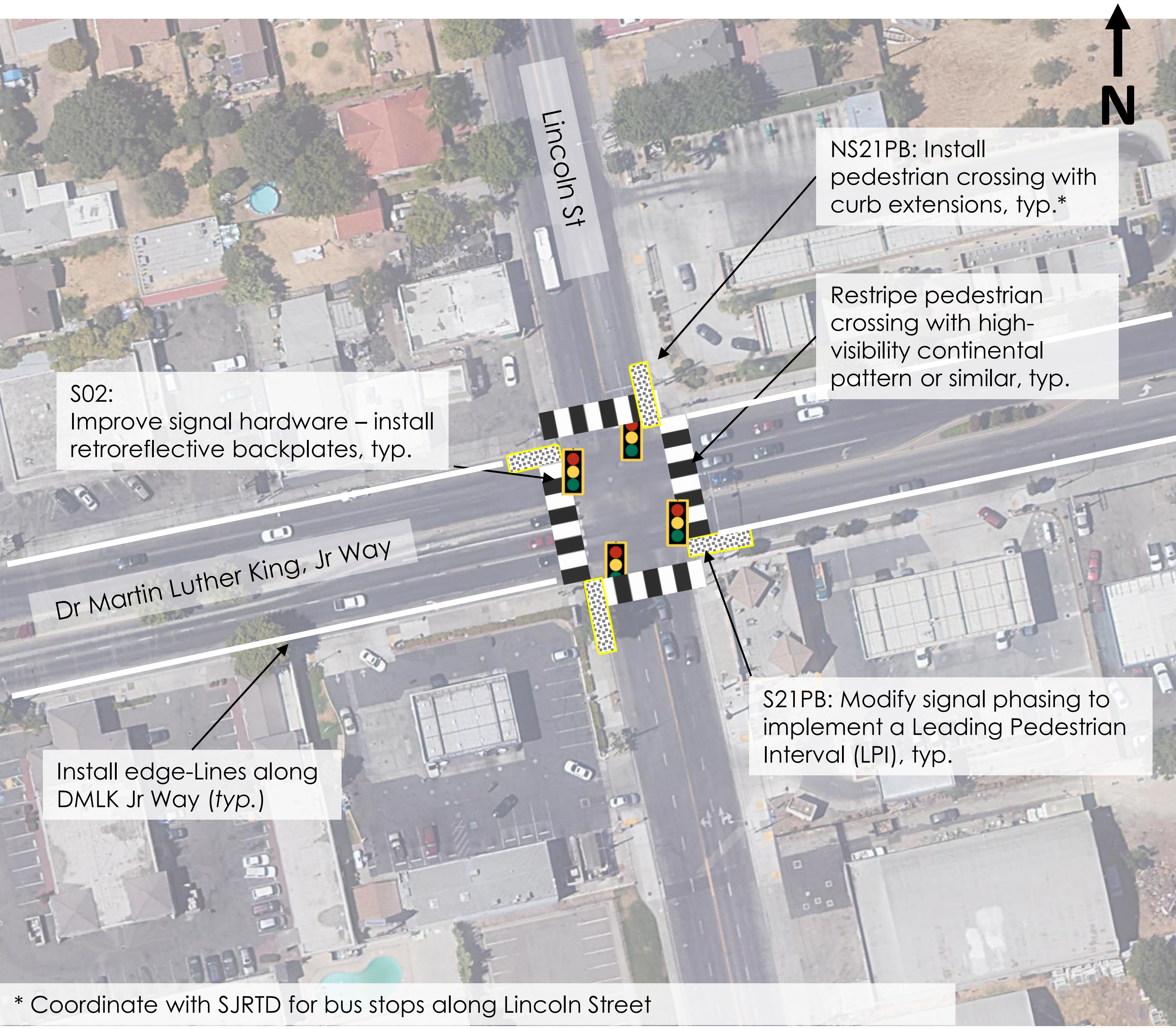
- The proposed project includes the following safety treatments, as shown in Figure 45:
  - Install retroreflective backing on signal heads to improve visibility of the signal indications.
    - This treatment is intended to address right-angle and rear-end collisions. 37 of the 66 collisions were either rear-end or broadside collisions. (S2)
  - Modify signal phasing to implement a leading pedestrian interval.
    - This treatment is intended to address pedestrian-involved collisions. 14 of the 66 collisions involved a pedestrian or bicyclist. (S21PB)
  - Install pedestrian crossings with curb extensions along Lincoln Street.
    - This treatment is intended to address pedestrian and bicyclist-involved collisions. 14 of the 66 collisions involved a pedestrian or bicyclist. (NS21PB)
  - Restripe pedestrian crossings with high-visibility continental pattern or similar on all approaches.
    - This treatment will encourage pedestrians to cross at designated locations. 14 of the 66 collisions involved a pedestrian or bicyclist.
  - Install edge-lines along Dr. Martin Luther King Jr Boulevard.

    - This treatment is intended to address run-off-road collisions. 2 of the 66 collisions were fixed object collisions.
- Cost Estimate: $734,800
- Planning-Level B/C Ratio: 12.89

Figure 45

Dr Martin Luther King, Jr Way and Lincoln Street

Project Layout, Existing Conditions, and Influence Area



Legend

Restripe crosswalks with high-visibility continental pattern or similar

Curb Extension

Improve signal hardware – install retroreflective backplates and additional signal heads

Install/upgrade pavement markers and striping through intersection

Note: Further developed concepts will account for truck turns per the City's truck map

Group B: Unsignalized Intersections

N PERSHING AVENUE AND TELEGRAPH AVENUE

The intersection between Pershing Avenue and Telegraph Avenue characterized merging location between these two roadways Pershing Avenue is a a four-lane, major collector divided by a raised median. Telegraph Avenue is a one-way, single-lane arterialthat merges into Pershing Avenue.

Although both roadways have pedestrian facilities, no pedestrian crossings are present. There are also no transit stops within 300' of this intersection. Pershing Avenue is signed as a Class III bike facility.

Single family residential dwellings compose the land use to the west of Pershing Avenue and the University of the Pacific is located to the east. Table 20 provides an overview of this intersection's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 20. Collision History (January 2015 to July 2020), N Pershing Avenue and Telegraph Avenue

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
N Pershing Avenue and Telegraph Avenue	16	2	1	4	2	7

Proposed Project:

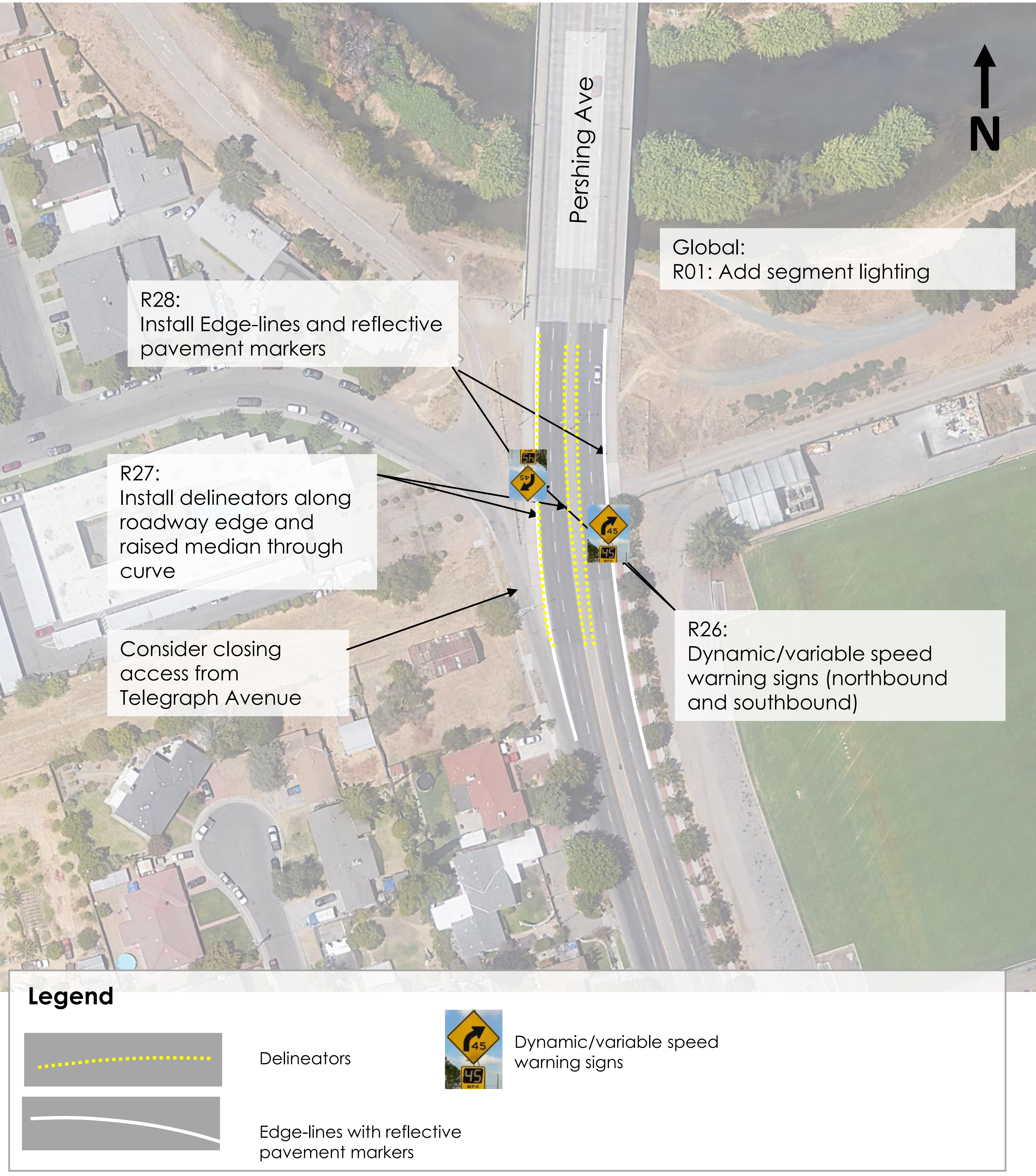
- The proposed project includes the following safety treatments, as shown in Figure 46:
  - Add segment lighting to increase intersection visibility.
    - This treatment is intended to address nighttime collisions. 7 of the 16 collisions occurred in dark conditions. (R1)
  - Install dynamic/variable speed warning signs to address excessive speeds.
    - This treatment is intended to address all collisions. 16 collisions occurred at this intersection. (R26)
  - Install delineators along the roadway edge and raised median through curve to provide driver guidance.
    - This treatment is intended to address fixed object collisions. 9 of the 16 collisions occurred at this intersection were associated with fixed objects. (R27)
  - Install edge-lines with reflective pavement markers to help drivers not leave the roadway.
    - This treatment is intended to address run-off-road collisions. 9 of the 16 collisions occurred at this intersection were associated with fixed objects. (R28)
  - Investigate closing access from Telegraph Avenue allowing emergency access only.
    - This treatment would remove conflicting movements at this intersection.

- Cost Estimate: $909,300
- Planning-Level B/C Ratio: 10.37

Figure 46

N Pershing Avenue and Telegraph Avenue

Project Layout, Existing Conditions, and Influence Area



SIERRA NEVADA STREET AND LINDSAY STREET

The intersection between Sierra Nevada Street and Lindsay Street is two-way stop control, with stop signs located along Lindsay Street. Sierra Nevada Street is a two-lane arterial road and Lindsay Street is a two-lane local road. Both roadways have on-street parking on both sides of the roadways.

Sierra Nevada Street is signed as a Class III bike facility. No pedestrian crossings are marked at this location to connect the sidewalks along both roadways. No transit stops are located within 300' of this intersection.

Commercial land use, including the Bank of America, is located on the northeast corner. The remaining corners are primarily residential dwellings. Table 21 provides an overview of this intersection's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 21. Collision History (January 2015 to July 2020), Sierra Nevada Street and Lindsay Street

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
Sierra Nevada Street and Lindsay Street	8	0	3	0	0	5

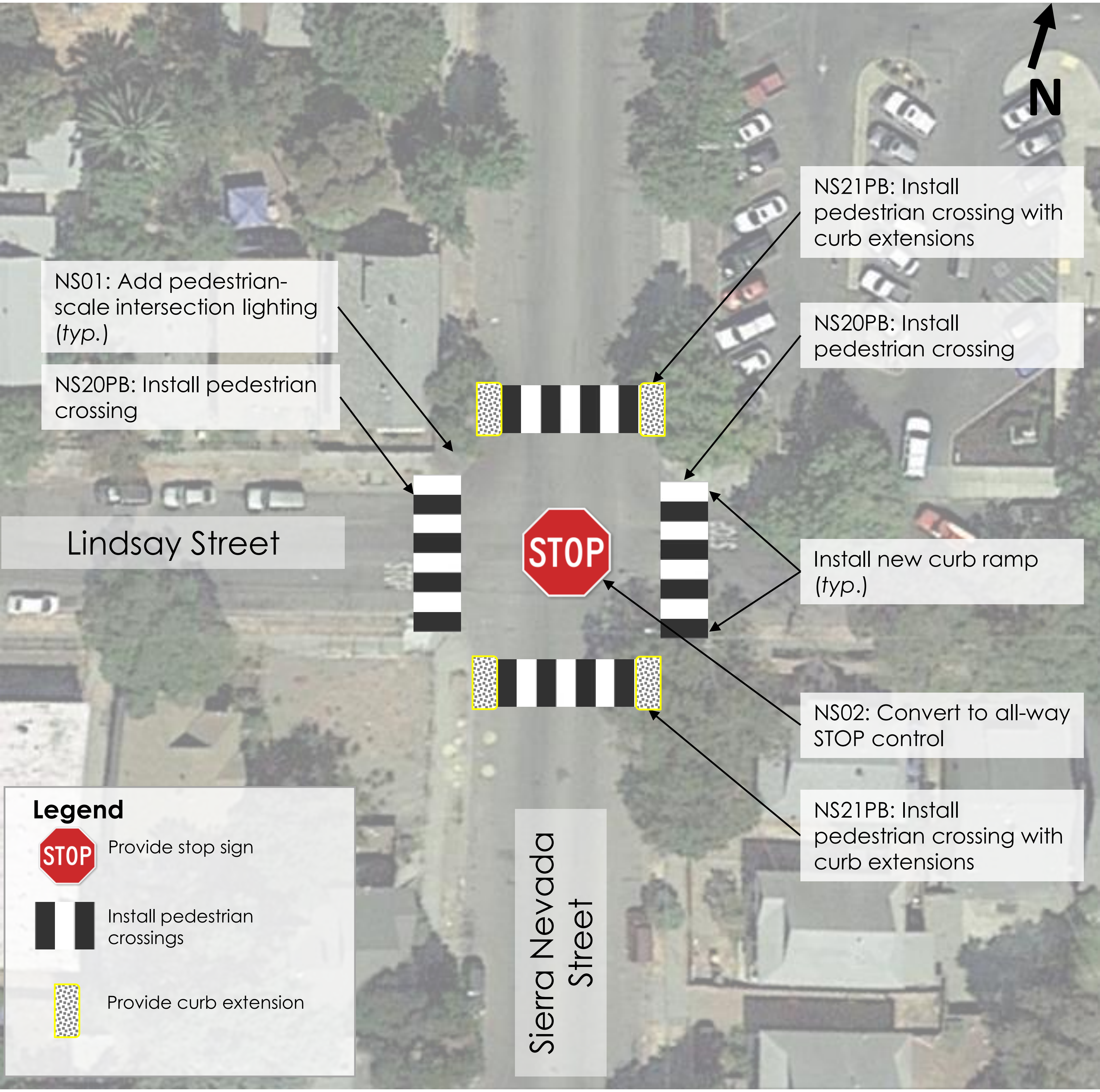
Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 47:
  - Provide pedestrian-scale intersection lighting to increase visibility of the intersection and pedestrians at the crossings.
    - This treatment is intended to address nighttime collisions. 2 of the 8 collisions occurred in dark conditions. (NS1)
  - Convert to all-way STOP control from 2-way control to provide more orderly movement throughout the intersection.
    - This treatment is intended to address left-turn and angle collisions. 2 of the 8 collisions were broadside collisions. (NS2)
  - Install pedestrian crossings across Lindsay Street.
    - This treatment is intended to address pedestrian and bicycle-involved collisions. 2 of the 8 collisions involved bicyclists or pedestrians. (NS20PB)
  - Install pedestrian crossings with curb extensions across Sierra Nevada Street.
    - This treatment is intended to address pedestrian and bicycle-involved collisions. 2 of the 8 collisions involved bicyclists or pedestrians. (NS21PB)
  - Install new curb ramps at all crossing to support crossings by all users.
    - This treatment should be developed in accordance with ADA Guidance.
- Cost Estimate: $1,200,000
- Planning-Level B/C Ratio: 21.06

Figure 47

Sierra Nevada Street at Lindsay Street

Project Layout, Existing Conditions, and Influence Area



MARTIN LUTHER KING JR BOULEVARD AND STANISLAUS STREET

The Martin Luther King Jr Boulevard and Stanislaus Street intersection is a two-way stop control intersection, with stop signs present on Stanislaus Street. Dr. Martin Luther Jr Boulevard is an arterial with dedicated left turn lanes on both approaches. A raised median is present on Dr. Martin Luther King Jr Boulevard on its west leg. Stanislaus Street is two-lane, local road. Both roadways have on-street parking.

Pedestrian crossings are present across Stanislaus Street, but there are no existing or planned, dedicated bike facilities. No transit stops are located within 300' of this intersection.

Commerical land uses are present in all four corners, including an auto shop, gas station and car wash. Table 22 provides an overview of this intersection's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 22. Collision History (January 2015 to July 2020), Martin Luther King Jr Boulevard and Stanislaus Street

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
Martin Luther King Jr Boulevard at Stanislaus Street	24	1	4	6	5	8

Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 48:
  - Install pedestrian crossings with curb extensions across Stanislaus Street.
    - This treatment is intended to address pedestrian and bicycle-involved collisions. 9 of the 24 collisions involved bicyclists or pedestrians. (NS21PB)
  - Install pedestrian crossing with HAWK signals as a mid-block crossing along Martin Luther King Jr Boulevard.
    - This treatment. This treatment is intended to address pedestrian and bicycle-involved collisions. 9 of the 24 collisions involved bicyclists or pedestrians. (NS21PB)
  - Install edge-lines with reflective pavement markers to help drivers not leave the roadway.
    - This treatment is intended to address run-off-road collisions. 1 of the 24 collisions occurred at this intersection were associated with fixed objects. (R28)
  - Install new curb ramps at all crossing to support crossings by all users.
    - This treatment should be developed in accordance with ADA Guidance.

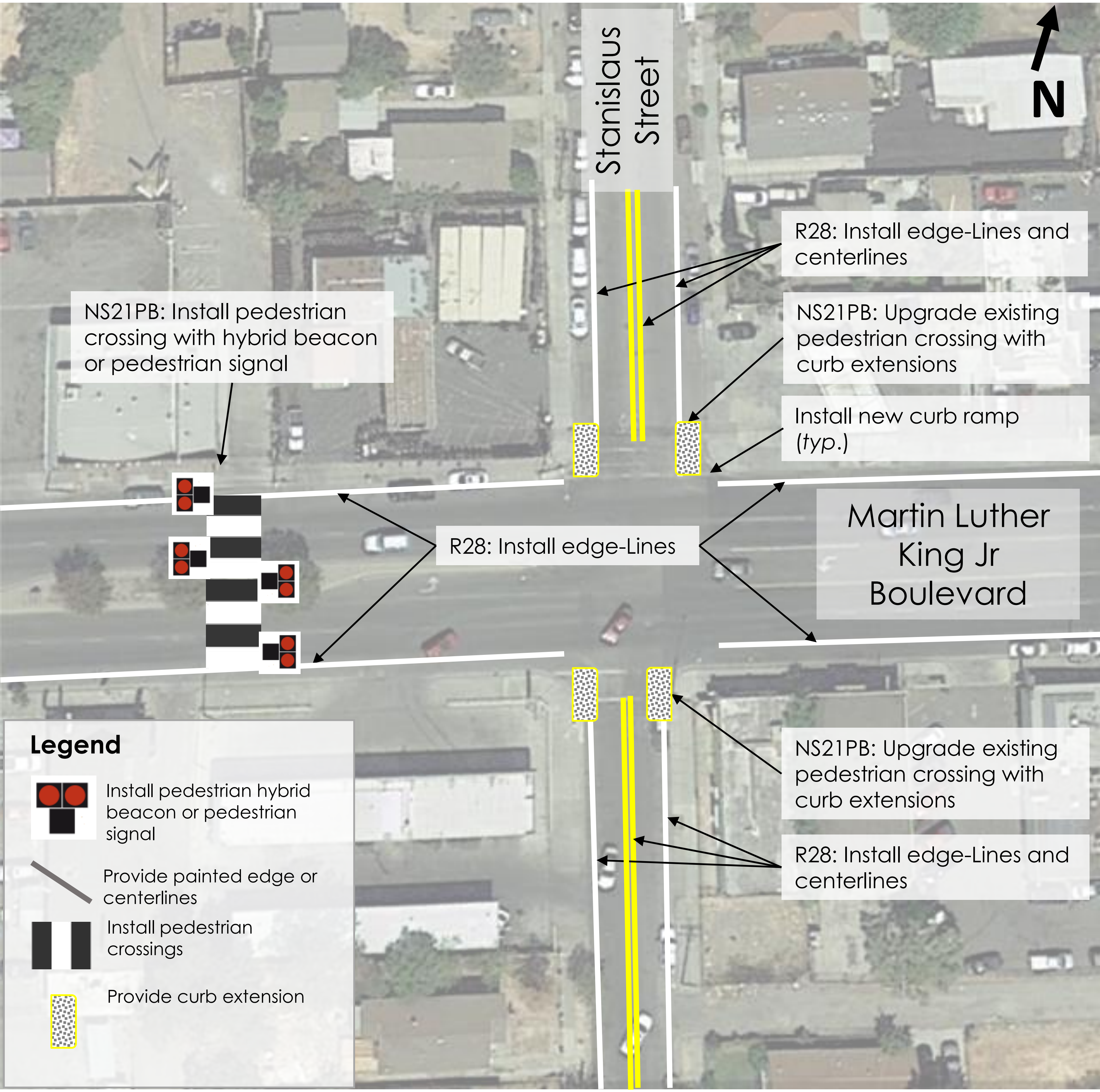
- Cost Estimate: $760,200

- Planning-Level B/C Ratio: 14.38

Figure 48

Martin Luther King Jr Boulevard at Stanislaus Street

Project Layout, Existing Conditions, and Influence Area



DR. MARTIN LUTHER KING JR BOULEVARD AND HARRISON STREET

The Dr. Martin Luther King Jr. Boulevard and Harrison Street is a three-legged, unsignalized intersection characterized by its proximity to I-5. Dr. Martin Luther King Jr Boulevard is a five-lane arterial divided by a landscaped, raised median. An eastbound left-turn lane is present along Dr. Martin Luther King Jr Boulevard. Harrison Street is a two-lane, local road with on-street parking. No left turn lanes are allowed from Harrison Street.

No pedestrian crossings are marked nor are there any existing or planned bicycle facilities. In addition, no transit stops are located within 300' of this intersection.

Commercial and retail land uses are present at this intersection, including a market, fast-food restaurant and motel. Table 23 provides an overview of this intersection's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 23. Collision History (January 2015 to July 2020), Martin Luther King Jr Boulevard and Harrison Street

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
Martin Luther King Jr Boulevard and Harrison Avenue	23	1	3	1	3	15

Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 49:
    - Install pedestrian crossing with Pedestrian Hybrid Beacon (i.e., HAWK signals) crossing along Martin Luther King Jr Boulevard.
        - This treatment is intended to address pedestrian and bicycle-involved collisions. 4 of the 23 collisions involved bicyclists or pedestrians. (NS21PB)
    - Extend existing median with striping to define left turn lane for I-5.
        - This treatment is intended to address rear-end and sideswipe collisions. 14 of the 24 collisions were rear-end or sideswipe collisions. (R28)
    - Install edge-lines with reflective pavement markers to help drivers not leave the roadway.
        - This treatment is intended to address run-off-road collisions. 3 of the 23 collisions occurred at this intersection were associated with fixed objects. (R28)
    - Install new curb along Martin Luther King Jr Boulevard to remove lane drop from I-5.
        - This treatment is intended to address sideswipe collisions. 4 of the 23 collisions occurred at the intersection were sideswipe collisions.
    - Install pedestrian crossing across Harrison Street.
        - This treatment is intended to address pedestrian and bicycle-involved collisions. 4 of the 23 collisions involved bicyclists or pedestrians.
    - Install new curb ramps at all crossing to support crossings by all users.

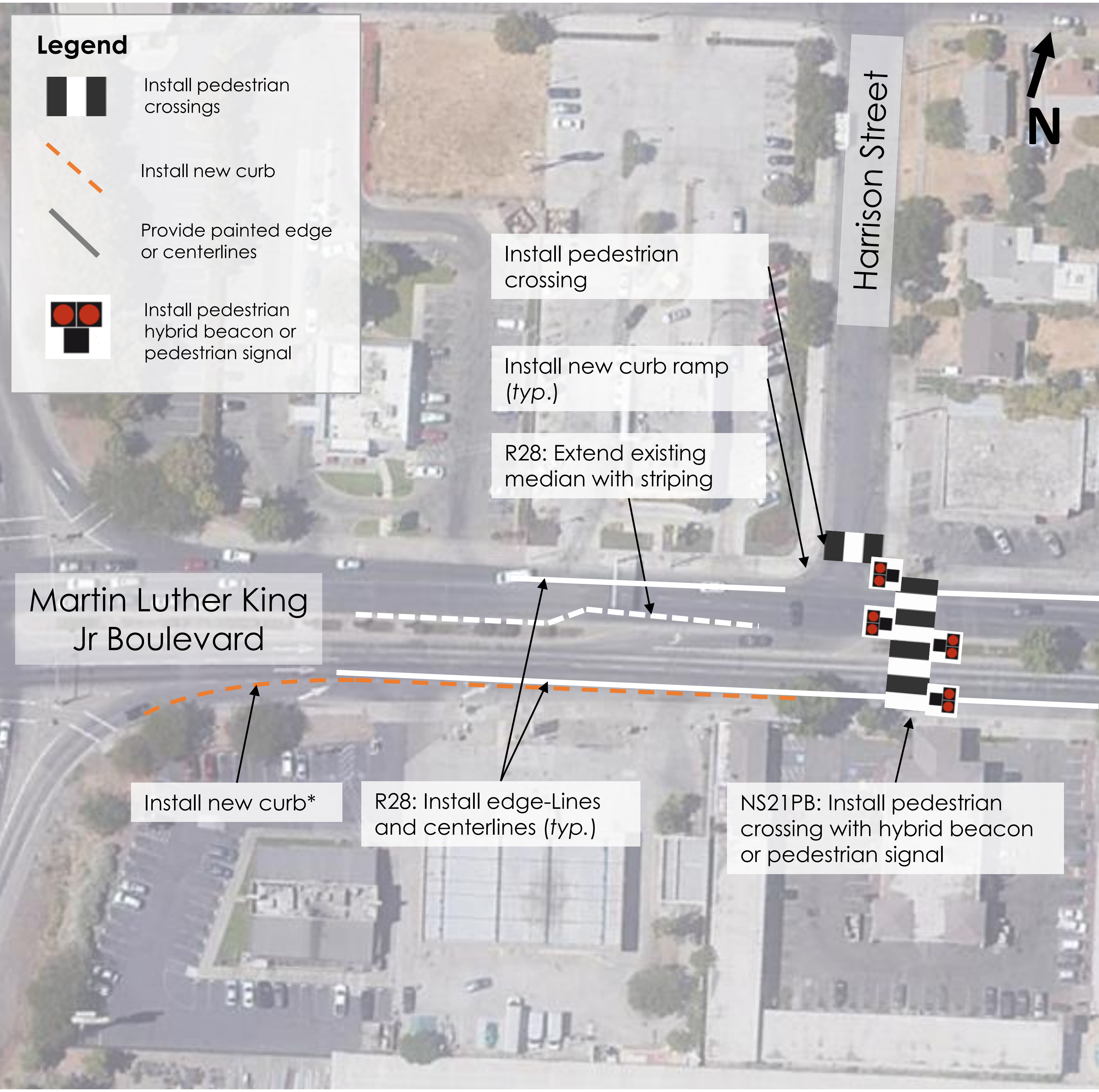
    - This treatment should be developed in accordance with ADA Guidance.

- Cost Estimate: $698,200
- Planning-Level B/C Ratio: 10.59

Figure 49

Martin Luther King Jr Boulevard at Harrison Street

Project Layout, Existing Conditions, and Influence Area



*This could be one using temporary curb or flex-posts until funding for full curb and gutter is available.

Group C: Roadway Segment Corridors

HAMMER LANE FROM LOWER SACRAMENTO ROAD TO TAM O'SHANTER DRIVE

The segment along Hammer Lane from Lower Sacramento Road to Tam O'Shanter Drive is an eight-lane arterial divided by a raised median.

Sidewalks are present on both sides of Hammer Lane with pedestrian crossings across Hammer Lane at major, signalized intersections. There are no mid-block crossings along this segment. Hammer Lane is categorized as a Class II bike facility. This existing bike facility is expected to intersect with future Class II bike lanes at El Dorado Street and Tam O'Shanter Drive as well as a future Class III bike facility at Lower Sacramento Road. Transit stops are located at Etna Street, El Dorado Street, Lan Ark Drive and Tam O'Shanter Drive.

Primarily commercial and retail land uses are located along Hammer Lane along this segment. Table 24 provides an overview of this segment's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 24. Collision History (January 2015 to July 2020), Hammer Lane from Lower Sacramento Road to Tam O'Shanter Road

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
Hammer Lane from Lower Sacramento Road to Tam O' Shanter Road	50	1	3	5	12	29

Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 50:
    - Provide pedestrian-scale intersection lighting to increase intersection visibility and pedestrians at the crossings.
        - This treatment is intended to address nighttime collisions. 19 of 50 collisions occurred in dark or dawn-dusk conditions. (R1)
    - Install white solid lane markings 200 feet upstream of the intersection on major road approaches and add broken white lines to left turn lanes.
        - This treatment is intended to address head-on and run-off-road collisions. 10 of the 50 collisions that occurred along this segment were head-on or fixed object collisions. (R28)
    - Convert the existing bike lane to 7-foot buffered bike lane by narrowing vehicle lanes to 10 feet.
        - This treatment is intended to address pedestrian and bicycle-involved collisions. 3 of the 50 collisions involved bicyclists or pedestrians. (NS33PB)
    - Install dynamic regulatory speed warning signs/radar speed feedback signs.

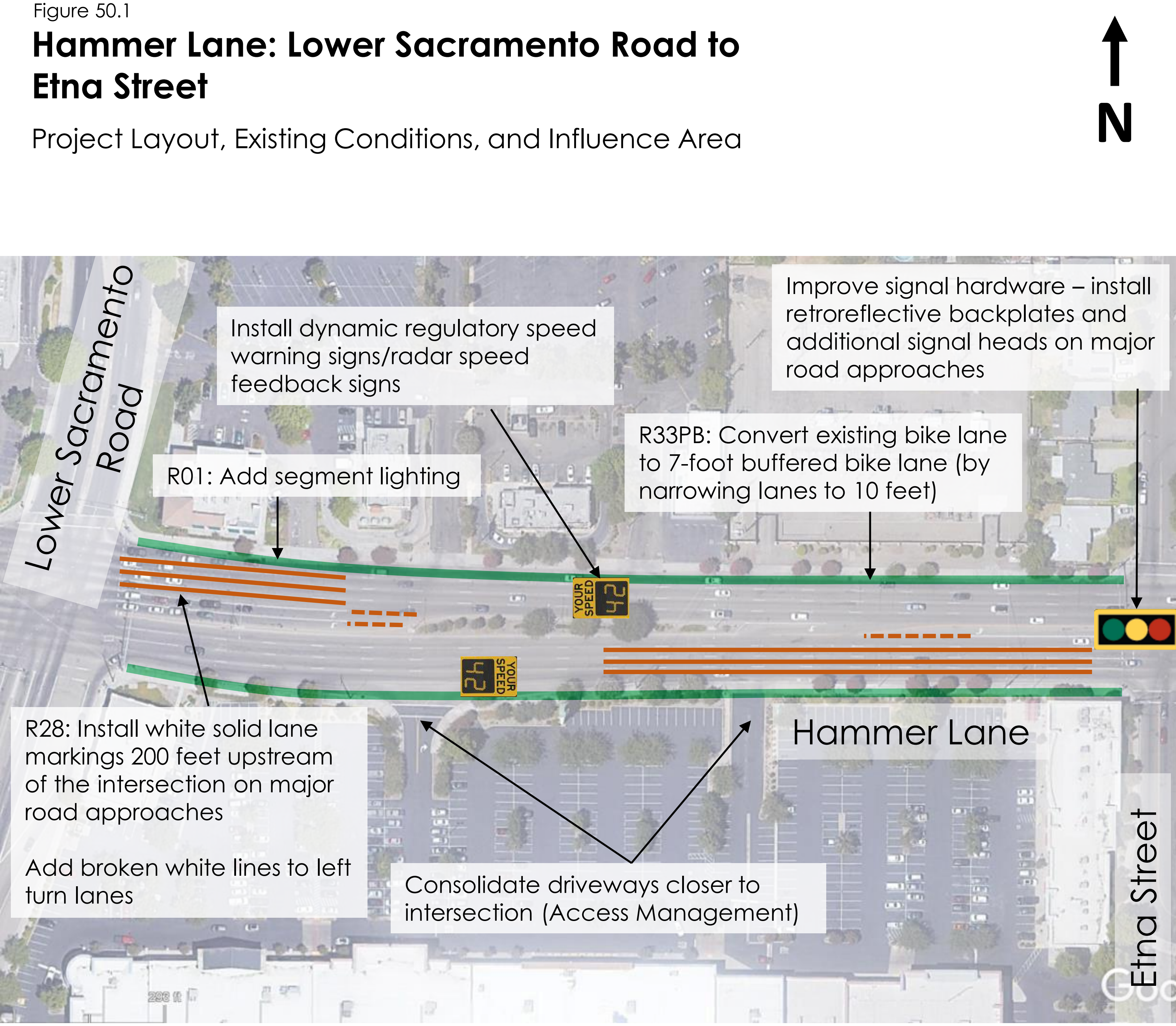
        - This treatment is intended to address collisions associated with unsafe speeds. 27 of the 50 collisions involved collisions reported with unsafe speeds.
    - Improve signal hardware by installing retroreflective backplates and additional signal heads on major road approaches.
        - This treatment is intended to address right-angle and rear-end collisions. 28 of the 50 collisions that occurred along this segment were broadside and rear-end collisions.
    - Consolidate driveways closer to major intersections.
        - This treatment is to improve access management and reduce conflicts.
    - Modify brick type crosswalk to regular crosswalk.
        - This is intended improve crosswalk accessibility and reduce long-term maintenance costs.

- Cost Estimate: $1,040,11
- Planning-Level B/C Ratio: 10.82

Figure 50.1

Hammer Lane: Lower Sacramento Road to Etna Street

Project Layout, Existing Conditions, and Influence Area



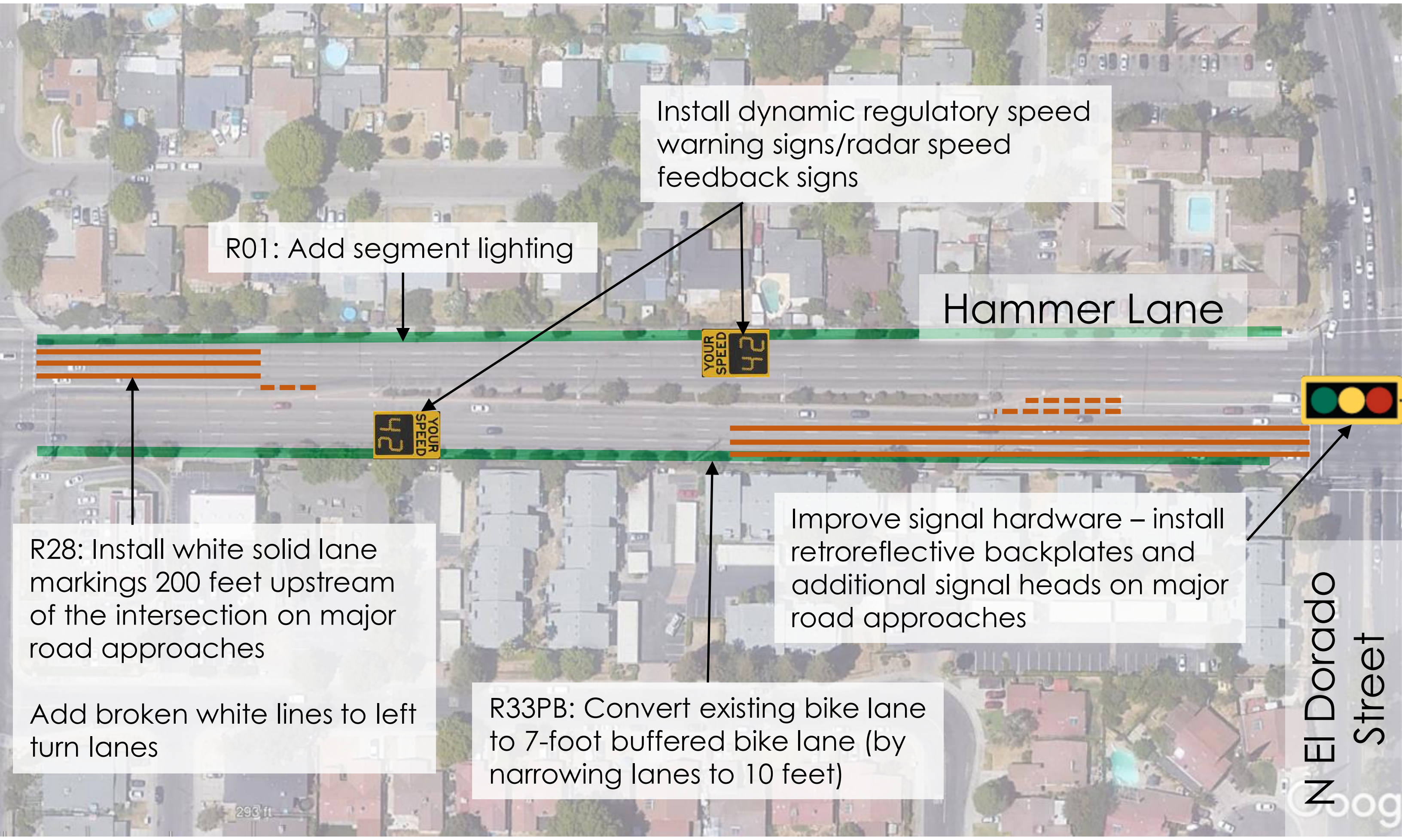
Legend

YOUR SPEED 42	Install dynamic regulatory speed warning signs
(signal)	Improve signal hardware – install retroreflective backplates and additional signal heads
(solid lines)	Install white solid lane markings 200 feet upstream of the intersection
(dashed line)	Add broken white lines to left turn lanes until the storage length
(green line)	Convert existing bike lane to buffered bike lane

Figure 50.2

Hammer Lane: Etna Street to N El Dorado Street

Project Layout, Existing Conditions, and Influence Area



Legend

Install dynamic regulatory speed warning signs

Improve signal hardware – install retroreflective backplates and additional signal heads

Install white solid lane markings 200 feet upstream of the intersection

Add broken white lines to left turn lanes until the storage length

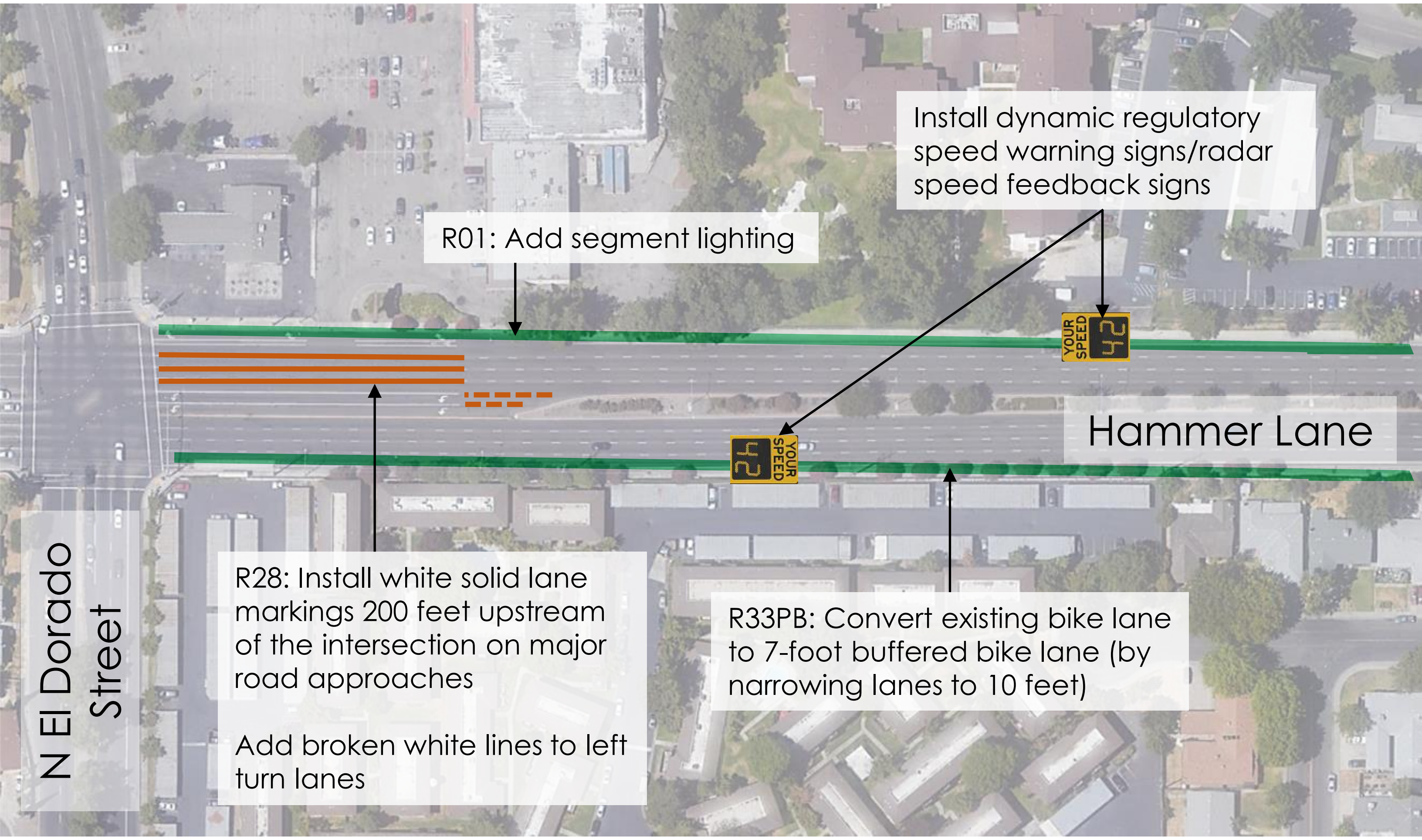
Convert existing bike lane to buffered bike lane

Figure 50.3

Hammer Lane: N El Dorado Street to 400 feet West of Lan Ark Drive

Project Layout, Existing Conditions, and Influence Area

N



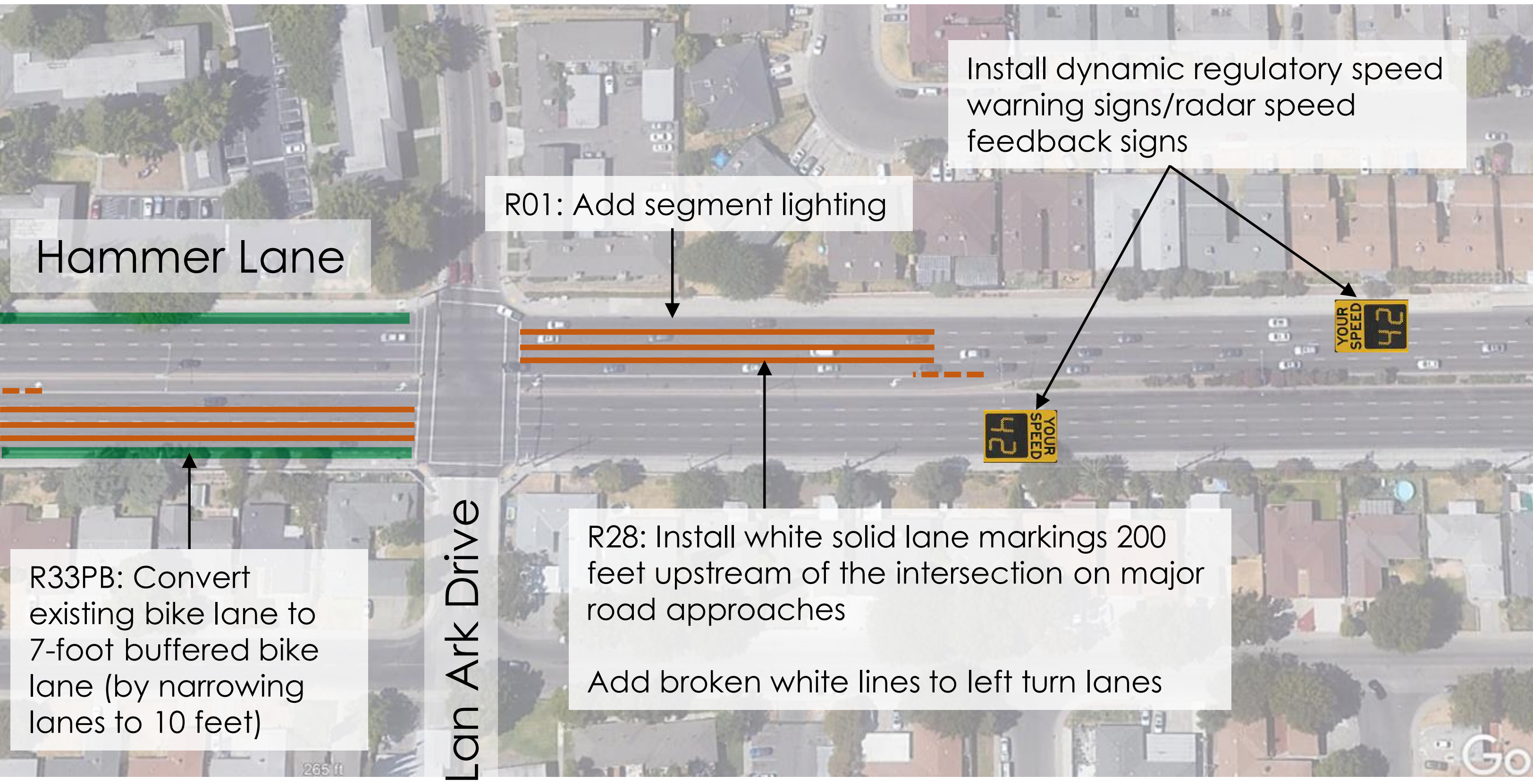
Legend

YOUR SPEED 42	Install dynamic regulatory speed warning signs
Orange dashed line	Add broken white lines to left turn lanes until the storage length
Orange solid lines	Install white solid lane markings 200 feet upstream of the intersection
Green line	Convert existing bike lane to buffered bike lane

Figure 50.4

Hammer Lane: 400 feet West of Lan Ark Drive to 500 feet West of Railroad Crossing

Project Layout, Existing Conditions, and Influence Area



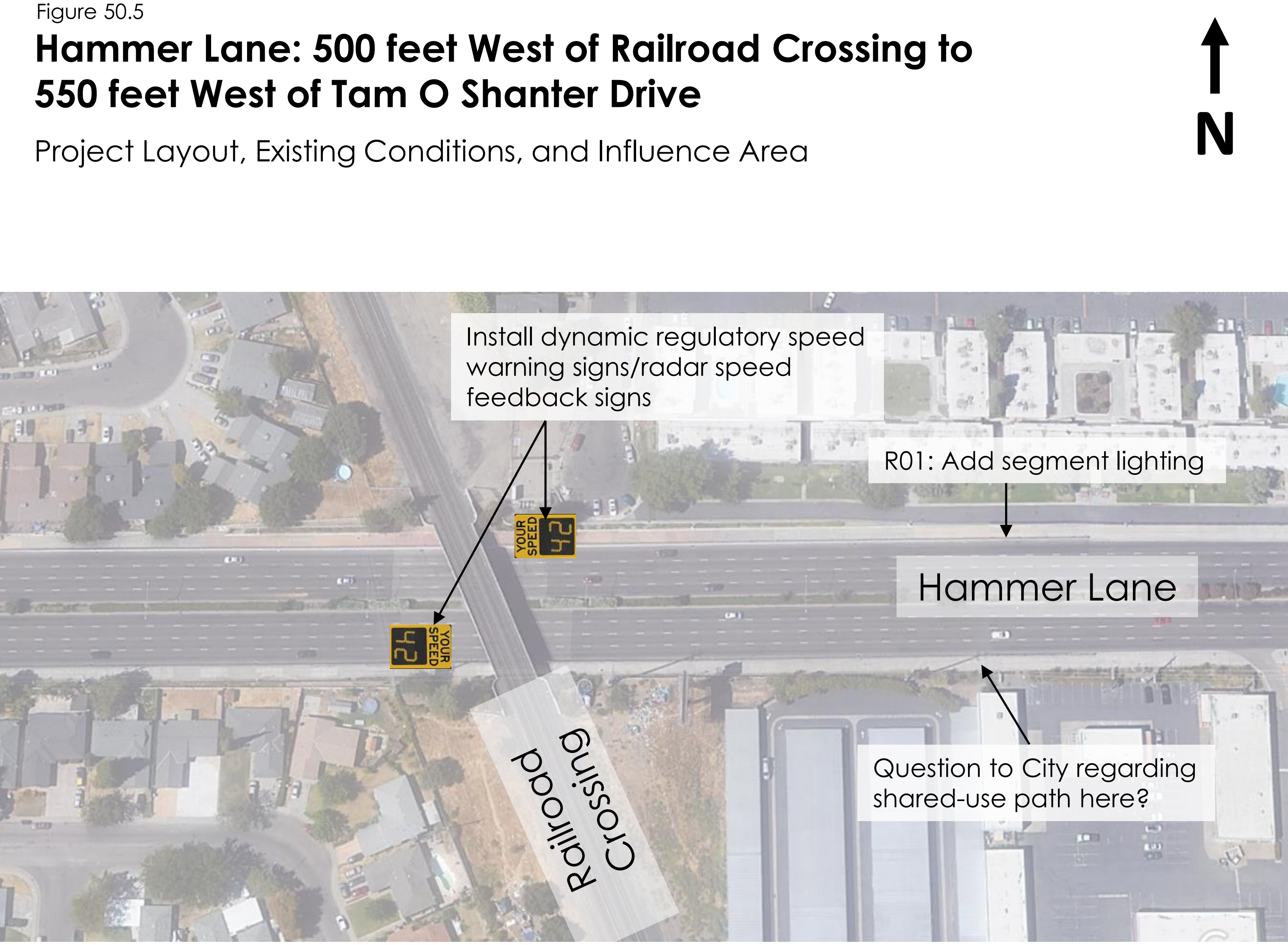
Legend

- YOUR SPEED 42 — Install dynamic regulatory speed warning signs
- Add broken white lines to left turn lanes until the storage length
- Install white solid lane markings 200 feet upstream of the intersection
- Convert existing bike lane to buffered bike lane

Figure 50.5

Hammer Lane: 500 feet West of Railroad Crossing to 550 feet West of Tam O Shanter Drive

Project Layout, Existing Conditions, and Influence Area



Legend

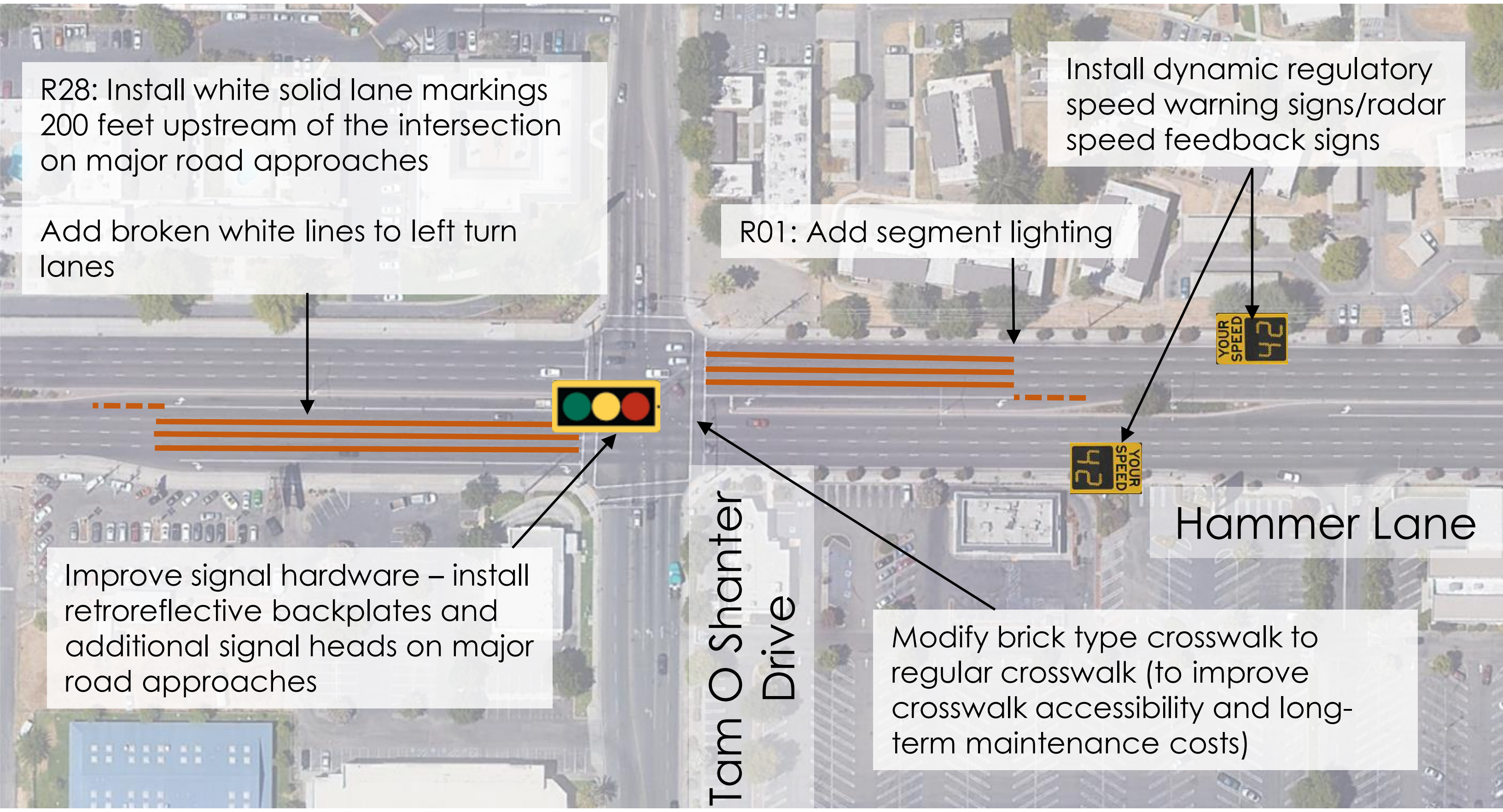
Install dynamic regulatory speed warning signs

Figure 50.6

Hammer Lane: 550 feet West of Tam O Shanter Drive to east of Tam O Shanter Drive

Project Layout, Existing Conditions, and Influence Area

N



Legend

YOUR SPEED 42	Install dynamic regulatory speed warning signs
(signal)	Improve signal hardware – install retroreflective backplates and additional signal heads
(solid lines)	Install white solid lane markings 200 feet upstream of the intersection
(dashed line)	Add broken white lines to left turn lanes until the storage length

EL DORADO STREET FROM LOWELL AVENUE TO CLAYTON AVENUE

The segment along El Dorado Street from Lowell Avenue to Clayton Avenue is an arterial with a two-way left-turn lane from Lowell Avenue to a raised median that begins 600' north of Clayton. This segment has three 3-legged unsignalized intersections and one 3-legged signalized intersection.

Sidewalks are present along the west side of the corridor from Lowell Avneue to 500' south of Ivy Avenue. There are no crosswalks or mid-block crossings along this segment. A Class II bike facility is planned along this section of El Dorado Street. This future bike facility is expected to intersect with a future Class I bike facility parallel to the Walker Slough Levee and two future Class III bike facilities on McKinley Avenue and Eighth Street. No transit stops are located along this segment of El Dorado Street.

Primarily commercial and residential land uses are located along this segment.Table 24 Table 25 provides an overview of this segment's reported collision history data from January 2015 to July 2020 including total collisions and injury severity.

Table 25. Collision History (January 2015 to July 2020), El Dorado Street from Lowell Avenue to South 900' of Clayton Avenue

Location	Total Collisions	Fatal	Severe Injury	Moderate Injury	Minor Injury	Property Damage Only
El Dorado Street from Lowell Avenue to South 900' of Clayton Avenue	18	1	3	1	8	5

Proposed Project:

- The proposed project includes the following safety treatments, as shown in Figure 51:
  - Install pedestrian crossing with Rectangular Rapid Flashing Beacons (RRFBs) just south of Lowell Avenue, at Ivy Avenue and just north of Walker Slough Levee.
    - This treatment is intended to address pedestrian and bicycle-involved collisions. 3 of the 18 collisions involved bicyclists or pedestrians. (NS21PB)
  - Implement a Road Diet by reducing travel lanes from 4 to 3 lanes and adding a two-way left-turn and bike lanes.
    - This treatment is intended to address head-on, left turn and rear-end collisions. 8 of the 18 collisions were rear-end or broadside collisions.
  - Install reflectors on fixed objects along the roadway provide driver guidance.
    - This treatment is intended to address fixed object collisions. 4 of the 18 collisions that occurred along this segment were associated with fixed objects. (R27)
  - Install pedestrian crossing across Wait Avenue.
    - This treatment is intended to address pedestrian and bicycle-involved collisions. 3 of the 18 collisions involved bicyclists or pedestrians.
  - Provide sidewalk infill to complete pedestrian network along El Dorado Street.

- This treatment is intended to address pedestrian and bicycle-involved collisions. 3 of the 18 collisions involved bicyclists or pedestrians.

- Cost Estimate: $1,662,600
- Planning-Level B/C Ratio: 7.72

Figure 51.1

El Dorado Street: Lowell Avenue to Ivy Avenue

Project Layout, Existing Conditions, and Influence Area

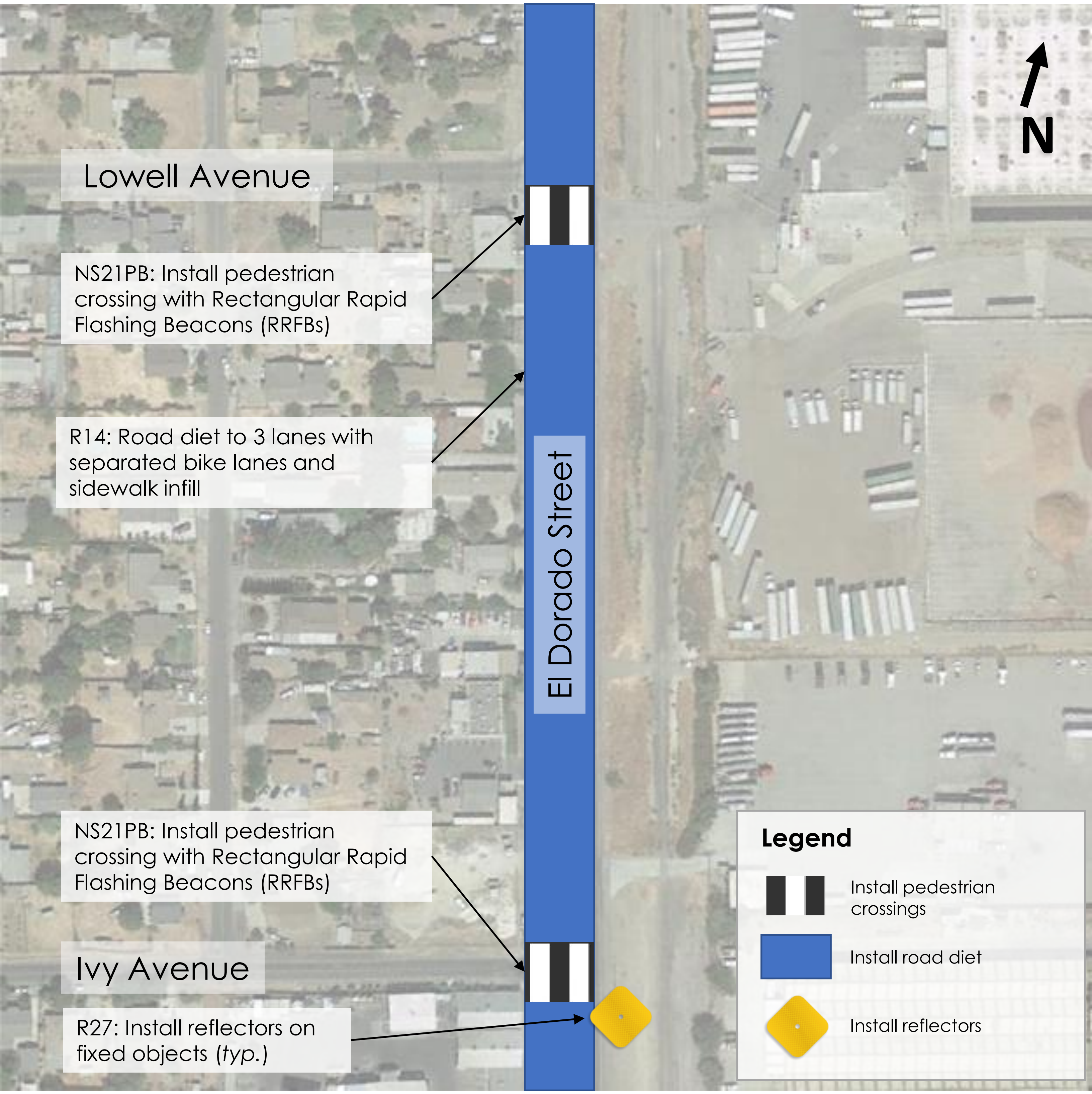


Figure 51.2

El Dorado Street: Ivy Avenue to Walker Slough Levee

Project Layout, Existing Conditions, and Influence Area

Figure 51.3

El Dorado Street: Walker Slough Levee to Wait Avenue

Project Layout, Existing Conditions, and Influence Area

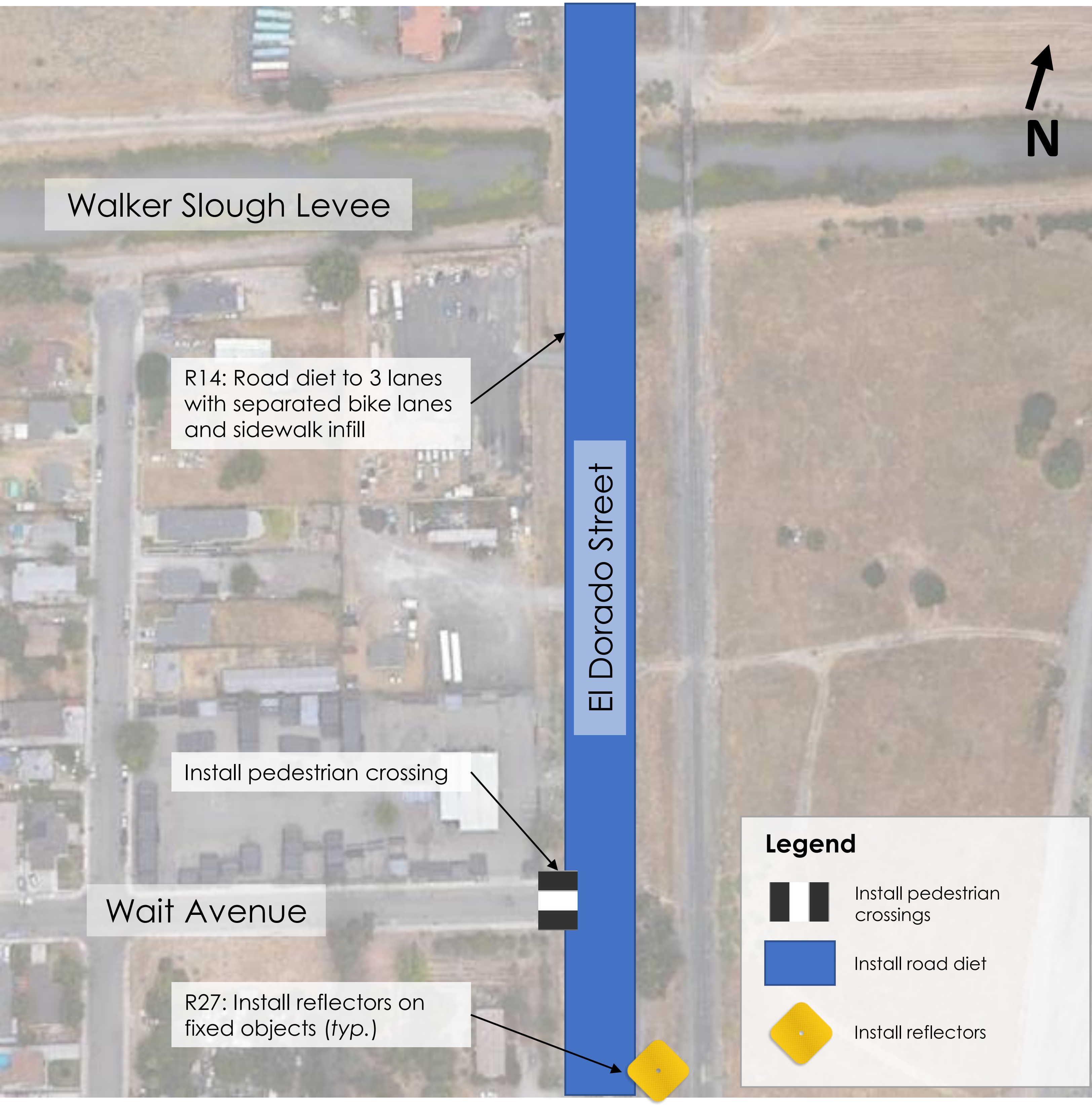
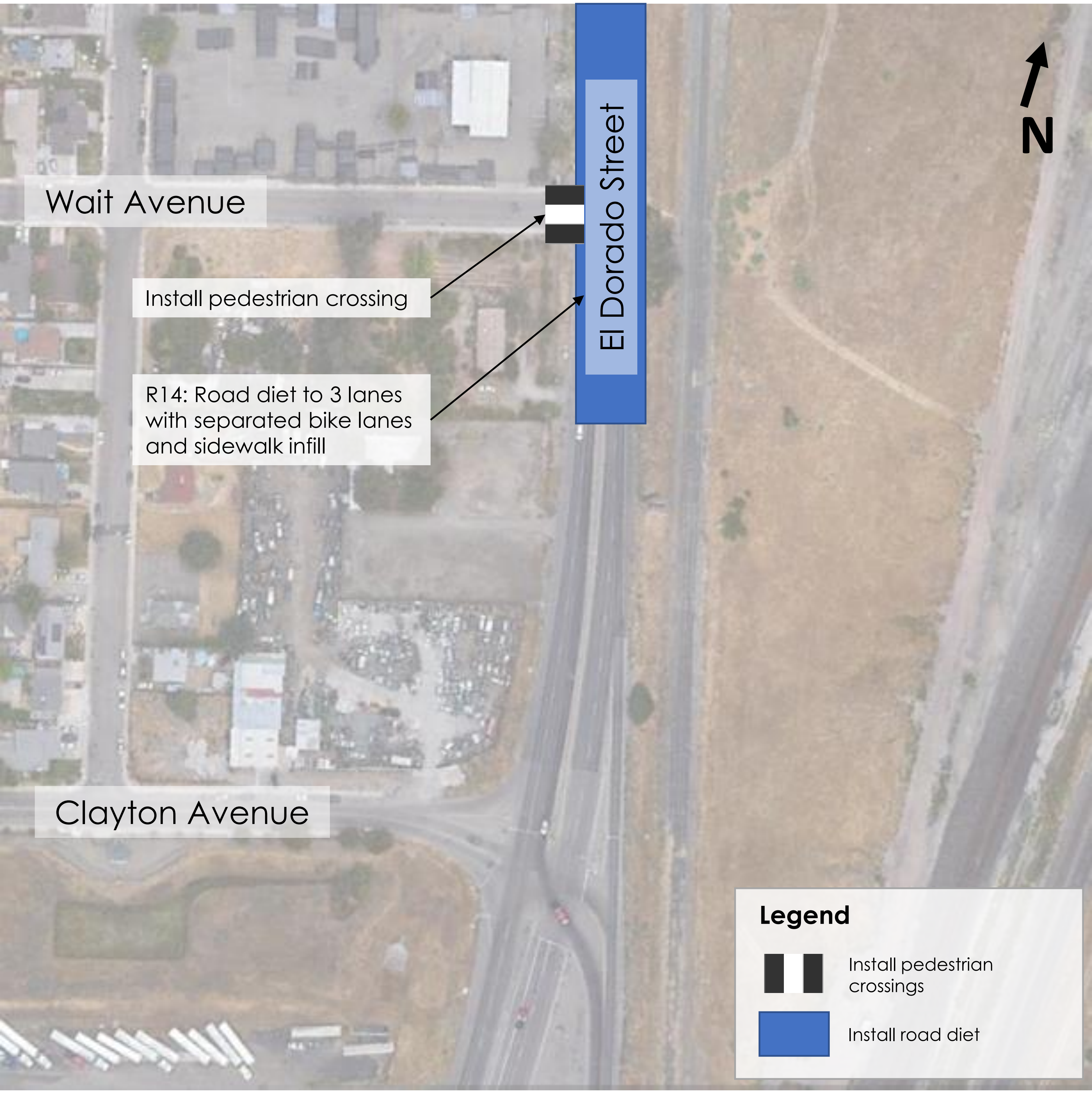


Figure 51.4

El Dorado Street: Wait Avenue to Clayton Avenue

Project Layout, Existing Conditions, and Influence Area



Non-Engineering Emphasis

This section presents non-engineering transportation safety countermeasures identified to address the systemic collision trends documented in the previous section. These countermeasures are intended to complement the engineering countermeasures described above and generally are intended to address behavioral factors contributing to collision risk. Countermeasures are grouped into law enforcement approaches, community enforcement approaches, education approaches and other innovative approaches. While non-engineering countermeasures are not eligible for HSIP funding, they can be funded through various other grant programs, including:

- **Active Transportation Program (ATP):** The California ATP provides funding for projects that improve walking and bicycling around the state, including both infrastructure and non-infrastructure projects. The Cycle 5 Call for Projects was released in Spring 2020 with $400 million of funding allocated.[9]
- **Office of Traffic Safety (OTS):** The California OTS offers grant funding for a wide variety of non-infrastructure traffic safety countermeasures. The next grant application period will open in December 2021.[10]

The strategies discussed in this section would be best implemented in coordination with the transportation safety partners listed previously.

ENFORCEMENT

Even when engineering countermeasures are implemented, failing to adhere to traffic laws can result in collisions of varying severity. Police enforcement can increase driver awareness and consequently reduce traffic collisions. Potential enforcement strategies to address collision patterns and trends in Stockton are presented below. However, enforcement strategies should be undertaken with due caution to avoid inequitable enforcement activities and evaluated to determine the strategy's impact. The following considerations can help lead to more successful outcomes for roadway safety enforcement strategies:

- Police officers should be trained properly beforehand.
- Campaigns should be tailored to suit the needs of different neighborhoods and demographics and should be designed and carried out to avoid targeting disadvantaged communities.
- Enforcement should be conducted with the help of staff support and awareness of the courts.
- Enforcement operations should begin with warnings and flyers before moving on to issuing citations.

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[9] https://dot.ca.gov/programs/local-assistance/fed-and-state-programs/active-transportation-program/cycle5

[10] https://www.ots.ca.gov/grants/program-information/

Collision data can help identify priority intersections and/or road segments and the times of the day when the collisions have occurred. This information can inform and guide the type of enforcement strategy to be selected at the most appropriate locations and time periods. City staff can also help monitor the impact of the enforcement strategy by coordinating with the Stockton Police Department to obtain and analyze enforcement records to help evaluate effectiveness and equity considerations.

Progressive Ticketing

Progressive ticketing is a method for introducing ticketing through a three-staged process. Issuing tickets is the strongest strategy of an enforcement program and it is usually reserved for changing unsafe behaviors that other strategies failed to change or that pose a real threat to the safety of road users. There are three main steps of an effective progressive ticketing program:

1. **Educating** - Establish community awareness of the problem. The public needs to understand that drivers are speeding and the consequences of this speeding for road safety. Raising awareness about the problem will change some behaviors and create public support for the enforcement efforts to follow.
2. **Warning** - Announce what action will be taken and why. Give the public time to change behaviors before ticketing starts. Fliers, signs, newspaper stories and official warnings from officers can all serve as reminders.
3. **Ticketing** – After the "warning" period, hold a press conference announcing when and where the police operations will occur. If offenders continue their unsafe behaviors, officers issue tickets.

Speed Enforcement in School Zones

Strict enforcement of speed laws in school zones is one law enforcement tool that can reduce the risk of severe and fatal injuries for children walking and bicycling to school as well as drivers. A 'zero tolerance' policy for speeders in school zones and increased fines for drivers who violate the posted school zone speed limit are potential approaches.

High Visibility Saturation Patrols

A saturation patrol (also called a blanket patrol or dedicated DWI patrol) consists of many law enforcement officers patrolling a specific area to look for drivers who may be impaired. These patrols usually take place at times and locations where impaired driving collisions commonly occur. Like publicized sobriety checkpoint programs, the primary purpose of publicized saturation patrol programs is to deter driving after drinking by increasing the perceived risk of arrest.

EDUCATION

Education strategies are focused on teaching road users road safety principles. These strategies can be developed to include interactive activities, comprehensive teaching notes, and information on road safety messages and concepts that can be taught at school or in the off-school activities. Kittelson identified the following five education-related strategies for the City of Stockton.

1. Road Safety Education to Children
2. Speed Monitoring Awareness Radar Trailer
3. Conspicuity Enhancements and Education
4. Vulnerable Road User Education
5. High-Visibility Cell Phone and Text Messaging Media Campaign

Road Safety Education to Children

Road safety education to children includes strategies such as safe routes to school, walking school bus, and bicycle trains that promote road safety to all users, particularly for pedestrians and bicyclists.

A 'safe routes to school' program encourages and enables children to walk and bike to school. This can improve their health, well-being, and roadway safety. This also results in less traffic congestion and emissions caused by school-related travel.

Walking school buses and bicycle trains encourage groups of children walking or biking to school, with one or more adults. The walking school buses, and bicycle trains have been put into practice by some of the schools in Sacramento, California; Chapel Hill, North Carolina; and Duluth, Georgia (SRTS Guide, 2021). These strategies or practices have shown communities and families that walking, and biking can be a viable and safe transportation option, and thus can be incorporated into their own daily travel patterns.

Speed Monitoring Awareness Radar Trailer

The speed trailer is an educational device that helps drivers become more aware of their speed in relation to the posted speed. This awareness tool can also help residents survey the traffic speeds in their own neighborhood. This trailer is usually deployed in a street or neighborhood for a few days so the residents can monitor the speeds on their own streets and become aware of their own driving behaviors.

Conspicuity Enhancements and Education

The purpose of enhancing conspicuity for pedestrians is to increase the opportunity for drivers to see and avoid pedestrians, particularly when it is dark. Over 70% of national pedestrian fatalities occur in the dark, and pedestrians who are more visible are less likely to be struck.

Educating pedestrians to wear reflective clothing and walk in well-lit areas can be implemented as targeted campaigns. The use of high visibility clothing and protective gear enhances safety. There is some limited evidence to suggest that a program aimed at increasing conspicuous and protective clothing could be successful.

Vulnerable Road User Education

The road safety education regarding vulnerable road users like pedestrians, bicyclists, and motorists includes strategies involving education from police officer. If the driver encroaches into the bike lane or fails to yield to the pedestrian at the crossing, the police officer pulls the driver over and hands them a flyer that has the information for drivers to adapt their behavior towards all road users; this can be in addition to a citation.

High-Visibility Cell Phone and Text Messaging Media Campaign

The High Visibility Enforcement model combines dedicated law enforcement with paid and earned media supporting the enforcement activity. Paid media includes advertisements on TV, radio, online, and via billboards, while earned media includes things like press events and news releases covering the efforts. Both types of media support enforcement activity by helping the public become aware of the enforcement activity, and to create the impression violators will be caught.

INNOVATIVE APPROACHES

This section notes innovative approaches to improve roadway safety by accelerating road safety understanding and technology, thereby helping transition to more sustainable and safer transportation systems. In line with the recent innovative approaches, the City of Stockton's Smart City Initiative project that directs the City towards a smart and connected world is underway (as of February 2021), and the project's focus areas include, but are not limited to:

1. Increase Digital Access and Equity,
2. Improve the Movement and Interconnectivity of People Through the City,
3. Create Safe, Accessible, Practical and Delightful Public Space,
4. Deliver Exceptional City Services,
5. Expand Constituent Engagement,
6. Spark Business Growth and Employment, and
7. Build a Platform for Learning.

The Road Safety Innovation List (2021) has identified the following new technologies and approaches that are innovating around safety management:

Artificial Intelligence and Deep Learning

This technology applies artificial intelligence and deep learning on traffic video feed, (such as existing CCTV traffic cameras) to perform automated video analysis of traffic flow for effective and immediate road safety diagnosis and evaluation of conflicts. The combination of artificial intelligence and vehicle-to-everything (V2X) technology is designed to predict vehicles and pedestrians' intent and prevent conflicts that may result in collisions. This technology is now being tested in autonomous vehicles and several applications are being developed for use by jurisdictions to apply at intersections or across whole networks (where video data is available).

Big Data

New "Big Data" information measures all kinds of activity in streets including volumes, paths, speeds, and behaviors of pedestrians, bicycles, different types of vehicles, wheelchairs, and scooters on the roadway. These data platforms provide data on curb-level activity and helps engineers and planners design safer and more efficient streets by helping to detect conflicts and address potential safety concerns before collisions occur.

Mobile phone data and machine learning algorithms are being designed to identify high-risk driver behavior before a collision occurs. Using the smart phone sensors, the behavioral data provides actionable insights that improve safety performance for all road users.

Fleet Related Technology

Vehicle fleet technology integrates the driver-assistive platooning system to all commercial fleets, and links the active safety systems between freight trucks, detects oncoming vehicles, pedestrians, and bicyclists and alerts drivers in advance to avoid them with real-time warnings.

FUTURE OUTREACH

Many of the non-engineering solutions discussed above require collaboration across multiple agencies going beyond the City's Department of Public Works. The City can work with the recommended safety partners to develop an approach for when and how some of these could be implemented.

EVALUATION AND IMPLEMENTATION

This chapter describes the steps the City may take to evaluate the success of this plan and steps needed to update the plan in the future.

Performance Measures

Measures the City can use to evaluate its ongoing success in improving roadway safety performance include:

- Total number of fatal and severe injury collisions on City roads.
- Number of fatal and severe injury collisions on City roads by the following categories:
  - Broadside collisions
  - Hit object collisions
  - Pedestrian-involved collisions
  - Collisions at the intersections and on the roadways listed as emphasis area locations

Fatal and severe injury collisions may be reported annually, with performance evaluated within the context of the latest five-year annual average to normalize for random fluctuations in collisions on a year-over-year basis.

Updating the Plan

This plan relies on collision data from January 1, 2015 to July 31, 2020. The City should review collision data for the key findings and performance measures to track progress annually. More substantial updates to the safety plan can occur at longer intervals (approximately every five years).

The City, in conjunction with its safety partners (i.e, PMT members), can assess the plan, consider new trends and technologies, and determine if an update to the plan is needed. As new strategies are identified, the group of safety partners may update goals and should assign champions for specific strategies and action items.

APPENDIX

FIELD REVIEW RISK ASSESSMENT

Kittelson reviewed the top ten intersections from two of the City of Stockton' High Incidence Intersection Report which ranks intersections by crash frequency. Two reports were run by the City of Stockton, one for intersection-related crashes, and another for intersections including crashes within 200 feet of the intersection. The top highest-frequency intersections for these two reports are presented in Table 26 below.

Table 26: Top Ten High Incidence Intersection Reports, August 1, 2015 – July 31, 2020

Rank	**Intersection**	**Rank**	**Intersection**
1	West Lane at Hammer Lane	1	West Lane at Hammer Lane
2	Pershing Avenue at March Lane	2	Pershing Avenue at March Lane
3	March Lane at El Dorado Street	3	Kelley Drive at Hammer Lane
4	Kelley Drive at Hammer Lane	4	March Lane at Quail Lakes Drive/Da Vinci Drive
5	West Lane at March Lane	5	March Lane at El Dorado Street
6	Quail Lakes Drive at Da Vinci Drive	6	West Lane at March Lane
7	Pacific Avenue at March Lane	7	Hammer Lane at El Dorado Street
8	Lafayette Street at El Dorado Street	8	Pacific Avenue at March Lane
9	Holman Road at Hammer Lane	9	Dr MLK Jr Boulevard at Airport Way
10(tie)	Hammer Lane at El Dorado Street	10	Harding Way at Center Street
10(tie)	Dr MLK Jr Boulevard at Airport Way		

Source: City of Stockton, Stockton Police Department/Traffic Section, High Incidence Intersection Report, August 27, 2020

While reviewing these intersections, Kittelson used imagery to review characteristics that could contribute to the crash potential at individual locations. The following geometry and multimodal considerations were reviewed at each of the intersections:

- **Geometry and Land Uses:**
  - Signal
  - Location of Signal
  - Traffic Control Signage
  - Presence of One-Way Couplets

- Skewed Approaches to Intersection
- Separated Boulevards
- Land Use Context
- Number of Lanes and Lane Configurations
- Condition of Pavement
- Presence of Railroads or Water Constraints
- Access Management

- **Multimodal Considerations:**
  - Presence and Alignment of Sidewalks and Crosswalks
  - Objects in Pedestrian Zones
  - Pedestrian Scale Lighting
  - Design of Pedestrian Ramps
  - Presence and Design of Bike Facilities
  - Access to Transit Stops

Although Kittelson reviewed the field conditions at only these twelve locations, there are likely other intersections that have similar characteristics that may pose comparable crash potential and could be combined for systemic safety treatments to proactively address the crash potential at each location.

OVERALL SUMMARY FINDINGS

Several common trends were found among the twelve intersections reviewed. These include:

- All have signals.
- All are missing pedestrian scale lightings.
- All have at least one corner without modern or contemporary pedestrian ramp design.
- Six are constrained by railroads or water features.
- Six required multiple crossings to connect between transit stops.
- Four have unprotected bike lanes.
- Three have at least one approach with a signal mast arm greater than MUTCD's recommendation of 180 feet from a stop bar.
- Three are in the vicinity of ramp terminals.
- Two are one-way couplets.
- One has a separated boulevard.

GEOGRAPHIC CORRIDORS

Through this field investigation, Kittelson identified three corridors in Stockton that have at least three intersections ranked among those with the highest frequencies. These include:

- Hammer Lane
- March Lane
- El Dorado Street

The field assessment of each of these corridors is summarized below.

Hammer Lane

Hammer Lane is a large east-west arterial in Stockton. This roadway provides a connection between I-5 and SR-99 in northern Stockton. Of the twelve intersections reviewed, four were located along Hammer Lane. These include:

- West Lane at Hammer Lane
- Kelley Drive at Hammer Lane
- Holman Road at Hammer Lane
- El Dorado Street at Hammer Lane

These four intersections demonstrated the following characteristics:

- All are signalized.
- All are missing pedestrian scale lighting.
- All require long pedestrian crossings.
- All have at least one corner without modern or contemporary pedestrian ramp design.
- All, except the intersection at Kelley Drive, have unprotected bike lanes.
- Kelley Drive is in the ramp terminal influence of I-5.
- The intersections at Holman Road and El Dorado Street appear to have land use patterns consistent with older land development patterns.
- All, except the intersection at Kelley Drive, appear to have deteriorated pavement.

Although these were four intersections were reviewed because of the high crash frequency at each one, it is likely that other locations along Hammer Lane have similar characteristics.

March Lane

March Lane is a large east-west arterial in Stockton. This roadway provides a route parallel to the Calaveras River. Of the twelve intersections reviewed, five were located along March Lane. These include:

- Pershing Avenue at March Lane
- March Lane at El Dorado Street

- West Lane at March Lane
- Pacific Avenue at March Lane
- March Lane at Quail Lakes Drive/Da Vinci Drive

These five intersections demonstrated the following characteristics:

- All are signalized.
- All are missing pedestrian scale lighting.
- All require long pedestrian crossings.
- All have at least one corner without modern or contemporary pedestrian ramp design.
- All, except the intersection at Pershing Avenue, do not have dedicated bike facilities.
- All, except for the intersection at El Dorado Street, require multiple crossings to make transit connections.
- All require different decision points for turning movements or lane merging. This is especially the case at Quail Lakes Drive/Da Vinci Drive which is influenced by the I-5 ramp terminal.

Although these were five intersections were reviewed because of the high crash frequency at each one, it is likely that other locations along March Lane have similar characteristics.

El Dorado Street

El Dorado Street is a large north-south arterial in Stockton. This roadway provides a parallel route to I-5. Of the twelve intersections reviewed, three were located along El Dorado Street. These include:

- March Lane at El Dorado Street
- Lafayette Street at El Dorado Street
- Hammer Lane at El Dorado Street

These three intersections demonstrated the following characteristics:

- All are signalized.
- All are missing pedestrian scale lighting.
- All are missing crosswalks or have crosswalks that do not follow a straight path.
- All have at least one corner without modern or contemporary pedestrian ramp design.
- All, except the intersection at Lafayette Street, have objects in the pedestrian zone.
- All, except the intersection with Hammer Lane, do not have dedicated bike facilities.
- All have driveways within 250 feet of the intersection.
- All, except the intersection at Lafayette Street, appear to have land use patterns consistent with older land development patterns.
- All, except the intersection at March Lane, appear to have deteriorated pavement.

Although these were three intersections were reviewed because of the high crash frequency at each one, it is likely that other locations along El Dorado Street have similar characteristics.