KITTELSON & ASSOCIATES
155 GRAND AVENUE, SUITE 900
OAKLAND, CA 94612
P 510.839.1742 F 510.839.0871

TECHNICAL MEMORANDUM

Dublin Bicycle and Pedestrian Master Plan

Level of Traffic Stress Methodology, Assumptions, and Results

Date:	July 15, 2020	Project #: 24392
To:	Sai Midididdi, TE	
From:	Mike Alston, RSP; Amanda Leahy, AICP; Erin Ferguson, PE, RSP; Michael Sahimi, AICP	

The City of Dublin (City) is updating the 2014 Dublin Bicycle and Pedestrian Master Plan (Plan). The Plan will serve as a comprehensive action plan for the City to provide improved bicycle and pedestrian facilities for its residents, employees, and visitors. As part of the baseline conditions and needs assessment, Kittelson & Associates, Inc. (Kittelson) is analyzing the bicyclist level of traffic stress (LTS) on the City's existing roadway network ("on-street LTS")and on the Class I path network ("path LTS"). This memorandum (memo) details the methodology and assumptions used in the on-street LTS analysis for the existing roadway network and the results of the on-street LTS and path LTS analyses. The path LTS methodology and assumptions are included as Attachment A. The memo is organized into the following sections:

- Background
- Methodology
- Available Data and Assumptions
- Existing Conditions LTS Results
- Map Results
- Attachment A: Class I Path LTS Methodology

BACKGROUND

The on-street LTS methodology used was developed by the Mineta Transportation Institute (MTI) and documented in the *Low-Stress Bicycling and Network Connectivity* report published in 2012;[1] it was further refined by Dr. Peter Furth of Northeastern University in 2017.[2] The on-street LTS measure is a rating given to a road segment or crossing indicating the traffic stress it imposes on bicyclists. It classifies road segments and intersections as one of four levels of traffic stress:

- LTS 1: Requires little attention to surroundings; suitable for most children

[1] Mekuria, Mazza C., "Low-Stress Bicycling and Network Connectivity" (2012). *All Mineta Transportation Institute Publications*. Book 4. http://scholarworks.sjsu.edu/mti_all/4

[2] The methodology is posted at http://www.northeastern.edu/peter.furth/criteria-for-level-of-traffic-stress/. This methodology is "Version 2.0," published in June 2017.

- LTS 2: Low traffic stress; suitable for most adults
- LTS 3: Moderate traffic stress for all bicyclists
- LTS 4: High stress; only suitable for experienced bicyclists

The on-street LTS methodology has recently been used by agencies such as Alameda CTC and the City of Oakland to assess bicycling conditions and is a best practice methodology for assessing these conditions in the transportation planning profession.

This memo describes the on-street LTS methodology implemented based on the versions developed in 2012 and updated in 2017.

METHODOLOGY

The on-street LTS methodology includes criteria for establishing the score along roadway segments as well as at intersections and crossings, since the features of a signalized or unsignalized intersection can also have an impact on bicyclist comfort along a path or roadway. This section outlines the methodologies and criteria for both facilities.

Roadway Segment LTS Methodology

The on-street LTS methodology for roadway segments provides criteria for the following three bicycle facility types:[3]

- Bike lanes alongside a parking lane
- Bike lanes not alongside a parking lane
- Mixed traffic (i.e., no bike lanes present).

Note that under this methodology, Class III bicycle routes are analyzed under the criteria for mixed traffic. In addition, physically separated Class I and Class IV bikeway segments (including parking-separated bike lanes) are always scored the lowest level of traffic stress between intersections, LTS 1. Under the Furth on-street methodology, Class I and IV bikeways are assumed to have the lowest level of stress since bicyclists are separated from interacting with vehicles. This analysis instead applies path LTS scores based on separate evaluation metrics for Class I paths. (See the next section, Path LTS, for discussion of Class I path LTS within the City.)

The methodology evaluation criteria for each of the three facility types are shown in Table 1 through Table 3. These criteria operate following the "weakest link" principle, where the criterion with the

[3] Bikeways can generally be classified as:
Class I: off-street bicycle-only or multi-use path
Class II: on-street bicycle lanes (can also include painted buffer)
Class III: signed on-street bicycle route
Class IV: physically-separated or protected on-street bike lanes

highest (worst) LTS determines the stress level of the segment. For example, if the bike lane width matches the values associated with LTS 1 but the speed limit indicates LTS 3, the segment would be considered to be LTS 3.

Table 1: Roadway Segment Criteria for Bike Lanes Alongside a Parking Lane

Number of Vehicle Lanes	Bike Lane Reach (Bike plus parking lane width)	Prevailing Speed		
		≤ 25 mph	30 mph	35 mph
1 lane per direction	15+ ft	LTS 1	LTS 2	LTS 3
	12-14 ft	LTS 2	LTS 2	LTS 3
2 lanes per direction (2-way)	15+ ft	LTS 2	LTS 3	LTS 3
2-3 lanes per direction (1-way)		LTS 2	LTS 3	LTS 3
other multilane		LTS 3	LTS 3	LTS 3

Notes:
1. Bike lane reach = Bike + Parking Lane Width.
2. If bike lane is frequently blocked, use mixed traffic criteria.
3. Qualifying bike lane must have reach (bike lane width + parking lane width) ≥ 12 ft.
4. Bike lane width includes any marked buffer next to the bike lane.
Source: Peter Furth, Northeastern University, http://www.northeastern.edu/peter.furth/criteria-for-level-of-traffic-stress/

Table 2: Road Segment Criteria for Bike Lanes and Shoulders Not Adjacent to a Parking Lane

Number of Vehicle Lanes	Bike Lane Width	Prevailing Speed					
		≤ 25 mph	30 mph	35 mph	40 mph	45 mph	50+ mph
1 thru lane per direction, or no striped centerline	6+ ft	LTS 1	LTS 2	LTS 2	LTS 3	LTS3	LTS 3
	4 or 5 ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
2 thru lanes per direction	6+ ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	4 or 5 ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
3+ lanes per direction	Any width	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4

Notes:
1. If bike lane / shoulder is frequently blocked, used mixed traffic criteria.
2. Qualifying bike lane / shoulder should extend at least 4 ft from a curb and at least 3.5 ft from a pavement edge or discontinuous gutter pan seam.
3. Bike lane width includes any marked buffer next to the bike lane.
Source: Peter Furth, Northeastern University, http://www.northeastern.edu/peter.furth/criteria-for-level-of-traffic-stress/

Table 3: Road Segment Criteria for Level of Traffic Stress in Mixed Traffic

Number of Lanes	Effective Average Daily Traffic (ADT)	Prevailing Speed						
		≤ 20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50+ mph
2-way street with no striped centerline	0-750	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	751-1500	LTS 1	LTS 1	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4
	1501-3000	LTS 2	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
1 thru lane per direction (1-way, 1-lane street or 2-way street with centerline)	0-750	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	751-1500	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4
	1501-3000	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
2 thru lanes per direction	0-8000	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	8001+	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
3+ thru lanes per direction	Any ADT	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4

Note: Effective ADT = ADT for two-way roads; Effective ADT = 1.5*ADT for one-way roads.
Source: Peter Furth, Northeastern University, http://www.northeastern.edu/peter.furth/criteria-for-level-of-traffic-stress/

Crossing LTS Methodology

Kittelson conducted LTS intersection crossing analysis for street or path intersections that are located along a link that is scored LTS 3 or 4 (i.e., high-stress facilities), since it is likely that the characteristics of a high-stress segment can affect the bicyclist experience when crossing from a low-stress street. The crossing methodology analyzes intersections and crossings for the following situations:

- Intersection approaches for pocket bike lanes (defined as a bike lane that is to the left of a dedicated right-turn vehicle lane)
- Intersection approaches for mixed traffic in the presence of right-turn lanes
- Intersection crossings for unsignalized crossings without a median refuge
- Intersection crossings for unsignalized crossings with a median refuge

The list above is provided by the Furth methodology and does not describe all circumstances. In Dublin, many Class I facilities cross at signalized intersections. See the next section, Path LTS, for a discussion of this topic.

Under the Furth methodology, the LTS at an approach is graded from LTS 1 through LTS 4 based on the criteria outlined in Table 4 through Table 7.

Table 4: Level of Traffic Stress Criteria for Pocket Bike Lanes

Configuration	Level of Traffic Stress
Single right-turn lane up to 150 ft. long, starting abruptly while the bike lane continues straight, and having an intersection angle and curb radius such that turning speed is < 15 mph.	LTS ≥ 2
Single right-turn lane longer than 150 ft. starting abruptly while the bike lane continues straight, and having an intersection angle and curb radius such that vehicle turning speed is < 20 mph.	LTS ≥ 3
Single right-turn lane in which the bike lane shifts to the left, but the intersection angle and curb radius are such that turning speed is < 15 mph.	LTS ≥ 3
Single right-turn lane with any other configuration; dual right-turn lanes; or right-turn lane along with an option (through-right) lane.	LTS ≥ 4

Source: Mekuria, Maaza. Low-Stress Bicycling and Network Connectivity, Mineta Transportation Institute, 2012.

Table 5: Level of Traffic Stress Criteria for Mixed Traffic in the Presence of a Right-Turn Lane

Configuration	Level of Traffic Stress
Single right-turn lane with length < 75 ft. and intersection angle and curb radius limit turning speed to 15 mph.	(no effect on LTS)
Single right-turn lane with length between 75 and 150 ft., and intersection angle and curb radius limit turning speed to 15 mph.	LTS ≥ 3
Otherwise.	LTS ≥ 4

Source: Mekuria, Maaza. Low-Stress Bicycling and Network Connectivity, Mineta Transportation Institute, 2012.

Table 6: Level of Traffic Stress Criteria for Unsignalized Crossings Without a Median Refuge

Speed Limit of Street Being Crossed	Width of Street Being Crossed		
	Up to 3 lanes	4-5 lanes	6+ lanes
Up to 25 mph	LTS 1	LTS 2	LTS 4
30 mph	LTS 1	LTS 2	LTS 4
35 mph	LTS 2	LTS 3	LTS 4
40+ mph	LTS 3	LTS 4	LTS 4

Source: Mekuria, Maaza. Low-Stress Bicycling and Network Connectivity, Mineta Transportation Institute, 2012.

Table 7: Level of Traffic Stress Criteria for Unsignalized Crossings with a Median Refuge at Least Six Feet Wide

Speed Limit of Street Being Crossed	Width of Street Being Crossed		
	Up to 3 lanes	4-5 lanes	6+ lanes
Up to 25 mph	LTS 1	LTS 1	LTS 2
30 mph	LTS 1	LTS 2	LTS 3
35 mph	LTS 2	LTS 3	LTS 4
40+ mph	LTS 3	LTS 4	LTS 4

Source: Mekuria, Maaza. Low-Stress Bicycling and Network Connectivity, Mineta Transportation Institute, 2012.

Path LTS

The on-street LTS methodology employed does not include a detailed path segment or crossing methodology to account for the various design factors that affect quality of service and user stress on Class I paths like those across the City. Thus, Kittelson created a parallel evaluation of path LTS that accounts for path segments and crossings to accompany the on-street LTS methodology. The intent of the path LTS methodology is to account for the varying qualities of service on paths throughout the City and to be able to carry forward the path analysis into prioritization and plan recommendations alongside the on-street LTS analysis. The details of the path LTS analysis are presented in Attachment A: Class I Path LTS Methodology. The results maps of the path LTS evaluation are included alongside the on-street LTS results in this memo.

AVAILABLE DATA AND ASSUMPTIONS

Kittelson obtained data from the City and compiled it in a spatial database to conduct the on-street and path LTS analyses. Where GIS data were not available, Kittelson combined field review, Google Earth aerial review, City input, and assumptions to build out necessary inputs. The data used in the analysis are shown in Table 8.

Table 8: Data Requirements and Assumptions

Data Requirement	Data Availability/Assumptions
Existing dedicated bicycle facilities (Class I, II, II buffered, and IV) in the City	Digitized the City's existing bicycle facilities. See Figure 1.
Presence of parking lanes adjacent to bike lanes	This attribute only applies where Class II facilities exist alongside parking (Table 1). Kittelson conducted field review of Class II locations and mapped the presence or absence of parking. See Figure 2.
Number of vehicle lanes	Kittelson used City-provided data, which was reviewed and confirmed. Kittelson reviewed missing locations to obtain complete network coverage. See Figure 3.

Data Requirement	Data Availability/Assumptions
Speed Limit	Kittelson utilized speed limit data provided by the City in shapefile format. On residential roads without speed limit data or posted speeds, speed limit of 25 mph was applied based on the City's prima facie speed limits.[4] See Figure 4.
Bike lane width	Kittelson conducted field reviews to determine bike lane widths where the methodology required them.
Bike lane buffer width	Kittelson conducted field reviews to determine bike lane buffer widths where the methodology required them.
Width of bike lane and adjacent parking lane	Kittelson conducted field reviews to determine parking lane widths adjacent to bike lanes where the methodology required this information.
Frequency of bicycle lane blockage	This attribute is a binary variable (i.e., whether the bicycle lane is frequently blocked or not) used to reassign facilities with a bike lane to be evaluated as mixed traffic facilities (see note, Table 2). Kittelson assumed that bike lanes next to driveways for large parking lots (such as retail centers) are frequently blocked and applied the mixed traffic criteria for those segments.
Average Daily Traffic	Kittelson used the ADT provided by City in shapefile and/or spreadsheet format. Where ADT was not available, ADT categories were estimated based on downstream volumes, adjacent roadways, or the general land use context around a facility. These generally included facilities that were clearly in the highest ADT category for analysis (8,001 +)
Centerline presence	Kittelson assumed collector streets are striped with centerlines and local/neighborhood streets were not. The functional classification designations came from the City's 2013 General Plan Circulation Element and from 2012 functional classification designation forms submitted to Caltrans. Where inconsistencies were present, Kittelson assumed a street to be the higher order designation between the two.
Presence of right turn lanes and features (e.g., number of lanes and length, and curb radius)	This attribute is required for intersection crossing analysis. Kittelson applied these manually based on Google Earth review on an as-needed basis.
Presence of pocket bike lanes and features (e.g., number of lanes and length, and curb radius)	This attribute is required for intersection crossing analysis. Kittelson applied these manually based on Google Earth review on an as-needed basis.
Median presence and width	This attribute is required for intersection crossing analysis. Kittelson applied these manually based on Google Earth review on an as-needed basis.

[4] https://dublin.ca.gov/2094/Speed-Surveys

EXISTING CONDITIONS LTS RESULTS

On-Street LTS

The available GIS data, field reviews, Google Earth review, and other assumptions documented above were applied using the methodologies outlined in this memo. The results of the on-street LTS analysis are shown in Figure 7.

- On-street LTS scores were first calculated for bidirectional segments utilizing the segment criteria outlined in Table 1 through Table 3 (with off-street paths receiving a score of LTS 1).
- For locations where low-stress facilities crossed high-stress facilities, the crossing LTS methodologies were applied as outlined in Table 4 through Table 7. For signalized intersections, locations with dedicated right turn lanes and/or pocket bike lanes were reviewed and the approach's LTS score was updated if intersection conditions would result in an increased level of stress. Likewise, for unsignalized intersections, LTS scores were updated as needed.

As shown in Figure 7, low-stress on-street facilities in the City generally consist of local residential roads without dedicated bicycle facilities. Arterial roads, such as Dublin Boulevard generally consist of higher-stress segments for bicyclists, due to features such as vehicular speeds, traffic volumes, and the number of travel lanes, regardless of the inclusion of bike lanes. In addition, low-stress roads are assessed as higher stress (i.e., downgraded to LTS 3 or 4) where they cross high stress facilities, meaning that some low-stress areas are "islands" isolated by high-stress segments and crossings. Figure 8 presents the City's network of low-stress facilities, which helps to highlight where gaps exist. For example, Fallon Road, Tassajara Road, San Ramon Road, and Dublin Boulevard create low-stress gaps in the on-street network.

Path LTS

As shown in Figure 12, Class IA multi-use paths most frequently score a path LTS of 2 given their width, shoulder, and wayfinding presence. Class IB sidepaths frequently score a path LTS of 3 given no wayfinding present along their segments. The path crossings vary but rarely exceed LTS 3 except at intersection crossings with high speeds, no horizontal/vertical elements, and no crossing markings or signage. Although path LTS values were assessed for every path crossing location, only the crossings with lower scores than the connecting path segments are shown in the mapped results. In other words, the only mapped crossings are those which degrade the segment path LTS score.

Combined Results

The on-street and path LTS results are presented together in Figure 13 to provide a full picture of connectivity citywide. Note that the directionality of the on-street LTS has been suppressed in order to simplify the level of detail shown; each on-street segment is displaying its highest (i.e., worst) LTS value in Figure 13 rather than directional LTS values.

NEXT STEPS

After City review and associated revisions to the results, these on-street and path LTS results will be carried forward to inform subsequent Task 3 latent demand analysis and Task 4 network prioritization processes.

MAP RESULTS

On-Street LTS Maps

Figure 1a: Existing Dedicated Bicycle Facilities (On-Street)

Figure 1b: Existing Dedicated Bicycle Facilities (Off-Street)

Figure 1c: Existing Dedicated Bicycle Facilities (Combined)

Figure 2: Presence of Parking Adjacent to Bike Lanes

Figure 3: Number of Vehicle Lanes

Figure 4: Speed Limits

Figure 5: Average Daily Traffic (ADT)

Figure 6: Roadway Functional Classifications

Figure 7: Level of Traffic Stress

Figure 8: Level of Traffic Stress (Low-Stress Facilities)

Class I Path LTS Maps

Figure 9: Existing Path Widths

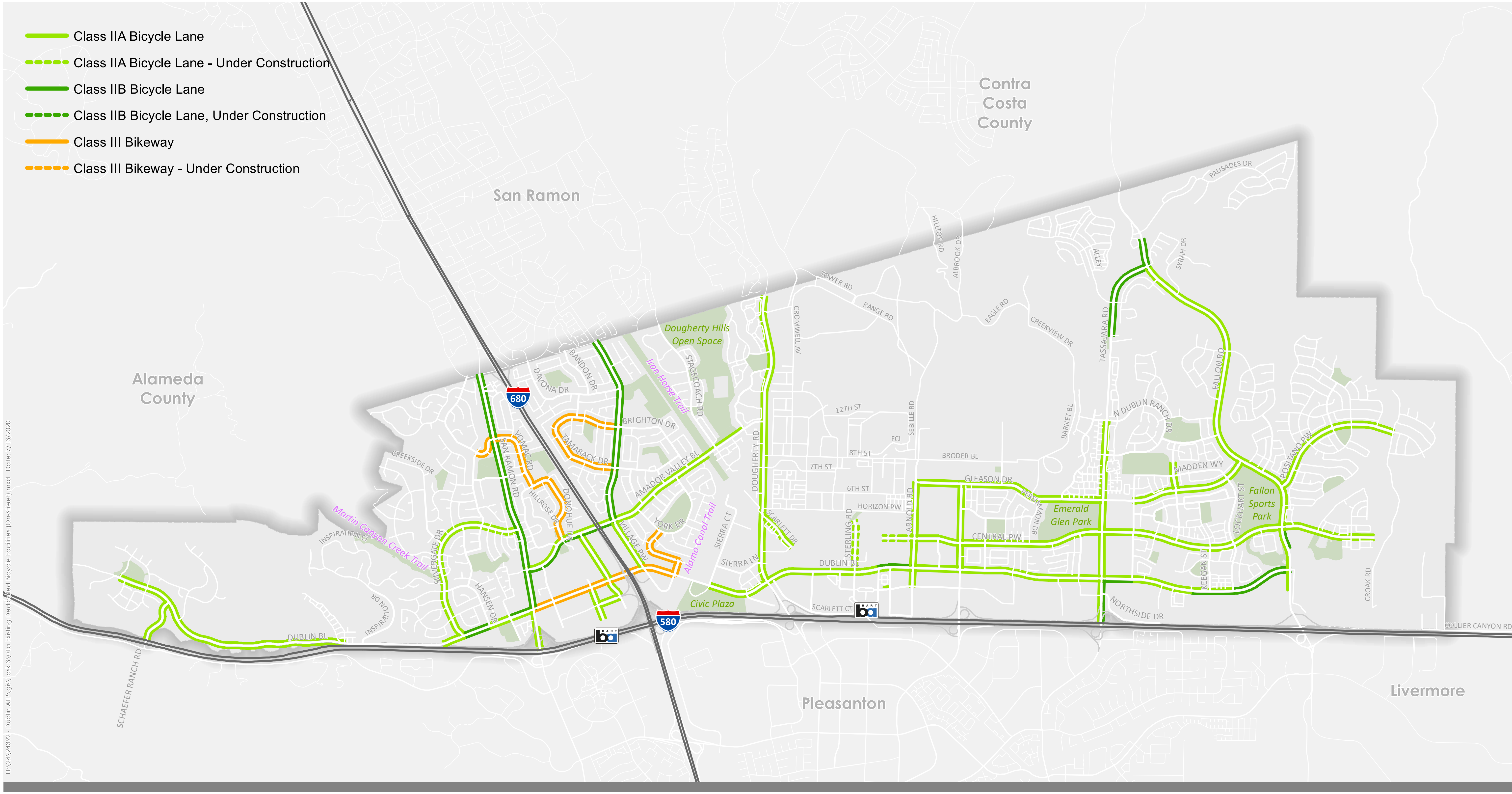
Figure 10: Existing Shoulder and Roadway Separation/Buffer

Figure 11: Existing Path Wayfinding

Figure 12: Path LTS (Segment and Intersection)

Combined

Figure 13: On-Street and Path LTS



DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

Figure 1a

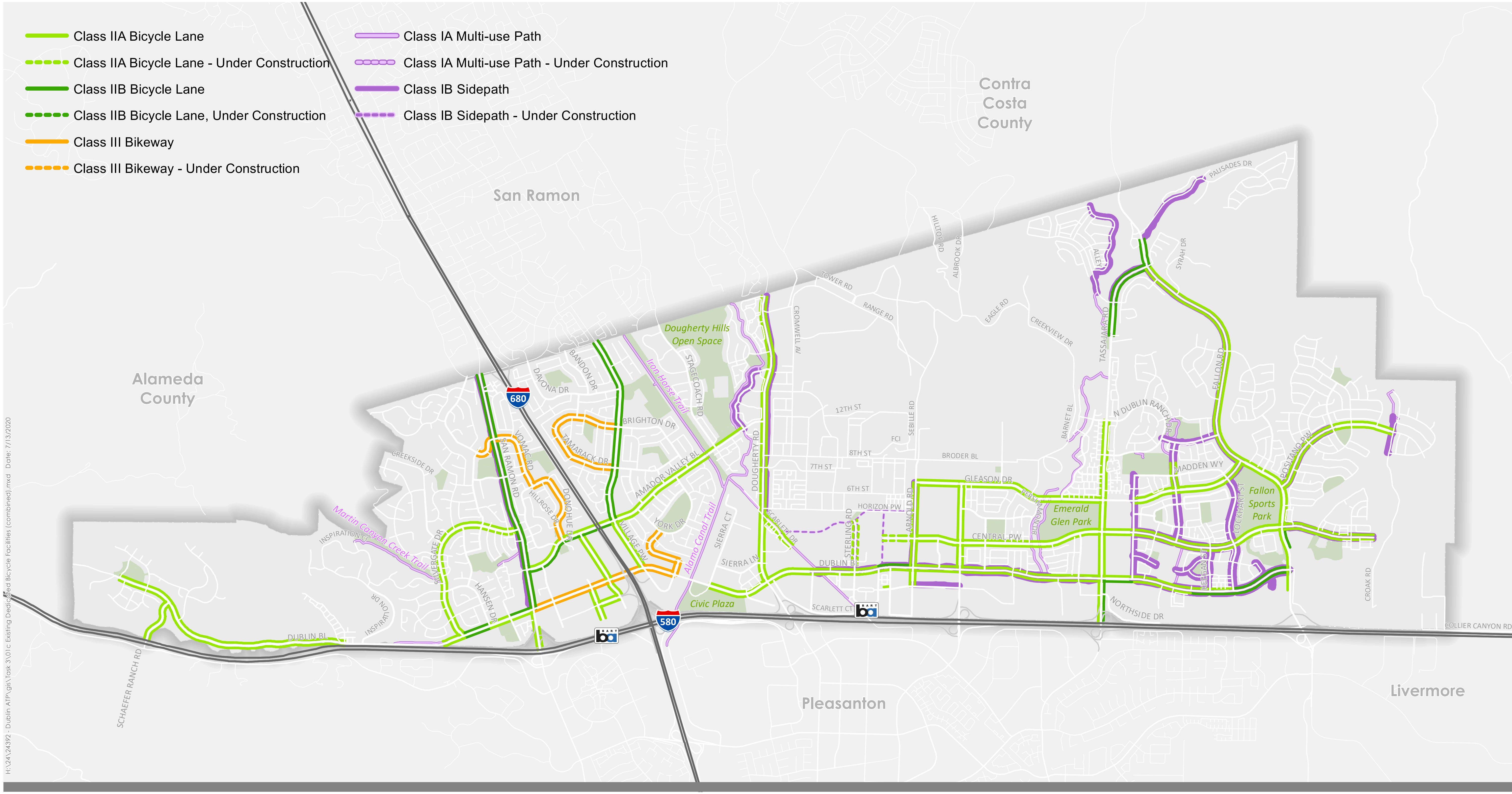
Existing Dedicated Bicycle Facilities (On-Street)
Dublin, California

Figure 1b

Existing Dedicated Bicycle Facilities (Off-Street)
Dublin, California

DUBLIN
CALIFORNIA

KITTELSON & ASSOCIATES



H:\24\24392 - Dublin ATP\gis\Task 3\01c Existing Dedicated Bicycle Facilities (combined).mxd Date: 7/13/2020

DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

Figure 1c

Existing Dedicated Bicycle Facilities (Combined)
Dublin, California

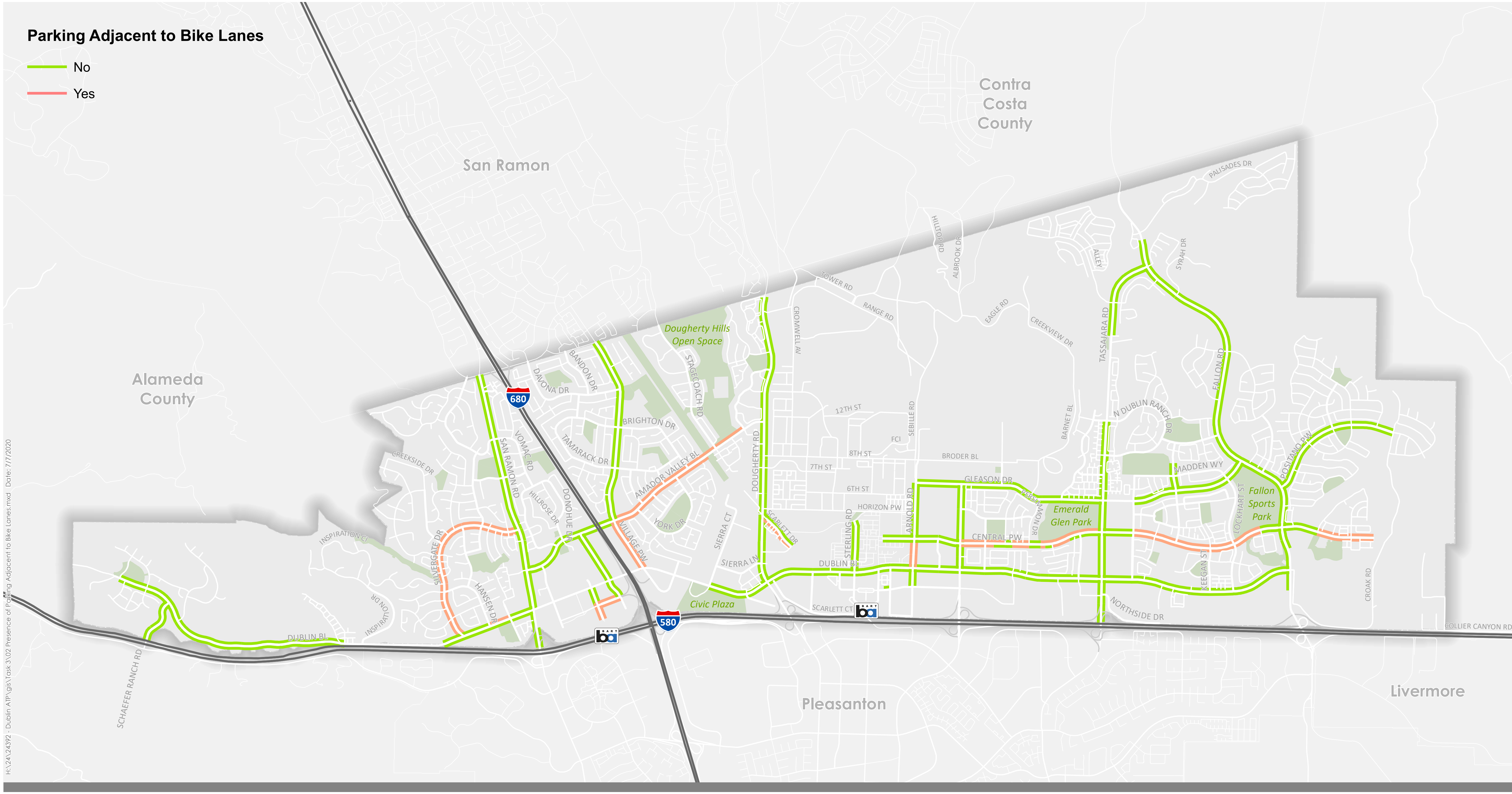


Figure 2

Presence of Parking Adjacent to Bike Lanes
Dublin, California

DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

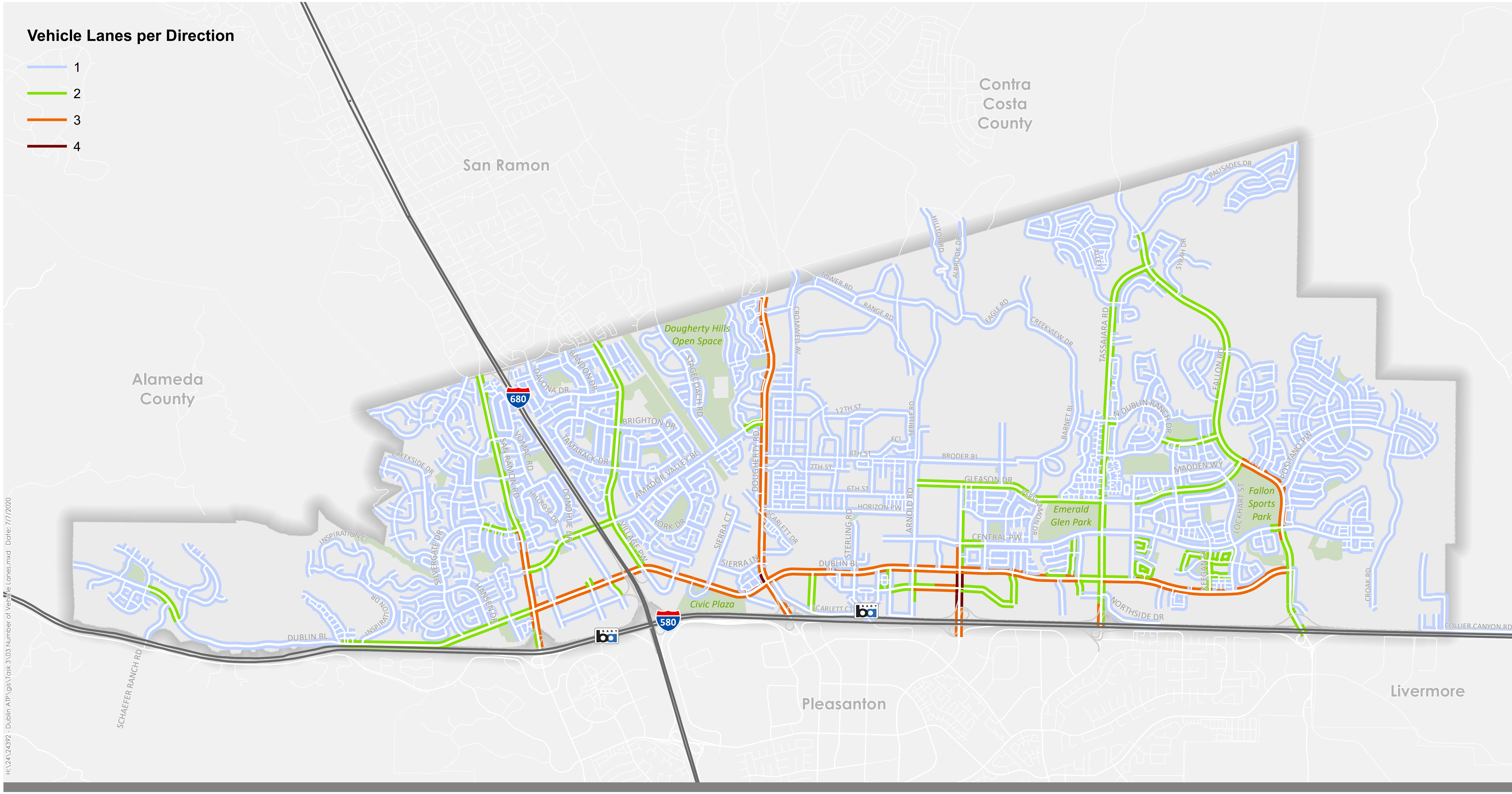


Figure 3

Number of Vehicle Lanes
Dublin, California

DUBLIN
CALIFORNIA

KITTELSON & ASSOCIATES

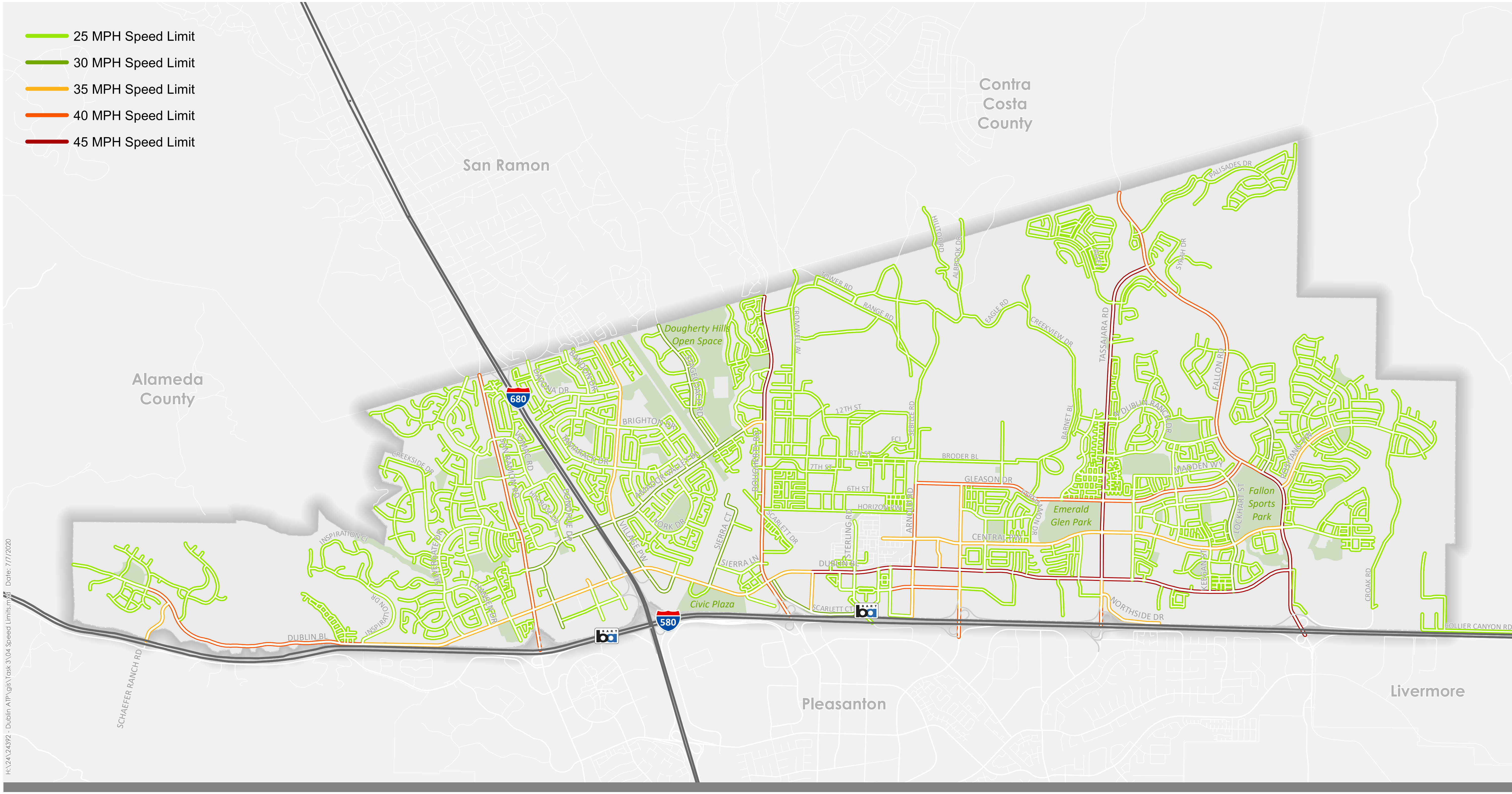
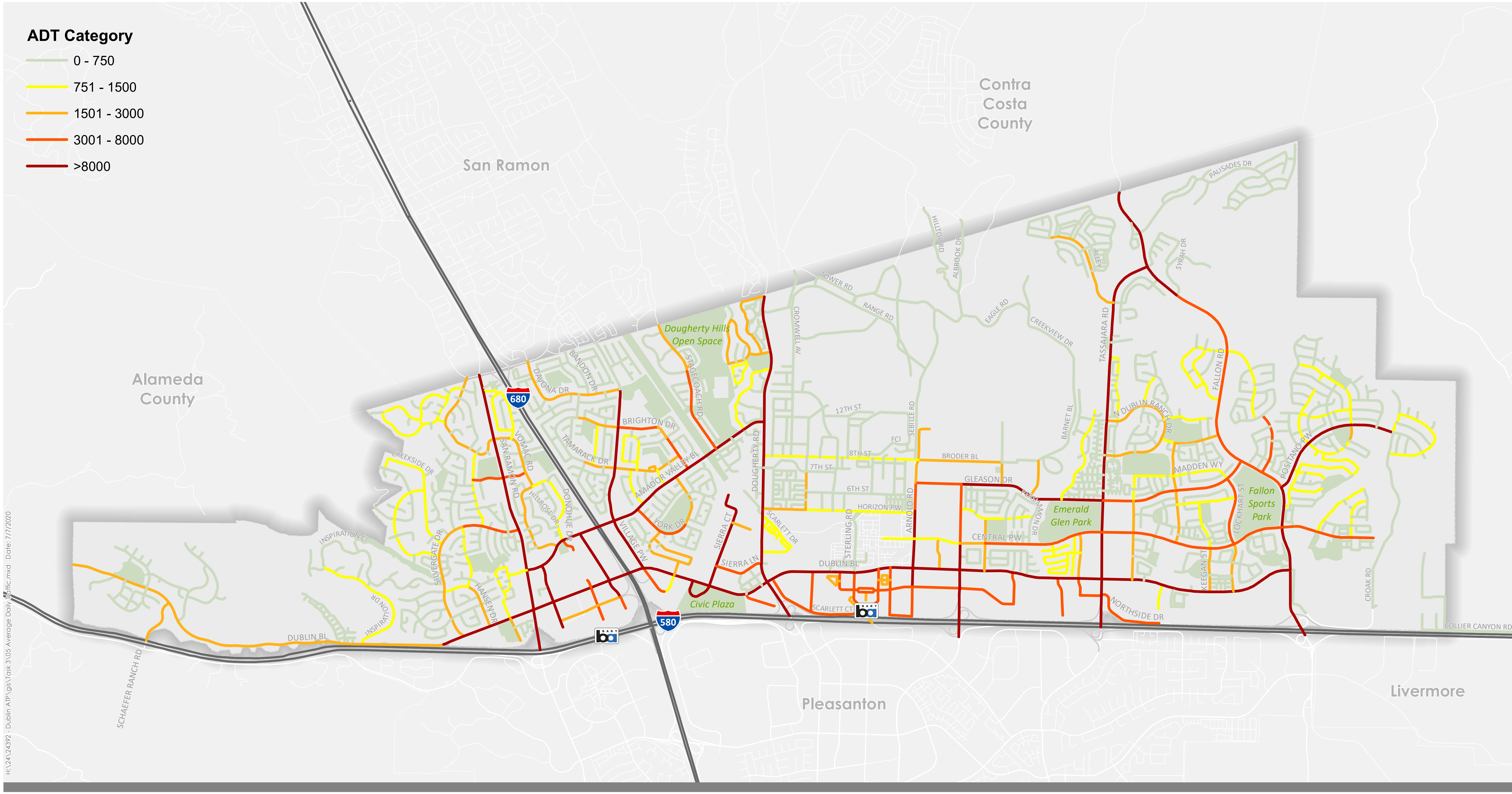


Figure 4

Speed Limits
Dublin, California



DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

Figure 5

Average Daily Traffic (ADT)
Dublin, California

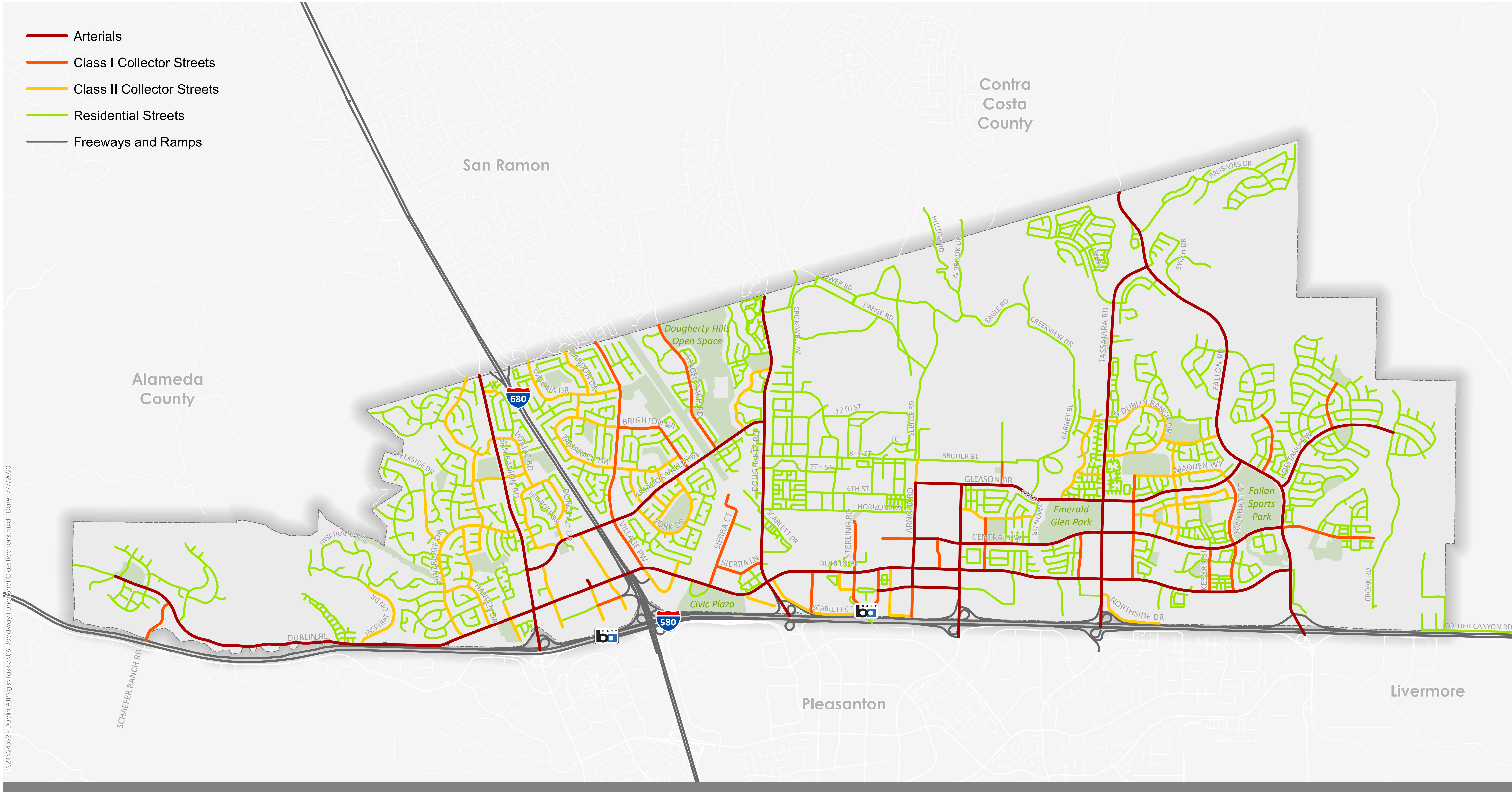


Figure 6

Roadway Functional Classifications
Dublin, California

DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

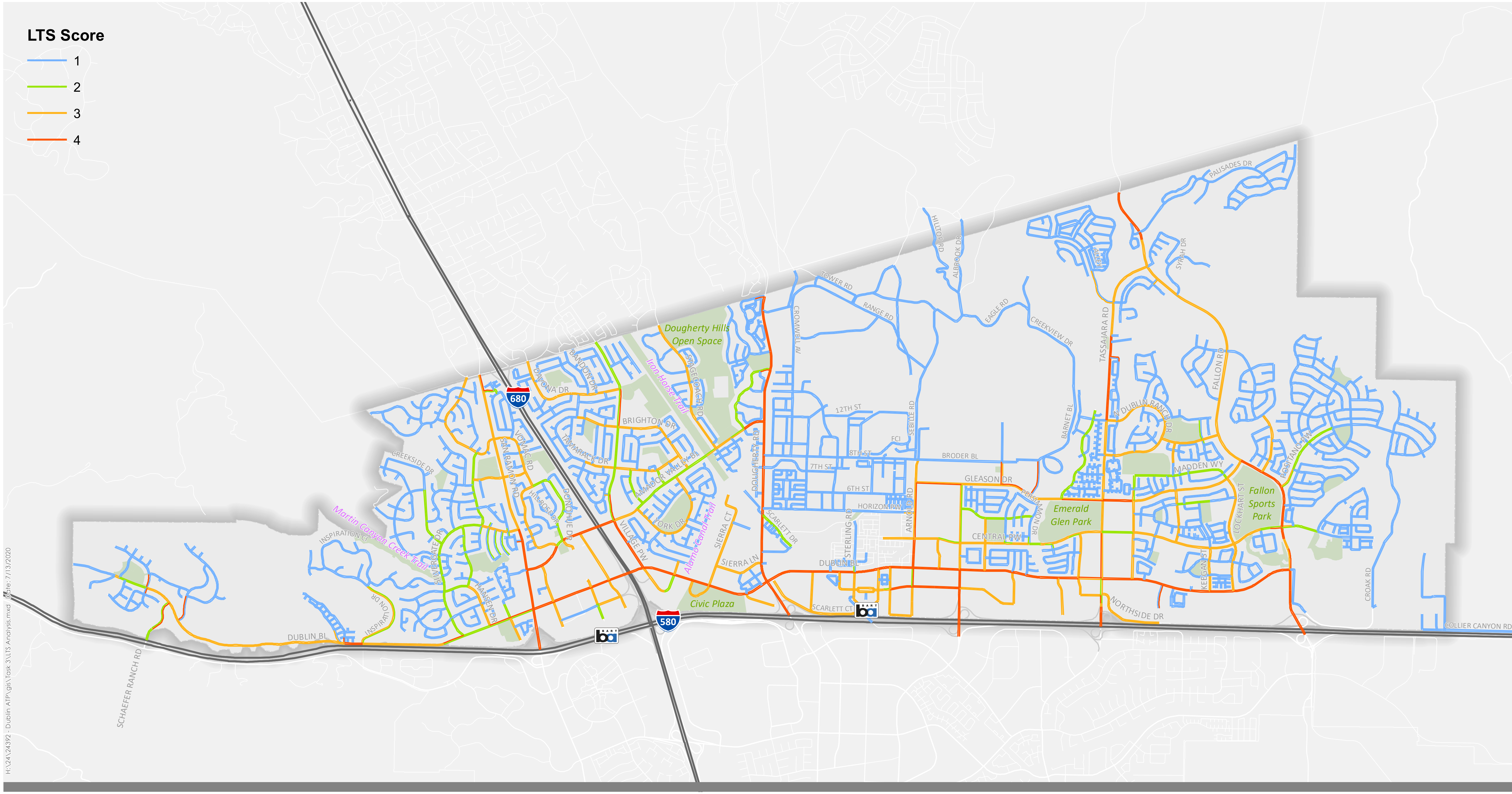


Figure 7

Level of Traffic Stress
Dublin, California

DUBLIN
CALIFORNIA

KITTELSON & ASSOCIATES

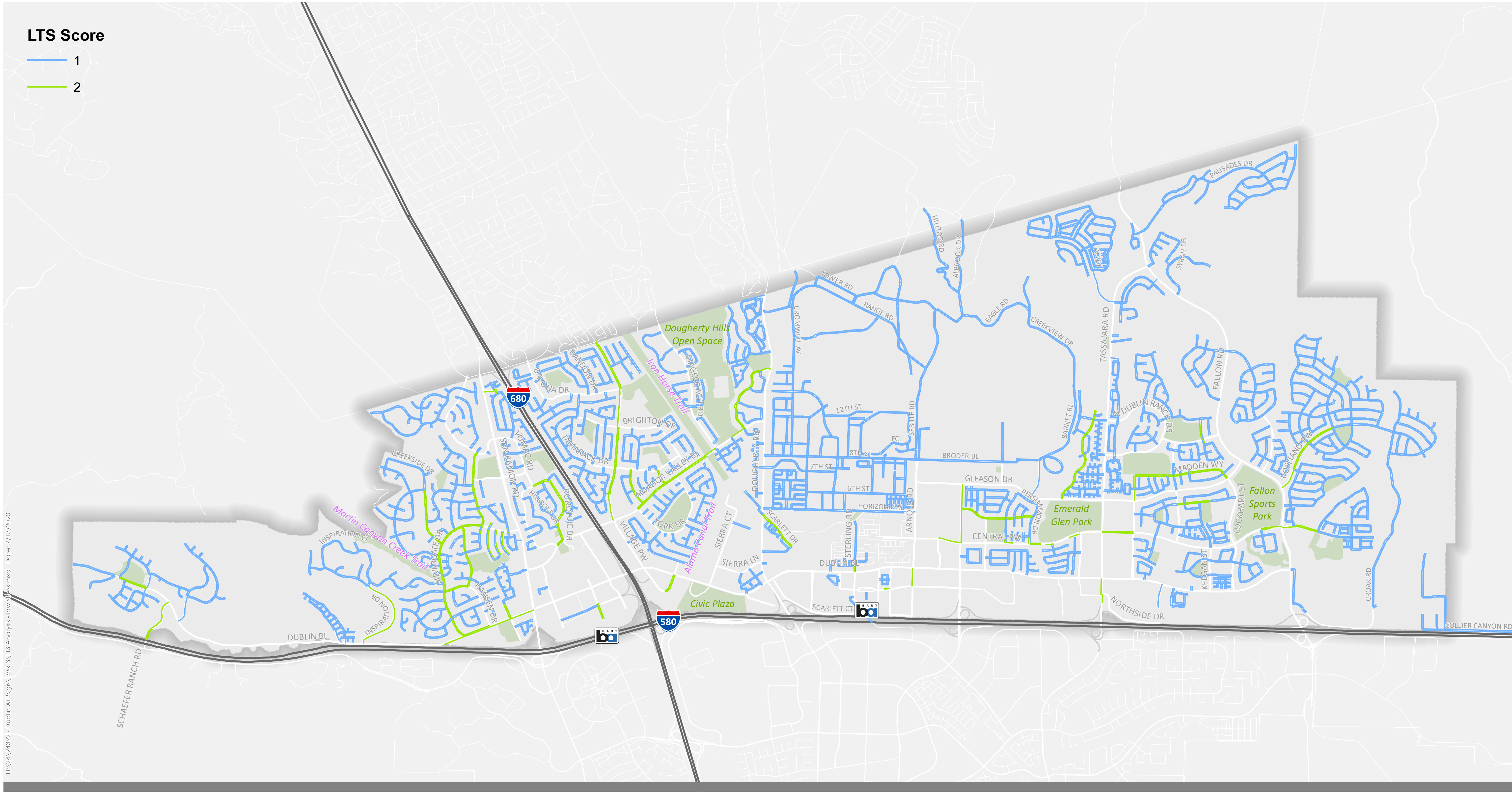
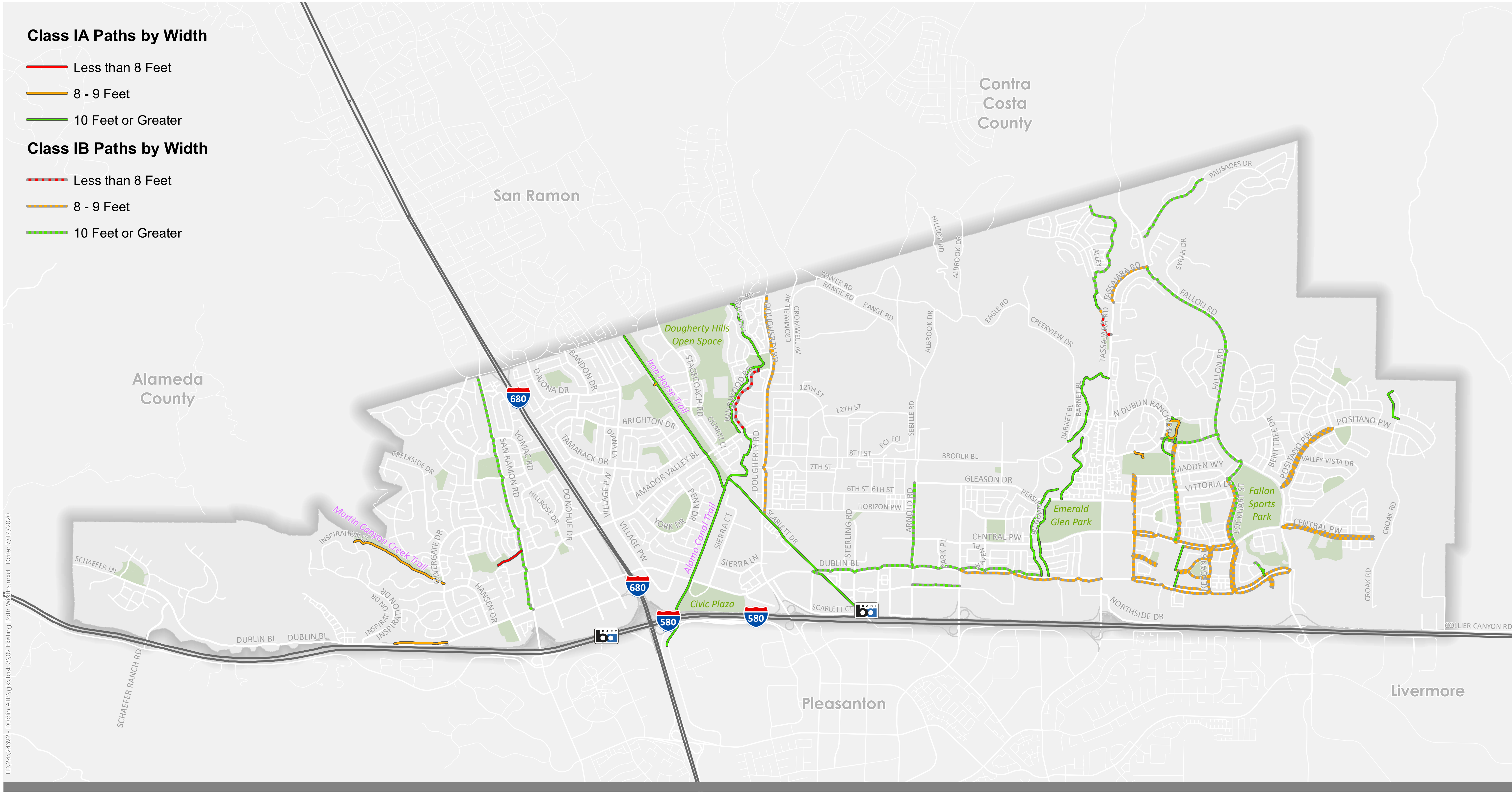


Figure 8

Level of Traffic Stress - Low Stress Facilities
Dublin, California

DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES



DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

Figure 9

Existing Path Widths
Dublin, California

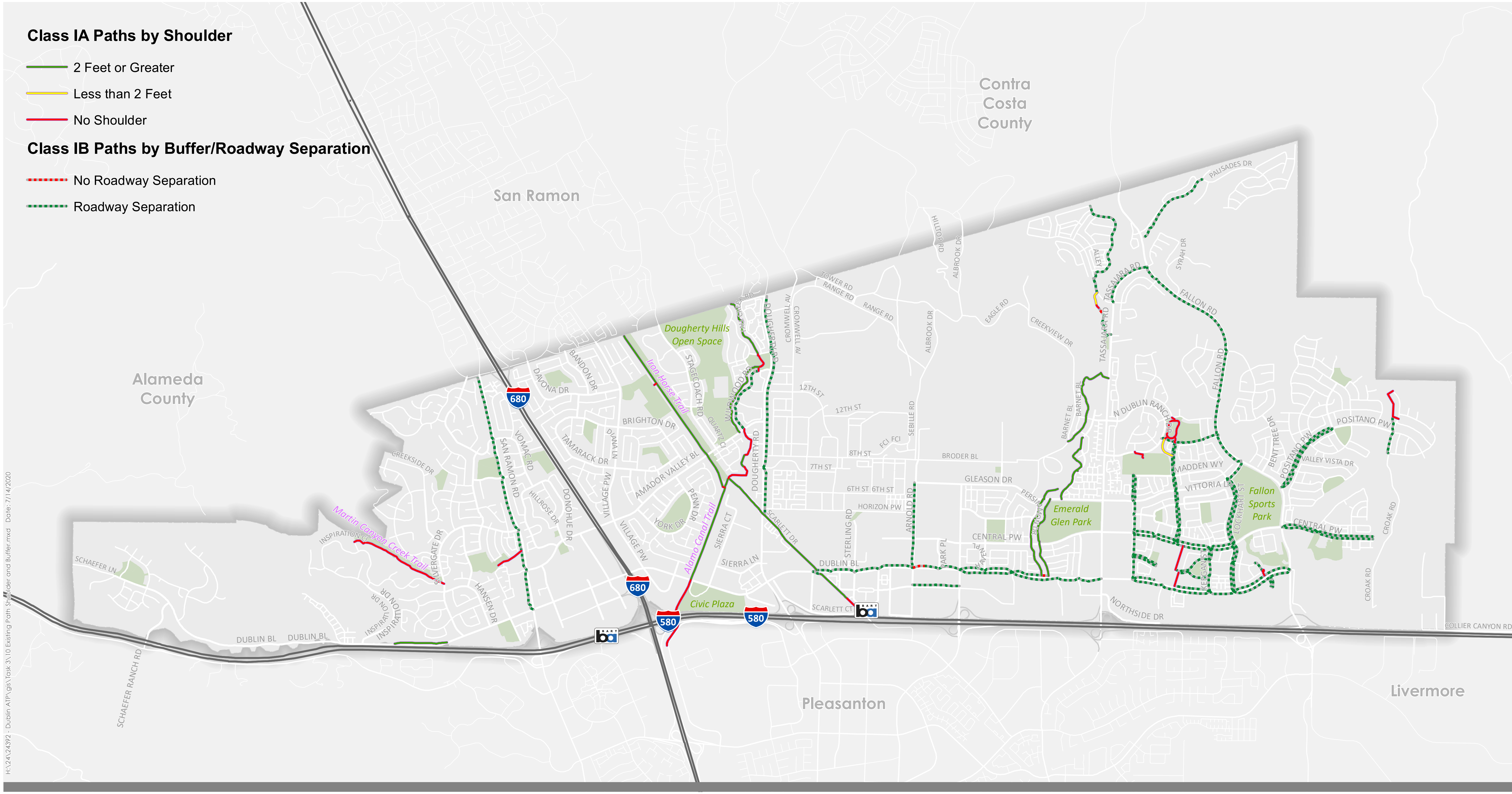
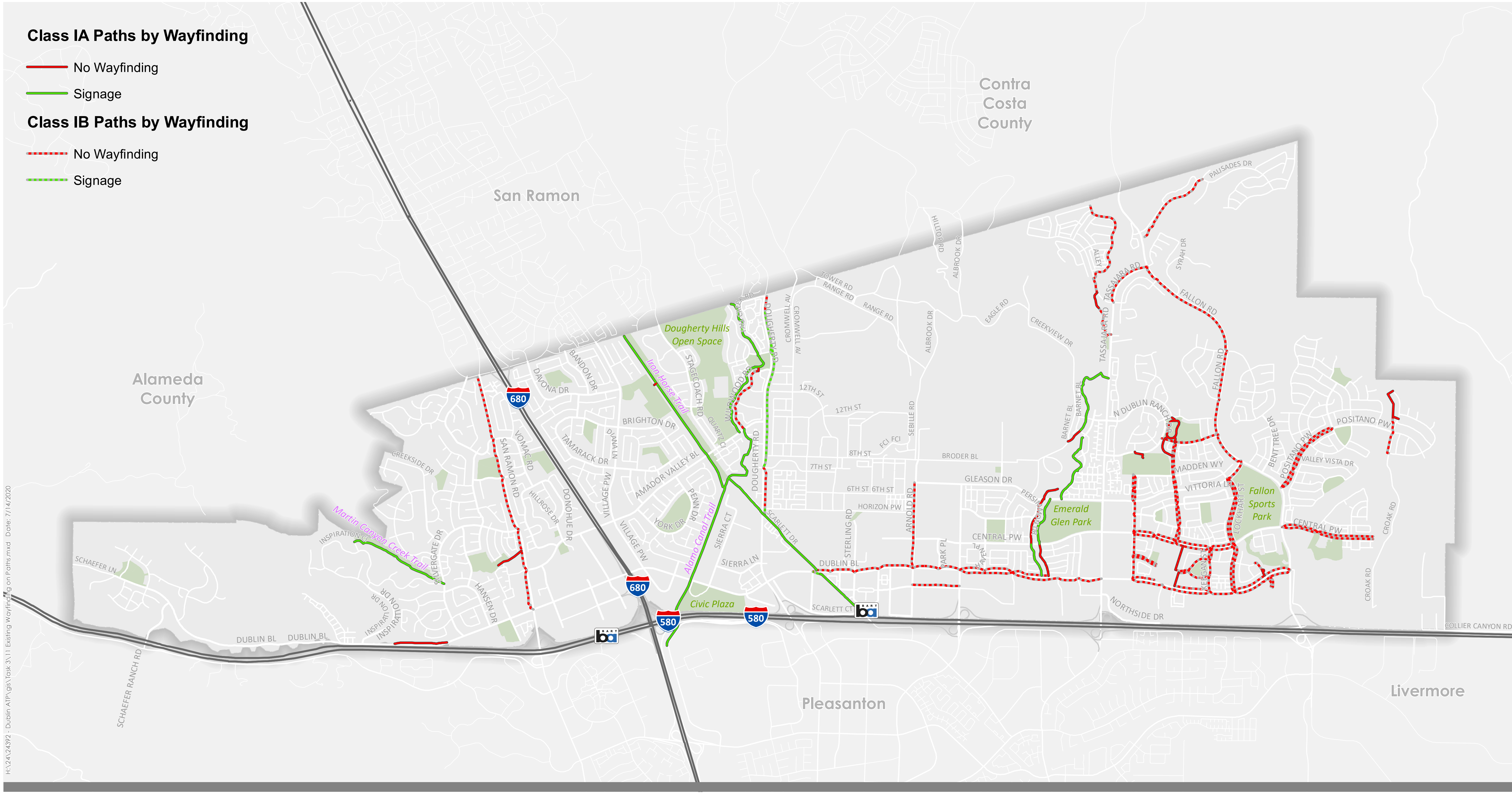


Figure 10

Path Shoulder and Buffer/Roadway Separation Presence
Dublin, California

DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES



H:\24\24392 - Dublin ATP\gis\Task 3\11 Existing Wayfinding on Paths.mxd Date: 7/14/2020

DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

Figure 11

Existing Wayfinding on Paths
Dublin, California

Figure 12

Path LTS - Segment and Crossing
Dublin, California

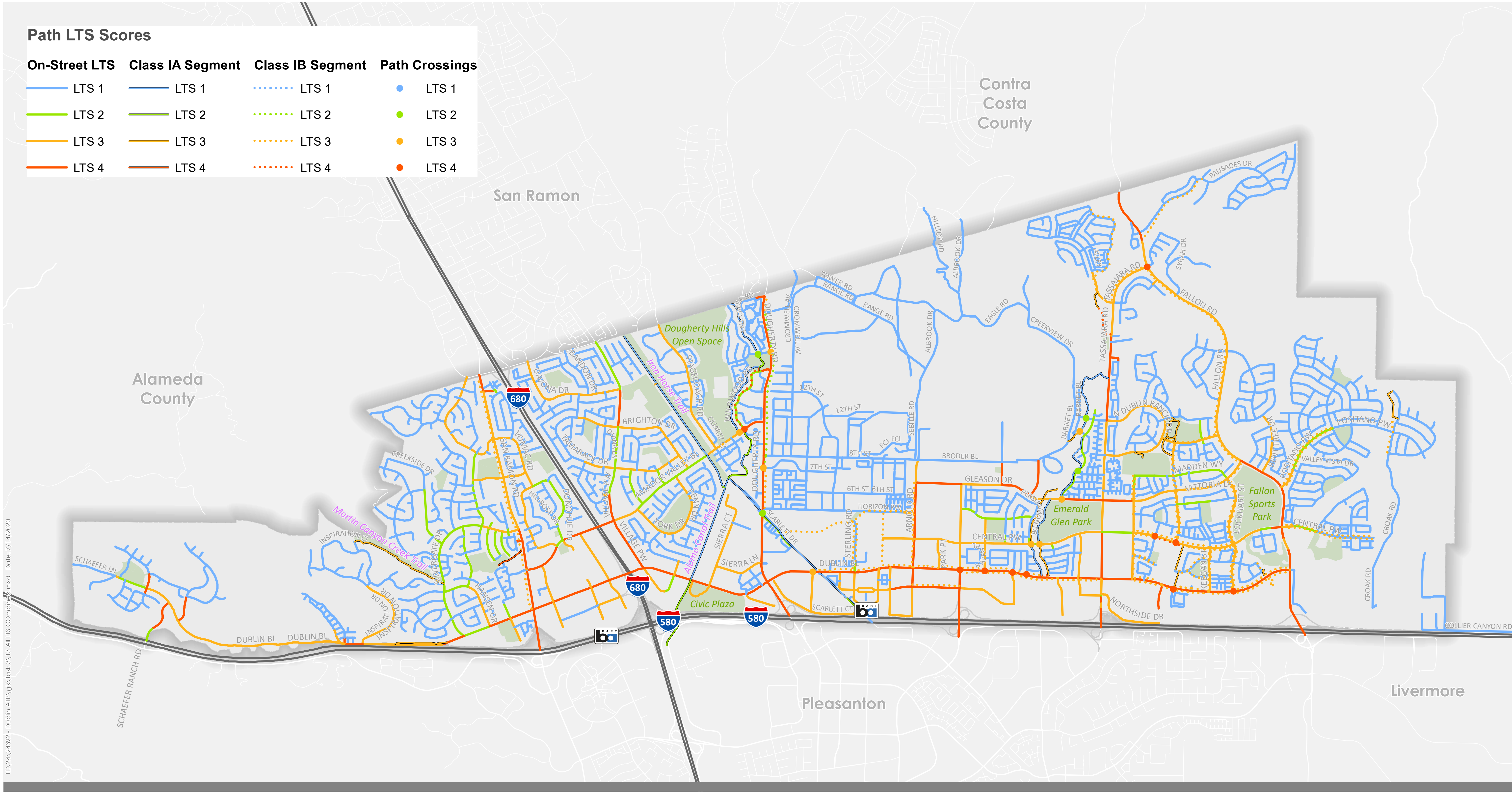


Figure 13

DUBLIN CALIFORNIA

KITTELSON & ASSOCIATES

On-Street and Path LTS
Dublin, California

ATTACHMENT A: CLASS I PATH LTS MEMORANDUM

KITTELSON & ASSOCIATES
155 GRAND AVENUE, SUITE 900
OAKLAND, CA 94612
P 510.839.1742 F 510.839.0871

MEMORANDUM

Date:	July 14, 2020	Project #: 24392
To:	Sai Midididdi, TE City of Dublin	
From:	Mike Alston, RSP; Amanda Leahy, AICP; & Michael Sahimi, AICP	
Project:	Dublin Bicycle and Pedestrian Master Plan	
Subject:	Class I Path LTS Methodology	

INTRODUCTION

The following memorandum presents a methodology for evaluating a level of stress along the City of Dublin's (City's) Class I path network. The City has an extensive network of designated Class I paths, provided as an alternative to on-street facilities, that vary in width, intersection treatments, and other features. In order to identify whether adequate service quality is provided on this network, these paths will be evaluated alongside the on-street level of traffic stress (LTS) methodology. The custom methodology, referred to as path LTS, will include four levels comparable to the typical level of traffic stress methodology:

- LTS 1: Requires little attention to surroundings; suitable for most children
- LTS 2: Low traffic stress; suitable for most adults
- LTS 3: Moderate traffic stress for all bicyclists
- LTS 4: High stress; only suitable for experienced bicyclists.

The City's Class I network consists of two relevant facility types:
- **Class IA Paths:** Multiuse paths along a separate alignment. Examples include the Iron Horse Trail and the Martin Creek Trail.
- **Class IB Sidepaths:** Sidepaths along the side of a roadway, which double as sidewalks. Examples include segments along the north side of Dublin Boulevard or the west side of San Ramon Road.

The 2012 Bicycle Master Plan did not subclassify Class I paths, but the distinction is necessary to evaluate the quality of service they provide. There are distinct elements of each (e.g., buffer between Class IB sidepaths and the roadway) that determine to the quality of service provided, so they are accounted for separately for this analysis. We will account for these elements to score Class IA and IB paths within the City of Dublin on a 1 to 4 path LTS rubric alongside the on-street LTS analysis. Note that all of the Class I facilities within the City are multiuse paths (i.e., serve bicyclists and pedestrians), given that they are either off-street connections or provided along the roadside such as the only off-street accommodation. Elements of the evaluation include the following:

- Segment characteristics
  - Width
  - Path shoulder and roadway separation/buffer
  - Wayfinding and path indication
- Intersection/crossing elements
  - Control strategy and crossing distance
  - Signal treatments
  - Horizontal or vertical geometric treatments
  - Marking and signs

Segments are defined as homogenous connections between street crossings: when any of the segment input characteristics along a Class I path change, the resulting segments will be split and evaluated separately for the resulting homogeneous components. Appendix A provides an inventory of Class I facilities including their widths.

SEGMENT CHARACTERISTICS

Width

The Class I paths within the City are intended to serve two-way bicycle travel. The width requirements to allow for two-way bicycle travel are greater than for one-way bicycle travel. Additionally, the HDM recommends that "Development of a one-way bike path should be undertaken only in rare situations where there is a need for only one direction of travel."

- The Caltrans *Highway Design Manual* cites a minimum paved width of 8 feet for two-way bicycle travel, with 10 feet preferred. (Section 1003.1 (1)(a))
- For locations with "heavy bicycle volumes … and/or significant pedestrian traffic … expected," the HDM states that the path "should be" greater than 10 feet wide (preferably 12 feet). (Section 1003.1 (1)(a))
- Class IA multiuse paths would expect less significant pedestrian traffic than Class IB sidepaths would because Class IB sidepaths typically also serve the purpose of a sidewalk.
- According to the FHWA *Bikeway Selection Guide*, "Conflicts between path users are a primary source of injuries and can result in a degraded experience for all users where paths are not wide enough to handle the mixture and volume of diverse users."[1]

[1] The FHWA *Bikeway Selection Guide* is available online at https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18077.pdf.

- The MassDOT *Separated Bicycle Lane Planning & Design Guide* provides guidance for separated bike lanes; it allows for a minimum of 8 feet (10 feet recommended) of width for bidirectional separated bike lanes to allow for two-way bicycle travel with fewer than 150 bidirectional bicyclists per hour. This does not account for pedestrian use.[2]

Width as a criteria for path LTS is combined with shoulder and roadway separation/barrier. See below and refer to Table 1.

Path Shoulder and Roadway Separation/Buffer

Shoulder:

Per Section 1003.1(1)(b), The HDM requires a minimum 2-foot-wide shoulder for Class I bike paths to serve as a recovery zone and to reduce conflicts with pedestrians. The shoulder should be composed of the same material as the path or should at least be free of vegetation: "adequate clearance from fixed objects is needed regardless of the paved width."

Roadway Buffer:

Per Section 1003.1(7), the HDM recommends one of the following forms of separation for paths adjacent to the traveled way:

- A minimum separation between the edge of pavement of a bicycle path and the edge of traveled way: at least 5 feet plus shoulder widths.
- For separation less than 10 feet, landscaping or other features that form a continuous barrier should be provided.

Landscaping buffers form an adequate continuous barrier along most Class IB sidepaths in the City.

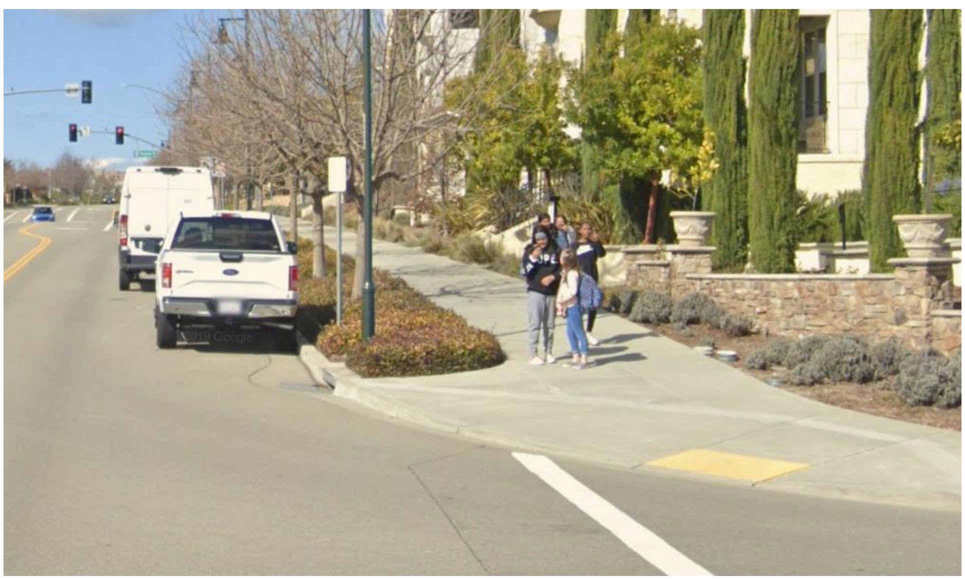
[2] Although this guidance is written for the Massachusetts Department of Transportation, it is recognized as relevant best practice guidance. It is available online at https://www.mass.gov/lists/separated-bike-lane-planning-design-guide.

Table 1: Path LTS Score based on Width/Buffer/Shoulder

Path LTS Score	Class IA Multiuse Path		Class IB Sidepath	
	Path width 8 ft ≤ x < 10 ft	Path Width ≥10 ft	Path Width 8 ft ≤ x < 10 ft	Path Width ≥10 ft
LTS 1	≥2 ft shoulder provided	Shoulder provided (any width)	n/a	Roadway buffer provided (continuous barrier or 10 ft separation)
LTS 2	<2 ft shoulder provided	No shoulder provided	Roadway buffer provided (continuous barrier or 10 ft separation)	n/a
LTS 3	No shoulder provided	n/a	n/a	No roadway buffer provided
LTS 4	n/a	n/a	No roadway buffer provided	n/a

Source: Kittelson & Associates, Inc.

Figure 1: Example Class IB sidepath along the east side of Brannigan Street south of Gleason Drive. The path is between 8 and 10 feet wide and continuous separation from the roadway is provided by landscaping. The path would be eligible for LTS 2 based on the width/buffer/shoulder criterion.



Source: Google Earth

Wayfinding and Path Indication

Designated path segments should be clearly marked as such, especially including Class IB sidepaths given that they double as sidewalks. The Caltrans HDM states the following regarding mixing bicyclists and pedestrians:

> Sidewalks are not to be designated for bicycle travel. Wide sidewalks that do not meet design standards for bicycle paths or bicycle routes also may not meet the safety and mobility needs of bicyclists. Wide sidewalks can encourage higher speed bicycle use and can increase the potential for conflicts with turning traffic at intersections as well as with pedestrians and fixed objects. In residential areas, sidewalk riding by young children too inexperienced to ride in the street is common. It is inappropriate to sign these facilities as bikeways because it may lead bicyclists to think it is designed to meet their safety and mobility needs. Bicyclists should not be encouraged (through signing) to ride their bicycles on facilities that are not designed to accommodate bicycle travel. - Section 1003.3(2)

Sidewalks are thus discouraged from designation as bicycle paths. However, provided that the other criteria can be met to provide for comfortable travel (i.e., the path is "designed to meet their safety and mobility needs"), pavement or signage indications of the facility should give pedestrians an expectation that they may encounter bicyclists (and vice versa). All users should be informed that the segment is in fact designated for use as a path and not a sidewalk. Signage and wayfinding alone are therefore necessary but not sufficient to provide a low-stress path facility. This is consistent with the "weakest link" approach for path LTS evaluation. Wayfinding alone will not lower an otherwise high path LTS score but it can degrade the score of an otherwise low path LTS score facility.

Table 2: Path LTS Score based on Segment Wayfinding/Indication

Path LTS Score	Class IA Multiuse Path or Class IB Sidepath
LTS 1	Pavement markings (see Figure 2) and wayfinding signage along trail
LTS 2	Wayfinding signage along path
LTS 3	None provided
LTS 4	n/a

Source: Kittelson & Associates, Inc.

Figure 2: Example pavement markings delineating road user space along a path in San Francisco, CA and (left) and indicating status as shared-use in Emeryville, CA (right)

Source: Flickr (left) and Kittelson & Associates, Inc. (right)

INTERSECTION/CROSSING ELEMENTS

Paths are reintroduced to motor vehicle conflicts at crossings, which can be a significant source of stress. Class IA and IB paths will be treated uniformly at intersections/crossings. According to the FHWA *Bikeway Selection Guide* (Guide), "Care should be taken at intersections and driveways … Crash patterns consistently show contra-flow movement of bicyclists are a main factor in crashes due to motorists failing to yield or look for approaching bicyclists." The Guide suggests the following to mitigate these conflicts:

- Application of separate phases at signals
- Reduced corner radii or raised crossings to slow drivers
- Improved sight lines
- Marked crossings and regulatory signs to improve driver awareness

The HDM cites two particular design elements for attention at crossings (1003.1(5)):

- Crossing control: Grade separation is desirable, followed by signalization. Where traffic is "not heavy," STOP or YIELD signs may be used for the path or for the cross street.
- Crossing location: "When crossing an arterial street, the crossing should either occur at the pedestrian crossing, where vehicles can be expected to stop, or at a location completely out of the influence of any intersection to permit adequate opportunity for bicyclists to see turning vehicles….Even when crossing within or adjacent to the pedestrian crossing, "STOP" or "YIELD" signs for bicyclists should be placed to minimize potential for conflict resulting from turning autos….In some cases, Bike Xing signs may be placed in advance of the crossing to alert motorists."

Based on these sources, the three elements to be incorporated in the Class I Path LTS will include:

- Control, geometry, and crossing distance
- Markings and signs
- Horizontal or vertical treatments

Because crossings at intersections deal with turning traffic but perpendicular trail crossings do not, separate criteria are appropriate for each, termed *intersection crossings* and *perpendicular crossings*.

Figure 3: Intersection Class IB Sidepath Crossing along Lockhart Street at Central Parkway (left) and Class IA Perpendicular Crossing along Tassajara Creek Trail at Central Parkway (right).

Source: Google

Control, Geometry, and Crossing Distance

Depending on the characteristics of the crossing, different control strategies and geometric design characteristics may be appropriate.

Intersection Crossings

Intersection crossings require path users to interact with turning vehicles and conflict points from all intersection approach legs. Because of this, crossing control and geometry can be used to affect conflicts in time (e.g., separate control phases) and space (e.g., separation or driver deflection).

Consistent with the recommendations in the FHWA *Bikeway Selection Guide*, physical design elements that slow drivers, enhance visibility, or both, can enhance a path's service quality. The following elements are included that would greatly improve the bicyclist' experience at crossings:

- A "bend-out" design (see Figure 4) or a protected intersection-style corner safety island that offsets the crossing from vehicle turning movements (only applicable at intersections). . Although this design treatment is most applicable to a Class II or Class IV bicycle lane, the separation benefit applies for intersection or driveway crossings along a Class IB sidepath.
- A bulb-out which reduces the curb return radius and turning movement speeds. This treatment is most effective when the lane geometry of the turning and receiving roadways force a driver to adhere to the reduced radius.
- A raised crossing, which includes vertical deflection and reduces driver speeds.
- A right-turn pocket or channelized vehicle turn lane with sufficient sight distance and geometry to encourage a comfortable provide a path crossing. The dedicated right-turn pocket or lane provides drivers the opportunity to yield without through traffic behind them.
- Signal phasing solutions including a separated bicycle signal phase or a leading pedestrian interval/leading bicycle interval, which provide separation in time between motor vehicles and path users.

Figure 4: "Bend Out" concept that pulls a bicycle crossing back from the curb to improve visibility to drivers

In applying this criterion, the geometric treatments are referred to as *horizontal or vertical treatments* and may be considered interchangeably.

Intersection Applicability

The criterion presented in Table 3 applies to path crossings either at a signalized intersection or along an uncontrolled roadway at an unsignalized crossing (i.e., the major street). For Class IB sidepaths crossing alongside a stop-controlled intersection, the criteria in Table 4 apply.

Table 3: Intersection Crossing LTS Score based on Control Strategy and Crossing Distance

Path LTS Score	Control Strategy and Crossing Distance			
	2-lane total cross-section (both roadways)		>2-lane cross-section (Either roadway)	
	Signalized Intersection	Unsignalized Intersection	Signalized Intersection	Unsignalized Intersection
LTS 1	Leading bicycle interval, separated signal phase, or horizontal/vertical elements	All-way Stop Control, parallel speed ≤ 25 mph	Separated bicycle signal phase	n/a
LTS 2	Parallel speeds <40 mph	All-way Stop Control, parallel speed > 25 mph; *OR* Parallel speeds ≤ 25 mph or with vertical/horizontal elements	Leading bicycle interval or horizontal/vertical elements	All-way Stop Control; *OR* Parallel speeds ≤25 mph or with vertical/horizontal elements
LTS 3	Parallel speeds ≥40 mph	Parallel speeds <40 mph	Parallel speeds <40 mph	Parallel speeds <40 mph
LTS 4	n/a	Parallel speeds ≥40 mph	Parallel speeds ≥40 mph	Parallel speeds ≥40 mph

Source: Kittelson & Associates, Inc.

Perpendicular Crossings

As discussed above, the control strategy appropriate for perpendicular crossings depends on the characteristics of the road being crossed: speed, volume, and crossing distance. For a simplified approach, the number of lanes provides a measure of crossing distance and a proxy for vehicle volume.

Table 4: Perpendicular Crossing LTS Score based on Control Strategy and Crossing Distance

Path LTS Score	Perpendicular Crossing Control Strategy and Crossing Distance	
	2-lane total cross-section	>2-lane cross-section
LTS 1	RRFB, PHB, or signal control; *OR* Raised crossing with yield control	Signal control
LTS 2	Stop or yield control, Cross street speed < 40 mph	RRFB, PHB *OR* Stop or yield control; cross street ≤ 25 mph
LTS 3	Stop or yield control; Cross street speed ≥ 40 mph	Stop or yield control; cross street speed > 25 mph
LTS 4	n/a	Stop or yield control; cross street speed ≥ 40 mph

Source: Kittelson & Associates, Inc.

Markings and Signs

This criterion only applies for intersection crossings, where drivers may not be expecting two-way or same-direction Class IB sidepath bicycle travel as they approach a crossing. (This includes all crossings at unsignalized intersections.) Thus, indication of a path crossing is helpful to reduce the stress of a facility. As previously described, the HDM (Section 1003.1(5)) recommends that crossing signs may be placed in advance of a crossing to alert motorists. Example signs include the combination of the MUTCD W11-15 and W11-15P signs, depicted in Figure 5, and described in Section 9B.18 of the California MUTCD. Figure 5 also depicts crossing markings already applied at various intersection crossings in the City.

Figure 5: W11-15 (left), Supplementary W11-15P (middle), and Path Pavement Markings in Dublin (right)

Source: CA-MUTCD; Google

Table 5: LTS Score based on Markings and Signage

Path LTS Score	Markings and Signage
LTS 1	Signage **and** pavement markings indicating path crossing
LTS 2	Signage **or** pavement markings indicating path crossing
LTS 3	No signage or pavement markings indicating a path crossing
LTS 4	n/a

Source: Kittelson & Associates, Inc.

Table 6: Combined Path LTS Criteria. Methodology observes a "weakest link" application whereby the highest score for any single criterion governs the overall path LTS score.

Criteria				LTS 1	LTS 2	LTS 3	LTS 4
Segment							
Class IA	Width / Buffer / Shoulder	Path Width: 8 ft ≤ x <10 ft		≥2 ft shoulder provided	<2 ft shoulder provided	No shoulder provided	n/a
		Path Width: ≥10 ft		Shoulder provided (any width)	No Shoulder provided	n/a	n/a
	Wayfinding / Indication			Pavement markings (see Figure 2); Wayfinding signage along path	Wayfinding signage along path	None provided	n/a
Class IB	Width / Buffer	8 ft ≤ x <10 ft		n/a	Roadway buffer provided (continuous barrier or 10 ft separation)[1]	n/a	No separation provided
		≥10 ft		Roadway buffer provided (continuous barrier or 10 ft separation)[1]	n/a	No separation provided	n/a
	Wayfinding / Indication			Pavement markings designating space for path users (see Figure 2); Wayfinding signage	Wayfinding signage along path	None provided	n/a
Crossing							
Intersection Crossing	Control, Geometry, Crossing Distance	2-lane Total Cross-Section (both roadways)	Signalized	Leading bicycle interval, separated bicycle signal phase, or horizontal/vertical elements	Parallel speeds <40 mph	Parallel speeds ≥40 mph	n/a
			Unsignalized	All-way stop control, parallel speeds ≤25 mph	All-way stop control, parallel speeds >25 mph *OR* Parallel speeds ≤25 mph or with vertical/horizontal elements	Parallel speeds <40 mph	Parallel speeds ≥40 mph
		>2-lane Total Cross Section (either roadway)	Signalized	Separated bicycle signal phase	Leading bicycle interval or horizontal/vertical elements	Parallel speeds <40 mph	Parallel speeds ≥40 mph
			Unsignalized	n/a	All-way stop control *OR* Parallel speeds ≤25 mph or vertical/horizontal elements	Parallel speeds <40 mph	Parallel speeds ≥40 mph
	Markings / Signs*			Signage **and** pavement markings indicating path crossing*	Signage **or** pavement markings indicating path crossing*	No signage or pavement markings indicating a path crossing*	n/a
Perpendicular Crossing	Control, Geometry, Crossing Distance	2-lane Total Cross-Section		RRFB, PHB, or signal control, *OR* Raised crossing with yield control	Stop or yield control, speed < 40 mph	Stop or yield control, speed ≥ 40 mph	n/a
		>2-lane Total Cross Section		Signal control	RRFB or PHB; *OR* Stop or yield control, cross street ≤ 25 mph	Stop or yield control, cross street > 25 mph	Stop or yield control, cross street speed ≥ 40 mph

*Criterion does not apply to all-way stop control crossings.
Source: Kittelson & Associates, Inc.

APPENDIX A: CLASS I FACILITIES – WIDTH INVENTORY

Table 7: Class I Facility – Width Inventory

Trail	Path Type	Location	Width
Martin Creek Canyon Trail	Class IA	Bidirectional - one side only	7’
Dublin Boulevard	Class IA	N side --- west of Silvergate	4.5’
San Ramon Road sidepath	Class IB	West side of roadway	10’
Unnamed trail branching west off of San Ramon Road	Class IA	Connection to Mape Memorial Park	Varies; 7-8’
Alamo Canal Trail	Class IA	Continuous	≥10’
Iron Horse Trail	Class IA	Continuous	≥10’
Dougherty Road	Class IB	E Side – Scarlett to N City Limits	9 to 14’ from Scarlett to Fall Creek; 8’ Fall Creek to N. City Limits
Dublin Boulevard	Class IB	N side -- Iron Horse Trail to Tassajara Creek	12’
Dublin Boulevard	Class IB	S side - Hacienda Drive to Tassajara Road	8’
Martinelli Way	Class IB	N side b/w Arnold and Hacienda	8.5’
Brannigan Street	Class IB	East side - Dublin to Fallon Middle School	8'
Brannigan Street	Class IA	West side - Gleason to Fallon Middle school	8’
Horizon Parkway (In Progress)	Class IB	N side - Scarlett to Arnold	10’
Sterling Road (In Progress)	Class IB	Both sides - Dublin to Horizon	10’
Iron Horse Parkway (In Progress)	Class IB	E Side – Dublin to Horizon	10’
Arnold Way	Class IB	W Side – Dublin to Gleason	≥10’
Central Parkway	Class IB	N side - Brannigan to Lockhart	8’
Central Parkway	Class IB	S side - Brannigan to Lockhart	Varies; 5-8’
Dublin Boulevard	Class IB	S side - Brannigan to Grafton	8’
Dublin Boulevard	Class IB	N side - Brannigan to Finnian Way	8’
Dublin Boulevard	Class IB	N side – Finnian Way to Grafton	7’
Tassajara Creek Trail	Class IA	Continuous	≥10’
Finnian Way	Class IB	S side - Brannigan St to Bray Commons	8’
Finnian Way	Class IB	N side - Brannigan St to Bray Commons	8’

Trail	Path Type	Location	Width
Grafton Street	Class IB	W side - Central to Fairfield Park	12’
Grafton Street	Class IB	E side - Central to Fairfield Park	8’
Lockhart Street	Class IB	E side - N of Dublin to Gleason	12’
Positano Pkwy	Class IB	S side - Fallon to school	8'
Positano Pkwy	Class IB	N side - Fallon to school	8'
Antone Way	Class IB	N side - Dublin Ranch to Fallon	40’
Fallon Road	Class IB	W side - Gleason to Tassajara	12'
Sterling Street	Class IB	Dublin to Central	8'
Central Parkway	Class IB	Fallon to eastern extents	8’
Central Parkway	Class IB	Fallon to eastern extents	8’
Wallis Ranch Drive	Class IB	W side between Tassajara Creek and Stags Leap	8'
Rutherford Drive	Class IB	E side from Tassajara to trail connection	8'
Trail parallel to Croak Road/Volterra Drive	Class IB	S. Terracina to N extents of Volterra	Varies; 9 - 10’