How Steep, Narrow, and Busy?
A Feasibility Analysis for Proposed Bikeway Networks

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This presentation describes three analytic tools for examining the feasibility of proposed bikeways. The tools are simple enough to apply over large geographic areas while robust enough to guide the planning and implementation of new facilities. They are (1) a street grade analysis based on average slope, maximum slope, and an overall difficulty factor; (2) a right-of-way analysis of street widths and prototypical cross-sections; and (3) a volume analysis that considers peak hour traffic in relation to the carrying capacity of the cross-sections. The following pages provide additional information and examples of these analyses.

These tools were developed for updating the Bicycle Master Plan of Oakland, California, a city of 400,000 people that encompasses 55 square miles. The planning process faced significant challenges in coping with the city's topography that ranges from sea level at the San Francisco Bay to 1,500 feet in the Oakland Hills. Bikeway connections were further complicated by an irregular street grid created by haphazard land speculation in the early twentieth century and the construction of urban freeways in the mid-twentieth century. See the following web site for additional information on this project:
www.oaklandpw.com/bicycling/bikeplan.htm

The analysis applied the following criteria to all streets on the recommended bikeway network from the 1999 Bicycle Master Plan plus a number of additional streets that were evaluated as potential alternatives. Overall, 700 segments of potential bikeway covering approximately 250 miles of roadway were included in this analysis.

- The ***Street Grade Analysis*** characterized hills by average slope, maximum slope, and a difficulty factor for recommending street grades that are appropriate on the bikeway network. For particular streets, the average slope and maximum slope were computed using overlapping GIS layers for the street grid and contour lines. A difficulty factor was developed to relate the steepness and length of a given hill through the following expression: (total elevation gain) * slope * slope * 10. This factor helps account for the relationship between steepness and length that shapes overall difficulty. The factor was normalized such that most hills in Oakland have a difficulty between 0 and 40, where the higher numbers indicate more difficult hills. All significant hills on the network were screened by these three criteria. In general, a hill was excluded from the network if it exceeded two or three of the criteria.

- The ***Right-of-way Analysis*** was based on the curb-to-curb right-of-way for all collector and arterial streets under consideration for inclusion in the bikeway network. The bulk of these data were from high-resolution aerial photographs (four pixels per foot). Additional data were gathered from fieldwork, feasibility studies, and the final design for new and pending projects. The analysis then identified proposed cross-sections based on the following "minimum" lane widths: 7' parking lanes, 5' bike lanes, 11' outer travel lanes, 10' inner travel lanes, and 10' two-way center turn lanes. (On streets with rapid bus lines, a minimum 11' inner travel lane was necessary.) In general, the "recommended" lane widths include 11' travel lanes and 9' parking lanes when adjacent to bicycle lanes (to encourage cyclists to ride outside of the door zone). The "maximum" lane widths identify a possible right-of-way allocation for which the next widest cross-section would also be feasible (using the "minimum" lane widths associated with that cross-section). For arterial and collector streets, proposed bikeways without adequate width to accommodate bike lanes were either rerouted to parallel streets or identified as arterial bike routes (Class 3A: shared lane treatment with wide outer lanes as per the "TS" and "WS" cross-sections).

- The ***Volume Analysis*** was completed for all segments in which the proposed cross-section would require the conversion of travel lanes to bicycle lanes. Peak hour volumes were compared to a threshold based on the service volumes for urban streets specified by the Highway Capacity Manual (2000, p. 10-10). Under the most urbanized conditions (Class IV) operating at a level of service E, each travel lane can be expected to accommodate roughly 800 motor vehicles per hour. This analysis used 1080 motor vehicles per lane per hour as the capacity threshold: 135% of the 800 vehicles specified by the Highway Capacity Manual. This analysis did not determine the ultimate feasibility of such lane conversion projects. Rather, it provided planning-level guidance on which segments merit further study at an engineering level to determine the operational viability of those proposed projects. The segments that failed the volume analysis were either rerouted to a different street or the proposed cross-sections were changed so as to accommodate the existing motor vehicle volumes.

Overall, these tools provided a means for revising Oakland's bikeway network based on data and thresholds that realistically addressed the key physical constraints to the implementation of new bikeways. This planning-level analysis identified *feasible proposals* that merit further study at an engineering level. This additional study of particular segments would then develop *feasible projects* for implementation. Because it is based on these quantitative evaluations and proposed cross-sections, the bikeway network provides greater direction and clarity to staff in pursuing bikeway implementation. The decision-making process is based on publicly available data and explicit thresholds that are easy for stakeholders to question, apply, and understand. Thus it also serves as a consensus-building tool amongst staff, the advocacy community, elected officials, and neighborhood groups on the location and type of proposed bikeways.

Street Grade Analysis -- Supplementary Information

Elevation and distance data were collected using overlaid GIS layers of Oakland's street grid with contour lines. In the Flatlands, the resolution of the contour lines is 10 feet. In the Hills, the resolution is 25 feet.

Explanation of Columns in the Attached Table

Street:	The segment of proposed bikeway with a significant hill, including major cross-streets
From:	Cross-street at the bottom of the hill within the segment identified by "Street"
To:	Cross-street at the top of the hill within the segment identified by "Street"
Elevation (lower):	Elevation of the nearest contour line to "From"
Elevation (upper):	Elevation of the nearest contour line to "To"
Elevation Gain:	"Elevation (upper)" minus "Elevation (lower)"
Distance:	Roadway distance between "From" and "To"
Average Slope:	"Elevation Gain" divided by "Distance" (aka "rise over run")
Maximum Slope:	For hills with varying slopes, the steepest stretch of roadway
Difficulty Factor:	A factor that accounts for both elevation gain and average slope in a single number. *Difficulty = (elevation gain) * (average slope) * (average slope) * 10* The factor is normalized such that "0" is easy and "80" corresponds to the steepest and longest hills in Oakland.
Re-route:	Preliminary recommendation for streets to avoid on the proposed bikeway network
Zone:	Because Oakland's topography is very different in different parts of the city, screening criteria were developed for each of the follow three zones:
Zone 1:	Flatlands (below MacArthur Blvd, Broadway, College Ave)
Zone 2:	Lower Hills (below Mountain Blvd, above Flatlands)
Zone 3	Upper Hills (above Mountain Blvd)

Screening Criteria

The following criteria are guidelines for appropriate hills on the proposed bikeway network. Proposed bikeways may be steeper than the recommended guidelines if (1) no alternative and superior street is available; or (2) the proposed bikeway is located in the Oakland Hills and provides a desirable recreational route.

	Average Slope	Maximum Slope	Difficulty
Flatlands (Zone1):	≤ 6%	≤ 8%	≤ 5
Lower Hills (Zone 2):	≤ 8%	≤ 10%	≤ 15
Upper Hills (Zone 3):	≤ 10%	≤ 12%	≤ 25

In the following table, shaded cells in the "Ave Slope", "Max Slope", and "Difficulty" columns indicate that the above screening criteria were not met for that particular segment.

Street Grade Analysis -- Sample Segments

Flatlands (Zone 1)

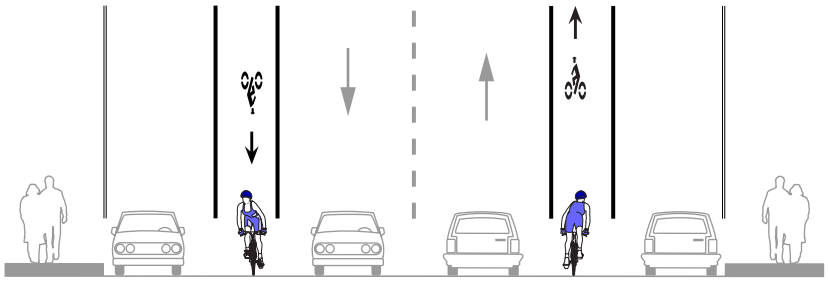
Street	From	To	Elevation (lower)	Elevation (upper)	Elevation Gain	Distance	Ave Slope	Max Slope	Difficulty	Re-route
14th Ave	E 24th St	E 31st St	60	130	70	2600	3%	3%	1	
Park Blvd (E 18th to I-580)	Newton	Grosvenor	20	175	155	5425	3%	6%	1	
Oakland Ave (below I-580)	Harrison St	MacArthur Blvd	40	100	60	1465	4%	10%	1	
23rd Ave	E 21st St	E 28th St	60	190	130	2790	5%	7%	3	
MacArthur Blvd (Dimond District)	Cannon	Montana	180	220	40	655	6%	6%	1	
Brookdale Ave (near High St)	Courtland	Fern	120	210	90	820	11%	14%	11	X
Logan (Brooklyn route)	Fruitvale	Coolidge	100	120	20	150	13%	13%	4	X
Brooklyn Ave (near Lake Merritt)	Newton	Hanover	30	90	60	335	18%	18%	19	X

Lower Hills (Zone 2)

Street	From	To	Elevation (lower)	Elevation (upper)	Elevation Gain	Distance	Ave Slope	Max Slope	Difficulty	Re-route
Park Blvd (I-580 to Leimert)	Grosvenor	Leimert	175	375	200	5480	4%	8%	3	
Moraga Ave (below Highway 13)	Pleasant Valley	Harbord	150	625	475	8180	6%	9%	16	
MacArthur Blvd (Lakeshore to Park)	Excelsior	Capell	20	170	150	2270	7%	7%	7	
Monterey Ave (west of 35th Ave)	Bennett Pl	Maiden Ln	400	650	250	3645	7%	11%	12	
Grosvenor Pl (near Trestle Glen)	Holman Rd	Park Blvd	100	150	50	550	9%	9%	4	
Trestle Glen (upper)	Valant	Park Blvd	200	350	150	1500	10%	12%	15	X
Lincoln Ave (below Highway 13)	Alida	Lincoln Way	375	650	275	2440	11%	12%	35	X
Carson St (above High St)	Fair	Davenport	300	375	75	445	17%	17%	21	X

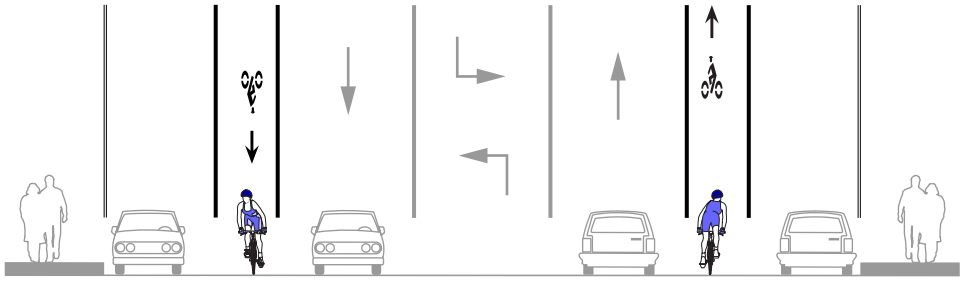
Upper Hills (Zone 3)

Street	From	To	Elevation (lower)	Elevation (upper)	Elevation Gain	Distance	Ave Slope	Max Slope	Difficulty	Re-route
Joaquin Miller via Butters Canyon	Mountain Blvd	Robinson	675	1075	400	9865	4%	10%	7	
Tunnel Rd to Skyline Blvd	Caldecott Ln	Elverton	650	1400	750	15140	5%	7%	18	
Campus Dr (from Redwood)	Redwood Rd	Merritt College	650	850	200	2215	9%	12%	16	
Joaquin Miller (below Skyline)	Mountain Blvd	Robinson	675	1075	400	4225	9%	11%	36	X
Redwood Rd	Mountain Blvd	Campus Dr	450	650	200	2100	10%	10%	18	
Golf Links Rd (above Mountain Blvd)	Mountain Blvd	Burgos Ave	175	300	125	1230	10%	15%	13	
Golden Gate Ave	Chabot	Broadway	275	325	50	455	11%	11%	6	
Redwood Rd	Campus Dr	Skyline Blvd	650	975	325	2860	11%	12%	42	X



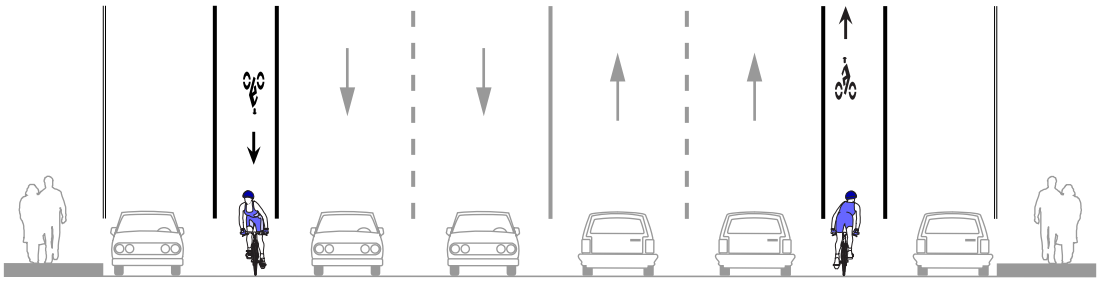
Minimum	7′	5′	11′	11′	5′	7′	46′
Recommended	9′	5′	11′	11′	5′	9′	50′
Maximum	9′	5′	14′	14′	5′	9′	56′

T2 Cross Section: 2 Lane Street, 46′-56′ Curb-to-Curb Width
Example (existing): MacArthur Blvd (Lincoln Ave to 35th Ave)



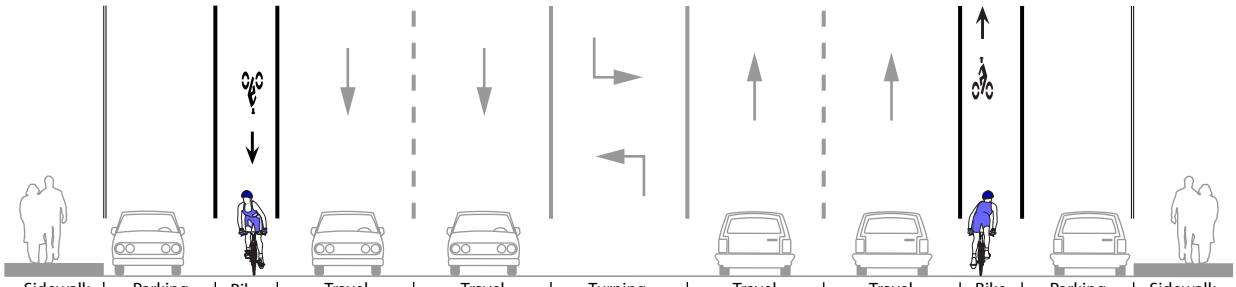
Minimum	7′	5′	11′	10′	11′	5′	7′	56′
Recommended	9′	5′	11′	11′	11′	5′	9′	61′
Maximum	9′	5′	13′	12′	13′	5′	9′	66′

T3 Cross Section: 3 Lane Street, 56′-66′ Curb-to-Curb Width
Example (existing): Bancroft Ave (50th Ave to 66th Ave)



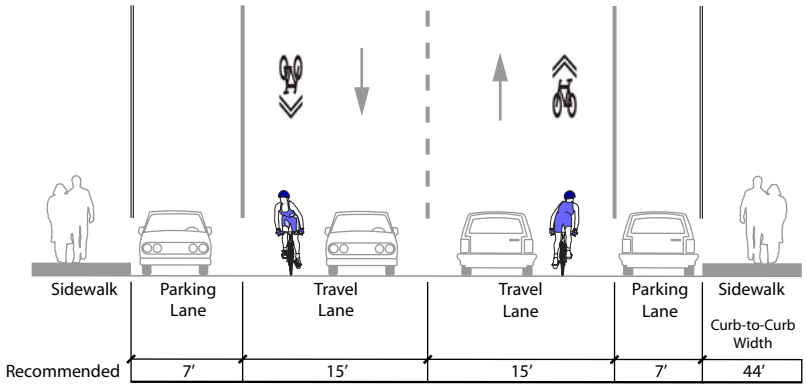
Minimum	7′	5′	11′	10′	10′	11′	5′	7′	66′
Recommended	9′	5′	11′	11′	11′	11′	5′	9′	72′
Maximum	9′	5′	12′	12′	12′	12′	5′	9′	76′

T4 Cross Section: 4 Lane Street, 66′-76′ Curb-to-Curb Width
Example (existing): Telegraph Ave (Woolsey St to Aileen St)

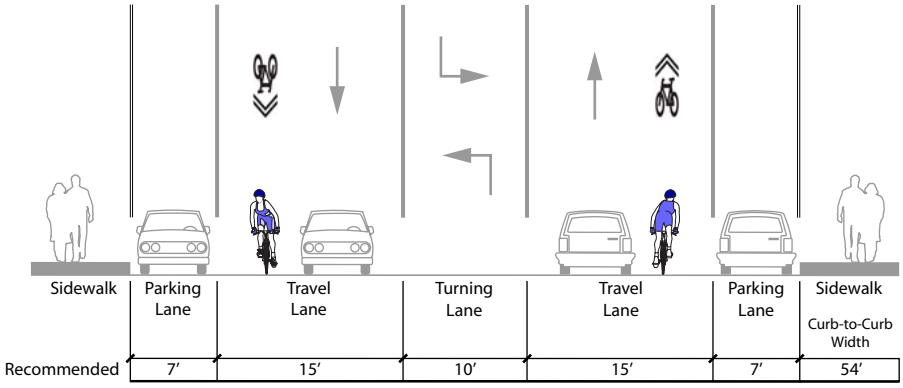


	Sidewalk	Parking Lane	Bike Lane	Travel Lane	Travel Lane	Turning Lane	Travel Lane	Travel Lane	Bike Lane	Parking Lane	Sidewalk
											Curb-to-Curb Width
Minimum		7′	5′	11′	10′	10′	10′	11′	5′	7′	76′
Recommended		9′	5′	11′	11′	11′	11′	11′	5′	9′	83′
Maximum		9′	5′	12′	12′	12′	12′	12′	5′	9′	88′

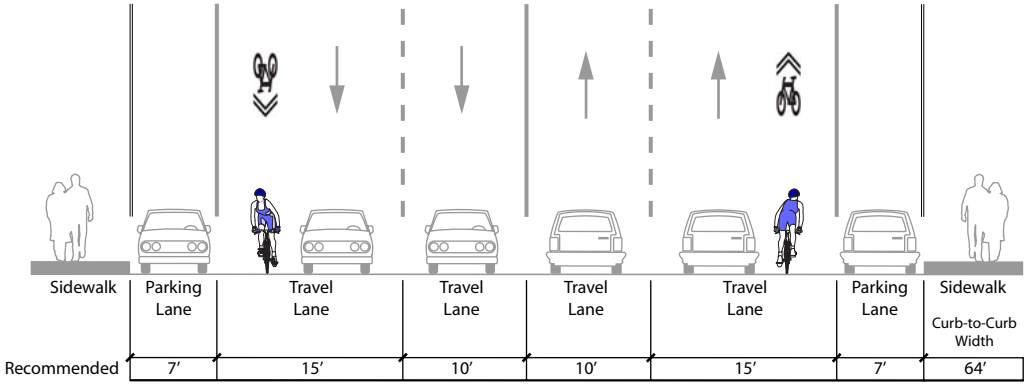
T5 Cross Section: 5 Lane Street, 76′-88′ Curb-to-Curb Width
Example (existing): Grand Ave (El Embarcadero to Bay Pl)



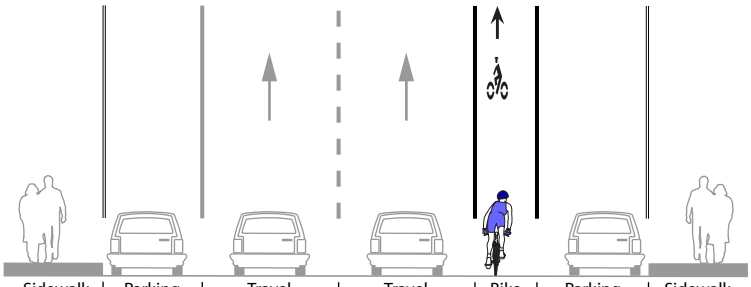
TS2 Cross Section: 2 Lane Street (Shared Lane), 42′-<46′ Curb-to-Curb Width
Example (proposed): Fruitvale Ave (MacArthur Blvd to Foothill Blvd)



TS3 Cross Section: 3 Lane Street (Shared Lane), 52′-<56′ Curb-to-Curb Width
Example (existing): Foothill Blvd (35th Ave to 41st Ave)

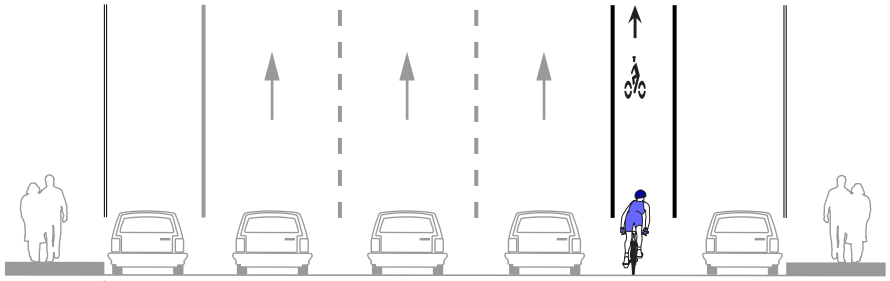


TS4 Cross Section: 4 Lane Street (Shared Lane), 56′-<66′ Curb-to-Curb Width
Example (proposed): MacArthur Blvd (35th Ave to High St)



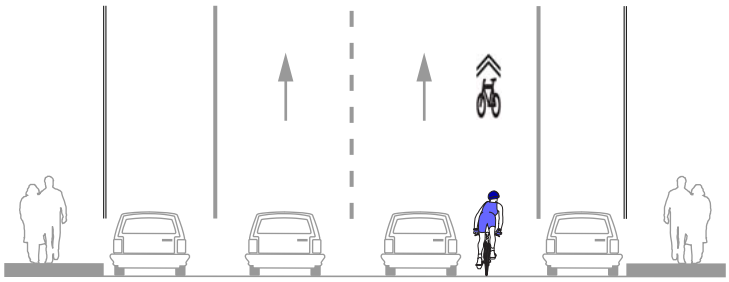
Minimum	7′	10′	11′	5′	7′	40′
Recommended	8′	11′	11′	5′	9′	44′
Maximum	8′	14′	14′	5′	9′	50′

W2 Cross Section: One-way Two-lane, 40′-50′ Curb-to-Curb Width
Example (existing): Bancroft Ave (42nd Ave to 50th Ave)



Minimum	7′	10′	10′	11′	5′	7′	50′
Recommended	8′	11′	11′	11′	5′	9′	55′
Maximum	8′	13′	13′	13′	5′	9′	61′

W3 Cross Section: One-way Three-lane, 50′-61′ Curb-to-Curb Width
Example (proposed): Franklin St (20th St to 14th St)



Recommended	7′	10′	15′	7′	39′

WS2 Cross Section: One-way 2 Lane Street (Shared Lane),
35′-<40′ Curb-to-Curb Width
Example (proposed): 9th St (Washington St to Broadway)

Bikeway Segments Database -- Explanation of Fields

The following fields and associated coding schemes were used to characterize the approximately 700 bikeway segments that were part of the overall analysis. A sample entry for one segment is included on the following page.

Roadway The roadway in question

ID A unique identification number of each roadway segment

From One end of the roadway segment

To The other end of the roadway segment

Length The length of the segment in both miles and feet.

Screening The current status of the programmatic transportation analysis for that segment

existing	The bikeway segment currently exists.
failed	The segment did not pass the transportation analysis but is being retained because it cannot be rerouted.
pass	Given the available data, the segment passed the transportation analysis.
reroute	The segment will be removed from the bikeway network. See "Notes" for the rationale.

Volume analysis A check indicates that a volume analysis was completed. This analysis applies to segments with lane reductions for which peak hour volume data was available.

Proposed Cross-section The proposed cross-section for the roadway segment. The basic cross-sections assume parallel parking on both sides. See the cross-section diagrams for details.

Impact The impact of applying the proposed cross-section (none, lane conversion, parking removal, removal of two-way center turn lane).

Variation Variations to the cross-sections described above.

(B1)	Bicycle lane in one direction only (not noted for one-way streets)
(CTL0)	No center turn lane. Indicates a variation on the T3 cross-section where there are two travel lanes in one direction and one travel lane in the other direction
(P0)	No parking
(P1)	Parking on one side of the street
(PD1)	Diagonal parking on one side of the street
(PD2)	Diagonal parking on both sides of the street

Primary Bike-way Network A prioritization tool to reflect the relative importance of various bikeway connections. Analogous to the distinctions between arterial/collector streets and trunk/local transit lines.

Prop. Class Proposed bikeway class for the roadway segment

Exist. Class Existing bikeway class

1999 Class Bikeway class proposed in the 1999 Bicycle Plan

Curb-to-Curb The curb-to-curb right-of-way of the roadway measured in feet.

Road Direction Roadway direction to the nearest compass points.

One-way Identifies one-way streets and the direction of traffic flow.

Median Identifies the presence of a median on the roadway segment.
[Five distinctions, not included here for brevity's sake.]

 # NE Lanes Number of travel lanes in the north or east direction

 # SW Lanes Number of travel lanes in the south or west direction

Parking Parking configuration on the roadway segment
[Six distinctions, not include here for brevity's sake.]

Transit Routes The bus lines running on the roadway segment. An "*" denotes that the line runs on only part of the segment.

Transit Type [Four distinctions, categorizing bus lines into a hierarchy based on ridership and headways.]

Truck Route A check indicates that the roadway segment is a city-designated truck route.

Peak Vol-NE Peak hour motor vehicle volumes in the north or east direction.

Peak Vol-SW Peak hour motor vehicle volumes in the south or west direction.

ADT Average daily traffic (total number of motor vehicles in both directions over a 24 hour period)

Notes Identifies irregularities along the segment and additional data sources. Provides rationales for significant decisions in the analysis.

City of Oakland Bicycle Master Plan
Bikeway Segment Database

ID: 130 **Roadway:** Market St

From: MacArthur Blvd **To:** San Pablo Ave

Existing Class: None **1999 Class:** 2

Proposed Class: Class 2 bike lane **Length (feet):** 2,807

On the Primary Bikeway Network? Y **Length (miles):** 0.5

Screening: pass **Performed a Volume Analysis?** ☑ Yes

Proposed Cross-section T3 **Variation:**

Impact: Lane conversion

On a Truck Route? ☐ Yes

Transit Type: M **Transit Routes** 88

Curb-to-curb (C2C) Width (feet) 56 **C2C Source:**

Road Direction: NS **One-Way direction flow:**

 # NE Lanes: 2 **# SW Lanes:** 2

Median: No median **Median Width:**

Parking: Parallel parking on both sides

Peak Hour Volume-NE: 320 **ADT:** 6,460

Peak Hour Volume-SW: 300 **Volume Source:**

Notes: As per Market St feasiblity study.