APPENDIX

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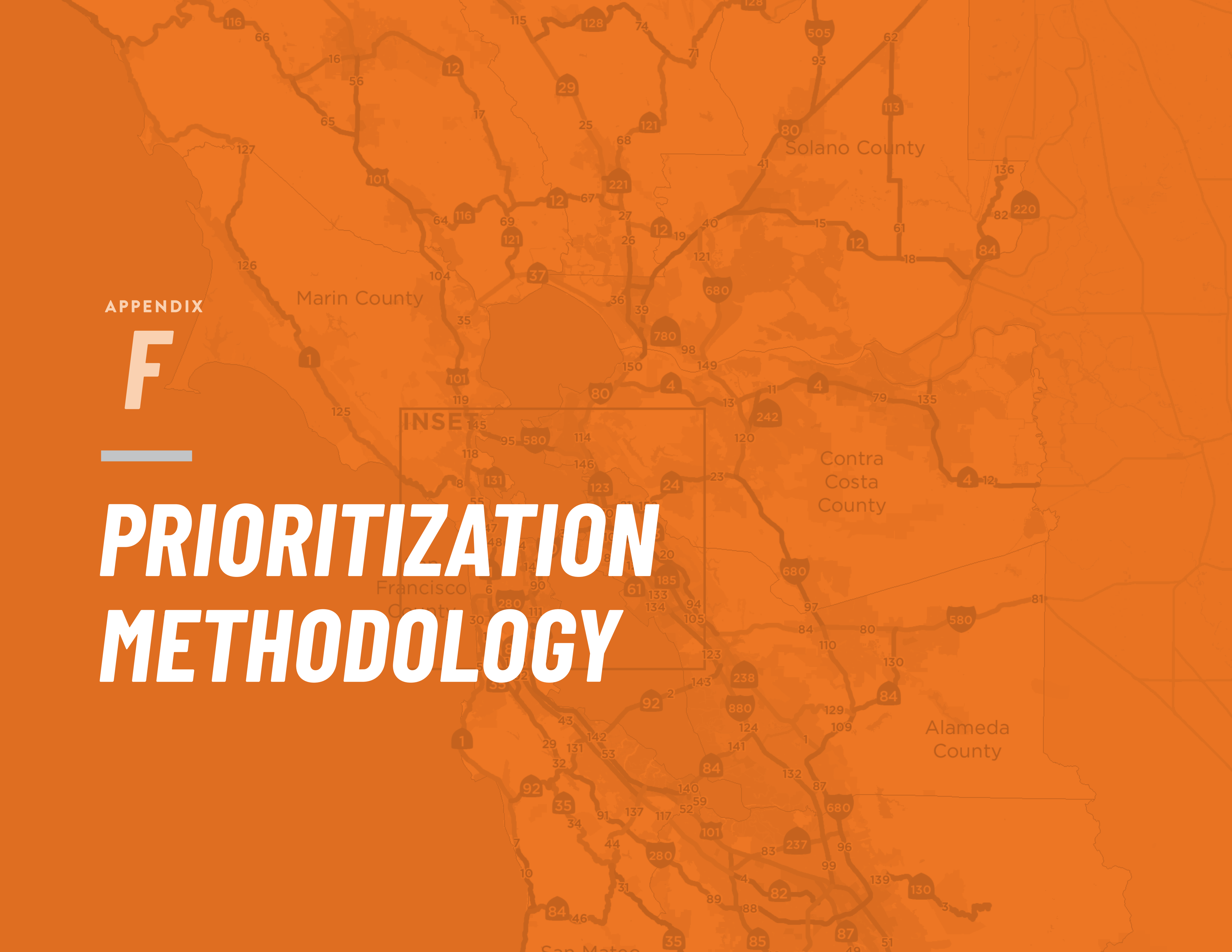
PRIORITIZATION METHODOLOGY



MEMORANDUM

To: Elliot Goodrich, Caltrans Bay Area

From: David Wasserman; Lisa Schroer; Libby Nachman; Mauricio Hernández, Alta Planning + Design

Date: July 27, 2021

Re: Caltrans Bay Area Bike Highways Study – Task 5 Prioritization Methodology

Introduction

This memo outlines the implemented prioritization methodology related to the Caltrans Bay Area Bike Highway Study. The memo includes a summary of analyses, data sources, and scoring utilized to prioritize Caltrans corridors for further design.

Units of Analysis

The project team first conducted analysis utilizing Highway Performance Monitoring System (HPMS) segments, approximately 500 feet long, and then aggregated within longer corridors that range from three to ten miles long. This multiscale analysis allowed the project team to leverage detailed data at the specificity of HPMS units while providing results that are useful for regional-scale analysis. The corridors are the primary unit through which highways are identified and prioritized for bike highway implementation.

Corridors were manually identified based on the route segmentation criteria outlined by the Caltrans Transportation Concept Report (TCR) Guidelines from 2012. According to these guidelines, corridors are bounded by points of network connectivity (i.e., major intersections); facility type; changes in capacity or operational constraints; district, county, or urban/rural boundaries; changes in function or use of the route (e.g., commute, interregional, trucking, recreational, etc.); major changes in ADT; changes in number of lanes; or significant changes in grades/terrain. Alta recommended corridor breaks based on these criteria along state highways throughout the nine-county region and adjusted the aggregated corridor segments based on Caltrans review and comments.

Analysis Phases

Analysis took place over four phases, each progressively narrowing the field of candidate corridors: i) suitability analysis, ii) geographic balancing, iii) feasibility analysis, and iv) final prioritization. The Suitability Analysis phase helped answer the question: “Where *should* bike highways be built along state-controlled highways?” based on criteria related to demand and equity. The *full set* of highway corridors within the region was scored according to their suitability. The Geographic Balancing phase produced a *reduced set* of segments with the highest suitability scores in the urban, suburban, and rural areas of the district and with key connectivity potential. This ensured the potential for bike highway implementation across diverse geographies. Next, the Feasibility Analysis phase analyzed the reduced set of corridors for practicality of construction: “Where *can* bike highways be built along state highways?” This phase utilized criteria including available right-of-way (ROW), grade separation, and intersection density to produce a feasibility score for each corridor.

Lastly, the Final Prioritization phase added the suitability and feasibility scores for corridors within the reduced set to produce a combined score. Corridors with the highest combined scores constituted the *final set* of corridors, to be considered for bike highway implementation. Combined scores were ranked to prioritize corridors within this final set. Corridors that did not emerge as top candidates based on this methodology but were known to be important candidates for bike highway development due to geographic balancing or other considerations, were manually elevated into to the final set. **Table 1** below provides a summary of each phase of the analysis and the data used for each portion of the process. Each phase is further explained in the sections below.

Table 1. Summary of Criteria

Criteria	Description	Data Source	Proposed Weight
Suitability Analysis			
Total Demand	Number of trips made by all modes along a corridor	MTC origin-destination flows	25%
Bicycle Demand	Number of bicycle trips made along a corridor	MTC origin-destination flows	25%
Equity	Socioeconomically disadvantaged communities	MTC Communities of Concern	50%
Geographic Balancing			
Counties	County boundaries	UC Census	-
Urban, Suburban, and Rural Tracts	Census tracts classified as urban, suburban, or rural based on population density.	Bureau of Labor Statistics LATCH data	
Feasibility Analysis			
Available ROW	Estimated ROW along state highways	ROW boundary polygons; HPMS lane count data	25%
Intersection Density	Number of intersections (three-legs or more) per mile	OSM street network	25%
Grade Separation	Presence of bridge, viaduct or tunnel	HPMS bridge/tunnel data	50%
Final Prioritization			
Suitability Score	Final score result from the suitability analysis	Alta	66.6%
Feasibility Score	Final score fresult from the feasibility analysis	Alta	33.3%

Suitability Analysis

The Suitability Analysis explored where bike highways *should* be built along state highway corridors. It included the following criteria and scoring:

- Total Demand (25% of suitability score)
- Bicycle Demand (25% of suitability score)
- Socioeconomic Equity (50% of suitability score)

The project team explored the possibility of including potential reduction of vehicle miles traveled (VMT) as a criterion for this analysis. However, based on available data sources, the project team concluded that VMT estimates would be highly correlated with demand estimates (e.g., corridors experiencing high demand would also have greater potential for VMT reduction). As such, including potential VMT reduction would not provide meaningful additional information about a particular corridor's suitability for bike highway implementation. To this end, demand estimates served as a proxy for potential VMT reduction. Additional information on the criteria used for this analysis is presented below.

Demand

Demand for bicycle travel along each corridor was analyzed in terms of both *Existing Bicycle Demand* and *Potential Bicycle Demand*. Each criterion comprised 25% of the overall suitability score. *Existing Bicycle Demand* was based on model estimates of the number of existing bicycle trips made along the trajectory of each corridor. This represents the immediate potential usage of a bike highway. *Potential Bicycle Demand* was based on model estimates of the number of bicycle-length trips that are currently made by *any mode* but have the potential to be made by bicycle. This demand represents the market potential, or the latent demand, for infrastructure that enables bicycling, such as a bike highway.

The Bike Highway Best Practices Memo and a review of trip lengths identified by MTC's modeled trip data informed the precise definition of a bicycle-length trip. Alta used 15 miles as a threshold for viable bicycling along low-stress bikeways with limited intersections.

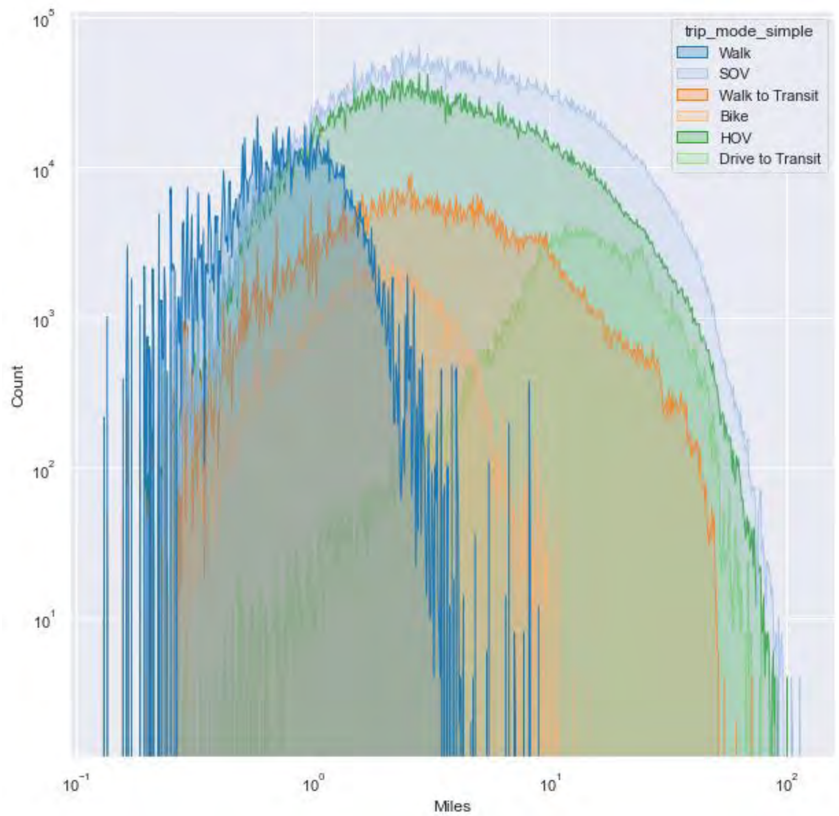


Figure 1. Log-scale Distribution of Trip Distances by Mode. Bicycle trips rarely exceeded 10 miles, and as a result we based our weighting on a combination of evidence from Bicycle Highway Best Practices Memo and insight from these trip distributions.

Data Sources

- Metropolitan Transportation Commission (MTC) Travel Model origin-destination (OD) flows
- OpenStreetMap (OSM) street network

Methodology

The project team estimated the approximate volume of bicycle-length trips currently made by bicycle (*Existing Bicycle Demand*) and all modes (*Potential Bicycle Demand*) for each HPMS segment based on Origin-Destination (OD) flows from the MTC travel demand model. Flows between OD pairs were attached to HPMS segments using the following procedure:

1. Draw straight lines, which we call OD lines, between the centroids of MTC traffic analysis zones (TAZs). The OD lines represent the trajectory of demand between each pair of zones, similar to “desire lines” that might be mapped in a site plan.
2. Attach counts of trips made by bicycles and bicycle-length trips made by all modes to the OD lines, providing an estimate of trip volumes along these trajectories.
    - Attach trip volumes from the OD lines to HPMS segments based on two factors: their proximity and angular similarity.
        - Proximity – ODs line were associated to facilities if they were within one-mile of the facility. This worked well across the study area and generated reasonable results.
        - Angular Similarity- OD lines had conditional weights assigned to them based on their angular similarity. This enabled the analysis to incorporate more OD flow lines into each segment evaluation than a purely binary metric with a strict angle threshold. The assigned weights were used to determine the number of trips to associate with any particular facility. The weights for angular similarity were assigned as follows:
            - 0 – 10 Degrees Relative Angle Difference 1.0
            - 10 – 20 Degrees Relative Angle Difference 0.9
            - 20 – 25 Degrees Relative Angle Difference 0.6

              25 – 30 Degrees Relative Angle Difference 0.2
            - 30 – 45 Degrees Relative Angle Difference 0.1
            - More than 45 Degrees Relative Angle Difference 0
    - Bicycle-length trips by all modes were evaluated so that the cyclable distances were weighted on a continuous basis. This weighting was informed by the project team’s review of trip distances for biking trips seen in MTC’s Travel Demand Model and the Bike Highways Best Practices Memo completed as part of Task 4 of this project. The assigned weights were used to determine the number of trips to associate with any particular facility. These weights were used in combination with angular similarity weights, thus if an angularity similarity weight was 0.5 and a suitable distance weight was 0.5, the number of trips associated to the segment from that OD line was 25% of its total. The weights for bicycle-length trips were assigned as follows:
        - 0 – 1 Mile Trips 0.25
        - 1 – 3 Mile Trips 0.75
        - 3 – 6 Mile Trips 1.0
        - 6 – 10 Mile Trips 0.75
        - 10 – 15 Mile Trips 0.25
        - More than 15 Mile Trips 0
3. Calculate quartile rankings for trips by all modes and by bicycle and converted those into ratings of 0 to 3 for *Total Demand* and *Bicycle Demand,* respectively. Because tabulated trip volumes were uncalibrated approximations, it is best to interpret them through a ranked index rather than as precise volumes.

Equity

The equity score emphasized the suitability of corridors within socio-economically disadvantaged communities where there might otherwise be bias due to historical and present-day systemic inequities. This score comprised 50% of the overall suitability score.

Data Sources

- MTC Communities of Concern (CoC)

Methodology

HPMS segments received an equity rating between 1 and 3 if they intersected an MTC CoC rated High, Higher, or Highest, respectively, and a rating of 0 if they did not intersect any CoC. The project team qualitatively reviewed CalEnviroscreen and Environmental Justice (EJ) Screen for the nine county study area to see if MTC’s CoCs could be complemented, but the regional nature of MTC’s non-urbanized area CoC datasets seemed to be sufficient. The instruction of a new equity dataset would have further complicated the methodology, so the study team elected to use CoCs solely for the equity analysis.

Geographic Balancing

The Geographic Balancing phase further reduced the set of potential corridors with the highest suitability scores across different geographies within the Bay Area region, ensuring that all parts of the regional were considered for bike highway implementation. Geographic Balancing accounted for the distribution of highway corridors within urban/suburban/rural areas throughout the region.

Data Sources

Bureau of Labor Statistics (BTS) Local Area Transportation Characteristics for Households (LATCH) urbanicity classifications.

Methodology

1. Dissolve BTS LATCH census tract polygons according to their three-level urbanicity classifications, creating polygons representing urban, suburban, and rural areas across the Bay Area region.[1]
2. Spatially join aggregated highway corridors to the zones and assign to their predominant land use classification.
3. Compute percentile values of the suitability scores relative to all scores in their assigned land use zones. These scores were used to identify the top candidates in each land use class.
4. Assign highway corridors with the highest suitability scores in each land use zone (i.e., urban, suburban, rural) to the reduced set of approximately 54 corridors, to be carried forward into the feasibility analysis. Top candidate corridors were identified by reviewing the top third of the distribution within in each relative percentile rank.

Feasibility Analysis

The Feasibility Analysis explored where bike highways *could* be implemented along the reduced set of corridors produced by the Suitability and Geographic Balancing phases. This analysis phase included the following criteria:

- Available ROW (25% of total feasibility score)
- Grade separation (50% of total feasibility score)
- Intersection density (25% of total feasibility score)[2]

Available ROW

Available ROW described the estimated ROW available for constructing a bike facility within a designated highway corridor. The study team used the recommendations in the Best Practices memo to inform this analysis. To this end, an estimated available width of 20 feet or more suggests, with reasonable confidence, that there is likely to be sufficient ROW for constructing a bike facility. Because GIS data sources for calculating ROW width are imprecise, the study team used a relative scoring method for each corridor.

Data Sources

- ROW boundary polygons
- HPMS lane count and functional classification data

[1] Initial approaches developed 27 groups by looking at the combination of counties and land use groups, but after review by the project team and Caltrans this led to unintuitive results with a high degree of score fracturing between different regions. As a result, county boundaries were dropped from the methodology.
[2] The Alta team found the initial weighting (33% each) to result in inconsistent scores that under emphasize the difficulty of implementing a bike highway at different grades of separation (ex. Elevated ROW). Based on this and feedback from the Caltrans project team, Alta modified the weights to place a higher emphasis on structures, and less on intersection-density as well as available ROW. This provided a more realistic score on project feasibility.

Methodology

Available ROW was calculated using the following procedure:

1. Measure the width of existing ROW perpendicular to highway centerlines at regular intervals within each HPMS segment at a spacing of about every 200 feet.
2. Take the median ROW width from those measurements across the corridor.
3. Use lane count and functional classification information for HPMS segments to estimate developed roadway width.[3]
4. Calculate difference between ROW width and developed roadway width to determine available ROW for each HPMS segment.
5. Score these differences on a 0 to 3 scale based on their quartile score across the segments.

Intersection Density

Intersection or Curb Cut Density measured the feasibility of constructing a continuous bike highway facility alongside highway segments based on the number of intersections along the segment. Intersections with perpendicular roads or major driveways are likely to pose engineering challenges and potentially increase the cost for construction substantially for a continuous bike highway facility. Curb cuts are also potential conflict points between bicycles and automobiles. To this end, the study team considered it less feasible to construct a safe and continuous bike highway facility along highway segments with more intersections per centerline distance.

Data Source

- OSM street network

Methodology

Intersection Density was calculated using the following procedure:

- Count intersections with any major public or private roadway, including those servicing major commercial and residential developments, within a narrow buffer from the centerline of each HPMS segment. The buffer distance parameter will be adjusted to capture only intersections that directly involve a given HPMS segment.
- Assign segments an intersection density rating of “probably infeasible” (0), “low feasibility” (1), “moderate feasibility” (2), or “probably feasible” (3) based on their intersection count quartile (inverted percentile – with higher being worse) across all segments in the study area.

Grade Separation

Despite the technical possibility of an engineered solutioned such as a cantilever bridge or tunnel expansion, construction of a bike highway along an existing Caltrans highway segment with *Grade Separation* due to the existence of a bridge, viaduct, or tunnel will likely be cost-prohibitive and therefore was considered infeasible in relation to this study. This criterion was given the highest weight as a result of a sensitivity analysis and its disproportional impact on cost and impact on project viability.

Data Source

- HPMS bridge/tunnel data

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[3] HPMS attributes related to geometrics are only available for a small subset of sampled corridors. As a result, the team assumed allocated ROW to be based on inferences from the number of through lanes (inferred when not available) and the functional classification. Interstates and State Highways were assumed to have shoulders whose combined widths were 40 feet (10 feet per lane, 2 shoulders per direction). All through lanes were conservatively assumed to be 13 feet wide. The combined allocated ROW width was inferred shoulder width combined with inferred through-lane width.

Methodology

Grade Separation was calculated using the following procedure:

1. Categorize HPMS segments based on whether they are within or along a structure (i.e., bridge, tunnel, or causeway).
2. Manually review segments within or along a structure to determine whether there are known adjacent paths or near-term opportunities for reallocating part of the cross-section as a physically separated path.
3. Derive the percentage of each final corridor, represented by an aggregated series of HPMS segments, that has either a tunnel, bridge, or causeway along them.
4. Assign on a 0 to 3 scale to each segment based on the percentage of the corridor that had structures: score of 3 - "probably feasible" if less than 10% of the corridor had structures; 2 if 10-20% of the corridor included structures, and 1 if 20-50% of the corridor had structures. Otherwise, classify segments along or within a structure as 0. Ratings of 0 and 3 were used so that the grade separation criterion is weighted consistently with other factors when they are combined into an overall feasibility score.[4]

Final Prioritization

The Final Prioritization phase added the suitability and feasibility scores to produce a combined score to help prioritize corridors for further investigation. This combined score was produced using the following weights for each of the final scores:

- Suitability – (66.6% of final score)
- Feasiblity – (33.3% of final score)

Following the review and approval of the methodology and results, two or three corridors will be recommended for additional study and design contextualization (see next section). Geographic balance may be taken into account in determining which corridors are recommended for further study. Detailed suitability and feasibility scores for the original HPMS segments will support fine-grained analysis of opportunities and constraints along each of the recommended corridors. The remainder of the final set corridors will be reserved as alternatives in case fatal flaws are discovered among the recommended corridors.

[4] The thresholds were determined based on a sensitivity analysis of how different thresholds highlight different corridors, and a review of the percent grade separated structure of major bridges and highways that were likely to require expensive parallel facility. Given these are very long corridors being evaluated, a binary score identifying if any grade separation was present would flag most of the facilities evaluated.

Additional Considerations for Selecting Corridors

While the suitability and feasibility scores take into account many of the critical factors associated with assessing the relative potential of a corridor as a bike highway, additional considerations will be needed when selecting highway segments for further design and implementation:

- *Grading*: As discussed in the Design Best Practices memo, a maximum grade of 6% is recommended along bike highways to maximize safety and relative comfort of users. Slope was not included in the suitability and feasibility methodology, though it may affects both suitability (user comfort) and feasibility (engineering complexity). However, some roadway segments were removed from consideration during geographic balancing due to known extreme slope. Additional corridors for consideration will need to be assessed for slope as well.

- *Regional Politics*: Political considerations were not captured in this methodology but will need to be taken into account. Bridge segments, for example, were not assessed for feasibility because the existing ROW may be fully built-out and traditional methods of building a bike highways across a bridge would involve complex and expensive engineering, such building a cantilever. However, regionally there have been examples where travel lanes have been repurposed as bike facilities (e.g., Bike path along the Richmond-San Rafael bridge) and this decision may be a political consideration over a technical feasibility consideration.