FEHR & PEERS

Memorandum

Date: November 8, 2024 *(revised 2/4/2025)*

To: City of San Diego

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Subject: City of San Diego Bike Master Plan Update (BMPU) - Connectivity Analysis Methodology

SD24-0523

Introduction

As a part of the City of San Diego (herein referred to as "the City") Bike Master Plan Update (BMPU), a connectivity analysis was conducted to identify locations within the City where bicycle facilities and network enhancement can provide the greatest connectivity to everyday destinations. The analysis results highlight segments with high levels of connectivity to a variety of destinations or attractions via low stress bicycling facilities, and parts of the City that may have high levels of destinations or attractions, but along high-stress facilities.

Based on feedback from the City Project Team and Technical Working Group, the connectivity analysis considered how accessible a variety of key destinations are from the surrounding areas (or travel sheds). The following destination types were used to understand where travel access and connectivity via low stress bicycle networks should be prioritized:

- ***Schools:*** Public and private grade schools as well as colleges and universities.
- ***Parks***: Access points to neighborhood and regional parks, beaches, and amusement parks.
- ***Transit Stops:*** Bus, light rail, commuter rail, and regional rail stops.
- ***Libraries:*** Public libraries
- ***Shopping Areas:*** A group of stores (including grocery stores, convenience stores, drug stores, etc.) and services as well Business Improvement Districts.
- ***Jobs:*** Number of jobs per census block.

The connectivity analysis assumed an average biking speed of 10 miles per hour, meaning the analysis assumed the average person will travel five miles on their bicycle in 30 minutes. While actual speeds may vary from person to person, this average was selected for planning purposes and aligns with best practices for considering all ages and abilities. For each destination type, three travel sheds were assessed and scored. Bike trips within each travel shed were assigned to all roads with or without bike facilities (since bicyclists could presumably share the road with vehicles).

Analysis Inputs

The analysis inputs included network features, destination types (represented by centroids/points), and Bicycle Level of Traffic Stress (LTS). Each data source is described below.

Network Features

The "Roads_All" layer network, downloaded from SanGIS, was used to create the bike traversable network. It was assumed that bicycles are allowed to traverse any road, with or without bike facilities. The network was set up to prohibit bicycles from traveling on roadways of the following functional classes:

- 1; Freeway to freeway ramp
- E; Expressway
- F; Freeway
- R; Freeway/expressway on/off ramp
- M; Military street within base

Destination Types

Destination Types are comprised of specific land uses or places that attract people and generate trips. See **Table 1**Table 2 for the destination types selected and their sources. Destination types were selected to represent everyday places where people may currently bike to or would more likely bike to if they could get to the destination on a low stress bicycle network.

Table 1: Data Sources for Destination Types

Destination Type	Layer Name	Source
Schools	Schools	SanGIS
	Colleges_SG	SanGIS
Parks	Park_Access_Points	City
	Places; Type field filtered to Amusement Park	SanGIS
Transit Stops	Transit_Stops_GTFS	SanGIS
Libraries	Places; Type field filtered to Library.	SanGIS
Shopping Areas	Places; Type field filtered to Shopping Center	SanGIS
	Two Manual Additions:* 1. One Paseo, 3275 Paseo Pl 2. 3239-45 El Cajon Blvd	Google and Fehr & Peers
	Business Improvement Districts**	SanGIS
Jobs per Census Block	OnTheMap (Census Blocks)	US Census Bureau

Source: Fehr & Peers (2024)
*Represents Shopping Centers not included in the SanGIS Database but are key neighborhood destinations for their communities. Centroids were manually added by Fehr & Peers Staff.
** In creating point features from the Business Improvement Districts polygon layer, one point of interest (POI) was assigned for every 2 million square feet of the polygons. This assignment approach was based on the approximate area of the Ocean Beach Business Improvement District, the smallest improvement district, ensuring the points accurately represent the size of each district.

Bicycle Level of Traffic Stress

Bicycle Level of Traffic Stress (LTS) is an analysis used to evaluate how comfortable and safe the transportation network feels for bicyclists. LTS maps the suitability of bicycles for streets and off-street paths by assigning a score of 1-4 to all segments. The four-category scale ranges from LTS 1 (lowest stress) to LTS 4 (highest stress). See **Table 2** for more information on LTS scoring.

LTS data was provided by San Diego Association of Governments (SANDAG) who performed this analysis at the regional scale as part of the recent Regional Vision Zero Action Plan. The LTS analysis was completed in November 2023. The City conducted LTS analyses for recent Community Plan Updates, but had only analyzed select neighborhoods at the time of the BMPU. The Fehr & Peers Project Team spot-checked the City's community-specific LTS scores against LTS regional scores and found them aligned, confirming applicability of the SANDAG LTS data set for use at the City scale.

Variables used by SANDAG to define Bicyclist Segment LTS include:

- Annual Average Daily Traffic
- Posted Speed Limit
- Number of Lanes Per Direction
- Directionality (One-way vs. Two-way)
- Presence of Centerline Yes No
- On-street Parking (Presence and Width)
- Dedicated Facilities (Bicycle Facility Type and Width)

Table 2: Four-Category LTS Score and Supportive Descriptions

LTS Score	Description	Bicyclist User Type
LTS 1	Minimal traffic stress, suitable for nearly all ages and abilities, including children trained for intersections. Cyclists are physically separated from traffic or in an exclusive bike zone alongside slow, single-lane traffic. Shared roads feature occasional low-speed motor vehicles, and intersections are easy to navigate.	All Ages and Abilities
LTS 2	Low traffic stress, appropriate for most cyclists, but requires more attention than segments with LTS 1. Cyclists are separated from traffic, in exclusive bike lanes, or on shared roads with low-speed vehicle interaction. Crossings are straightforward, and bike lanes at right-turn areas provide clear priority for cyclists. Crossings are not difficult for most adults.	Interested by Concerned

LTS 3	Moderate traffic stress, acceptable to experienced urban cyclists. Cyclists have dedicated lanes next to moderate-speed traffic or share lanes on lower-speed, non-multilane streets. Crossings may be longer or involve mixing with vehicles operating at moderate speed, but still considered acceptably safe to most adults.	Enthused and Somewhat Confident
LTS 4	High traffic stress, suitable only for a small portion of cyclists. This level involves riding alongside higher-speed, high-volume traffic with minimal or no separation, appealing mainly to highly experienced riders.	Strong and Fearless / Highly Confident

Source: Almdale, Schoner, and Sanders (2023) *Working toward an improved representation of Level of Traffic Stress, comfort, and systemic safety risk factors for people walking, biking, and rolling – Draft,* page 2

Analysis Process

The connectivity analysis was conducted using the following steps:

- ***Step 1:*** Develop bicycle travel sheds for all destinations by destination type
- ***Step 2:*** Calculate a "travel shed score" for each roadway segment within the travel shed of a destination, by destination type
- ***Step 3:*** Calculate a normalized segment score by destination type between 0-1
- ***Step 4:*** Combine each destination type's normalized segment score to arrive at the "connectivity score" for each segment. Since there are six (6) destination types, the maximum score for any segment is 6.[1]

Steps 1 through 4 are described in detail in the sections below.

Step 1: Develop Travel Sheds for all Destinations

Three bicycle travel sheds for all destinations were developed using ArcGIS Pro, assuming a 10 mile per hour (mph) travel speed for bikes. The three travel sheds included: 0-5 minutes, >5-15 minutes, and >15-30 minutes. See **Figure 1** for an example travel shed developed for a library destination.

[1] Note that all roadway segments received a score for each destination type between 0-1. The scores are then summed up for the six (6) destination types. This process represents equal weight placed on each destination type. It is possible to weight destination types differently if community values indicate a higher emphasis is placed on a certain destination type.

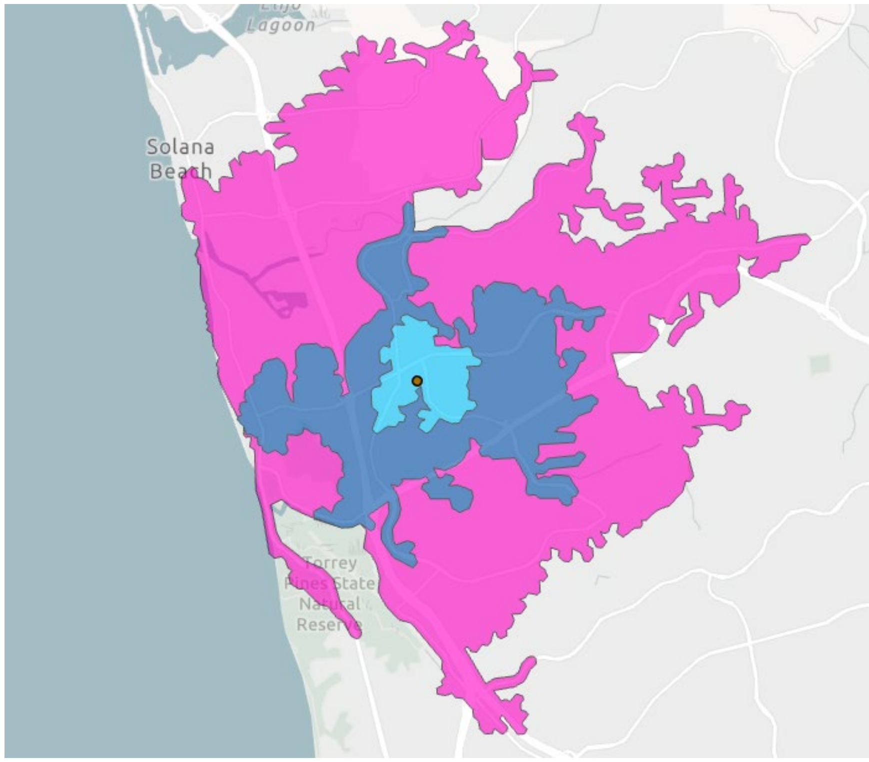


Figure 1: Example of the Bicycle Travel Sheds for Carmel Valley Library, Light Blue = 0-5 minutes, Dark Blue = >5-15 minutes, and Magenta = >15-30 minutes

The three travel sheds were developed for all destination points within each destination type. For destinations that are schools, parks, transit stops, libraries, and shopping areas, the travel sheds are drawn around the land use centroid. For jobs, the travel shed is drawn around any census block that contains at least one job. The number of jobs within the census block is also a critical input, and is accounted for in Step 2.

Step 2: Travel Shed Scores by Destination Type

The next step was performed for each destination type separately. Since there are many destinations for each destination type, there are many travel sheds that overlap one another.

For each individual destination (in the schools, parks, transit stops, libraries, and shopping area types), the roadway segments within that destination's travel shed were assigned a travel shed score as follows:

Travel Shed Score for Each Destination (except jobs):

- 0 – 5 minutes travel shed = All segments within a 5-minute travel shed are assigned a Travel Shed Score of 3

- >5 – 15 minutes travel sheds = All segments within the greater than 5 – 15-minute travel shed are assigned a Score of 2
- >15 – 30 minutes travel sheds = All segments within the greater than 15 – 30-minute travel shed are assigned a Score of 1

Travel Shed Score (for jobs):

For jobs, the travel sheds were drawn around any census block that has at least one job. The travel shed scores are weighted and assigned based on the number of jobs in the census block. A weighted connectivity score was calculated based on total employment of each census block. For example, a census block with 100 total jobs would be scored as follows:

- 0 – 5 minutes travel shed = All segments within a 5-minute travel shed are assigned a Travel Shed Score 300
- >5 – 15 minutes travel sheds = All segments within the greater than 5 – 15-minute travel shed are assigned a Score 200
- >15 – 30 minutes travel sheds = All segments within the greater than 15 – 30-minute travel shed are assigned a Score 100

In other words, the score reflects the number of jobs within the Census Block multiplied by 3, 2, or 1, for each respective travel shed.

Step 3: Calculate Normalized Segment Score

For each destination type, the travel shed scores were summed for each individual road segment in the network. Because there are numerous destinations within each destination type, an individual roadway segment likely falls into travel sheds for several destinations within the same destination type, receiving points for each travel shed.

For illustration, consider a segment near multiple shopping area destinations. Suppose that the segment is within travel sheds of 20 shopping area destinations, resulting in the following travel sheds:

- Within 0-5 travel sheds = 5 destinations
- Within >5-15 travel sheds = 5 destinations
- Within >15-30 travel shed for 10 destinations

The process of calculating the travel shed score for this segment is described in **Table 3**.

Table 3: Travel Shed Score for Process for Described Example

Travel Shed	Score for each Destination in Travel Shed		Quantity of Destinations within Travel Shed		Total Travel Shed Score
0-5 mins	3	*	5	=	15
>5-15 mins	2	*	5	=	10
>15-30 mins	1	*	10	=	10
				Travel Shed Score	35

Source: Fehr & Peers (2024)

In this example, the segment would receive a shopping area destination type total travel shed score of 35.

Once this summation process is complete for all segments by destination type. The total score is normalized by dividing the total travel shed score by the maximum travel shed score for each destination type to arrive at a score between 0-1.

Continuing with the example above, suppose the highest individual segment travel shed score is 100 for the shopping area destination type, then the example segment above would have a normalized score of 35/100=0.35. All segments are assigned a normalized score for each destination type.

Step 4: Calculate the Connectivity Score

To calculate the connectivity score for each roadway segment, the normalized travel shed scores for each destination type are summed. Since there are six (6) destination types, connectivity scores range is between 0-6. This process represents equal weight placed on each destination type. It is possible to weight destination types differently if community values indicate a higher emphasis is placed on a certain destination type, however, for this process each destination type was assigned equal weight and importance.

To understand how this process is applied to a segment, see example below:

For illustration, consider an individual road segment in the network may have received the following normalized scores by destination type:

Table 4: Normalized Score by Destination Type for Described Example

Destination Type	Normalized Score
Schools	0.1
Parks	0.1
Transit Stops	0.8
Libraries	0
Shopping Areas	0.25
Jobs per Census Block	0.5
Total Connectivity Score	**1.75**

Source: Fehr & Peers (2024)

In this example, the sample roadway segment has a connectivity score of 1.75 out of a total of 6.

Analyzing Connectivity By LTS

A primary purpose of developing connectivity scores for roadway segments is to understand which segments provide connections to high levels of (or many) everyday destinations and to what extent people can bicycle to those destinations. Bicycle LTS provides insight into how comfortable a roadway segment is to bicycle on. Ideally, roadways that have high levels of connectivity would also be comfortable to bicycle on. This combination of high connectivity and high comfort (LTS 1 or 2) results in bicycling being a viable travel option and encourages bicycling.

High LTS (or uncomfortable bicycle conditions) was defined as LTS greater than 2, and low LTS (comfortable bicycle conditions) was defined as less than or equal to 2.

High connectivity was defined as a connectivity score above average (3), and low connectivity as a score below average.

Segments were sorted into one of four categories:

- **High Connectivity and High LTS**: Roadway segments where there are many destinations near the segment, but the route is uncomfortable.
- **High Connectivity and Low LTS**: Roadway segments where there are many destinations near the segment, and the route is comfortable.
- **Low Connectivity and High LTS**: Roadways where there are few destinations near the segment, and the route is uncomfortable.
- **Low Connectivity and Low LTS:** Roadways where there are few destinations near the segment, but the route is comfortable.

In general, improving the LTS in the high connectivity/high LTS category would likely result in the greatest shift from driving to bicycling and elevate bicycling as a viable transportation option for the most people to reach everyday destinations.

Figures 2 through 4 illustrate citywide Connectivity scores, LTS scores, and LTS/connectivity score maps, respectively.

Next Steps

The purpose of this analysis is to identify locations in the City where bicycle facilities and network enhancements can provide the greatest connectivity to everyday destinations. The analysis highlights segments with high connectivity to destinations and identifies if there is a low stress network available to access these areas.

As part of the next steps, the Project Team will be evaluating the connectivity analysis with network facility layers, such as existing, designed, and planned, to understand gaps and opportunities in the current network. The primary intent will be to understand if areas with high connectivity are accessible via a low stress network, either along the high connectivity segment or via a low stress parallel street. A preliminary evaluation will be performed as part of the State of the Network, with a more formal process developed as part of the network development included as part of Phase 2.

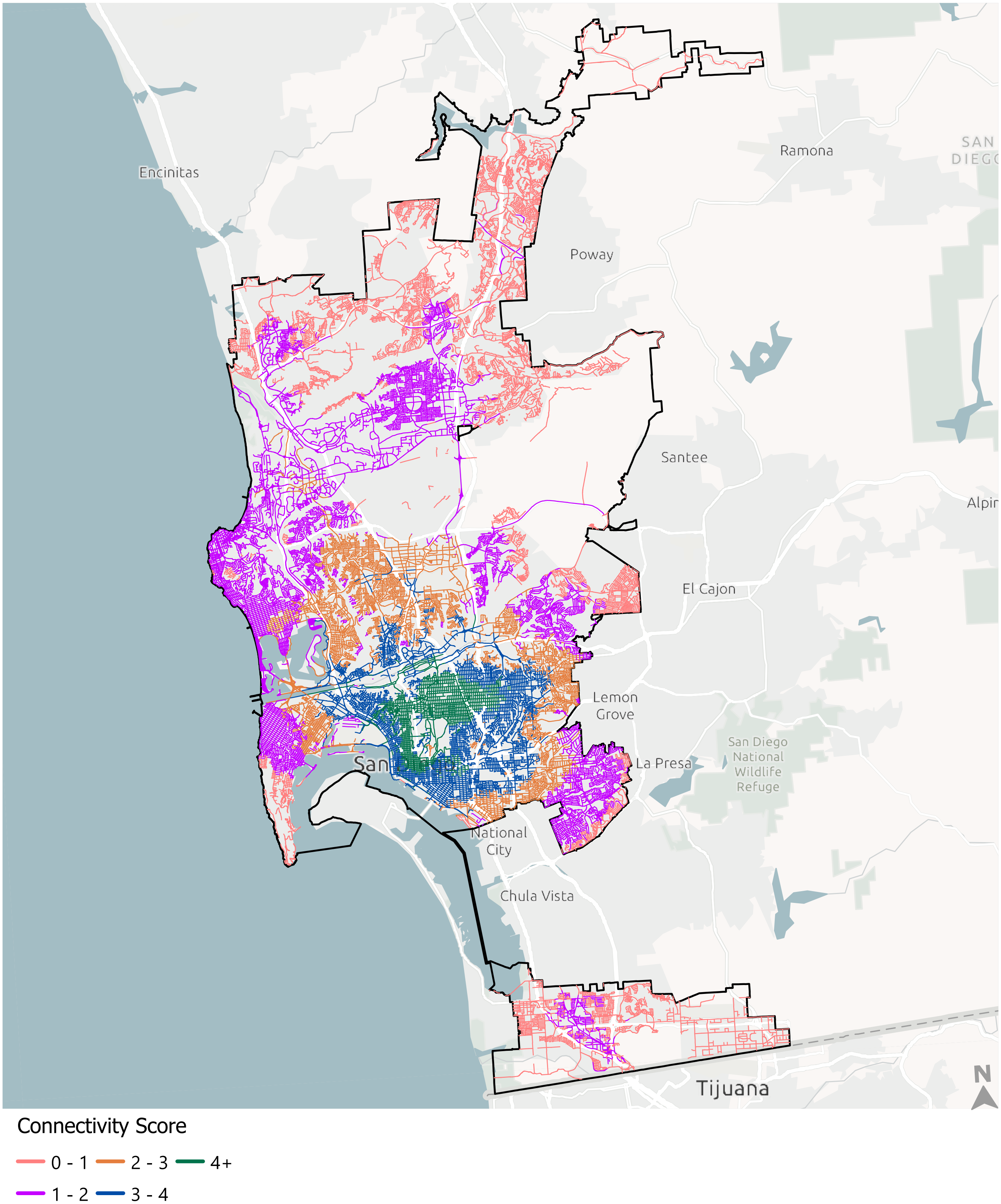
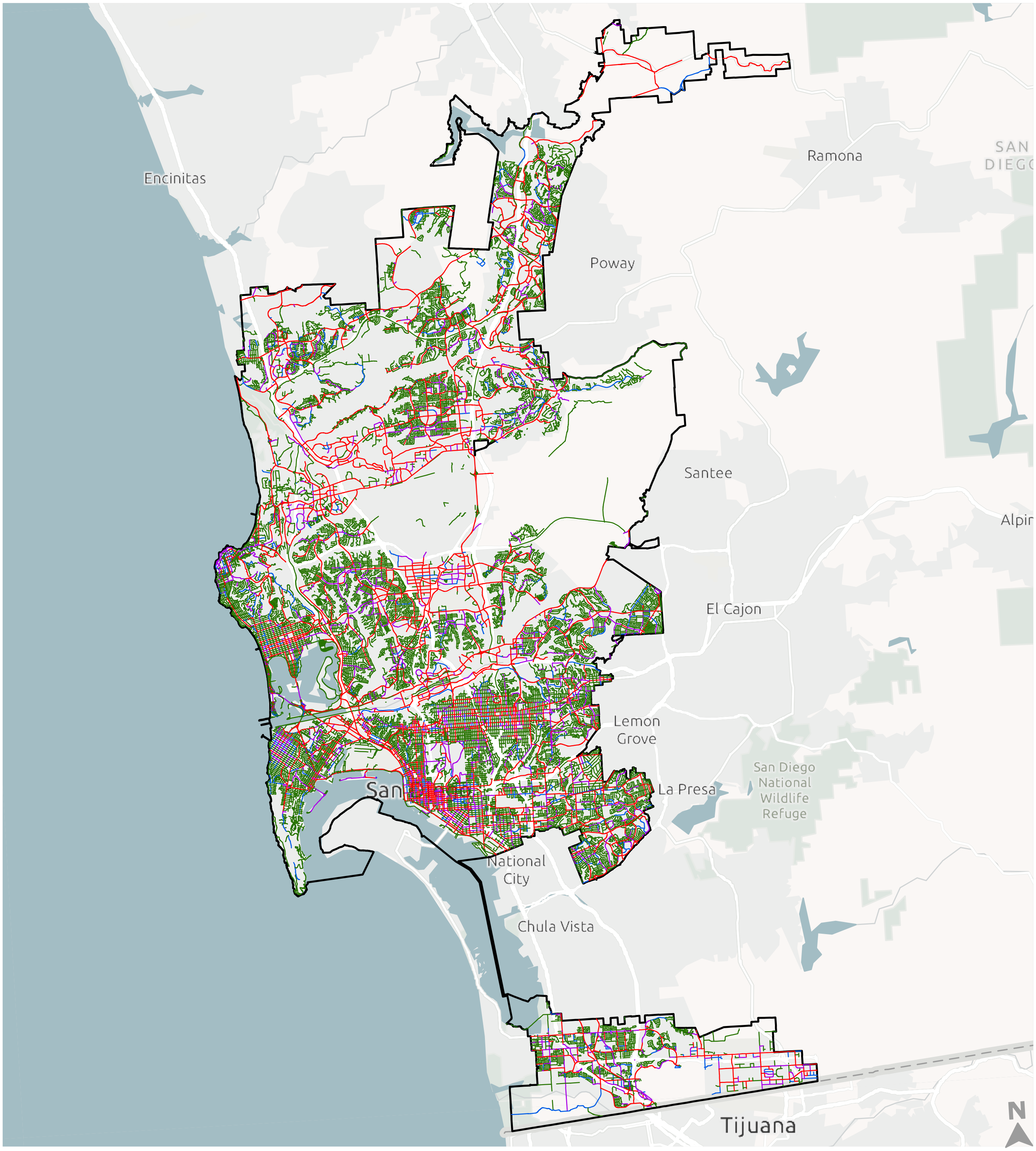


Figure 2

City of San Diego Bike Connectivity Score

Source: Fehr & Peers, 2024

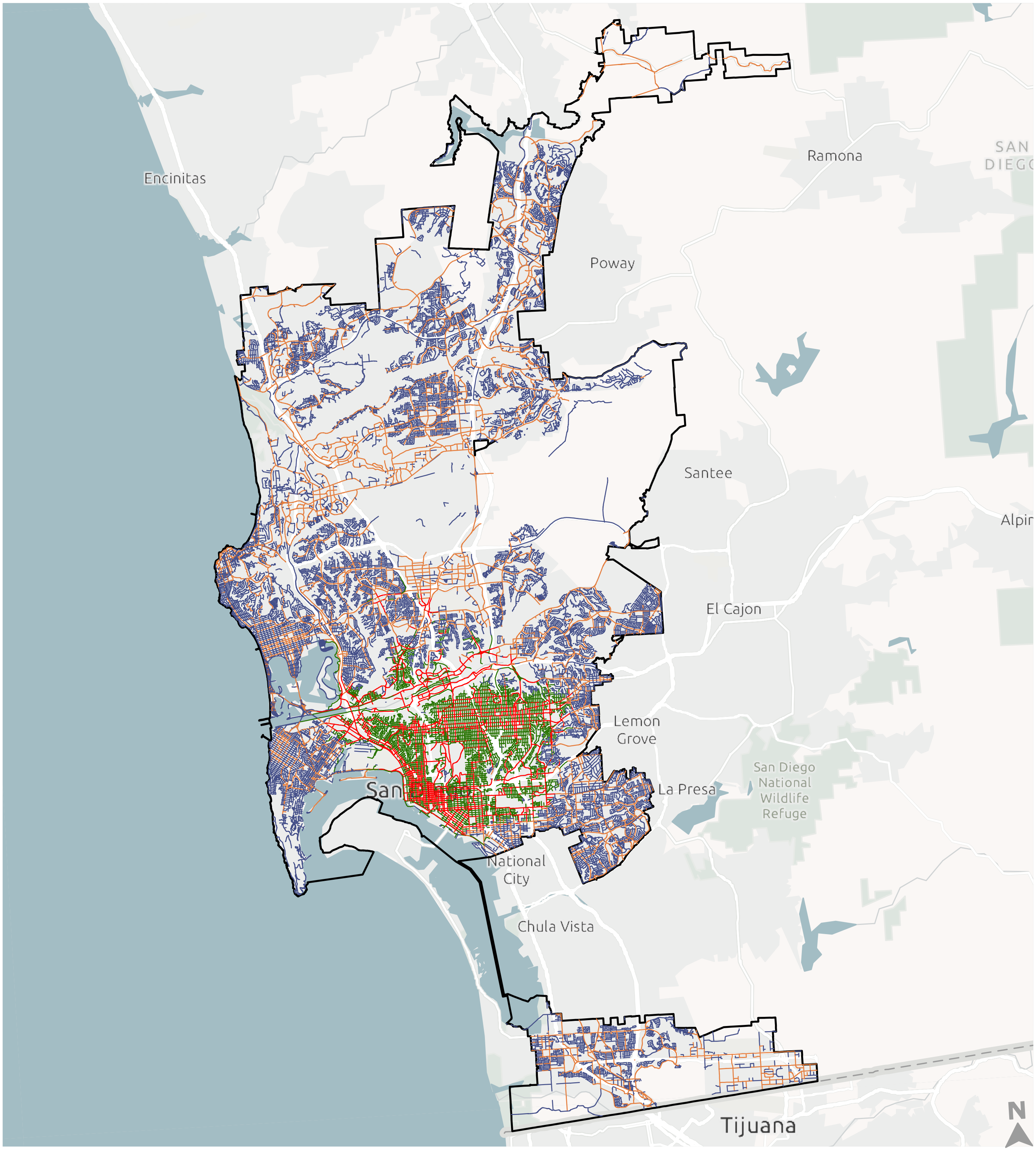


Bike Level of Traffic Stress (LTS)

1
3
2
4

Figure 3

City of San Diego Bike Level of Traffic Stress (LTS)
Source: SANDAG, 2024



High LTS / High Connectivity
Low LTS / High Connectivity
High LTS / Low Connectivity
Low LTS / Low Connectivity

Figure 4

City of San Diego Bike LTS / Connectivity

Source: Fehr & Peers, 2024