TOOLE DESIGN

2 OLIVER STREET
SUITE 305
BOSTON, MA 02109

617.619.9910
TOOLEDESIGN.COM

MEMORANDUM

August 4, 2023 (originally submitted September 7, 2022)

To: Yixuan Lin
Organization: Monroe County Department of Planning & Development
From: Theja Putta and Michael Blau
Project: Monroe County Countywide Active Transportation Plan

Re: Task 4.1 Bicycle Traffic Stress and Network Analysis – FINAL

Introduction

Network connectivity can be a difficult concept to describe, understand, and crucially to measure. While traditional methods of aggregating mileage of bike lanes or measuring as-the-crow flies distance between destinations and bike facilities are easy to measure, they fail to capture the importance of having an interconnected network of low-stress bike routes connecting people to their destinations. Bicycle Network Analysis (BNA) aims to capture the importance of the interconnectedness of bicycle routes by measuring access to destinations.

There are four main components to this analysis which are described in greater detail in the following sections of this document.

1. Data Consolidation
2. Level of Traffic Stress
3. Connectivity Analysis
4. BNA Scores

Data Consolidation

BNA requires many datasets to accurately measure and visualize a bicycle network's connectivity. These datasets do not follow the same structure, which warranted a data consolidation process so that all the necessary information can be joined to one routable network that can be used for subsequent processes in the analysis.

Routable Network

Connectivity analysis requires a routable street network consisting of segments and intersections. For this analysis, we imported a routable network from Open Street Map (OSM)[1] which is a crowdsourced geographic database of the world. The imported network contains all streets and paths where bicycle travel is allowed. It

[1] https://www.openstreetmap.org/

excludes limited-access highways, private roads, and roads that are used as driveways and alleyways that generally do not form part of the larger network. The OSM network has information needed for this analysis like number of lanes, speed limit, and bike facility information. However, this data is not always complete or up-to-date. We used the following data to complement the routable network data from OSM:

- Annual Daily Traffic (ADT)
- Speed Limit
- Number of Lanes
- Parking Lane Presence
- On-street bike facilities and off-street trails

We downloaded all datasets from the New York State Roadway Inventory Layer, with the exception of bike facilities, which the Genesee Transportation Council provided. We joined the above data to the routable OSM network using a combination of automated geospatial and manual processes. Lastly, we filled remaining data gaps that were not addressed through this data join process using assumed values based on functional classification of streets.

Level of Traffic Stress

Level of Traffic Stress (LTS) is the likely amount of stress a bicyclist faces due to roadway and traffic conditions. It was first proposed by Furth, Mekuria, and Nixon in 2012.[2] LTS values can range from 1 to 4, with LTS 1 being the lowest stress and LTS 4 being the highest stress. LTS 1 and LTS 2 are generally considered low-stress, which is acceptable to the majority of the adult population. Furth has since released updated LTS criteria (v.2.0)[3] with more refined stress values for segments. A segment's LTS value depends on factors such as number of lanes, traffic volume, speed, presence of bike facility, parking lane, width of bike lanes, etc. In addition to the stress values for a segment, there can also be stress at intersection crossings, which varies depending on the number of crossing lanes, speed, volume, and traffic control device present at the intersection.

The LTS criteria used in this analysis are a slight modification of LTS v2.0 to align with FHWA Bikeway Selection Guide thresholds and NACTO bikeway selection guidelines. In addition to offering better alignment with these guidelines, the modification also includes Toole Design's experience working with communities throughout the Mid-Atlantic and around the country to reflect real-world experiences of stress based on public input from dozens of projects. These LTS criteria are shown in Appendix A. Using the LTS criteria, every segment in the routable OSM network is assigned a stress level. In addition to the segment stress, crossing stress values are also assigned where appropriate. Generally speaking, higher crossing stress applies to lower functional class streets when they cross a higher functional class street without any intersection control like traffic signals or median crossing islands. An example from Monroe County is Hudson Avenue on the north side of Rochester, which intersects with many residential streets that are only stop-controlled.

Figure 1 shows a map of all segments in the County classified by LTS values. Many of the busier roads in the area are high-stress – unless they have a high-quality bike facility along them – which leads to a disconnected network, since low-stress residential roads do not form longer continuous routes across higher-stress roads. LTS

---

[2] Furth, P., Mekuria, M., and Nixon, H. (2012). Low-Stress Bicycling and Network Connectivity. Mineta Transportation Institute. https://transweb.sjsu.edu/sites/default/files/1005-low-stress-bicycling-network-connectivity.pdf

[3] Furth, P. (2017). Level of Traffic Stress Criteria for Road Segments, version 2.0. https://cpb-us-w2.wpmucdn.com/sites.northeastern.edu/dist/e/618/files/2014/05/LTS-Tables-v2-June-1.pdf

calculations also include feedback from local sources who identified bike boulevard segments in Rochester with traffic calming elements that have reduced traffic speeds and volumes; these segments received lower stress score as a result.

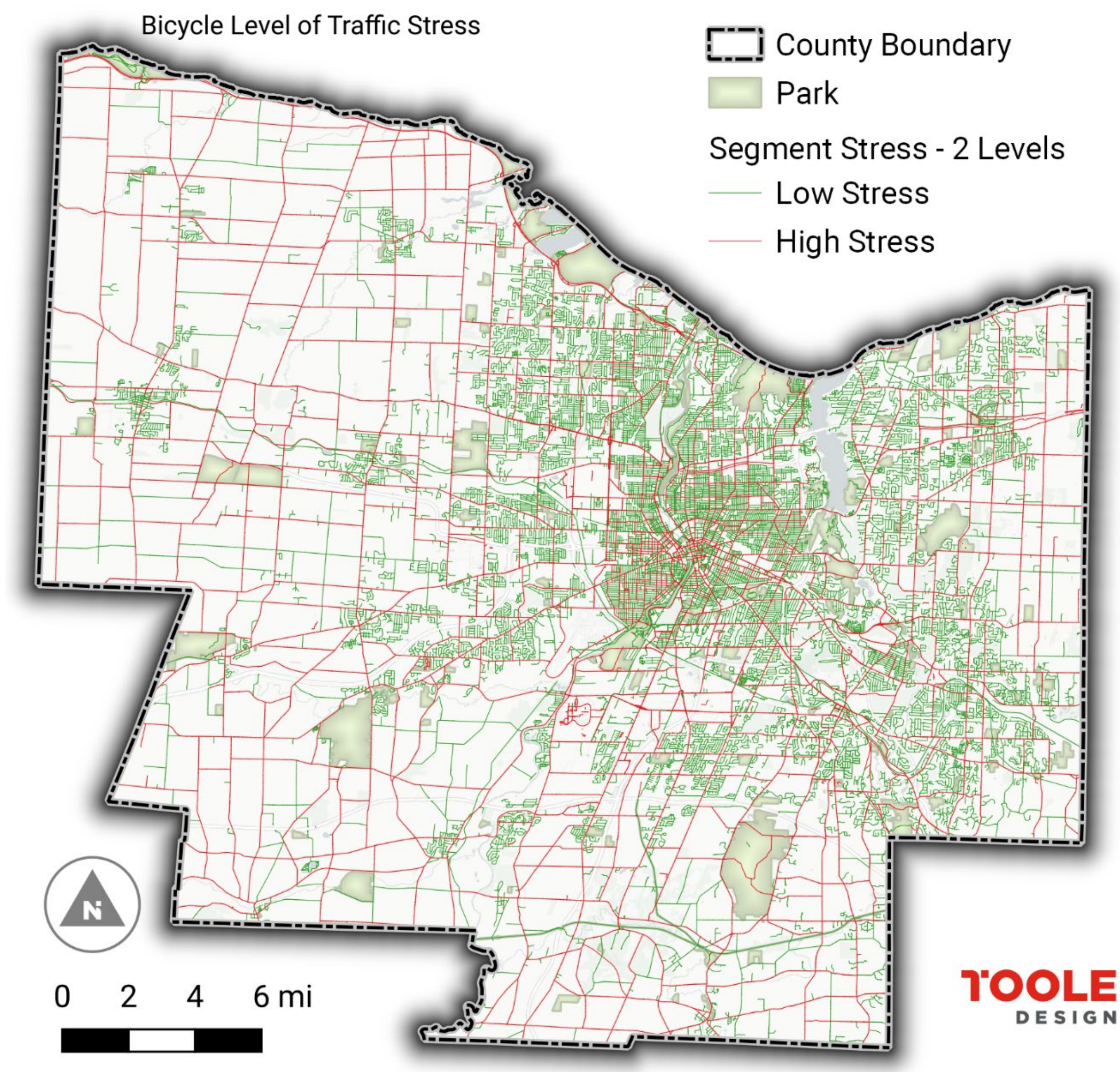

Figure 1: LTS Map of Monroe County

Connectivity Analysis

BNA performs a connectivity analysis at a block-to-block level. For each census block, a shortest path is calculated both along the low-stress network (LTS 1-2) and overall network (LTS 1-4) within three miles. Travel along the low-stress network often requires longer distances than the overall network, which can be a barrier when the low-stress distance far exceeds the overall network distance. This forces bicyclists to travel farther in order to follow more comfortable routes. To account for this, a maximum detour of 25 percent is applied to low-stress routes when compared to overall network distance. BNA's routing algorithm takes into account both segment stress and crossing stress – a low-stress route is possible only if it does not require travel along any high-stress links or across any high-stress crossings. The output of this analysis is a list of census block pairs that are connected using either the low-stress links or all links.

BNA Scores

The final step of BNA is to assign a score to each block on a scale of zero to 100 based on the destinations that can be reached using both low-stress and high-stress networks, with higher scores suggesting greater accessibility to destinations. The destinations used in the analysis include different categories based on the type of destinations. Each census block is assigned a score for each individual type of destination and scores are aggregated based on weights assigned to that destination type. Appendix B lists all destinations and their weights.

A location's BNA score depends on two factors:

1) Whether there are destinations nearby, and
2) Whether the low-stress network connects to those destinations.

In other words, the low-stress network is only one aspect of accessibility to destinations. If the low-stress network does not connect to any destinations, it is of limited value for people bicycling. In this analysis, we calculated two types of BNA measures with each one highlighting the two factors:

- Measure 1 – A measure that highlights the difference between high-stress and low-stress networks (Figure 2). Note: this is the original BNA measure and most akin to what is reported by PeopleForBikes in their online BNA portal.
- Measure 2 – A recalculated Measure 1 that incorporates destination density (Figures 3 and 4).

Measure 1

This measure first looks at the total number of destinations of each type that are connected to each block using the high-stress network. It then looks at how many of those destinations are also accessible using only the low-stress network. The magnitude of this measure depends on the difference between the destinations accessible using the two networks. If a block does not have access to a certain type of destination using the high-stress network, that destination sub score is not included in the final measure. This step ensures that only the destination types that are reachable on the network within a three-mile distance are considered in the overall measure. This measure is useful in identifying locations that have a large difference in connectivity between the low-stress and high-stress networks. The result is that some outlying areas with fewer destinations show high connectivity if those destinations are accessible by both low-stress and high-stress networks.

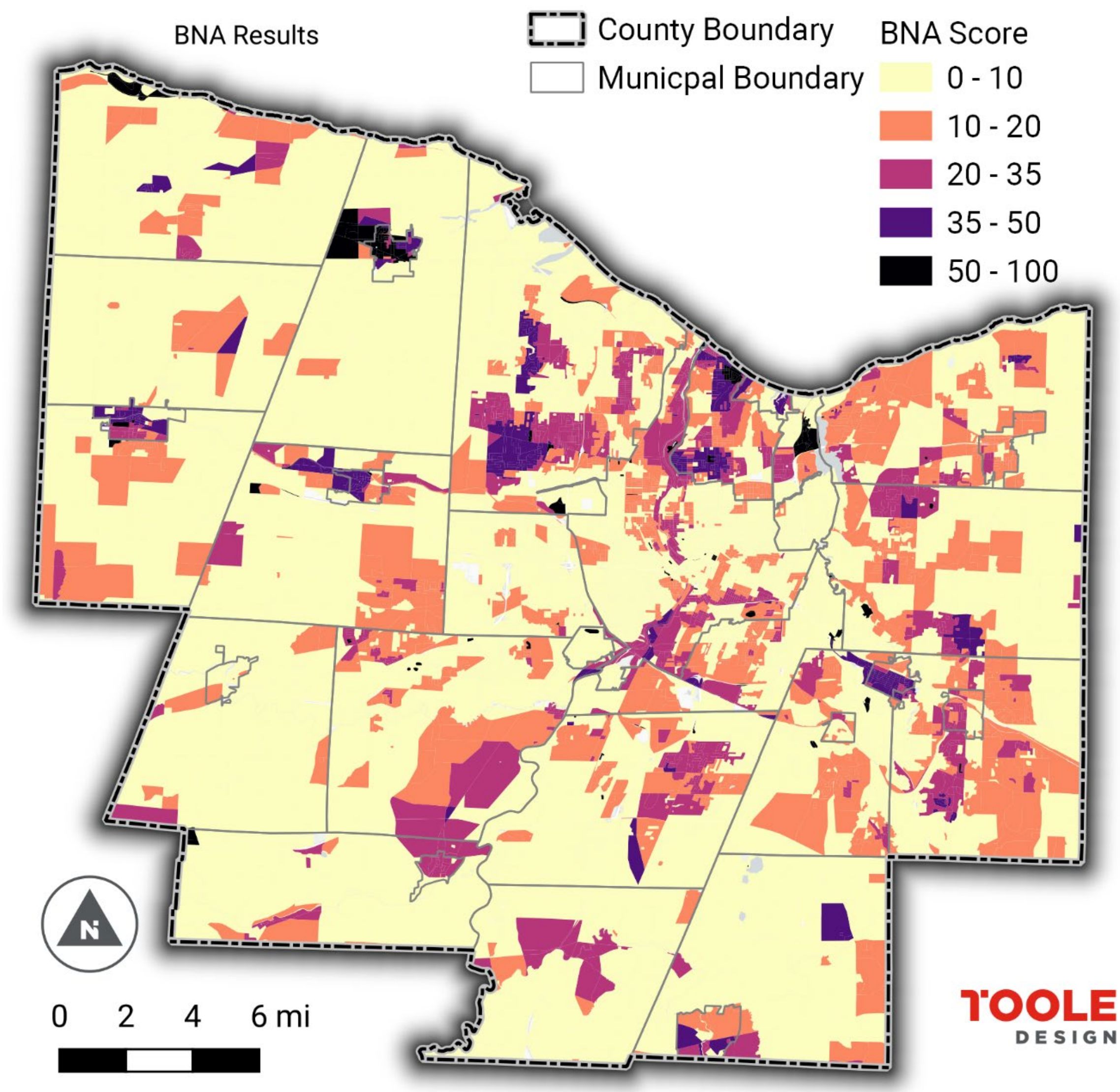

Figure 2: BNA Score - Measure 1

Measure 2

Like Measure 1, this measure starts by looking at the number of destinations reachable using high-stress and low-stress networks from each block. However, any block without overall network access (including high-stress routes) to a given destination type automatically gets a score of zero for that destination type. This means that blocks with higher scores have more destinations nearby and those destinations are accessible by the low-stress network, whereas in Measure 1, blocks can get higher scores even if there are not many destinations nearby. This measure is a useful way to combine the effect of both the low-stress network and proximity to destinations. As a result, destination-rich areas get higher scores than the outlying areas if those destinations are accessible using the low-stress network.

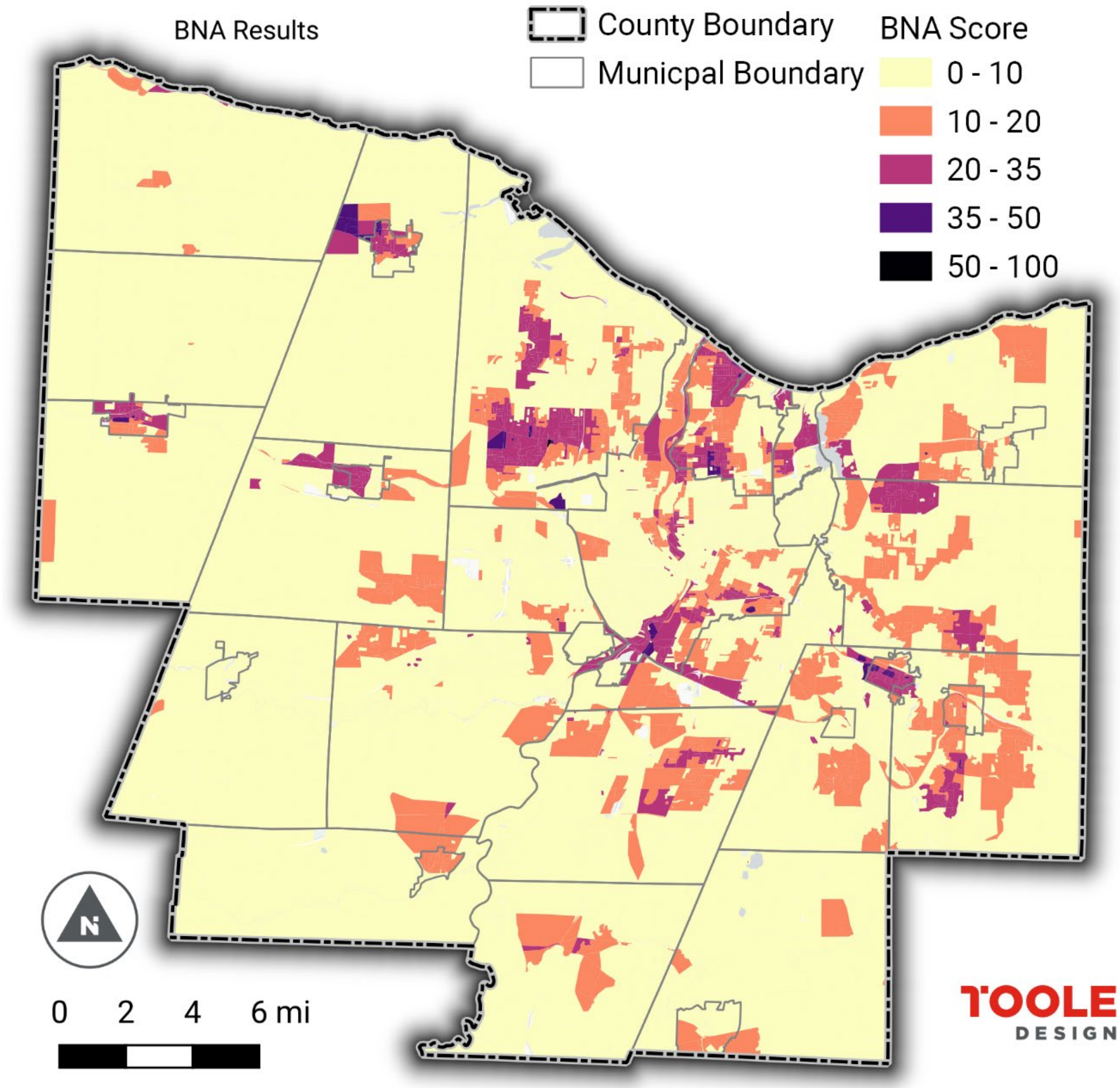

Figure 3: BNA Score - Measure 2

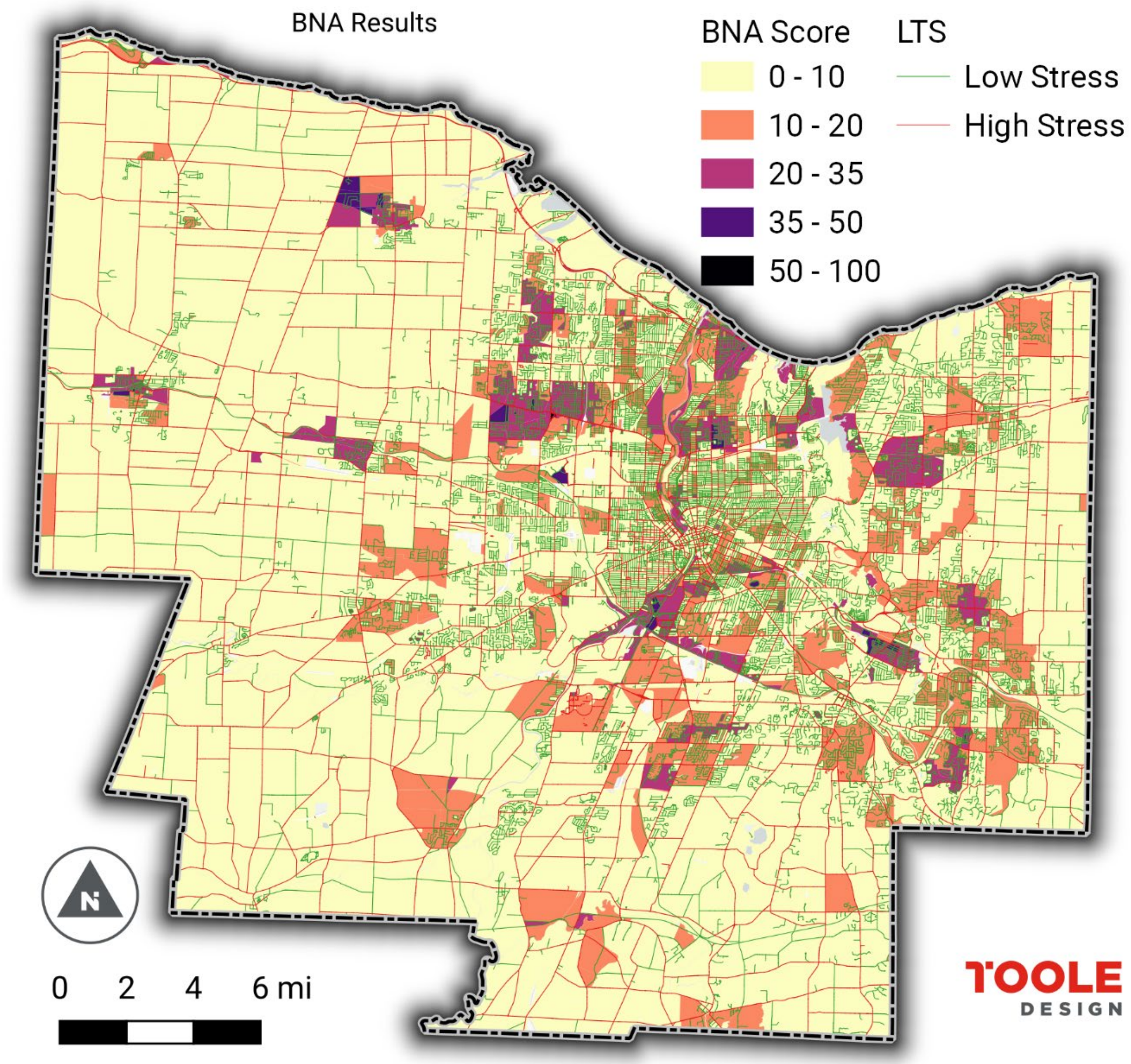

Figure 4: BNA Measure 2 and LTS Scores

Caveats

BNA scores for large census blocks should be treated with caution and some skepticism. Block sizes in rural areas are large, and if a rural census block has access from one part of the block to the low-stress network, it may score highly. For example, the larger census blocks in Honeoye Falls score higher than the surrounding area because destinations are accessible via one or two low-stress routes (there are fewer routing options in rural areas), which increases the score significantly. Conversely, large census blocks with few routing options may have especially low scores if those routes do not provide any access to destinations.

Key Findings[4]

Preliminary observations from the BNA results are listed below. We anticipate refining this section with the help of Monroe County and the Project Advisory Committee.

- Connectivity is limited within Rochester to two areas:
  1. The south side, particularly the neighborhoods along the Genesee Riverway Trail (Plymouth-Exchange, South Wedge, University of Rochester, and Strong Memorial Hospital campus).
  2. The north side, particularly the neighborhoods along the Genesee Riverway Trail (Edgerton, Upper Falls, Riverside Cemetery area, parts of the Maplewood Historic District, and Charlotte).

  The east and west sides of Rochester have low scores, with some minor exceptions.
- The greatest low-stress connectivity in the region is across the river from northwest quadrant of Rochester, in the southwest portion of Irondequoit. This area includes Ridge Road, Titus Avenue, St Paul Boulevard, and many smaller residential streets. The area mostly lacks bicycle infrastructure, but may score highly due to the number of destinations accessible within isolated blocks of low-stress connections. Destinations in this area include schools, parks, retail, and homes, as well as core services (see Appendix B).
- The west side of Monroe County scores low on the BNA. Most parts of the Towns of Hamlin, Clarkson, Riga, and Wheatland score between zero and 10. This is likely due to fewer destinations in those areas, plus a lack of bicycle infrastructure and low-stress routes. Communities along the Canal Trail are an exception, with the Villages of Brockport and Spencerport scoring higher than their surroundings. Outside of Spencerport, the Town of Ogden also has higher connectivity, most likely due to the Canal Trail.
- Low-stress connectivity is higher though still disjointed among suburban communities on the east and south sides of Rochester. The Towns of Webster, Penfield, Pittsford, Brighton, Perinton, Henrietta, and Mendon all score moderately, with pockets of higher connectivity in villages (such as East Rochester and Honeoye Falls), as well as the Rochester Institute of Technology, the commercial area around Empire Park in Webster and Penfield, and the southeast corner of Chili.

Next Steps

Once the BNA outputs are reviewed and approved by Monroe County and the PAC, the project team will compare the results to the trip potential analysis to find areas with high active transportation potential and low connectivity. We will also overlay results with public engagement comments from in-person events and the online webmap. Areas in need of improvement according to both analysis results and public feedback will serve as a starting point to develop a high-level proposed active transportation network that includes corridors and roadways primed for active transportation.

---

[4] All findings refer to Measure 2.

APPENDIX A

LTS Tables

Mixed traffic criteria

Number of lanes	Effective ADT*	Prevailing Speed ≤ 20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50+mph
Unlaned 2-way street (no 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 4	LTS 4
	1501-3000	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 3	LTS 3	LTS 4	LTS 4	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 4	LTS 4
	1501-3000	LTS 2	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4
	3001-6000	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
	6001-10000	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
	10001+	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
2 thru lanes per direction	0-6000	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	6001-12000	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
	12001+	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
3+ thru lanes per direction	any ADT	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4

* Effective ADT = ADT for two-way roads; Effective ADT = 1.67*ADT for one-way roads

Bike lanes and shoulders not adjacent to a parking lane

Number of lanes	Bike lane width	Prevailing Speed ≤ 25 mph	30 mph	35 mph	40 mph	45 mph	50+ mph
1 thru lane per direction, or unlaned	6+ ft	LTS 1	LTS 1	LTS 2	LTS 3	LTS 3	LTS 4
	4 or 5 ft	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4
2 thru lanes per direction	6+ ft	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	LTS 4
	4 or 5 ft	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	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, use 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.

Bike lanes alongside a parking lane

Number of lanes	Bike lane reach = Bike + Pkg lane width	Prevailing Speed ≤ 20 mph	25 mph	30 mph	35 mph	40+ mph
1 lane per direction	15+ ft	LTS 1	LTS 1	LTS 2	LTS 2/3*	LTS 4
	14 ft	LTS 2	LTS 2	LTS 2/3*	LTS 3	LTS 4
	12-13 ft	LTS 2	LTS 2/3*	LTS 2/3*	LTS 3	LTS 4
2 lanes per direction (2-way) 2-3 lanes per direction (1-way)	15+ ft	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
	14 ft	LTS 2/3*	LTS 2/3*	LTS 3	LTS 4	LTS 4
	12-13 ft	LTS 2/3*	LTS 2/3*	LTS 3	LTS 4	LTS 4
other multilane		LTS 3	LTS 3	LTS 3	LTS 4	LTS 4

Notes
1. If bike lane is frequently blocked, use mixed traffic criteria.
2. Qualifying bike lane must have reach (bike lane width + parking lane width) ≥ 12 ft
3.Bike lane width includes any marked buffer next to the bike lane.
* Rating depends on parking turnover. Low turnover (i.e. residential) = LTS 2, high turnover (i.e. commercial or mixed use) = LTS 3

APPENDIX B

BNA Destinations

Category	Category Weight	Category Destinations	Destination Weight
People	15	Population - Block level	N/A
Opportunity	25	Jobs - Block level	35
		Schools	35
		Colleges	10
		Universities	20
Core Services	25	Doctors	20
		Dentists	10
		Hospitals	20
		Pharmacies	10
		Supermarkets	25
		Social Services	15
Recreation	10	Parks	60
		Community Centers	40
Retail	15	Retail Locations from OSM	N/A
Transit	10	Bus stops and stations from OSM	N/A