Measuring Multimodal Network Connectivity

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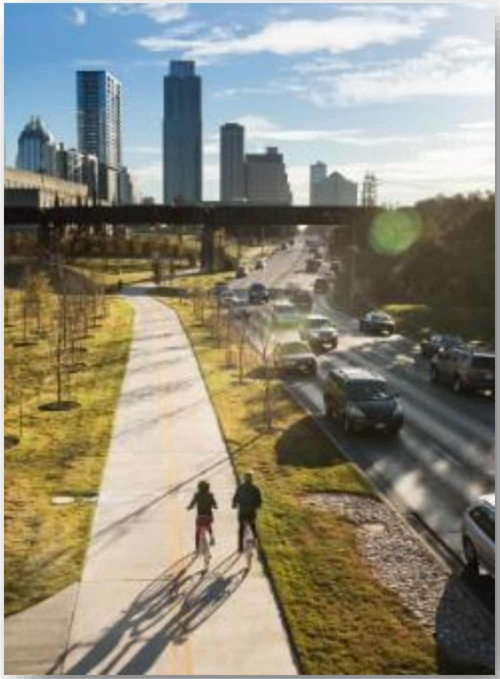

Tuesday, April 24, 2018

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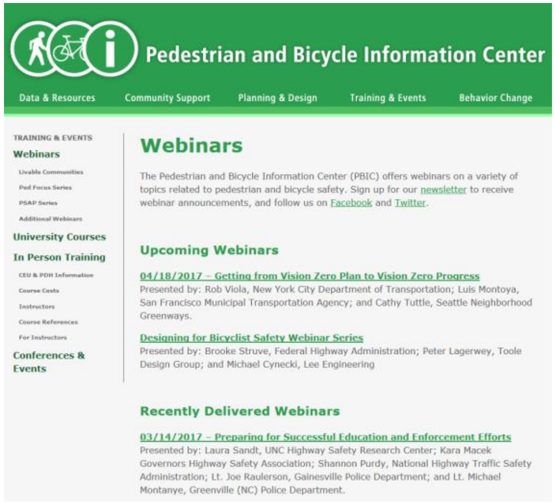

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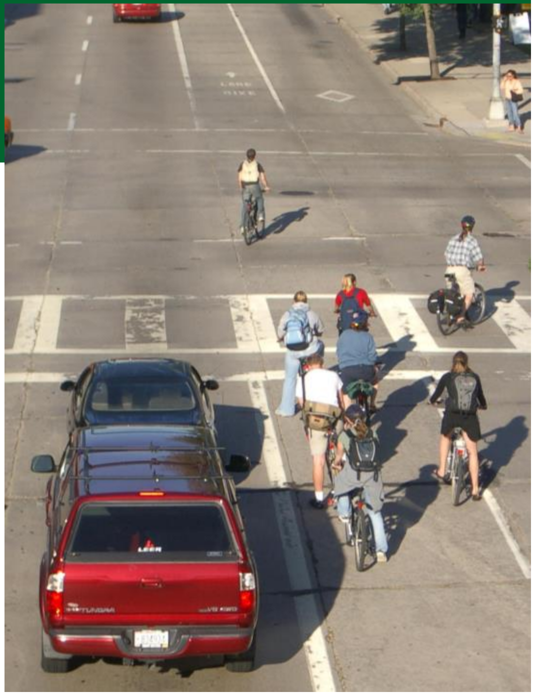

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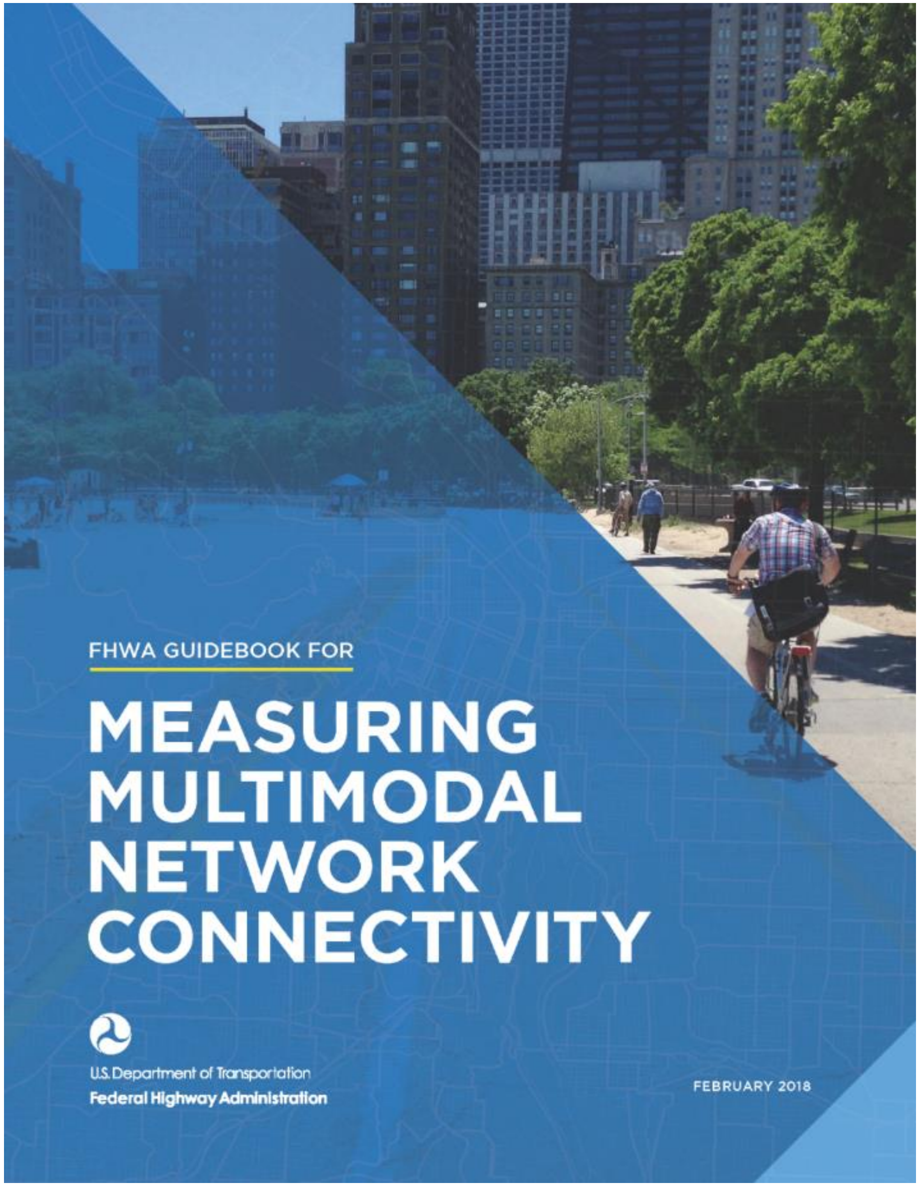

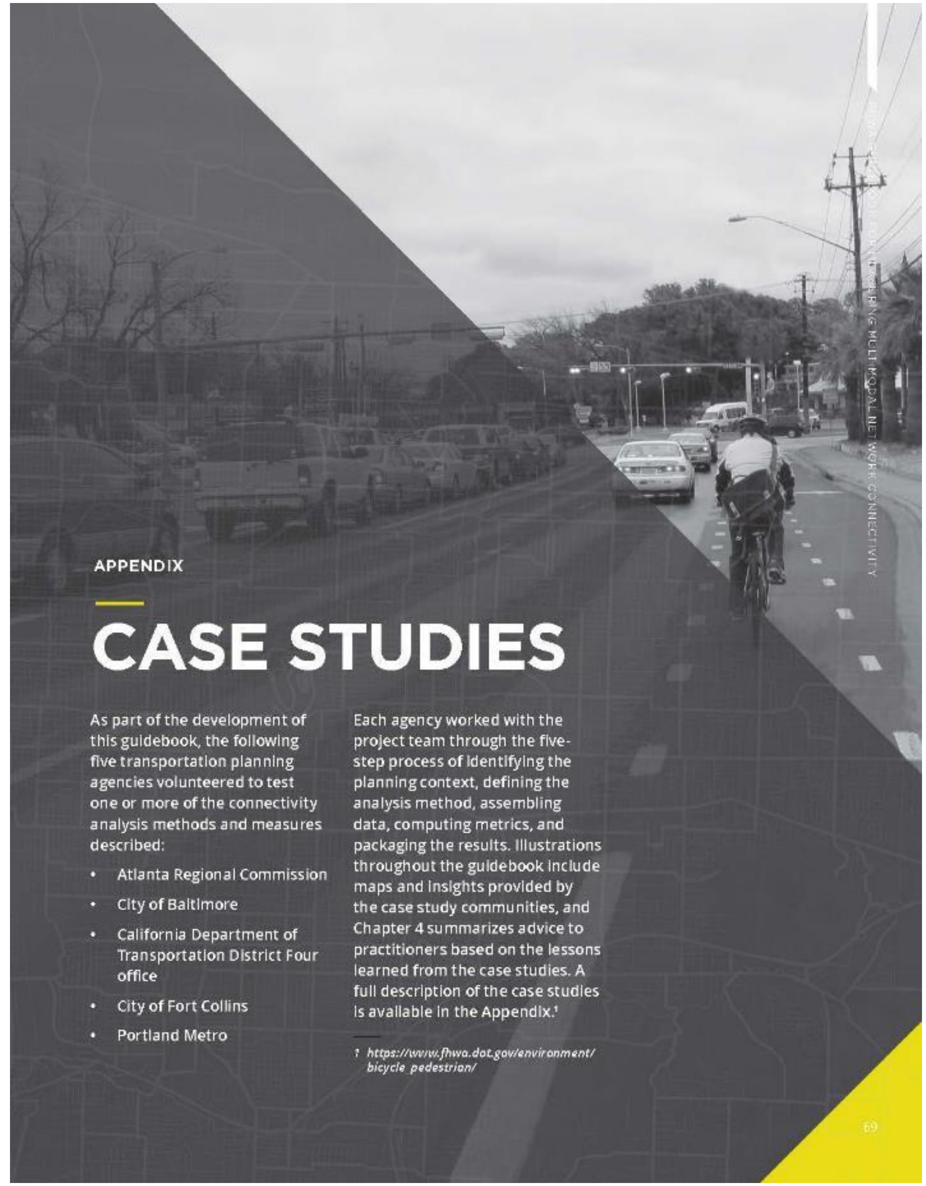

APPENDIX

CASE STUDIES

As part of the development of this guidebook, the following five transportation planning agencies volunteered to test one or more of the connectivity analysis methods and measures described:

- Atlanta Regional Commission
- City of Baltimore
- California Department of Transportation District Four office
- City of Fort Collins
- Portland Metro

Each agency worked with the project team through the five-step process of identifying the planning context, defining the analysis method, assembling data, computing metrics, and packaging the results. Illustrations throughout the guidebook include maps and insights provided by the case study communities, and Chapter 4 summarizes advice to practitioners based on the lessons learned from the case studies. A full description of the case studies is available in the Appendix.[1]

1 https://www.fhwa.dot.gov/environment/bicycle_pedestrian/

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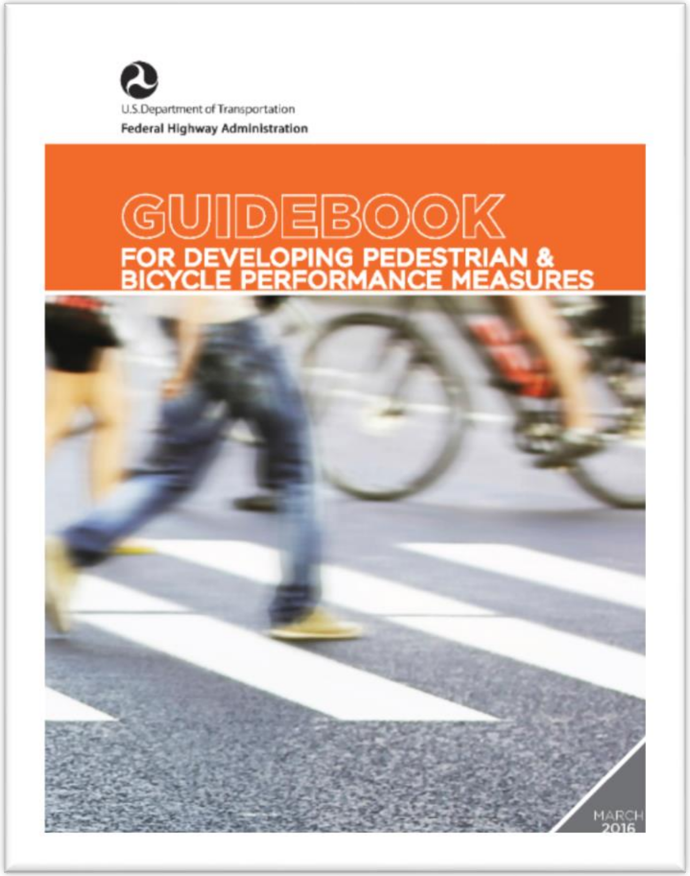
www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_connectivity

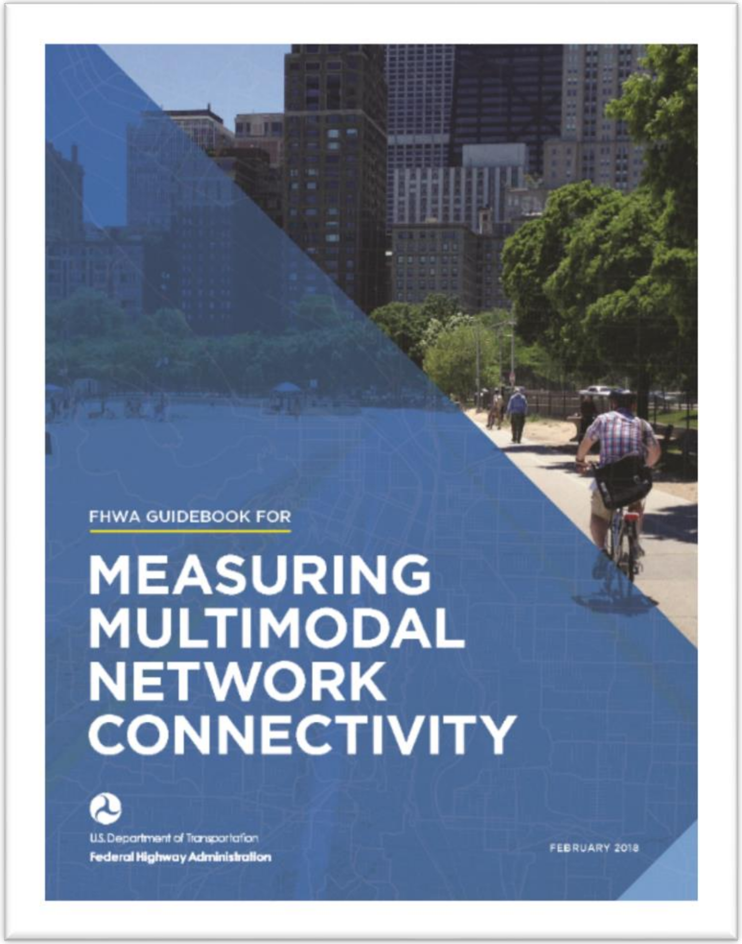
Project Team

- FHWA
  - Technical Leaders: **Gary Jensen**, Christopher Douwes
  - Reviewers: Wesley Blount, Bruce Friedman, Elizabeth Hilton, Dave Kirschner, Jeremy Raw, Gabe Rousseau, Shari Schaftlein
  - Special thanks to Dan Goodman
- Consultant Advisors
  - ICF: **Hannah Twaddell**, Jon Walker, Lindsay Martin; special thanks to Eliot Rose
  - Alta Planning + Design: **Kim Voros**, Hugh Louch, Cat Cheng; Erin David; special thanks to Frank Proulx
  - Portland State University Transportation Education and Research Center: **Joseph Broach,** Jennifer Dill, Kelly Clifton, Claire Lust

Companion Guides



www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/performance_measures_guidebook



www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_connectivity

Methodology

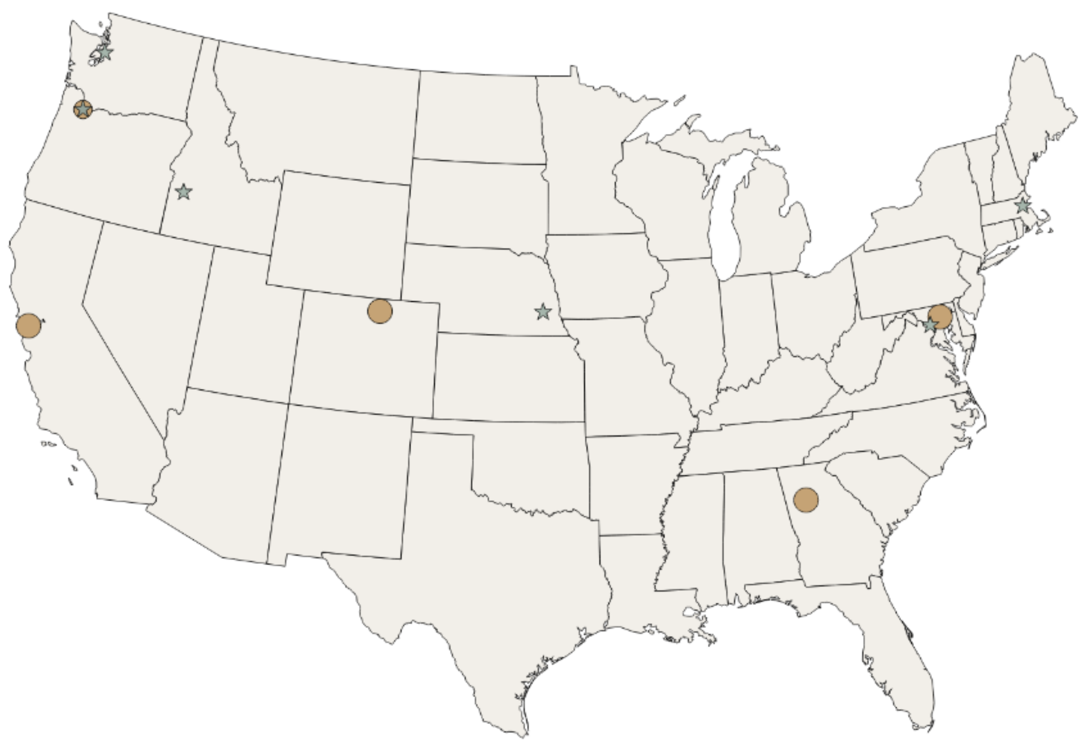
Research & Practice Scan

Case Studies (5 Agencies)

Phone Interviews (8 agencies)

57 articles & reports

61 planning documents

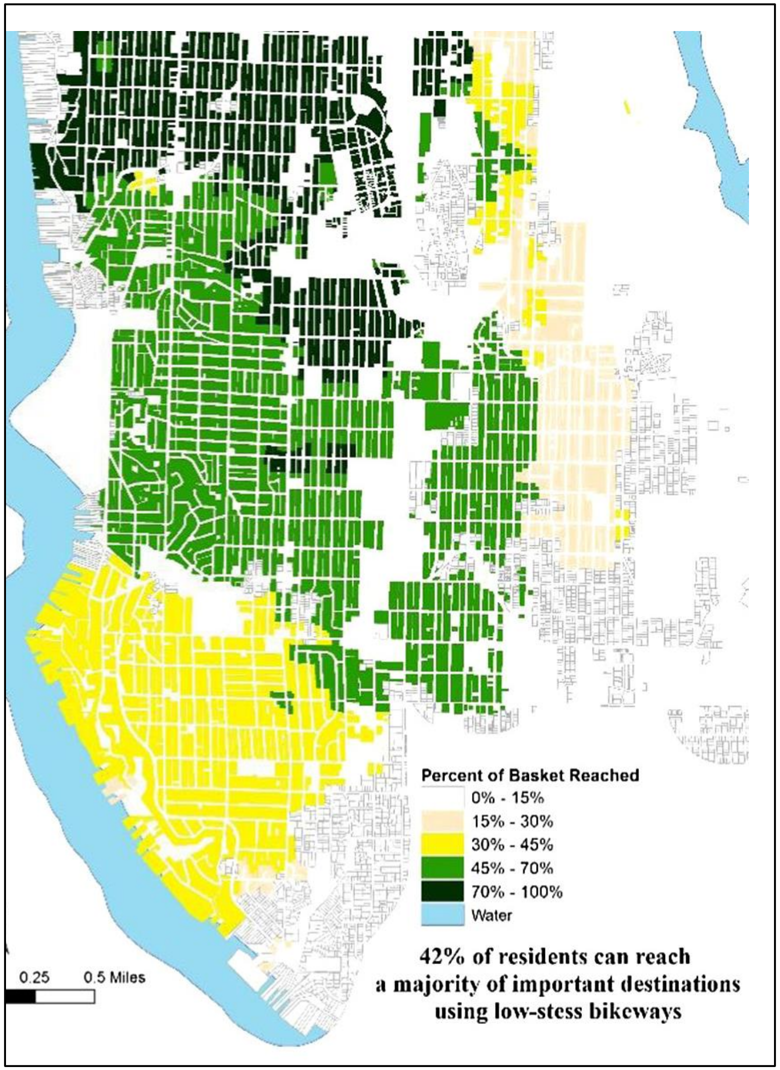


Who’s On the Line?

- What type of agency/ organization do you represent?
  - Federal Agency
  - State Agency
  - Regional Agency (e.g., MPO, Regional Commission/ Council)
  - Local Agency (e.g., City, County, Municipality)
  - Nonprofit agency
  - Consultant practice
  - Other

What is multimodal connectivity?

- Networks are accessible, interconnected pedestrian and/or bicycle transportation facilities that allow all users to safely and conveniently get where they want to go.
- Connectivity is the extent to which bicyclists and pedestrians can make comfortable trips from beginning to end when traveling to destinations throughout a community.



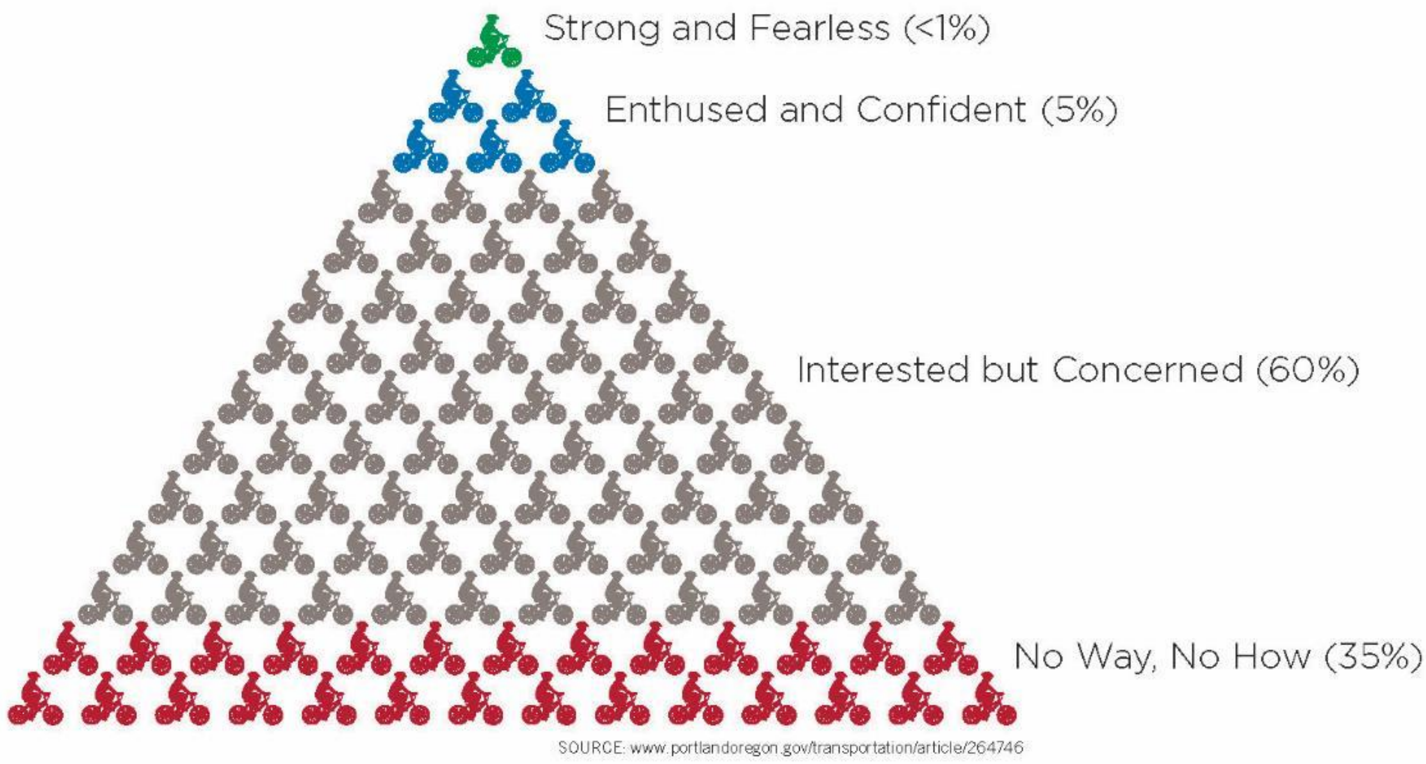
Map credit: Lowry 2016

Why Measure Multimodal Connectivity?

- Set goals and track progress
- Compare alternative plan scenarios
- Prioritize projects that close gaps and resolve barriers
- Advance goals for safety, equity, health, and quality of life

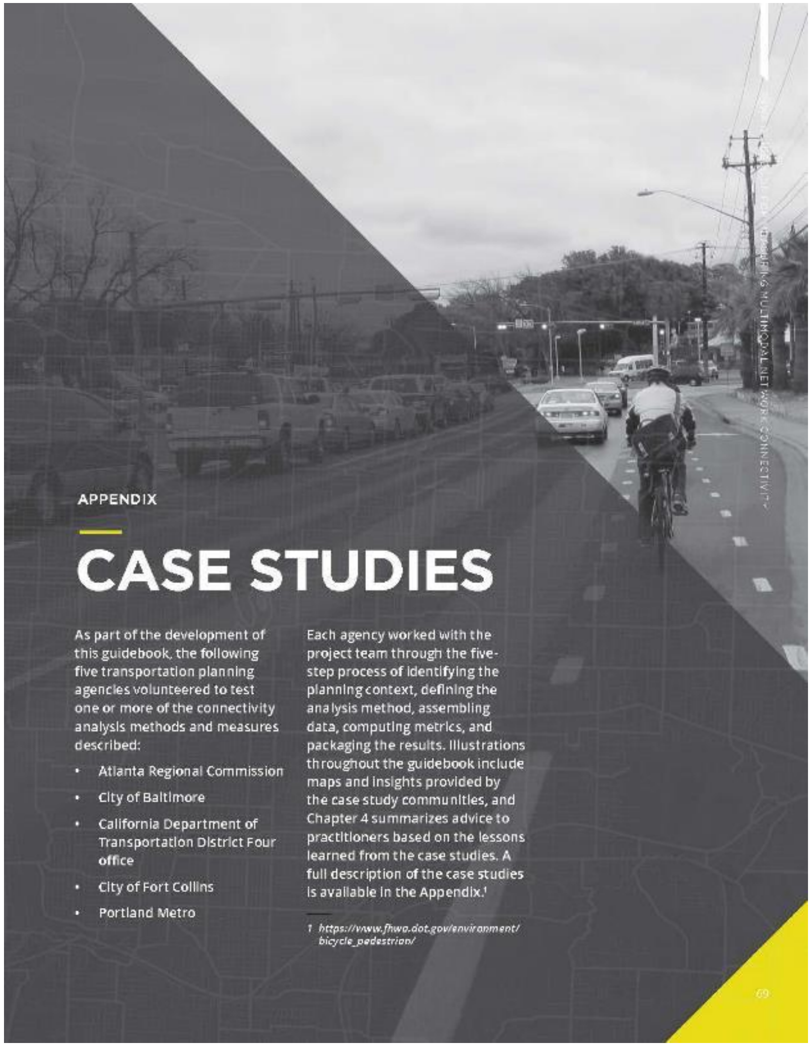
Photo credit: Second Wave Media

Who Needs Multimodal Connectivity?



Case Study Stories

Agency, *Lead Staff*	Project
Atlanta Regional Commission, *Byron Rushing*	Connectivity measure to support livable centers
City of Baltimore, *Valorie LaCour, Jay Decker*	Measuring pedestrian connectivity in a dense urban area
Caltrans, *Sergio Ruiz*	Bicycle connectivity across highways
City of Fort Collins, *Tessa Gregor*	Bicycle network assessment comparison
Portland Metro, *Lake McTighe*	Regional connectivity measures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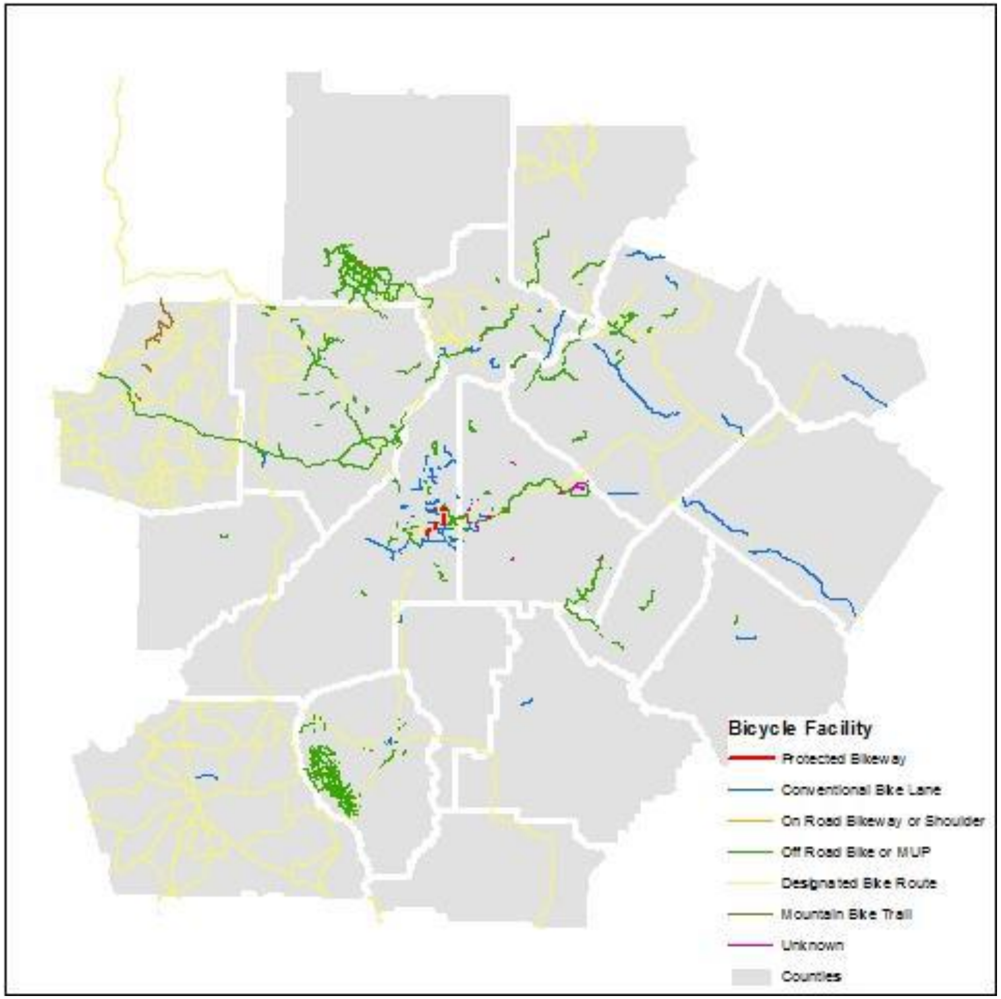
1 https://www.fhwa.dot.gov/environment/bicycle_pedestrian/

Atlanta Regional Commission

- Develop standard local bicycle connectivity measures and analysis methods for low stress facilities
- Identify projects for regional Livable Communities Initiative grant program
- Achieve regional bicycle connectivity goals



Atlanta Regional Commission

- Midtown: Main center, has numerous facilities. Plan: add protected facilities along key routes.
- Decatur: Walkable town center. Plan: connect commercial areas to regional trails.
- Perimeter: North suburban activity center, large mall, big-box retail. Plan: Add bike facilities.
- Woodstock: North suburban city center. Plan: expand on and off-street bike path network.
- West End: Historic neighborhood. Plan: improve local/ regional bike access.

Midtown

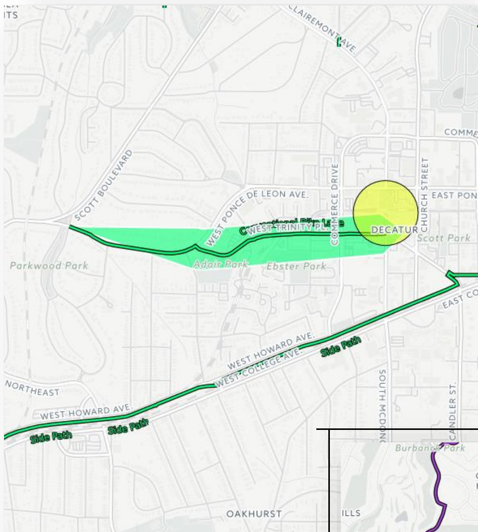
Decatur

Perimeter

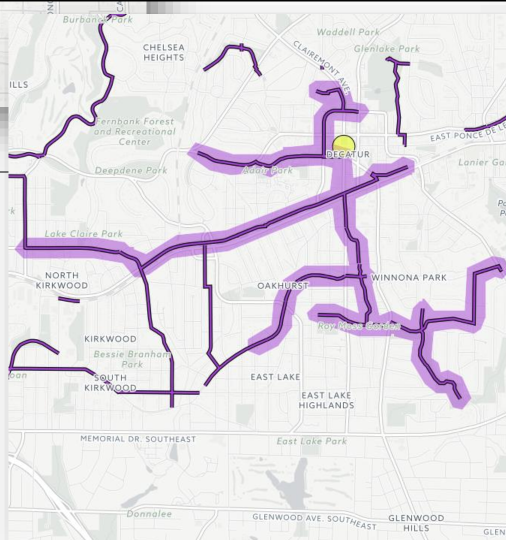
Woodstock

West End

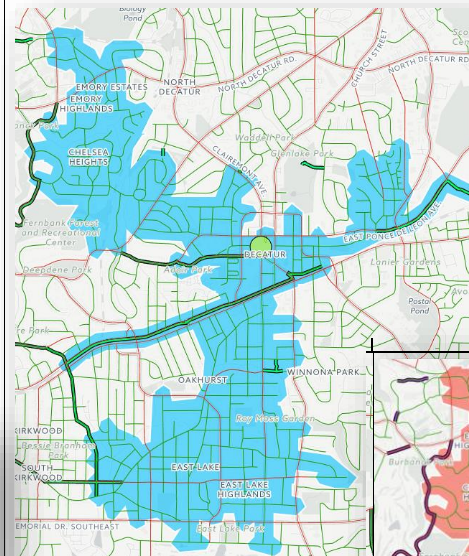
Decatur Transit Station Area Example



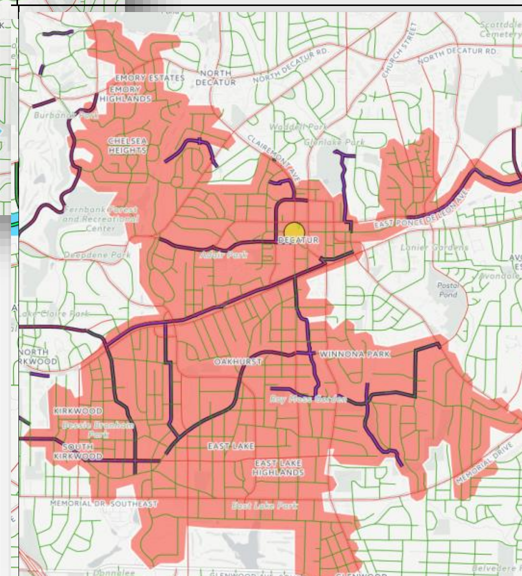
Current Facilities



Planned Facilities



Current Low Travel Stress Network

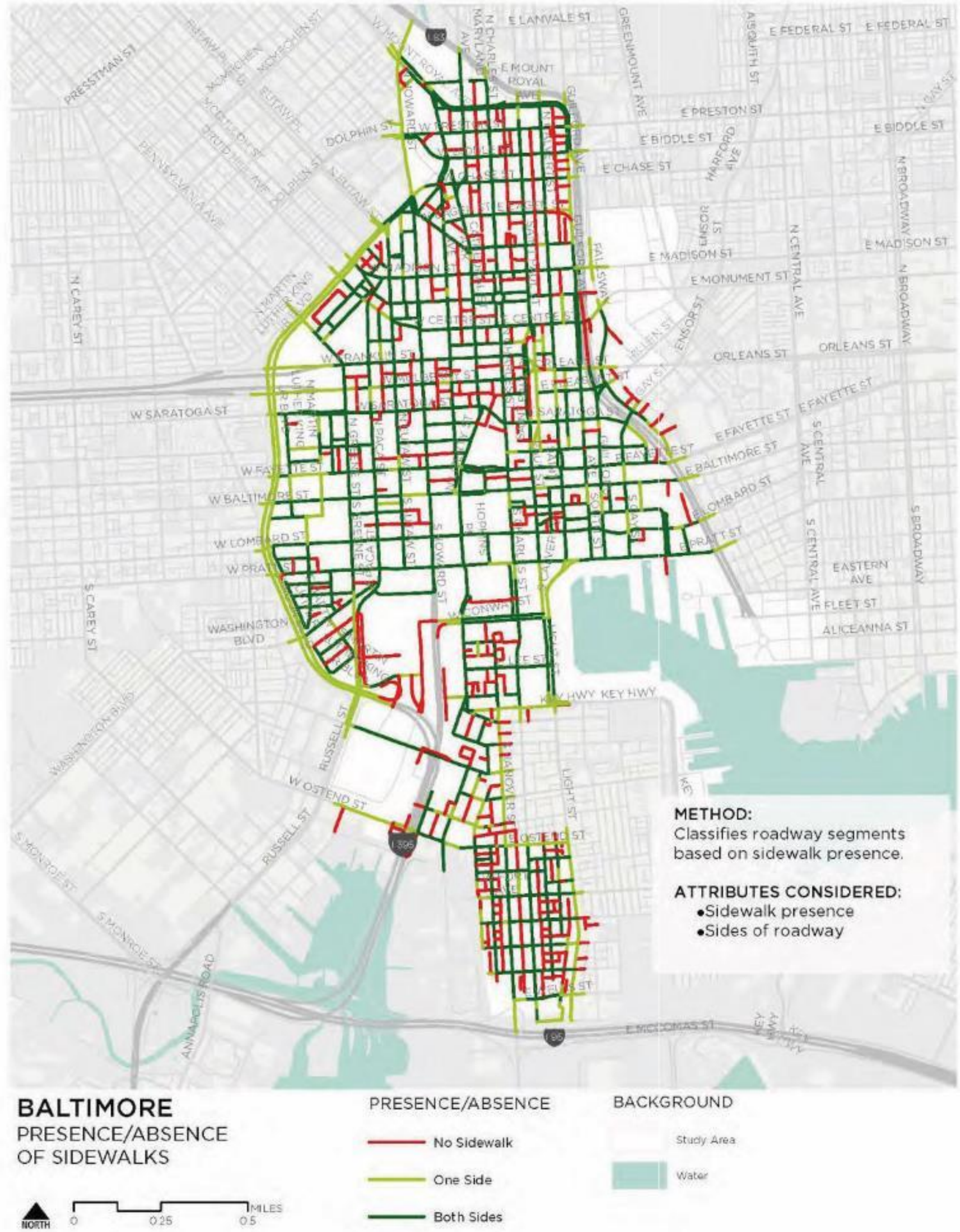


Planned Low Travel Stress Network

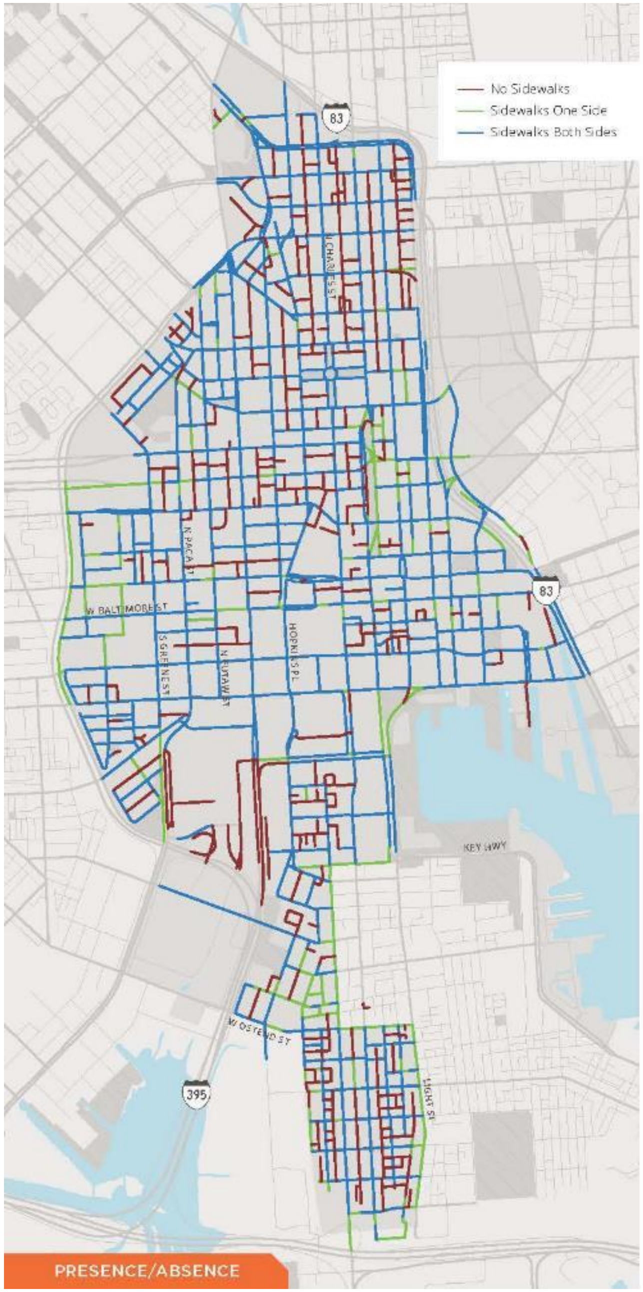
City of Baltimore

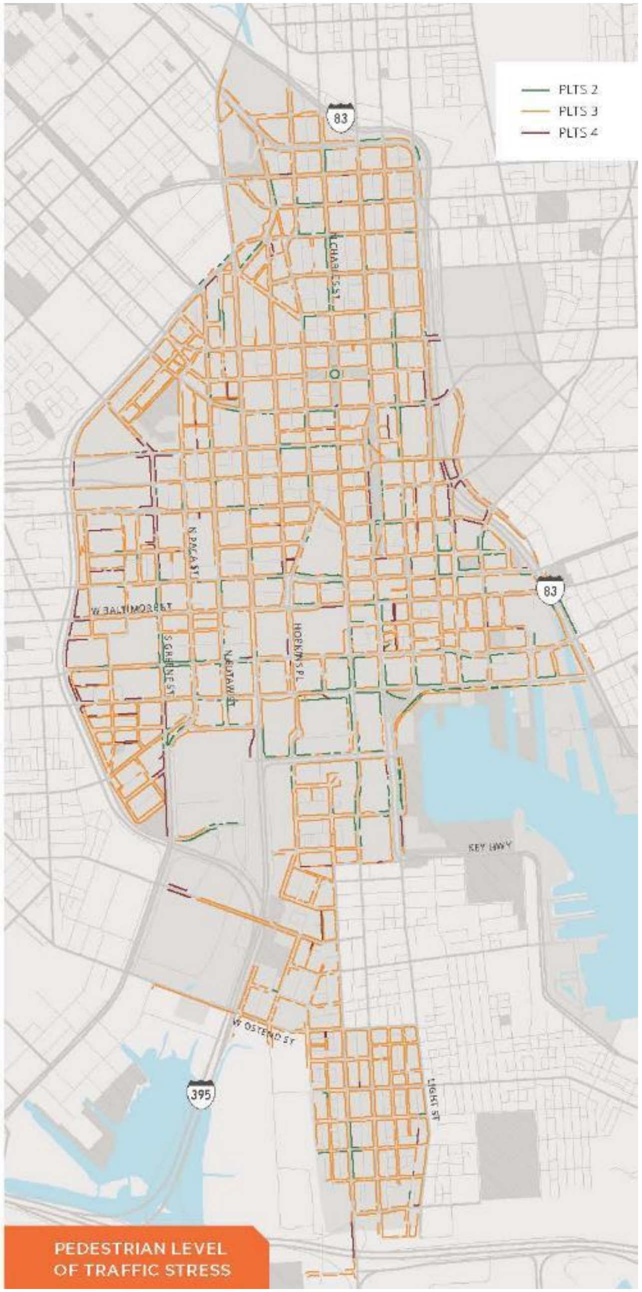
City of Baltimore

- What does connectivity assessment look like in a robust network?
- Focus on accessibility



Measuring Multimodal Network Connectivity



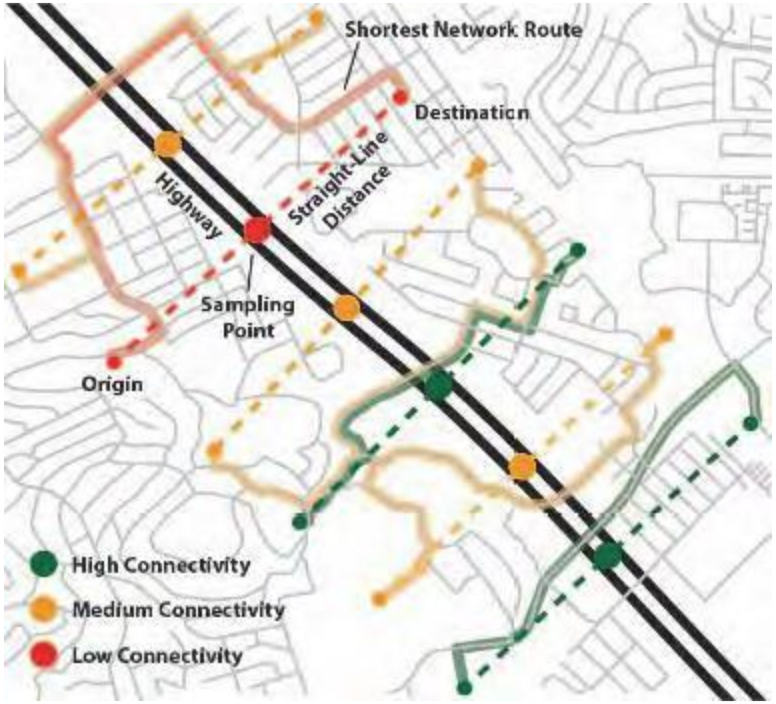


Caltrans District Four

- Plan assesses network need for crossing improvements by overlaying:
  - Potential bicycle demand
  - Supply and quality of bicycle access
  - Safety
  - User comments

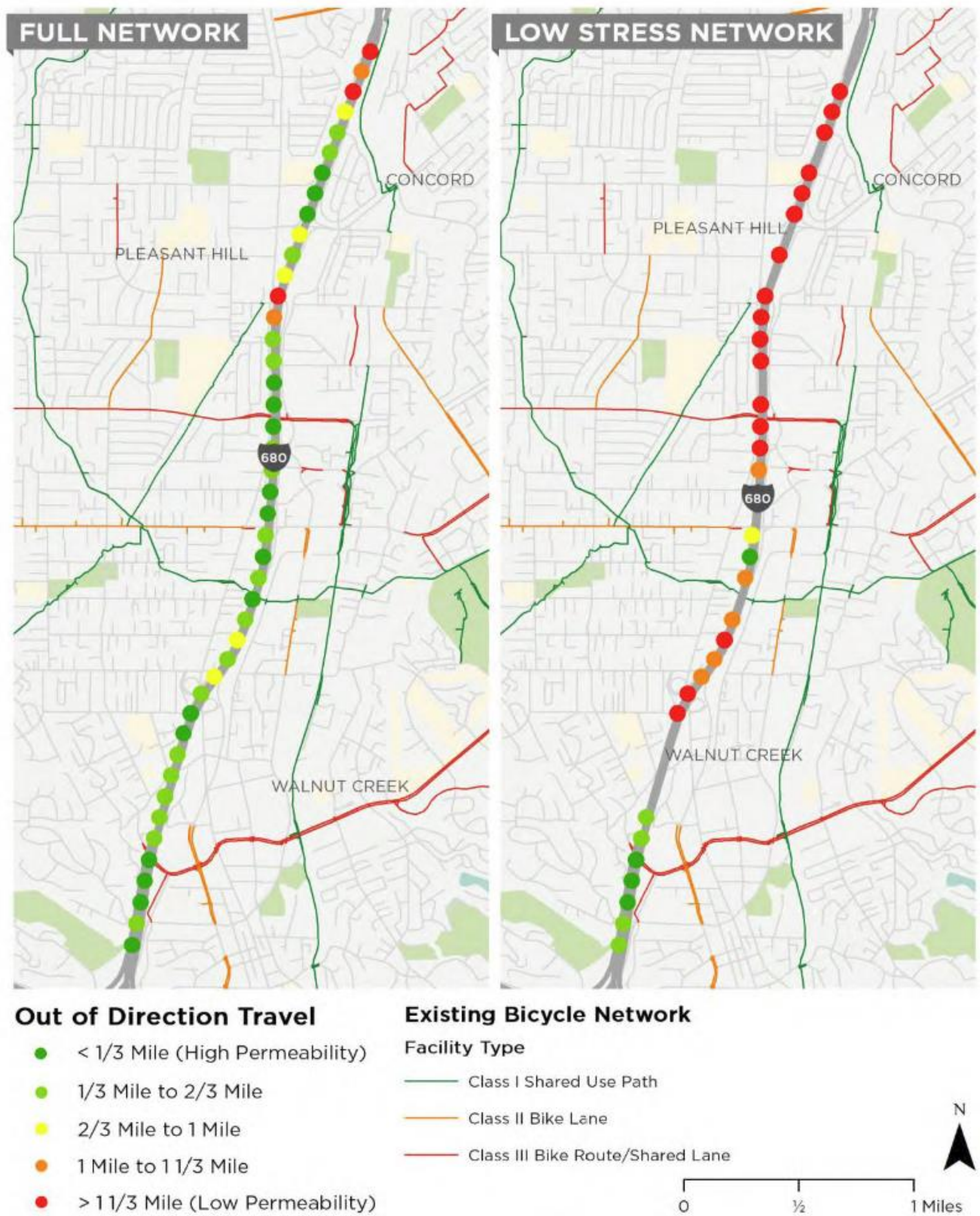
Caltrans District Four

- Route Directness Index (RDI) used to assess the crossing quality and opportunity at regular points along the corridor



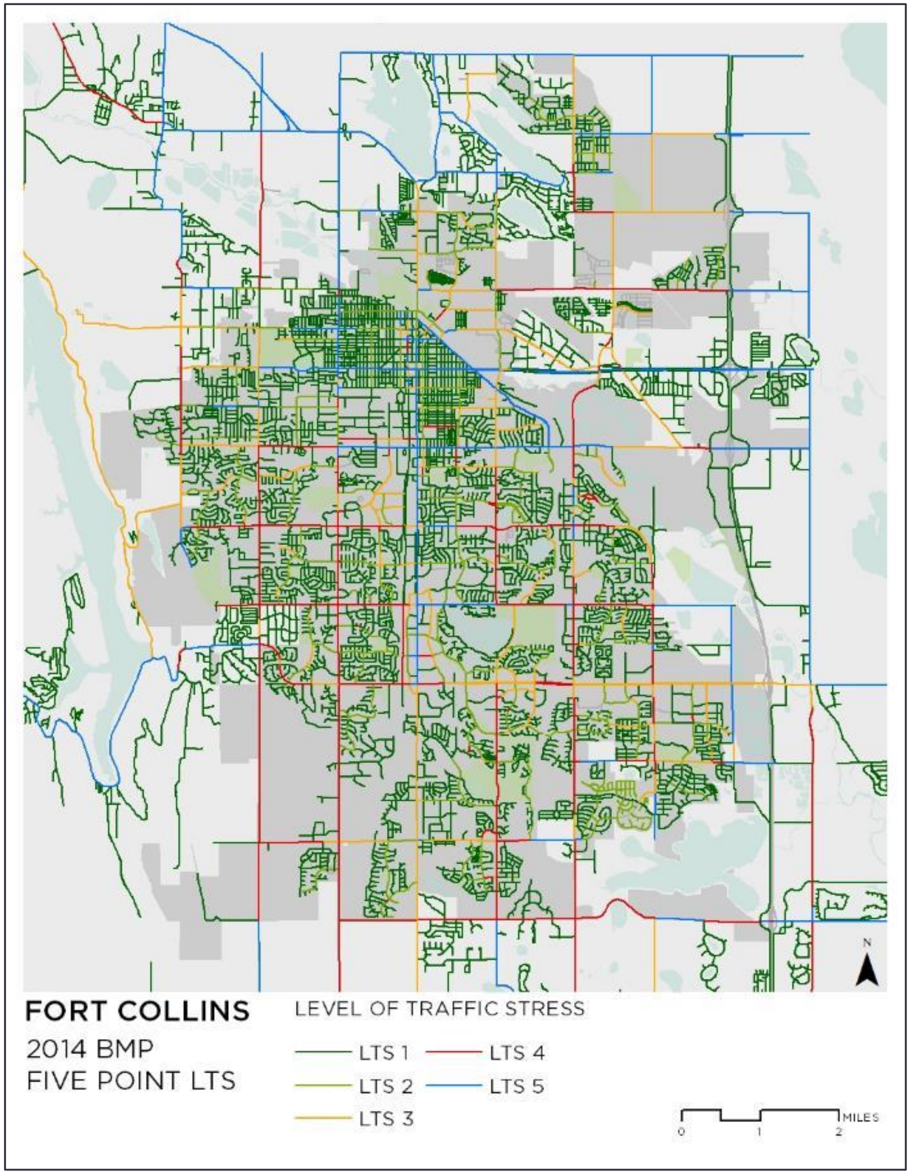
Measuring Multimodal Network Connectivity

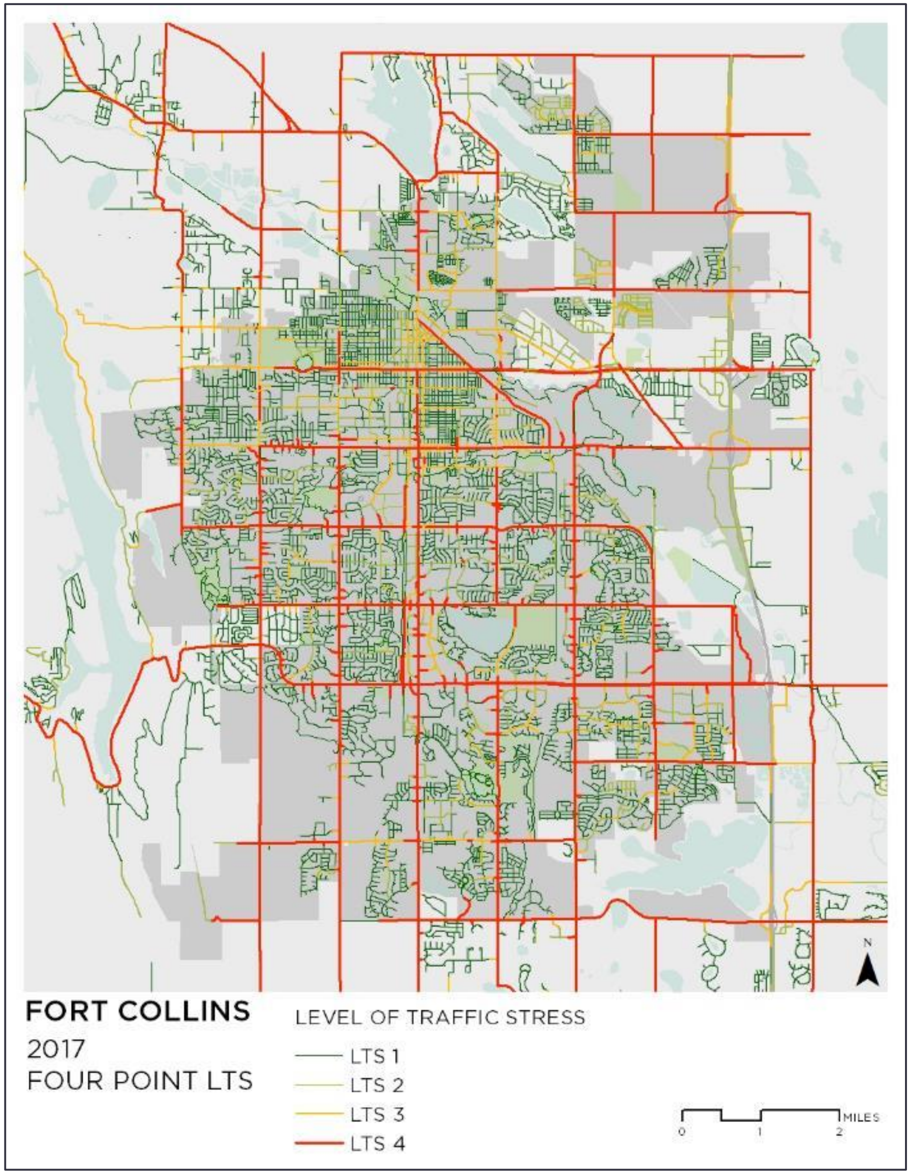
Corridor 1: I-680, Contra Costa County



Fort Collins, CO

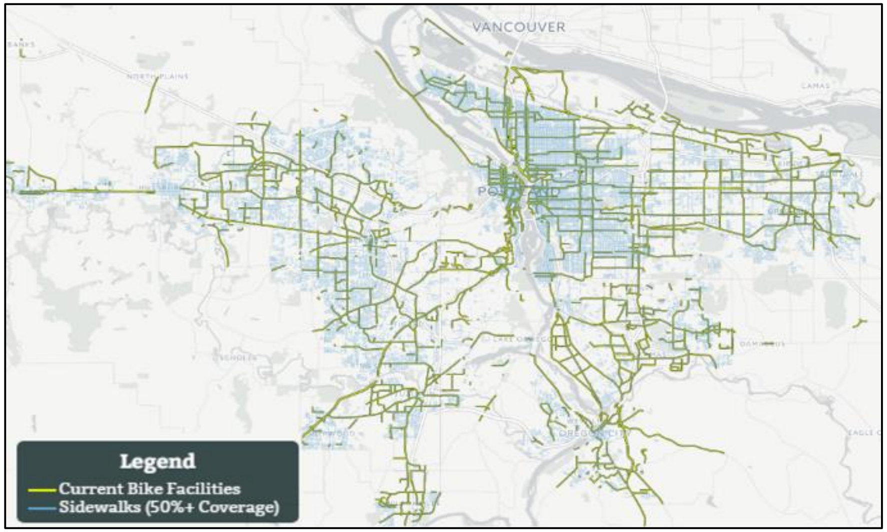
- Transportation Master Plan Update
- How to take network to next level
- Track over time
- Integrate with other modal analysis

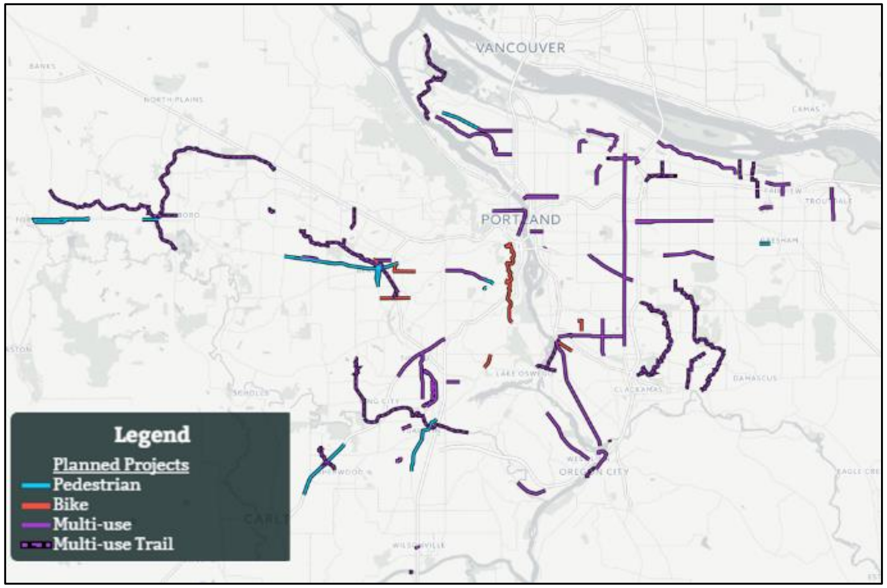

FORT COLLINS
2014 BMP
FIVE POINT LTS
LEVEL OF TRAFFIC STRESS
LTS 1
LTS 4
LTS 2
LTS 5
LTS 3
MILES
0
1
2
N


FORT COLLINS
2017
FOUR POINT LTS
LEVEL OF TRAFFIC STRESS
LTS 1
LTS 2
LTS 3
LTS 4
MILES
0
1
2
N

Portland Metro

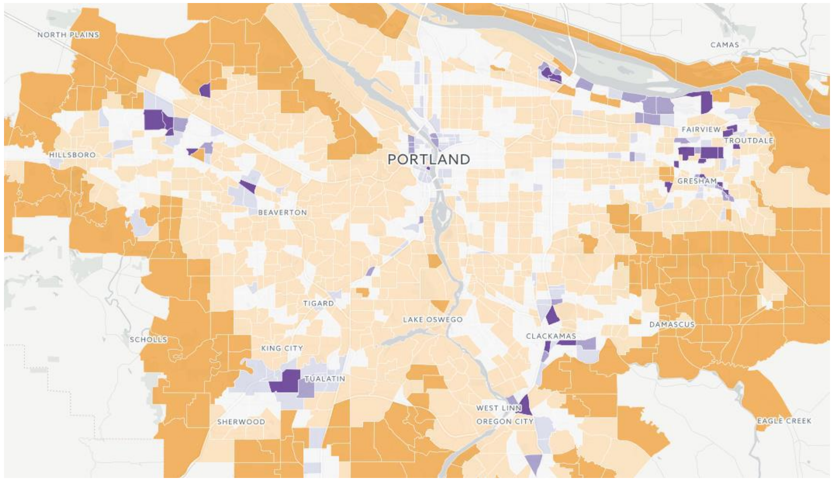
- See if areas that perform well align with areas that are generally considered well suited for bicycling and walking.
- Determine whether the measures adequately reflect change due to planned projects.
- Refine the definitions of measures and the process for calculating them.
- Identify opportunities to simplify measures.



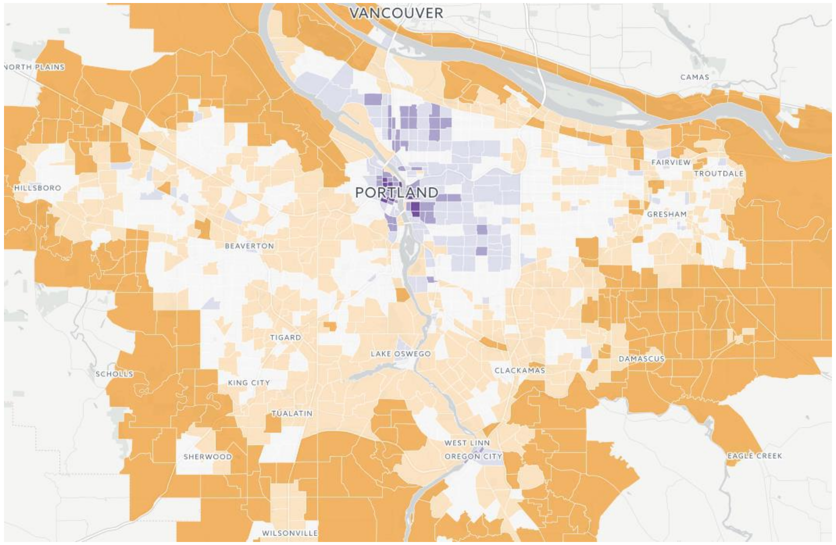


Portland Metro Metrics Per Census Tract

- **Street density**: linear miles of streets **Street connectivity**: ratio of intersections to linear street miles.
- **Sidewalk density**: linear miles of street segments with more than 50 percent of sidewalks completed.
- **Sidewalk connectivity**: ratio of sidewalk density (miles of street segments with more than 50 percent of sidewalks completed) to total linear miles of streets.
- **Bikeway density**: linear miles of street segments with bikeways completed .
- **Bikeway connectivity**: ratio of bikeway density (miles of street segments with bikeways completed) to total miles of streets.
- **Trail density**: miles of trails completed



Consolidated measures, bikeway emphasis



Consolidated measures, pedestrian emphasis

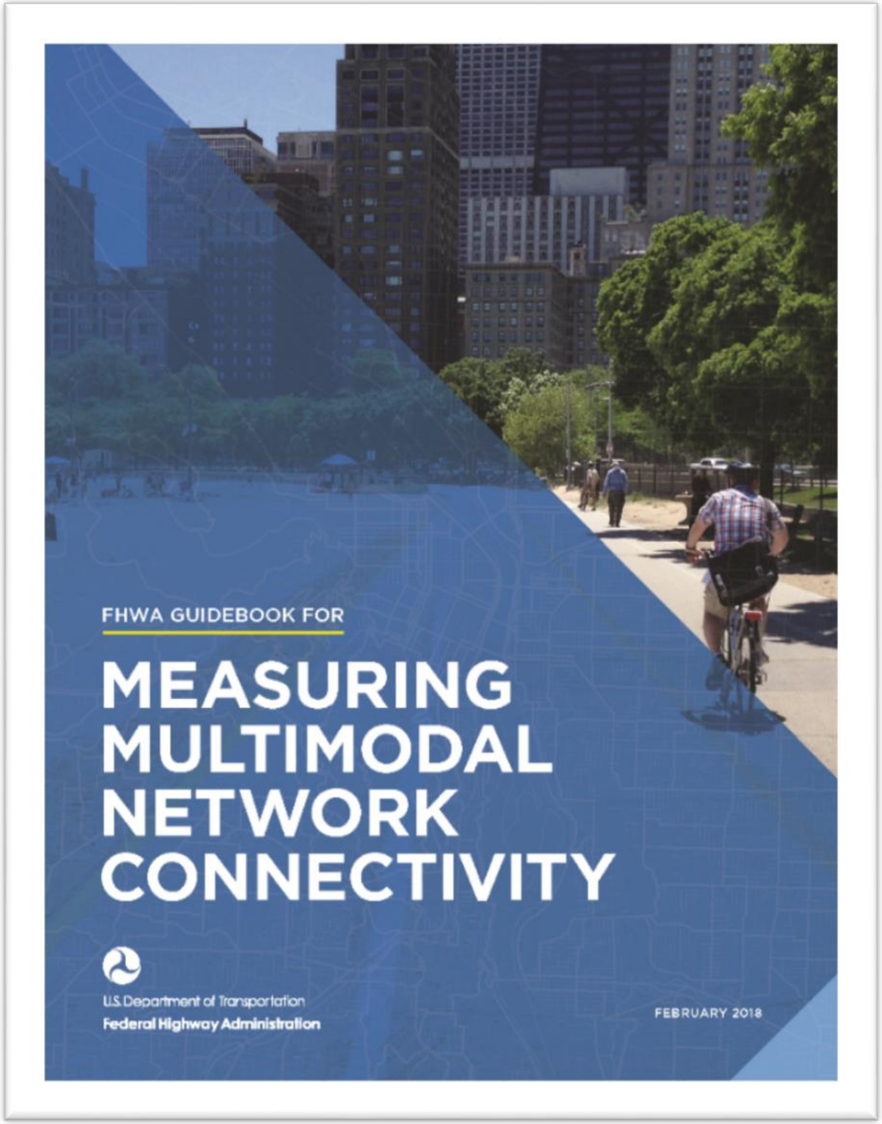
Poll – What's Your Story?

Which of the case study connectivity issues applies to your community, too…? Check all that apply!

- Broken pavement
- Accessibility to persons with disabilities
- Physical gaps in the network
- Sparse network (low density)
- Heavy-traffic highway crossings
- Fast moving car traffic
- Long distances between places
- Others? Type in the chat pod!

Guide Contents

- Connectivity Analysis Process
- Fact Sheets on Connectivity Analysis Methods
- Fact sheets on Connectivity Analysis Measures
- Lessons Learned



Connectivity Analysis Process

STEP 1

Identify the planning context

Clarify the purpose of the analysis, the decision(s) it will support, and the planning processes it will inform

STEP 2

Define the analysis method

Decide which method(s) and measures are best suited to the purpose of the analysis, and will make productive use of available resources

STEP 3

Assemble the data

Define the base network and assemble facility attribute and other relevant data

STEP 4

Compute metrics

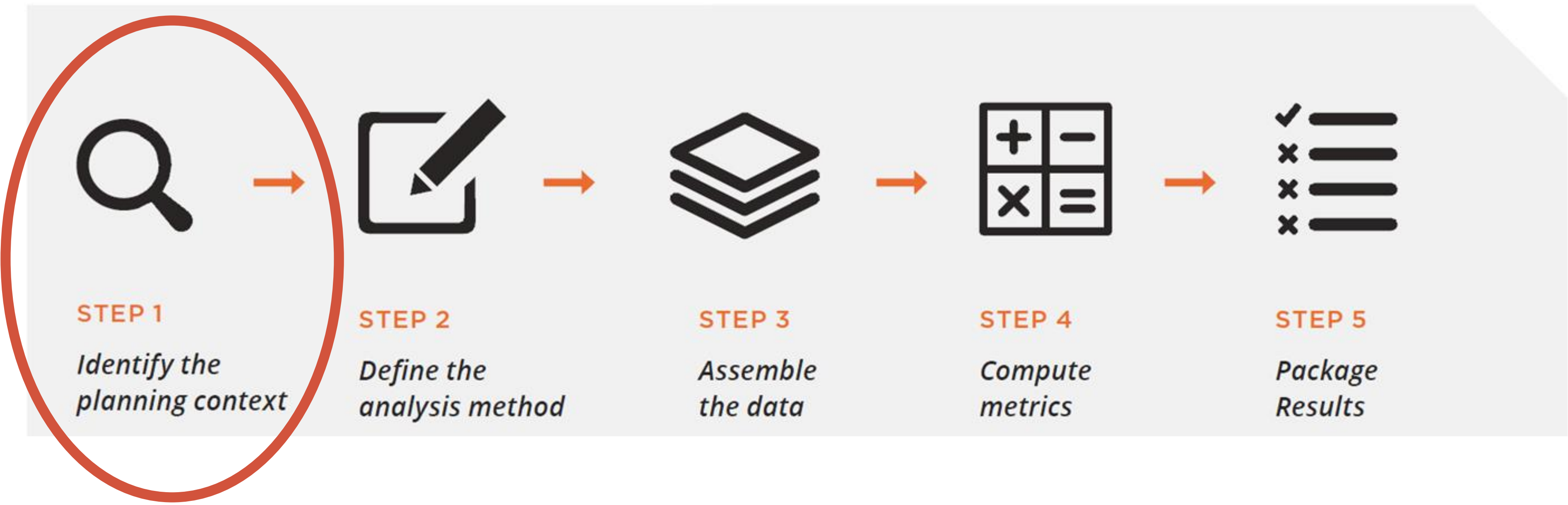
Run the analysis to calculate connectivity for selected links, routes, and areas

STEP 5

Package Results

Develop overlays, visualizations, and other presentation materials to support the decisionmaking process

Step 1 – Planning Context



Decisionmaking Process

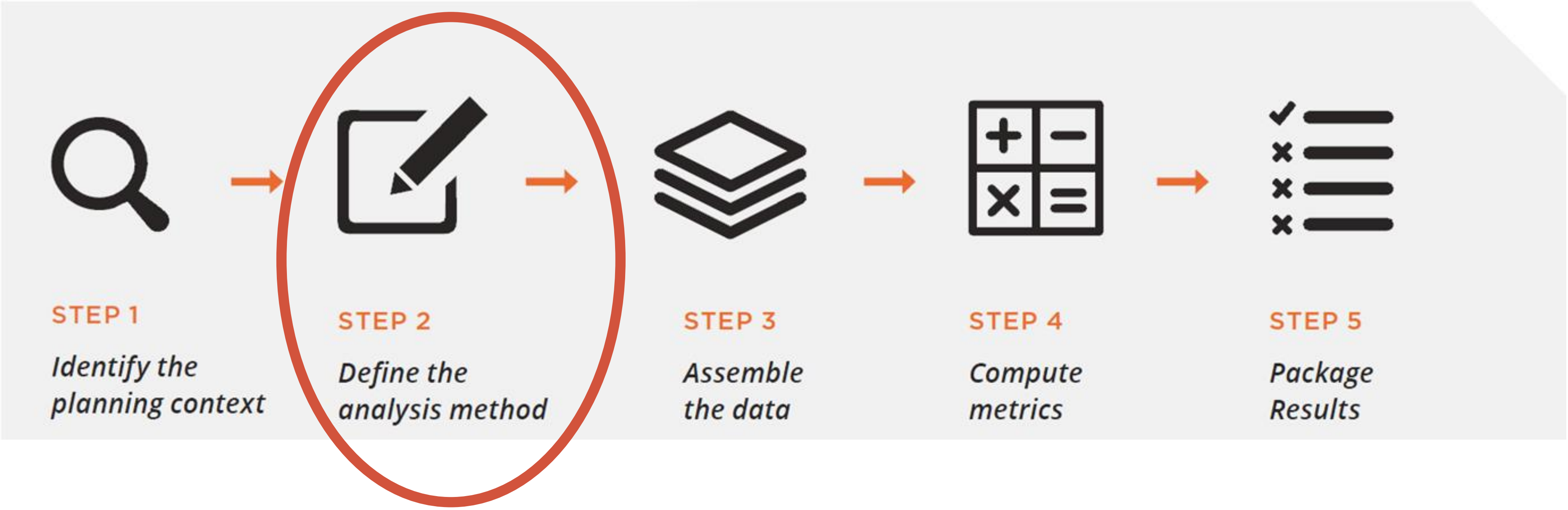
USDOT 2016. Transportation Planning Process Briefing Book.

Planning Context

- Key questions, problems or decisions
- Relevant plans or policies
- Existing and planned networks
- Agency's role in advancing connectivity
- Analysis scale

Caltrans District 4 case study

Step 2 – Define the Method



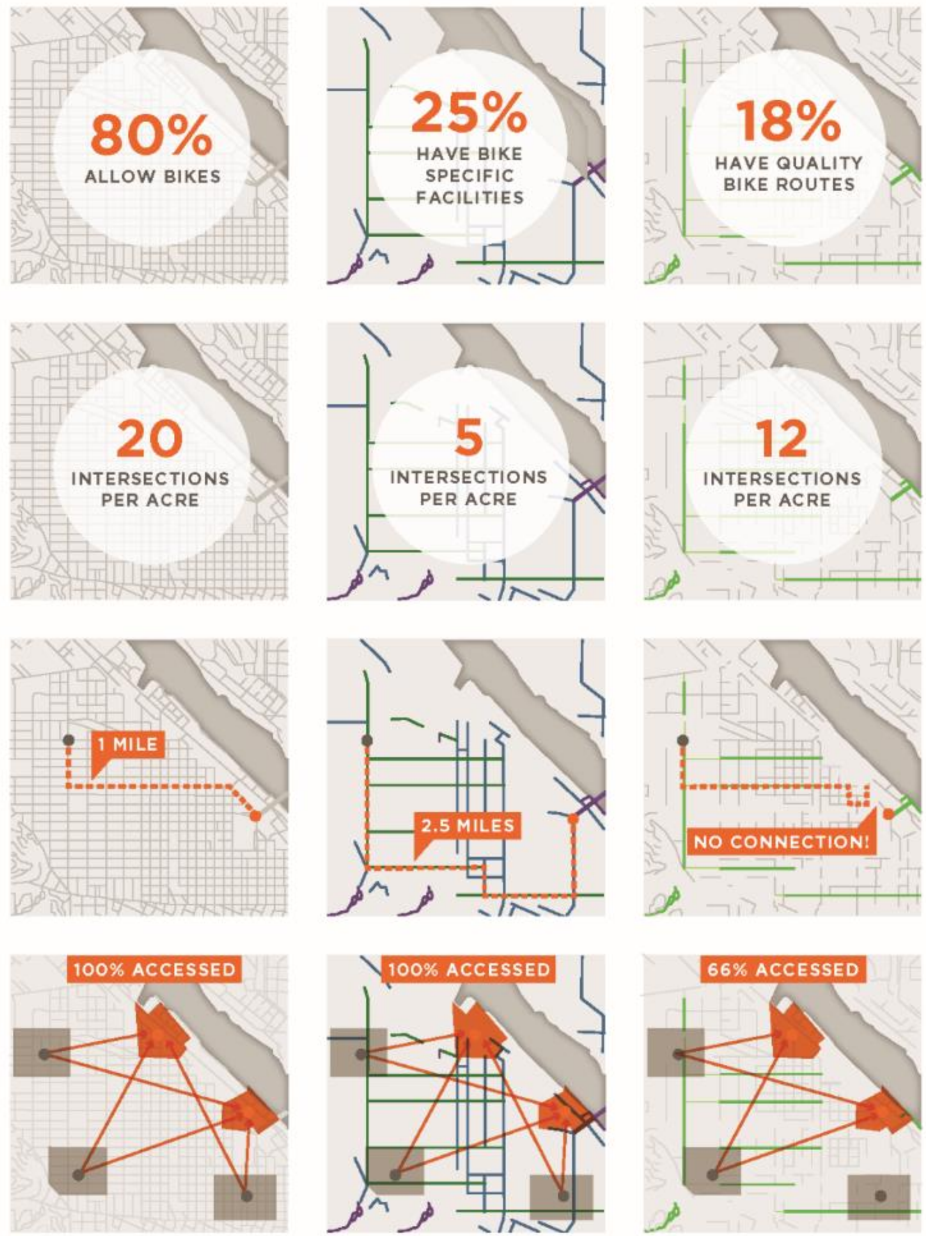
All | Designated | Low Stress

Network Completeness

Network Density

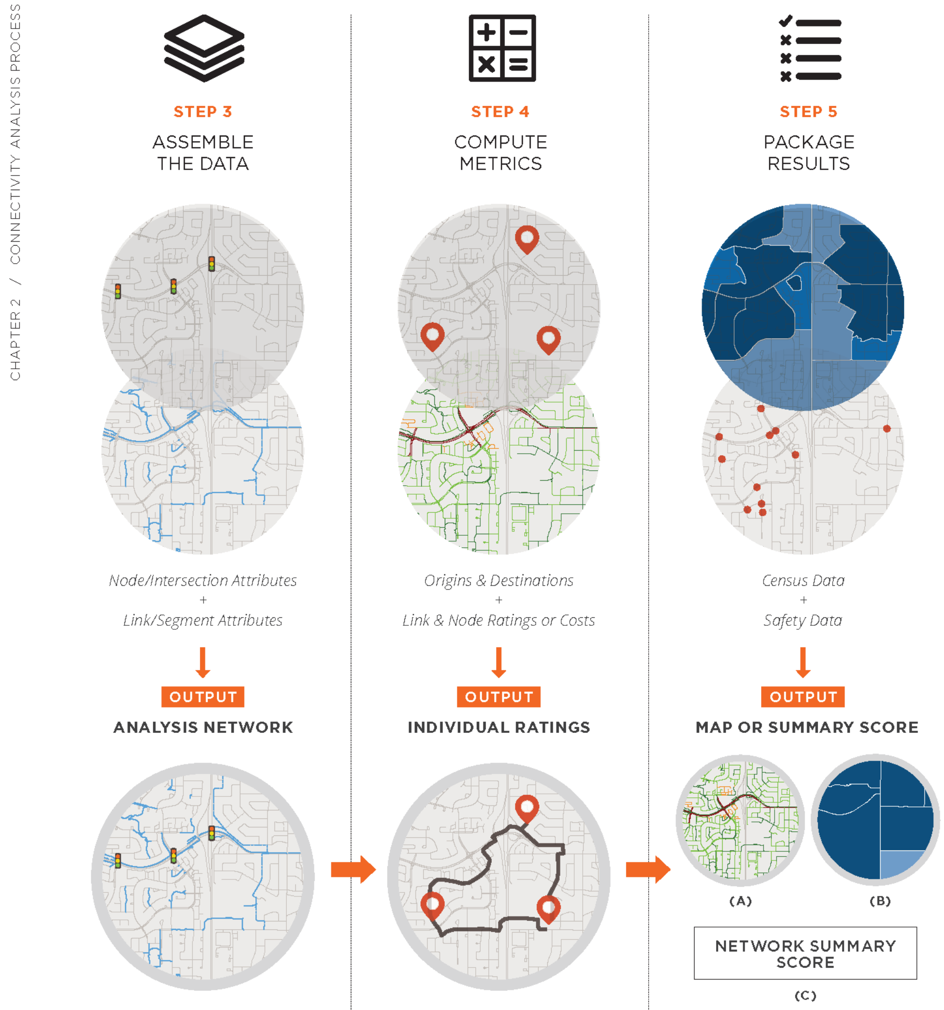
Route Directness

Accessibility to Destinations

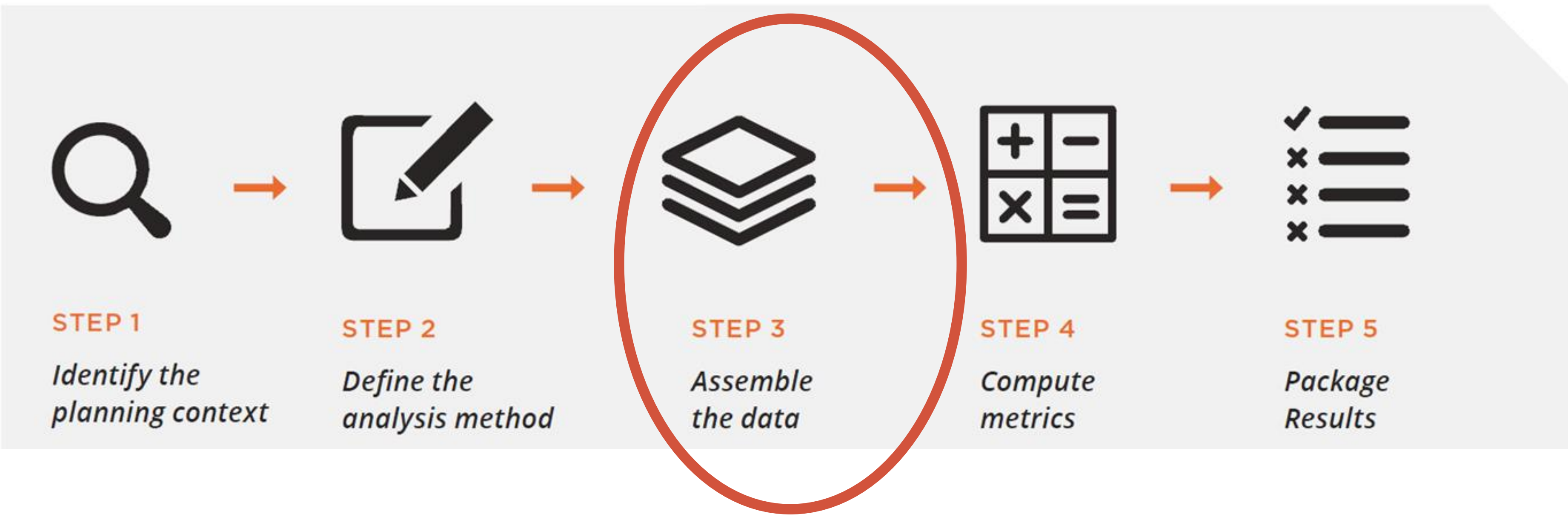


Network Quality

Steps 3-5: Measure Connectivity



Step 3 – Assemble Data



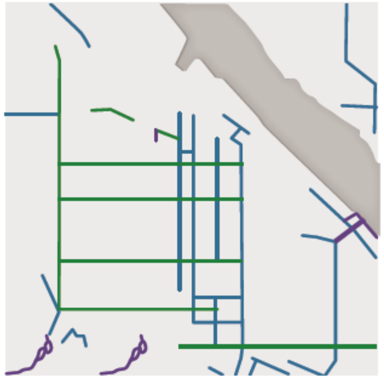
Define the Network

- For meaningful results, measure network that:
  - addresses planning question(s)
  - people will actually use
- Strive to build better data on facilities, people and places
- Update & archive over time

All Streets

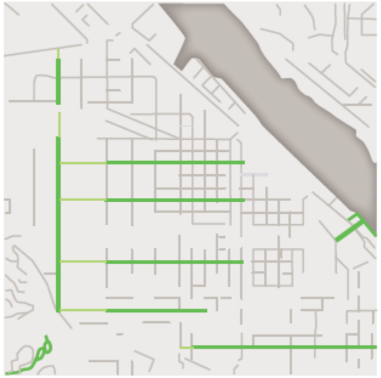
- All streets (& trails) where walking or cycling permitted

Facility-based



- Sidewalk
- Sidepath
- Shared Use Path
- Bike Lane (
- Separated/ Protected Bike Lane
- Buffered Bike Lane
- Bike Boulevard/ Nbhd. Greenway
- Paved Shoulder

Quality-based



- Level of Service (LOS)
- Level of Traffic Stress (LTS)
- Preference-based models

Street Network Data

- Bicycle and Pedestrian Facility Data
  - Designated facility types
  - Intersection features
  - Slope (terrain)
- Supporting Data
  - Roadway design characteristics (e.g. lane count/width, parking, turn lanes)
  - Traffic volume and/or speed
  - Heavy vehicle traffic
  - Potential obstacles (e.g. driveways)

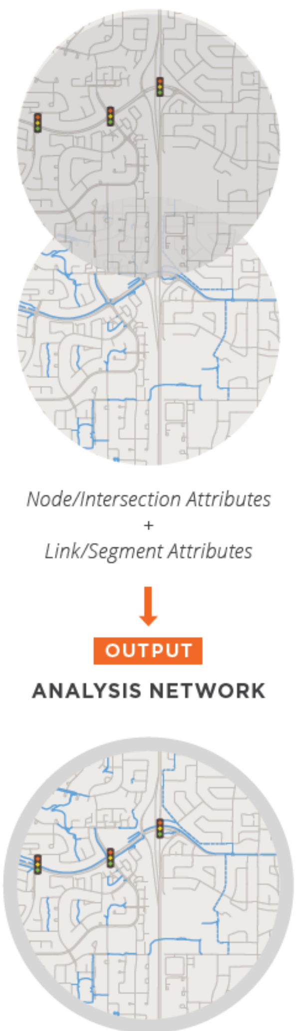


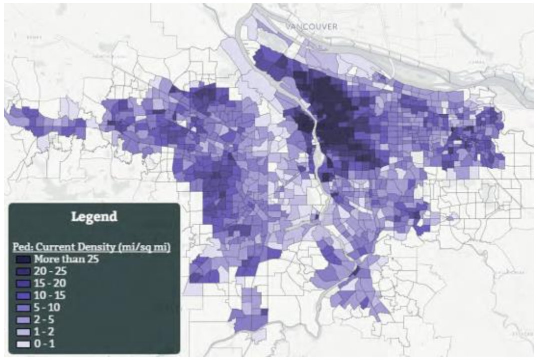
Table 4: *Bicycle and Pedestrian Network Facility Types*

FACILITY TYPE	DEFINITION
Sidewalk	That portion of a which is intende
Sidepath	A shared use pat
Shared Use Path	A bikeway physic within the highw
Bike Lane	A portion of roac pavement markir
Buffered Bike Lane	Conventional bic bicycle lane from
One-Way Separated Bike Lane / One-Way Protected Bike Lane / One-Way Cycle Track	An exclusive one and that is physi
Contraflow Bike Lane	A portion of the direction from tr
Contraflow Buffered Bike Lane	A buffered bike l direction from tr
Contraflow Separated Bike Lane / Protected Bike Lane / Cycle Track	A separated bike direction from tr
Two-Way Separated Bike Lane / Two-Way Protected Bike Lane / Two-Way Cycle Track	An exclusive two and that is physi
Bike Boulevard / Neighborhood Greenway	A street segment through bicycle t
Paved Shoulder	The portion of th emergency use, paved, are often

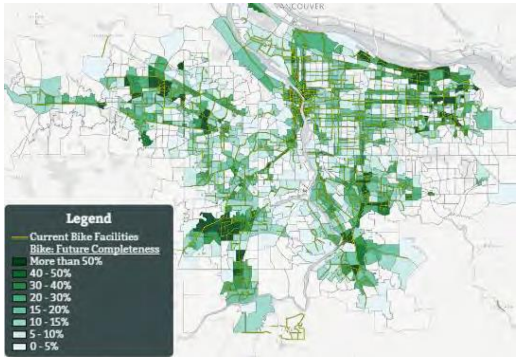
People and Place Data

- **Form-based** measures can be calculated using only network data
- **Route-based** measures require additional data on where people live and what they need to access

Form-based

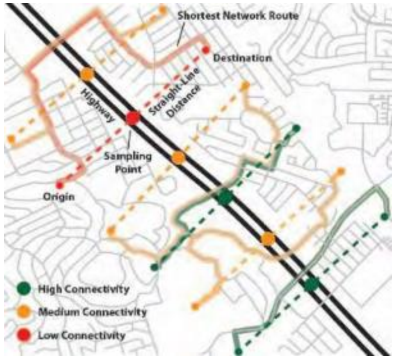


Sidewalk Density

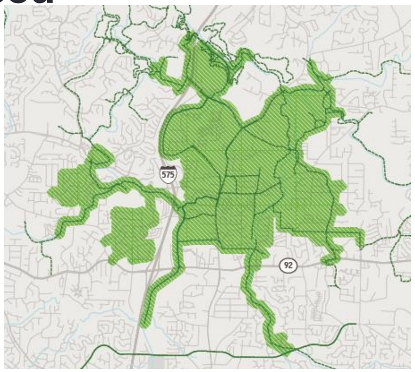


Bicycle Facility Completeness

Route-based



Route Directness



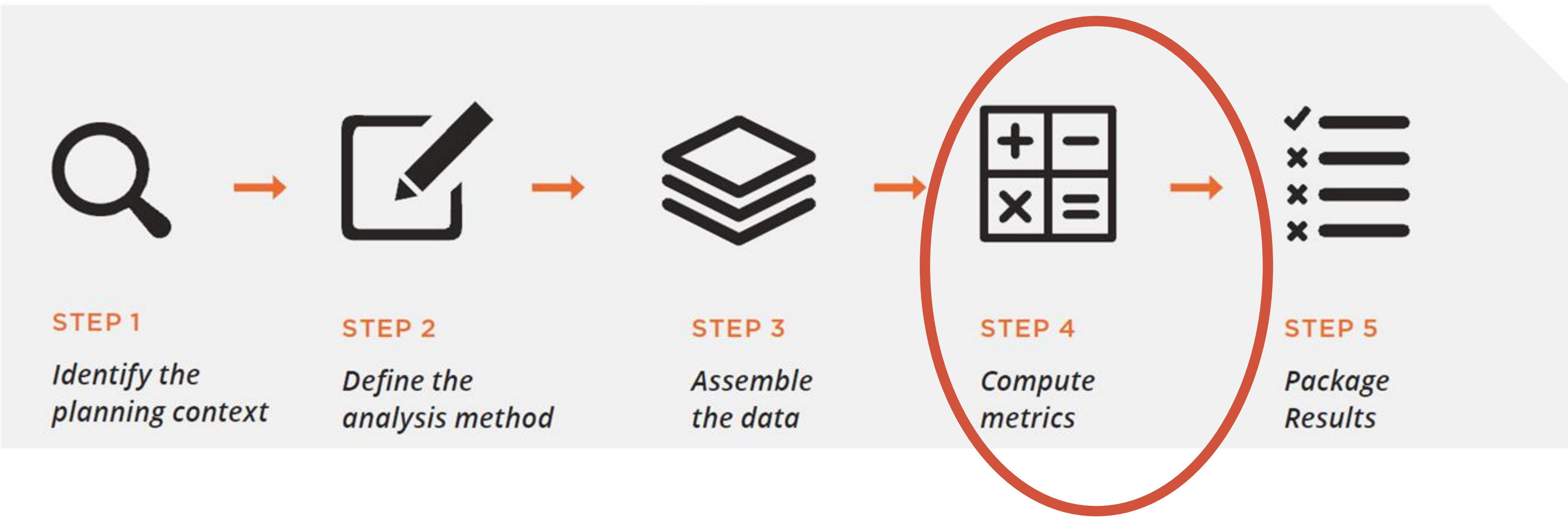
Access to Destinations

Poll – What Do You Know About Your Nonmotorized Networks?

What kind of nonmotorized facility data typically available to the agency(ies) with whom you work?

- Shared-use paths
- Bike lanes
- Signed routes
- Bicycle boulevards
- Sidewalks
- Crosswalks
- Traffic signals
- Number of lanes
- Traffic volumes and / or speed
- Other? Type in the chat pod!

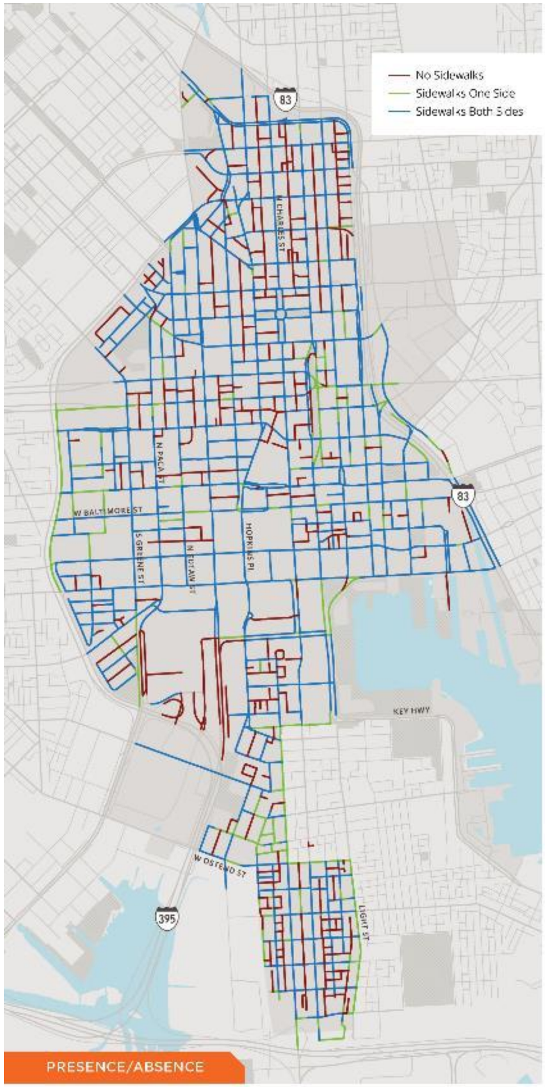
Step 4 – Compute Metrics

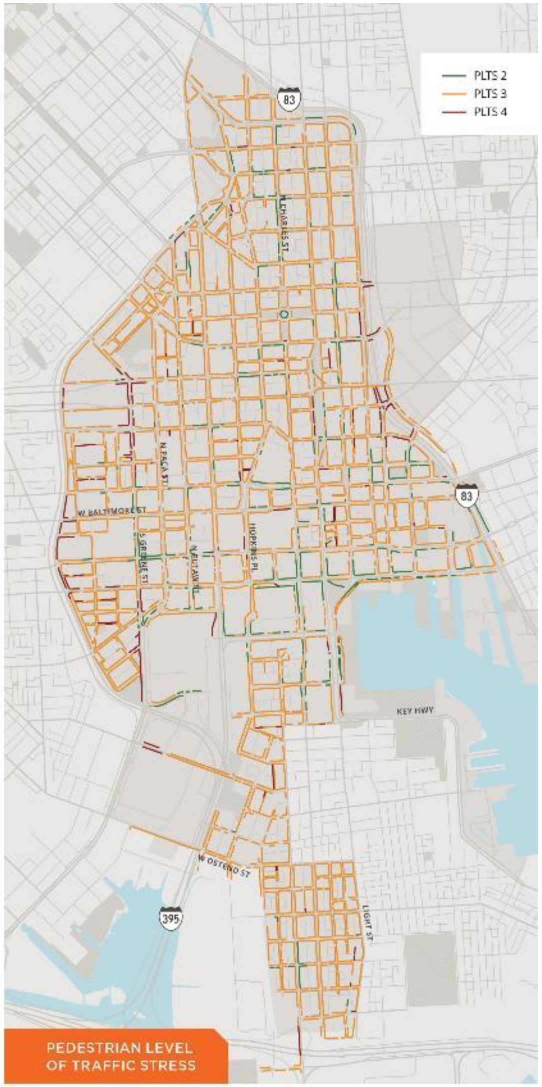


Network Completeness

- Data relatively easy to collect.
- Metrics are easy to communicate
- Metrics can be tracked over time

- Not easily comparable from area to another





City of Baltimore

Network Density

- Data inputs can be very simple
- Widely applied and understood
- Particularly appropriate to walking

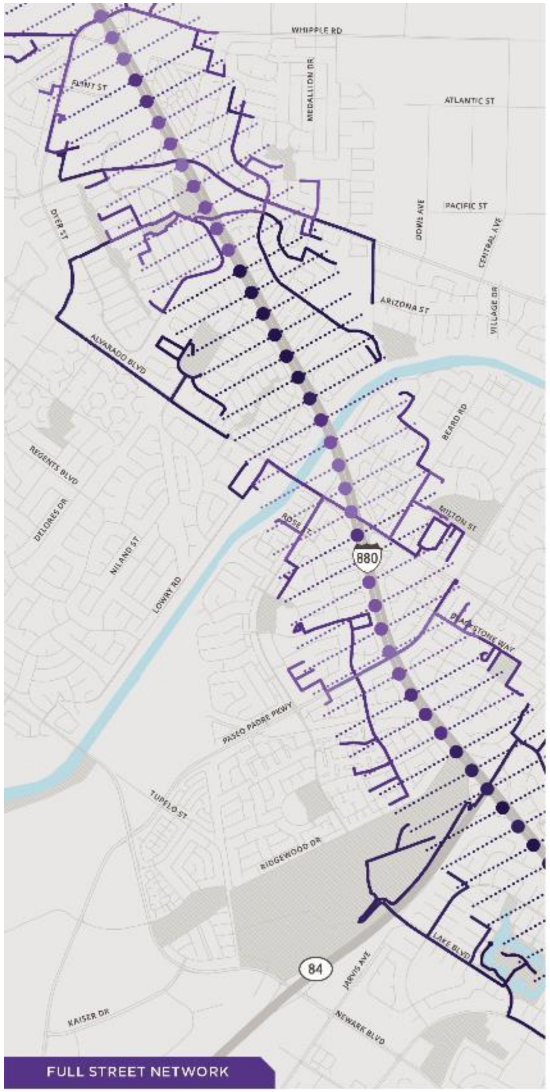
- Consider facility quality for a more meaningful metric

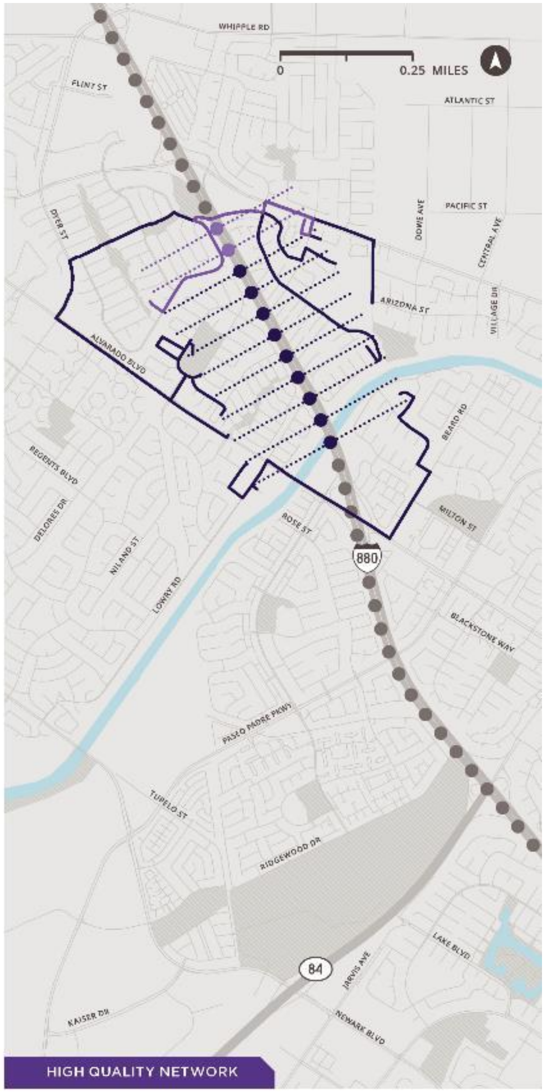
Portland Metro

Route Directness

- Provides detailed analysis for areas with robust existing networks
- Can demonstrate the level of connectivity among destinations

- May require significant data preparation and labor

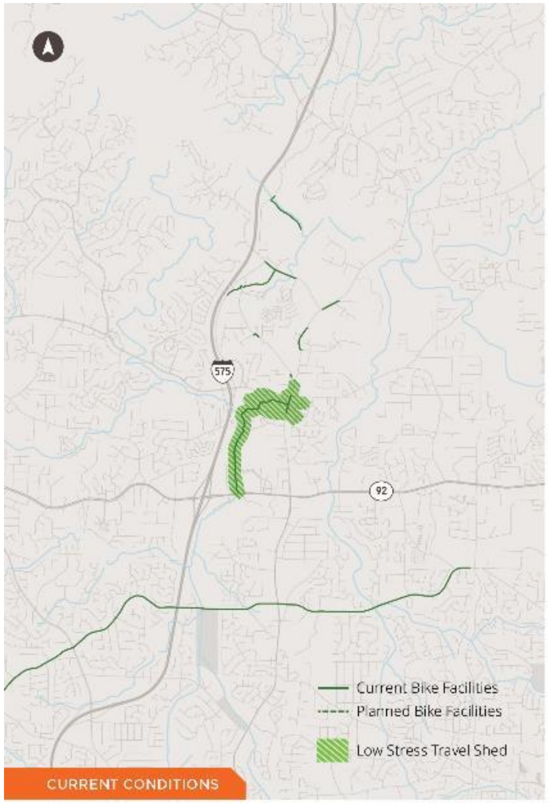


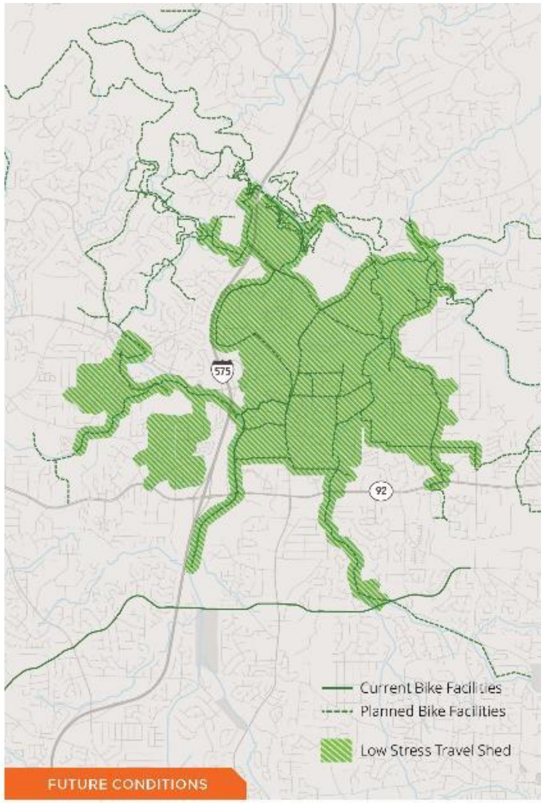


Access to Destinations

- Well suited to identifying and prioritizing projects

- May be data and labor intensive
- Results may be hard to interpret and/or act upon

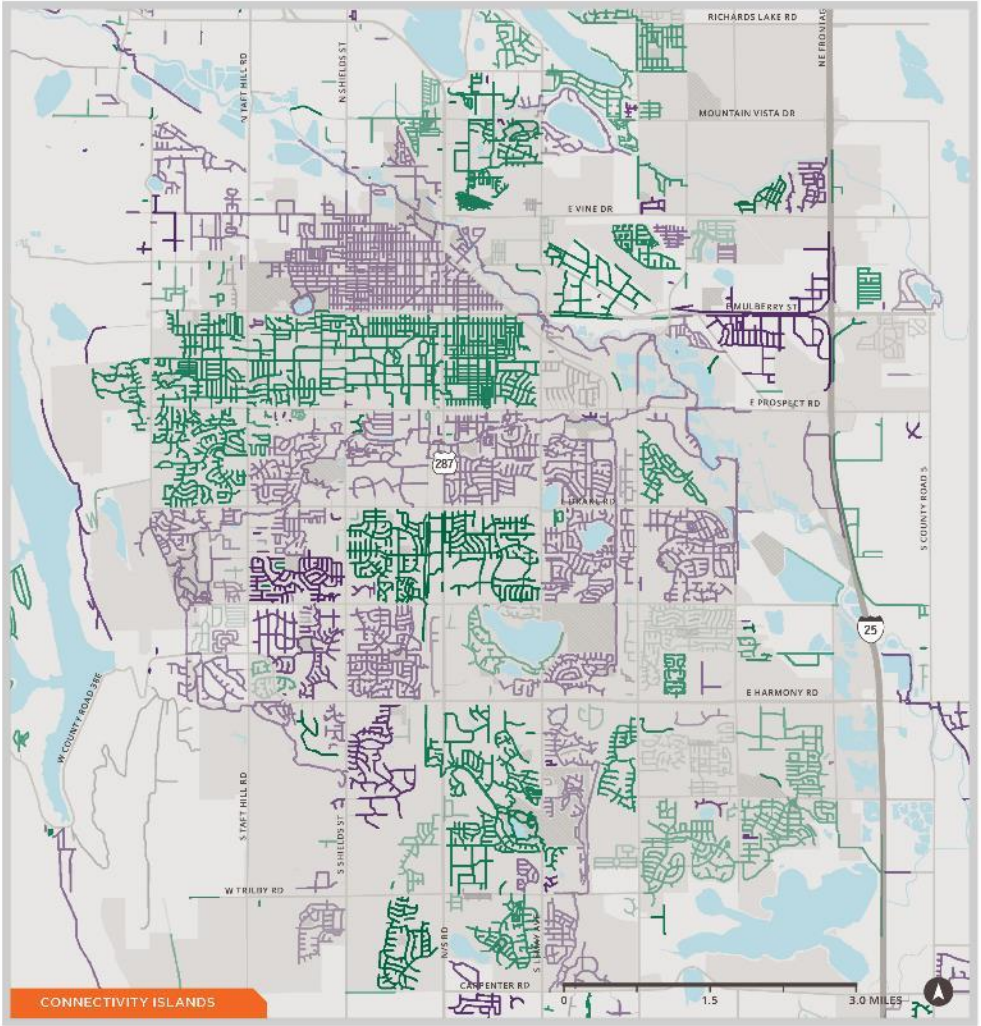




Network Quality

- Can be easily applied to design and improvement strategies
- Can be used to understand impact of planned and implemented facilities

- Typically data intensive
- Most useful with a mature bike/ped network



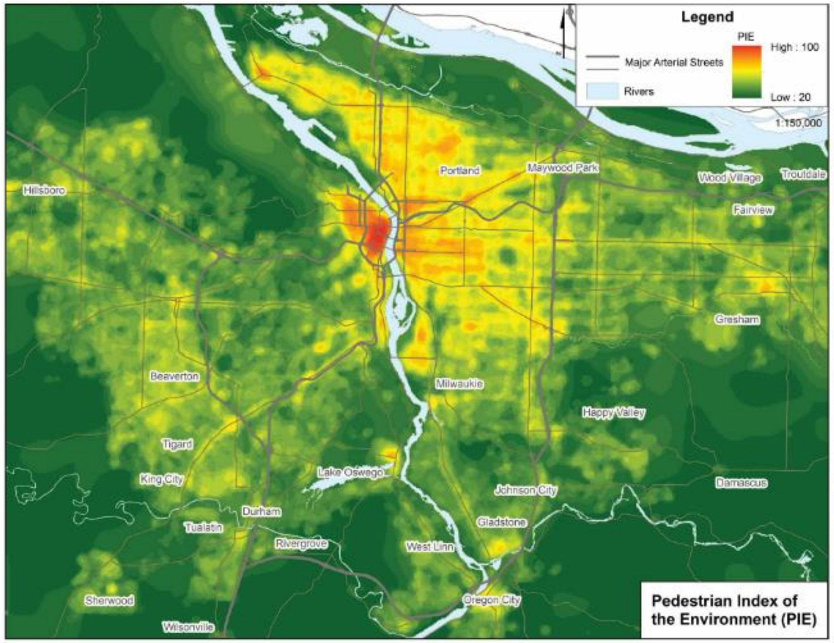
Poll – Which Methods Have You Used?

What kind of nonmotorized network connectivity analysis methods have you or your agency used?

- Completeness
- Density
- Directness (travelsheds)
- Access to Destinations
- Quality
- Other? Type in the chat pod!

Connectivity Analysis Measures

- Bicycle Level of Service
- Bicycle Level of Traffic Stress
- Bicycle Low Stress Connectivity
- Bicycle Route Quality Index
- Pedestrian Index of the Environment
- Pedestrian Level of Service
- Pedestrian Level of Traffic Stress



Portland Region Pedestrian Index of Environment

CONNECTIVITY MEASURE

BICYCLE LEVEL OF TRAFFIC STRESS (BICYCLE LTS)

What is the extent to which bicyclists feel safe and comfortable using the network, particularly on streets where they share space with motorized traffic?

MODE	METHOD	OUTPUTS	CONNECTIVITY ANALYSIS METHODS	ACCESSIBILITY	USE IN PRACTICE	LEVEL OF EFFORT
Bicycle	Classify roadway links by type by highest stress attribute	Traffic stress rating of 1 through 4 for street segments and intersection	Completeness, Density, Directness, Accessibility to Destination, Quality	Explicit consideration of accessibility for people with disabilities: **No**	Common	MODERATE

DESCRIPTION

Measures and rates traffic stress for street segments and intersections, based on different types of cyclists' presumed comfort level near motor vehicle traffic. The components of the network are scored on a four point scale relating to user types and confidence levels. Links and intersections are classified based on their most stressful feature, and routes are classified by the most stressful link or intersection between a given origin and destination.

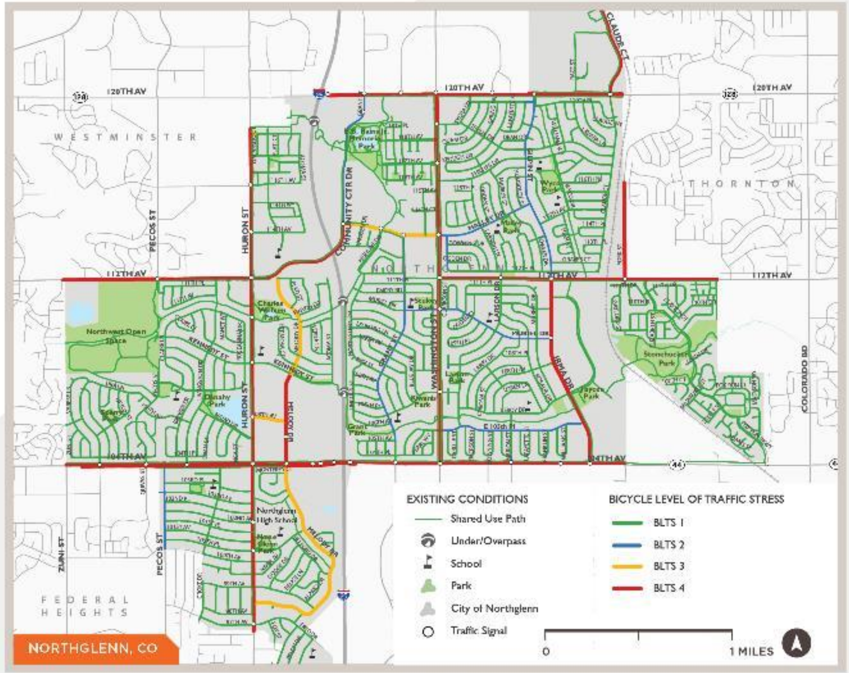
Bicycle Level of Traffic Stress (Bicycle LTS) is based on the concept of the maximum level of traffic stress that will be tolerated by specific groups of existing and potential cyclists (Mekuria, Furth, and Nixon 2012). The classification scheme is loosely based on both the Types of Cyclist (not interested, interested but concerned, enthused and confident, and strong and fearless) line of research from Portland, Oregon (Dill and McNeil 2013), and also on Dutch age-group based bicycle facility planning standards. Most analysis has focused on LTS 2, a level thought to be acceptable to many interested adult cyclists. The Bicycle LTS measure is extended to capture connectivity through route selection and maximum detours using approximations from empirical studies of cyclist route choice.

EXAMPLE PLANNING APPLICATION(S)

- To identify problems and develop strategies to improve the users' perceived and actual experience, particularly in situations where multiple modes share a common facility
- To compare the availability and directness of low-stress routes to all possible routes on the street network

TYPICAL DATA

- Roadway centerline, including number of lanes and posted speed
- Bicycle infrastructure, including type and width
- On-street parking presence, including width
- Signalized intersections
- Turn lane locations and length
- Not recommended for locations with limited, incomplete, or inconsistent data
- Planners should consider adjusting the user type definitions in an LTS model to reflect the demographics of riders relevant to a specific planning context



Source: City of Northglenn Department of Transportation. 2017. "Connect Northglenn: Bicycle and Pedestrian Master Plan."

PEER APPLICATION

- In Oregon, the Department of Transportation calls for Bicycle LTS as the preferred measure for Regional Transportation Plans and Transportation System Plans. It can also be used on a screening-level basis for project development and development review. The methodology is outlined in the state's most recent update of its Analysis Procedures Manual, which includes strategies for rural applications that consider shoulder width as well as traffic volumes and speeds.[1]

1 *http://www.oregon.gov/ODOT/Planning/Pages/APM.aspx*

ADVANTAGES

- Specifically considers user (and potential user) differences
- Simple interpretation, making it suitable for use in a variety of contexts
- Captures the quality of a wide range of facilities and crossings, with a strong focus on the extent to which motor vehicle traffic makes cyclists feel unsafe
- For a complex measure, it has been widely applied and the framework is familiar to many practitioners
- Can be applied at route level for broader range of applications

CONSIDERATIONS

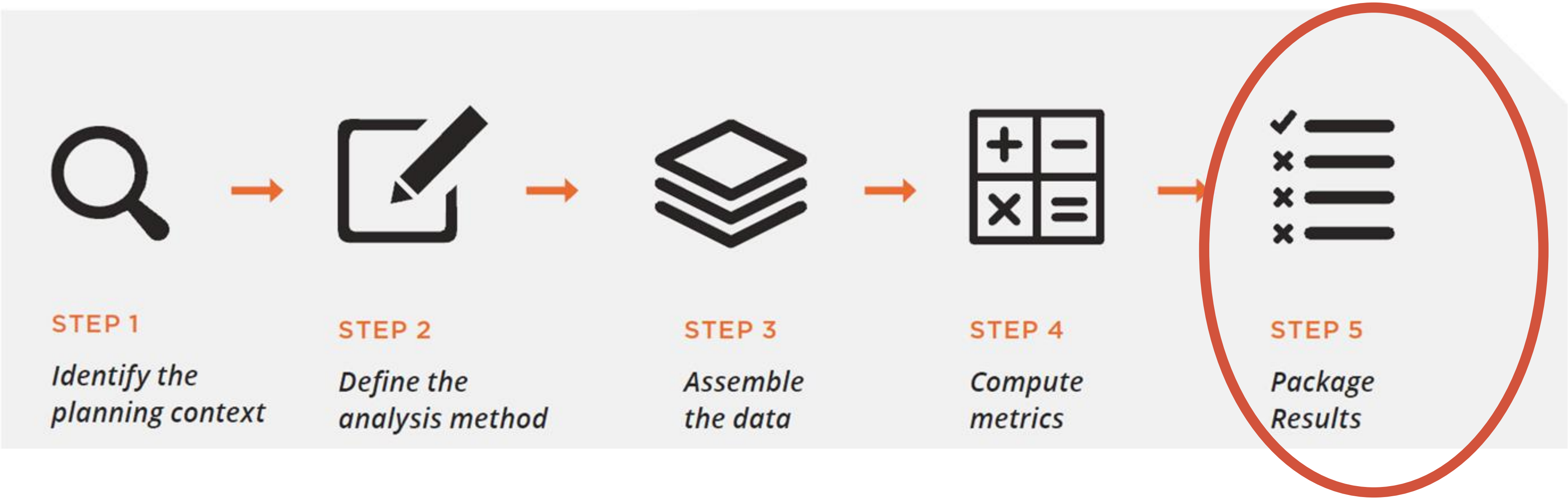
- Data-intensive and assumptions can impact the usefulness of the results
- Classification scheme is not strongly supported by preference data
- "All or nothing" classification, sensitive only to "weakest link" improvements
- Methods are not yet validated against behavior/use data

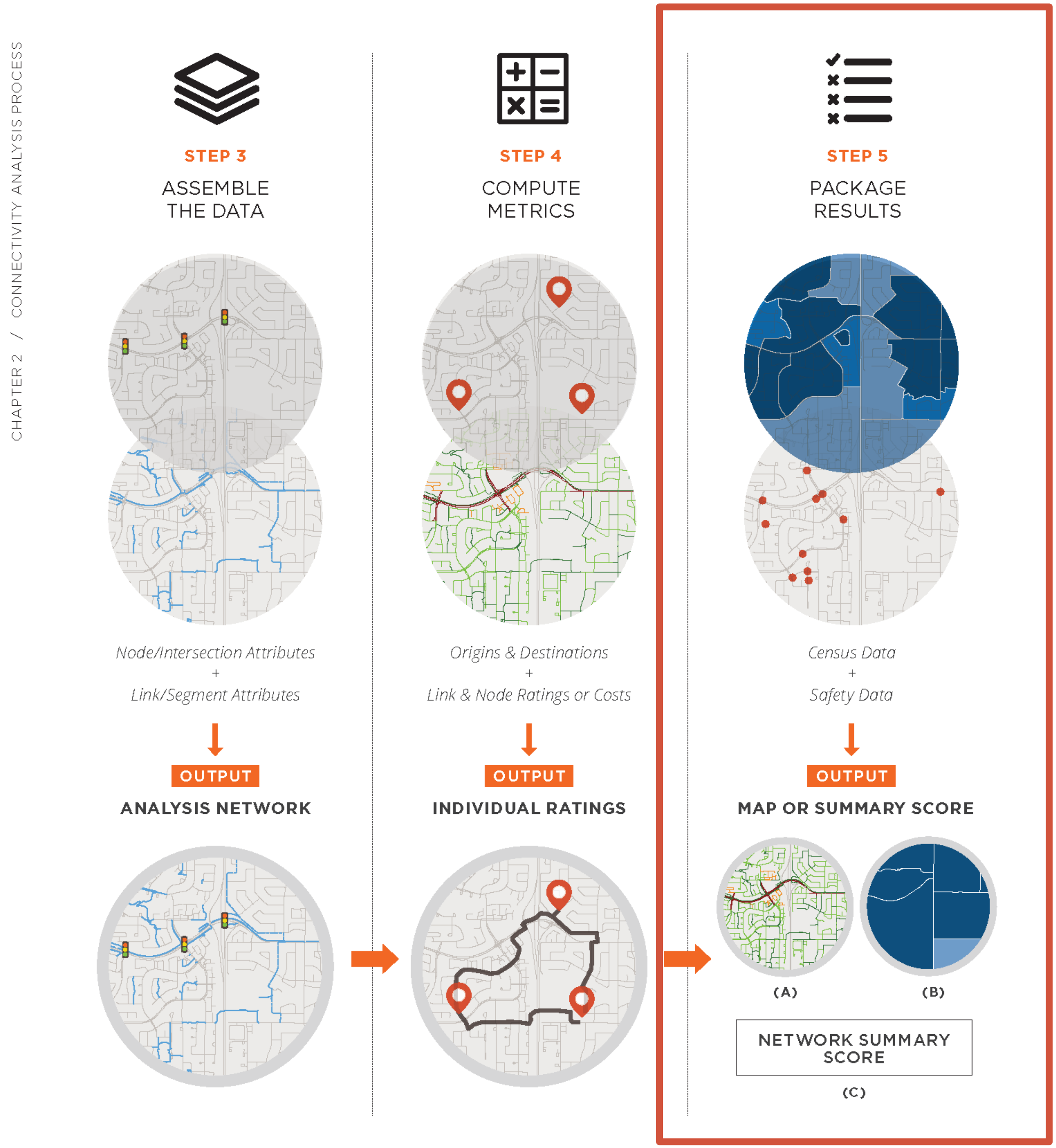
Poll – Which Measures Have You Used?

What kind of nonmotorized connectivity analysis measures have you or your agency used?

- Bicycle Level of Service
- Bicycle Level of Traffic Stress
- Pedestrian Level of Service
- Pedestrian Level of Traffic Stress
- Other? Type in the chat pod!

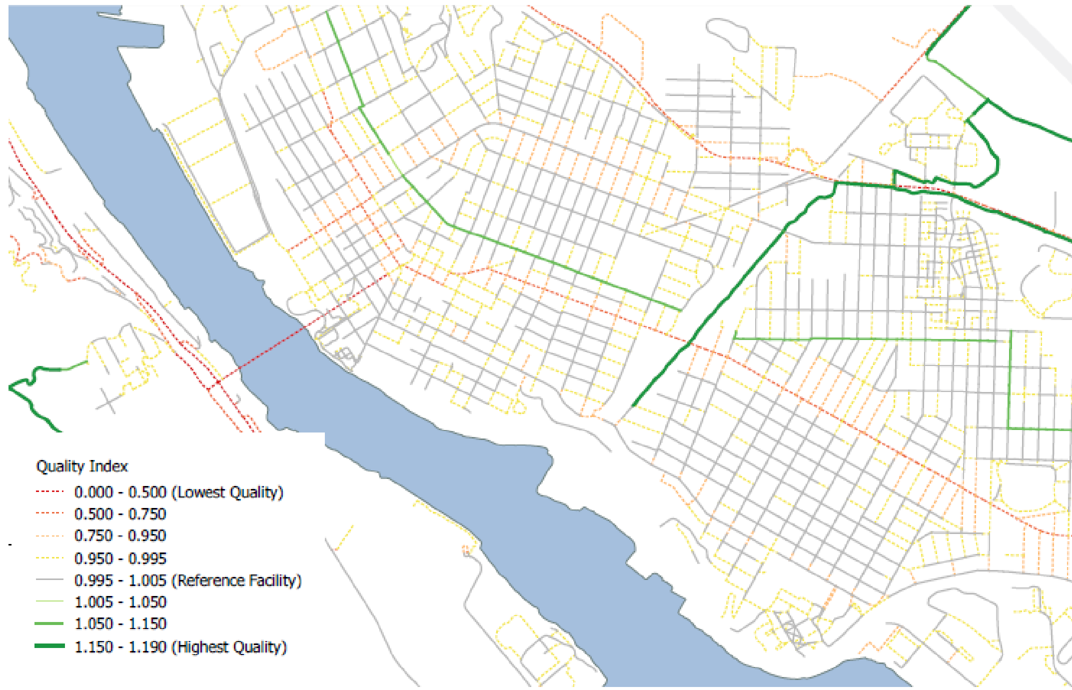
Step 5 – Package Results




CHAPTER 2 / CONNECTIVITY ANALYSIS PROCESS
STEP 3
ASSEMBLE THE DATA
Node/Intersection Attributes
+
Link/Segment Attributes
OUTPUT
ANALYSIS NETWORK
STEP 4
COMPUTE METRICS
Origins & Destinations
+
Link & Node Ratings or Costs
OUTPUT
INDIVIDUAL RATINGS
STEP 5
PACKAGE RESULTS
Census Data
+
Safety Data
OUTPUT
MAP OR SUMMARY SCORE
(A)
(B)
NETWORK SUMMARY SCORE
(C)

Packaging Results: Visual Analysis

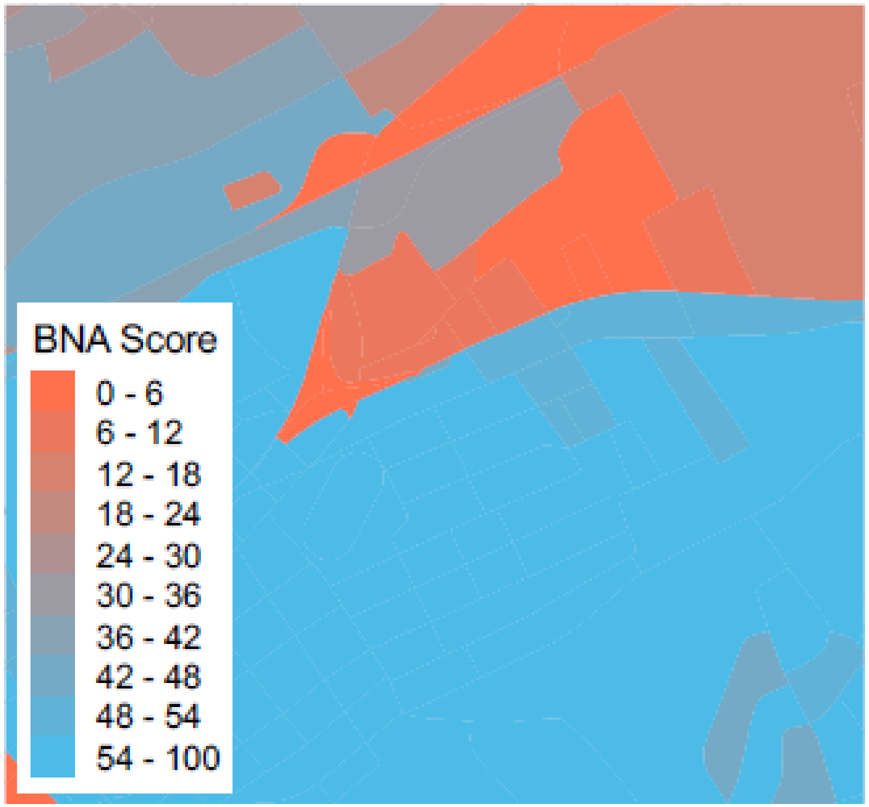
- Common approach to identify network gaps and opportunities
- Difficult to make objective comparisons



Route Quality Index (RQI) – quality rating of segments and intersections

Packaging Results: Small Area Scores

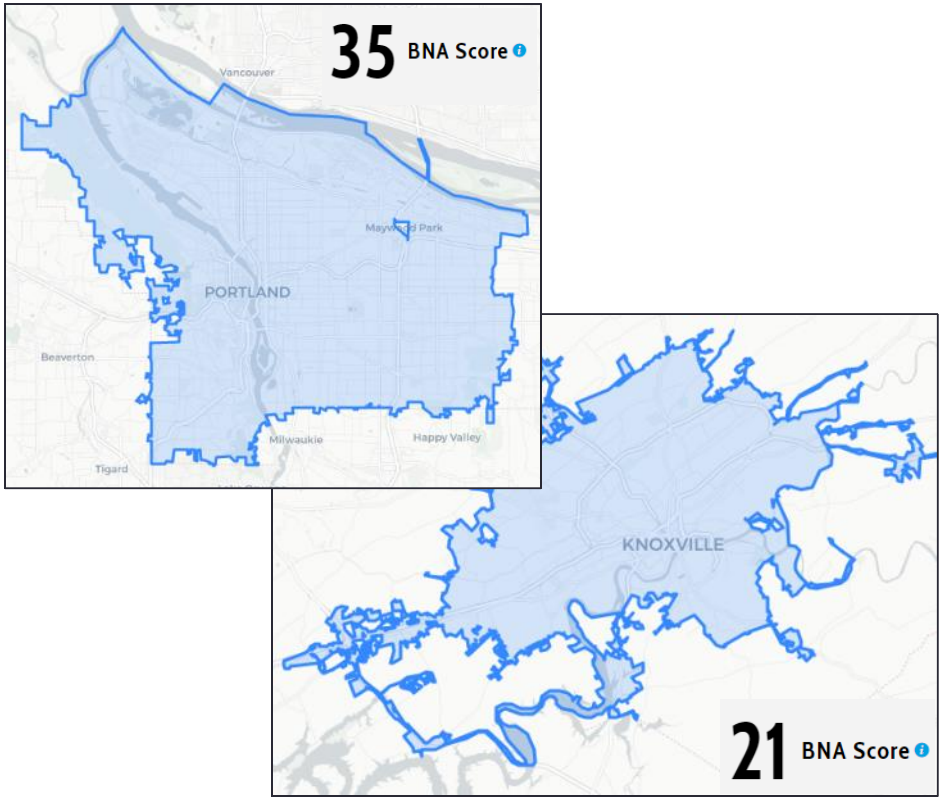
- Summarize link or route scores to small areas
- Easier to compare across areas or over time



Bicycle Network Analysis Tool (PeopleForBikes) – access to "baskets" of destination types by census block

Packaging Results: Network Scores

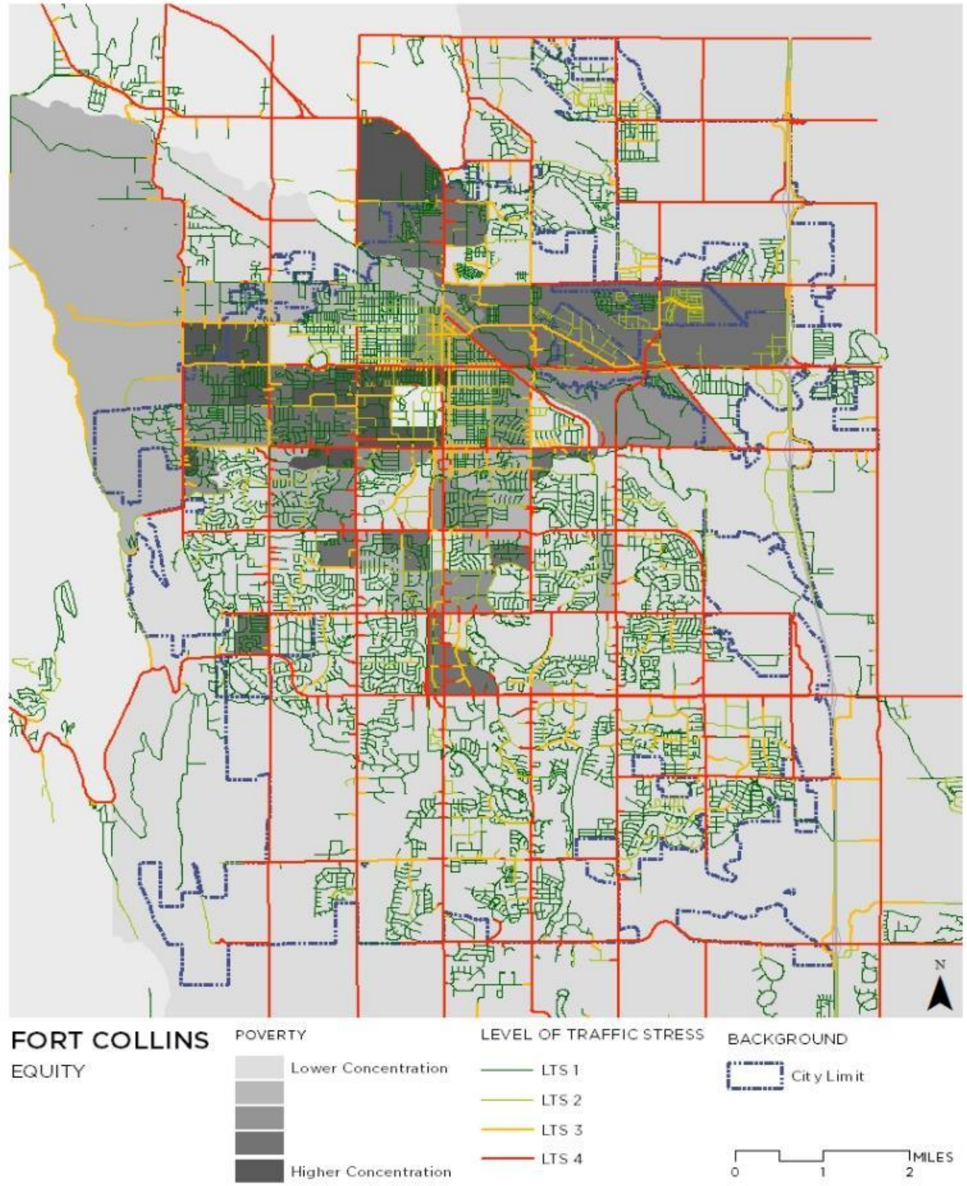
- Summarize scores to entire network
- Comparable over time and among different network alternatives



Bicycle Network Analysis Tool (PeopleForBikes) – population-weighted small area scores for regional networks

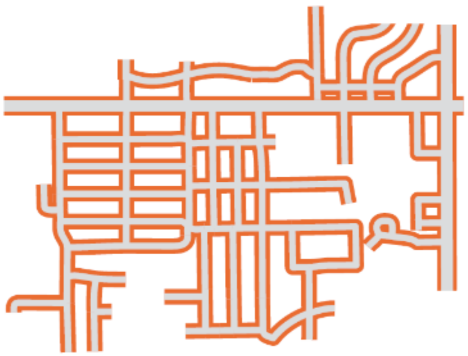
Overlay and Prioritize

- How does connectivity relate to other priorities?
- What data will you need?
  - Safety (injury / fatal collisions)
  - Equity (low income / minority populations)
  - Access to destinations (employment centers, schools)
  - Usage (mode share, counts)



Poverty Data Overlaid on Level of Traffic Stress Analysis (Fort Collins)

Lessons Learned



- Clearly define the network vision and analysis goal.
- Select a method appropriate for the intended application and study area context.
- Select measures that can be tracked over time.
- Consider implications of modifying methods/ measures.
- Promote consistent data standards and storage parameters.
- Test measures before committing to them; be prepared to conduct secondary research and validation.
- View the picture from several perspectives.

Discussion

- Send us your questions
- Follow up with us:
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  - Kim Voros kimvoros@altaplanning.com
  - Joe Broach jbroach@pdx.edu
  - General Inquiries pbic@pedbikeinfo.org
- Archive at www.pedbikeinfo.org/webinars