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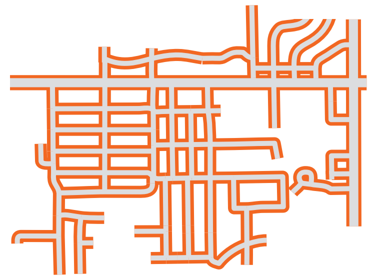


WHAT ARE MULTIMODAL NETWORKS?

Networks are accessible, interconnected pedestrian and/or bicycle transportation facilities that allow all users to safely and conveniently get where they want to go.

INTRODUCTION

ABOUT THIS GUIDEBOOK

In 2016 the United States Department of Transportation (USDOT) Federal Highway Administration (FHWA) published a *Guidebook for Developing Pedestrian and Bicycle Performance Measures* that presents methods for measuring walking and bicycling performance and activities and embedding them into the transportation planning and decisionmaking process (U.S. Department of Transportation 2016). Building on the 2016 guidebook, this resource focuses on pedestrian and bicycle network connectivity and provides information on incorporating connectivity measures into state, metropolitan, and local transportation planning processes. Connectivity measures can help transportation practitioners identify high priority network gaps, implement cost-effective solutions that address multiple needs, optimize potential co-benefits, and measure the long-term impacts of strategic pedestrian and bicycle investments on goals such as improving safety, system efficiency, network performance, and access to key destinations. Toward that end, this resource should be used in conjunction with self-evaluation and transition plans to evaluate needs for pedestrians with disabilities.

WHAT IS MULTIMODAL NETWORK CONNECTIVITY?

Connectivity is one of several concepts commonly used in transportation performance measurement to describe the ease with which people can travel across the transportation system. At its simplest level, network **connectivity** addresses the question, "Can I get where I want to go easily and safely?" **Multimodal** network connectivity adds the dimension of travel choices to the picture: "Can I get where I want to go easily and safely in whatever way I choose—for example, walking, bicycling, using transit, or driving?" A connected multimodal network allows people to travel by whatever mode they choose, including people who do not drive or do not have access to a motor vehicle.

Key Components of Pedestrian and Bicycle Network Connectivity

This guidebook outlines five core components of multimodal network connectivity, as listed below, with a focus on pedestrians and bicyclists. While these components are all related, the distinctions between them provide a framework for selecting connectivity measures that address specific questions. The guidebook describes analysis methods and supporting measures associated with each of these components.

- **Network completeness** – How much of the transportation network is available to bicyclists and pedestrians?
- **Network density** – How dense are the available links and nodes of the bicycle and pedestrian network?
- **Route directness** – How far out of their way do users have to travel to find a facility they can or want to use?
- **Access to destinations** – What destinations can be reached using the transportation network?
- **Network quality** – How does the network support users of varying levels of experience, ages, abilities, and comfort with bicycling or walking?

These analysis methods involve assessments of one or more types of performance measures, such as average trip lengths and the numbers of jobs accessible within a given distance of a multimodal route. The FHWA *Guidebook for Developing Pedestrian and Bicycle Performance Measures* (2016) provides detailed discussions of these and many other measures. It is a useful companion to this guidebook, which focuses on connectivity analyses, by providing technical information on computing a broad range of bicycle and pedestrian performance measurements.

HOW CAN MULTIMODAL NETWORK CONNECTIVITY ANALYSES SUPPORT TRANSPORTATION DECISIONS?

Although connectivity analysis methods and measures are still evolving, a growing body of research points to the key role of high-quality, connected networks in making bicycling and walking safer, more convenient, and more prevalent (Buehler and Dill 2016; Tal and Handy 2012). Since connectivity has a strong influence on the likelihood of achieving these types of outcomes, planners can use ongoing connectivity assessments as leading indicators of the potential for the outcomes to ultimately occur, even though actual changes in travel behavior or safety impacts may take time to become fully evident.

The outputs generated by connectivity analyses enhance accountability by helping decisionmakers weigh the potential outcomes of planned multimodal connectivity investments. Connectivity assessments can help transportation agencies and stakeholders examine questions such as: If we make it easier for pedestrians and bicyclists to cross busy streets, will the roadways be safer for all users? Or if we make sure every neighborhood has bike paths to schools and jobs, would more people bike to these destinations? Multimodal connectivity measurement can inform the iterative, comprehensive process of planning and implementing complete multimodal networks shown in Figure 1. Table 1 identifies relevant questions that connectivity analyses can inform at each step of the planning process.

WHO CAN USE THIS GUIDE?

While this guide can be informative for people involved in all aspects of transportation decisionmaking, the

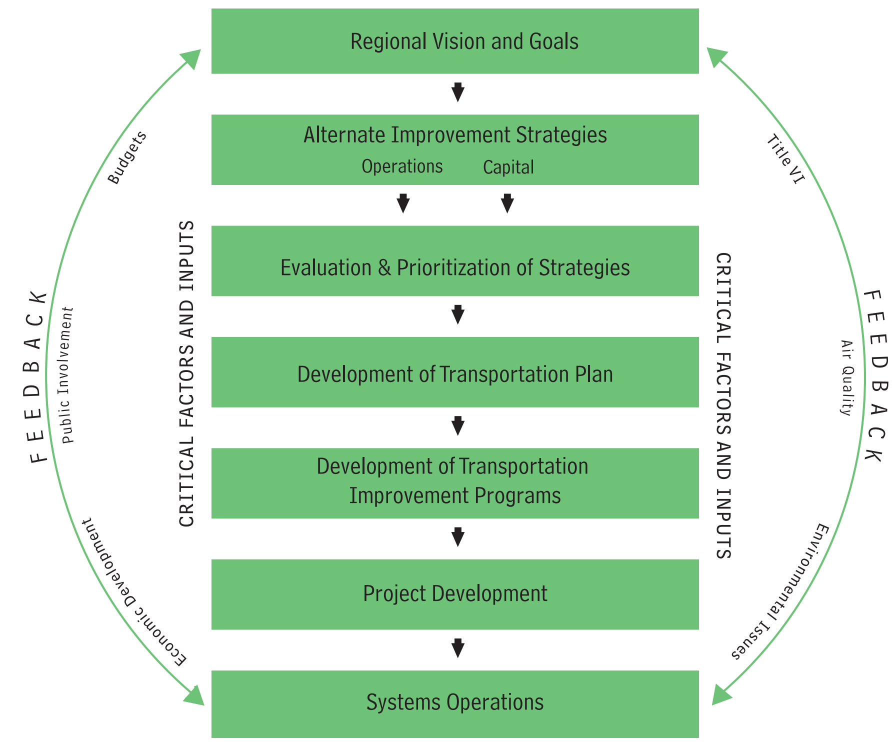


Figure 1. *Transportation Planning, Decisionmaking and Implementation. Source: U.S. Department of Transportation. 2016. "The Transportation Planning Process Briefing Book." https://www.fhwa.dot.gov/planning/publications/briefing_book*

MEASURING MULTIMODAL NETWORK CONNECTIVITY POSITIONS A TRANSPORTATION AGENCY TO:

- Enhance access to jobs, training, schools, and economic centers
- Accelerate project delivery by capturing efficiencies in economies of scale, project sequencing, construction phasing, financing, and community involvement
- Increase accountability of efforts to increase mobility options and system efficiency
- Prioritize infrastructure investments that fill gaps and address barriers in the transportation network, and that increase safety for all users
- Partner with the private sector to provide innovative multimodal transportation services and capture opportunities relating to shared-use mobility and automated and connected technology

material is targeted to planners and analysts who conduct the analyses that support the decisionmaking process. For those who desire a broad understanding of the concepts and methods involved in assessing connectivity, Chapter 1 offers a high-level overview of the analysis process. Readers are introduced to concepts of bicycle and pedestrian networks common to all measures of connectivity.

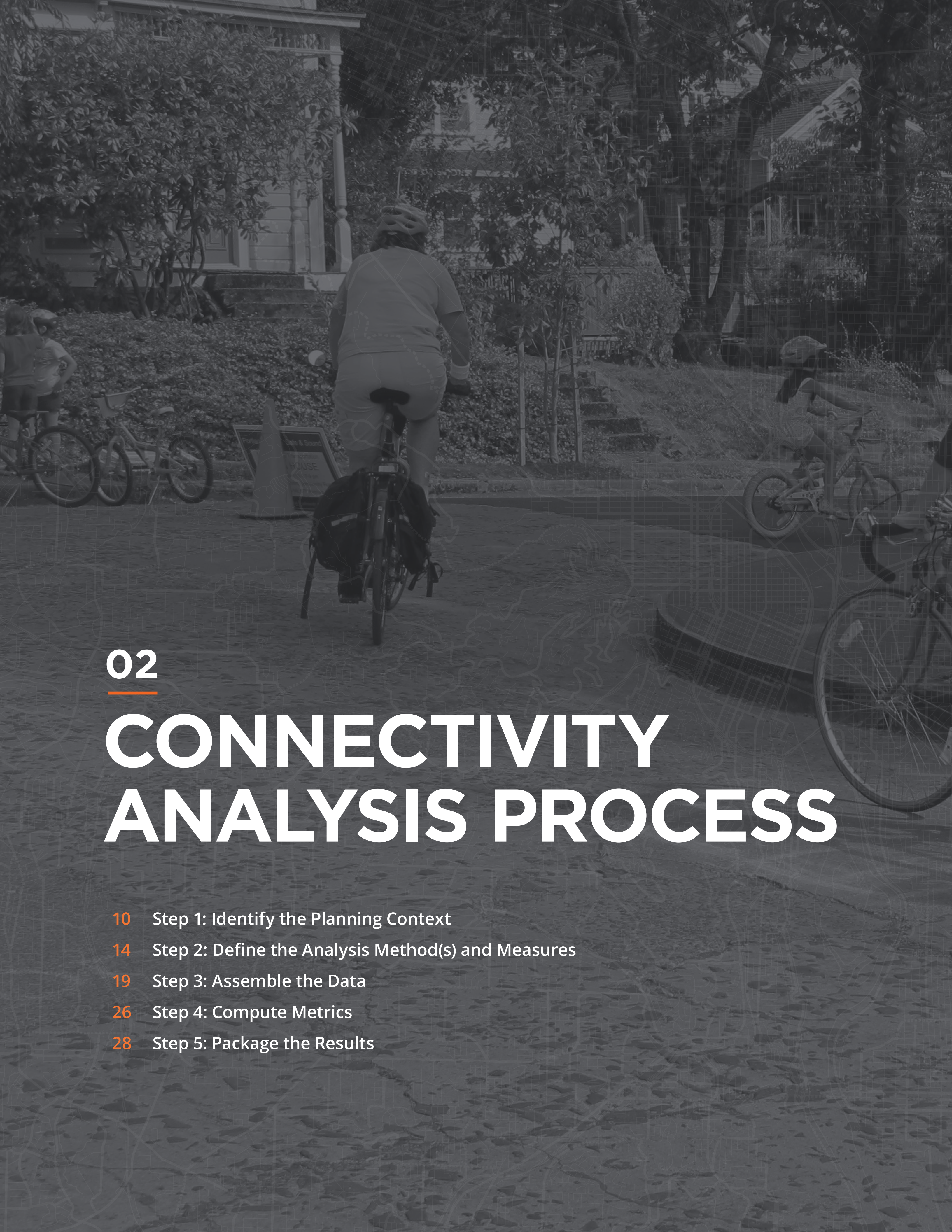
For those who want a deeper understanding of the technical process, Chapter 2 provides a step-by-step approach for conducting a connectivity analysis, supplemented in Chapter 3 by a series of fact sheets on analysis methods and measures. Chapter 4 summarizes lessons learned from practitioners in case study communities, and the Appendix provides descriptions of five case study assessments conducted as part of the research to develop this guide. Referenced throughout the report, these case studies highlight opportunities, challenges, and notable practices as well as illustrations of different ways of implementing the connectivity analysis steps.

WHAT IS ACCESSIBILITY?

The word “accessibility” can take on different meanings depending upon the context in which it is used. Broadly, it is about the ability to reach destinations safely and conveniently. It has long been associated with the usability of facilities by individuals with disabilities, but is also often used by transportation planners as a synonym for general pedestrian, bicycle, and transit connectivity. This guide uses the moniker “Access to Destinations” when referring to analysis methods and measures for examining pedestrian and bicycle connections between origins and destinations.

Table 1: *Assessing Multimodal Connectivity Throughout the Planning Process*

PLANNING PROCESS STEP	RELEVANT PLANNING TASKS	QUESTIONS INFORMED BY CONNECTIVITY ANALYSIS
Vision and Goals	Monitoring and Benchmarking	• What are the needs, priorities, and desires of community members and stakeholders? How and where do they want to see connections that will support their everyday needs and their bigger-picture goals, such as economic revitalization and job growth? • How has multimodal network connectivity changed over time? • How does connectivity in one area compare to other similar communities, regions, or states?
Alternate Improvement Strategies	Gap Identification Needs Assessment	• Where are missing or low-quality connections in existing facilities? Where are fixes needed?
Evaluation and Prioritization of Strategies	Scenario Analysis Project Prioritization	• How do different projects or strategies compare when it comes to improving the connectivity of the network? • What small but important improvements, such as connecting a bike route bisected by a highway intersection or fixing broken sidewalks, could make a big difference in achieving local goals for access to jobs, training, and essential services for all users?
Development of Transportation Plan	Scenario Analysis Gap Identification Needs Assessment Project Prioritization	• What destinations can people reach by biking and walking? • Which neighborhoods have higher or lower accessibility to the network or to specific destinations? • How does multimodal connectivity relate to other planning issues such as safety, system use, job growth, and equity?
Development of Transportation Improvement Programs	Project Prioritization	• How can the most cost-effective connectivity improvement be achieved while still advancing other high-priority needs? • How can funding be leveraged to best improve connectivity and achieve multiple agency goals for economic revitalization and job growth?
Project Development and System Operations	Feedback Loop to Inform Iterative Plan Updates	• How can multimodal connectivity be maintained or improved during project construction? • How can multimodal connectivity be preserved and enhanced during routine system maintenance and operation?



02

CONNECTIVITY ANALYSIS PROCESS

STEP 1

Identify the planning context

STEP 2

Define the analysis method

STEP 3

Assemble the data

STEP 4

Compute metrics

STEP 5

Package results

Figure 2. *Steps of the 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

CONNECTIVITY ANALYSIS PROCESS

This guide provides a step-by-step framework for selecting and applying connectivity measures to help make decisions that are grounded in a comprehensive vision, supported by clearly defined goals and measurable objectives. Organized around the five steps shown in Figure 2, this chapter describes the terminology and procedures, while highlighting practical examples in each step.

In many real-world applications, the steps above will require an iterative process; for example, initial connectivity calculations might highlight errors or other deficiencies in underlying data that need to be corrected. As part of the development of this guidebook, five communities participated in case study applications of the analysis tools and measures discussed (Table 2). References to the case study results appear illustratively throughout the guidebook and are summarized in the Appendix.

Table 2: *Connectivity Analyses in Case Study Communities*

	ATLANTA	BALTIMORE	CALIFORNIA	FORT COLLINS	PORTLAND
STEP 1 ***Identify the planning context***	Identify potential bicycle projects that would improve access to local centers in urban and suburban locations, using a regionally consistent approach that can inform regional funding decisions	Develop more sensitive pedestrian network connectivity measure for citywide planning, benchmarking, and accessibility to destinations	Measure bicycle mobility across high speed state highway corridors for project planning, prioritization, funding, and benchmarking	Analyze bicycle network quality and connectivity, repeatable over time for citywide planning and benchmarking	Identify bike/ walk connectivity gaps and evaluate how well Regional Transportation Plan (RTP) projects address the gaps
STEP 2 ***Define the analysis method***	Access to destinations (centers) via bicycle networks: a) Facility-based b) Quality-weighted (level of stress)	Network completeness: a) Facility-based (sidewalks) b) Quality-weighted (level of stress)	Directness of routes crossing the highway that use facilities that meet a minimum quality	Network completeness and access to destinations via low-stress network	Selected facility-based measures developed as part of RTP update, as well as two statistically consolidated measures
STEP 3 ***Assemble the data***	Planned and existing routable networks, designated bicycle facilities, level of traffic stress segment ratings, population, community centers/ boundaries	Centerline network, posted speed, number of lanes, sidewalks, curb ramps, bicycle facilities, land use, traffic signals, number of lanes, parking	Routable network open to bikes, roadway functional class, state highway corridor centerlines	Routable network, bicycle facilities, lane widths, turn lanes, parking, posted speeds, trails, traffic signals, topography, and land use	Existing and planned bicycle and pedestrian facilities, on-street and trail, transportation and equity planning areas
STEP 4 ***Compute metrics***	3-mile travelsheds along low-stress networks calculated in GIS	Sidewalk presence and two quality-weighted scores for each network link	Level of traffic stress rating for each segment, and shortest paths along lower-stress network at regular intervals	Level of traffic stress, route directness from Census blocks to schools on low-stress network, and link centrality	Seven form-based metrics computed at traffic analysis zone (TAZ) level; two consolidated measures derived from factor analysis
STEP 5 ***Package results***	Travelshed maps, population within travelshed by area	Network link maps and tabular result summaries aggregated to neighborhood	Route directness ratings along corridors, and tabular summaries by corridor	Connectivity island (network gap) maps, and equity overlays	Current and percent change maps by TAZ; overall change by metric and equity-focus area

STEP 1

IDENTIFY THE PLANNING CONTEXT

As an initial step, agencies need to identify the planning context and specific steps or questions that a network connectivity analysis will inform. Analysis performed without this context in mind is unlikely to provide the right information. Further, many connectivity measures are technically complex, and results can be challenging to understand and communicate in isolation. The analysis goal should be to provide answers to questions posed by specific planning tasks, while acknowledging and coordinating with the broader agency planning and policy context where possible.

Once defined, the specific analysis purpose will guide the rest of the connectivity analysis. As the case study examples in Table 2 illustrate, some key parameters to consider when defining the planning context include mode (bikes, pedestrians, or both); analysis scale (local areas, corridors, or regionwide); and the role of the agency (local or state network ownership/ operation, regional planning and technical assistance). Specifically, the questions discussed below will help define the analysis context.

? WHAT ARE THE KEY QUESTIONS, PROBLEMS, OR DECISIONS TO BE INFORMED BY THIS ANALYSIS?

The specific planning context will, to a large extent, define connectivity analysis parameters, including the mode focus (pedestrian, bicycle, or both), scale, and key outputs. The Atlanta Regional Commission (ARC) case study, for example, focused on local analysis of bicycle network gaps around specific locations, while the Portland Metro case study sought to inform region-wide connectivity for pedestrians and bicyclists without specific destinations in mind. Measures, data, and summarization techniques will naturally vary between such different cases.

? WHAT RELATED PLANS AND POLICIES MIGHT INFORM OR BE INFORMED BY THIS ANALYSIS?

In addition to the specific analysis context, an agency's broader planning context can provide useful input into the design of connectivity analyses and the selection of specific methods. Aligning measures with existing plans and policies can help decisionmakers interpret results or allow agencies to substitute simpler measures that more efficiently capture the implementation of current plans and policies. For example, the Portland Metro case study connectivity analysis borrowed aggregation areas and equity definitions from their broader regional planning context. This helped to align connectivity findings with related regional plan data and policies. The City of Lincoln (Nebraska) developed an interactive network gap analysis tool that could be used to support specific planning tasks throughout their broader Complete Streets program (Lincoln/Lancaster County Planning Department 2015). The tool is updated and used regularly by staff and can be pulled up in any agency planning meeting to provide connectivity information.

Relevant plans and policies to consider in identifying connections to broader policy or planning context include the following:

- **Current bicycle and pedestrian plans:** One simple way to analyze connectivity is to measure the percentage of planned facilities that have been built. This approach can be meaningful when a community has developed a detailed, consensus-based bicycle and/or pedestrian plan, but it is less meaningful if the plan is dated or has only received limited stakeholder feedback or approval. It also doesn't account for the fact that some projects will have a relatively more important impact on the overall network than others and that this isn't necessarily determined by the size of the project.
- **Other transportation policies:** Connectivity measures can also capture the extent to which other transportation policies are being implemented. For example, in communities that have adopted complete streets standards, it may be useful to measure the

percentage of street-miles with bicycle and pedestrian facilities. Some communities have minimum street spacing standards that could serve as a basis for assessing the density of the bicycle and pedestrian network.

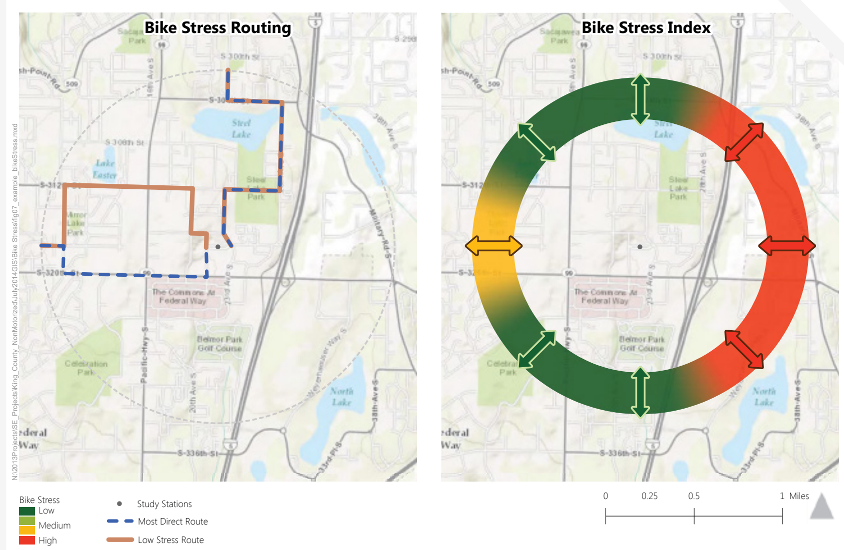
- **Precedent:** In communities that have previously conducted a connectivity analysis, it may be useful to be consistent with the measures used before for benchmarking purposes.

WHAT ARE THE RELEVANT EXISTING AND/OR PLANNED NETWORKS?

Since connectivity analyses are inherently tied to bicycle and pedestrian networks, identifying the relevant network or networks is a necessary part of identifying the planning context. For example, in the California case study analysis, Caltrans was interested only in network connectivity across specific highway corridors. This informed method selection in subsequent steps; for instance, a method meant to summarize connectivity across an entire network or within areas (e.g. on either side of the highway) would not have been suitable. In the Portland Metro case study example, all bicycle and pedestrian facilities were included as attributes of the base year network, but planned projects included only those identified in the 10-year regional Active Transportation Plan (ATP). The ATP was the primary process the connectivity analysis was meant to inform. Method selection then focused on measures of system completeness and density to capture the impact of ATP projects on the bicycle and walking networks. More detailed discussion of defining analysis networks is provided under Step 3.

WHAT IS THE AGENCY'S ROLE IN ADVANCING MULTIMODAL CONNECTIVITY?

The agency conducting the connectivity analysis does not always own or have primary planning responsibility for the network. And, even for those that do have planning or jurisdictional authority, connectivity assessments that consider only the roadways and facilities within an agency's control will often not be as useful as ones that



Source: King County Metro and Sound Transit. 2014. "Non-Motorized Connectivity Study." http://metro.kingcounty.gov/programs-projects/nmcs/pdf/nmcs-report-091214.pdf

HOW TRANSIT AGENCIES HAVE USED CONNECTIVITY ANALYSIS

Transit agencies typically do not have jurisdiction over pedestrian and bicycle facilities beyond their station sites, and funding for improvements is limited outside of major capital projects. TriMet (Oregon) and King County Metro (Washington) each developed pedestrian and bicycle connectivity tools and analyses that helped local jurisdictions make more informed decisions about improving access to transit (TriMet 2011; King County Metro and Sound Transit 2014; TriMet 2016). Both agencies noted that, in addition to prioritizing planned projects, the connectivity analyses and tools had been useful for writing grant applications, and at least one jurisdiction (City of Beaverton, Oregon) had used the resulting methodology in updating its Active Transportation Plan (City of Beaverton 2017). The agencies suggested that it was important to work with localities early in the analysis process to get “buy in” on design and data standards, further noting the key intermediary role of the regional MPO.

consider the function of those facilities within the larger network.

Agencies without direct control over network facilities may still wish to provide technical support, help to secure funding to network owners for project implementation, or simply consider how their own facilities interface with others. For example, metropolitan planning organizations (MPOs) and transit agencies may provide connectivity analysis data or tools to local jurisdictions. In the Atlanta case study example, one goal of the MPO was to further development of a standardized, repeatable bicycle network connectivity analysis that could be conducted by local jurisdictions for grant funding applications. The California case study analysis recognized that the state highway system posed barriers to bicycle and pedestrian connectivity, so Caltrans focused their analysis on assessing directness of nonmotorized routes that crossed their facilities. The text box on the previous page provides further examples from transit agencies that produced tools or analysis for use by owners of bicycle and pedestrian networks that provided access to transit facilities.

WHAT IS THE APPROPRIATE SCALE FOR THIS ANALYSIS?

The scale of analysis is affected by the specific purpose and context of the analysis. Is the planning need a high-level sketch of the network as a whole, with limited details on the characteristics and quality of individual links? Should connectivity be summarized to specific areas? For example, will the study overlay with supporting data to measure progress toward equity goals? Or does the planning context require more

Source: Atlanta Regional Commission. 2014. "Bicycle Pedestrian Plan – Walk. Bike. Thrive!" http://atlantaregional.org/plans-reports/bike-pedestrian-plan-walk-bike-thrive

PROMOTING LOCAL CONNECTIVITY FROM A REGIONAL PERSPECTIVE

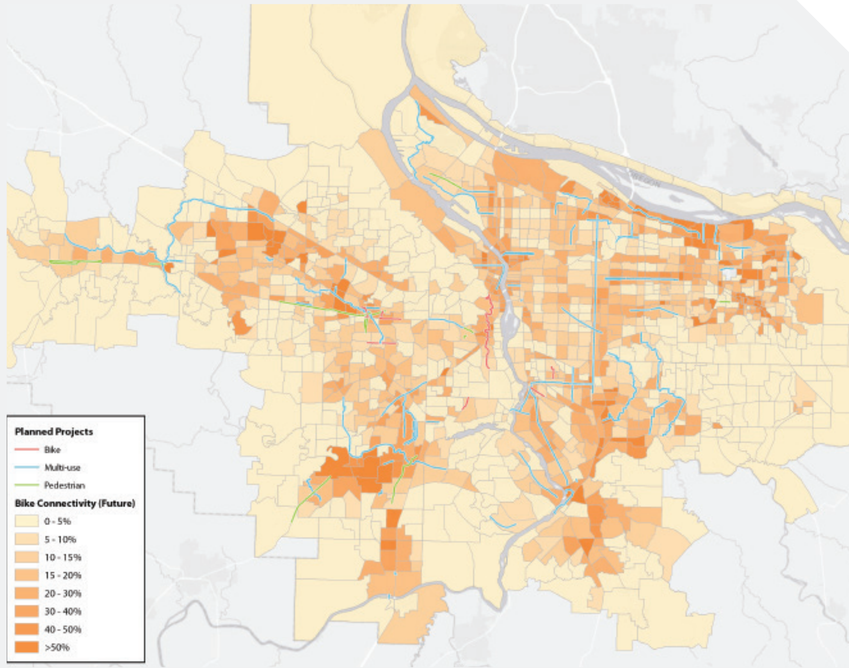
MPOs conduct regional analyses but also serve an important role in assisting and promoting consistency and innovation in local planning. The Atlanta Regional Commission (ARC) is the regional planning agency for the ten-county Atlanta (GA) metropolitan region. In its 2007 bicycle and pedestrian plan, ARC identified bicycle improvements along key regional corridors based on a detailed analysis of bicycle level of service, but found it difficult to coordinate implementation among the many local transportation agencies that had jurisdiction over segments of these corridors. The agency tried a different approach in its 2014 bicycle and pedestrian plan by identifying frameworks for ARC and local agencies to plan better together rather than identifying specific regional projects (Atlanta Regional Commission 2014). The plan includes some detailed guidelines on connectivity, such as connected network serving key destinations with bikeways spaced a half-mile apart, but focuses primarily on connectivity standards and measures that promote a coordinated but customized approach among localities.

in-depth descriptions of the quality of routes that connect specific origins and destinations?

Data availability is another consideration when determining the scale of an analysis. Some agencies find that required data is hosted in various departments or across different jurisdictions, all with different standards and maintenance procedures. Data can be maintained at varying levels of detail and one department or agency's database may omit specific attributes that another department needs. In other instances, data may not be readily available and will need to be collected or purchased to conduct the analysis.

When analysis is based on facility quality (e.g. level of service or perceived stress/attractiveness) or specific destinations, it is possible to collect more detailed data and conduct a more sophisticated analysis than larger-scale assessments with limited data availability. Typically, larger-scale analyses and tools have relied on simpler measures due to limited data availability. However, larger scale does not necessitate simpler measures. If data are available, large-scale measures can be more fine-grained and facilitate reuse for smaller-scale assessment as part of the planning process. For example, the Atlanta case study was able to reuse region-wide network link quality scores for a new analysis of local access to specific local centers. Had the regional analysis been done with simpler or coarser measures, the old analysis would not have been useful at the new, smaller analysis scale. With these tradeoffs in mind, the scale—and complexity—of the analysis is ultimately driven by both the specific planning context as well as the resources available for data collection, agency and jurisdiction coordination, GIS and related analysis, and data maintenance.

Chapter 3 of this guidebook provides brief fact sheets about analysis types and specific metrics and tools that can be used to assess connectivity at a variety of scales and at varying levels of complexity. The fact sheets in Chapter 3 identify potential scales of application and key questions each analysis type might help an agency to answer.



SCALING UP DETAILED DATA FOR REGIONAL ANALYSES

While Portland Metro's scale is relatively large and its data is highly complex, its selected connectivity metrics represent a relatively simple approach due to the scope of their analysis for long-range network planning. For its regional transportation plan, Metro focuses on a simplified network of regionally significant bicycling and walking corridors. Because the focus is on regional connections, and data on many local planned and existing facilities are outside of this scope, a more detailed connectivity analysis would be of limited value.

Such analysis is applied in other planning processes within the agency. For example, the regional travel demand modeling process includes a state-of-the-art bicycle model that measures connectivity quality in a highly detailed manner.

STEP 2

DEFINE THE ANALYSIS METHOD(S) AND MEASURES

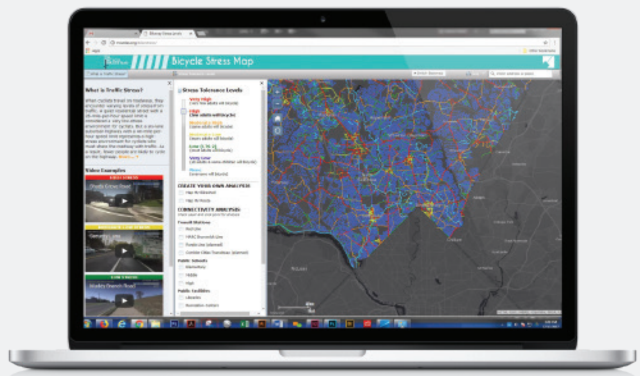
After establishing the planning context and analysis goals in Step 1, the next step is to define an appropriate analysis method, including the specific measures to be used and the data required. Often, there will be many ways to answer the planning questions at hand. A connectivity analysis might include multiple measures that are aggregated or summarized in a variety of ways in order to visualize the information comprehensively. Complex analyses and measures can provide more nuanced results, but this must be balanced against increasing data and resource requirements.

CONNECTIVITY ANALYSIS METHODS

This guide focuses on five fundamental connectivity analysis methods, as listed below, summarized in Table 3, and illustrated in Figure 3.

- Network completeness
- Network density
- Route directness
- Access to destinations
- Network quality

Three of the methods—completeness, density, and directness—focus on the efficacy of the network's design. There is considerable overlap among the three categories, and recent work has shown that systematically combining measures from each may provide a more complete view of network connectivity (Schoner and Levinson 2014). The fourth method, access to destinations, incorporates the land use context in order to illustrate the level to which the network facilitates movement to, from, and between important origins and destinations. Finally, network quality analyses enable planners to consider the experiences of nonmotorized network users, such as safety, convenience, and comfort, which can make a critical difference in the overall usefulness and performance of the system.



CHOOSING THE RIGHT MEASURE FOR THE COMMUNITY

Montgomery County (MD) considered a wide range of metrics to support its bicycle planning process (Montgomery County 2014). The selection process was iterative. They scanned other plans and FHWA reports/resources, and also had discussions with the county's Citizen Advisory Group about goals and metrics. A key desire was a metric that did not use qualitative data, but instead would provide hard numbers "to have bicycling taken seriously." The availability of data was also an important consideration. They noted whether existing data were available, and if not, whether they would be able to collect it.

In the end, they chose to modify an existing network quality measure (Level of Traffic Stress) to better suit suburban conditions within their jurisdiction. The base metric was combined with various overlays to support multiple connectivity analyses and is publicly available as an interactive map.

Source: Montgomery County. 2016. "Bicycle Stress Map." http://mcatlas.org/bikestress/.

Table 3: *Multimodal Connectivity Analysis Methods and Measures*

ANALYSIS METHOD	KEY QUESTION	EXAMPLE MEASURES	SCALE	PLANNING TASK
Network Completeness	How complete is the planned bicycle and pedestrian network?	• Percent of planned nonmotorized facility-miles that are complete • Miles of planned nonmotorized facilities that have been built	• Small area • Large area	Monitoring and Benchmarking
	What portion of streets contain nonmotorized facilities?	• Percent of street-miles with nonmotorized facilities • Percent of street-miles that meet level of service or low-stress thresholds	• Small area • Large area	Needs Assessment, Scenario Analysis
Network Density	Does the street network allow for travel between destinations via a number of routes?	• Intersection density • Connected node ratio • Block length • Network density (street-miles per square mile)	• Route • Small area • Large area	Needs Assessment; Scenario Analysis
	Do designated bicycle and pedestrian facilities allow people to travel between destinations via a number of routes?	• Network density of nonmotorized facilities (lane miles per square mile) • Intersection density of nonmotorized facilities	• Small area • Large area	Scenario Analysis, Project Prioritization
Route Directness	Do nonmotorized facilities allow users to travel throughout a community via direct routes?	• Out of direction travel as a percentage of shortest path route • Network permeability	• Corridor • Small area • Large area	Scenario Analysis, Gap Identification, Project Prioritization, Benchmarking
Access to Destinations	How well do bicycle facilities connect to key destinations?	• Nonmotorized travelshed size • Number of homes/jobs accessible by bike/foot • Accessibility indices (e.g. Walk Opportunity Index) • Number of homes/jobs accessible by bike/foot using a certain level of network quality	• Corridor • Small area • Large area	Needs Assessment, Gap Identification, Project Prioritization
Network Quality	What is the objective quality of connectivity provided by an existing or planned network?	• Percent or area of network with high ratings for nonmotorized Level of Service, Bicycle Route Quality, or Pedestrian Index of Environment • Percent or area of network with low ratings for Level of Traffic Stress	• Link • Route • Small area • Large area	Needs Assessment, Gap Identification, Scenario Analysis

Source: FHWA

CONNECTIVITY ANALYSIS MEASURES

Analysis methods can be supported by a number of different measures, each of which presents specific data requirements, advantages, and disadvantages. In general, the connectivity assessment methods for density and completeness have the lowest data and computation needs. Data can often be assembled from existing sources, either within an agency or via U.S. Census or other public network data. Route directness and destination access typically will require network path analysis with routable network data (i.e. with defined connections) and place data that may be more difficult to assemble. Network quality-based analyses generally require more detailed data describing on- and off-street facilities, such as street configurations, traffic volumes and/or speeds, and more specific bicycle and pedestrian facility details. Table 3 provides an overview of the connectivity analysis methods and methods described in this guidebook. Chapter 3 includes fact sheets with more information about the five analysis methods and a selected array of measures.

THE IMPORTANCE OF DEFINING THE ANALYSIS NETWORK

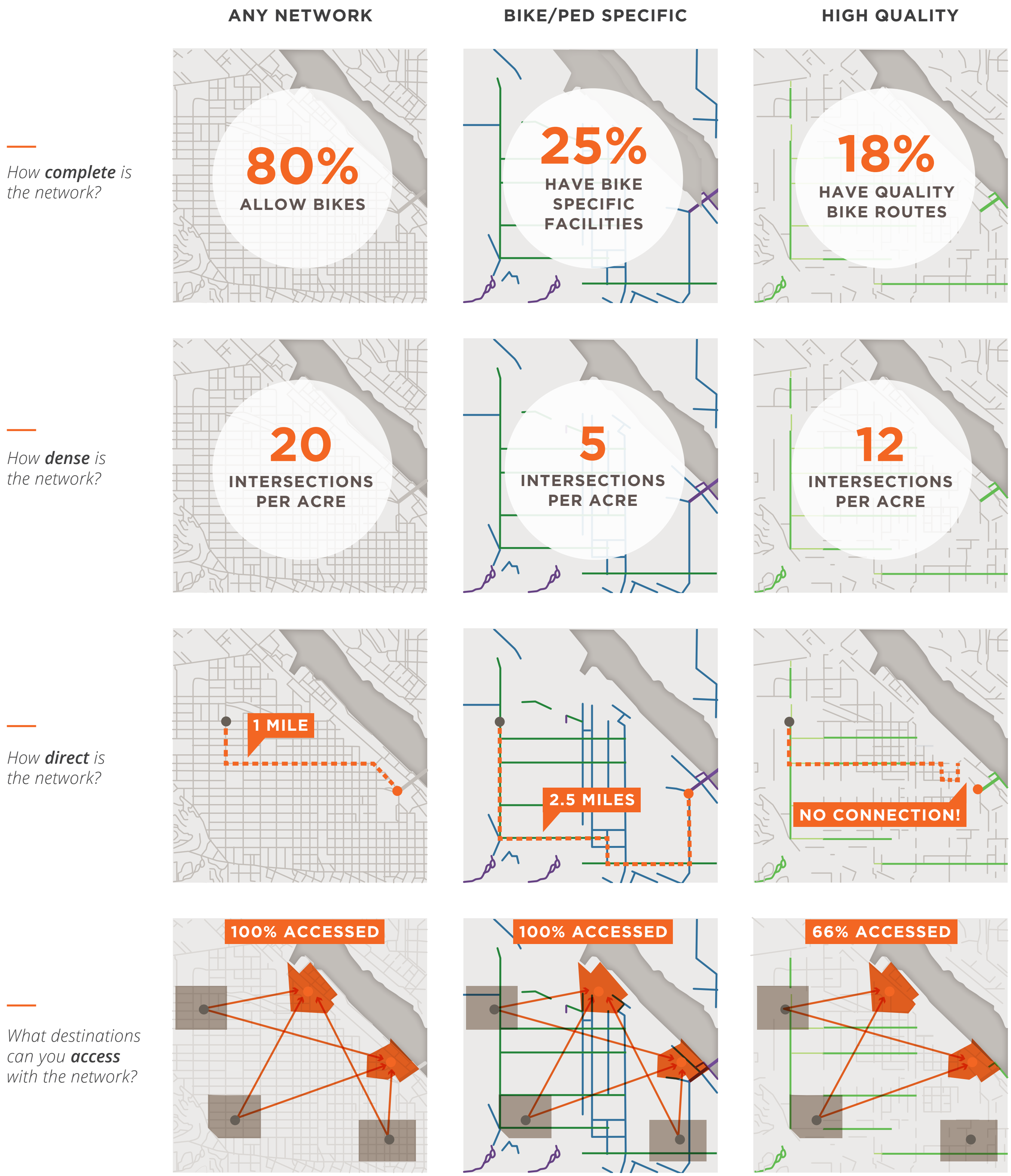
A fundamental element of conducting a multimodal network connectivity analysis is determining the types and characteristics of transportation facilities to be included in the base network. This decision has a strong bearing on the metrics and conclusions that can be drawn from the analysis. The types of networks that are typically assessed include all roadways (and perhaps trails), roadways and trails that have designated bicycle and pedestrian facilities, or roadways and trails that have specific combinations of attributes (especially adequate separation from motor vehicle traffic). Often, the latter classification is based on thresholds meant to be comfortable for all users. Incorporating network quality into the definition of bicycle and pedestrian network connectivity is consistent with assessing other types of modal connectivity. For example, unimproved roadways or alleyways may be removed from assessment of many motor vehicle networks, and the available clearance afforded by overpass height is incorporated into the assessment of freight route connectivity.

In the Baltimore case study, pedestrian network completeness was initially measured based on whether each link had sidewalks or not. This initial result was then compared with a completeness measure based on a quality rating metric that took into account a variety of attributes related to perceptions of stress. Many links that appeared “complete” in the initial analysis did not meet quality thresholds for low-stress connectivity, and area scores by each metric varied greatly.

In addition to the binary approach of including or removing links based on quality thresholds as portrayed in Figure 3, recent preference-based weighting techniques include all available links but assign relative quality weights based on the characteristics of each link. However applied, including elements of network quality as an assessment method produces a more robust and nuanced understanding of the physical network. Both facility-based and quality-weighted networks and supporting data are discussed more fully in Step 3.

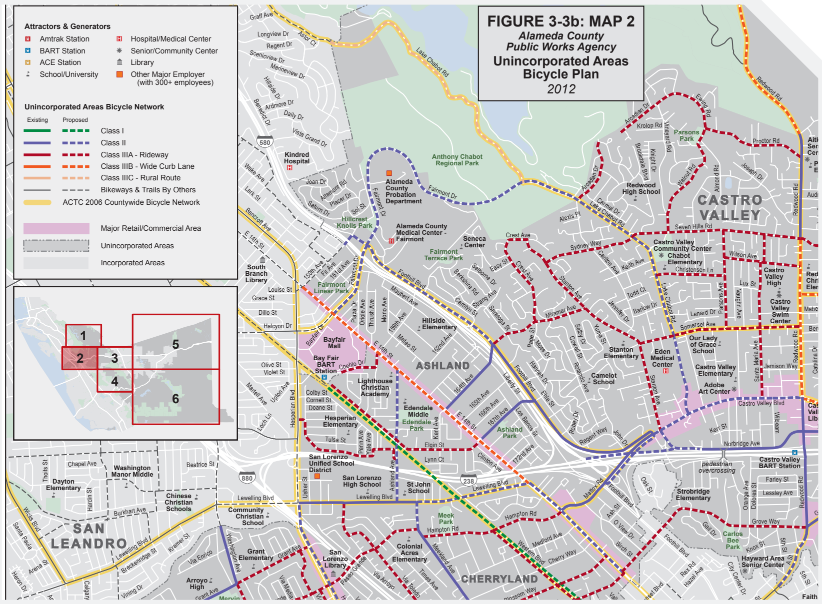
Figure 3. *Connectivity Analysis Methods*

This graphic depicts differences that can result from selecting different base networks for a connectivity analysis. The rows depict four of the five analysis methods (excluding the Network Quality method). The columns represent connectivity analyses conducted for three different base networks: 1) All streets; 2) Designated pedestrian and bicycle facilities; and 3) High-quality facilities identified through a Network Quality assessment.



ADAPTING EXISTING MEASURES TO LOCAL CONTEXTS AND DATA

Agencies sometimes find that existing measures or data definitions do not fit the local context. In other cases, an agency may determine that specific data requirements cannot be met nor can the agency find a suitable alternative measure. In such cases, existing measures have sometimes been modified, or, less commonly, agencies have developed a new measure. There are significant downsides to these approaches, most notably in weakening links to research support and validation, comparability to other applications, and the often-significant development and testing time required to modify or create new metrics. In some cases, the benefits of a localized measure may outweigh the costs. Examples of measure (Montgomery County, MD) and data (Alameda County, CA) adaptations are provided in this chapter. The case study applications for Baltimore, Atlanta, Portland Metro, and California each involved adapting data or methods to suit local planning needs, data availability, and local context.



Source: Alameda County Transportation Commission. 2012. "Alameda County Bicycle and Pedestrian Plan for Unincorporated Areas." https://www.acpwa.org/s/Bike-Ped-Plan-for-Unincorporated-Final.pdf.

ADAPTING CONNECTIVITY MEASURES TO FIT LOCAL DATA AND GOALS

The Alameda County (CA) Bicycle and Pedestrian Plan for Unincorporated Areas (2012) recognized the need to modify existing bicycle facility definitions to survey existing conditions and support planning outside of urban areas. Taking the California Department of Transportation Bikeway Categories as a starting point (Class I: Paved Bike Path, Class II: Bike Lane, Class III: Bike Route), four additional categories were created and coded in the bicycle network: Class IA: Unpaved Trail Bikes Allowed, Class IIIA: Low/Slow Traffic Bike Route (Rideway), Class IIIB: Bike Route with Wide Curb Lanes, and Class IIIC: Rural Bike Route with Wide Shoulders. These classifications were used, among other things, to identify segments where low-cost spot improvements could connect existing facilities. Total miles of each facility type (current and proposed) were also calculated as a basic measure of aggregate network connectivity.

The Kansas City (KS) Walkability Plan (2003) adapted Pedestrian Level of Service (PLOS) to summarize existing pedestrian environments across the city. Links were scored on an A to F rating scale, mapped, and manually grouped into areas of similar walking quality. The overview was used to target more detailed analyses, including public input, in areas where improvements to increase the Pedestrian Level of Service (PLOS) might be needed.