Defining Connected Bike Networks

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What is a "connected bike network"?

A connected bike network provides a safe and comfortable transportation experience, enabling people of all ages and abilities to get where they want to go. Consider the road network as an example. When people get in a car to go somewhere, they rarely give much thought to whether the road can get them to their destination or if they feel secure taking children with them. In other words, the road network for motor vehicles in the U.S. connects to the places people need to go in a generally consistent, reliable, and comfortable way.

Bike networks in the U.S. rarely function the same way. In many places, it isn't a given that people can get from one place to another on a bike on a network that feels safe. For example, Figure 1 shows the area accessible by bike from the highlighted census block using the low stress (blue) and high stress (red) network. Notice that busy arterials create a boundary around the low stress bikeshed. Additionally, it isn't uncommon for a low-stress bike facility, like a protected bike lane (also known as a separated bike lane or cycle track), to end abruptly, leaving a rider on a street that feels unsafe by virtue of the volume and speed of motor vehicle traffic. Research indicates that concern about safety around motor vehicles is a key barrier to increasing ridership (PeopleForBikes, 2014).

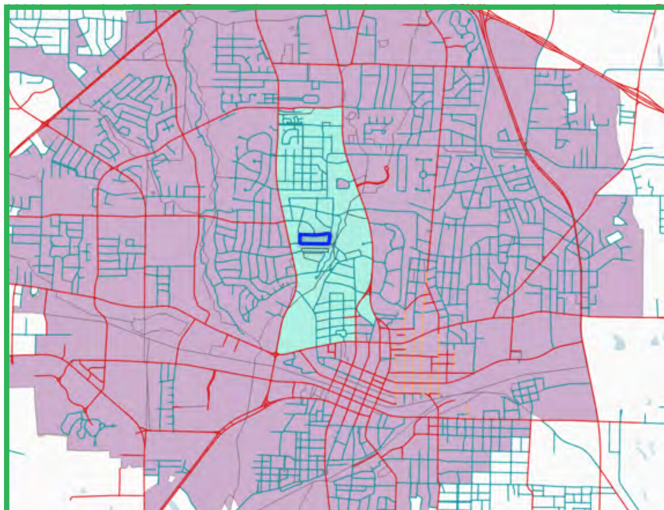

Figure 1. Low-Stress (blue) and high-stress (red) bikeshed in Longview, TX

A "connected bike network" functions just like the road network. It offers people multiple ways to get where they want to go and a safe, comfortable experience for people of all ages and abilities. In order to meet the needs of everyone, a connected bike network should be, by definition, low-stress and high-comfort. Such a network can include a variety of facilities, from a protected bike lane or a quiet neighborhood street to a shared-use path. High-stress facilities such as a conventional bike lane on a street with a 45 mph speed limit may not meet the needs of people of all ages and abilities and would therefore not be considered part of a connected bike network. In this conceptualization, a connected bike network gets people where they want to go and offers a comfortable way to get there.

Why do connected bike networks matter?

Connected bike networks increase ridership and improve safety. In 2007, the city of Seville, Spain focused on connecting a bike network across the entire city, fully separating network facilities from auto traffic to make it safe and comfortable for people of all ages and abilities to ride. Between 2006 and 2013, the network grew from just 12 km of protected bike lanes to 152 km spanning the entire city. With these improvements (and other bike-friendly policies and programs), the city observed a 435 percent increase in the number of bike trips and a 61 percent drop in bike-motor vehicle crash rates (Marqués & Hernández-Herrador, 2017).

After 20 to 30 years of what are at times piecemeal street-by-street improvements, a similar trend is happening in the U.S. Some of the country's leading cities on bike infrastructure are shifting their attention toward linking individual projects into complete, connected multimodal networks. For example: In 2014, Austin, TX, and Seattle, WA, set out to address traffic congestion by updating their bike master plans to prioritize mode shift. Their revised plans call for improving networks of streets until it becomes attractive for people not currently biking to choose to do so. Tallahassee, FL, is currently repurposing travel lanes on key arterials and spur streets to create a network of protected bike lanes and off-street paths leading from Florida State University through downtown to the Gulf coast, 16 miles away. New York City, NY, has been working consistently to connect its network; in 2016 it closed two key links to motor vehicle traffic, creating a single nine-mile string of protected bikeways from Brooklyn up the length of Manhattan to the Bronx.

These efforts have been supported at the national level. For example, the Federal Highway Administration (FHWA) published a ***Strategic Agenda for Pedestrian and Bicycle Transportation*** that includes connected networks as a cornerstone national goal. FHWA has also recently published numerous planning and design resources to help partners and stakeholders implement connected networks at the local, regional, and state level.

Just north of the U.S.-Canada border is an excellent North American example of a city investing rapidly in a connected low-stress network and accelerating the growth of biking. Vancouver started building a downtown network of protected bike lanes in 2010 in the face of intense opposition from businesses worried about parking loss and residents concerned about congestion. From 2011 to 2015, bike commuting in the city increased from 4 percent (National Household Survey for Vancouver City, Statistics Canada, 2011) to 10 percent (Annual Monitoring Report & Safety Action Plan, 2016). Vancouver's downtown business association now praises the network and the mayor, a vocal supporter of bicycle improvements and programs, was reelected twice.

These examples demonstrate the value in shifting away from focus on the "low-hanging fruit" of bike infrastructure – streets with excess auto capacity or unused parking – and toward the most important roads for bicycle connectivity, even if they require difficult tradeoffs. These changes may be more politically difficult, but if chosen well they promise bigger payoffs in ridership and safety – a promise supported by research.

Pucher and Buehler (2016) analyzed data from 10 American cities that have focused efforts to improve and connect their bike networks over the last 15 years: Portland, OR; Washington, DC; New York, NY; Minneapolis, MN; San Francisco, CA; Cambridge, MA; Chicago, IL; Seattle, WA; Los Angeles, CA; and Philadelphia, PA. Across all 10 cities there is evidence of increased ridership with a simultaneous reduction in crashes, fatalities, and severe injuries.

The authors and others are quick to point out that more research is needed and that not all bike facilities are created equal, either in terms

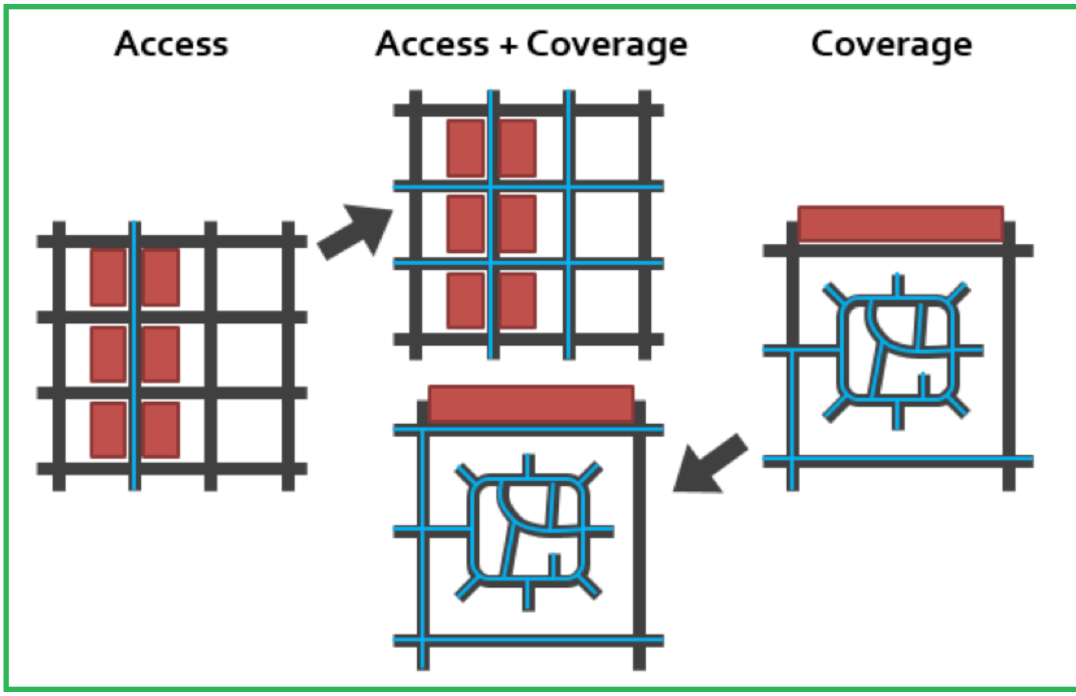

Figure 2. Ease of Access and Coverage

Legend:

Blue lines indicate low stress network segments

Black lines indicate high stress network segments

Red boxes indicate destinations

of increasing ridership or improving safety. For example, a study of 74 U.S. cities found that dense bike networks with direct connections were the most likely to increase bike commuting (Schoner & Levinson, 2014). Similarly, a study examining a variety of bike facility types in Vancouver and Toronto found that the odds of a crash occurring on protected bike lanes on roads without parked cars was 89 percent lower than on major streets (with parked cars and no bike infrastructure). The odds of a crash occurring on low volume residential streets without any bicycle facilities was 56 percent lower than on major streets (Teschke et al., 2012).

To summarize: connected bike networks can grow ridership and improve safety. Best of all, people want them. A recent poll conducted by Princeton University (2016) found that 58 percent of Americans support an increase in funding for biking and walking, up from 47 percent in 2012. Another 30 percent support maintaining current levels of funding for walking and biking. These priorities are reflected in U.S. cities with initiatives like Vision Zero, and at the highest levels of government. In fact, during her confirmation hearing, U.S. Secretary of Transportation Elaine Chao stated that "safety will continue to be the primary objective."

How do we measure connected bike networks?

Two key factors that define connected bike networks are connectivity and comfort. Following are the most common measurement approaches to each.

Connectivity

Connectivity reflects the degree to which people can get where they want to go on the bike network. It is composed of two key factors, access and coverage. Access reflects the degree to which people can get to key destinations on the network, and coverage reflects ease with which all destinations can be accessed on the network (see Figure 2).

The key feature of access measures is that they require the prioritization of particular destinations (Handy & Niemeier, 1997). In contrast, measures of coverage reflect how well the network gets people to all locations throughout the network (Rayfield et al., 2011). The strengths of coverage approaches complement the weaknesses of access approaches and vice versa. For example, coverage measures don't require assumptions about where

Traffic Stress Tolerance	Type of Transportation Cyclist*	LTS Level of Comfort	Description
Less	**No Way, No How**	Not Applicable	Not interested in riding a bicycle for transportation.
	Interested but Concerned	LTS 1 (incl. children) LTS 2 (not incl. children)	Little tolerance for traffic stress with major concerns for safety. Strongly prefer separation from traffic on arterials by way of protected bike lanes and paths.
	Enthused and Confident	LTS 1, LTS 2, LTS 3	Some tolerance for traffic stress. Confident riders who will share lanes with cars, especially on rural roads, but prefer separated bike lanes, paths, or paved shoulders on roads with higher traffic levels.
More	**Strong and Fearless**	LTS 1, LTS 2, LTS 3, LTS 4	High tolerance for traffic stress. Experienced riders who are comfortable sharing lanes on higher speed and volume arterials. These riders may use protected bike lanes and paths if available but will ride without them as well.

Figure 3. Level of Traffic Stress and the Four Types of Bicyclists
*These category names were developed by Roger Geller of the City of Portland Office of Transportation in 2006.

people travel, but they don't account for factors like land use. As a result, the two measures are best used in conjunction with one another.

Comfort

Comfort reflects the degree to which people feel safe from contact with motor vehicles while riding on the bike network. There are a variety of "Level of Service" (LOS) measures that differ with respect to the specific method of calculation, but all generate a comfort score based on characteristics of the roadway (LaMondia & Moore, 2014).

Although LOS approaches have proven useful in measuring bicycle network comfort, they share some common issues. First, data limitations are a barrier for many agencies in that they don't collect the relevant data on a community-wide basis. Second, existing LOS measures only take into account a limited number of facilities – not including protected bike lanes – so emerging facilities like protected bike lanes are difficult to score. Finally, LOS measures aren't related to a specific standard of comfort, so we don't know if the mainstream population would feel comfortable on a given segment.

PlacesForBikes Bike Network Analysis

As part of its PlacesForBikes program, PeopleForBikes is developing a **Bike Network Analysis (BNA)** designed to quantify the degree to which people can get to key destinations on a comfortable, connected bike network. Key destinations include core services (e.g., grocery stores and healthcare), opportunity (e.g., jobs and education), transit, recreation, and retail.

The tool is based on OpenStreetMap (OSM) and uses a modified Level of Traffic Stress approach taking into account factors such as road classification (e.g., primary, secondary, etc.), type of bike facility, speed limits, number of lanes, parking, and width of bike facilities. Intersections are scored taking into account the classifications of crossing streets, intersection control, number of crossing lanes, crossing speed limits, and median islands.

Although there are limitations to this approach (e.g., data availability in OSM), the goal is to provide a tool that all communities can use to measure the quality of their bike networks and track progress as they move toward building complete, connected bike networks. The PlacesForBikes Network Connectivity scoring is open-source so that anyone can use or modify it.

To address these limitations, Mekuria et al. (2012) developed a method of classifying road segments based on how comfortable different types of users should feel on them. The Level of Traffic Stress (LTS) method uses four categories of stress that roughly correspond to Roger Geller's (2006) four categories of bicyclists (see Figure 3). One of its differentiating characteristics is that the LTS approach assigns the worst rating encountered on a trip to the entire trip. For example, if a trip follows mostly low stress roads but requires a stressful crossing that rates LTS 4, the whole trip receives a rating of LTS 4, meaning that only the most committed riders would be expected to make the trip.

Because of its explicit connection to types of riders, intuitive interpretation, and usage of available data, the LTS approach has become a standard for measuring the comfort of bicycle networks. Since its original publication, research has built on the LTS framework. For example, Lowry et al. (2016) simplified and extended the original LTS measurement model with less stringent data requirements and incorporated newer facility types such as protected and buffered bike lanes. Cities and advocacy organizations are adapting the LTS methodology to help them understand and improve the quality of their local bicycle networks (see sidebars for examples).

FHWA's Measuring Multimodal Network Connectivity Project

FHWA is currently working on a project on *Measuring Multimodal Network Connectivity*. This project will synthesize and present a range of options for measuring multimodal network connectivity and tracking change over time. It will result in a national guidebook to help transportation agencies select connectivity measures based on the data and technical tools available, scale of analysis, and point in the planning process. The guidebook will be grounded in real-life examples from transportation practice, including five case studies based on in-depth technical assistance provided to the following agencies:

1. Fort Collins, CO
2. Baltimore, MD
3. Atlanta Regional Commission (Metropolitan Planning Organization)
4. Metro (Portland Region Metropolitan Planning Organization)
5. Caltrans District 4 (State Department of Transportation region serving San Francisco/Oakland/Marin)

The resource will be published in fall 2017 and will be available on FHWA's **website**.

What are we working toward?

The shared goal is to accelerate progress in building complete, connected bike networks, a concept that is gaining momentum in the U.S. As described in the sidebar above, FHWA is focusing on how connected bike networks address key goals such as improved safety across all modes, better transportation system efficiency, and economic development. To inform this effort, FHWA developed a ***Bike Network Mapping Idea Book*** that links the idea of complete, connected bike networks to the transportation planning and decision-making process.

Cities are also refocusing their efforts to build complete networks – programs like **Complete Streets** are an example. There are also several programs offered by organizations like **PeopleForBikes** and the **League of American Bicyclists** that foster the development and institutionalization of connected bike networks. The research is clear, connected bike networks increase ridership and ultimately create safer places for everyone.

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