Network Connectivity for Low-Stress Bicycling

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ABSTRACT: For a bicycling network to attract the mainstream population, a critical attribute is *low-stress connectivity*, that is, providing routes between people's origins and destinations that do not require cyclists to use links that exceed their tolerance for traffic stress, and that do not involve an undue level of detour. A set of criteria are proposed by which road segments, intersection approaches, and intersection crossings can be classified into four levels of traffic stress (LTS), of which LTS 2, based on Dutch bikeway design criteria, represents the traffic stress that most adults will tolerate.

As a case study, every street in San Jose, California was classified by LTS. Maps in which only lower stress links are displayed reveal a city divided into islands within which low-stress bicycling is possible, but separated from one another by barriers that can only be crossed using high stress links. Such maps can help guide network development by revealing barriers such as arterial streets that lack intersections with both safe crossing provision and low-stress approaches.

A summary measure of connectivity, the connectivity ratio for a given LTS, is the fraction of daily trips connected at that LTS. For San Jose, the fraction of work trips up to 6 miles long that are connected at LTS 2 is 4.7%. This figure would almost triple by implementing a modest slate of improvements aimed at connecting low-stress streets and paths with each other.

When considering bicycling, much of the population displays intolerance for the stress imposed by motor traffic due to risk of injury and, to a lesser extent, noise and exhaust fumes. This is evidenced in the large difference in bicycle usage between countries with and without widespread provision of low-stress bicycling infrastructure such as cycle tracks (1) as well as in surveys in which respondents cite traffic danger as one of the chief reasons for not riding a bike and express a strong preference for bicycling on segregated paths and low-volume local streets (2). Geller (3) classifies the adult population into four groups, with size estimates shown in parentheses:

- Strong and fearless (<1%): Willing to ride in almost any traffic situation.
- Enthused and confident (7%): Willing to ride on busy, wide roads if a designated bicycling space (bike lane or shoulder) is provided.
- Interested but concerned (60%): Uncomfortable next to fast traffic or negotiating with traffic on busy roads.
- No way, no how (33%): Shows no interest in riding a bike

Among those willing to use a bike, the “interested but concerned” group, elsewhere called “easy riders” or “traffic-intolerant riders” (4), is estimated to represent nearly 90% of all cyclists and potential cyclists. While Geller’s estimates are rough, it is probably not an exaggeration to characterize the mainstream population as traffic-intolerant.

It has been shown that where more bicycle route facilities are provided, more people will ride a bike (5, 6). However, simply measuring miles of bike facilities can be misleading. First, some designated bicycling facilities exceed a level of stress that most people will tolerate. An example is the bike lanes along San Diego’s Camino del Norte, with speed limit 55 mph, where cyclists are expected to weave across one lane of 55 mph traffic and then ride for 900 ft with two lanes of fast-moving traffic on their right and four lanes on their left. Second, bikeways are often not connected to each other, diminishing their ability to connect people to destinations. Third, cities have many quiet streets that are not designated as bike facilities yet offer a low-stress environment; they belong in a bicycling network defined as the “links on which people are willing to ride.”

In order to attract more of the mainstream population to cycling, a primary concern should be developing a network of low-stress routes that connect people’s homes with destinations such as workplaces, schools, shopping, and recreation areas. In many American communities, it can be impossible to ride a bicycle between two given points without using links with high levels of traffic stress. This means that for the traffic-intolerant population, many destinations are inaccessible by bicycle.

The objective of this research was to develop mapping tools and summary measures for visualizing and evaluating the connectivity of bicycling networks limited by users’ tolerance for traffic stress. Using San Jose, California, as a case study, every street and path in the city was classified by level of traffic stress in order to answer questions such as “How many people could get from home to their workplace without using links that exceed a given level of traffic stress?” and “From a given point, what part of the city is accessible using only links that do not exceed a given level of traffic stress?”

TRAFFIC STRESS CRITERIA

Several researchers have developed methods for classifying road segments by the degree of stress they impose on cyclists. Sorton and Walsh (7) used criteria along three dimensions: traffic volume in the curb lane, traffic speed, and width of the curb lane (including any existing bike lane or shoulder). The criteria were chosen by informal consensus of a large number of cyclists. The Bicycle Level of Service (BLOS) model for road segments (8) and the Bicycle Compatibility Index (BCI) (9) use complex formulas to estimate a comfort rating using a larger set of factors including presence of a bike lane, presence of a parking lane, and whether the area is residential. The formulas were estimated from ratings given by subjects to different road situations. Efforts to apply the same modeling approach to intersections were not as successful (10).

A new classification scheme was developed because those found in the literature require data that is not readily available – particularly, traffic volumes and lane widths. Additionally, Sorton and Walsh's method does not account for the important effects of curbside parking or the availability of bike lanes. The BLOS and BCI models are "black boxes" in the sense that even if all the data for a street section are available, its classification cannot be known without resorting to complex calculations. Consequently, their classifications have little meaning to planners and citizens.

The new classification scheme has four levels of traffic stress (LTS), defined in Table 1, that correspond directly to Geller's first three classes of the adult population, plus a fourth level for children because of their lower ability to control a bike along a narrow course, negotiate with traffic, and cross streets safely. Defining stress criteria in correspondence with a population classification makes them more directly applicable in evaluating how well different populations are served.

Criteria were established classifying for road sections, intersection approaches, and intersections by LTS based on a synthesis of previous research as well as the experience of various cities in that have tried to attract a wide populations to bicycling using different kinds of facilities. Criteria for LTS 2, which corresponds to the mainstream, traffic-intolerant adult population, are based primarily on Dutch design guidelines (11) that have proven successful in attracting the mainstream population, with 80% of the Dutch adult population riding a bike weekly and a male / female split of cyclists close to 50/50 (1).

Table 1. Levels of Traffic Stress (LTS)

LTS 1	Presenting little traffic stress and demanding little attention from cyclists, and attractive for a relaxing bike ride. Suitable for almost all cyclists, including children trained to safely cross intersections, On road sections, cyclists are either physically separated from traffic or are in an exclusive bicycling zone next to a slow traffic stream with no more than one lane per direction, or are in mixed traffic with a low speed differential and demanding only occasional interactional with motor vehicles. Next to a parking lane, cyclists have ample operating space outside the zone into which car doors are opened. Intersections are easy to approach and cross.
LTS 2	Presenting little traffic stress but demanding more attention than might be expected from children. On road sections, cyclists are either physically separated from traffic or are in an exclusive bicycling zone next to a well-confined traffic stream with adequate clearance from a parking lane, or are on a shared road where they interact with only occasional motor vehicles with a low speed differential. Where a bike lane lies between a through lane and a right-turn lane, it is configured to give cyclists unambiguous priority where cars cross the bike lane and to keep car speed in the right-turn lane comparable to bicycling speeds. Crossings are not difficult for most adults.
LTS 3	Offering cyclists an exclusive cycling zone (e.g., bike lane) requiring little negotiation with motor traffic, but in close proximity to moderately high speed traffic; or mixed traffic requiring regular negotiation with traffic with a low speed differential. Crossings may be stressful, but are still considered acceptably safe to most adult pedestrians.
LTS 4	Requiring riding in close proximity to high speed traffic, or regularly negotiating with moderately high speed traffic, or making dangerous crossings.

Cycle tracks and shared use paths, which offer a physically separate cycling zone, have LTS 1. Bike lanes and mixed traffic can present a full range of stress levels depending on their characteristics.

Criteria for bike lanes are given in Table 2. Traffic speed and cyclist operating space are uniformly recognized in the literature as key variables. Next to a parking lane, the operating space available for cycling depends not on the width of the bike lane, but on its reach from the curb. Also, lower speed criteria apply next to parking lanes where cyclists face moving hazards on their right (car doors) as well as on their left.

Table 2. Traffic Stress Criteria for Bike Lanes

		LTS 1	LTS 2	LTS 3	LTS 4
Alongside a parking lane	Street width (through lanes per direction)	1	-	2 or more	-
	Reach from curb (sum of bike lane and parking lane width, including marked buffer and paved gutter)	15 ft or more	14 or 14.5 ft[a]	13.5 ft or less*	-
	Speed limit or prevailing speed	25 mph or less	30 mph	35 mph	40 mph or more
	Bike lane blockage (common in commercial areas)	rare	-	frequent	-
Not alongside a parking lane	Street width (through lanes per direction)	1	2, if directions are separated by a median	more than 2, or 2 without a median	-
	Reach from curb (sum of bike lane and parking lane width, including marked buffer and paved gutter)	6 ft. or more	5.5 ft. or less	-	-
	Speed limit or prevailing speed	30 mph or less	-	35 mph	40 mph or more
	Bike lane blockage (typically applies in commercial areas)	rare	-	frequent	-

[a] On non-commercial streets with speed limit ≤ 25 mph, any reach is acceptable for LTS 2.

Consistent with Dutch practice, the proposed criteria take number of through lanes rather than daily traffic volume as a key measure of traffic flow, except where bicycles are in mixed traffic. Where cyclists have their own lane, the volume of traffic in the neighboring lane is not so important; more critical is the turbulence that occurs with multilane traffic, which includes greater variance in speed, merging and weaving maneuvers, and a more confusing environment in which a cyclist is more likely to go unnoticed.

Bike lane blockage is also introduced as a criterion because it forces cyclists into mixed traffic. Field research in three commercial zones in the Boston area found that 45% of cyclists had to leave the bike lane because it was blocked (12) for reasons such as double parked cars, cars making a parking maneuver, people getting into or out of cars, and stopped buses.

When aggregating over dimensions, the dimension with the worst LTS governs the LTS of the section, as in Sorton and Walsh (7). Thus, for example, if a road section meets LTS 3 criteria for one dimension and LTS 1 or 2 criteria for the other dimensions, it will be classified LTS 3.

Criteria for mixed traffic sections are given in Table 3. Speed thresholds are lower than when cyclists have a bike lane, because cyclists exhibit less stress when in a marked bike lane than when in a shared lane (13, 14). Shared *streets* (streets without a marked centerline) are considered less stressful than shared *lanes*, because a marked centerline gives the appearance of reserving space for motor traffic in which bikes are intruders and blockers; by contrast, the lack of a centerline guides motorists to keep to the center, effectively reserving the margins for bikes, and emphasizes that road space is meant to be shared. Dutch guidelines specify that streets with mixed bike and motor traffic should have low traffic speed and no centerline (15). Dutch guidelines (11) also indicate that on streets without a centerline, traffic volume becomes an important factor, because where traffic exceeds a threshold between 2,000 and 4,000 vehicles per day, traffic tends to divide into two lanes, making road-sharing more stressful. Traffic volume was omitted from the proposed criteria because this data is not generally available, and because the practice in many American cities is to omit centerlines only on low volume streets.

Table 3. Level of Traffic Stress in Mixed Traffic

	Through Lanes per Direction			
Speed Limit	no marked centerline	1	2	3+
Up to 25 mph	1	2	3	4
30 mph	2	3	4	4
35+ mph	4	4	4	4

Right turn lanes can create stressful weaving conflicts and confusion over right of way on intersection approaches. Criteria for intersection approaches with right turn lanes are given in Table 4, with Dutch guidelines used as a basis for LTS 2. They aim to create a low-stress environment by making the cyclist's right of way at the merge point unambiguous and by ensuring that traffic in the right turn lane will be going at bicycling speed. American guidelines permit a wider range of configurations, including situations in which a bike lane on the right of the road ends, and then reappears later as a pocket bike lane (a bike lane between a right turn lane and through lane), forcing the cyclist to yield and merge through across a traffic lane.

Where no pocket bike lane is marked, it is common behavior for through cyclists to use the right turn lane, which works well if right turn volume is low and the turn lane is configured to ensure a low traffic speed.

Criteria for approaches with right turn lanes apply to the entire block on which they are present.

Table 4. Level of Traffic Stress for Intersection Approaches with Right Turn Lanes

	Configuration	Level of Traffic Stress
With pocket bike lane	Single right turn lane up to 150 ft long, starting abruptly while the bike lane continues straight, and intersection angle and curb radius such that turning speed is ≤ 15 mph.	2
	Single right turn lane longer than 150 ft starting abruptly while the bike lane continues straight, and intersection angle and curb radius such that turning speed is ≤ 20 mph.	3
	Single right turn lane in which the bike lane shifts to the left, but intersection angle and curb radius are such that turning speed is ≤ 15 mph.	3
	Single right turn lane with any other configuration; dual right turn lanes; or right turn lane along with an option (through-right) lane	4
Without a pocket bike	Single right turn lane with length ≤ 75 ft; intersection angle and curb radius limit turning speed to 15 mph.	(no effect on LTS)
	Single right turn lane with length between 75 and 150 ft; intersection angle and curb radius limit turning speed to 15 mph.	3
	Otherwise	4

Unsignalized crossings can be a barrier if the street being crossed has many lanes or fast traffic. Criteria for unsignalized crossings are presented in Table 5. Dutch criteria for unsignalized crossings (which apply equally to pedestrians and cyclists) do not allow any crossing of more than two lanes. In this respect the LTS 2 criteria depart from Dutch practice by allowing crossings of streets with up to 4 through lanes plus a turning lane, where the speed limit is 30 mph or less. Such crossings may be unpleasant and perhaps unsafe (statistically speaking), but are a barrier to most American adults.

To apply crossing stress classification in a network model seeking paths that do not exceed a given stress level, one modeling device would be to model all crossings as links; however, this greatly expands the network size. Instead, the stress involved in crossing a main street was applied to the approaching block(s) of the side street.

Table 5. Level of Traffic Stress for Unsignalized Crossings.

	Width of Street Being Crossed		
Speed Limit of Street Being Crossed	Up to 3 lanes	4 - 5 lanes	6+ lanes
Up to 25 mph	1	2 (1)	4 (2)
30 mph	1	2	4 (3)
35 mph	2	3	4
40+ mph	3	4	4

Note: Values in parentheses apply if there is a median pedestrian refuge

Using these criteria, every street and path segment in the city of San Jose, California was assigned a level of traffic stress. (The network modeled actually extended beyond city limits because the city's irregular boundaries make it such that the shortest path between two points can involve travel through a neighboring community.) A large majority (64%) of the street- and path-miles have the lowest rating of traffic stress, reflecting the prevalence of local streets, while 20% have LTS 4.

The main data sources used were a regional streets database that gives number of lanes, speed limit, and classification (roads classified "residential" were assumed to have no centerline marked), a regional path database. Field data on bike lane width and right turn lane configurations was carried out at selected points. More case study details are found in the project report (16).

BARRIERS AND LOW STRESS ISLANDS

While most of the street-miles in the case study have low traffic stress, they are often poorly connected to one another except within small neighborhoods; between neighborhoods, the only connection is often a higher stress link. As a result, a map limited to low stress links can have the appearance of of ice floes, with clusters of connected segments separated from one another by high-stress barriers. An example from central San Jose is given in Figure 1.

Another way to illustrate a connectivity problem is to show clusters of connected low-stress street segments in different colors, as illustrated in Figure 2. There, one can see that San Jose State University (SJSU) and San Jose City College (SJCC) belong to different clusters, indicating that there is no route between them that is limited to LTS 2 or lower. The three long, narrow clusters represent shared use paths that have few connections to low-stress streets because they run along creeks in canyons that are not crossed by local streets.

Three main kinds of barriers separate low-stress clusters from one another. One is linear features that require grade-separated crossings such as freeways, railroads, and creeks. Due to the cost of grade separated crossings, crossing points tend to be widely spaced. This in turn concentrates traffic, so that many of the crossings use wide roads. Some crossings have long, intersection-free approaches that foster high speed, and some have on- and off- ramps. Freeway crossings lacking access ramps are helpful for low-stress connectivity, as are linear barriers with footbridges. San Jose has 11 footbridges linking local streets that were severed by freeway construction, creating ideal low-stress bike routes.

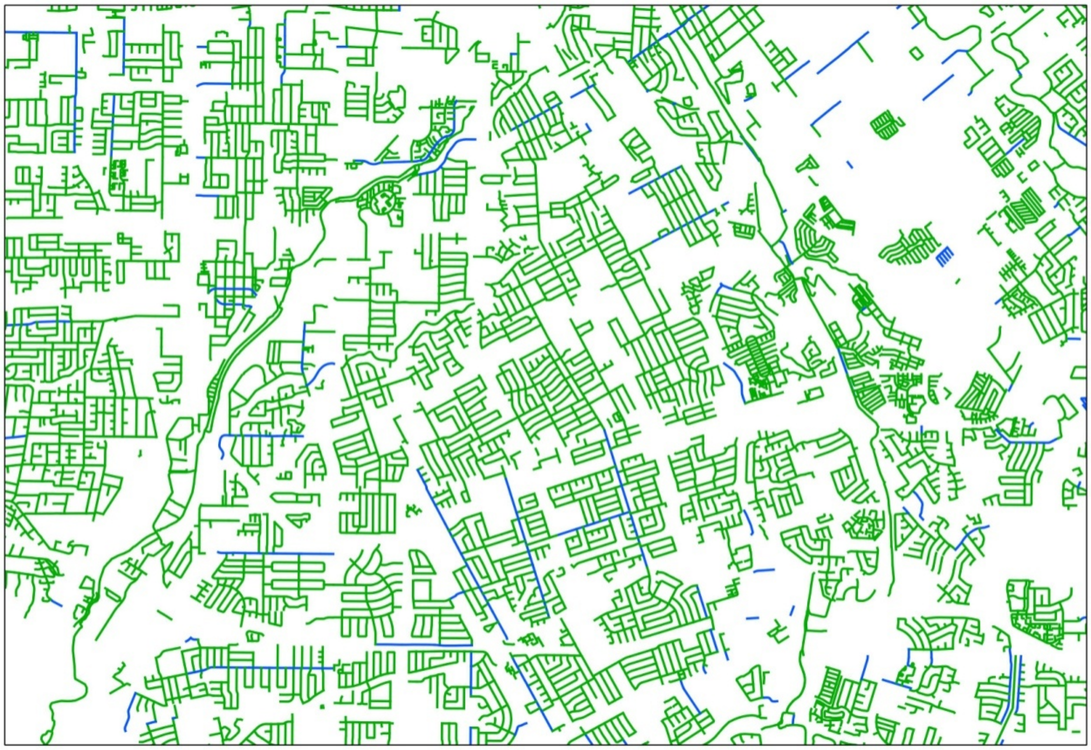

Figure 1. Stress map showing only LTS 1 (green) and LTS 2 (blue) links.

A second common type of barrier is multilane, high-speed arterial streets. There, low stress crossings require intersections with safe crossing provisions *and* low-stress approaches. Intersections along arterials often provide one or the other, but not both. Intersections with local streets often lack safe crossing provisions, and while intersections with higher-traffic cross streets have safe crossing provisions, those cross streets are often too stressful to ride on in themselves, unless they have cycle tracks. Where junctions with minor collectors are signalized, the approaches on the minor collectors have often been widened by adding right turn lanes, raising the stress of the approach.

A third type of barrier is breaks in the street grid. In newer suburban areas, grids are often deliberately incomplete in order to force through traffic to use arterials; an unfortunate side effect is that they also force through bikes onto the arterials. “Permeable barriers” (closed to cars, but passable for foot traffic) are preferred, because they allow for low-stress bike connectivity without enabling cut-through motor traffic.

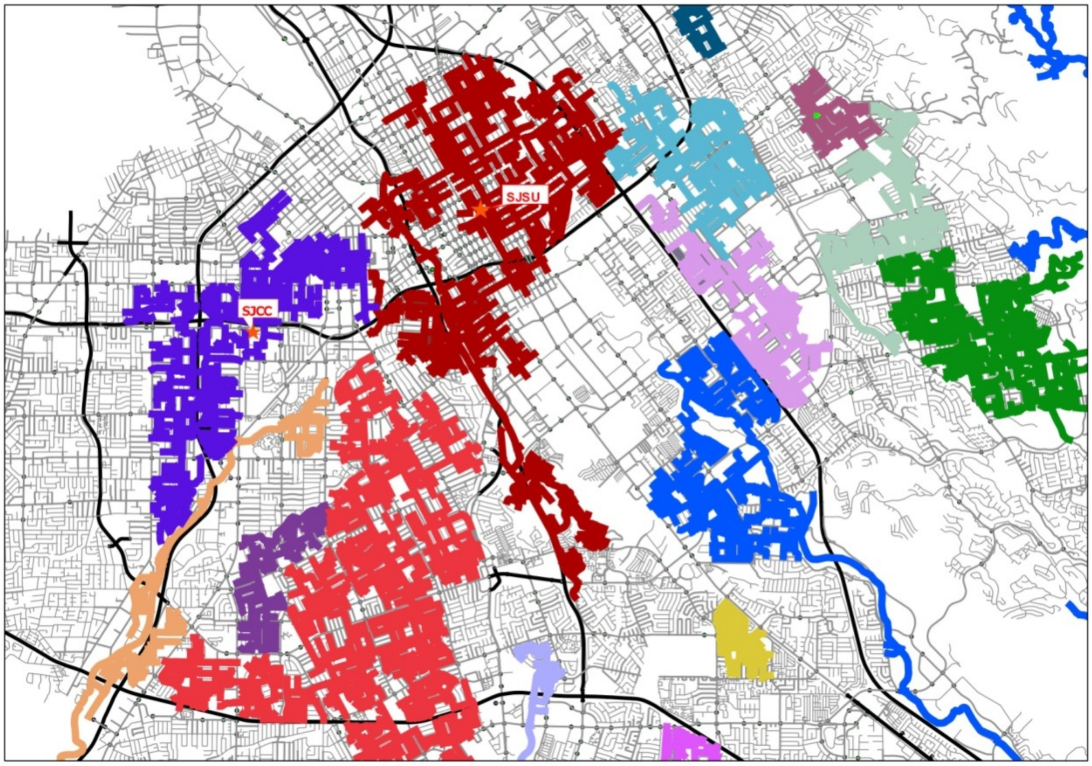

Figure 2. Some connectivity clusters at LTS 2. Markers indicate San Jose State University (SJSU) and San Jose City College (SJCC).

CIRCUITY CRITERIA AND POINT-TO-POINT CONNECTIVITY

Cyclists have a limited willingness to go out of their way to find a lower stress bike route. One study of non-recreational cyclists in Vancouver, B. C. (17) found that 75% of cyclist trips were within 10% of the shortest distance possible on the road network, and 90% were within 25%. This small level of average detour is consistent with a 1997 study of bicycle commuters (18). However, they also found that people were more likely to go out of their way to take a route with more green cover and more bicycle-actuated signals. Broach, Glebe, and Dill (19) found that commuting cyclists in Portland, Oregon were willing, on average, to add 16% to their trip length to use a bike path, and to add 11% to use a low-stress route along local streets. For non-commuting cyclists, those figures are 26% and 18%, respectively.

For this study, two points are said to be connected at LTS k if there is a route connecting them that avoids links with LTS > k and whose length, L_k, satisfies the following detour criterion:

$$L_k / L_4 \le 1.25, \quad \text{OR} \quad L_k - L_4 \le 0.33 \text{ mi} \tag{1}$$

where L_4 = the shortest path using links of any level of stress. In other words, the low stress route must not be more than 25% longer (or, for short trips, more than 0.33 miles longer) than the shortest route. Additional research would be of value to refine this criterion, including accounting for other factors that affect route choice such as hills, frequent signal delay, natural beauty, and crime.

When aggregating links to form a route, "weakest link" logic is applied, in that the LTS of a route equals the LTS of the most stressful link. That can be distinguished from the more common situation in network analysis in which link costs (travel time, impedance) are added.

The detour criterion is not accounted for in connectivity cluster analysis. Where it is applied, points belonging to the same cluster may actually not be connected. For example, in Figure 2, the large holes and irregular shape of some of the connectivity clusters are such that many pairs of points within the same cluster cannot be connected without excessive detour.

SUMMARY MEASURE OF CONNECTIVITY

In principle, one could query every pair of points in the network to determine which pairs are connected at each LTS. At the population level, results for these pairs should be weighted, given more weight to origin-destination (O-D) pairs that are frequently used. Where a trip table (daily volume of trips between pairs of zones) is available, a summary measure of the ability of a bicycling network to provide connectivity at a given LTS is the fraction of trips in the trip table whose origin and destination are connected at that LTS. Mathematically,

$$cr_k = \frac{\sum_{i,j} T_{ij}\delta_{ijk}}{\sum_{i,j} T_{ij}} \tag{2}$$

where cr_k = connectivity ratio for LTS k, T_{ij} = number of trips per day from i to j, and δ_{ijk} = indicator of whether origin i is connected to destination j at LTS k. If a large fraction of a region's daily trips can be made by bike at a low level of traffic stress, then that bicycle network serves the mainstream population well; if not, it suggests that a deficient bike network is hampering widespread bicycle use.

For the city of San Jose, the connectivity ratio at each level of traffic stress was calculated for work trips using a trip table obtained from the local metropolitan planning agency. Three adaptations were made in recognition of the nature of bicycling: using a small geographical unit, discounting long trips, and discounting very short trips.

Regional trip tables normally use traffic analysis zones (TAZs) as the geographic unit of analysis. For evaluating low-stress bicycling connectivity, TAZs were considered too large a geographic unit for analysis because many have internal barriers such as freeways and arterials lacking low-stress crossings such that one part of the TAZ may be connected to a low stress route while another is not. Therefore, demand data was disaggregated to Census block level. Origins were allocated over blocks within a TAZ in proportion to block population. Lacking block-level employment data, destinations were distributed over blocks in proportion to block area and an attraction coefficient reflecting the relative strength of the zoned land use in attracting trips, following the approach used in (20). Attraction coefficients were developed for almost 100 land use codes, ranging from 3 for the core area to 0.01 for single family residential with one-acre zoning.

For analyzing connectivity, demand was assumed concentrated at the centroid of each block, with connectors to all the vertices of the street network surrounding or within a block. Block *i* was considered connected to block *j* if any of the vertices of block *i* were connected to any of the vertices of block *j*. That way, for example, a business fronting on a high-stress street could still be accessible at low stress if any vertex of the block it belongs to is incident to a low-stress link. The rationale was that if people can find a low-stress route to any corner of the block in which their destination is, they can finish the trip by riding or walking along the sidewalk.

With this fine a level of disaggregation, evaluating connectivity implies finding shortest paths between every vertex pair in the street and path network. This in turn required efficient data processing, since the network used had 29,200 vertices.

Because the appeal of bicycling as a competitive mode of transportation declines at long distance, the sums in equation 2 can be limited to block pairs no further apart than, say, 5, 6, or 8 miles in order to focus on trips with the greatest potential for mode shift. Likewise, it makes sense to exclude block pairs so close to one another that walking is more convenient than bicycling. In the San Jose case study, in lieu of applying a lower distance limit, block pairs within the same TAZ were excluded from the sums in equation 2.

CASE STUDY RESULTS

The connectivity ratio for work trips in San Jose was calculated for the current state of the roads and paths as well as for an improvement scenario with a slate of 67 improvements whose locations are shown in Figure 3. They were conceived by analyzing maps of connectivity clusters, with the goal of connecting streets and paths that already have low traffic stress. Of these 67 improvements, 40 are spot treatments for intersection safety. The slate also includes 11 striping and signage projects, 11 short sections of connector path, and 5 cycle track projects. The prevalence of intersection projects highlights the important role that intersections play in creating or undoing barriers to low-stress cycling.

With the proposed slate of improvements, many of the connectivity clusters at LTS 2 combine to form a single large cluster, as shown in Figure 4 (compare Figure 2). However, the large holes in this cluster make it such that many OD pairs are still unconnected at LTS 2 due to the detour criterion. In addition, a large employment area north of the downtown remains outside this large cluster.

Table 6 shows before-after comparisons of the connectivity ratio for work trips for the different levels of traffic stress with different distance limits. Poor connectivity at low stress levels is clear in the base case, with only 0.4% of work trips up to 6 miles long connected at LTS 1, and only 4.7% connected at LTS 2. Under the improvement scenario, those figures rise to 1.0% and 12.7%, respectively, an increase by a factor of nearly 3.

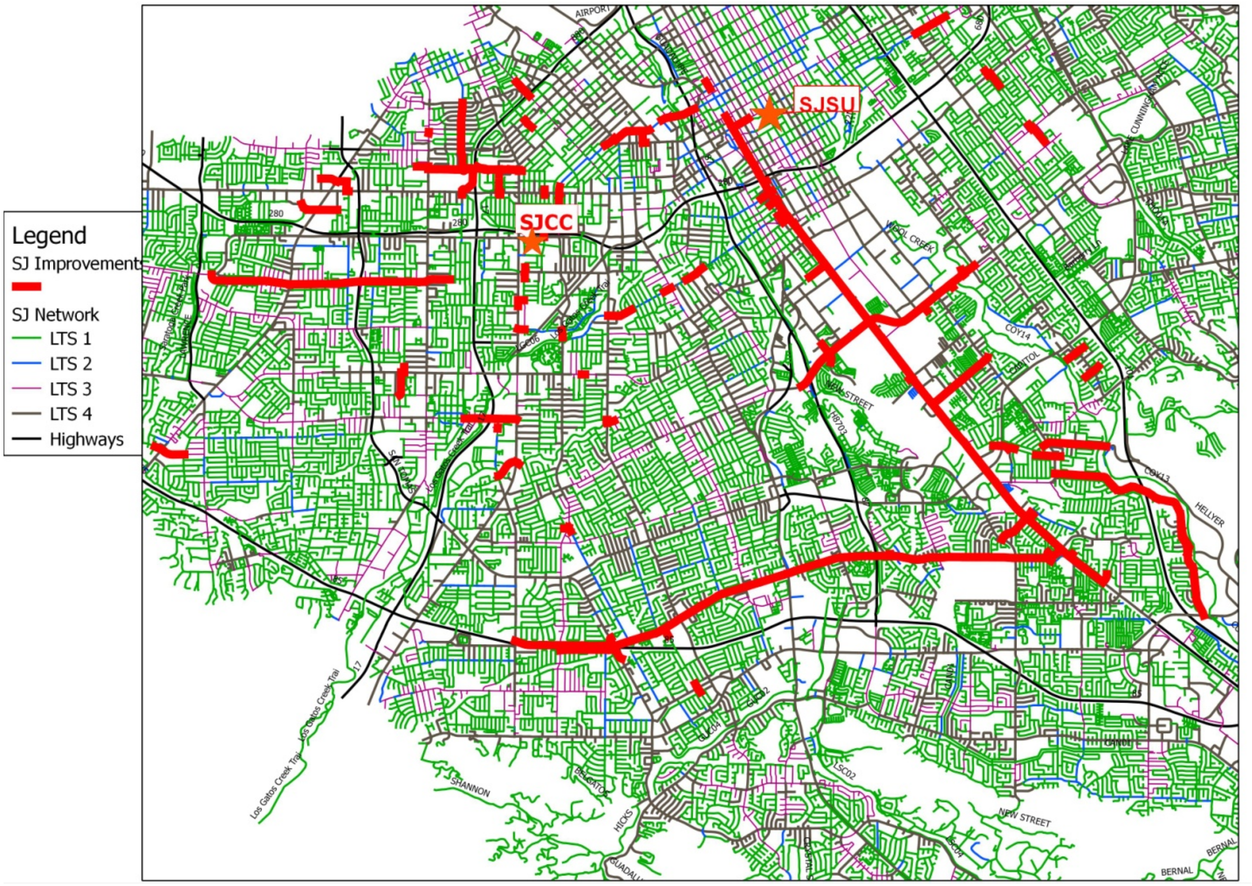

Figure 3. Location of Proposed Improvements.

In the base case, the far greater connectivity ratios at LTS 3 than at LTS 2 reflects the common American policy of emphasizing bike lanes on busy arterials, which represent the majority of the LTS 3 links. This policy can be contrasted with focusing network development on lower-stress “bike boulevards” (routes using low-traffic streets) and cycle tracks. The even greater difference between LTS 3 and LTS 4 indicates that in the current case, many barriers remain uncrossable except at the highest level of traffic stress.

The poor low-stress connectivity in the base case is undoubtedly a large reason that San Jose’s bicycle share for work trips over the previous decade was only 0.6% (21). The substantial increase in connectivity possible by making improvements that emphasize connecting streets that already have low traffic stress shows considerable potential for increasing bicycling’s mode share with modest investment.

CONCLUSIONS AND FURTHER RESEARCH

The mainstream population is intolerant of high traffic stress. Planners and advocates need stronger and clearer criteria for traffic stress in order to design bicycling facilities that meet users’ needs. The criteria proposed in this research demonstrate the feasibility of developing criteria that are readily understood, require only a modest amount of data, and account for the key factors by which motor traffic deters people from using a bicycle. They can undoubtedly be refined and extended – for example, to one-way streets and roundabouts.

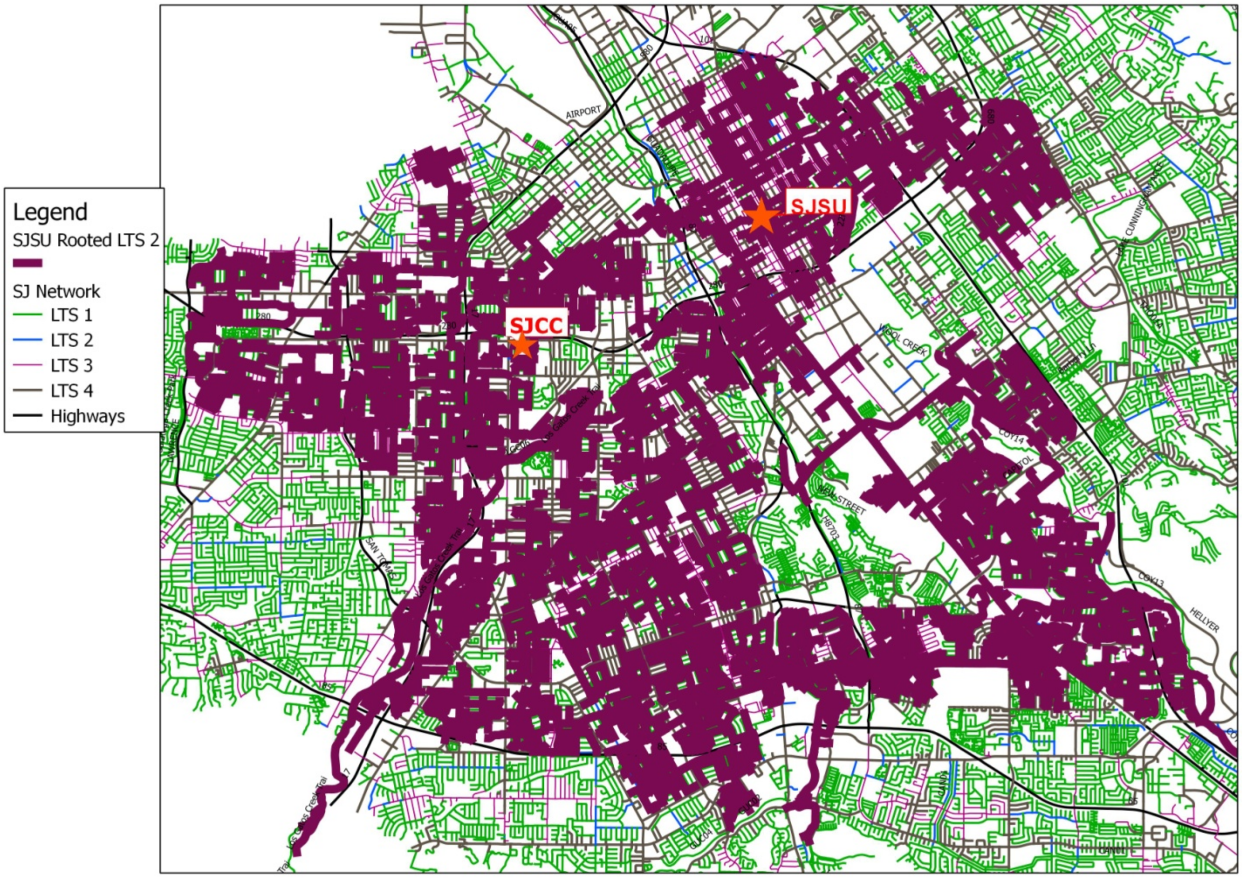

Figure 4. Central connectivity cluster at LTS 2 with the proposed slate of improvements.

Connectivity is a critical component of any transportation network, and for bicycling networks aimed at serving the mainstream population, it is meaningful only if links are limited to those with low traffic stress. Bicycling improvements are often proposed on the basis of increasing connectivity, without the benefit of a measure. This research demonstrates a method for visualizing connectivity as well as a method for measuring connectivity at the population level, giving planners the ability to quantify how much a certain improvement or set of improvements will increase connectivity. This approach can be extended to trips of all types, including safe routes to school. It would also be interesting to research the possibility of developing practical connectivity measures that do not require trip tables, as that would substantially reduce the computational burden involved.

Table 6. Fraction of Work Trips Connected at Different Levels of Traffic Stress

a. Existing Case

	Trip Length			
	< 4 mi	< 6 mi	< 8 mi	All
LTS 1	0.7%	0.4%	0.3%	0.2%
LTS 2	7.7%	4.7%	3.4%	2.2%
LTS 3	22.6%	16.4%	13.2%	8.9%
LTS 4	100.0%	100.0%	100.0%	100.0%
Total trips	78,673	136,652	189,439	292,396

b. Improvement Scenario

	Trip Length			
	< 4 mi	< 6 mi	< 8 mi	All
LTS 1	1.7%	1.0%	0.8%	0.5%
LTS 2	14.9%	12.7%	11.1%	7.9%
LTS 3	27.4%	22.7%	20.0%	14.6%
LTS 4	100.0%	100.0%	100.0%	100.0%
Total trips	78,673	136,652	189,439	292,396

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