Evaluating Bicycle and Pedestrian Quality of Service

Hillsborough County, Florida

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GLOSSARY

BEQI – Bicycle Environmental Quality Index

BLOS – Bicycle Level of Service

BNA – Bicycle Network Analysis

BPAC – Bicycle and Pedestrian Action Committee

CDOT – Charlotte Department of Transportation

FDOT – Florida Department of Transportation

FHWA – Federal Highway Administration

HCM – Highway Capacity Manual

HMPO – Hillsborough Metropolitan Planning Organization

LOS – Level of Service

LTS – Level of Traffic Stress

MMLOS – Multimodal Level of Service

MUTCD – Manual on Uniform Traffic Control Devices

NACTO – National Association of City Transportation Officials

NCHRP – National Cooperative Highway Research Program

OSM – OpenStreetMap

PEQI – Pedestrian Environmental Quality Index

PLOS – Pedestrian Level of Service

SANDAG - San Diego Association of Governments

TCQSM – Transit Capacity and Quality of Service Manual

USDG – Urban Street Design Guide

VMT – Vehicle Miles Traveled

INTRODUCTION

The Hillsborough Metropolitan Planning Organization (HMPO) identified a need to rethink the way they evaluate the pedestrian and bicyclist experience on the roadways in Hillsborough County, Florida. This report summarizes: (1) a review of national best practices, (2) a methodology to evaluate corridor Level of Traffic Stress (LTS) for bicyclists and pedestrians and results for functionally classified roadways in Hillsborough County; and (3) a methodology to evaluate bicycle and pedestrian conditions at intersections and results for Hillsborough County.

EXISTING METHODOLOGY

HMPO currently uses a multimodal transportation database to store countywide highway performance data. The database is linked to the HMPO's mapping system via linear referencing. In 2012, HMPO began incorporating multimodal level of service (MMLOS) data into the database. The purpose of this effort was to create a single-source database that could be updated and used for future countywide MMLOS calculations. The current methodology allows for project-level comparisons across multiple modes. It allows engineers and planners to evaluate the effects of different roadway cross-sections and intersection configurations through various modes and user groups.

HMPO's primary concern with the existing methodology is that it does not reflect the current perception of multimodal users. For example, the current methodology would assign a letter grade "C" to a roadway with a five-foot paved shoulder, indicating an acceptable level of service (LOS) for bicyclists, regardless of the number of travel lanes, vehicle volumes, or vehicle speeds. However, a recent study conducted by the Florida Department of Transportation (FDOT) District 5 showed that with the presence of a conventional on-street bike lane, more than 80% of bicyclists observed still chose to ride on the sidewalk. This result suggests a mismatch with the way multimodal quality of service is being evaluated and the way many users of the roadway system perceive that service.

The current methodology is also limited in its application. For people to feel comfortable walking or biking, they must feel safe for the entire trip. However, the current methodology focuses on segment LOS, or travel parallel to motorized vehicle traffic, and does not account for intersection conditions. Intersections are where bicyclist and pedestrians can have the greatest exposure to conflict and inadequate design can greatly affect their safety and comfort.

The methodology also does not account for innovations in multimodal infrastructure. The City of Tampa has worked diligently to implement the City's first cycle track downtown on Cass Street and-both the City and County are implementing a robust network of trails. The added benefit to users provided by these facilities cannot be captured with the current methodology.

REVIEW OF BEST PRACTICES

Literature Review

A literature review of a range of methodologies that evaluate LOS and other performance metrics for non-automobile modes was completed to develop a baseline understanding of best practices. A summary of the documents reviewed, the authors, and the key takeaways from each of the documents is provided in ***Table 1***.

Table 1: Summary of Documents Reviewed for Literature Review

Document	Date	Authors/Institute	Key Takeaways
The Highway Capacity Manual's Method for Calculating Bicycle and Pedestrian Levels of Service: the Ultimate White Paper https://www.lewis.ucla.edu/wp-content/uploads/sites/2/2014/09/HCM-BICYCLE-AND-PEDESTRIAN-LEVEL-OF-SERVICE-THE-ULTIMATE-WHITE-PAPER.pdf	2014	University of California, Los Angeles - Lewis Center for Regional Policy Studies and Institute of Transportation Studies Herbie Hu and Robin Liggett	• Reviews the Bicycle Level of Service (BLOS) and Pedestrian Level of Service (PLOS) components of MMLOS. • The Highway Capacity Manual (HCM) models are based on studies of participants in Florida and with limited testing outside of Florida. • The HCM models were constructed based on variables known to influence walking and bicycle at the time and do not account for the full range of variables and innovation currently of interest to planners. • Review of PLOS: ○ *Intersection score* – number of lanes crossed as greatest contribution, followed by vehicle speed and volume; less sensitive to pedestrian delay and refuge islands ○ *Link score* – width of walking area, separation from vehicles, and vehicle volumes play largest role; insensitive to sidewalk quality, lighting, and sidewalk width beyond 10' • Review of BLOS: ○ *Intersection score* – function of roadway width and type of bicycle facility; insensitive to innovative treatments (i.e. bike boxes) ○ *Link score* – influenced by vehicle volumes (particularly trucks), vehicle speeds, and type of bicycle facility; insensitive to innovative treatments (i.e. green paint) and bicycle crowding • It is possible to validate PLOS and BLOS and include sensitivity to innovative treatments. The authors argue this effort would be resource-intensive and there may be other metrics and policies that have replaced the need for such a detailed evaluation.

Document	Date	Authors/Institute	Key Takeaways

NCHRP 616: Multimodal Level of Service Analysis for Urban Streets
 	
http://www.trb.org/Publications/Blurbs/160228.aspx
	2008	Transportation Research Board
		
		Richard Dowling, David Reinke, Aimee Flannery, Paul Ryus, Mark Vandehey, Theo Petritsch, Bruce Landis, Nagui Rouphail, and James Bonneson
			• Used video labs in four (4) metropolitan areas to have participants rate their satisfaction with the driving, walking, and bicycling conditions shown in the videos. Developed regression models to predict participants' average rating based on the conditions the participants observed (e.g., traffic volumes, facility characteristics)
			• Video lab approach was not applicable for transit; instead, documented relationships between ridership and service quality were used primarily to develop the transit model
			• The models were tested for reasonableness and refined through a series of workshops/field tests with local, regional, and state transportation agency staff in ten (10) metropolitan areas across the U.S.
			• Models predict LOS for the automobile, transit, bicycle, and pedestrian modes on urban arterials and collectors.
			  ○ Auto – Uses stops per mile and average speed as the primary variables
			  ○ Transit – Primary variables are bus headways, perceived travel time, and the pedestrian LOS score
			  ○ Bicycle – Combination of the cyclist's experience at intersections and on street segments
			  ○ Pedestrian – Segment and intersection level of service and mid-block crossing difficulty
			• Addresses nine (9) limitations of the HCM 2000 methodology.
			• The uniform definition of LOS used in the models provides a consistent basis for comparing levels of service across modes.
			• Research led to bicycle, pedestrian, transit, and automobile perception methods in HCM 2010.

PeopleForBikes, Bicycle Network Analysis https://bna.peopleforbikes.org/#/methodology	2017	PeopleForBikes	• The Bicycle Network Analysis (BNA) Score is a methodology recently developed by PeopleForBikes to measure how well the existing bicycle network connects people with places they want to go. • The methodology combines a simplified Level of Traffic Stress (LTS) analysis with U.S. Census data to understand how the low-stress network connects residents, jobs, and community. • In the simplified LTS analysis, the methodology distills streets down to "low" or "high" stress based on bicycle facility type (e.g. cycle track, buffered bike lane, bike lane, shared traffic), the number of travel lanes, speed and street width. • Census blocks receive a score out of 100 based on their connectivity to streets determined to be low stress, normalized by the population in that census block. • The spreadsheet tool developed to complete these calculations is publicly available. • PeopleForBikes has also created an online mapping tool that has mapped this information and calculated the BNA score for most cities.

Document	Date	Authors/Institute	Key Takeaways

MTI Report 11-19: Low-Stress Bicycling and Network Connectivity
 	
http://transweb.sjsu.edu/PDFs/research/1005-low-stress-bicycling-network-connectivity.pdf
	2012	Mineta Transportation Institute, San Jose State University
		
		Maaza C. Mekuria, Ph.D., PE, PTOE, Peter G. Furth, Ph.D., and Hilary Nixon, Ph.D.
			• Reviews the LTS criteria developed to measure low stress connectivity for the bicycle network.
			• Previous research supports that Americans have varying levels of tolerance for traffic stress—a combination of perceived dangers and stressors such as noise and exhaust fumes—associated with riding a bike in the roadway. While a small portion of the population is comfortable riding in mixed traffic, most people are “traffic-intolerant.”
			• For the widest possible segment of the population to be attracted to bicycling, the most fundamental condition is a low stress trip with minimal detour between their origin and destination.
			• LTS is rated from “LTS 1,” which is a level that most children can tolerate, to “LTS 4,” which is a level that may only be tolerable by strong and fearless cyclist in rare cases. A more detailed summary of LTS 1 through 4 conditions is provided below:
			  ○ LTS 1 – This condition presents little traffic stress and demands little attention from bicyclist. Bicyclists are either physically separated from traffic, have a dedicated space next to slow-moving traffic, or operate in mixed traffic where speed differentials are minimal. Intersections are easy to approach and cross.
			  ○ LTS 2 – This condition presents little traffic stress. While comfortable for most adults, it requires a little more attention than expected from children. This condition can include separated bike facilities, bike lanes with adequate clearance from the travel lane and parking lane, and mixed traffic with low speed differentials.
			  ○ LTS 3 – This condition has higher traffic stress than LTS 2 (e.g. higher traffic speeds and volumes) but is substantially less than a multilane roadway. This condition can also include bike lanes that are next to moderate-speed traffic.
			  ○ LTS 4 – A condition that is typically experienced in mixed traffic on multilane roadways. LTS 4 includes all level of traffic stress above LTS 3.
			• Components that affect the LTS score are largely based on traffic speed, traffic volume, number of travel lanes, the presence of parking, and whether a separated bike lane is present.
			• Traffic stress for segments is determined based on 3 classes of bikeways: separated bikeways, bike lanes, and mixed traffic:
			  ○ Physically separated bike lanes are LTS 1. These include cycle tracks, shared use paths, trails, and other bicycle-only facilities separated from traffic. LTS 1 does not include sidewalks unless they have been designated for bicycle use.
			  ○ A bike lane’s LTS varies based on street width, bike lane width, traffic speed, and bike lane blockage. The metric with the lowest LTS ranking governs the link’s LTS.
			  ○ Sometimes it is known that a bike lane or cycle track is blocked on a regular basis due to loading activities, double parking, etc. In these cases, the segment is LTS 3.

Document	Date	Authors/Institute	Key Takeaways
			○ The greatest factors influencing LTS in mixed-traffic operations are the number of travel lanes and the speed limit or observed speeds. Streets that are under 3 lanes and have a speed limit of 25 mph are LTS 1 (if the streets do not have a marked center line or are classified as residential) or LTS 2. • Like the segment analysis, intersection approaches can be scored based on the right turn condition (with or without a pocket bike lane) and the crossing condition (based on traffic speed, the number of travel lanes, and whether the intersection is signalized with the presence of a median) • Previous research in Vancouver, B.C. found that 75 percent of bicycle trips were within 10 percent of the shortest trip distance and 90 percent of bicycle trips were within 25 percent of the shortest trip. This finding indicates that many bicyclists are willing accept up to a 25 percent detour to have a low-stress experience. • The LTS methodology also allows practitioners to evaluate overall network connectivity. • The paper also explores measures for connectivity and, specifically, the fraction of trips that can be made by bicycle without exceeding a given level of traffic stress or requiring an excessive detour.
Expectations and Implications of Multimodal Street Performance Metrics: What's a Passing Grade? http://www.lewis.ucla.edu/wp-content/uploads/sites/2/2014/09/EXPLORATION-AND-IMPLICATIONS-OF-MULTIMODAL-STREET-PERFORMANCE-METRICS.pdf	2014	University of California Transportation Center Madeline Brozen, Herbie Huff, Robin Liggett, Rui Wang, and Michael Smart	• Reviewed four (4) multimodal methodologies: Fort Collins, San Francisco Bicycle Environmental Quality Index (BEQI) and Pedestrian Environmental Quality Index (PEQI), Charlotte BLOS/PLOS, and HCM 2010 MMLOS • The Fort Collins methodology assumes infrastructure is built to city-specific design criteria and is therefore difficult to apply elsewhere. • Charlotte and San Francisco place more emphasis on safety and less on walkability. • The HCM 2010 and BEQI/PEQI measures appeal to a more universal approach, where Charlotte BLOS/PLOS is more location-specific. • Authors argue a single-grade letter score depicts misleading views of bicycle and pedestrian experiences. The letter does not always correspond to users' experience on the street and limits the public's ability to engage in discussion about roadway performance. • If an agency's goal is to improve traveler satisfaction across all modes, HCM 2010 would be the best choice. • Improved safety or geometric design would be better evaluated with the Charlotte BLOS/PLOS. • BEQI/PEQI and Charlotte LOS are relatively easy tools to use for calculating current and potential LOS. HCM is the most difficult tool to use and has little ability to account for small infrastructure improvements.

Document	Date	Authors/Institute	Key Takeaways

Network Connectivity for Low-Stress Bicycling
 	
http://www1.coe.neu.edu/~pfurth/Furth%20papers/2013%20Network%20Connectivity%20for%20Low%20Stress%20Bicycling%20(Furth,%20Mekuria)%20TRB%20compendium.pdf
	2013	TRB Annual Meeting, 2013
		
		Peter G. Furth, Ph.D. and Maaza C. Mekuria, Ph.D., PE, PTOE
			• A research white paper on the LTS methodology, developed to measure the level of traffic stress perceived by most riders based on traffic speed and number of travel lanes.
			• The LTS methodology is more meaningful to planners and citizens because Bicycle Level of Service models and the Bicycle Compatibility Index are "black boxes" in the sense that developing a classification requires complex calculations.
			• The LTS calculation is determined based on characteristics such as traffic speed, number of travel lanes, bike lane width, and parking lane presence through various tables. These tables provide an LTS rating, based on the characteristics. The LTS for a given intersection, approach, and/or segment is governed by the worst (highest) LTS rating in the tables. For instance, if a segment is determined to be LTS 3 based on one characteristic but is LTS 1 or 2 based on another characteristic, the segment rating is LTS 3.
			• Bicyclists are willing to accept up to a 25 percent detour for longer trips, and up to a 33 percent detour for shorter trips, to have a less stressful experience.
			• Many networks develop "low stress islands," where barriers break up segments of the network that are otherwise considered low stress. There are three main kinds of barriers:
			  ○ Linear features that require grade-separated crossings, such as freeways, railroads, and creeks.
			  ○ Multilane, high-speed arterial streets.
			  ○ Breaks in the street grid, such as cul-de-sacs.
			• A measure of connectivity is important to assess how well the network serves most of the population. Connectivity can be measured by taking the number of trips between an origin and destination that can be made by bicycle at a given LTS (for instance, LTS 2), with limited detours, and dividing the result by the total number of trips. The answer provides the fraction of trips that can be made by bicycle.
			• A case study at San Jose State University demonstrated how the areas accessible via low stress trips can be mapped. Mapping connectivity allows planners to identify key corridors and connections where improvements can unlock low stress islands.

SUMMARY OF INTERVIEWS

To provide depth to the literature review, interviews were conducted with subject matter experts from two cities, the City of Charlotte and the San Diego Association of Governments (SANDAG), as well as from the Federal Highway Administration (FHWA). A summary of the themes identified through the interviews is outlined in ***Table 2***, below. The detailed interview notes can be found in Appendix A.

Table 2: Subject Matter Expert Interview Summary

Agency	Person(s) Interviewed	Themes
Charlotte Department of Transportation Charlotte, NC	Scott Curry, Pedestrian Coordinator Tracy Newsome, Ph.D. Transportation Planner	• City developed P/BLOS methodology to evaluate how intersections were serving pedestrians and bicycles. • The methodology has been applied to every signalized intersection in the City and the City has a database of the LOS for all intersections. • P/BLOS is used, along with congestion and safety measures, to inform small-area planning efforts and to identify priority intersection locations for improvements. • The City developed and adopted the Urban Street Design Guide (USDG). This provides specific street design guidance based on the "place" of the street.
SANDAG San Diego, CA	Mike Calandra, Senior Transportation Modeler	• SANDAG uses an activity-based model to evaluate changes in mode split resulting from various changes to auto, transit, and bicycle infrastructure. • They found that adding/removing bicycle links has a greater impact on mode choice than changing the type of bicycle facility. • They do not currently have the ability to evaluate pedestrian infrastructure and cannot assign bicycle and pedestrian trips at the link level. • SANDAG reports vehicle miles traveled (VMT) for every project and can track VMT by origin and destination pairs. • Adding active transportation links in the model is a way to mitigate VMT. The model can evaluate the varied effects of bicycle infrastructure in urban and rural contexts.
FHWA National	Dan Goodman, Office of Human Environment Livability Team	• When evaluating trade-offs between modes, there will always be a comparison to traditional LOS. It is important to understand the limitations of LOS and everything that goes into the planning process. • The P/BLOS components of MMLOS are helpful inputs. The BLOS methodology is not refined enough for today's condition and does not include recent innovations, such as cycle tracks. It can be hard to move the needle for P/BLOS. Widening the sidewalk, for example, shows little benefit in the analysis. • A new tool was recently created to limit the time and expense of performing system-wide LTS analysis.

REVIEW OF EXISTING METHODOLOGIES

This section summarizes the findings from the literature review of each methodology. Each sub-section outlines the methodology, provides example applications, and identifies the data requirements as well as the challenges and opportunities within those applications.

Multimodal Level of Service (MMLOS)

Overview

The 2010 HCM introduced MMLOS analysis for urban streets. The HCM MMLOS analysis provides a LOS model for each of the four (4) modes (automobile, transit, bicycle, and pedestrian) for arterial and collector roadways. The LOS measures are based on traveler perceptions. The pedestrian, bicycle, and automobile equations were developed based on participant-rated conditions of over 90 typical segments. The transit model was based on traveler response data to changes in transit service quality. For example, when service frequency or travel time is improved, ridership increases. All four (4) models incorporate multiple service quality factors as inputs, in contrast to relying solely on delay.

This paper focuses on the MMLOS procedures found in the 2010 HCM. The *HCM 6th Edition: A Guide for Multimodal Mobility* was updated to reflect the TCQSM, 3rd ed., and minor changes were made to BLOS and PLOS. The sources reviewed centered on the 2010 HCM and there has not yet been a comprehensive evaluation of the refinements made to MMLOS in the 6th Edition of the HCM.

Application

The MMLOS method defines the following terms:

- Intersection — Signal, roundabout, or stop-controlled
- Link — Portion of the street between two (2) signalized intersections
- Segment — Combination of a link and its downstream signalized intersection
- Facility — Two (2) or more consecutive segments

The pedestrian and bicycle modes can be evaluated at the intersection, link, segment, and facility level. Vehicular LOS can be evaluated at the intersection, segment, and facility level. The transit LOS model is limited to segment and facility operations. The LOS thresholds are the same for all modes. They were designed so the modal LOS scores can be directly compared to each other and to reflect similar average traveler satisfaction across modes. The HCM also provides LOS methods for off-street pedestrian and bicycle facilities, including walkways offset more than 35 feet from the street, pedestrian-only streets, stairways, and shared-use paths.[1]

[1] HCM 2010: Highway Capacity Manual. Washington, D.C. Transportation Research Board, 2010.

Table 3 summarizes the key factors for pedestrians and bicyclists and their effect on LOS. A (+) indicates that a higher value for that variable positively impacts LOS. A (-) indicates that a higher value negatively impacts LOS.

Table 3: Key Factors of HCM MMLOS

Pedestrians	Bicyclists
Link LOS	
Outside travel lane width (+) Bicycle lane/shoulder width (+) Buffer presence (e.g., on-street parking, street trees) (+) Sidewalk presence and width (+) Volume and measured speed of vehicle traffic in outside travel lane (–)	Volume and measured speed of traffic in outside travel lane (–) Heavy vehicle percentage (–) Pavement condition (+) Bicycle lane presence (+) Bicycle lane, shoulder, and outside lane widths (+) On-street parking utilization (–)
Intersection LOS	
Permitted left turn and right-turn-on-red volumes (–) Cross-street motor vehicle volumes and speeds (–) Crossing length (–) Average pedestrian delay (–) Right-turn channelizing island presence (+)	Width of lanes (+) Cross-street width (–) Motor vehicle traffic volume in the outside lane (–)

(+) Higher value has positive impact to LOS
(-) Higher value has negative impact to LOS

At the project level, practitioners can use the HCM MMLOS to evaluate the tradeoffs of various street designs in terms of their effects on the auto driver's, transit passenger's, bicyclist's, and pedestrian's perceptions of the quality of service provided by the street. The individual mode scores can be used to understand the degree to which an urban street meets the needs of all users and the effect various alternatives have on the level of service. This analysis can be conducted for an entire network of streets and used to prioritize bicycle and pedestrian improvements[2].

[2] Richard Dowling et al., *NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets*, Transportation Research Board, 2008.

Data Needs

Table 4 summarizes the data required, by mode, for the MMLOS evaluation. This evaluation is the most data-intensive of the methodologies considered, but agencies can rely on default values for many of the inputs to reduce the data requirements. NCHRP Report 825 provides guidance on when to use default values and gives suggested values. Relevant excerpts from the report are provided in Appendix B. Software, such as ARTPLAN, is also available to assist with data entry and computation.

Table 4: MMLOS Data Needs

Pedestrians	Bicyclists
Segment LOS	
– Segment length – Vehicle speed – Vehicle flow rate – Number of through lanes – Width of outside through lane – Width of bicycle lane – Width of paved outside shoulder – Median type and curb presence – Pedestrian flow rate – Proportion of on-street parking occupied – Downstream intersection width – Presence of sidewalk – Total walkway width – Effective width of fixed objects – Buffer width – Spacing of objects in buffer – Distance to nearest signal-controlled crossing – Legality of midblock pedestrian crossing – Percent of sidewalk adjacent to window, building, or fence – Pedestrian delay – Pedestrian LOS score for intersection	– Segment length – Vehicle speed – Vehicle flow rate – Number of through lanes – Width of outside through lane – Width of bicycle lane – Width of paved outside shoulder – Median type and curb presence – Percent heavy vehicles – Proportion of on-street parking occupied – Number of access points – Pavement condition – Bicycle delay – Bicycle LOS score for intersection

Pedestrians	Bicyclists
Intersection LOS	
All intersections: – Vehicle flow rate – Number of lanes – Number of right-turn islands – Pedestrian flow rate – Crosswalk length – Crosswalk width Signalized: – Total walkway width – Corner radius – Right-turn-on-red flow rate – Permitted left-turn flow rate – Midblock 85th percentile speed – Signal timing (walk, pedestrian clear, rest in walk, cycle length, yellow change, red clearance, duration of phase serving pedestrians) – Present of pedestrian signal heads Two-Way Stop Controlled: – Presence of raised median Rate at which motorists yield to pedestrians – Degree of pedestrian platooning	– Vehicle flow rate – Number of lanes – Width of outside through lane – Width of bicycle lane – Width of paved outside shoulder – Bicycle flow rate – Proportion of on-street parking occupied – Street width – Signal timing (cycle length, yellow change, red clearance, duration of phase serving bicyclists) *No methodology for two-way stop controlled intersections

Challenges

A key challenge to applying HCM MMLOS is that it is data intensive and can be difficult to use. Because of its wide use, however, there are existing software packages, such ARTPLAN, which can aid in the evaluation process.

MMLOS has limited ability to account for small infrastructure improvements[3].

The PLOS does not currently account for the presence of lighting, the condition of the sidewalk, and sidewalk widths greater than 10 feet.

At a link level, the HCM BLOS is most sensitive to heavy vehicle volumes, degree of separation from motorized vehicle traffic, and the presence of on-street parking. It is relatively insensitive to overall traffic volumes and speeds and does not directly incorporate the number of travel lanes, other than to determine the traffic volume in the lane closest to bicyclists. At a facility level, a large constant in the equation makes it difficult to achieve a letter grade above C for any facility.[3] This makes it difficult to use facility LOS to document improvements to bicycle service when upgrading an on-street facility to a separated facility. The constant in the facility equation and the size of the range for each LOS letter at the link level were modified in the *HCM 6th Edition* to address these concerns. BLOS does not consider innovative bicycle treatments that were not widely used in the U.S. at the time of the research, such as bicycle boxes, colored paint, bicycle signals, and cycle tracks.

Opportunities

MMLOS incorporates operational characteristics to a greater degree than other methodologies explored. Some of the heaviest weighted variables in the MMLOS calculations include heavy vehicle (truck) volumes and percentage of on-street parking.[3]

Of the methods explored, HCM MMLOS is the best suited for comparisons across modes. The method was developed specifically to allow comparisons of different allocations of the street right-of-way between travel modes. The model can be adapted to and validated for local conditions to improve its validity and to calibrate the level of service scores to local experience and perception. This effort is resource and time intensive, but can address several of the challenges mentioned, such as, including additional factors into the PLOS and recalibrating the bicycle score to reflect the current users' perceptions.

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[3]Madeline Brozen et al., "Exploration and Implications of Multimodal Street Performance Metrics: What's a Passing Grade?" University of California Transportation Center, 2014.

Level of Traffic Stress Analysis

Overview

The Level of Traffic Stress (LTS) methodology is used to predict how bicyclists will experience the road. Unlike the Bicycle Level of Service methodology, the LTS methodology looks at the user tolerance for different types of facilities and traffic conditions, in which there are certain conditions that must be met for biking to be accessible to the mainstream public. The methodology uses a weighted compilation of traffic volume, traffic speed, number of travel lanes, roadway and lane width and presence of parking to determine an LTS classification of 1 through 4. "The *Level of traffic stress 1 (LTS 1) is meant to be a level that most children can tolerate; LTS 2, the level that will be tolerated by the mainstream adult population; LTS 3, the level tolerated by American cyclists who are "enthused and confident" but still prefer having their own dedicated space for riding; and LTS 4, a level tolerated only by those characterized as "strong and fearless."*[4]

The methodology is anchored by LTS 2, which mimics Dutch standards for acceptable bicycle conditions. This standard has been proven to be acceptable to most vulnerable users, and a robust network of LTS 1 and LTS 2 facilities can serve most of the population.[4]

The methodology classifies bicycle facilities into three (3) types: (1) physically separated bicycle facilities, (2) bicycle lanes, and (3) streets with mixed traffic. The most intensive part of the analysis is assigning an LTS to streets with mixed traffic. ***Table 5*** classifies street LTS based on two (2) main data points: street width and speed.

Table 5: Criteria for Level of Traffic Stress in Mixed Traffic

Speed Limit	Number of Lanes		
	2-3 lanes	4-5 lanes	6+ lanes
Up to 25 mph	LTS 1 or 2*	LTS 3	LTS 4
30 mph	LTS 2 or 3*	LTS 4	LTS 4
35+ mph	LTS 4	LTS 4	LTS 4

*Note: Use lower value for streets without marked centerlines or classified as residential and with fewer than 3 lanes; use higher values otherwise.

(Source; Table 4 from MTI, P. 21)

While the LTS methodology considers roadway and traffic characteristics, which are central aspects that affect a person's decision to bike, it does not consider other stressors, such as pavement quality, crime, noise, and aesthetics.[4]

[4] Maaza C. Mekuna, Ph.D. et al., *MTI Report 11-19: Low Stress Bicycling & Network Connectivity*, Mineta Transportation Institute: San Jose State University, 2012.

Applications

The LTS methodology has been applied in several cities and counties to evaluate their systems and to develop either design guidance for projects or specific plans for projects and improvements. Montgomery County, Maryland developed a bicycle planning guide based on the LTS methodology. It used basic concepts of speed and traffic volumes to provide guidance on an appropriate bicycle facility that would meet most of the population’s needs to bike based on the street context. The planning guide provided a case example in Bethesda, Maryland where the LTS methodology was used to evaluate the entire network and prioritize improvements to “unlock” the low-stress network.

The LTS methodology is best applied using link and intersection data within GIS. A GIS shapefile that has any combination of speed, volumes, number of lanes, and presence of parking can be used to map the LTS score for streets. This allows practitioners to easily evaluate the network and identify projects that would have the highest return in terms of “unlocking” low-stress islands of streets that already exist in the network.

The LTS can also evaluate the “connectivity” of the network by calculating the percentage of low-stress islands that are connected to each other via a low-stress facility.

Data Needs

Table 6 summarizes the data used in the LTS methodology and how it is used to “inform” the LTS score.

Table 6: LTS Data Inputs

Data Set	Recommended or Required?	Purpose
Average Daily Traffic Volume	Required	This informs how much traffic exposure the bicyclist experiences.
Speed	Required (Observed speeds recommended when possible)	Speed provides a measure of the comfort a bicyclist experience when a vehicle passes in mixed traffic. Traffic speeds that exceed 30 mph are less tolerable by most of the population.
Number of Travel Lanes	Recommended	Number of travel lanes is a good indicator of traffic volumes when volume data are not available. The number of travel lanes and ADT can also highlight cases in the network where streets that are one-lane but experience 8,000+ ADT can move the needle from an LTS 1 or 2 to LTS 3. Although the street is one-lane and low speed, the peak-hour experience of having a steady stream of cars pass a bicyclist exceeds the majority of the population's traffic stress tolerance.
Presence of Parking	Recommended	The presence of parking is particularly needed for LTS 3 and 4 streets to determine an appropriate bicycle facility. In most conditions a bike lane is not acceptable between a parking lane and a travel lane.
Presence of a Bicycle Facility (and Type)	Required	The existing bicycle network is necessary to understand whether the road is stressful for bicyclist. The roadway characteristics can indicate an LTS 4, but the presence of a separated facility would classify that same corridor as an LTS 1. A cycle track, side path, or any facility physically separated from traffic and requires minimal attention from bicyclist would be rated an LTS 1. This may include a cycle track that uses a parking lane to physically separate the bike lane from traffic. A local street with low traffic volumes and traffic speeds below 25 mph and a bike lane adjacent to the curb (no parking) would be an LTS 2 or 3, while a condition with no bicycle facility present or a facility that encourages mixing with traffic speeds over 30 mph would be an LTS 4.

Challenges

The LTS methodology requires relatively simple and available data points. The methodology application is usually in a mapping format in GIS. Developing a data set that has all the required and recommended data points in a link and intersection data set that can be mapped in GIS can be time consuming and expensive.

The methodology also heavily depends on speed data. In many cases, posted speed limits are more readily available than observed speeds. This can create misleading LTS scores, as posted speeds can be regularly exceeded by the daily traffic. In these cases, the results of the methodology usually require a higher quality "truth vetting" process with local stakeholders and practitioners.

Opportunities

The LTS methodology is a widely recognized methodology that provides a representation of the comfort of a bicycle and roadway network for bicyclist in the context of most of the population. It is also a methodology that steers the planning and design process from implementing bicycle facilities that “fit” in the right-of-way to context-appropriate design based on the traffic stress of the street.

Despite what can be an intense effort to compile data into a GIS format for mapping, the ability to map scores and use the LTS to look at overall connectivity in a network is helpful to practitioners as they focus and prioritize projects. This allows for practitioners to identify projects that leverage existing low stress streets and implement high-return facilities.

Bicycle Network Analysis Score

Overview

The BNA Score is a methodology that was recently developed by PeopleForBikes to measure how well the existing bicycle network connects people with places they want to go. The methodology combines a modified LTS approach with U.S. Census data and OpenStreetMap (OSM). The methodology compiles employment and household data to evaluate how the low-stress network is serving trips.

The methodology identifies census tracts that are accessible via the low-stress network within a 10-minute biking trip and assuming no more than a 25 percent route diversion. The total number of destinations accessible on the low-stress network compared with the total number of destinations that are within biking distance regardless of whether they are accessible via the low-stress network is calculated to understand the ratio of destinations accessible on the low-stress bike network to those not accessible on the low-stress bike network.

The methodology also considers types of destinations and assigns points on a scale of 0–100 for each destination type based on the number of destinations available on the low-stress network, as well as the ratio of low-stress destinations to all destinations within biking distance.[5]

The BNA's six (6) scoring categories are:

- People
- Opportunity
- Core Services
- Recreation
- Retail
- Transit

Where there are mixed destination types, the category score is combined for both category place types. Weights for each destination type are used to represent their relative importance within the category. For census blocks where a destination type is not reachable by either high-stress or low-stress means, that destination type is excluded from the calculations. For example, the Opportunity score within a city with no institute of higher education is produced by excluding the Higher Education destination type so the score is unaffected by its absence[5].

The methodology uses weighted scores for each category to calculate one overall score. The weights of these score categories are provided in ***Table 7*** below. Once the weighted scores are compiled, they are normalized by the population to develop a score of 1 to 100.

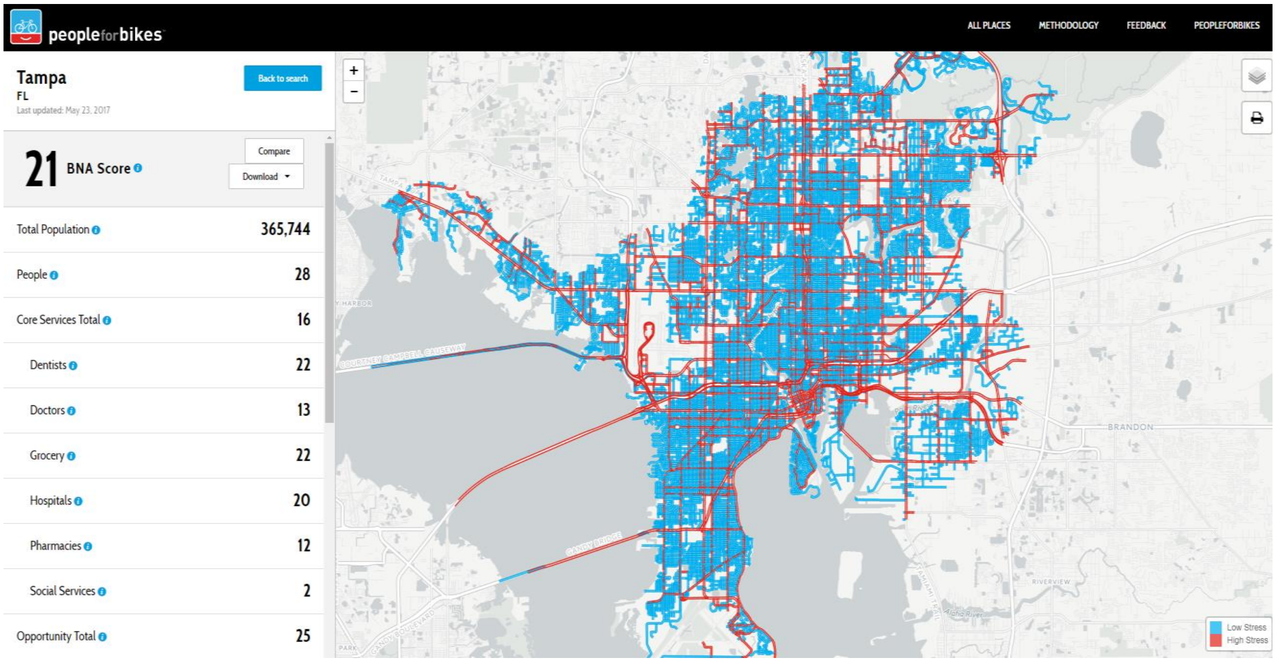
Table 7: Scoring Category and Corresponding Weight

Scoring Category	Weight	Measure
People	15	Population
Opportunity	20	Employment
		K-12 education
		Technical/vocational school
		Higher education
Core Services	20	Doctor offices/clinics
		Dentist offices
		Hospitals
		Pharmacies
		Supermarkets
		Social services
Recreation	15	Parks
		Recreational trails
		Community centers
Retail	15	Retail shopping
Transit	15	Stations/transit centers

Application

The BNA score methodology is very new as it was only released in 2017 by PeopleForBikes. The most relevant application has been a web-based tool that has calculated several cities' overall BNA score. A screenshot of the LTS map and BNA score (out of 100) for Tampa, FL is provided in ***Figure 1***.

Figure 1: BNA Score and mapping for Tampa, FL from PeopleForBikes Web Tool, 2017



Data Needs

The BNA score combines the LTS analysis with publicly available U.S. Census data. The more precise and accurate the data in the LTS analysis, the more likely the BNA score reflects reality. In the web tool, the BNA depends on OSM data, which tags segments and intersections with key data points that the analysis then streamlines into a “High” or “Low” stress rating. For instance, the presence of a cycle track indicates a low-stress segment while any condition where bikes mix with traffic going over 20 mph is a high-stress segment. A summary of how facilities at the segment and intersection level are scored as “High” or “Low” is provided in ***Table 8*** and ***Table 9.*** The only exception to these tables is in the case where a segment is classified as “residential” or “unclassified” in OSM. Almost all these cases include mixed traffic conditions where the segment is considered low-stress if the speeds are less than 30 mph. The only cases where the segment would be high-stress is in two (2) cases where the speed limit is 25 mph and (1) there is one (1) travel lane, parking on one side of the street, and the road width is less than or equal to 18 feet, or (2) there is one (1) travel lane with parking on both sides of the street and the road width is less than or equal to 26 feet.

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[5] Website: https://bna.peopleforbikes.org/#/methodology, 2017

Table 8: Segment Stress Based on Bicycle Facility and Roadway Characteristics

Facility Type	Speed (mph)	Number of Lanes	Parking	Facility Width	Stress
Cycle track					Low
Buffered bike lane	> 35	> 1			High
		1			High
	35	> 1			High
		1	Yes		High
			No		Low
	30	> 1	Yes		High
			No		Low
		1			Low
	<= 25				Low
Bike lane without parking	>30				High
	25-30	> 1			High
		1			Low
	<= 20	> 2			High
		<= 2			Low
Bike lane with parking				>= 15 ft	*Treat as buffered lane*
				13-14 ft	*Treat as bike lane without parking*
				< 13 ft	*Treat as shared lane*
Shared lane	<= 20	1			Low
		> 1			High
	> 20				High

Table 9: Intersection Stress Based on Bicycle Facility and Roadway Characteristics

Intersection Control	Number of Crossing Lanes	Crossing Speed Limit	Median Island	Stress
None/yield to cross traffic	> 4			High
	4	>30		High
		30	Yes	Low
			No	High
		<= 25		Low
	< 4	> 30	Yes	Low
			No	High
		<= 30		Low
RRFB	> 4			High
	4	>= 40		High
		35	Yes	Low
			No	High
		<= 30		Low
	< 4	> 35	Yes	Low
			No	High
		<= 35		Low
Signalized, HAWK, four-way stop, or priority based on class				Low

U.S. Census data is used to evaluate how well the LTS network connects places and people at the census tract level. The census tract data applied includes:

- Population
- Employment
- K-12 education
- Technical/vocational schools
- Higher education
- Doctor offices/clinics
- Dentist offices
- Hospitals
- Pharmacies
- Supermarkets
- Social services

- Parks
- Recreational trails
- Community centers
- Retail shopping
- Stations/transit centers

The required U.S. Census data are available online by downloading the census tract GIS shapefiles.

Challenges

The BNA score is a new application; therefore, challenges and opportunities are still being identified and confirmed. The most apparent challenge is the street data set that informs the LTS in the web-based tool uses a flexible data set, OSM, which anyone can contribute to, introducing biases. While OSM is free, publicly available, and good for some cities, for many others it is non-existent or incomplete, limiting the jurisdictions that can use the web-based tool.

The BNA score also evaluates connectivity based on a 10-minute bicycle trip. Research has shown that people on bikes are usually willing to travel up to 3 miles by bike, which exceeds the 10-minute trip threshold. This also does not show a high return for a longer, high-quality facility that connects two (2) major destinations that are more than 10 minutes apart. The BNA score, for instance, would show that a separated facility on a long bridge does not have a high impact on the connection between two (2) communities on either side of the bridge if it is longer than a 10-minute trip by bicycle. The analysis also does not consider some recreational trips, such as connectivity to nightlife. Lastly, the methodology is limited to network applications versus a specific corridor or project.

Opportunities

The BNA score is the first bicycle planning methodology to incorporate land use and destinations into the planning process in a computational way. The methodology evaluates the network and streets based on how well people are connected to places and opportunities. This gives an across-the-board look at how well the overall network is serving its adjacent land uses and helps practitioners identify and prioritize improvements that will serve those needs.

Charlotte's Pedestrian/Bike LOS (PLOS and BLOS)

Overview

The Charlotte Department of Transportation (CDOT) developed a methodology to evaluate the level of service for pedestrians and bicyclists at intersections based on design features. The key design features considered include crossing distance, roadway space allocation to crosswalks, bike lanes, sidewalks, medians, corner radius, and traffic signal characteristics. The methodology provides a point rating based on certain design elements. Design elements that are less comfortable for bicyclists and pedestrians receive lower points, and in some cases negative points, while design elements that are favorable for bicycles and pedestrians receive more points. The sources for each category are compiled into one (1) final score. The methodology provides a range of points for LOS 'A' through 'F', and the intersection is assigned a P/BLOS letter based on where its composite score falls in the pre-determined ranges.

Application

CDOT has applied this methodology as part of their small-area planning efforts and intersection prioritization processes. The City calculates P/BLOS for all signalized intersections in the City to assist in evaluating whether the intersection design features are serving the basic needs of pedestrians and bicyclists. Currently CDOT uses a spreadsheet tool to calculate the P/BLOS for every signalized intersection in the City.

Data Needs

The data for the P/BLOS calculations can be extrapolated from as-built plans, Google Earth measurements, and field measurements and observations.

The data required to calculate the PLOS include:

- The number of travel lanes to cross and the presence and width of a median refuge.
- Pedestrian signal phase that conflicts with a left turn or right turn.
- Pedestrian signal display details, such as whether a pedestrian signal is present and if so whether there is a leading pedestrian interval, a countdown display, and whether the Flash Down Walk/Countdown phase accommodates a walking speed of less than or equal to 3.5 ft./sec.
- Corner radius or the characteristics of a pedestrian refuge, when present.
- Presence of a NO RIGHT TURN ON RED sign.
- Crosswalk type, such as raised crosswalks, high visibility (zebra stripe), or low visibility (only two parallel lines), and crosswalk presence.

The data required to calculate the BLOS includes:

- Presence of a bike lane on the approach.
- Traffic speeds on the approach.
- Left-turn signal phasing.
- Stop bar location.
- Right-turn conflict and whether right turns are permitted on red.
- Number of travel lanes a bicyclist must cross.

The CDOT developed tables where scores were assigned based on the relative characteristics of each of these data points. The scores are combined for one (1) total score and the methodology provides a corresponding LOS with each score.

Challenges

The methodology provides an objective measure to help understand the trade-offs of a project against traditional vehicle measures (e.g., volume/capacity ratio), but the P/BLOS cannot be compared directly to auto LOS. The P/BLOS methodology assesses design features that affect comfort and safety, while the automobile LOS assesses delay, a measure of convenience. This makes it difficult to use the methodology to determine the trade-offs for different design decisions since the results of the metrics do not use the same scale. For instance, an auto LOS 'C' is typically considered an acceptable performance for an urban intersection. However, a LOS 'C' for the P/BLOS does not always translate to a design condition that most of the population will tolerate.

For instance, the BLOS methodology would assign LOS 'D' to an approach with a 12-foot shared travel lane, a speed of 35 mph, a protected opposing left turn, right-turns on red, and four (4) travel lanes to cross. Recent research has shown that this condition would not be tolerable for most of the population to ride a bike.

Opportunities

The methodology allows practitioners to assess how certain improvements will affect pedestrian and bicycle level of comfort on a project and intersection level. Practitioners can evaluate which design elements will have the highest impact, and the magnitude of points allocated seems to correlate with the magnitude of impact the treatments will have relative to each other. For instance, for PLOS, the scoring gives three (3) times as many points for reducing left and right-turn conflicts as implementing textured or high-visibility crosswalks.

Summary of Findings

This literature review summarized five (5) methodologies that can be used to quantify multimodal experiences along and across roadways. Some of the methodologies explored, such as the HCM MMLOS, provide a way to compare all four (4) modes; while, other methodologies, such as the LTS, are tailored for one (1) mode. Likewise, some methodologies can be applied at the project level to evaluate trade-offs, while others focus more on network-level evaluation to aid in project identification and prioritization. ***Table 10*** summarizes the mode, analysis level, and application for each methodology explored and provides an overview of the data needs and relative difficulty of application.

Table 10: Summary of Multimodal Methodology Applications

Methodology	Mode				Analysis Level			Data Needs	Difficulty	Application (Project or Network Level)
	Ped.	Bicycle	Transit	Auto	Intersection	Corridor	Network			
HCM Multi-Modal Level Of Service (MMLOS)	●	●	●	●	●	●	●	High*	High	Project or Network
Level of Traffic Stress (LTS)	○	●	○	○	◐	●	●	High	High	Project or Network
Bicycle Network Analysis (BNA) Score	◐	●	○	○	○	○	●	Low	Low	Network
Transit Capacity & Quality of Service Manual (TCQSM)	○	○	●	○	●	●	●	Varies	Varies	Varies
Charlotte PLOS and BLOS	●	●	○	○	●	○	○	Low	Low	Project or Network

● Meets the Need ◐ Partially Meets the Need ○ Does Not Meet the Need

*Agencies can rely on default values for many inputs to reduce the data requirements.

HILLSBOROUGH COUNTY METHODOLOGY & APPLICATION

In coordination with the Bicycle and Pedestrian Action Committee (BPAC), the MPO decided to move forward with a level of traffic stress analysis for corridor conditions and to adapt the Charlotte PLOS and BLOS intersection methodology for use in Hillsborough County. The following sections describe the methodologies, as applied in the County.

Bicycle Level of Traffic Stress

The bicycle Level of Traffic Stress (LTS) methodology was applied in Hillsborough County, Florida to conduct a network-level assessment of existing bicycle conditions on streets within the County. The LTS analysis uses a "weakest link" method of assigning stress level; this reflects the reality that people on bikes experience the various types of traffic stress (speed of traffic, volume of traffic, degree of separation from traffic, incursions into their space) simultaneously. If even one of these factors is excessive, then the whole street segment is a high stress experience for most potential riders.

A lot of factors (and therefore data) are necessary to understand the rider experience and determine the resulting stress level. However, a roadway stress level can be determined on as few as one factor. Thus, it is logical to begin classification efforts with the most complete and granular data type available. In the case of Hillsborough County, roadways are first evaluated based on whether they have existing bike facilities. The methodology has two (2) assessment processes, one for roadways with a bicycle facility and one for mixed traffic conditions. The following five (5) factors are considered in both: (1) traffic speed; (2) surrounding land use; (3) traffic volume (as assumed from the number of travel lanes); (4) the level of separation from traffic; and, (5) incursions into the space used by people on bikes (e.g. high turnover parking).

The LTS score ranges from an LTS 1, which is comfortable for most of the general population, to an LTS 4, which is uncomfortable for even experienced bicyclists. The LTS scores can help plan a complete bicycle network that is useful to the general population, leverage low-stress streets that are already comfortable for most people, and help identify the appropriate bicycle facility based on key characteristics of the street.

Mixed Traffic Assessment Process

The missed traffic assessment is applied to roadways without a bicycle facility and roadways with shared lane markings (sharrows), as shown in ***Figure 2***. The process and data needed for an LTS assessment of streets where bikes are expected to operate in mixed traffic is shown in ***Figure 3***.

Figure 3 illustrates that an LTS designation can be made of all roadways with mixed traffic conditions with just the posted speed limit, number of travel lanes and adjacent land use type. This data is available through the MPO's GIS library. Additional information on the GIS process used for the evaluation is provided in **Appendix C**.

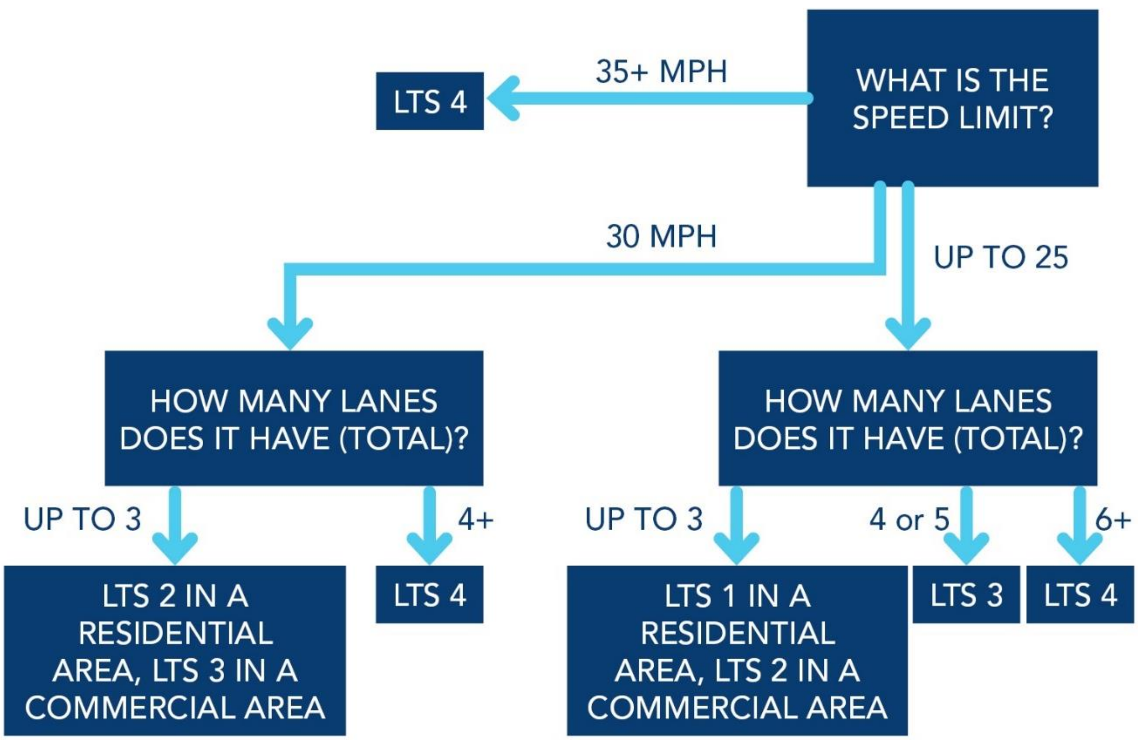
Figure 2: Mixed Traffic Bicycle Facilities

No Bicycle Facility

Shared Lane Marking/Sharrow

Source: NACTO, Urban Bikeway Design Guide

Figure 3: Mixed Traffic LTS Assessment Process

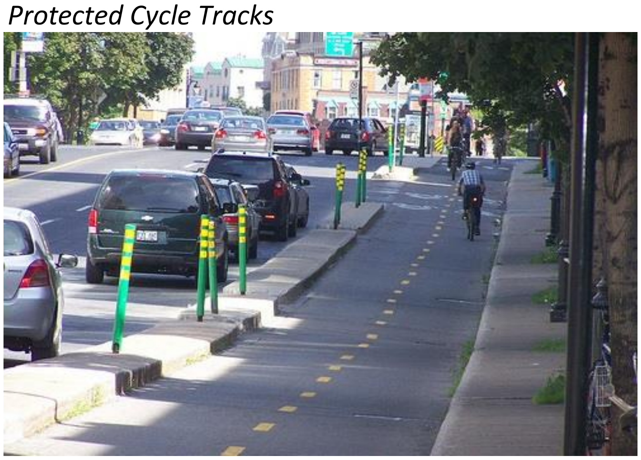


Bicycle Facility Corridor Assessment Process

Facilities with a dedicated bicycle facility (shown in ***Figure 4***) are evaluated using the process outlined in ***Figure 5*.** For streets with bicycle facilities, the first data type assessed is whether the bike facility is physically separated from motor vehicle traffic. Separated facilities include cycle tracks, shared use paths, and multi-use trails. Streets with bike lanes or buffered bike lanes will be assessed based on posted speed and whether they are adjacent to parking. Signed routes and sharrow facilities are assessed using the mixed traffic method show in ***Figure 3***, since they do not provide designated space for bicyclists.

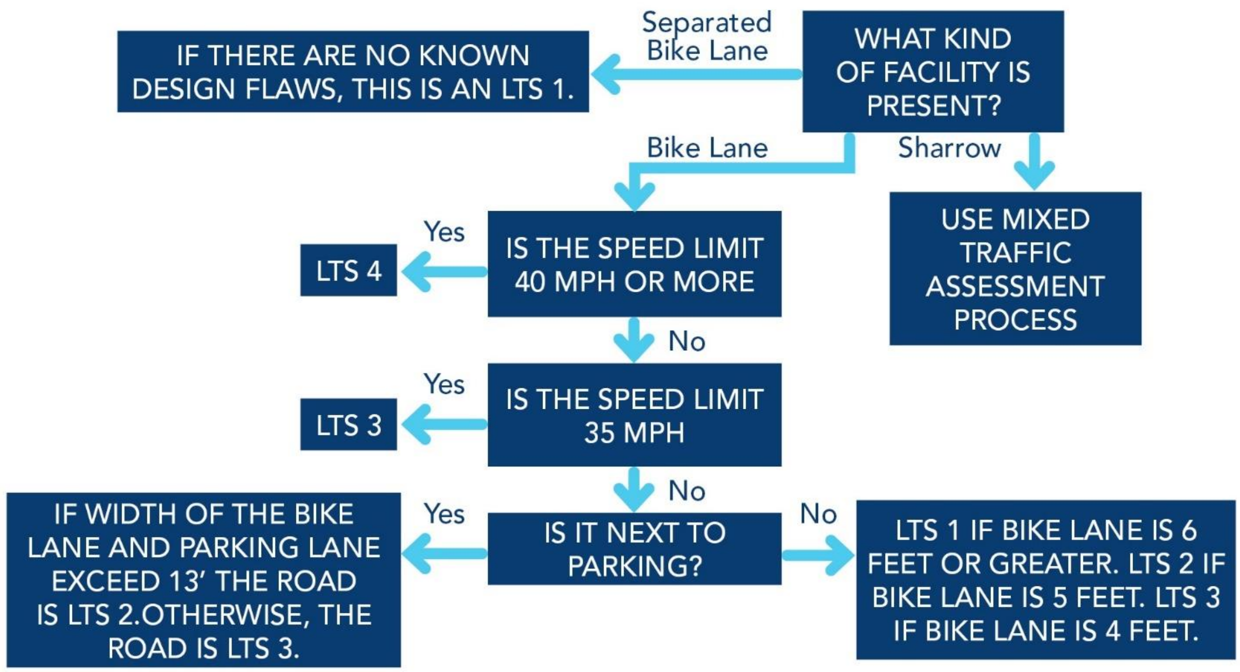
It is anticipated that several roadway segments with bike lanes will have speed limits below 35 mph. As shown in ***Figure 5***, it is necessary to take the presence of a parking lane and its width into account. It was assumed that parking lanes throughout the County are seven feet wide, consistent with the City of Tampa's design standard. Additional information on the GIS process used for the evaluation is provided in **Appendix C**.

Figure 4: Examples of Dedicated Bicycle Facilities

Separated Facilities	**On-street, Unprotected Facilities**
Protected Cycle Tracks 	*Conventional Bike Lane* 
Shared Use Path/Multi-Use Trail 	*Buffered Bike Lane* 

Source: NACTO, Urban Bikeway Design Guide

Figure 5: LTS Assessment of a Corridor with a Bike Facility



Bicycle LTS Evaluation

Application of this methodology will produce an LTS designation for all roadways in Hillsborough County that reflects the comfort experience of a bicyclist on the facility, in an efficient, defensible and streamlined manner. The results of the evaluation are shown in ***Figure 6***. About 90% of the functionally classified roadways in Hillsborough County are LTS 3 or 4 road segments. Most of the segments that were evaluated as LTS 1 are in downtown Tampa. It's important to note that local streets, which make up a large part of the network, are assumed to be low-speed with an LTS 1.

Figure 7 shows the bicycle network that is suitable for the general population. This includes LTS 1 and 2 streets and trails.

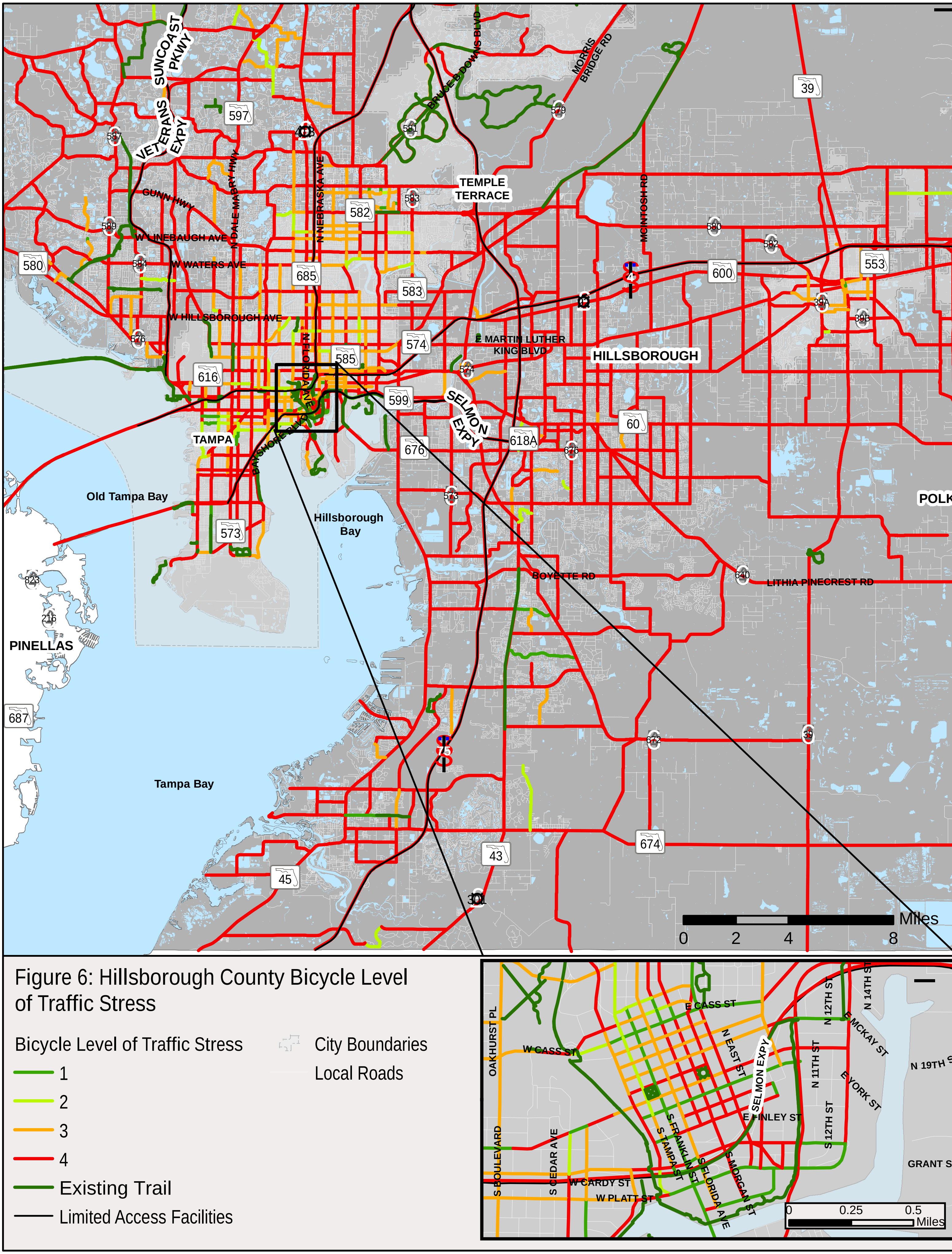
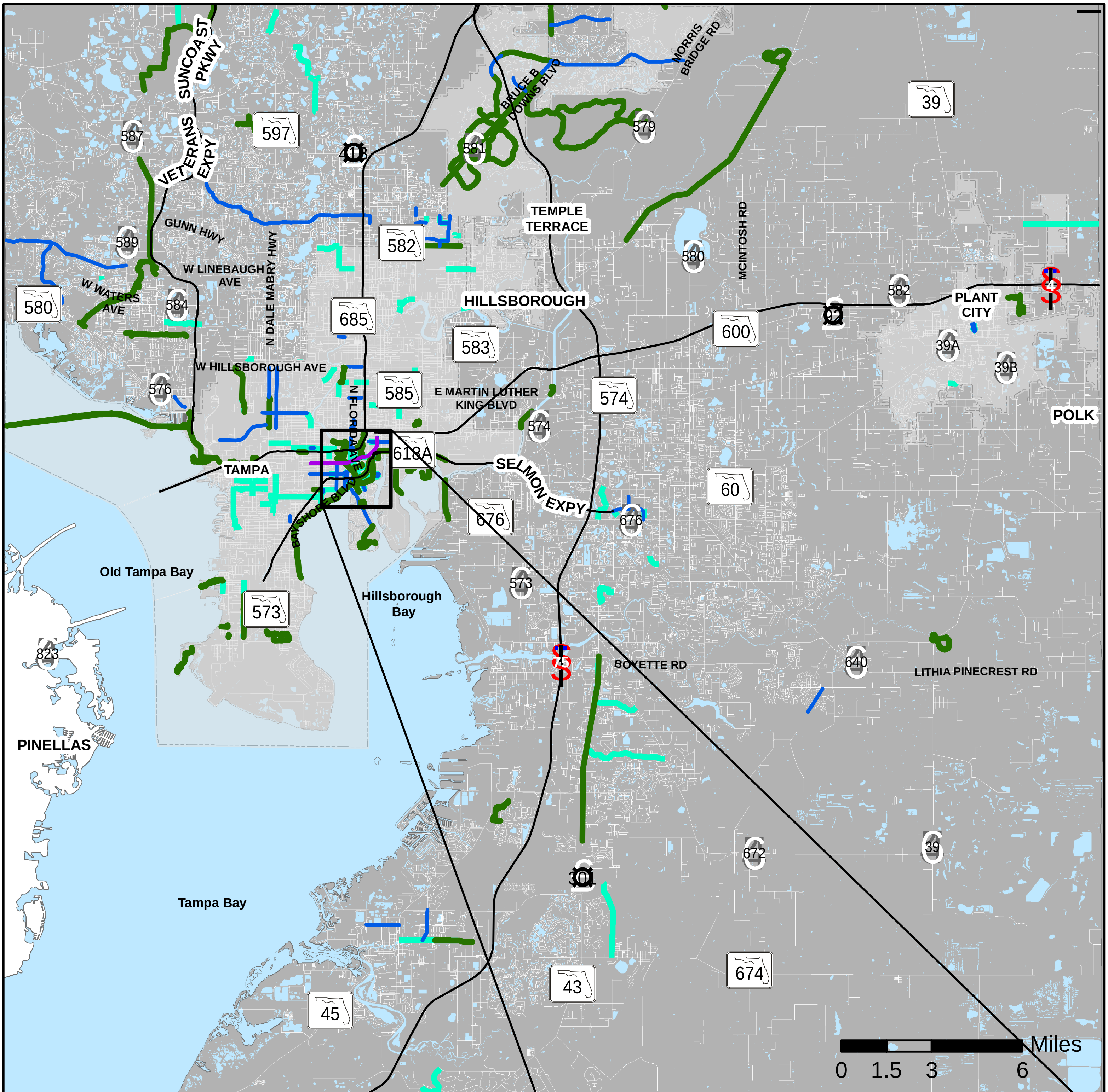


Figure 6: Hillsborough County Bicycle Level of Traffic Stress



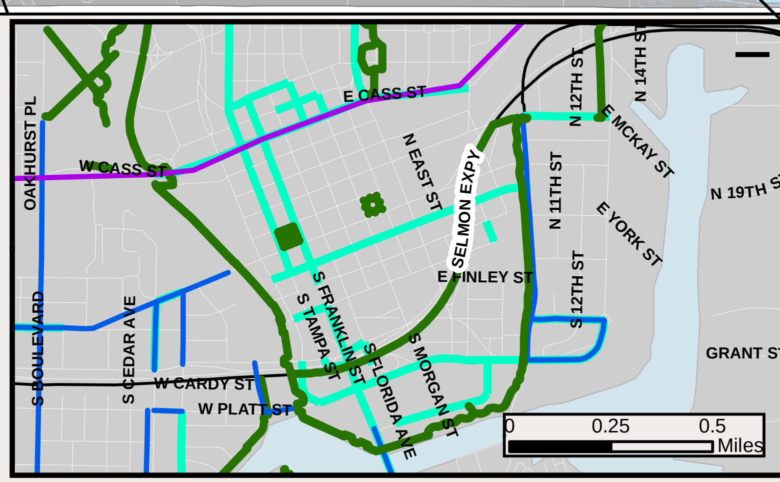


Figure 7: Bicycle Network Suitable for **the General Population**

Pedestrian Level of Traffic Stress

The pedestrian LTS methodology was created for the Hillsborough MPO to conduct a network-level assessment of existing walking conditions on streets within the County. Like bicycle LTS, pedestrian LTS analysis uses a “weakest link” method of assigning stress level. The factors include presence of sidewalk, speed of traffic, volume of traffic, number of vehicular lanes, degree of separation from traffic, and frequency of pedestrian crossings.

Many factors (and therefore data) are necessary to understand the pedestrian experience and determine the resulting stress level. However, a roadway stress level can be determined on as few as one factor. Thus, it is logical to begin classification efforts with the most complete and granular data type available. As shown in Figure 8, roadways are first evaluated based on whether they have a five-foot sidewalk on both sides of the roadway and then if a trail is present. From there, the volume and speed of traffic is reviewed, followed by the degree of separation from traffic, and finally the frequency of pedestrian crossings.

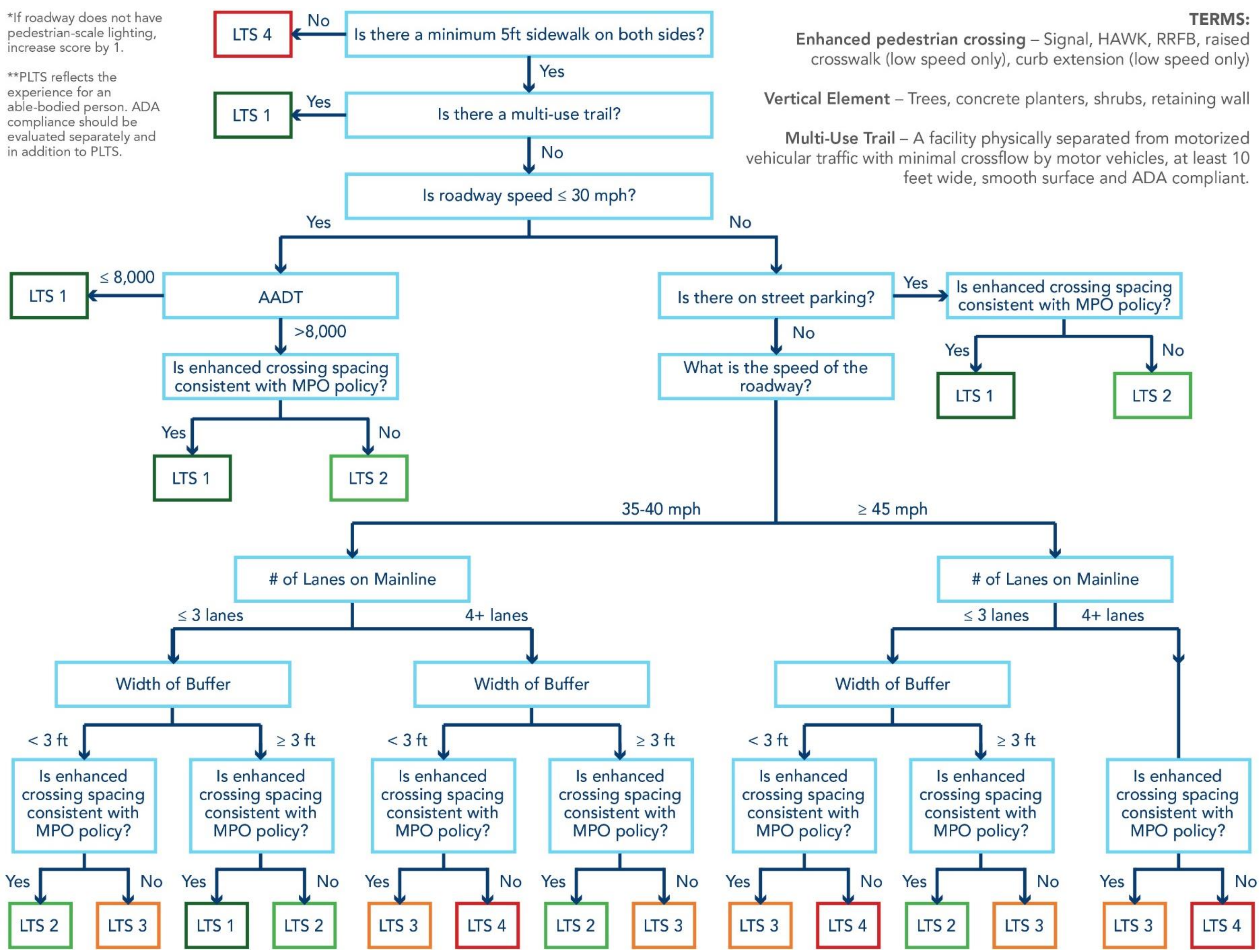
The LTS score rages from 1 to 4 and represent the following conditions for able-bodied persons of all ages:

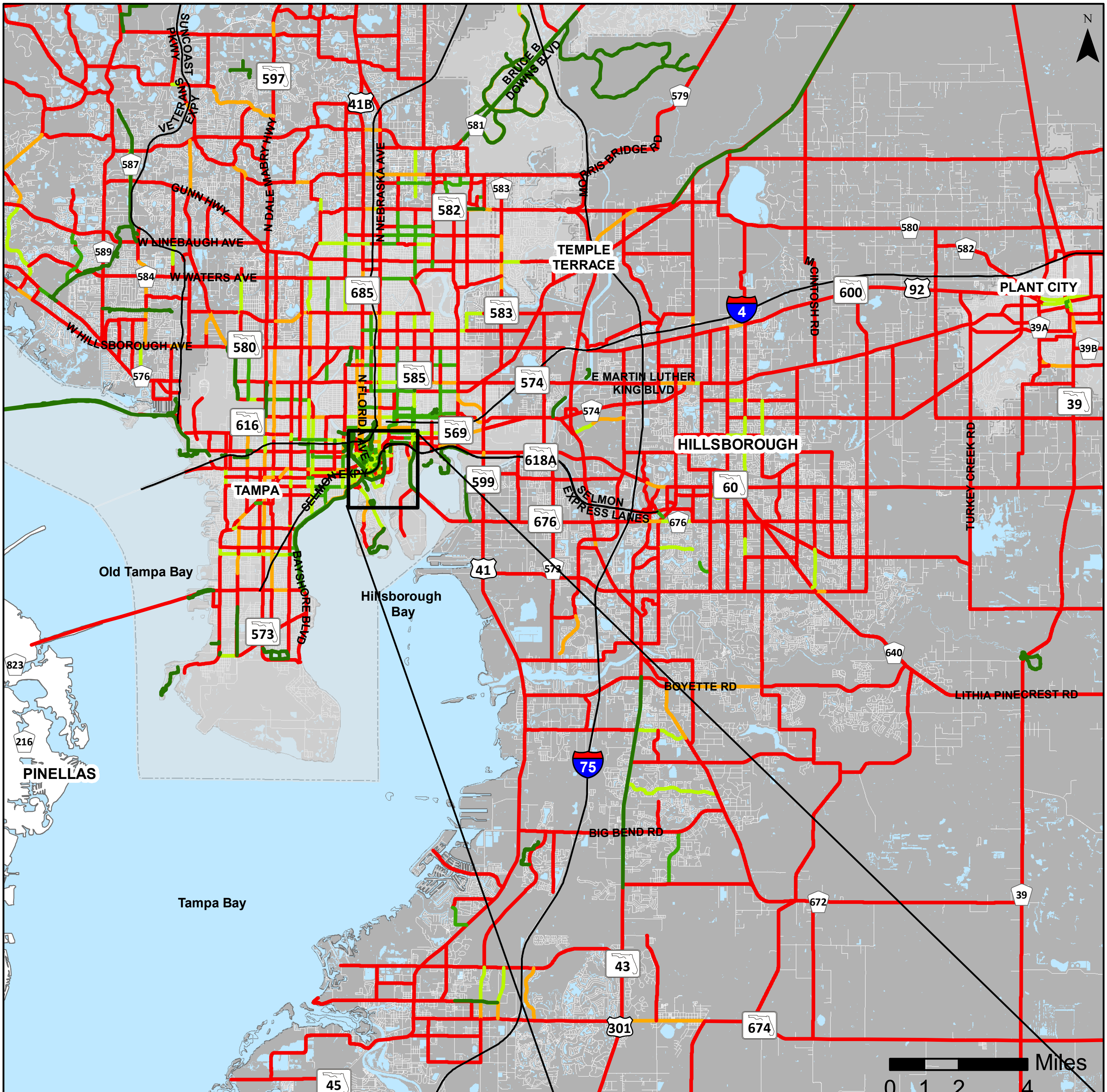
- LTS 1: Safe, well-connected, comfortable sidewalk network
- LTS 2: Safe, well-connected sidewalk network
- LTS 3: Safe sidewalk network
- LTS 4: Sidewalk gaps create potentially unsafe conditions

The pedestrian LTS methodology does not address Americans with Disability Act (ADA) compliance. All pedestrian facilities should be ADA compliant. Local agencies should refer to their ADA transition plans for existing barriers and methods to address them.

The results of the evaluations are shown in ***Figure 9***. About 77% of the functionally classified roadways in Hillsborough County are LTS 3 or 4 road segments. Most of the segments that were evaluated as LTS 1 are in downtown Tampa. The majority of LTS 4 streets are such because they do not have sidewalk on both sides.

Figure 8: Pedestrian LTS Methodology





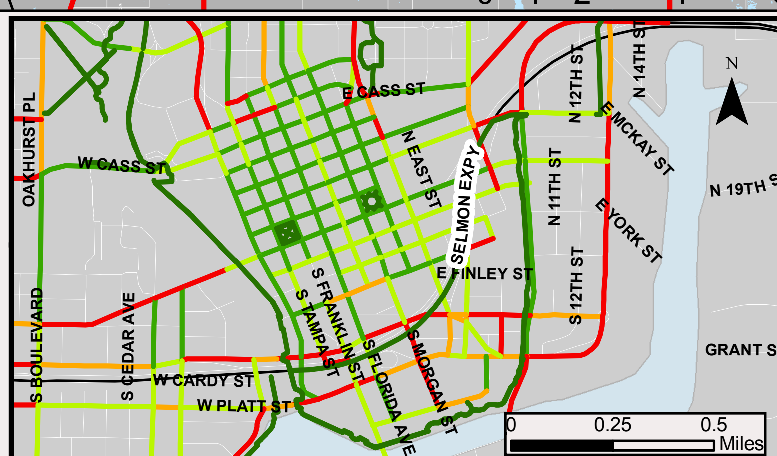


Figure 9: Hillsborough County Pedestrian Level of Traffic Stress

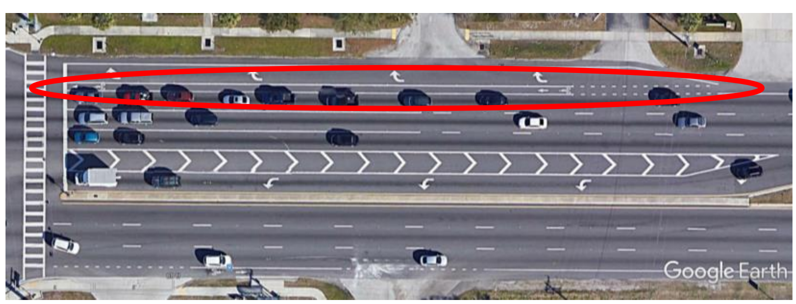
Pedestrian Level of Travel Stress

- 1
- 2
- 3
- 4
- Existing Trail
- Limited Access Facilities
- City Boundaries
- Local Roads

Bicycle Intersection Methodology

The approach to evaluate bicycle conditions at intersections is adapted from the LTS methodology. The LTS methodology, as developed by Peter Furth, et al, assigns a score to the approach of every intersection. The factors considered include: the approach segment LTS score, presence of right turn with or without a pocket bike lane, and speed of right turns. The methodology developed for Hillsborough County includes these and additional design elements, described in ***Table 11***. The evaluation methodology, shown in ***Figure 10*** and ***Figure 11***, assigns a score to the north/south and east/west movements of the intersection. This results in two (2) scores per intersection. Intersections can receive a score of Great, Good, Poor, or Worst in each directions of travel. The results of the analysis are presented in ***Figure 12***.

Table 11: Bicycle Intersection Design Considerations

Protected Intersection A protected intersection for bicycles uses islands and painting to force right turning vehicles to cross a bicycle lane at a perpendicular angle. This improves visibility, minimizing changes for conflict. The bicyclist can continue through the intersection or make a right turn within the bike lane. Bicyclist complete a left turn in two (2) stages, moving with the through traffic in each direction.	 Source: https://peopleforbikes.org/blog/and-then-there-were-two-salt-lake-citys-protected-intersection-opens/
Pocket Bike Lane A pocket bike lane is a bike lane located between the through travel lanes and the right turn lane. This allows bicyclists going straight to avoid the "right hook", or the conflict point between the cyclist and a right turning vehicle.	

Bike Signal A bicycle signal is used in addition to existing traffic signals and provides custom guidance for bicyclists, such as a leading bicycle interval, an all bicycle interval or different clearance times as applicable.	  Source: Google / NACTO, Urban Bikeway Design Guide
Bike Box A bicycle box is a painted area in front of the stop bar for bicyclists to wait for a green light. This allows for the bicyclists to proceed through the intersection ahead of the vehicles. Bike boxes also make left-turn movements easier, as bicyclists can enter the left-turn lane via the bike box.	 Source: Google
Two-Stage Turn Queue Boxes A two-stage queue crossing allows a bicyclist to make a left turn without crossing opposing traffic. A bicyclist travels in one direction with through traffic, waits in the queue box, and then travels the other direction with through traffic to complete the left-turn.	 Source: NACTO, Urban Bikeway Design Guide

Figure 10: Bicycle Intersection Evaluation when a Bike Lane is Present

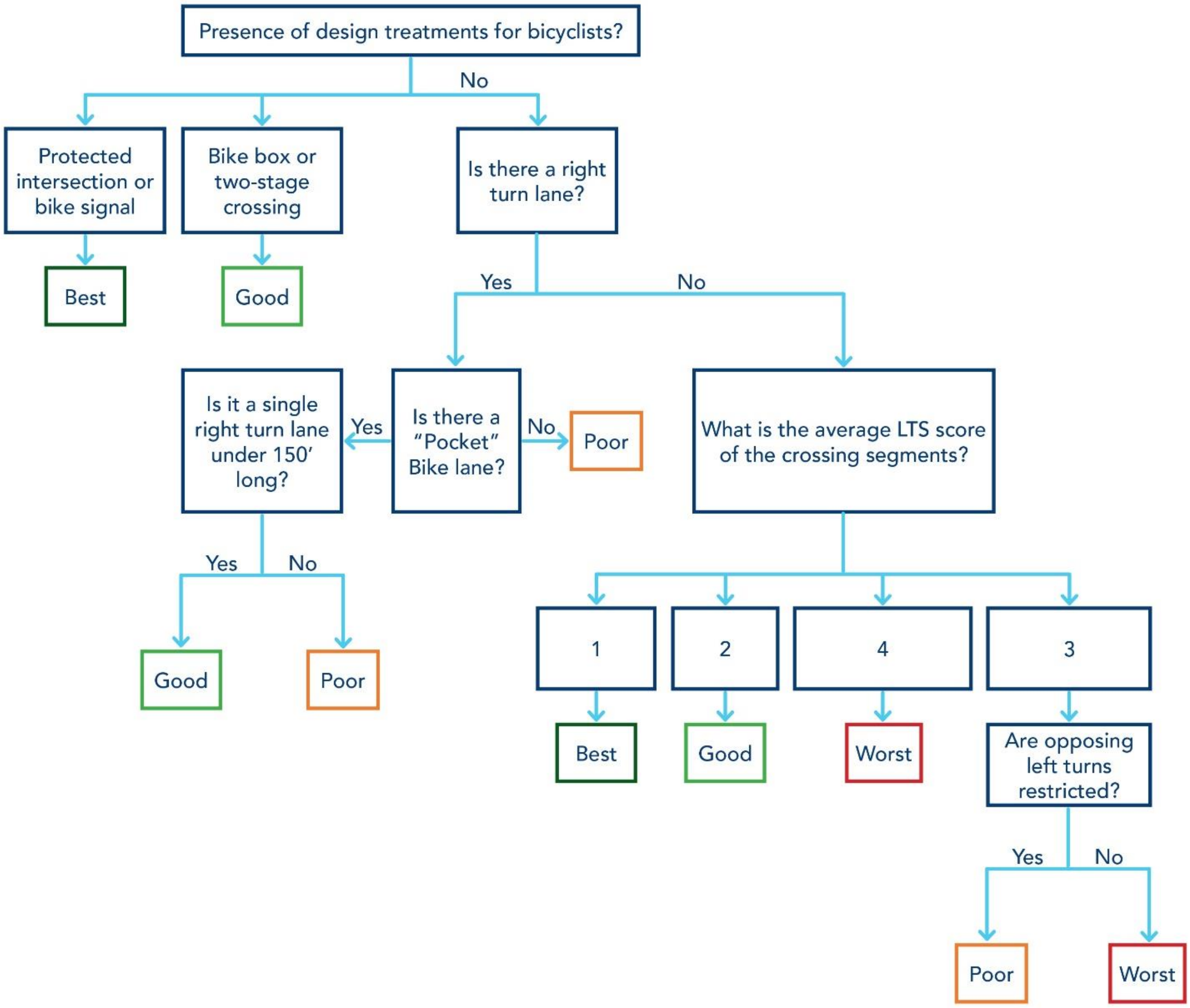
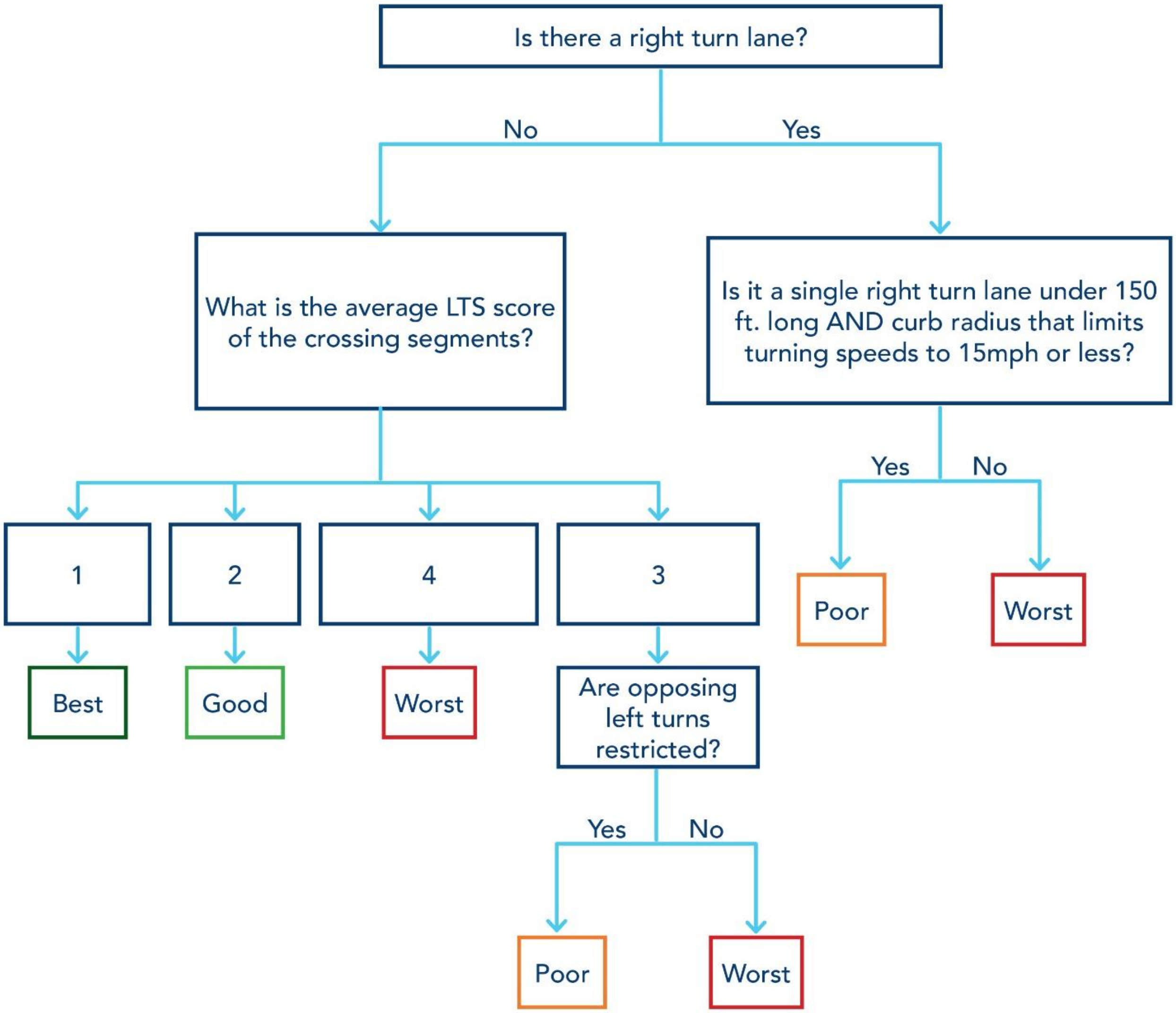
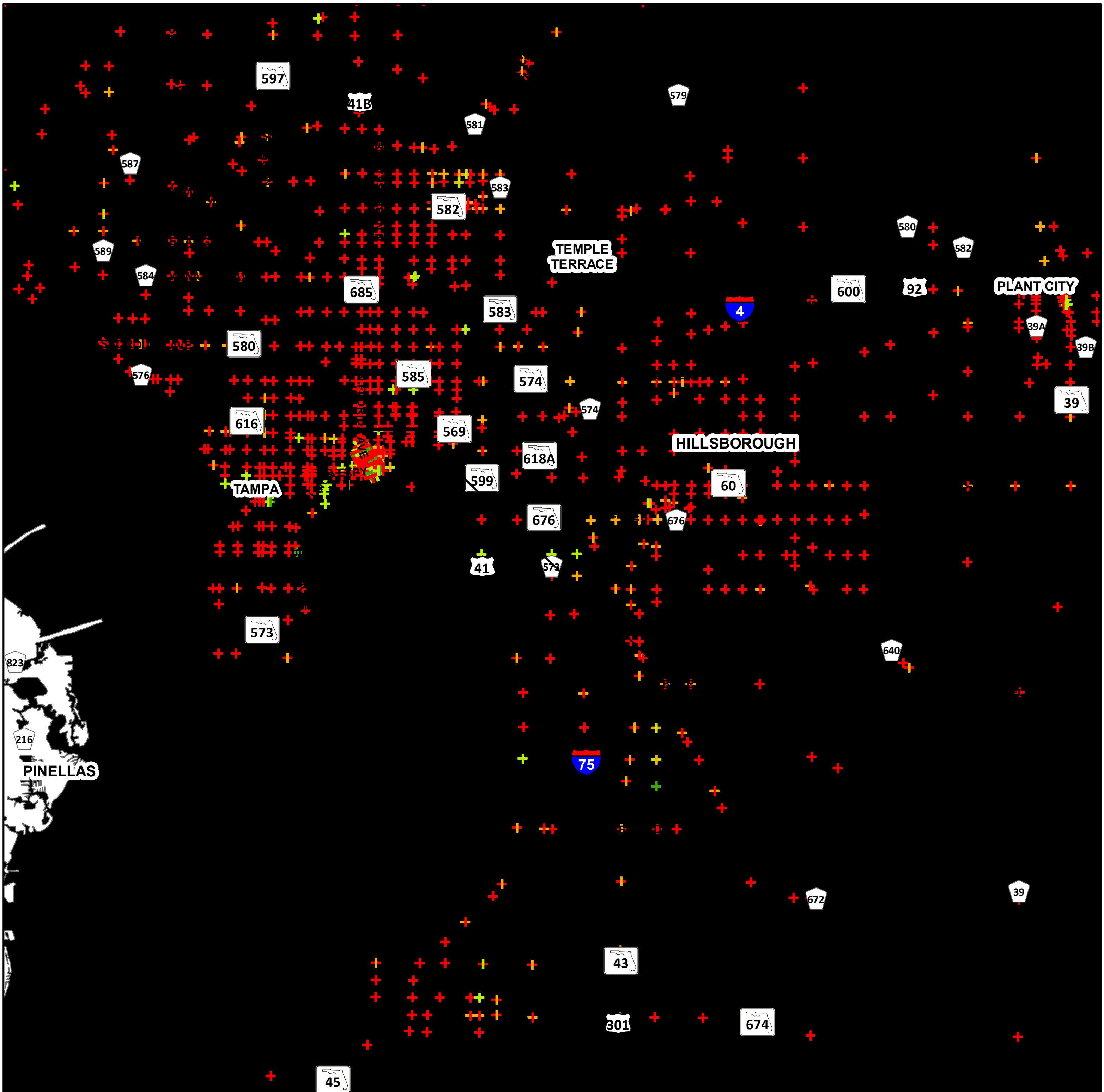


Figure 11: Bicycle Intersection Evaluation when a Bike Lane is Not Present





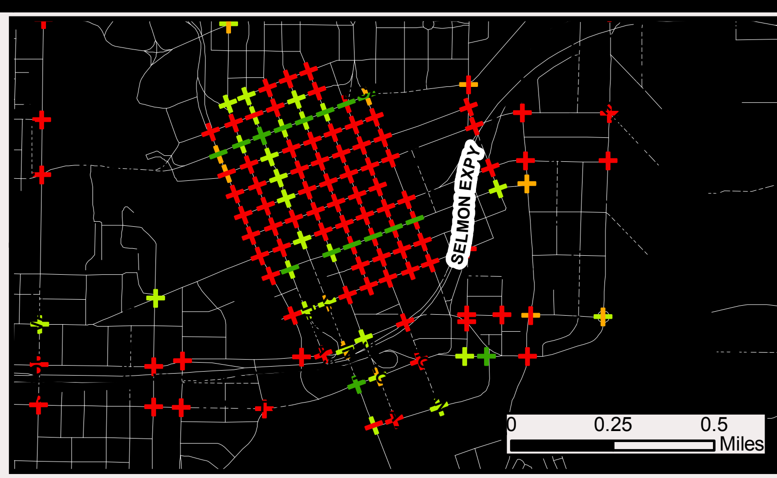


Figure 12: Bicycle Intersection Scores

N/S Score	E/W Score
Best	Best
Good	Good
Poor	Poor
Worst	Worst

Limited Access Facilities

City Boundaries

Local Roads

Pedestrian Intersection Methodology

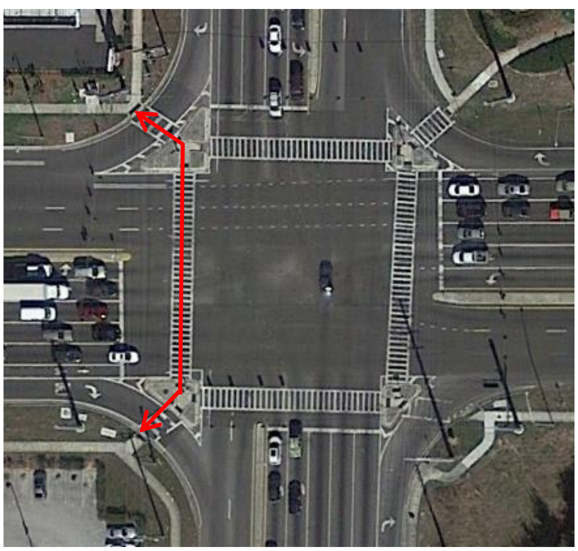
Following the bicycle intersection methodology, the pedestrian intersection methodology follows a similar "weakest link" evaluation. The evaluation focuses on the mainline crossing, the approach with the highest number of crossing lanes, and includes factors that make an intersection feel safe and comfortable for pedestrians attempting to cross. The methodology for signalized and unsignalized intersections is presented in ***Figure 18*** through ***Figure 23***. The individual factors are described in following sections.

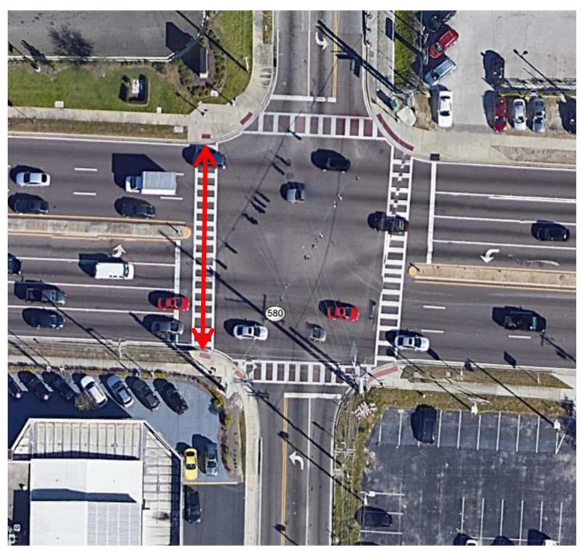
Pedestrian Crossing

Each intersection was checked for the presence of a marked crossing on each approach and if adequate crossing time is provided, for signalized intersections. The crossing time is determined using the length of the crossing and the walk and flash don't walk time provided, according to signal timing plans provided by Hillsborough County and the City of Tampa.

Pedestrian crossing distance was measured using Google Earth satellite images. The entire crossing distance was measured in the center of the crosswalk, including any distances across channelized islands, as shown in ***Figure 13***.

Figure 13: Pedestrian Crossing Distance





Adequate crossing time was defined in two ways:

- Time for a person to cross at 3.5 ft/s during the flash don't walk time, and
- Time for a person to cross at 3.0 ft/s during the walk and flash don't time.

The limit of 3.5 feet per second represents a comfortable walking pace and is the value recommended in the Manual for Uniform Traffic Control Devices (MUTCD). The limit of 3 feet per second is to accommodate pedestrians with disabilities requiring more crossing time. The crossing must meet both requirements in order to be considered adequate.

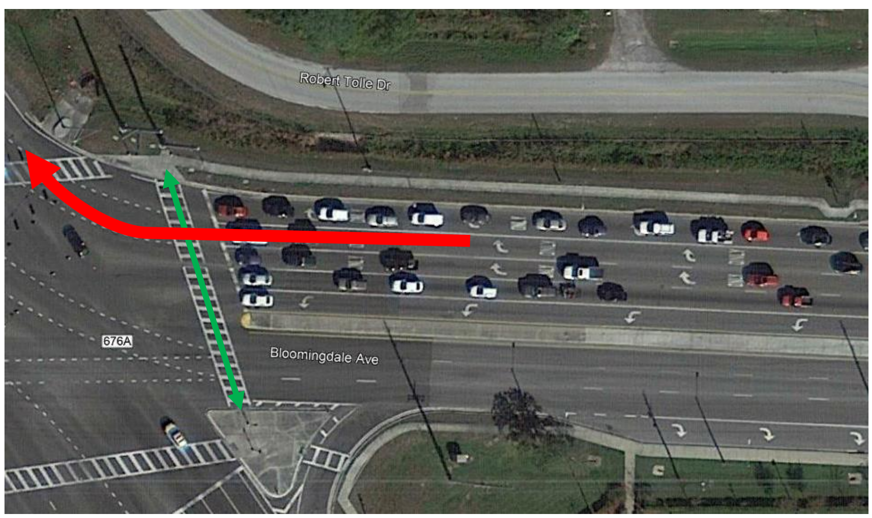
In general, the methodology requires the presence of a crossing with adequate crossing time on all four legs to receive a score of Neutral, Good, or Great. When the mainline has four lanes or less, an exception is given when the land use does not warrant the crossing. For example, if an intersection quadrant is taken up by an interstate pier and there is no destination, it may be appropriate to not mark the crossing. This causes some inconvenience for those crossing diagonally but has minimal effect on overall connectivity.

Turn Conflicts

A pedestrian faces many potential vehicle conflict points when crossing at an intersection. At signalized intersections, four (4) turn conflicts that are particularly challenging for pedestrian were reviewed.

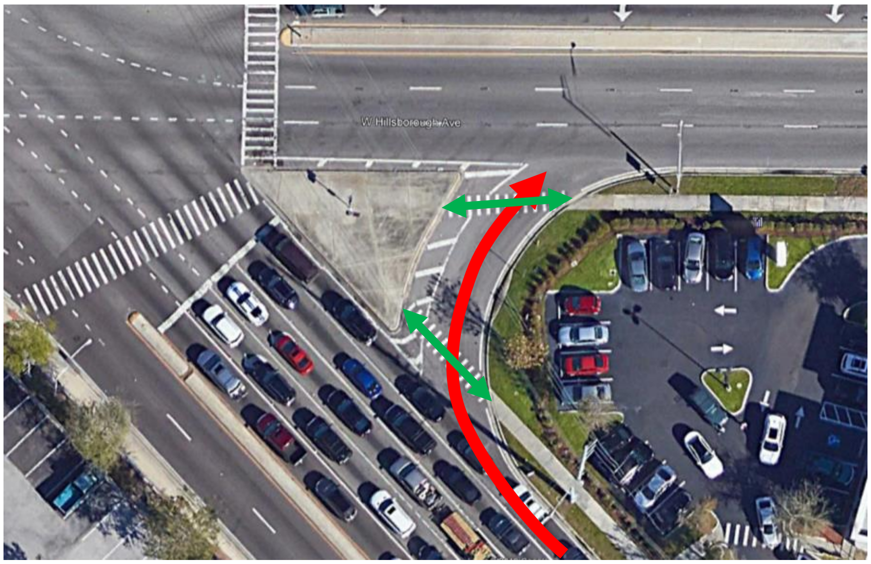
The first conflict is multiple right-turn lanes with right-turn on red permitted. This is any leg which has two (2) or more right-turn lanes (see ***Figure 14***) which can turn right on red. In Florida, right on red is permitted unless otherwise posted. This turn conflict was only counted if the turn was completed over an existing pedestrian movement.

Figure 14: Example of Approach with Multiple Right-Turn Lanes



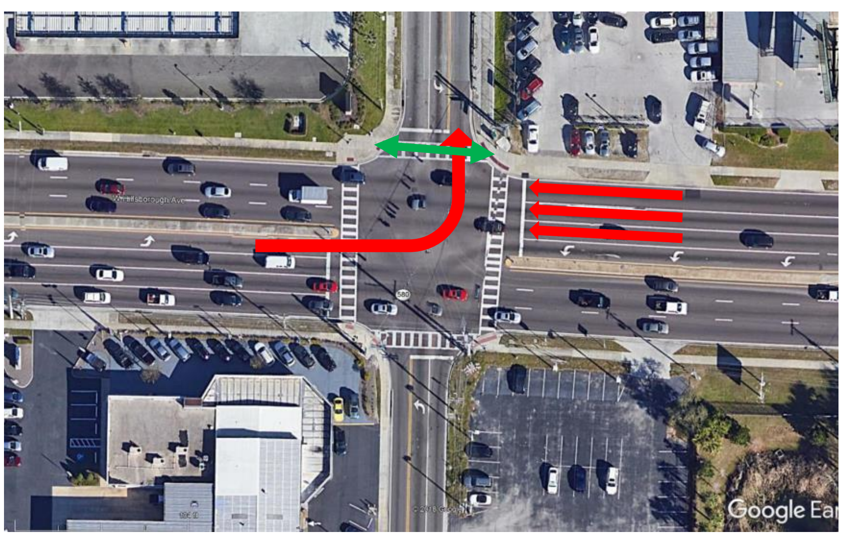
The second conflict is a yield controlled or free channelized right turn. A channelized right turn has a striped or raised median separating the turn lane from the through lanes (see ***Figure 15***). The conflict is recorded when the movement is yield controlled or free (where the right turn lane becomes a full lane after the turn) and there is a pedestrian crossing present.

Figure 15: Example of Approach with a Channelized Right-Turn



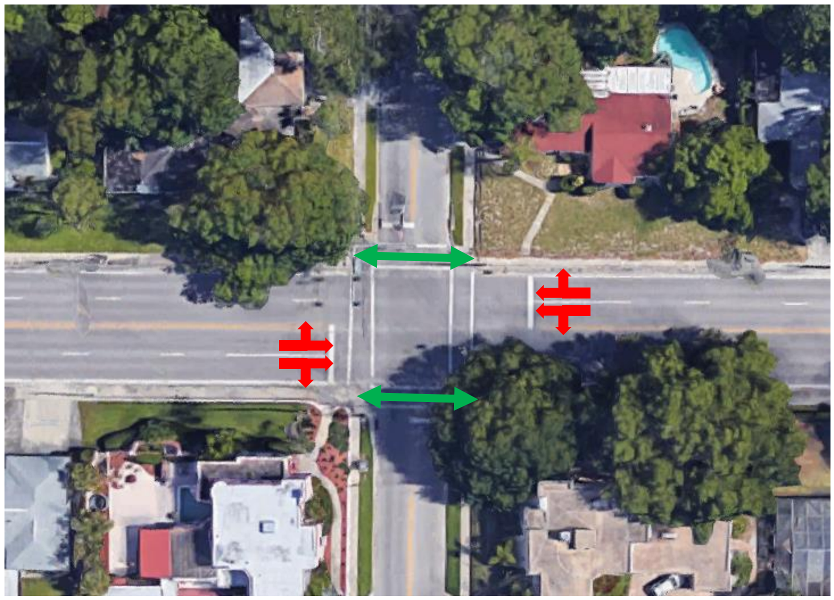
The third conflict is a permitted (or protected-permitted) left turn that has two or more conflicting through lanes (see ***Figure 16***). A permitted left turn who must find a gap in two (2) or more conflicting through lanes may not focus on the crosswalk when looking for a gap, creating a potential high-speed conflict with pedestrians.

Figure 16: Example of Approach with a Permitted Left-Turn and Two or More Conflicting Through Lanes



The final conflict is a permitted (or protected-permitted) left turn on the mainline without a turn lane (see ***Figure 17***). A permitted left turning vehicle on the mainline may face additional pressure as vehicles queue behind them and take a smaller gap in traffic, ignoring the crosswalk.

Figure 17: Example of Approach with a Permitted Left Turn on the Without a Turn Lane



Pedestrian Delay

Pedestrian delay was calculated using HCM 2010 equation 18-71:

$$delay = \frac{(C - g_{walk})^2}{2C}$$

where C is cycle length, g_{walk} is walk time plus 4 seconds, and delay is calculated in seconds.

Pedestrian Treatments

The following additional features for pedestrians were considered in the evaluation:

- *All pedestrian phase (pedestrian scramble) with concurrent pedestrian phases* – An all pedestrian phase adds a phase during a traffic signal cycle where all vehicle traffic is given a red light and all pedestrian movements are given a walk sign. Diagonal movements across the intersection may or may not be permitted during this phase. An all pedestrian phase included in addition to concurrent pedestrian/vehicle phases is an ideal condition to minimize delay and vehicle conflicts.
- *Pedestrian phase on recall on one or more legs* – When the pedestrian phase is on recall, the walk sign to cross comes up during every cycle, without a pedestrian needing to push the pedestrian button every cycle. A pedestrian phase on recall allows shorter pedestrian delays, particularly if someone arrives during the walk interval.

- *Leading pedestrian interval on one or more legs* – A leading pedestrian interval allows pedestrians to enter the intersection seconds before vehicles. This increases pedestrian safety by reducing conflicts with left and right-turning vehicles.
- *No right-turn on red on one or more legs* – In Florida, right-turn on red is permitted unless otherwise signed. Vehicles turning on red conflicts with both the opposing through vehicles and the opposing pedestrian movement. Pedestrians traveling in the opposite direction of traffic will typically be out of the sight line of a driver looking for a gap to make a turn on red. Restricting right-turn on red eliminates this conflict.
- *Median refuge island on the mainline* – A median refuge island is an area of at least five (5) feet providing a place for pedestrians to stand and wait for traffic if unable to complete a crossing in one cycle.

The results of the pedestrian intersection analysis are presented in ***Figure 24***.

Figure 18: Pedestrian Signalized Intersection Evaluation – Four or Less Total Crossing Lanes on the Mainline

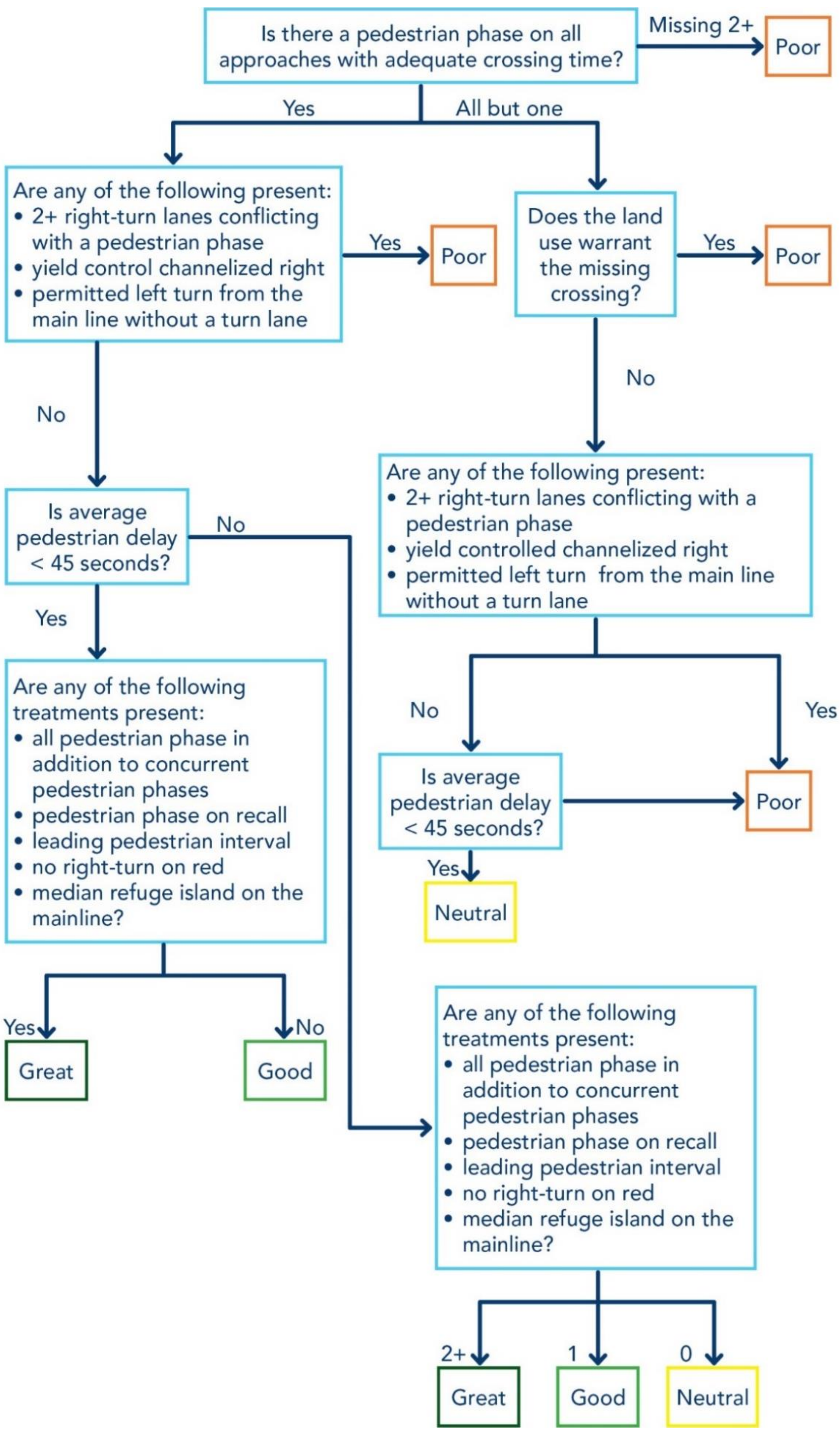


Figure 19: Pedestrian Signalized Intersection Evaluation – Five to Seven Total Crossing Lanes on the Mainline

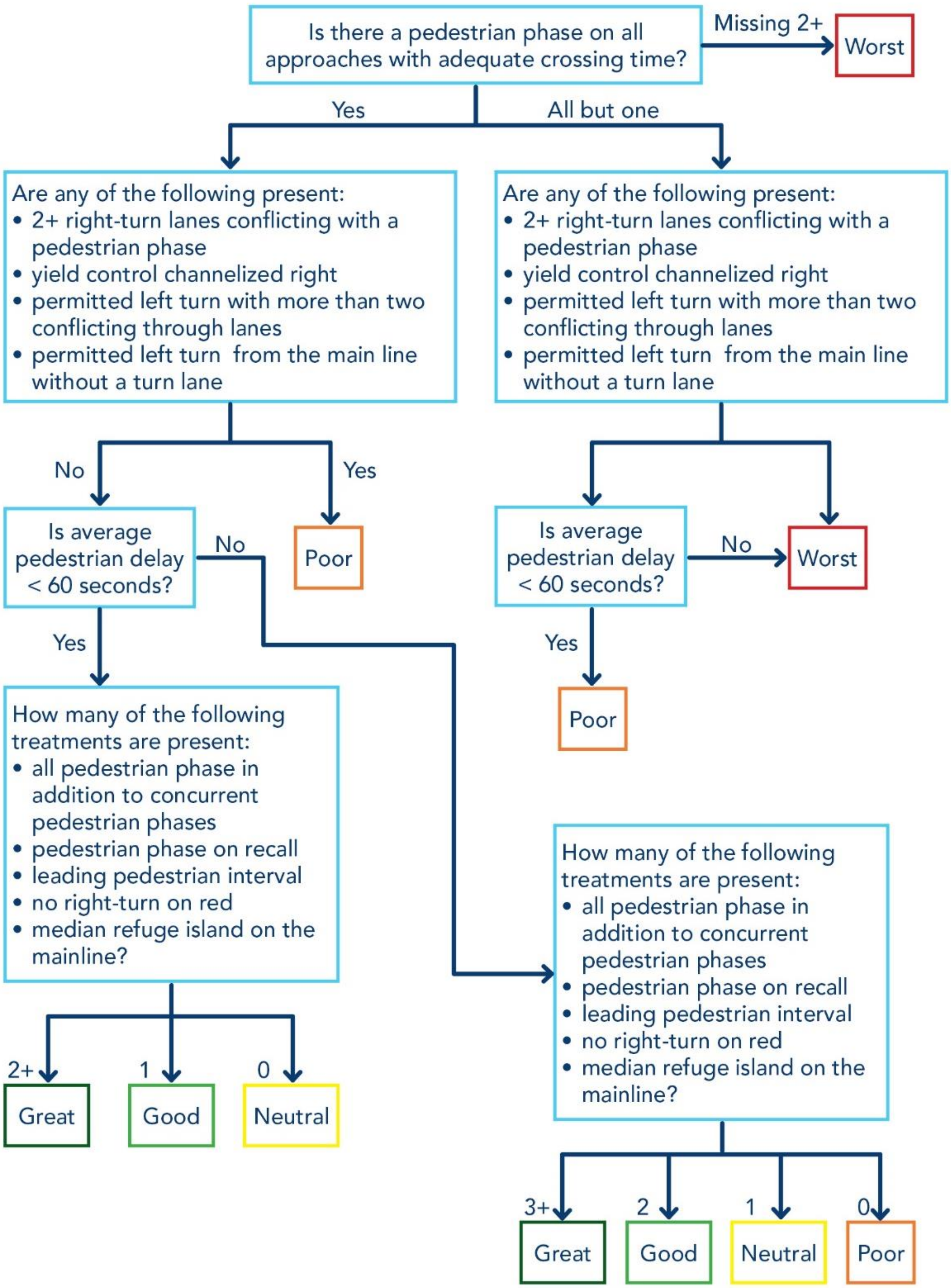


Figure 20: Pedestrian Signalized Intersection Evaluation – Eight or More Total Crossing Lanes on the Mainline

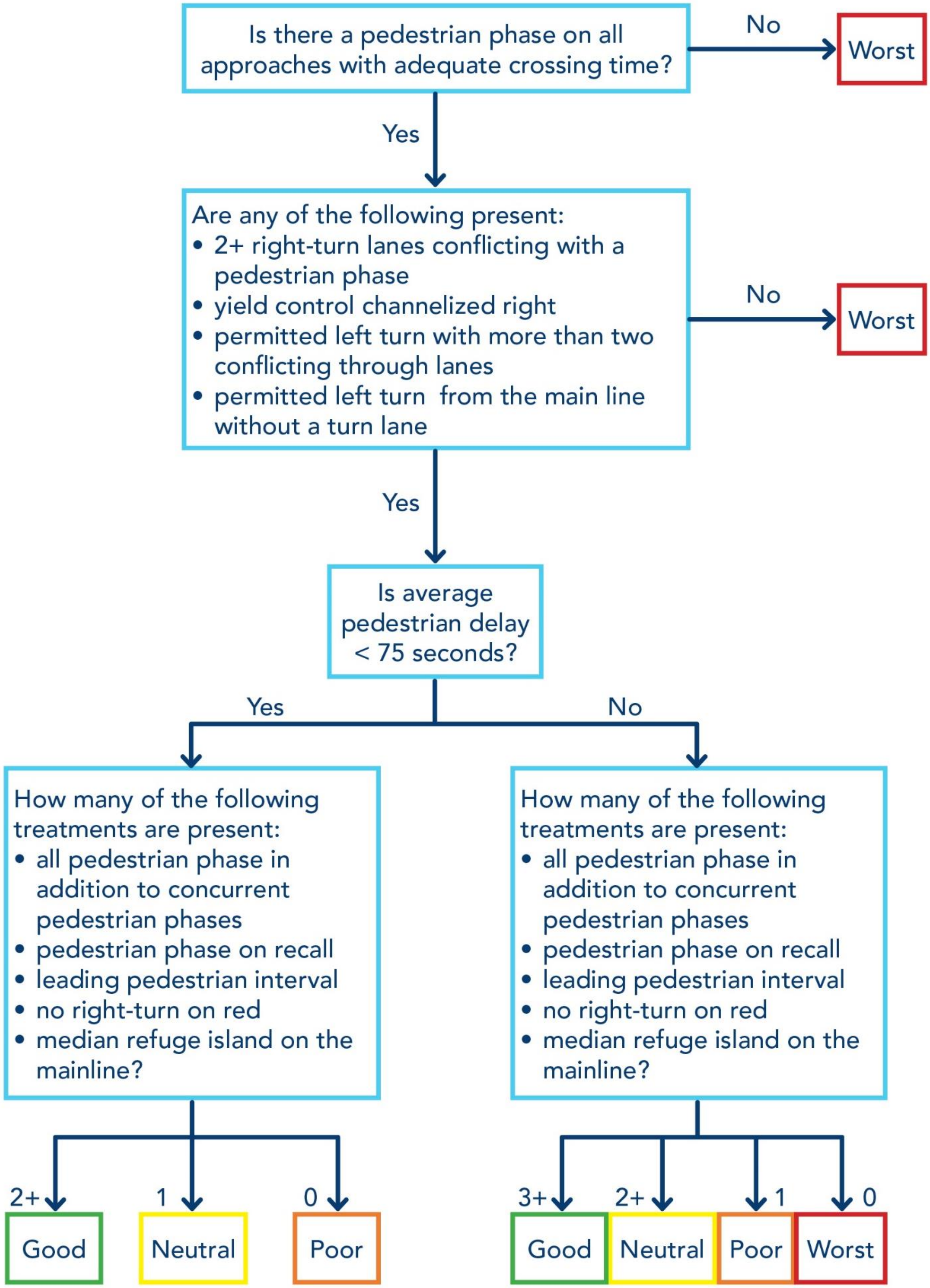


Figure 21: Pedestrian Unsignalized Intersection Evaluation – Four or Less Total Crossing Lanes on the Mainline

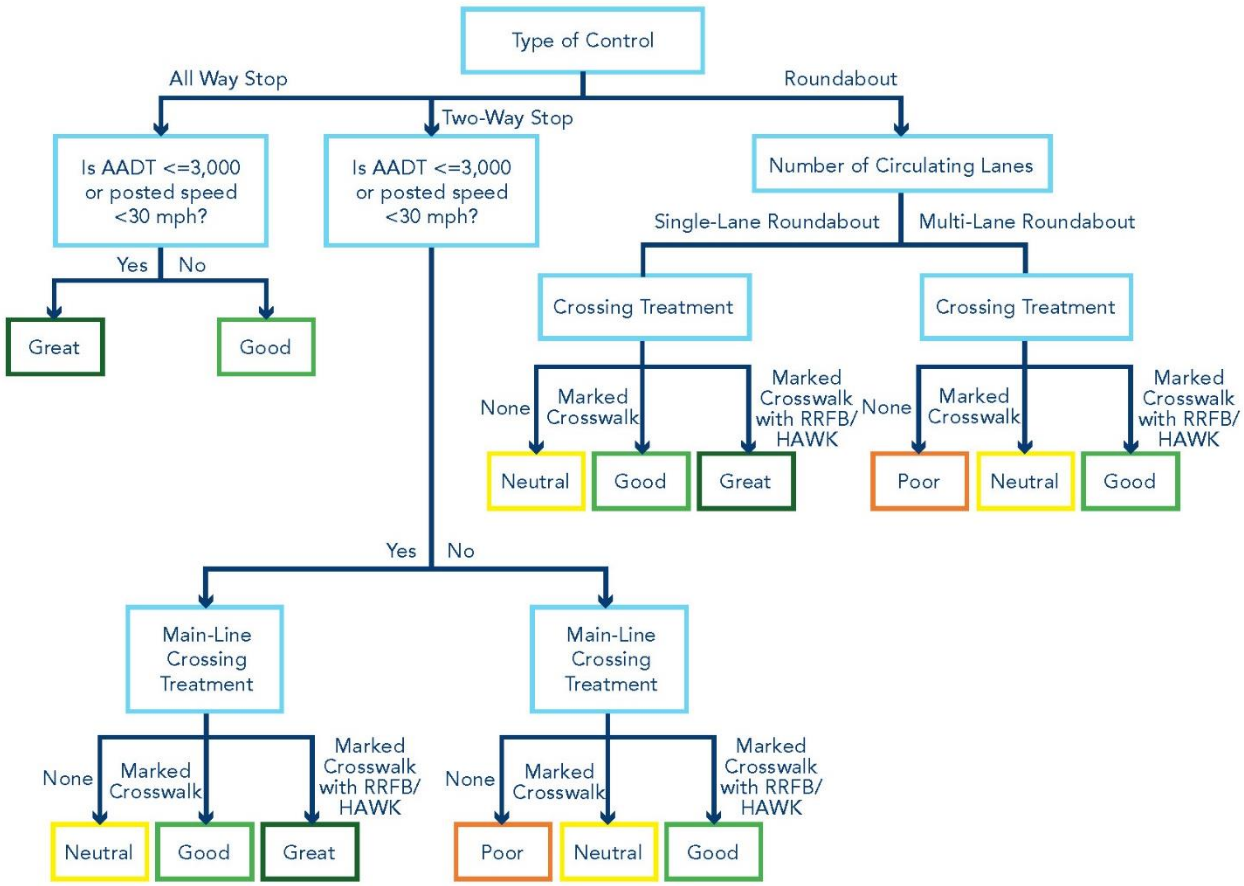


Figure 22: Pedestrian Unsignalized Intersection Evaluation – Five to Seven Total Crossing Lanes on the Mainline

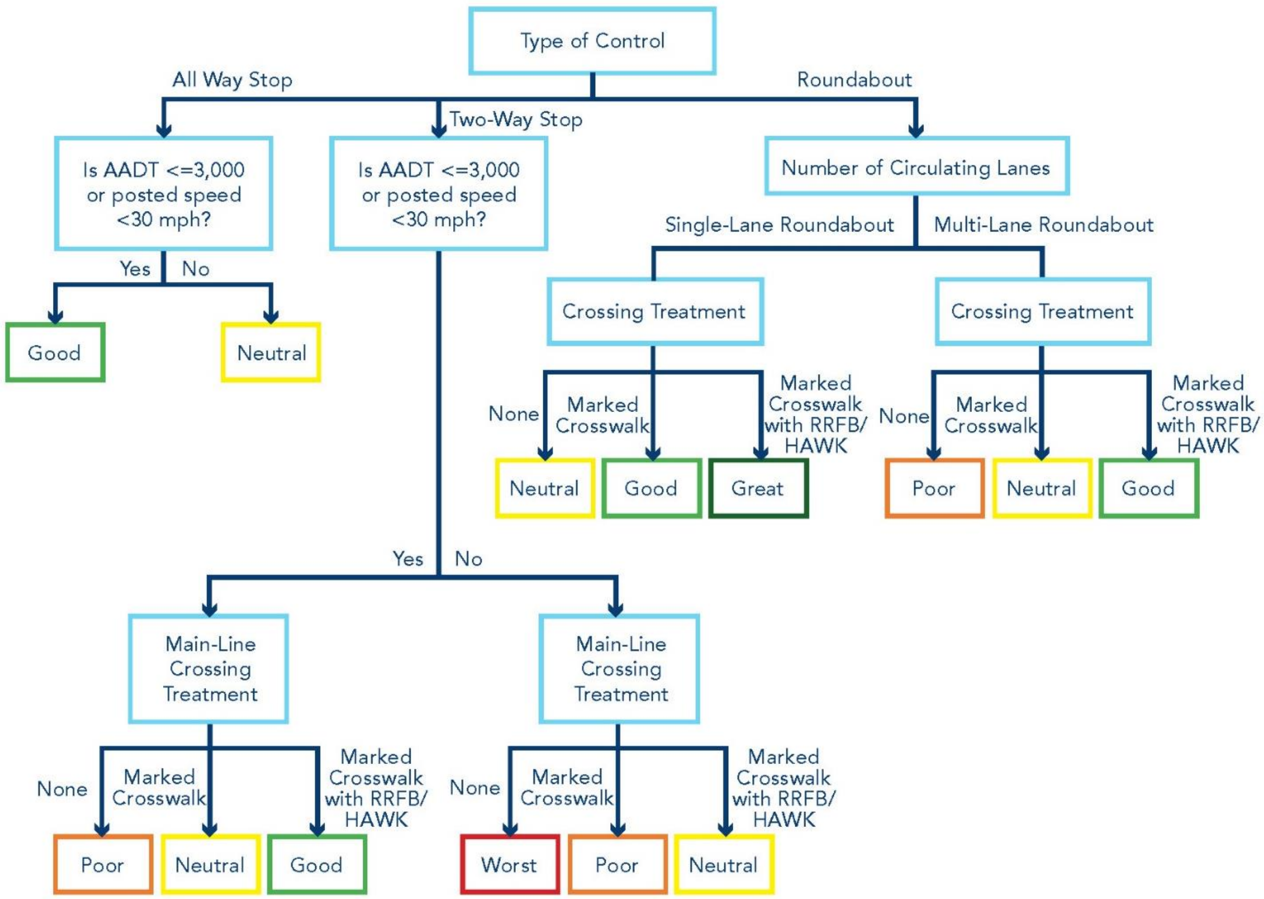
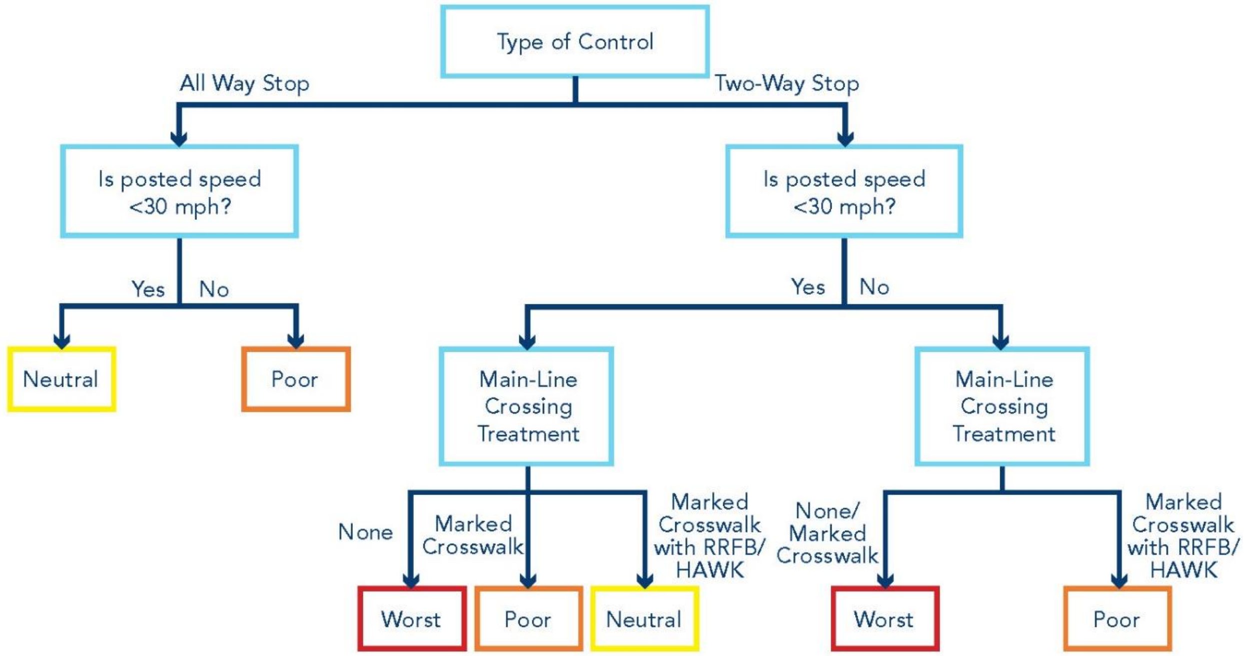


Figure 23: Pedestrian Unsignalized Intersection Evaluation – Eight or More Total Crossing Lanes on the Mainline



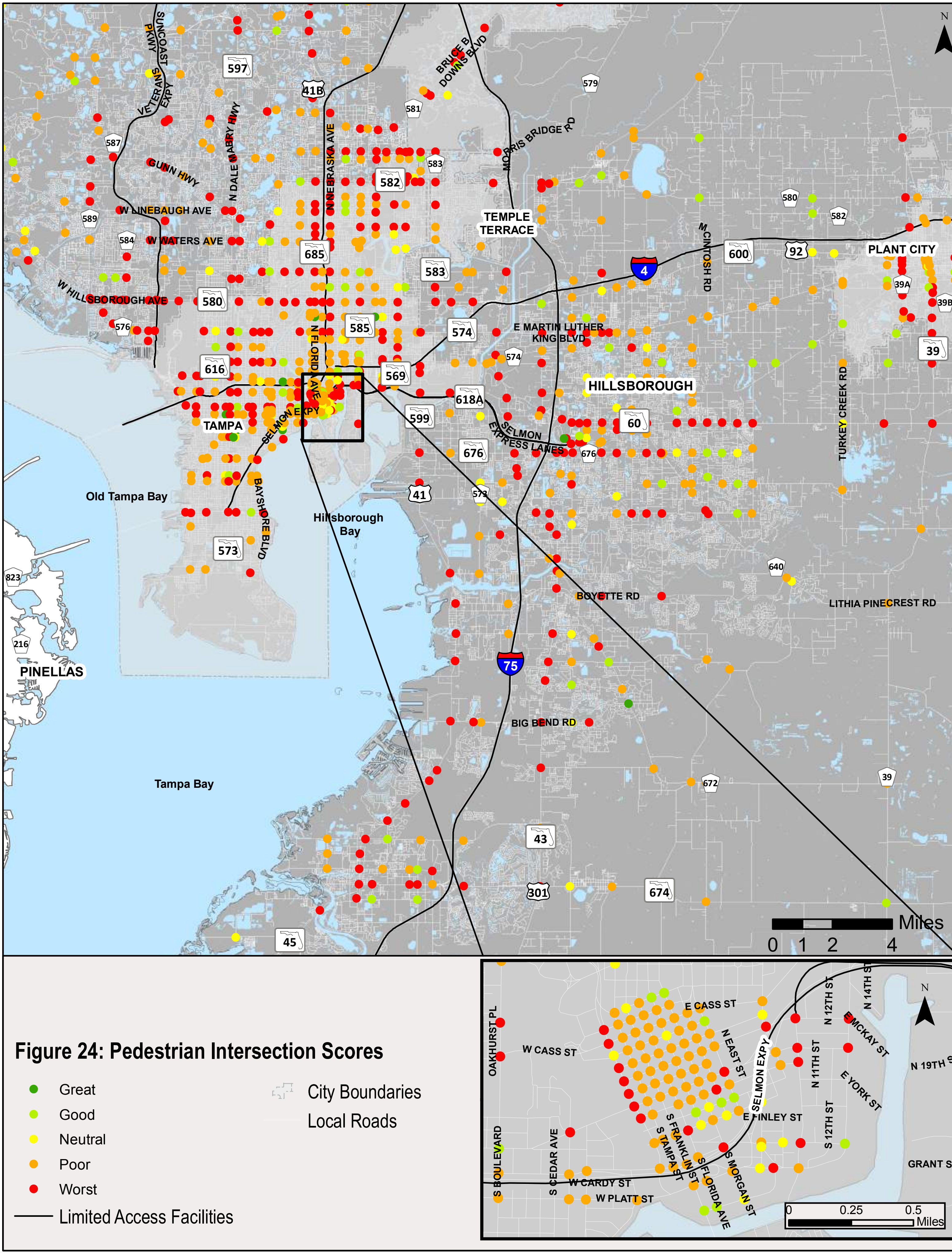


Figure 24: Pedestrian Intersection Scores

CONCLUSION & FUTURE USE

This report summarizes the Hillsborough MPO's methodology to evaluate bicycle and pedestrian conditions along segments and at intersections and presents countywide results. The methodology was developed based on an extensive literature review of current practices as well as best practices across the country. The Hillsborough MPO's objective was to develop a customized methodology that incorporated national best practices in evaluating pedestrian and bicycle level of comfort and safety while addressing unique considerations specific to Hillsborough County.

The results presented in this report identify opportunities and challenges at the corridor and intersection level for pedestrians and bicyclists. The results will be used to inform MPO planning and project prioritization. As a result of this project, the MPO has an updated intersection and segment database that will be updated as projects are built.

The methodologies can also be applied at the project-level to help understand trade-offs between modes. In addition to the methodologies and results presented in this report, the MPO has developed several guides and policies to assist at the project-level. This includes a *Bicycle Facilities Toolkit*, a *Pedestrian Crossing Treatment Guide* and a *Pedestrian Crossing Spacing* policy. These guides and policies incorporate design and policy best practices from national resources.

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Appendix A Interview Notes

Hillsborough MPO MMLOS White Paper: Sister MPO Interview

City: Charlotte DOT
Interview Attendees: Scott Curry (CDOT), Tracy Newsome (CDOT), Brett Boncore (KAI), Caitlin Doolin (KAI), Jennifer Musselman (KAI)
Date: June 15, 2017

Tracy Newsome is a transportation planner with the Charlotte Department of Transportation (CDOT). She was one of the main authors of the City's Urban Street Design Guidelines (USDG), which were developed in the mid-2000s. The P/BLOS methodology came from the USDG. She is heavily involved in policy development, area plans, and implementation of the capital program.

Scott Curry is an urban design and Pedestrian Program Manager for CDOT. He is responsible for the walkability initiative and manages the pedestrian program – funding from city council to build crosswalks and sidewalks.

1. **What is your agency's role in project development and decisions regarding modal trade-offs within projects? How is funding allocated to the projects you develop and manage?**

- CDOT handle many types of projects within city limits and works with the state on state maintained roadways.
- CDOT performs a lot of the modeling work for the CRTPO and works with them on the LRTP get projects on the priority list.
- There are a lot of different funding sources and programs.
    - CDOT has a history of putting forth bonds and getting them approved by the public.
    - CDOT has spent about $450M of city funds on complete streets improvements.
    - The pedestrian program gets about $7.5M every year from bonds, which come out every two years.
- CDOT tries to be opportunistic and always looks for opportunities to partner to get more projects done and done more quickly.

2. **What is the planning and design process for capital projects? How do you determine modal priority within a project?**
    - At least one representative from planning and design is on every CDOT project.
    - The USDG contains a six step planning and design process and the P/BLOS methodology. CDOT has used this process for the last 10 years
    - Now, the idea of complete streets and modal trade-offs is institutionalized. The process is so ingrained; engineers and planners have the same expectations. Trade-off discussions don't need to happen explicitly anymore. There is still a trade-off discussion that uses some form of the 6-step process (such as surrounding land use and constructability). There is a systematic and purposeful discussion on what needs to happen on every project.
    - CDOT tries to get a minimal level of pedestrian and bicycle facility in every widening project. Retrofits are more difficult but there is still an expectation CDOT will try to incorporate ped/bike facilities.

- CDOT has a street classification system (boulevards, avenues, parkways, etc.) and within those classifications there are different expectations for what ped and bike infrastructure should look like. For examples, if something is designated as a main street, the pedestrian is the priority. As you move toward a parkway, the auto is more emphasized
- The classification is a human-based assessment that relies on data (GIS, volume, lanes, bike/ped LOS when available).
- CDOT developed a classification for each street on the thoroughfare plan. They take advantage of ongoing/upcoming studies to update the initial classification and do more detailed planning and design.

3. **What tools do you use to evaluate how well the network is serving pedestrians, bicycles and/or transit? What criteria/methodology is used to determine the LOS for each mode?**
    - At the beginning of every project, they start with USDG and goals for the project.
    - CDOT does not use BLOS and PLOS on every project. It is a tool they use to support decisions. It was used more when USDG and complete streets were newer.

4. **How has the Pedestrian LOS methodology affected project decisions and selection (both negative and positive)?**
    - CDOT maintains B/PLOS and uses the data to describe existing conditions when doing an area plan. CDOT analyzes P/BLOS for signalized intersections as part of area plans. There is a spreadsheet to help with calculation. BLOS/PLOS is then used to prioritize which intersections need to make their way to a project. CDOT looks at congestion, safety, PLOS, BLOS, and multimodal connectivity to rank intersection projects.

5. **How does the City's Pedestrian LOS methodology consider intersection capacity?**
    - Every project still looks at vehicular capacity and a v/c ratio. Most of the residence are still using automobile to get around.
    - CDOT has done 30 road diets in the city. They started with the 'easier' ones. There are no set thresholds on when to consider road diets, but the accepted volumes are marching higher now that they've picked off the low hanging fruit.
    - CDOT has found a sliding scale for acceptance of congestion on different types of facilities. Residents expect speeds to be slower on main streets.
    - CDOT has started looking at the length of the peak hour to see how long congestion is lasting and has found that residents can accept a longer peak hour in some cases.
    - There is more congestion on suburban roads where this is not as much network

6. **How long have you been using your current process? What is attractive or compelling about the process you currently use to evaluate projects and/or the transportation network? Does the process have any shortcomings?**

    - CDOT has been using the USDG for the past 10 years and has gotten some great projects.
    - The process was based on assumption that we were not going to make things worse for motorists, only better for cyclists. There are cases where the community is asking for things that are not an option. CDOT has reached a point where the improvements needed to increase capacity are not palatable to the community and they are needing to make more tradeoffs between vehicular and bike/ped.

- There is a healthy tension between staff focused on different modes.
- Some projects have accepted higher congestion for short periods or certain circumstances
- CDOT sometimes has a harder time having the trade-off conversation on NCDOT roads.

Hillsborough MPO MMLOS White Paper: Sister MPO Interview

Agency: FHWA
Interview Attendees: Dan Goodman (FHWA), Caitlin Doolin (KAI), Jennifer Musselman (KAI)
Date: 6/20/2017

1. **What is your agency's role in project development and decisions regarding modal trade-offs within projects? How is funding allocated to the projects you develop and manage?**
   - FHWA's role is in the planning process. They provide guidance and setup the conditions for a good planning process. One outcome of a good planning process is a way to prioritize projects. FHWA shares information on methodologies so agencies can create good project prioritization.
   - A lot of prioritization happens for the Transportation Alternatives Program (TAP). FHWA sets up the rules of the game and makes sure everyone follows them.
   - FHWA recently published guidebook for bike/ped performance measures. Those measures could be used for project prioritization. The guidebook links measures with a community's goals. For each measure, there are examples of how to track the measure.
   - NCDOT has done some good prioritization work.
   - NCHRP research project 07-17 provides guidance on project selection and prioritization.

2. **What has the Multi-Modal Network study FHWA is leading revealed to date? Are there any common themes of where cities are struggling and succeeding in terms of evaluating multi-modal projects?**
   - Dan will send a literature review from the network work done in Baltimore. The report will be published in the fall.

3. **How are cities considering trade-offs for projects between different modes? How does vehicle capacity factor into those considerations?**

   - There will always be a comparison to traditional LOS. Folks are acknowledging that vehicular LOS can be a helpful input into the planning processes, but we need to understand what it is, and is not, telling us. We can't use it to extrapolate everything in the system. We need other things to get a holistic understanding of everything that goes into the planning process.
   - Dan will share a white paper on this topic if it's public.

4. Have you ever applied the HCM's MMLOS methodology to evaluate projects or the transportation network? If so, what were its strengths? What were its shortcomings?

   - MMLOS and P/BLOS are helpful inputs. A lot of people are using them, and they are informing things in a helpful way.
   - BLOS is based on research that was done quite a while ago in Florida. It was done on field analysis. At that point, no one was building separate bike lanes and cycle tracks. The methodology is not refined enough for today's conditions.

- It is hard to move the needle for P/BLOS. Widening the sidewalk, for examples, shows little benefit in the analysis.

5. Have you ever applied the Level of Traffic Stress methodology to projects or to evaluate the network? If so, what were its strengths? What were its shortcomings?
    - There was a white paper published last month on low stress network for bikes.
    - Martha/Kyle developed an algorithm to measure low stress connectivity. An agency inputs open street map data into the tool, and it measures connectivity for the community. The output is only as good as the data going in. The current methodology can be expensive and time consuming to run all the data and keep it up to date. This tool may be a way to get around that.

Recommendation for follow-up discussions: Colorado DOT (Betsy Jacobson), Washington DOT, Minneapolis MPO and Philadelphia MPO.

Hillsborough MPO MMLOS White Paper: Sister MPO Interview

Agency: SANDAG
Interview Attendees: Mike Calandra (SANDAG), Sarah McKinley (Hillsborough MPO), Caitlin Doolin (KAI), and Jennifer Musselman (KAI)
Date: 7/11/17

Questions:

1. Please describe your role within SANDAG.

   Mike Calandra is a travel demand modeler and model application specialist with SANDAG. He runs the model for SANDAG plan updates and to support local jurisdictions and consultants in their planning efforts.

   SANDAG has a service bureau that is the consulting arm and allows us to contract to external partners. SANDAG has 19 member agencies. The service bureau is on standby to help any of the member agencies. For local jurisdictions the work is usually city/community wide or for a corridor. On the private side, projects are usually for a specific site.

2. What type of methodologies do you apply when modelling? Have you ever applied the HCM's MMLOS methodology to evaluate projects or the transportation network? If so, what were its strengths? What were its shortcomings?

   SANDAG uses an activity based model. Mike uses the model to perform network and land use analysis. SANDAG can do custom scenarios in one or both areas. Mike recommended taking an incremental approach and change one thing at a time. Network changes are usually highway or arterial related and can be transit related.

   Modeling the active transportation network is a new paradigm. The model currently does not have ped/bike assignments. When they change the active transportation network changes can't be seen on a link level but can be seen in overall mode choice. The active network focuses on bicycle classifications. Changes in classification have small changes in mode choice output. Adding/removing bicycle links have a larger impact on the mode choice. A similar analysis does not yet exist for pedestrian infrastructure.

   Active transportation modeling is best applied at the community or city level where there are more opportunities to change the network and see changes in the results. The model is used for both needs identification and project identification. The city can use the model to prioritize infrastructure within the community. At the regional level, SANDAG uses the model to prioritize highway/arterial, transit, and active projects.

   SANDAG uses the model and HCM procedures to find capacity on highways and arterials. Consultants may use model outputs to perform their own MMLOS calculation, but SANDAG does not do the calculations.

3. How long have you been using your current process? What is attractive or compelling about the process you currently use to evaluate projects and/or the transportation network? Does the process have any shortcomings?

   The biggest issue with model calibration is the amount of data required. There is lack of information on arterials. For freeways, Caltrans has a performance monitoring system that continuously being collects volume and speed data. For transit, SANDAG has a count system and is moving toward APC data. Arterials are under the jurisdiction of each city. Some cities have not done traffic counts for 10+ years.

4. Is SANDAG exploring use of performance measures beyond LOS?

   The State of California removed LOS from legislature and replaced it with VMT. There are no guidelines on how to do it just yet, and every jurisdiction is doing it a little bit differently. SANDAG is starting to report VMT for every project. They can use the model to pull the VMT apart by origins and destinations. Adding active transportation links in the model is a way to mitigate VMT. There is no one size fits all approach for the VMT trade-off of bicycle infrastructure. In the activity based model, adding a bike facility in an urban or rural context will have different effects on VMT.

Appendix B HCM MMLOS Sample Default Values

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 825

Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual

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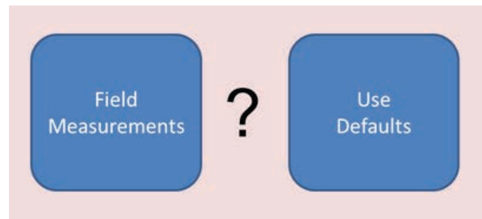
F. Default Values to Reduce Data Needs

1. Overview



Many HCM computational methods require a number of input parameters. For a detailed operations analysis, this can be an advantage, as the performance measure output by the method reflects many different factors that can influence the result. However, for planning and preliminary engineering analyses, the number of inputs can pose a challenge. The desired information may not yet be known, the level of effort required to gather the data may be out of proportion to the aims of the analysis, or a combination of these and other considerations can make it difficult to supply a particular input value.

One solution to applying HCM methods to planning and preliminary engineering analyses is to substitute *default values* for those inputs that cannot be measured directly. Using default values instead of field-measured values may introduce some error into the analysis results, but other data used for planning analyses (particularly forecast demand volumes) may have much greater uncertainties associated with their values and, consequently, much greater impact on the results. Furthermore, the goal of these types of analyses is not to make final decisions about roadway design and control elements, but rather to identify potential problems or to screen large numbers of alternatives; in these cases, precise results are neither required nor expected.

It is important to recognize that HCM input data have a hierarchy that varies according to the context of the planning and preliminary engineering application: There are applications where certain input data can be and must be measured. (These data are identified as "required inputs" in subsequent sections.) There are planning and preliminary engineering applications where certain input data can and should be estimated sensibly based on local and planned conditions; Section F4 addresses this situation. Finally, as discussed in Section F2, there are applications where certain data need not be measured and a general default value can be used instead. Parts 2 and 3 of the Guide provide simple default values for analysis situations where the analyst has deemed a locally measured value is not necessary.

This section provides guidance on applying default values to HCM methods and on developing local default values to use in place of the HCM's national defaults.

2. When to Consider Default Values

The decision to use a default value in place of a field-measured value should consider a number of factors, including:

- **The intended use of the analysis results.** In general, the less precisely that analysis results will be presented (e.g., under, near, or over capacity versus a particular LOS versus a specific travel speed estimate), the more amenable the analysis is to using default values, or tools based on default values, such as service volume tables. Similarly, the farther away a final decision is (e.g., identifying potential problem areas for further analysis versus evaluating a set of alternatives versus making specific design decisions), the less potential exists for incorrect decisions to be drawn from the analysis results due to the use of a default value.

- **The scale of the analysis.** The larger the geographic scale of the analysis (i.e., the greater the number of locations that need to be analyzed), the greater the need to use default values due to the impracticality of collecting detailed data for so many locations.
- **The analysis year.** The farther out into the future that conditions are being forecast, the more likely that information will not be known with certainty (or at all), and the greater the need to apply default values.
- **The sensitivity of the analysis results to a particular input value.** Sections H through O of this Guide provide information about the sensitivity of analysis results to the inputs used by a given HCM operations method. Input parameters are characterized as having a low, moderate, or high degree of sensitivity, depending on whether a method's output changes by less than 10%, 10% to 20%, or more than 20%, respectively, when an input is varied over its reasonable range. The lower the result's sensitivity to a particular input, the more amenable that input is to being defaulted.
- **Ease of obtaining field or design data.** According to the HCM (2016), input parameters that are readily available to the analyst (e.g., facility type, area type, terrain type, facility length) should use actual values and not be defaulted.
- **Inputs essential to an analysis.** A few inputs to HCM methods, such as demand volumes and number of lanes, are characterized as "required inputs" and should not be defaulted. When the purpose of the analysis is to determine a specific value for a required input (e.g., the maximum volume for a given LOS), the HCM method is run iteratively, testing different values of the input until the desired condition is met.
- **Local policy.** State and local transportation agencies' traffic analysis guidelines may specify that particular inputs to HCM methods can or should not be defaulted.

3. Sources of Default Values

Once a decision has been made to use a default value for a particular methodological input, there are several potential sources for obtaining a default value. These are, in descending order of desirability according to the HCM (2000):

- **Measure a similar facility in the area.** This option is most applicable when facilities that have not yet been built are being analyzed and the scope of the analysis does not require measuring a large number of facilities.
- **Local policies and standards.** State and local transportation agencies' traffic forecasting guidelines may specify, or set limits on, default values to assume. Similarly, these agencies' roadway design standards will specify design values (e.g., lane widths) for new or upgraded roadways.
- **Local default values.** When available, local default values will tend to be closer to actual values than the HCM's national defaults. Heavy vehicle percentage, for example, has been shown to vary widely by state and facility type (Zegeer et al. 2008). The next subsection provides guidance on developing local default values.
- **HCM default values.** If none of the above options are feasible, then the HCM's national default values can be applied.

4. Developing Local Default Values

This section is adapted from HCM (2016), Chapter 6, Appendix A.

Local defaults provide input values for HCM methods that are typical of local conditions. They are developed by conducting field measurements in the geographic area where the values will be applied, during the same time periods that will be used for analysis, typically weekday peak periods. For inputs related to traffic flow and demand, the peak 15-minute period is recommended as the basis for computing default values because this time period is most commonly used by the HCM's methodologies.

When an input parameter can significantly influence the analysis results, it is recommended that multiple default values be developed for different facility types, area types, or other factors as appropriate, as doing so can help reduce the range of observed values associated with a given default and thus the error inherent in applying the default. The *K*- and *D*-factors used to convert AADT volumes to directional analysis hour volumes are two such parameters. For urban streets, other sensitive parameters include peak hour factor, traffic signal density, and percent heavy vehicles. For freeways and highways, sensitive parameters include free-flow speed and peak hour factor.

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Appendix C Level of Traffic Stress GIS-Based Evaluation

The Level of Traffic Stress (LTS) methodology relies on available GIS data, including roadway network attributes and adjacent land use. This appendix outlines the steps used in the GIS-based evaluation of bicycle LTS. The method used in this study to classify bicycle LTS has six phases:

1. Data Post Processing,
2. Mixed Traffic Assessment Process,
3. Assessment of a Corridor with a Bike Facility,
4. Manual Adjustments

1. Data Post Processing

The base Hillsborough County route network file was used a basis for this analysis. The file attributes are provided in ***Table C-1***. The following fields were added:

1. ELU to denote segments within 500-feet of a commercial land use (“C”). Commercial land uses were identified using the Florida Department of Revenue (DoR) for 2017 parcel shapefile. Table C-2 lists the land use categories considered commercial land use.

2. BK_LN field to denote type of bicycle facility present (no bicycle lane present [“N”]; bicycle lane present [“B”]; separated bicycle facility [“S”]).
    a. Presence of a bicycle lane (“B”) was determined with the bicycle lane width field (BLS_WIDTH). If a segment has a bicycle lane width of four feet or higher (including shoulders), then it is classified as having a bicycle lane, with a ”B” in the BK_LN field.
    b. Presence of a separated bicycle facility (“S”) was determined using the sidewalk width field (SW_WIDTH). Separated facilities are considered two-way if the sidewalk width is 10 feet or wider. All roadway facilities that were classified as 10’ wide or greater in Downtown Tampa were checked via a google earth audit. There are many areas in a downtown setting where a 10’ wide sidewalk is used for outdoor seating, planters, street furniture etc. These sidewalks were reclassified manually based on the presence or absence of a bike lane in the street. Trails and cycle tracks were manually added.
    c. All facilities with sharrows, a signed route, or with bike lane width (BLS_WIDTH) of less than four feet, are classified as not having a bicycle lane (BK_LN field = “N”).

Table C-1. Simplified land use categories used in ELU Field

Attribute	Description
HWY_SEGMEN	Segment identifier
HWY_SECTIO	Segment identifier
ROADWAYID	GIS Route Identifier
BEGMILEPOS	Beginning milepost – Milepost number
ENDMILEPOS	Ending milepost – Milepost number
ONSTREET	Segment street name
FROMNODE	Intersecting street at start of segment
TONODE	Intersecting street at end of segment
LANES_BASE	Number of lanes in both directions
AADT_BASE	Current AADT
MSV_BASE	Maximum Service Volume
LOS_BASE	LOS of Current Year
LOS_STANDA	LOS at standard
SECTION_LA	Predominant number of lanes from children segments
SECTION_AA	Weighted average of AADT from children segments
SECTION_MS	Weighted average of MSV from children segments
SECTION_LO	LOS of Section
FED_FUN_CL	Federal functional class - generalized; based on 2010 census
SORT_VALUE	Sort field for report
JURISDICTI	Agency code (CR=County Roads, PC=Plant City, SR=State Roads, T/TA=Tampa Roads)
LOCATION	COT=City of Tampa, RSA=Rural Service Area, USA=Urban Service Area, TSA=Tampa SA, PC, TT=Temple Terrace
Speed_Limi	Speed limit in mph
LocalFuncC	Local Functional classifications scheme 2015
HC_REGULAT	Identifies if roadways are regulated in HC Comp Plan
TA_REGULAT	Identifies if roadways are regulated in TA Comp Plan
PC_REGULAT	Identifies if roadways are regulated in PC Comp Plan
TT_REGULAT	Identifies if roadways are regulated in TT Comp Plan
POST_SPD	Posted Speed
OSL_WIDTH	Outside Lane Width (in feet) - compares to Narrow, Typical, and Wide in ARTPLAN
OSL_FLAG	Outside Lane Width - OSL > 12' = WOL (Wide Outside Lane Width)
OSP_PERC	Percent of Segment covered with On-Street Parking
OSP_FLAG	On-Street Parking (Y or N)
PAV_COND	Pavement condition using 1-5 (FHWA criteria)
PAV_FLAG	Pavement condition (DES=Desirable, TYP=Typical, UND=Undesirable)
BLS_WIDTH	Bike lane shoulder width in feet
EFF_WIDTH	Width of one direction of travel
SW_COV1	Percentage of sidewalk coverage N/E
SW_COV2	Percentage of sidewalk coverage S/W
SW_COVFL	Sidewalk coverage flag
SW_WIDTH	Sidewalk width in feet
SW_FLAG	Sidewalk Width Flag
SEP_WIDTH	Separation width
BP_FLAG	Barrier present flag
HWY_SCENAR	Link to Unique scenario identifier (1-9999)

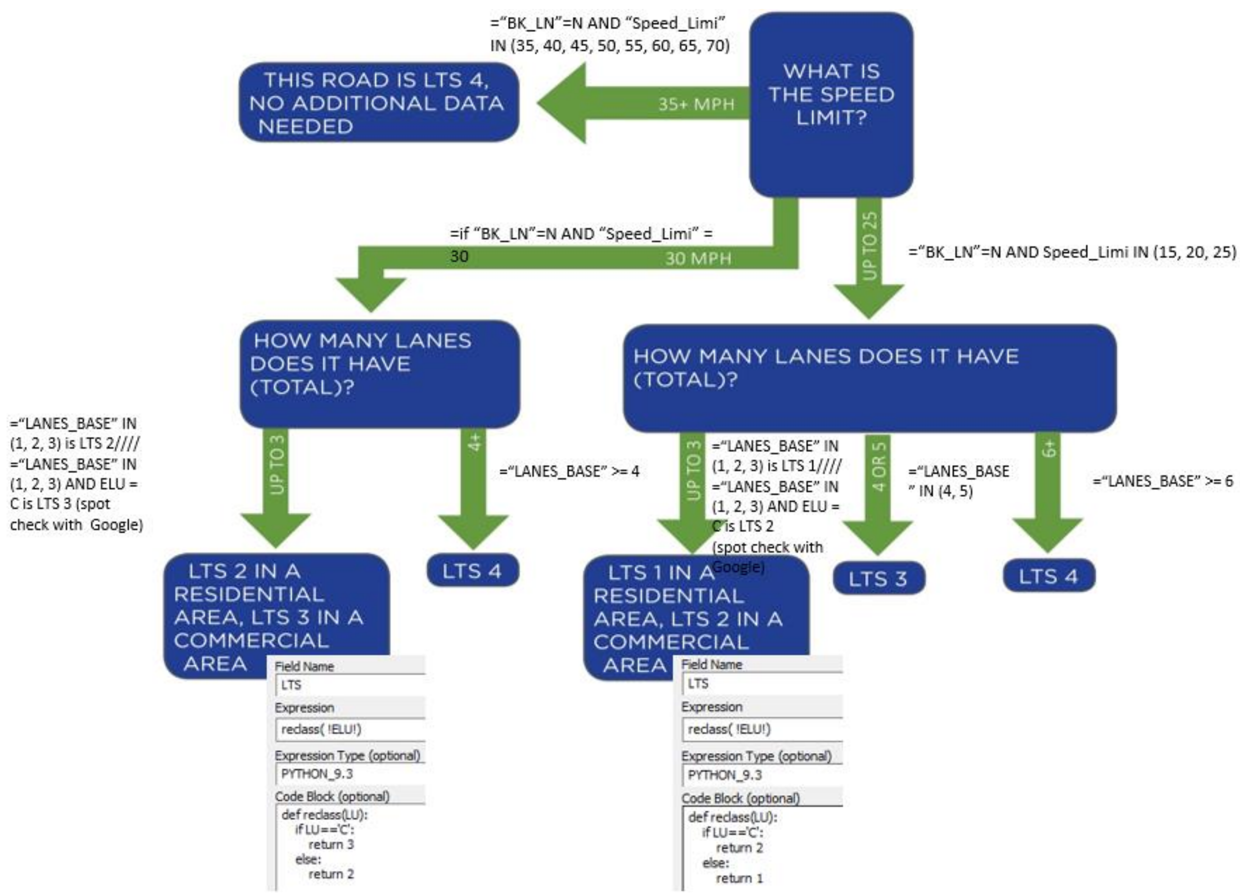
Table C-2. Commercial Land Uses

Detailed Land Use Description
Vacant Commercial
Stores, one story
Mixed use - store and office or store and residential combination
Department Stores
Supermarkets
Regional Shopping Centers
Community Shopping Centers
Office buildings, non-professional service buildings, one story
Office buildings, non-professional service buildings, multi-story
Professional service buildings
Airports (private or commercial), bus terminals, marine terminals, piers, marinas
Restaurants, cafeterias
Drive-in Restaurants
Financial institutions (banks, saving and loan companies, mortgage companies, credit services)
Insurance company offices
Repair service shops (excluding automotive), radio and T.V. repair, refrigeration service, electric repair, laundries, Laundromats
Service stations
Auto sales, auto repair and storage, auto service shops, body and fender shops, commercial garages, farm and machinery sales and services, auto rental, marine equipment, trailers and related equipment, mobile home sales, motorcycles, construction vehicle sales
Parking lots (commercial or patron), mobile home parks
Wholesale outlets, produce houses, manufacturing outlets
Florists, greenhouses
Drive-in theaters, open stadiums
Enclosed theaters, enclosed auditoriums
Nightclubs, cocktail lounges, bars
Bowling alleys, skating rinks, pool halls, enclosed arenas
Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned)
Camps
Race tracks (horse, auto, or dog)
Hotels, motels

2. Mixed Traffic Assessment Process

The Mixed Traffic Assessment Process is completed on segments without a bike lane or separated facility (BK_LN="N"). ***Figure C-1*** provides the logic in both SQL and Python to conduct the mixed traffic assessment process. The first question selects out and classifies segments that have a posted speed ("Speed_Limi") of 35 or higher as LTS 4. The next question divides segments with a speed limit of 30 mph and segments with a speed limit of 25 mph or less. From there, the LTS score is determined based on total number of lanes ("LANES_BASE") and presence of commercial lane use ("ELU" = "C").

Figure C-1: Mixed Traffic GIS Assessment Process

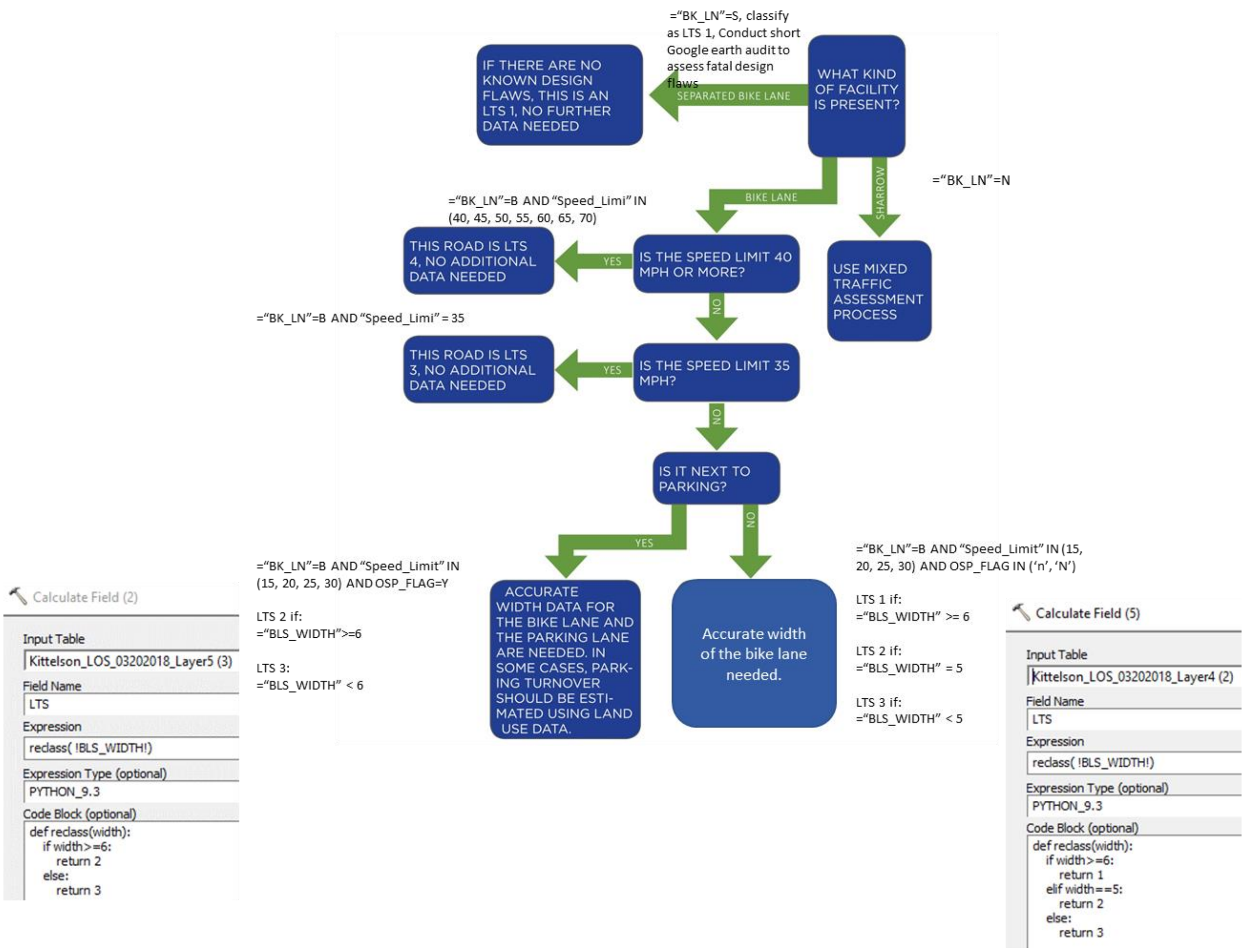


3. Assessment of a Corridor with a Bicycle Facility

Segments with a bicycle facility are evaluated using the process described in ***Figure C-2***. Segments with a separated bicycle facility, as defined in step 1 (BK_LN="S"), are assigned an LTS 1.

Segments with a conventional bike lane (BK_LN="B") are analyzed first based on speed. Segments with a posted speed 40 mph or greater are classified as LTS 4. Segments with a posted speed of 35 mph are classified as LTS 3. Segments with a posted speed of 30 mph or less are evaluated based on presence of on-street parking (OSP_FLAG=Y) and the combined width of parking (assumed to be seven feet) and the bike lane (BLS_WIDTH).

Figure C-2: Bicycle Facility GIS Assessment Process



4. Manual Adjustments

Segments with a separated facility were reviewed for design flaws, such as utility poles in the sidewalk limiting the effective width. Manual adjustments to the LTS score were made as needed. Additionally, there are two streets in downtown Tampa that have or soon will have a two-way cycle track. These facilities are not accounted for in the Hillsborough County roadway network file and were manually updated to account for the separated facility.