Quantifying Multimodal Performance for Long Range Planning

April 14, 2017

Introduction

The City of San Diego recently embarked on an effort to develop transportation performance measures to help guide the long-range decision-making processes in support of achieving a balanced multimodal transportation system. Chen Ryan Associates, Inc. has been working with the City of San Diego to identify and develop a standardized approach to analyzing pedestrian and bicycle facilities and networks. To understand and identify the methodologies, techniques and standards that are currently being used within the practice, a series of practitioner interviews were conducted within the transportation planning industry. Based on this survey, it was found that the performance measures can most commonly be classified into the following categories: transportation demand, facility quality, network connectivity, safety and accessibility. The team also studied existing practices within the industry and made recommendations on which measures, techniques and performance thresholds would be best suited for the City of San Diego. These recommendations are detailed in a White Paper submitted to the City of San Diego titled *Active Transportation Assessments: Integrating Bicycle and Pedestrian Evaluation in Long Range Planning*. This is an ongoing effort between the City and Chen Ryan Associates. These measures, techniques and performance thresholds will create a standardized framework for the City of San Diego's long-range transportation planning efforts and are applicable to corridor-level studies, as well as community-wide planning efforts.

While the overall goal of the effort is to develop a set of measures, techniques and performance thresholds for all of the major modes of travel, this paper primarily focuses on the active transportation components of the effort. The following sections of this paper present the active transportation performance measures evaluated and considered for the effort, discusses the process used to select the preferred measures, and provides a summary of the methodology and application of the measures. Finally, this report discusses the lessons learned from the initial applications of the measures within the Midway-Pacific Highway, Old Town San Diego, Mission Valley and Kearny Mesa Community Plan Update Mobility Studies.

Survey of Existing Practices

A review of previous active transportation studies and planning documents was conducted to delineate the scope of various active transportation metrics discussed in practice-oriented literature, as well as in various agency planning documents. Additionally, practitioners from a range of agencies and consulting firms known for innovation in the pedestrian and bicycle planning field were interviewed to seek their knowledge and opinions on effective active transportation performance measures[1].

As shown in **Table 1**, the survey of existing practices revealed four key categories of active transportation performance measures, including 1) those focused on *active transportation demand* or *propensity for walking and cycling*, 2) those assessing the *quality of the walking and cycling environment*, 3) those measuring *bicycle and pedestrian network connectivity*, and 4) those evaluating *active transportation safety and accessibility.*

[1]A complete list of documents reviewed and practitioners interviewed is provided in Chapter 2 of the *Active Transportation Assessments: Integrating Bicycle and Pedestrian Evaluation in Long Range Planning* White Paper.

Table 1: Categories of Active Transportation Performance Measures

Performance Measure Category	Description
Demand or Propensity	Performance measures that assess the actual or likely demand for walking and cycling
Quality of Service	Performance measures that assess the comfort of the travel environment for cyclists and pedestrians
Connectivity	Performance measures that assess directness of travel or level of out-of-direction travel required by cyclists and pedestrians
Safety & Accessibility	Performance measures that assess the level of risk to pedestrians and cyclists for encountering conflict with vehicles, and the level of access for disabled populations traveling along the public right of way

Source: Chen Ryan Associates, March 2017

Table 2 summarizes the assessment tools identified for calculating pedestrian and bicycle performance measures which were considered for more in-depth review and application by the City of San Diego. The table also summarizes the category of performance measures – either demand, quality, connectivity, or safety and accessibility. Several of the assessment tools listed have applications for both active transportation modes.

Table 2: Assessment Tools for Calculating Active Transportation Performance Measures

Assessment Tools	Transportation Mode	Demand or Propensity for Walking/Cycling	Quality or Level of Service	Network Connectivity	Safety & Accessibility
Pedestrian Environmental Quality Index (PEQI)	Pedestrian		✓✓		✓
Highway Capacity Manual 2010 (HCM2010)	Bicycle and Pedestrian		✓✓		✓
SANDAG Walkability Index	Pedestrian	✓✓		✓	
Fort Collins Multi-Modal Level of Service	Bicycle and Pedestrian		✓✓	✓	
San Diego Pedestrian Priority Model	Pedestrian	✓✓		✓	✓
Travelsheds	Bicycle and Pedestrian			✓✓	
Network Density	Bicycle and Pedestrian			✓✓	
Collision Frequency	Bicycle and Pedestrian				✓✓
City of San Diego Bicycle Priority Model	Bicycle	✓✓		✓	
Bicycle Environmental Quality Index	Bicycle		✓✓		
Bicycle Level of Traffic Stress (LTS) and Low-Stress Connectivity Analysis	Bicycle		✓✓	✓✓	

Source: Chen Ryan Associates, March 2017

Notes:
✓✓ Two checks suggest that this tool is primarily related to the performance measure indicated.
✓ One check indicates that this tool incorporates a factor related to the performance measure indicated

Preferred Analysis Measures

Based upon the evaluation of existing measures, our investigation determined to adopt tools which represent each of the categories (demand, quality, connectivity and safety) of the multimodal planning analysis process. The following criteria were recommended to determine the selection of the most fitting assessment tools for the City of San Diego:

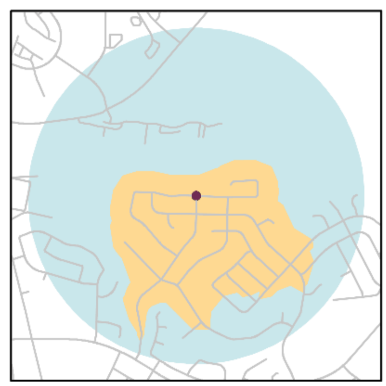
- Data is available for calculating measure under future conditions;
- Tool is sensitive to future recommended improvements and will show expected change relative to existing conditions;
- Data collection is reasonable in terms of time and cost requirements;
- The assessment tool is relevant to both individual corridor/intersection study areas as well as community-wide study areas.

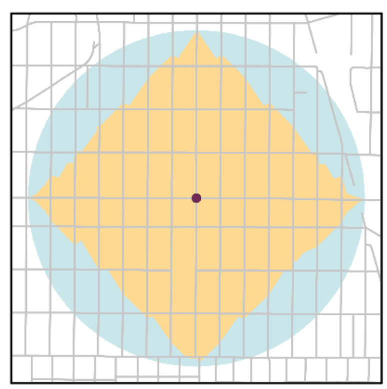
Details of the actual selection process and why certain methods were chosen are provided in the full *Active Transportation Assessments* White Paper.

Bicycle Performance Measures

After consideration of existing practices, the team recommended a series bicycle assessment tools covering the categories of performance measures – demand, connectivity, quality, network assessment and safety, and indicates whether the recommended bicycle assessment tools meet the desired analysis criteria, as listed at the beginning of this section.

Bicycle Priority Model (Demand) - The team elected to continue using the Bicycle Priority Model to assess demand. The Bicycle Priority Model was developed during the City of San Diego Bicycle Master Plan Update (adopted in 2011), and assesses two forms of cycling demand: inter-community – long trips, typically occurring on higher classification circulation roads, and intra-community – shorter, utility-driven trips which may occur on a variety of streets. Demand measures are used to assist with project prioritization.





One-Mile Bicycle Travelshed Ratio (Connectivity) - To assess connectivity, the team elected to use a one-mile bicycle travelshed ratio. A one-mile bicycle travelshed ratio measures how much area one can travel by bicycle along a street network given one mile from a fixed origin, divided by the area of a one mile radius circle. The image to the right illustrates the difference in area between a travelshed on a disconnected street network and a travelshed on a connected street network. This provides an objective measurement of the connectivity of the network of bikeable roadways.

Level of Traffic Stress and Low-Stress Connectivity (Quality) - The team adopted Bicycle Level of Traffic Stress (LTS), which has been used in other regions, for its assessment of network quality. Developed by the Mineta Institute, LTS primarily considers speed and number of travel lanes as variables and assigns simplified stress scores which roughly approximate to conditions acceptable to Geller's[2] well-known cyclist demographic typologies: *Strong & Fearless, Enthused & Confident, Interested but*

[2] Geller, Roger. 2006. *Four Types of Cyclists*. Portland Department of Transportation.

Concerned, and *No Way No How*. In this context, quality bicycle facility would be equated to low stress roadways (LTS 1 or 2), which are designed to cater to the sizable but mostly untapped *Interested but Concerned* bicycling demographic.

Low-Stress Connectivity (Network Assessment) - An innovative component of LTS is its application in connectivity analysis. LTS scores are assigned to network links and subsequently used to model if direct "low stress connectivity" exists between chosen origins and destinations. This is particularly important to measure, due to the greater exposure to hostile conditions in which active transportation modes experience, where trip-making and route choice can be more sensitive to facility quality and environment. For this reason, assessing only the pure network connectivity is an incomplete capture of the actual performance of the system since it only addresses the pure connectivity, but does not assess if people will actually be comfortable using the facilities provided. The combined existing and future low stress connectivity analysis enable planning practitioners to empirically quantify how different parts of the community will be served by the projects.

5-Year Bicycle Collision History (Safety) – To assess safety, the team reviews 5-years of bicycle collision data which is geocoded based on location (intersection or segment) and organized based on cause. Bicycle collision history is used to assist with prioritization and identify critical areas of need.

Pedestrian Performance Measures

After consideration of existing practices, the team recommended a series of pedestrian assessment tools covering the categories of performance measures – demand, connectivity, quality, network assessment and safety, and indicates whether the recommended pedestrian assessment tools meet the desired analysis criteria, as listed at the beginning of this section.

Pedestrian Priority Model (Demand): The team elected to continue using the City's Pedestrian Priority Model, which combines the overlay of trip attractions (land uses), trip productions (population), and trip detractors to provide a composite assessment of pedestrian demand within the City. Demand measures are used to help determined a refined pedestrian study area and to assist with project prioritization.

Half-Mile Walking Travelshed Ratio (Connectivity): A half-mile walking travelshed ratio measures how much area one can walk along a street network a distance of half mile from a fixed origin, divided by the area of a half mile radius circle. This provides an objective measurement of the connectivity of pedestrian network. This assessment is nearly identical to the bicycle connectivity counterpart, though it analyzes connectivity at a shorter, more pedestrian-oriented travel distance.

Pedestrian Environmental Quality Evaluation (Quality): To assess quality, the team decided not to pursue a pre-established measure among those which were surveyed. PEQI was developed by the San Francisco Department of Public Health to prioritize improvement in pedestrian infrastructure during the planning process. The team appreciated aspects of PEQI, particularly the application of quality scores to sidewalk segments and crossing legs; however, the team wanted to reduce the number of inputs and emphasize the measure's objective inputs (e.g. sidewalk width and buffer) over its subjective inputs (e.g. aesthetics and noise). As a result, the team designed its own pedestrian evaluation measure called *Pedestrian Environmental Quality Evaluation* (PEQE), which is more suited to the City's criteria and goals.

As noted, PEQE is modeled after PEQI, but with fewer inputs which allow for more feasible collection over a larger study area. The resulting outputs were made to be easier to calculate and more intuitive, an attribute which has drawn inspiration from Bicycle Level of Traffic Stress. Result outputs consist of simplified "high", "medium" and "low" scores. The use of only objective inputs also make it more suitable for future conditions analysis. For a complete discussion of the PEQE methodology and its scoring inputs and thresholds, see the *Active Transportation Assessments* White Paper.

PEQE's result outputs and thresholds were designed in such a way to generate threshold changes from "low" to "medium" with improvements such as ADA compliance and safe crosswalks with signalized intersection treatments which favor pedestrians. This assessment tool was created with the vision of performing quality network analysis and being able to empirically measure the mobility benefits of improvements using existing and future conditions networks.

Quality Walkshed (Network Assessment) - An additional desired end sought by the team was for the ability to perform *quality* connectivity analysis using only quality network links (as opposed to pure *network* connectivity using all links). As stated in the previous section, exposure to hostile conditions in which active transportation modes makes trip-making and route choice more sensitive to facility quality and environment. For this reason, the team wanted to develop a quality connectivity measure that is pedestrian-specific, drawing upon the example of what Low-Stress Connectivity analyzes for bicycle travel.

To replicate this analysis in the pedestrian realm, the team developed a process which applies the methods used in the low-stress bicycling connectivity analysis to the pedestrian environment, by using the recommended performance measure (PEQE).

Quality connectivity analyses using a subset of quality links (which includes both sidewalk and crossing legs) determined by PEQE analysis is currently undergoing testing in the Mission Valley and Kearny Mesa Community Plan Update Mobility Studies. Lessons from those initial applications will be discussed in the final section of this report.

5-Year Pedestrian Collision History (Safety) – To assess safety, the team reviews 5-years of pedestrian collision data which is geocoded based on location (intersection or segment) and organized based on cause. Pedestrian collision history is used to help determine a more refined study area and to assist with prioritization, and identify critical areas of need.

Preferred Thresholds

This section presents thresholds related to each of the assessment tools presented in the previous sections. Minimum thresholds for each travel mode and performance measure are intended to balance and prioritize multimodal transportation recommendations. Currently, thresholds are being tested in four Community Plan Update Mobility Studies, Midway Pacific Highway, Old Town San Diego, Mission Valley and Kearny Mesa. The thresholds were established based on industry recommendations and engineering judgment. As noted, testing and research is still being performed on these thresholds and they have not been finalized at this point.

Table 3 displays the rating thresholds being applied for the facility quality and network analysis evaluation metrics. The evaluation metrics, demand and safety, are used primarily to help determine study area and prioritization; therefore, they are not used in the evaluation thresholds.

Table 3: Multimodal Analysis and Evaluation Thresholds

Mode	Analysis	Type	High	Medium	Low
Pedestrian	**PEQE**	Quality	7+ Points	4-6 Points	3 or fewer points
	Travelshed Ratio	Network Connectivity	50%+ coverage from origin	30% - 49% coverage from origin	Less than 30% coverage from origin
	Quality Walkshed Ratio	Quality Connectivity	40%+ coverage from origin	30% - 39% coverage from origin	Less than 30% coverage from origin
Bicycle	**LTS**	Quality	LTS 1	LTS 2	LTS 3 & 4
	Travelshed Ratio	Network Connectivity	50%+ coverage from origin	30% - 49% coverage from origin	Less than 30% coverage from origin
	Low-Stress Connectivity	Quality Connectivity	Can reach 50%+ of surrounding Traffic Analysis Zones (TAZ) from origin TAZ	Can reach 25% to 49% of TAZs from origin TAZ	Can reach less than 25% of TAZs from origin TAZ

Source: Chen Ryan Associates, March 2017

There are different goals set for all modes depending on route typology. The City of San Diego is looking to assign Route Types, based on a roadway's transportation characteristics and interaction with adjacent land uses. The typologies include classes such as *District* and *Corridor*, which correspond to roadways in the community expected to have the highest pedestrian activity. The intent of utilizing Route Types is to dictate levels of recommendations and treatments for different roadways and to assist with prioritization.

Lessons Learned from Application of Measures

Thus far, LTS and Low-Stress Connectivity, along with PEQE and Quality Walkshed, have been tested in several Community Plan Update Mobility Studies, including: Midway-Pacific Highway, Mission Valley, Kearny Mesa and the Linda Vista Comprehensive Active Transportation Plan.

The performance of Low-Stress Connectivity network analysis requires point data to serve as origins and destinations. Thus, in order to practice assessing low stress connectivity, origins and destinations need to be created. The team developed the approach to use the centroids of Traffic Analysis Zones (TAZ) containing trip production or attraction land uses and model all shortest paths between them. Within Network Analyst, it is possible to determine shortest routes from one point to all other points. This analysis is performed only with links scoring LTS 1 or 2. For each TAZ, the percentage of all other TAZs accessible by low stress roads is subsequently calculated. The origin-destination shortest path analysis is an automated process in GIS, but visual inspection of the outputs is recommended. This analysis was first used in the Midway-Pacific Highway Community Plan Update Mobility Study and has subsequently used in Mission Valley and Kearny Mesa. In future conditions, this analysis is repeated with a new network which assumes LTS score changes along streets brought about by projects which improve bicycling conditions. Future conditions testing using Low-Stress Connectivity have occurred in Midway-Pacific Highway community and generated meaningful evidence of mobility improvements from bicycle projects. Low-Stress Connectivity in Midway-Pacific Highway community has enabled the network impacts of individual bicycle facility projects to be quantifiably measured.

The development of PEQE also envisions using quality connectivity analysis methodologies in a similar manner to LTS's low-stress connectivity; however, tailored to the travel behaviors of pedestrians and data collection limitations. PEQE analysis from TAZ to TAZ was initially considered as a part of the Midway-Pacific Highway Community Plan Update Mobility Study but later was abandoned as it was determined to be an ineffective measure. Analyzing trips from TAZs to all other TAZs via shortest paths, as was performed in Low-Stress Connectivity, makes less sense for pedestrians because of the shorter distances most pedestrians travel compared to cyclists, and would also require scoring PEQE for all walkways in the community. The practice since has shifted away from origin-destination based shortest path analysis and toward using the metric as a walkshed analysis from an origin location, with scoring assigning grades to those origins. Additional complexities in pedestrian analysis compared to bicycle analysis are that there are two sides of a street and the pedestrian using a walkway can travel in either direction on either side of the street. Intersection legs also add to the complexity because it is possible for an intersection with four poor legs to still be traversable, if the sidewalks score fair and the pedestrian makes a 90 degree turn. This essentially eliminates the ability to use centerline data and makes much of the automation advantages that can be possible with PEQE because every analysis run has to be inspected to determine if the outputs are accurate.

In the Mission Valley Community Plan Update Mobility Study, the origin points used for quality walkshed were the project's study intersections within the 'pedestrian study area' subset of roads. However, conducting quality walkshed analysis from locations within the pedestrian study area has also proven to have complications. Since only a subset of PEQE scores have been generated, quality walkshed can only be analyzed on the links and intersections that have been measured in PEQE. The outputs created from only performing quality walkshed on PEQE links only have been flawed for two reasons: it ignores the mobility impacts of non-pedestrian study area links which the pedestrian might take, and origin locations analyzed on the periphery of the pedestrian study area have their quality walkshed scores differently due to having fewer directions to travel. Subsequently, after these issues, transit stations have been used as origin locations for quality walkshed analysis.

Conclusion

The use of LTS with Low-Stress Connectivity and PEQE with quality walkshed has been applied in three planning City of San Diego Community Plan Update Mobility Studies. There have been very few methodological problems with LTS and Low-Stress Connectivity – the methods have not undergone any changes since the initial application of the analyses in the Midway-Pacific Highway Community Plan Update Mobility Study. The development of PEQE as a measurement has worked effectively for its purposes, while the application of quality walkshed connectivity is still undergoing an iterative testing process in the Mission Valley and Kearny Mesa studies.

As the transportation planning and engineering fields shift away from solely utilizing vehicular level of service for environmental analysis and facility sizing, it is becoming increasingly important for jurisdictions, including the City of San Diego, to develop a standardized approach to analyzing pedestrian and bicycle facilities and networks. The use of the methods described in this paper has provided the City a promising start in that endeavor. It has also provided the City a way to communicate with public constituents and decision makers, and show analytically, the results of planning for active transportation.