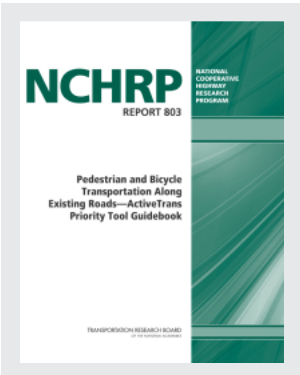

Pedestrian and Bicycle Transportation Along Existing Roads ActiveTrans Priority Tool Guidebook

DETAILS

87 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-30854-0 | DOI 10.17226/22163

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 803

Pedestrian and Bicycle Transportation Along Existing Roads—ActiveTrans Priority Tool Guidebook

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Kittelson & Associates, Inc.
Reston, VA

Subscriber Categories
Pedestrians and Bicyclists • Administration and Management • Planning and Forecasting

Research sponsored by the American Association of State Highway and Transportation Officials
in cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2015
www.TRB.org

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

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The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP REPORT 803

Project 07-17
ISSN 0077-5614
ISBN 978-0-309-30854-0
Library of Congress Control Number 2015934797

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Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

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AUTHOR ACKNOWLEDGMENTS

This guidebook was prepared under NCHRP Project 07-17 by Toole Design Group, LLC. Peter Lagerwey was the Principal Investigator. Robert Schneider, Ph.D., Assistant Professor University of Wisconsin–Milwaukee served as the Co-Principal Investigator. In addition to Mr. Lagerwey and Dr. Schneider, primary authors of this report included Michael Hintze, AICP, LEED® AP; James Elliott, AICP; and Jennifer Toole, AICP, ASLA of Toole Design Group. Contributing authors included Karla Kingsley; Matt Bell; Joe Bessman, P.E., P.T.O.E.; Erin Ferguson, P.E.; and Jessica Horning of Kittelson & Associates, Inc., as well as Benjamin Sigrist (Toole Design Group), Daniel Goodman, AICP (when with Toole Design Group) and Jamie Parks (when with Kittelson & Associates).

FOREWORD

By Christopher J. Hedges
Staff Officer
Transportation Research Board

This guidebook presents the "ActiveTrans Priority Tool (APT)," a step-by-step methodology for prioritizing improvements to pedestrian and bicycle facilities, either separately or together as part of a "complete streets" evaluation approach. The methodology is flexible, allowing the user to assign goals and values that reflect those of the agency and the community. It is also transparent, breaking down the process into a series of discrete steps that can be easily documented and communicated to the public. The guidebook is supplemented by a CD that contains a programmed spreadsheet to facilitate implementation of the ActiveTrans methodology, as well as a final report that documents the research approach, findings, and conclusions.* The guidebook will be very useful to planners and other staff responsible for the most effective allocation of scarce resources to where they will provide the most benefit.

Conditions for pedestrians along existing roads and bridges have wide-ranging impacts on whether public transportation services are used, whether students walk to school, whether people walk to local services, and whether people walk for general health. Over the years, sidewalks have not been included on many arterial, collector, or even local roads and bridges on the United States road network. Where sidewalk segments do exist along roadways, they are often not connected, leaving the sidewalk networks fragmented. The accessibility of the road system for pedestrians is inhibited not only by the lack of sidewalks, but also on other missing facilities such as safe crossing areas and waiting areas for transit services.

The lack of adequate bicycle facilities has also been an issue. While bicyclists can take advantage of the existing roadway system, there are situations in which improved facilities would be particularly beneficial. These situations may involve younger and inexperienced riders or areas where there are large differentials in speed between bicycle and vehicular traffic (e.g., high-speed rural roads and freeways).

When needs are addressed with limited resources, the basic steps to fulfilling these needs include identifying the problem, quantifying the problem, identifying cost-effective solutions, prioritizing needs, securing funding, and ensuring implementation. These steps are well established for new highway projects at the federal, state, and local levels, where well-developed methodologies, processes, and dedicated funding sources exist to improve conditions for vehicular traffic. However, such processes are rarely in place to add or improve

*Notice to readers regarding the CD accompanying this report, CRP-CD-163: the CD menu will only open in Silverlight-compatible browsers. If your browser does not have the Silverlight plugin installed, you will be prompted to install or activate the plugin. See the readme file on the disk for further information.

pedestrian or bicycle facilities to the existing roadway network. In fact, the number of pedestrian and bicyclist facilities that would benefit from retrofitting is largely unknown. Furthermore, walking and biking needs are often considered jointly within an organization, although the needs of each may be quite different.

Under NCHRP Project 07-17, a research team led by the Toole Design Group developed ActiveTrans, a prioritization tool and guidebook based on an extensive review of research and in-depth interviews. ActiveTrans takes the user through a prioritization process using 10 essential steps: defining the purpose of the prioritization exercise, selecting factors that reflect agency and community objectives, assigning weights to the various factors, selecting variables that can be measured, assessing available data, assessing available technical resources, setting up the tool, measuring and inputting data, scaling the variables to ensure they are comparable, and creating a list of projects in priority ranking. The draft methodology was pilot tested in 11 separate agencies, and the feedback acquired was used to enhance and refine the final version.

CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

ActiveTrans Priority Tool Overview

This guidebook presents the ActiveTrans Priority Tool (APT), a step-by-step methodology for prioritizing pedestrian and bicycle improvements along existing roads. The APT is intended to be used by planners and other agency staff charged with managing a pedestrian or bicycle prioritization effort. It is designed to encourage practitioners to prioritize pedestrian and bicycle improvement locations by establishing a clear prioritization process that is:

- **Responsive to agency/community values:** Transportation agencies often make decisions based on a defined set of goals or values of the communities they serve.
- **Flexible:** Rather than being a rigid, "one-size-fits-all" tool, the APT is flexible and allows practitioners to choose the most appropriate approach that reflects agency/community values and resource availability.
- **Transparent:** The APT is designed to facilitate transparency by breaking the prioritization process down into a series of discrete steps, each of which can be easily documented and explained to the public.
- **Responsive to** the unique needs of pedestrians and bicyclists.

How the ActiveTrans Priority Tool May Be Used

The APT can be used to rank pedestrian or bicycle facility improvement locations along existing roads. Since the needs of pedestrians and bicyclists are different, the APT is designed to address each mode separately; however, the APT can also be used as part of a complete streets prioritization process that considers pedestrian and bicycle improvements together.

The APT can assist an agency in identifying areas or locations for improvements, but does not provide guidance for determining pedestrian or bicycle facility design solutions. For such guidance, agencies are encouraged to use other resources that address pedestrian and bicycle facility design, such as the various guides produced by the American Association of State Highway Transportation Officials (AASHTO) and National Association of City Transportation Official (NACTO), the *Manual for Uniform Traffic Control Devices* (MUTCD), and the Public Right-of-Way Accessibility Guidelines (PROWAG), among others.

Different types of agencies may use the APT in different ways. State or regional agencies responsible for distributing funding to local agencies may use the APT to evaluate proposed improvements based on policy objectives. Local agencies with an identified list of bicycle or pedestrian improvements may use the APT to establish which improvements are implemented in the near, medium, and long term.

Finally, agencies may apply the APT only once or iteratively. An example iterative process might include applying the APT three times: first to identify and rank corridors (iteration 1), then to identify intersections within high-ranking corridors for field assessment (iteration 2), and finally to rank and prioritize specific improvements identified through the field assessment (iteration 3).

Key Terms

Below is a list of key terms used in the APT. It is important for readers to be familiar with these terms.

Improvement Locations: Improvement locations are the specific intersections, roadway segments, or areas that are considered during the prioritization process. For example, a prioritization process may seek to identify the top 10 intersections for pedestrian crossing improvements in a neighborhood with 100 intersections. This prioritization process would have 100 improvement locations.

Factors: Factors are categories used in the prioritization process to express community/agency values and group variables with similar characteristics. For example, the Demand factor includes variables such as population density, employment density, proximity to schools, proximity to shopping, and other characteristics related to the potential to generate pedestrian and bicycle activity. Including certain factors and weighting those factors differently allows an agency to express what its constituents value or care most about.

Weights (Weighting): Weights are numbers used to indicate the relative importance of different factors based on community or agency values. For example, if a community decides that the Safety factor is more important than the Constraints factor, it would give the Safety factor a higher weighting. The unweighted factor score is multiplied by the weight number to determine the weighted factor score.

Variables: Variables are characteristics of roadways, households, neighborhood areas, and other features that can be measured. Variables are the core elements of the prioritization process. For example, "roadway traffic speed" and "neighborhood population density" are variables. Variables can be measured using quantitative or qualitative data values.

Measures: Measures are the specific metrics used to quantify variables. There is often more than one way to measure a variable. For example, "roadway traffic speed" can be represented by the measure of "85th percentile speed" (which is often gathered from a speed study) or by the measure of "posted speed limit" (which can be observed from signs in the field or from a roadway database).

Data Values: Data values are the quantitative or qualitative values used to express the measures in the prioritization process. For example, data values may be "30 miles per hour" on a roadway segment, "100 people per square mile" within a quarter-mile buffer of an intersection, or "2 crashes" reported at an intersection.

Scaling: Scaling (or normalizing) involves identifying a common numeric scale (e.g., 0 to 10) for all variables and adjusting the data value for each variable to fit this scale. The purpose of scaling is to make variables with different data value ranges comparable to one another. Otherwise, variables with high data value ranges (e.g., population) might far outweigh variables with low numerical ranges (e.g., crashes) when the prioritization score is calculated. Scaling should ideally be done based upon a mathematical formula, and agencies should not attempt to affect the influence of variables through scaling—this is done through weighting.

Prioritization Scores: Prioritization scores are the final scores for each discrete improvement location considered in the prioritization process. They are the result of multiplying the scaled

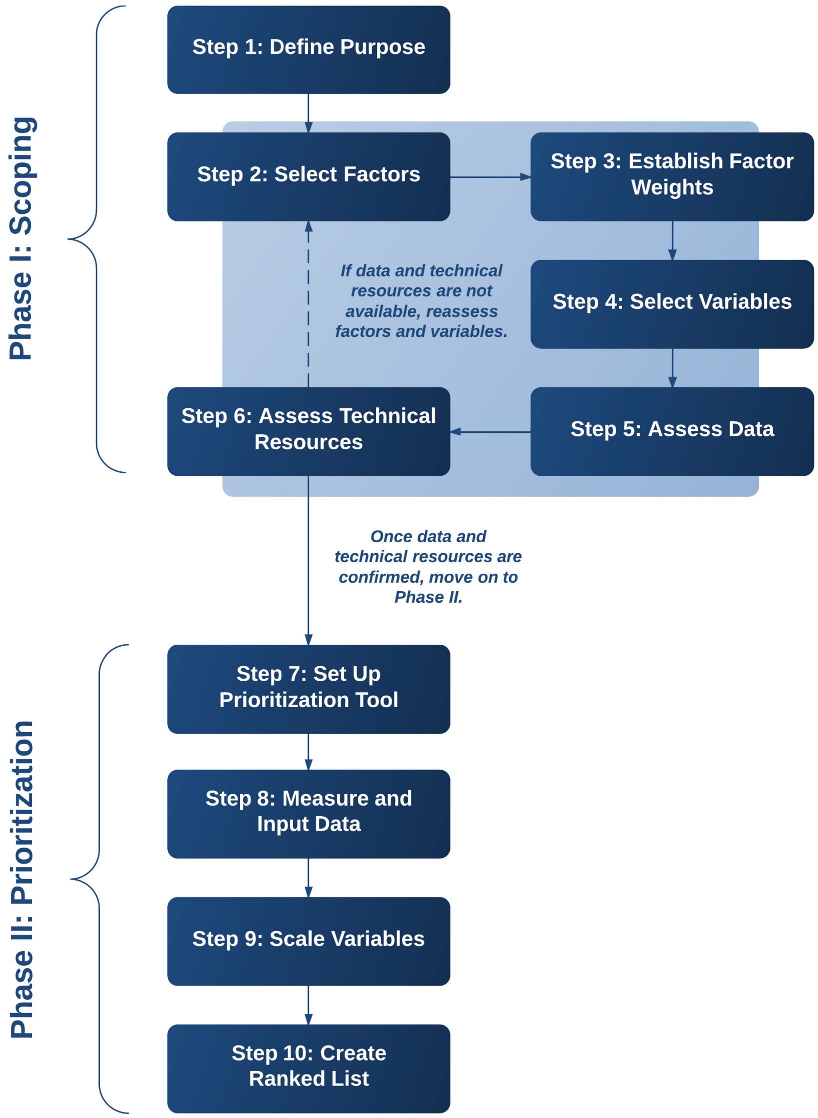

Figure 1. ActiveTrans priority tool methodology.

data values by specific weights and summing these values across all factor categories. These prioritization scores are typically ranked from highest to lowest to create the final prioritized list. For example, each roadway segment that is being prioritized will receive a final prioritization score. The roadway segment with the highest score will be the top priority for project implementation.

The APT consists of 10 steps divided into two phases (Figure 1).

Phase I: Scoping

Phase I consists of the initial deliberation and preparation necessary for an agency to set up an effective prioritization process. Phase I starts at a high level, defining the broad purpose of the prioritization effort. This initial scoping phase becomes more focused as variables, data, and technological resources are considered. The six steps in Phase I are:

Step 1—Define Purpose.

Step 2—Select Factors.

Step 3—Establish Factor Weights.

Step 4—Select Variables.

Step 5—Assess Data.

Step 6—Assess Technical Resources.

While the steps in Phase I may proceed in a linear fashion, the process also may advance iteratively; that is, the outcome of a later step may require an agency to revisit one or more previous steps. For example, if an agency finds that it does not have the data (Step 5) or technical resources (Step 6) needed to analyze certain selected factors (Step 2) or variables (Step 4), than it might need to reassess the feasibility of including those factors or variables in the prioritization.

Phase II: Prioritization

The goal of Phase II is to calculate prioritization scores for each improvement location based on the purpose, factors, weights, variables, and technical resources identified in Phase I. Phase II is a more linear process that includes the following steps:

Step 7—Set Up Prioritization Tool.

Step 8—Measure and Input Data.

Step 9—Scale Variables.

Step 10—Create Ranked List.

A programmed spreadsheet and user guide (see Appendix A, Programmed Spreadsheet User Guide) have been developed as a part of this study to assist agencies with implementing Phase II of the APT. The programmed spreadsheet is designed to be used "off the shelf," saving agencies time that would otherwise be spent setting up a prioritization tool. The user guide includes technical details on how the programmed spreadsheet can be used to score and rank projects.

ActiveTrans Priority Tool Phase I: Scoping

The goals of Phase I are to define the purpose of the prioritization effort, determine how community/agency values should be expressed through factor selection and weighting, and select variables to represent the chosen factors, while taking into account data availability and technical resources.

Step 1: Define Purpose

At the outset of a prioritization exercise, it is important to identify a clear purpose. Key questions include:

- **Mode.** Will the prioritization exercise address pedestrian improvements, bicycle improvements, or both?
- **Improvement Specific or Not Improvement Specific.** Does the agency have a specific type of improvement in mind, such as sidewalk retrofits or bicycle lanes, or is the aim to identify locations where improvements are needed but to determine the type of improvements later (e.g., roadway segments to receive ADA improvements)?
- **Goals.** What are the improvements intended to accomplish? Is the aim to increase the number of walking and biking trips, improve safety, or advance economic development? Is there a combination of goals defined in a master plan document?
- **Number of Improvement Locations.** In general, how many improvement locations will be prioritized? (Note that the precise number of improvement locations may not be known during this initial step.)
- **Improvement Location Type/Extent.** What type or extent of improvement locations will be prioritized? Are the locations confined to one spot or area (e.g., intersection improvements), roadway segments or corridors, or entire neighborhoods?

In some cases, an agency may approach the prioritization exercise with a good sense of the answers to these questions and will be able to move through Step 1 relatively quickly. In other cases, the agency may have to go through a process of deliberation or stakeholder engagement to arrive at the answers. The key outcome of Step 1 is that the purpose of the exercise is as clearly defined as possible before moving on to Step 2.

Step 2: Select Factors

Two key reasons for conducting a prioritization process is to make the most out of limited resources and to spend public funds in a transparent way that reflects community/agency values and priorities. These values and priorities will differ from community to community.

For example, one community/agency might choose to emphasize safety while another might prioritize demand over all other factors. Others may choose to incorporate multiple values in their prioritization process and weight factors in terms of their importance (see Step 3).

This APT methodology identifies nine factors that are commonly considered in prioritization processes and can be used to reflect a range of community/agency values. The factors include:

- Stakeholder Input.
- Constraints.
- Opportunities.
- Safety.
- Existing Conditions.
- Demand.
- Connectivity.
- Equity.
- Compliance.

These nine factors are included in the programmed spreadsheet that accompanies the APT.

The goal of Step 2 is to select which factors among those presented here, as well as others identified locally, are relevant given the established prioritization purpose. This section includes definitions for each factor along with general guidance regarding the factor's relevance for different prioritization purposes. The order in which factors are presented does not reflect their relative importance.

Agencies may choose to include other factors that more directly relate to a specific policy objective (e.g., public health, greenhouse gas reduction), funding source, or other community priority identified through a stakeholder process. Whatever factors are ultimately chosen, the process and rationale for selecting them should be documented so that they can be explained to stakeholders.

Table 1 shows how each of the nine factors described below may apply to some common pedestrian or bicycle prioritization purposes. The example prioritization purposes shown in Table 1 are not intended to be comprehensive, but are provided as illustrative examples.

Tip: Public Involvement

The Stakeholder Input factor is the place to quantify public input on each of the improvement locations. However, community members can also help shape the prioritization *process.* For example, the public can help to identify which factors are most relevant given the project purpose and community values (Step 2). They can also help to establish weights (Step 3). For example, as part of a public workshop, participants could recommend factors that should be used in the prioritization process and then participate in a weighting exercise. In the exercise, each participant could be given a set number of points that they would have to distribute among the factors, to indicate which are more important and should therefore be more heavily weighted.

Stakeholder Input

The Stakeholder Input factor considers the amount of public feedback in support of (or against) a pedestrian or bicycle improvement at a particular location. Stakeholder input is important to consider because most agencies serve in the public interest. When and how often an agency decides to incorporate stakeholder input into the prioritization process will depend on existing processes and protocols, as well as the nature of the projects being prioritized. The Stakeholder Input factor can be represented by a recommendation in an adopted local plan or by a citizen advisory committee, or via quantitative documentation of requests/comments from the public.

Constraints

This factor addresses the relative level of difficulty in implementing a pedestrian or bicycle project. Constraints are important to consider because they can

Table 1. Example prioritization purposes and relevant factors.

Common Prioritization Purpose Examples	Stakeholder Input	Constraints	Opportunities	Safety	Existing Conditions	Demand	Connectivity	Equity	Compliance
Corridor									
Given 20 high pedestrian-crash corridors in a region, identify four to receive grant funding for safety enhancements.	◐	◐	◐	●	●	●	○	●	◐
Given 10 candidate corridors for sidepath construction, identify the top three for implementation.	●	◐	●	●	●	●	●	◐	○
Segment									
Given a planned bicycle network consisting of approximately 500 miles of recommended facilities (bike lanes, cycle tracks, shared lane markings, etc.), select 50 miles for implementation in the next five years.	●	●	●	◐	●	●	●	●	○
Given a neighborhood where sidewalks are absent, select 30 segments to construct new sidewalks over the next three years.	●	◐	◐	●	●	●	◐	●	○
Intersection/Crossing									
Given a regional trail with 50 unsignalized roadway crossings, identify 12 to implement safety enhancements.	●	○	◐	●	●	◐	○	◐	●
Given 500 locations where curb ramps are missing in a municipality, identify an initial 50 locations for ramp installation using available grant funding.	●	◐	◐	◐	○	●	◐	●	○
Given a city with more than 500 signalized intersections, identify the 30 priority traffic signals to be converted to accessible pedestrian signals when they are upgraded or replaced.	●	○	◐	●	●	●	◐	●	●
Area									
Given a county with 30 elementary schools, rank the designated schools zones to determine which ones should be further evaluated for future pedestrian improvements.	●	○	◐	●	●	◐	○	●	●
Given a city that consists of 15 defined neighborhoods, prioritize two for the initial focus of a complete streets evaluation.	◐	○	○	●	●	●	●	●	●
Given a city with 20 neighborhood commercial centers, rank all 20 centers in terms of their need for additional bicycle parking.	●	○	◐	○	●	●	○	◐	○

● = Very relevant ◐ = Less relevant ○= Not likely relevant

drain agency resources when implementing pedestrian or bicycle projects. Many constraints are framed in terms of cost, and may include right-of-way acquisition, facility design, mitigation and construction, available funding (internal and external), environmental impacts, existing regulations and standards, tradeoffs among modes, and staff resources. The Constraints factor may be less quantifiable when improvements are unspecified or when the prioritization exercise applies to a relatively large geographic area, such as a neighborhood, school district, city or region. In these cases costs may be difficult or impossible to estimate. The Constraints factor may also be less relevant when prioritizing a list of improvements of similar cost. For example, cost may not be a highly relevant factor for marking crosswalks, because crosswalk projects are relatively inexpensive and can be implemented within the existing roadway right-of-way.

Opportunities

The Opportunities factor quantifies the ability of an agency to take advantage of resources that can support project implementation. These resources may be financial or political. They are important to consider because they save time and money when implementing pedestrian or bicycle projects. For example, financial opportunities include whether or not a proposed improvement is eligible for grant funding, can draw from a dedicated funding source, can be incorporated into a scheduled roadway reconstruction or resurfacing project, or can be provided by private developers through development requirements/agreements. Political opportunities could include support for pedestrian or bicycle improvements from elected representatives in different parts of the community or leaders of different local agencies.

Safety

The Safety factor accounts for the risk of a pedestrian or bicyclist being involved in a traffic collision (or crash). Safety is important because pedestrians and bicyclists are particularly vulnerable to being injured or killed when struck by a motor vehicle. In addition, concerns about safety can be a significant barrier to people choosing to walk and bicycle. In the APT methodology, the Safety factor is evaluated primarily in terms of reported pedestrian and bicycle crashes and crash rates. Pedestrian and bicycle crash types and location patterns are different and should be evaluated separately. Roadway characteristics play a significant role in determining where pedestrian and bicyclist crashes occur in a community. Therefore, as agencies consider priorities for pedestrian and bicycle improvements at different locations, it is important to assess pedestrian and bicycle crash risk.

Existing Conditions

The Existing Conditions factor includes physical conditions that have an impact on pedestrian or bicycle safety, comfort, or demand, such as whether or not a sidewalk exists, the number of travel lanes, or the presence of a buffer. The Existing Conditions factor also includes travel behaviors that influence conditions for walking and bicycling, such as motor vehicle volumes and speeds. Consequently, the Existing Conditions factor is likely to be highly relevant for the majority of prioritization purposes, especially those who emphasize Safety and Demand.

Demand

The Demand factor represents existing or potential pedestrian and bicycle activity levels. Demand is a key factor to consider if an agency's aim is to add new pedestrian or bicycle facilities where they will be most used. Likewise, if the aim of the prioritization process is to identify improvements that will have the greatest impact on reducing crash rates or pedestrian exposure, then the number of pedestrians who might benefit from each safety improvement is relevant.

Existing pedestrian and bicycle demand can be measured by counting the number of people on foot and bike at a given time and location. Potential or latent pedestrian and bicycle demand can be measured by considering the proximity of pedestrian or bicycle improvement locations to bicycle and pedestrian attractors or generators, such as schools, universities, parks, transit facilities, and mixed-use and high-density land uses.

An increasing body of evidence supports the concept of latent demand. For example, the Non-Motorized Transportation Pilot Program (FHWA) demonstrated that walking and bicycling investments often led to an increase in the total number and rate of people walking and bicycling in the community. Consequently, analyzing latent demand enables communities to focus resources and investments on areas with the greatest potential for multimodal trips, even if current levels of walking and bicycling trips are low.

Connectivity

The Connectivity factor accounts for the degree to which a project allows pedestrians or bicyclists to travel comfortably and continuously throughout their community. Connectivity is a relevant factor when prioritizing new pedestrian and bicycle facilities on existing roadways, such as new sidewalks and bicycle lanes, particularly when the new facility fills a gap between existing facilities. According to the literature review and agency survey conducted as part of the study that informed this guidebook (See the NCHRP Project 07-17 Final Report for details), connectivity tends to be more commonly considered by agencies for bicycle improvements along roadways than pedestrian improvements. The Connectivity factor may be less important when prioritizing improvements to existing pedestrian and bicycle facilities, which are likely to already be part of an existing pedestrian and bicycle network.

Equity

The Equity factor represents the degree to which opportunities for safe and convenient pedestrian and bicycle travel are distributed evenly to all groups within a community. Taking equity into account can help agencies ensure that pedestrian and bicycle improvements serve the needs of all transportation system users. The Equity factor includes socioeconomic characteristics such as age, income, automobile ownership, race/ethnicity, and health or disability status. For example, good pedestrian and bicycle facilities may be especially important in neighborhoods where driving is less common due to low levels of car ownership.

Compliance

The Compliance factor captures whether or not existing infrastructure is compliant with current pedestrian and bicycle standards and guidelines. This is sometimes an important factor for agencies because they may face a liability risk if their facilities do not meet existing local, state, or national codes or standards. For example, a key variable under the Compliance factor for pedestrian improvements is whether an existing facility is compliant with Public Right-of-Way Accessibility Guidelines (PROWAG). This could include non-compliant curb ramps or sidewalk locations where a utility pole blocks the pedestrian travelway. This factor could also encompass existing bicycle facilities that are not compliant with the latest national or state guidelines or standards (e.g., an existing bike lane that is only three feet wide). This factor overlaps with the Existing Conditions factor, but it is considered separately because Compliance is often a specific focus of prioritization efforts.

Step 3: Establish Factor Weights

The purpose of Step 3 is to assign weights to each of the factors selected in Step 2.

Weights are numbers used to indicate the relative importance of different factors based on community values and the prioritization purpose. For example, if a community decides that the Safety factor is more important than the Constraints factor, it would give the Safety factor a higher weight number. When the prioritization process is implemented in Phase II, the unweighted factor score will be multiplied by the weight number to determine the weighted factor score. Factors with higher weights receive higher weighted factor scores. The programmed spreadsheet that accompanies the APT allows users to establish factor weights and then automatically applies these weights to prioritization scores.

Before establishing weights, it may be helpful to consider the total number of relevant factors and the relative impact each factor will have if the factors are weighted equally. Figure 2 shows the relative importance of each factor when different numbers of factors are selected.

The next step is to decide whether some factors are more important given community values and the prioritization purpose, and to adjust the factor weights accordingly. There are many reasons to weight factors differently and there is no single "right" way to weight any particular

Tip: Weighting

The process of establishing weights leads agencies to think about which factors are really necessary for implementing the prioritization analysis. If a factor selected in Step 2 is given a particularly low weight relative to other factors in Step 3, that factor will have a correspondingly low impact on the final prioritization score. Agencies should ask if it's worth including such a low-weight factor in the final prioritization. If the answer is "yes," agencies should consider how many variables they select within the low-weight factor and the amount of effort they put into measuring those variables, since the relative impact of each variable may be very low.

Some agencies may wish to apply weights at the **variable level** rather than the factor level (note: variables are discussed in Step 4). Doing so may have advantages and disadvantages. Advantages include the ability to have an added level of refinement within a factor category. For example, the Demand factor may include multiple variables, including proximity to schools, proximity to transit, and employment density. If it is determined that proximity to schools is the most important of these variables, then it may make sense to weight the school variable more heavily than the other component variables of Demand. The disadvantage of weighting at the variable level is an added level of computational complexity, which may require additional staff resources and may be more difficult to explain to the public. The complexity of the calculations increases even more when weighting is done at both the factor level and the variable level. Therefore, it is generally recommended that agencies choose between assigning weights at the factor or variable levels rather than trying to apply weights at both levels. Whatever weighting scheme an agency ultimately decides to pursue, it is important to carefully document how the weights were applied, so anyone reviewing the process can understand how the weights influence the final outcome.

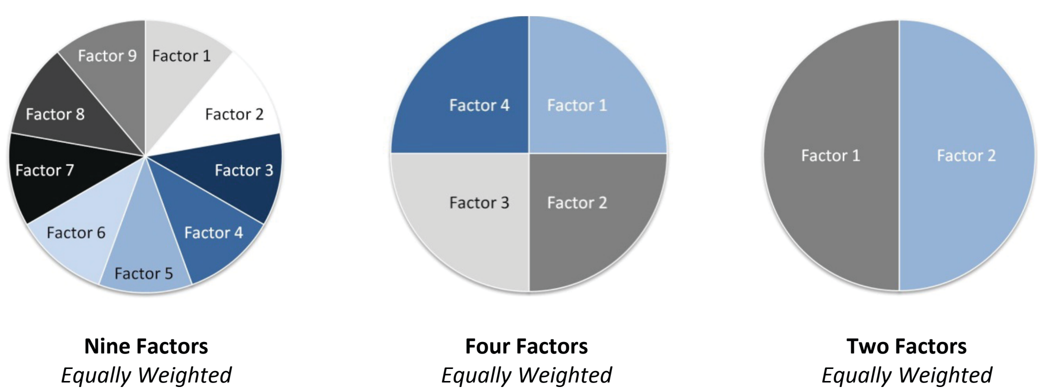

Figure 2. Relative impact of factors if factors weighted equally.

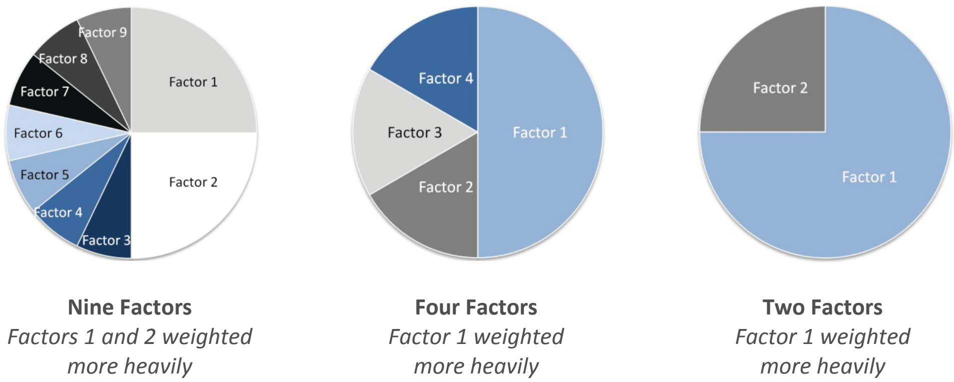

Figure 3. Relative impact of factors if factors weighted differently.

set of factors. That being said, the process should be transparent. Existing research and public input should be incorporated into weighting decisions where possible and applicable. Existing plans and policies can also provide a strong and defensible rationale for weighting decisions. Finally, the rationale should be carefully documented, so it can be explained to stakeholders. Figure 3 shows how applying different factor weights can impact the relative importance of the factor when different numbers of factors are selected.

Step 4: Select Variables

Variables are characteristics of roadways, intersections, neighborhood areas, and other features that can be measured. Variables are the core components of the prioritization process. Each prioritization factor is represented by a set of related variables. The selection of specific variables for each factor is informed by the prioritization purpose (Step 1), data needs and availability (Step 5), and an assessment of technical resources (Step 6). The example variables listed in each of the tables in this section are based on:

- The project literature review and agency survey (See the NCHRP Project 07-17 Final Report).
- Other best practice guidance from organizations such as NCHRP, Federal Highway Administration (FHWA), Association of American State Highway and Transportation Officials (AASHTO), National Association of City Transportation Officials (NACTO), and Institute of Transportation Engineers (ITE).
- The professional experience of the research team.

Practitioners who apply the prioritization method can choose to add other variables to suit their local needs.

Stakeholder Input

Stakeholder Input is often qualitative, involving informal discussions among elected officials, stakeholder groups, individual citizens, and agency staff. To ensure an objective, transparent prioritization process, stakeholder input should be well documented. Some input such as public comments or requests may be documented and quantified over an indefinite period of time (e.g., a telephone hotline) or as part of a targeted planning process (e.g., through surveys or public meetings).

With the advent of online tools such as electronic surveys, interactive mapping, and social media, agencies have the ability to inexpensively receive public input that can help identify where there are safety issues, demand for infrastructure, needed connections, etc. However, in

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Tip: Variables

In addition to the guidance on variables provided below, there are general rules of thumb for selecting which variables to include under a given factor:

- Only include variables for which there are values for all improvement locations. In other words, it is not advisable to use the variable if you only have data for a portion of the locations. The value can be zero.
- Avoid variables that do not differ meaningfully across the range of improvement locations. In the absence of meaningful variation, the data cannot help distinguish between these locations.
- Avoid using too many variables. More variables do not necessarily create a better prioritization process. The more variables within a given factor category, the more time consuming the process and the less significance each individual variable will have. However, it is possible to weight individual variables to give certain variables more importance than others. (See *Tip: Weighting* in Step 3.)

NOTE: The programmed spreadsheet developed to accompany the APT allows practitioners to choose from among a list of the most relevant variables for each factor category based on the prioritization purpose and data availability.

many communities, the deployment of such tools should be supplemented by other outreach methods such as meetings, tabling, etc. that target populations that may not be reached using technological tools.

Stakeholder input may come in the form of complaints or comments about particular deficiencies such as missing sidewalks or through suggestions for facility improvements in specific locations (e.g., add a pedestrian crossing signal, stripe a bicycle lane). Some public suggestions for improvements may not be ideal for a specific location and may not meet specific engineering guidelines or safety standards. However, these suggestions may indicate an underlying issue that should be explored.

Data that is more qualitative in nature, such as the priorities of elected officials or recommendations of staff familiar with local constraints and opportunities, is also valuable when prioritizing projects. How this type of information is used depends on the size of the community and the decision-making power of elected leaders and agency staff. Where the community is in terms of implementation also matters; for instance, communities with less prior history implementing bicycle and pedestrian improvements may have more “low-hanging fruit” projects—those that can easily be identified with qualitative input from elected officials or staff. In other communities, the most straightforward projects may have already been implemented and an emphasis on quantitative methods may be more appropriate.

Table 2 shows example Stakeholder Input variables and their application.

Constraints

Constraints variables (Table 3) are limitations an agency may encounter when planning/designing pedestrian or bicycle improvements. Constraints variables are more nuanced than other categories of variables and often require case-by-case knowledge and evaluation. Constraints can often be expressed in terms of units of time, cost of construction, land acquisition, etc.

Table 2. Stakeholder Input variables.

Example Variables	Relevance*		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be, considering their purpose.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Number of public comments about specific issue received by phone or online from citizens	●	●	S, Cr, Co, A
Identification/inclusion of a particular improvement location in adopted plans	●	●	S, Cr, Co, A
Number of comments received at public meetings or through a public survey during a master planning process	●	●	S, Cr, Co, A
Supported by advisory committee or decision-making body	●	●	S, Cr, Co, A

Opportunities

Opportunity variables (Table 4) are attributes of projects that increase their potential to be implemented. While opportunities and constraints are both aspects of project feasibility, accounting for each separately allows agencies to assign different weight to Constraints and Opportunity variables depending on the prioritization purpose.

Cost/Benefit Considerations

Constraints and Opportunities are sometimes studied separately from the prioritization process through a cost/benefit analysis, which is more often done on a small number of priority projects rather than a longer list. Tools for evaluating the costs and benefits of individual projects require detailed data. Examples of these tools include:

- *NCHRP Report 552* (Krizek et al. 2006) provides guidelines to evaluate bicycle facilities based on their construction and maintenance costs and their environmental, economic, public health, and other benefits due to increased bicycle mode share. These guidelines have been

Table 3. Constraints variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Project implementation cost (including design, engineering, and construction costs, which depend on right-of-way availability, utility relocation, and topography)	●	●	S, Cr, Co
Presence of environmental or historic features that may create significant barriers to construction	◐	◐	S, Co, A
Staffing (time needed to plan and implement projects)	●	●	S, Cr, Co, A
Multi-jurisdictional coordination	●	●	S, Cr, Co
Life-cycle costs	◐	●	S, Cr, Co

Table 4. Opportunities variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Projects that are candidates for a specific funding source (e.g., grant, targeted improvement fund)	●	●	S, Cr, Co, A
Projects that could be implemented through future land development or roadway construction	●	●	S, Cr, Co
Planned roadway improvements that may accommodate pedestrian or bicycle facilities (e.g., repaving or reconstruction projects)	●	●	S, Cr, Co

operationalized as *Costs-Demand-Benefits Analysis Tool* available from the Pedestrian and Bicycle Information Center.

- The *New Zealand Transport Agency Economic Evaluation Manual* (2010) is one of the most advanced multimodal cost/benefit approaches available. However, it requires a thorough evaluation of each project, including (among other things) an analysis of the change in travel time for pedestrians and bicyclists, the predicted change in pedestrian and bicycle crashes and injury severity levels (from crash prediction models), and the change in noise levels experienced by pedestrians.

Macro-scale cost/benefit evaluations have been used to assess the impacts of pedestrian or bicycle infrastructure investments in a particular community over multiple years (Barnes 2004, Lawrie et al. 2006, Bicycle Federation of Wisconsin 2006, East Florida Regional Planning Council 2011, Gotschi 2011) and to estimate the impacts of different levels of national pedestrian and bicycle investment (Gotschi and Mills 2008). The World Health Organization, Regional Office for Europe (2011) has also developed a tool to evaluate the health impacts of pedestrian and bicycle investments at the community level. However, macro-scale cost/benefit approaches typically do not apply to the type of prioritization described in this report.

Safety

Safety variables (Table 5) can be evaluated using pedestrian or bicycle crash data. Most reported pedestrian crashes are collisions between motor vehicles and pedestrians, and most reported bicycle crashes are collisions between motor vehicles and bicyclists. However, some crashes involve collisions between pedestrians and bicyclists or are single-person incidents. These crashes are often underreported.

Pedestrian or bicycle crashes may be clustered in certain “hot spots,” which may include specific intersections or roadway corridors. These “hot spots” may indicate the need for roadway design improvements. For example, there is a well-studied correlation between pedestrian crashes and roadway variables such as traffic volume, vehicle speed, and number of vehicle lanes (Zegeer et al. 2005). This relationship is discussed further in the Existing Conditions section.

It is also important to recognize that pedestrian and bicycle crashes tend to occur in locations with higher pedestrian and bicycle volumes. The risk of a pedestrian or bicycle crash occurring may actually be lower in some locations with many crashes than in other locations with few crashes (Schneider et al. 2009a; Schneider et al. 2012). Therefore, variables in the Safety factor category may also express the rate of pedestrian or bicycle crashes, which is the total number of

Table 5. Safety variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Total number of pedestrian/bicycle crashes	●	●	S, Cr, Co, A
Fatal and severe injury pedestrian/bicycle crashes	●	●	S, Cr, Co, A
Pedestrian/bicycle crash rate	●	●	S, Cr, Co, A
Proportion of pedestrians walking in the roadway	◐	○	S
Proportion of pedestrians complying with "Don't Walk" signals	◐	○	Cr
Proportion of bicyclists complying with red lights	○	◐	Cr
Proportion of motorists complying with right-turn-on-red restrictions	◐	◐	Cr
Proportion of motorists yielding to pedestrians in crosswalks	◐	○	Cr
Number of "near misses" involving pedestrians/bicyclists	◐	◐	S, Cr, Co, A

pedestrian or bicycle crashes during a specific time period divided by a measure of exposure for that time period. Examples of exposure measures include:

- The pedestrian crossing volume multiplied by the perpendicular motor vehicle volume at a crosswalk.
- The pedestrian crossing volume at a crosswalk or intersection.
- The total bicycle volume (including all right-, left-, and through-movements) at an intersection.
- Census tract pedestrian or bicycle commute-to-work mode share.
- Census tract population.

Individual variables or combinations of variables in the Demand category can also be proxies for pedestrian or bicycle exposure. The most accurate exposure variables have the most direct relationship with the actual risk of a crash, such as the time pedestrians or bicyclists spend in locations where they may come into contact with motor vehicles. However, specific data on pedestrian or bicycle volumes are usually not available, so more general measures of exposure are often used.

The severity of pedestrian and bicycle crashes can also be considered as a prioritization variable. Crash injury severity is often classified according to a scale, such as no injury, minor injury, severe injury (requiring hospitalization), or fatal injury. In general, pedestrian and bicyclist injuries are more severe when they involve vehicles traveling at higher speeds (Rosén et al. 2011). Therefore, fatal and severe injury crashes are often concentrated on higher-speed roadways. Fatal and severe injury crash rates can also be calculated, as described above.

Pedestrian and bicycle crashes are less frequent than motor vehicle crashes in most communities. However, only a fraction of pedestrian and bicycle crashes are reported to police (Stutts and Hunter 1998). Therefore, in some situations, it can be helpful to consider behaviors associated with pedestrian or bicycle crashes (Zegeer et al. 2004). Also, in some locations, it may be possible to observe behaviors that nearly cause a crash. These "near misses" can help represent the Safety factor in cases where pedestrian and bicycle crash data is unavailable or limited.

There are many variables listed under the Existing Conditions factor category that impact safety, such as traffic speed and roadway/intersection lighting. Agencies should consider including these variables if safety is a priority and may choose to do so under either the Safety or Existing Conditions factor.

Existing Conditions

Existing Conditions variables (Table 6) represent the characteristics of roadways and crossings. The identification of appropriate Existing Conditions variables depends on the prioritization purpose. For example, an effort to prioritize locations for new pedestrian signal heads would include crossing-specific variables, while a process focused on sidewalk gap prioritization would not. When selecting variables for the Existing Conditions category, it is not necessary (or advisable) to use all of the variables identified in Table 6. Instead, variables should be chosen carefully based on what is important to local stakeholders, data availability, and what variables provide differentiation between improvement locations.

Existing research and tools for evaluating bicycle and pedestrian level of service, comfort, and traffic stress can provide guidance when selecting Existing Conditions variables. The *Highway Capacity Manual* (HCM) Multimodal Level of Service Methodology includes Pedestrian Level of Service and Bicycle Level of Service tools to evaluate the suitability of roadway segments and intersections for walking and bicycling (Dowling et al. 2008). The Bicycle Level of Traffic Stress also provides a method for assessing the level of comfort for bicyclists on roadway segments and intersections (Mekuria et al. 2012).

Safety-based guidelines and tools, such as the FHWA marked crosswalk guidelines (Zegeer et al. 2005), the FHWA Pedestrian Intersection Safety Index and Bicycle Intersection Safety Index (Carter et al. 2006), and the FHWA Crash Modification Factors Clearinghouse (FHWA 2014) are also useful for informing the analysis of existing conditions. Variables used in these tools, such as the presence of a raised median or a right-turn-on-red restriction could be used as Existing Conditions variables.

Appendix C provides references for example Existing Condition variables listed in Table 6. Table 6 and Appendix C show how example Existing Condition variables correspond with variables used in common pedestrian and bicycle suitability assessment tools. For more design guidance on these variables and further support for including them in a prioritization process, see references such as the *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities* (2004), *AASHTO Guide for the Development of Bicycle Facilities* (2012), *FHWA Pedestrian Safety Guide and Countermeasure Selection System* (2013), *FHWA Bicycle Safety Guide and Countermeasure Selection System* (2014), *NACTO Urban Bikeway Design Guide* (2012), and *NACTO Urban Street Design Guide* (2013).

Demand

Demand (Table 7) can be evaluated directly with variables such as pedestrian or bicycle counts and pedestrian or bicycle mode shares from household surveys. It is becoming more common for jurisdictions to conduct counts of pedestrian and bicyclists. However, neither counts nor surveys identify areas where more people would be walking or bicycling if conditions were better (latent demand). Demand can also be represented by proxy variables, such as population density, employment density, and proximity to attractors such as parks, schools, and employment centers.

Table 6. Existing Conditions variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose. Appendix C provides references for the variables listed in this table to assist practitioners in finding additional information.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Traffic speed[1]	●	●	Cr, S, Co
Traffic volume and composition (percentage of heavy vehicles)	●	●	Cr, S, Co
Right-turning traffic volume	◐	●	Cr
Right-turn-on-red restricted/allowed[2]	●	●	Cr
Signal timing (pedestrian and bicycle delay)[3]	●	●	Cr
Type of traffic control (e.g., traffic signal, stop sign)	●	●	Cr
Presence of crosswalk warning signage or beacons	◐	◐	Cr
Number of general-purpose travel lanes	●	●	Cr, S, Co
Number of designated right-turn lanes on the crossing at intersections	●	●	Cr
Total crossing distance	●	●	Cr
Curb radius	◐	◐	Cr
Presence of a median or crossing island	◐	◐	Cr
Presence and utilization of on-street parking[4]	●	●	S, Co
Width of outside through lane	○	●	S, Co
Presence and width of bicycle lanes	●	●	S, Co
Presence and width of paved shoulders	●	●	S, Co
Roadway pavement condition	○	●	S, Co
Presence/degree of separation/buffer separation between modes	●	●	S, Co
Frequency of driveway crossings	◐	●	S, Co
Presence and width of buffer between sidewalk and moving traffic	●	○	S, Co
Presence and width of sidewalk	●	○	S, Co
Presence of traffic calming measures (chicanes, speed humps, etc.)	◐	◐	Cr, S, Co

Existing Conditions Variable Notes:

[1]**Traffic Speed.** As motor vehicle speeds and volumes increase, pedestrians and bicyclists feel less comfortable walking and bicycling along roadways. Higher vehicle speeds result in less driver reaction time (higher potential for crashes) and more severe injury from vehicle collisions with pedestrians or bicyclists. Both pedestrians and bicyclists are more comfortable when they have more separation from moving motor vehicle traffic. More frequent driveways along a roadway segment (especially busy commercial driveways) increase the potential for conflicts between vehicles and pedestrians/bicyclists and may also reduce the level of comfort for pedestrians and bicyclists.

[2]**Right-Turn-on-Red Restricted/Allowed.** Right-turn-on-red restrictions are also important to consider because they have been associated with significant pedestrian and bicycle crash reductions (FHWA 2014).

[3]**Signal Timing (pedestrian and bicycle delay).** The length of time pedestrians are required to wait at a signalized crossing (delay) also impacts safety—the longer the wait time, the more likely it is that the pedestrian or bicyclist will cross the street against the signal.

[4]**Presence and Utilization of On-Street Parking.** The presence of occupied on-street parking tends to affect pedestrians and bicyclists differently. A line of parked cars provides a physical barrier between moving traffic and pedestrians, so it improves pedestrian comfort. However, on-street parking creates a risk of car doors being opened in front of bicyclists, which reduces bicyclist comfort.

Table 7. Demand variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose. Appendix C provides references for the variables listed in this table to assist practitioners in finding additional information.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Population density	●	●	S, Cr, Co, A
Employment density	●	●	S, Cr, Co, A
Commercial retail property density/proximity	●	●	S, Cr, Co, A
Transit station or stop density/proximity	●	●	S, Cr, Co, A
Density/proximity of attractors (grocery stores, restaurants, coffee shops, banks, parks, schools)	●	●	S, Cr, Co, A
Proximity to college/university campuses	●	●	S, Cr, Co, A
Bicycle facility density/accessibility (e.g., multi-use trail, bicycle lane, cycle track, bicycle boulevard)	○	●	S, Cr, Co, A
Number of boardings at transit stops	●	◐	S, Cr, Co, A
Proportion of residents living in poverty or without access to an automobile (NOTE: Socioeconomic characteristics may also be included under the Equity factor)	◐	◐	S, Cr, Co, A
Evidence of a worn path (in locations where sidewalks are missing)	◐	○	S, Co
Density/proximity of bike-share docking stations	○	◐	S, Cr, Co, A
Roadway slope	○	●	S, Co
Roadway density/connectivity	◐	●	A

Pedestrian Demand

Pedestrian demand tends to be fairly localized and is largely driven by the distribution and density of land uses that attract pedestrians. Several regression models have been created to estimate pedestrian volumes at intersections based on proxy variables (Schneider et al. 2012). The most common, statistically-significant proxy variables identified in existing pedestrian volume models are listed as "very relevant" in Table 7.

Bicycle Demand

In contrast to pedestrians, bicyclists typically travel longer distances, so the area from which a particular attractor may draw bicyclists from is larger. According to weighted data from the 2009 National Household Travel Survey (NHTS), approximately three-quarters of reported pedestrian trips are shorter than one mile. By contrast, approximately three-quarters of reported bicycle trips are shorter than three miles (FHWA 2009). Therefore, the demand for bicycling around a particular attractor (e.g., school, shopping district, transit station) should be assessed with a larger buffer than is used for pedestrian demand.

Bicycle facilities such as multi-use trails, cycle tracks, bicycle lanes, and bicycle boulevards may have a strong influence on bicycle demand in certain corridors because some bicyclists are willing to divert from the shortest possible route to use these facilities (Dill and Gliebe 2008).

Regression models have been developed to estimate bicycle volumes at intersections (Griswold et al. 2011). Common proxy variables for bicycle demand were identified and are listed as example variables for this methodology in Table 7.

Appendix C provides references for each of the example Demand variables listed in Table 7.

Connectivity

Connectivity variables (Table 8) represent the degree to which a particular improvement location relates to and improves the functionality of the existing pedestrian or bicycle facility network. Roadway network density and intersection density can also be used to represent Connectivity at a broader neighborhood or regional level. These types of density variables represent the number of different routes that pedestrians or bicyclists can travel from one location to another. Pedestrian and bicycle routes are generally more direct when there is a denser, more connected roadway system.

Equity

Equity includes socioeconomic variables that are integrated into the prioritization process to ensure pedestrian or bicycle improvements provide access to vulnerable populations or areas with low-income and/or minority populations. Data for these variables come from multiple sources, including the American Community Survey, public health agencies, regional planning agencies, and school districts. Socioeconomic data are typically collected from household surveys. Therefore this information is readily available for geographic areas (e.g., census tract or block group, jurisdictional boundaries). An entire area may be prioritized for pedestrian or bicycle improvements based on socioeconomic variables, or a specific corridor or intersection improvement that is located within a given underserved area may be prioritized. For example, areas with vulnerable populations (e.g., persons with disabilities, seniors, and children) may be target areas for curb ramp upgrades, median crossing islands, or special treatments such as leading pedestrian intervals.

Equity-related variables such as income and car ownership are also related to pedestrian and bicycle demand. For example, low-income populations typically rely more on transit and

Table 8. Connectivity variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Intersection density (number of four-leg intersections per square mile—represents the connectivity of the street network as a whole)	●	●	Co, A
Roadway segment density (miles of roadway per square mile—represents the connectivity of the street network as a whole)	●	●	Co, A
Pedestrian/bicycle barrier (e.g., heaved sidewalk sections, utility poles in sidewalk, no pedestrian/bicycle detection/activation at signalized crossing, no safe access across high-volume/speed road)	●	●	S, Cr, Co
Pedestrian/bicycle facility coverage (percentage of roadways with sidewalks/bicycle facilities)	●	●	Co, A
Connects to an existing pedestrian/bicycle facility	●	●	S, Cr, Co

Table 9. Equity variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Household automobile ownership	●	●	S, Cr, Co, A
Household income	●	●	S, Cr, Co, A
Percent unemployed	●	●	S, Cr, Co, A
Proportion of population under age 18	●	●	S, Cr, Co, A
Proportion of population over age 64	●	○	S, Cr, Co, A
Proportion of population with physical disabilities	●	○	S, Cr, Co, A
Minority populations	●	●	S, Cr, Co, A
Proportion of school children receiving subsidized lunches	◐	◐	S, Cr, Co, A
Proportion of population with asthma or diabetes	◐	◐	S, Cr, Co, A
Proportion of population that is overweight or obese	◐	◐	S, Cr, Co, A

walking, so the need for pedestrian facilities in neighborhoods with low-income households is higher. Table 9 provides a list of equity variables and their applications.

Many agencies are also concerned with geographic equity. These geographies may be defined by neighborhood boundaries, sectors or districts, municipal boundaries, county boundaries, or regional boundaries. Agencies can address geographic equity by:

- Assigning each improvement location an identifier that corresponds to its geographic area. The final prioritized list can then be sorted by geography and high-ranking improvement locations from each geographic area can be selected for implementation.
- Prioritizing geographic areas separately. For example, if an agency has four sub-areas, it could do a separate prioritization process for each sub-area. The agency could then make a separate policy decision about how much funding or resources to dedicate to each sub-area.

Compliance

Compliance variables (Table 10) indicate whether or not an improvement location meets current standards or guidelines. Compliance variables correspond with specific facility types such as sidewalks, curb ramps, and bike lanes. For some facilities such as curb ramps, compliance may be central to the prioritization purpose.

Step 5: Assess Data

The availability of data is a critical consideration in determining what variables to include in a prioritization exercise; data availability varies substantially across cities, towns, counties, metropolitan planning organizations (MPOs), and state DOTs. In an ideal world, data would be available in an easy-to-use format to represent all variables that are relevant and important to a given

Table 10. Compliance variables.

Example Variables	Relevance		Potential Location
	Ped	Bike	
Note: The relevance designations in this table are meant to provide general guidance. Ultimately, variable relevance depends on the prioritization purpose. Agencies are encouraged to review each variable and consider how relevant it may be considering their purpose.	● = Very relevant ◐ = Less relevant ○ = Not likely relevant		S = Segment Cr = Crossing Co = Corridor A = Area
Facilities not compliant with local, state, and federal design requirements or guidelines	●	●	S, Cr, Co
Sidewalk condition—segments that are not compliant with accessibility guidelines (e.g., clear width obstructions, vertical heave obstructions)	●	○	S, Co
Curb ramps that are not compliant with ADA guidelines (e.g., excessive slopes, lack of level landings)	●	○	Cr, Co, A
Bicycle facilities that are not compliant with national or state bicycle design guidelines or standards (e.g., AASHTO, NACTO)	○	●	S, Co, A

agency/community and project type; however, this is usually not the case. Data availability may constrain the possible options for prioritization. In addition, the availability of technical resources [e.g., technological tools such as geographic information system (GIS) and staff capabilities] may also determine what data can be used, and therefore, the breadth of prioritization options. The initial scoping effort (Phase I) typically involves an iterative approach in which data and technical capabilities lead to rethinking or reframing the original purpose, factors, and variables. Assessing technical resources is discussed in more detail under Step 6.

This section describes types of data that may be used to express the variables identified in Step 3 and offers guidance on sources of these data, including collecting new data, where necessary. The data assessment process is illustrated in Figure 4.

Data collection may occur both in Step 5 and Step 8. In Step 5, after an agency assesses its available data and identifies any data gaps, it may choose to revisit the selected variables and choose a suitable proxy variable for which it has data.

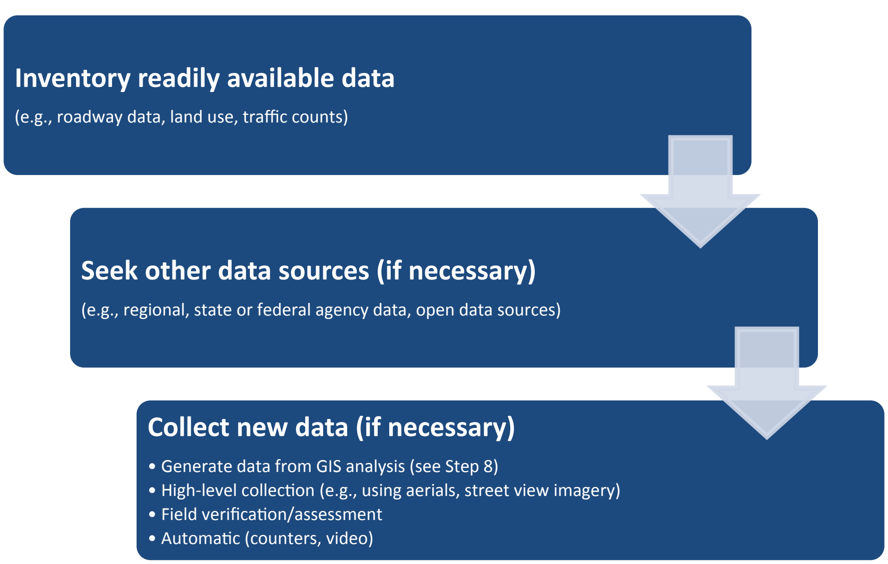


Figure 4. Data assessment process.

Alternatively, in Step 8, when an agency must input data into its prioritization tool, it may acquire data from other sources, generate data using GIS or other tools, or collect new data using other methods. Other potential sources include data that may have been collected by an agency for a different purpose; data that resides in a different department within the same organization (e.g., location of park facilities); or sources external to the organization, such as an MPO, school district, transit agency, or a data aggregator such as Data.gov.

Below is a discussion of the data that may be most appropriate for expressing variables identified under each factor category (Step 3). Tables provide a summary of potential data sources and/or methods for collecting or generating data for each key variable. The guidance is intended to help agencies be strategic about fulfilling their data needs. **It is important to keep in mind that a higher number of variables does not necessarily result in a more thorough prioritization.**

Stakeholder Input Data

Stakeholder input may be incorporated into the prioritization process both quantitatively and qualitatively (Table 11). The number of public comments/requests regarding a particular issue or facility may be documented and inputted as a raw data value. Qualitative stakeholder input such as staff knowledge of constraints and opportunities, political support, etc. is also valid to incorporate into a prioritization process. While qualitative stakeholder input data may also be incorporated into the scoring process, it may be more effectively used as a pre- or post-screen. For example, among 10 ranked improvement locations, those that have been vetted by staff from a feasibility point of view, or have strong support of an advisory committee or decision-making body may be moved to the top of the list.

Constraint Data

Most constraints can often be expressed in terms of monetary units for labor, time, materials, land acquisition, and other costs. However, in many cases, accurate costs require considerable effort to develop, and if the list of projects to be prioritized is long, it may not be possible

Tip: Regional Agencies

Regional agencies relying on local data to prioritize pedestrian or bicycle projects may face challenges related to the consistency of data across a region. For example, data may be available in some jurisdictions, but not others, or data may be formatted differently from jurisdiction to jurisdiction. Because of these inconsistencies, regional agencies may be forced to omit certain factors or variables they may want to use in a prioritization effort or commit resources to process or collect data in order to have consistent datasets.

Many regional agencies have Census, population, or employment data as well as police crash reports that can be used to evaluate the Demand and Safety factors. In addition, Stakeholder Input (e.g., is a project identified in a local plan) may be another factor regional agencies could easily include. Regional agencies may also have a unique perspective on opportunities such as planned projects at the state or local level that may have regional significance and choose to include these considerations under the Opportunities or Connectivity factors.

Table 11. Data considerations/sources for Stakeholder Input variable examples.

Example Stakeholder Input Variable	Data Considerations/Sources
Number of public comments about specific issue received by phone or online from citizens	Requests/complaints compiled on a map or in a database
Identification/inclusion of a particular facility or location in adopted plans	Comprehensive plans, master plans, transportation plans, etc.
Number of comments received at public meetings or through a public survey during a master planning process	Comments compiled on a map or in a database
Supported by advisory committee or decision-making body	Documentation such as meeting minutes, memoranda

to develop these cost estimates for every project. Therefore, in some cases, it may be useful to express constraints as an order of magnitude (e.g., low, moderate, high). Table 12 shows data considerations/sources for potential Constraints variables.

Opportunities Data

Data that are used to measure opportunities (Table 13) may be quantitative (e.g., amount of available funding) or qualitative (e.g., potential for development). As described earlier, opportunities are often studied separately through a cost/benefit analysis. However in situations where opportunities can be quantified as part of a prioritization process, the data sources below should be considered.

Table 12. Data considerations/sources for Constraints variable examples.

Example Constraints Variable	Data Considerations/Sources
Project implementation cost (including design, engineering, and construction costs, right-of-way availability, utility relocation)	Planning-level cost estimates; costs of comparable projects, or an actual cost estimate specific to a project. The Pedestrian and Bicycle Information Center (PBIC) has information on typical costs and cost considerations for different types of pedestrian and bicycle improvements. Alternatively, an order of magnitude cost (e.g., low, moderate, or high) may be used as long as it is made clear what each level means, and some adjustments are made for projects of different scales (i.e., a per-mile cost).
Presence of environmental or historic features that may create significant barriers to construction	Staff/agency knowledge or experience. Requires an understanding of regulatory requirements. Other sources of information may include mapped critical areas (e.g., streams, wetlands, steep slopes), previous environmental studies that encompass the improvement location.
Staffing (time needed to plan and implement projects)	Staff/agency knowledge or experience. Requires an understanding of all project components and staff time (or contractor services) needed to address each component.
Multi-jurisdictional coordination	Staff/agency knowledge or experience. Requires an understanding of plans and processes of overlapping or adjacent jurisdictions and time for coordination.
Life-cycle/maintenance costs	Staff/agency knowledge or experience. Requires an understanding of material life-cycles and maintenance considerations; public works staff may be able to provide insights and estimates.

Table 13. Data considerations/sources for Opportunities variable examples.

Example Opportunities Variable	Data Considerations/Sources
Projects that are candidates for a specific funding source (e.g., grant, targeted improvement fund)	Knowledge of grant sources and focus area, as well as funding levels
Projects that could be implemented through future land development or roadway construction	Development applications and permits, knowledge of regional projects, priorities, and working with partners
Planned roadway improvements that may accommodate pedestrian or bicycle facilities (e.g., repaving or reconstruction projects)	Knowledge of capital improvement plan and timing of planned roadway improvements

Safety Data

Pedestrian and bicycle crashes and injury severity are likely to be important variables under the Safety factor. Crash data typically consists of records of reported crashes. In order to be useful on a large-scale basis, these data must be geocoded (mapped) to specific locations. Pedestrian and bicycle crash data are often available from police crash databases (see Table 14). As stated previously, these databases include only crashes that are documented in police reports, so they tend not to capture crashes that do not involve a motor vehicle (e.g., falls, collisions with objects), or in some cases minor collisions between motor vehicles, pedestrians, and bicyclists (Stutts and Hunter 1998; Aultman-Hall and LaMondia 2004). In many communities, pedestrian and bicycle crashes in parking lots and on other private property are also not captured by police crash reports. In some cases, state DOTs or MPOs aggregate and organize crash data and provide crash datasets to local agencies.

Table 14. Data considerations/sources for Safety variable examples.

Example Safety Variable	Data Considerations/Sources
Total number of pedestrian/bicycle crashes	Police crash database, often available at the state or local level
Fatal and severe injury pedestrian/bicycle crashes	Police crash database, often available at the state or local level
Pedestrian/bicycle crash rate	Police crash database combined with measure of exposure (e.g., pedestrian/bicycle counts, pedestrian/bicycle demand proxy variables)
Proportion of pedestrians walking in the roadway	Pedestrian counts (generally manual counts in the field, with instruction to note pedestrians in roadway)
Proportion of pedestrians complying with “Don’t Walk” signals	Pedestrian counts (generally manual counts in the field, with instruction to note “Don’t Walk” compliance)
Proportion of bicyclists complying with red lights	Bicycle counts (generally manual counts in the field, with instruction to note red light compliance)
Proportion of motorists complying with right-turn-on-red restrictions	Vehicle counts (generally manual counts in the field, with instruction to note right-turn-on-red movements)
Proportion of motorists yielding to pedestrians in crosswalks	Vehicle counts (generally manual counts in the field, with instruction to note yielding rates)
Number of “near misses” involving pedestrians/bicyclists	Multimodal counts (generally manual counts in the field, or based on video footage of a location)

As discussed under Step 4 (Select Variables), the Safety factor may also be expressed using the crash rate, which is dependent upon exposure measures, such as pedestrian and bicycle counts, motor vehicle counts, or combinations of variables in the Demand category.

Since pedestrian and bicycle crashes are relatively infrequent, most communities should use several years of data to identify crash patterns. As a rule of thumb, patterns of pedestrian or bicycle crashes can be identified from three to five years of data, depending on the overall number of crashes each year. In general, communities should not consider more than 10 years of crash data, since older data may not reflect changes in pedestrian activity patterns or pedestrian facility improvements.

Obtaining Additional Safety-Related Data

When gathering pedestrian or bicycle crash data, agencies should consider the following steps:

1. Identify how many years of data are needed.
2. Get the crash data from an agency that has already mapped it.
3. If no data is available from existing sources, map crash locations using police reports. The FHWA Pedestrian and Bicycle Crash Analysis Tool (Harkey et al. 2006) can be applied to identify specific crash types.
4. Understand the limitations of the data. For example, police report assessments of injury severity may not be reliable and police officers may not file reports for all crashes involving pedestrians and bicyclists.

Field data collection is typically required to document behaviors that are associated with pedestrian or bicycle crashes and to observe "near misses." As a result, data for this type of surrogate Safety variable is often expensive to collect, and may only be feasible to use when prioritizing a small number of projects or locations.

A number of agencies, including Fort Collins, CO, and Madison, WI, have developed "close-call" reporting mechanisms that allow pedestrians or bicyclists to use a telephone hotline or website to report incidences in which their safety was compromised. Because bicycle- and pedestrian-related crashes are typically underreported, such mechanisms offer another way to collect safety-related data and address issues before they result in a crash. Self-reporting apps for smart phones have also been developed in a number of locations (e.g., the "Bike Accident Toolkit" app initially developed for Boston University). These apps allow users to efficiently capture important information following a crash or near-crash, and to indicate if the problem is related to a physical hazard in the roadway or a design issue that needs to be addressed.

Existing Conditions Data

The Existing Conditions factor encompasses many potential variables as described in Step 4. The data chosen for this factor will depend (perhaps more than any other factor) on the prioritization purpose. Data used to express the variables identified in Step 4 are typically compiled into datasets that contain multiple values representing different aspects of the roadway (Table 15). For example, roadway data may include pavement width, channelization, average daily traffic (ADT), and speed data that would be useful for a variety of pedestrian and bicycle prioritization purposes. In addition to roadway or centerline data, agencies may have specific inventories for infrastructure such as sidewalks, curb ramps, pedestrian signals, signage, crosswalks, and bicycle facilities. Agencies may not have complete inventories of these facilities for all locations being considered in the prioritization process. In cases for which no data or partial inventories are available, agencies may need to collect additional data or choose different variables that do not require the missing data. In some cases, it may be possible to identify a suitable proxy with complete data for all improvement locations.

Table 15. Data considerations/sources for Existing Conditions variable examples.

Example Existing Condition Variable	Data Considerations/Sources
Traffic speed	Posted speed as surrogate for actual speeds, or 85th percentile speeds based on speed studies
Traffic volume and composition (percentage of heavy vehicles)	ADT or annual average daily traffic (AADT) with percent truck volumes, often found in street centerline database
Right-turning traffic volume	May be attribute data within traffic volume database, but more typically obtained from targeted traffic study
Right-turn-on-red restricted/allowed	May be attribute of signal database, sign inventory
Signal timing (pedestrian and bicycle delay)	May be attribute of signal database
Type of traffic control (e.g., traffic signal, stop sign)	Signal database, sign inventory, street-level imagery
Presence of crosswalk warning signage	Sign inventory, street-level imagery
Number of general-purpose travel lanes	Typically an attribute within street centerline data, aerial imagery
Number of designated right-turn lanes on the crossing at intersections	Typically an attribute within street centerline data, channelization plans, aerial imagery
Width of outside through lane	Typically an attribute within street centerline data, aerial imagery
Roadway pavement condition	Pavement Condition Index or Survey, or must be field-collected
Total crossing distance	Curb-to-curb width typically an attribute within street centerline data, aerial imagery
Curb radius	Aerial imagery, or must be field-collected
Presence of a median or crossing island	May be attribute data within street centerline data, aerial imagery
Location is a transition between on-road and off-road bicycle facilities	Bicycle facility inventory data, aerial imagery
Presence and utilization of on-street parking	On-street parking lanes may be attribute data within street centerline data or a parking inventory, sign inventory may be used to identify parking presence or restrictions, parking utilization may be available where networked pay stations are in use, otherwise typically generated through field-based parking studies
Presence and width of bicycle lanes	May be attribute data within street centerline data or bicycle facility inventory, aerial imagery, or must be field-collected
Presence and width of paved shoulders	May be attribute data within street centerline data, aerial imagery
Presence/degree of separation/buffer separation between modes	May be attribute of sidewalk inventory, street centerline data, aerial imagery, or must be field-collected
Frequency of driveway crossings	Typically generated through field studies or aerial imagery
Presence and width of buffer between sidewalk and moving traffic	May be attribute of sidewalk inventory, street centerline data, aerial imagery, or must be field-collected
Presence and width of sidewalk	Sidewalk inventory, gap inventory (may be complete inventory or inventory targeted to specific purpose); street centerline data, aerial imagery
Presence of traffic-calming measures (chicanes, speed humps, etc.)	Aerial imagery, or specific database that has been created to inventory traffic calming measures
Sidewalk condition	Sidewalk inventory, gap inventory (may be complete inventory or inventory targeted to specific purpose), or must be field-collected

Existing Conditions datasets are commonly in digital format (spreadsheet or GIS), but some agencies may have data available only in hard copy. Depending on the level of complexity of the prioritization purpose (i.e., number of improvement locations, number of factors, number of variables), hard copy data may need to be digitized so it can be used in either a spreadsheet-based or GIS database prioritization tool.

Obtaining Additional Data to Measure Existing Conditions

Depending on the prioritization purpose and the variables that are selected, additional Existing Conditions data may be inventoried by a local agency for use in the prioritization process. Some of the desired data may be possible to collect from free, online imagery sources or through GIS analysis, while other data may require direct field observations.

Data collection often requires consideration of resources in terms of staff or contract labor. In general, inventories that can be completed using aerial imagery are less expensive than inventories from street-level imagery and much less expensive than inventories requiring direct field observations. Examples of inventories that might be completed using aerial imagery include sidewalk and bike facility inventories. Examples of inventories that might be completed using street-level imagery include the presence of signs, street furniture, or curb ramps. Collection of data in the field may be required for things such as curb ramp ADA compliance, curb radius, and sidewalk condition. Data elements such as traffic volumes and speeds and turning movements may be collected using automated technologies. While online imagery sources can save time and effort, measurements from these images are not as precise as field measurements and the images may be dated.

Table 16 suggests data sources or tools that can be used to inventory data for Existing Conditions variables.

Detailed roadway data may be impractical to consider for prioritization efforts that cover large geographic areas. Therefore, general roadway network characteristics can be calculated or

Table 16. Data sources/tools for inventorying data and related Existing Conditions variable examples.

Inventory Data Source/Tool	Can Be Used to Inventory Data for These Variables
Aerial imagery	• Sidewalk and buffer presence and width • Marked crosswalk presence and type • Median island presence and width • Bicycle facility presence and width • Lane width/shoulder width • Pedestrian crossing distance
Street-level imagery (e.g., video log, street view)	• Curb ramp presence • Truncated domes presence • Pedestrian/bicycle-related signage • Major sidewalk obstructions • Pedestrian signal heads • Pedestrian push buttons
Direct field observation (using technological data collection tools or manual observations)	• More precise lane width/shoulder width • Traffic volume • Traffic speed • Sidewalk condition • Crosswalk condition • Pavement condition • Curb ramp slope • On-street parking presence and occupancy

estimated for an entire neighborhood or district. Examples of general roadway network measures include:

- Percentage of households within X miles of a bikeway or walking route.
- Percentage of roadways with sidewalks on both sides (pedestrian).
- Percentage of roadways with sidewalks on one side (pedestrian).
- Percentage of roadways with no sidewalks (pedestrian).
- Percentage of arterial roadways with a designated bicycle facility (bicycle).
- Ratio of bicycle facility miles (including multi-use trails) to total roadway miles (bicycle).
- Percentage of roadways that are arterial roadways (pedestrian/bicycle).
- Percentage of roadways that have more than two lanes (pedestrian/bicycle).

These measures are often suitable for initial prioritization between neighborhoods or districts before a more specific prioritization process is undertaken within certain focus areas.

Demand Data

Pedestrian and bicycle demand can be measured directly through counts and surveys or through proxy data, such as population density and employment density.

Data Used to Measure Demand Directly

Demand can be measured directly using counts or survey data. Table 17 shows the differences between the two data sources.

One national-level data source, the ACS, gathers enough data over a five-year period to estimate the number of households without access to a vehicle and the percentage of workers who commute regularly by walking or bicycling in most census tracts in the United States. Census tracts are often small enough to provide neighborhood-level vehicle access data and commute data, either of which can be useful for representing Demand in a prioritization framework. However, it is important to recognize several ACS commute data limitations:

- Commute data include only trips to work. Shopping, recreational, and other types of trips are not represented.

Table 17. Differences between count and survey data to represent demand.

	Data Collection Scale	Information Available	Data Type	Examples
Count Data	Counts of bikes or pedestrians collected at roadway intersections, segments, or crossing locations	Existing activity levels at a specific location	Population (includes all people passing through the count location within a given time period)	Two-hour counts done manually by human counters at a particular location Continuous count data collection using automatic counter technology on a roadway or path segment
Survey Data	Survey data collected from households or individuals at national, state, regional, or local level	Overall pedestrian or bicycle mode share for a community	Sample (the survey polls a representative portion of the population and the results are extrapolated to the whole population)	National Household Travel Survey (NHTS) U.S. Census Bureau's American Community Survey (ACS) Local or regional-level household travel surveys

- Commute data represent only the most common, longest-distance mode that people used to travel to work during the week before the survey. People who walked or bicycled to work one or two days during the previous week and people who walked or bicycled as a part of a longer-distance automobile or public transit commute are not counted among walking or bicycling trips.

At the regional level, several studies have used GPS units to document the spatial travel movements made by survey participants (Dill and Gliebe 2008; Hood et al. 2011). Household Travel Surveys such as the Chicago Travel Tracker Survey (2008) have also collected travel routes using GPS. While GPS route data do not quantify the total number of people using a particular facility, this information can illustrate preferences for particular routes, which may be useful for prioritization.

Data Used as a Proxy for Demand

Demand can also be represented by proxy data. Common demand proxy variables and data sources are listed in Table 18. The practitioner should be aware of correlations that may exist among several of these variables. For example, where population density is high, it is likely that transit boardings are also high. Including correlated variables may result in an overweighting or double counting for the Demand factor.

Table 18. Data considerations/sources for Demand proxy variable examples.

Example Demand Proxy Variable	Data Considerations/Sources
Population density	Population of given geography divided by its area
Employment density	Employment is often compiled at the regional level and made available to local agencies by request from the Census Transportation Planning Package for traffic analysis zones. Density is calculated by dividing the number of employees by a measure of area Longitudinal Employer-Household Dynamics (LEHD) is another U.S. Census program that can provide employer/employee data estimates.
Commercial retail property density/proximity/accessibility	Parcel data
Transit station or stop density/proximity/accessibility	Point data typically maintained by transit agency
Density/accessibility/proximity of key attractors (schools, parks, community facilities)	Parcel data, point data layers for specific land use attractor types
Proximity to college/university campus	Parcel data
Bicycle facility density/accessibility	Facility inventory
Presence of sidewalk	Sidewalk inventory
Roadway density/connectivity	Street centerline data
Roadway slope	May be calculated using topographical data and length of segment, may also be part of street centerline data
Number of boardings at transit stops	Daily, monthly, or annual boardings may be available from the transit agency, or may be an attribute of stop location point data or transit route data; may include patrons with bicycles.
Socioeconomic characteristics (e.g., proportion of neighborhood residents living in poverty or without access to an automobile)	U.S. Census data (block group-level data may be most appropriate for projecting demand). Note: This type of data may also be used for variables within the Equity factor.
Proximity to or number of bike share docking stations	Point data layer of bike share stations

Obtaining Additional Data to Measure Demand

If a local agency does not have population density, employment density, or land use data, the county or regional planning agency may have some or all of this data available and may be able to provide it in a format that is usable for the prioritization process.

Guidance on methods and technologies for collecting pedestrian and bicycle count data has been developed (NCHRP 07-19; *NCHRP Report 797*) and is available through the Transportation Research Board.

Tools such as Walk Score, Bike Score, and Google Maps (discussed in more detail under Step 6), may also be used to provide data values and estimate demand for pedestrian and bicycle improvements.

Connectivity Data

Determining the degree to which a proposed pedestrian or bicycle facility improvement enhances Connectivity (i.e., the functionality of the pedestrian or bicycle network) is dependent upon having an accurate inventory of existing facilities and/or knowledge of barriers and facility gaps. Assessing pedestrian connectivity usually requires having a sidewalk inventory, which may include detailed information on the condition of existing sidewalks. For bicycles, assessing connectivity usually requires having an inventory of existing bicycle facilities, and perhaps additional knowledge of streets that are most suitable or utilized for biking. The latter information may be obtained through a planning process, through surveys, or through interactive mapping tools (Table 19).

Obtaining Additional Data to Measure Connectivity

Aerial imagery tools may be used to collect pedestrian and bicycle inventory data (see Step 6 for more information). Some agencies have used volunteers or paid staff to collect pedestrian facility extent data (Schneider et al. 2005). Such collection efforts may be citywide or focused in specific areas (e.g., within a half mile of all schools), and may include multiple attributes, such as sidewalks, pedestrian signals, curb ramps, lighting, crosswalks, and signage.

Table 19. Data considerations/sources for Connectivity variable examples.

Example Connectivity Variable	Data Considerations/Sources
Intersection density (represents the connectivity of the street network as a whole)	Street centerline data—number of intersecting roadway segments per square mile: three-way may be distinguished from four-way
Roadway segment density (represents the connectivity of the street network as a whole)	Street centerline data—miles of roadway per square mile
Pedestrian/bicycle barrier (e.g., non-ADA-compliant sidewalk sections, no pedestrian/bicycle detection/activation at signalized crossing, no safe access across high-volume/speed road)	May be attribute of sidewalk inventory or derived from field assessment, bicycle facility inventory, signal database, documented resident request/complaint
Pedestrian/bicycle facility coverage (percentage of roadway with sidewalks/bicycle facilities)	Pedestrian/bicycle facility as percentage of centerline mileage in defined geographic areas from a sidewalk or bikeway facility inventory and street centerline data
Connects to pedestrian/bicycle facility	Sidewalk or sidewalk gap inventory, bicycle facility inventory, signal database, or derived from field assessment, documented resident request/complaint

Table 20. Data considerations/sources for Equity variable examples.

Example Equity Variable	Data Considerations/Sources
Household automobile ownership	U.S. Census, ACS
Household income	U.S. Census, ACS
Proportion of population under age 18	U.S. Census, ACS
Proportion of population over age 64	U.S. Census, ACS
Proportion of population with physical disabilities	U.S. Census, ACS
Proportion of children receiving subsidized lunches	School district enrollment data
Proportion of population with asthma or diabetes	Public health agency community surveys or health profiles (geographic extent of this data may vary considerably)
Proportion of population that is overweight or obese	Public health agency community surveys or health profiles (geographic extent of this data may vary considerably)

Equity Data

Table 20 shows example data considerations and/or sources for Equity variables. Some types of Equity data, such as neighborhood automobile ownership overlap with pedestrian or bicycle demand proxy data. Equity data may be considered at different geographic extents (e.g., sector, neighborhood, within one mile of all schools). Generally, census tract–level data is most appropriate for measuring equity at the neighborhood level. Geography itself may also be an important Equity variable for agencies and the political interests they serve. Census boundaries are available as **Topologically Integrated Geographic Encoding and Referencing** (TIGER) boundary data, which can be downloaded from the U.S. Census website or Data.gov.

Compliance

Some agencies may want to prioritize pedestrian or bicycle improvements based on compliance with accessibility or other guidelines or standards. Many agencies maintain inventories of existing infrastructure that may include information about whether or not a particular feature such as a sidewalk, curb ramp, or bike facility is present, as well as information about the feature's condition (Table 21). Condition information may include whether or not the feature meets current standards or guidelines, such as ADA (PROWAG), AASHTO or NACTO.

Table 21. Data considerations/sources for Compliance variable examples.

Example Compliance Variable	Data Considerations/Sources
Sidewalk segments that are not compliant with accessibility guidelines (e.g., clear width obstructions, vertical heave obstructions)	Sidewalk width or presence of obstruction that results in non-compliant clear width may be attributes of sidewalk inventory; targeted field assessment.
Curb ramps that are not compliant with ADA guidelines (e.g., excessive slopes, lack of level landings)	Curb ramp condition, including ADA compliance may be attribute of a curb ramp or sidewalk inventory; targeted field assessment.
Bicycle facilities that are not compliant with national or state bicycle design guidelines or standards (e.g., AASHTO, NACTO)	Bike lane width may be attribute of bicycle facility inventory or street centerline data; remote or targeted field assessment.

Obtaining Additional Data to Measure Compliance

If existing data are not available, or are only partially complete in terms of geographic scope or needed data fields, some information may be obtained using aerial imagery that is widely available for free through online applications. For example, the presence of curb ramps at intersections, or sidewalks along a given corridor may be obtained by panning through the corridor using street-level imagery. However, other essential Compliance measurements, such as sidewalk cross-slope and vertical discontinuities, almost always need to be obtained from field assessment.

Step 6: Assess Technical Resources

The APT can be used by agencies with a range of available data, staff resources, and technical capabilities. The purpose of Step 6 is to select a technological platform (e.g., spreadsheet, GIS, manual tabulations) that will be used to implement the prioritization process. Each platform has advantages and disadvantages. As part of Step 6, agencies should assess their existing technical resources and capabilities to determine if existing resources are sufficient, or if new resources will be needed. If new resources are not available, then the purpose and/or prioritization variables will need to be modified.

The standard platform for the APT methodology is a spreadsheet (see Phase II discussion). While a programmed spreadsheet has been developed to accompany the APT, and may be used by many agencies, the prioritization framework can be implemented independently of the spreadsheet platform. For example, the framework that is illustrated in the programmed spreadsheet can also be applied using more manual approaches such as on paper or within a word processor application. Alternatively, agencies can use more advanced technologies, such as GIS as a platform for the prioritization process as a whole and to streamline individual components of the prioritization process, for example, to measure geospatial relationships. See Appendix B for guidance on applying this methodology using GIS.

Each of the technological platforms has advantages for prioritization processes with particular characteristics. Table 22 highlights these advantages. Additional information is provided below.

Spreadsheet

A programmed spreadsheet has been developed to accompany the APT, which agencies may use in its "off-the-shelf" form or choose to modify based on their needs. Built-in scaling formulas, weighting, and sorting capabilities of the spreadsheet make it relatively easy to implement the prioritization analysis process. While the programmed spreadsheet includes the nine factor categories and preloaded variables for each factor, the user may modify or add variables based on data availability and change the default weights for each factor category to better reflect community values. In addition, spreadsheet functions can also be used to create new variables. For example, if an agency has the number of pedestrian crashes reported at each intersection during the last five years in one spreadsheet column and the estimated number of pedestrian crossings at each intersection over the last five years in a second column, the spreadsheet can easily divide the first column by the second column for all rows to create a new variable representing crash rate at each intersection.

The prioritization spreadsheet accompanying the APT is organized so that the improvement locations are entered in the left-hand column and the desired prioritization variables (organized by common factor categories) are shown in the top rows, as shown in Figure 5. Data that quantify each variable for each improvement location can be gathered from various sources and

Table 22. Advantages of specific technological platforms in the prioritization process.

Prioritization Process Characteristics	Advantages of Technological Platforms
Process considers a large number of projects or locations and/or project considers many variables.	Electronic spreadsheet and GIS technologies are often more efficient than manual processes for handling large amounts of data.
Variables require spatial queries or other spatial analysis.	GIS can be used to measure these relationships from existing GIS datasets. GIS can do spatial measurements for all prioritization locations simultaneously. Alternatively, spatial relationships may be determined manually using online aerial imagery tools or rectified aerial photography.
New variables are calculated from existing data.	Spreadsheets can copy data efficiently from other existing electronic sources and can be used to calculate new variables. Spatial analysis tools in GIS can also be used to create new variables.
Weights are applied to identify top-priority projects or locations.	Built-in spreadsheet functions are ideal for calculating rankings and sorting projects or locations with the highest priority scores. Note that it is typically easier to do these calculations and sorting tasks in a spreadsheet than on paper or in a GIS database.
Results need to be communicated clearly on maps.	Results of prioritization can be displayed on maps produced by GIS. GIS maps can also show spatial relationships between the prioritization variables and final results, improving transparency of the process.

entered in each cell of the spreadsheet. Each location can be ranked and sorted easily to identify top priorities.

A spreadsheet approach also has several disadvantages:

- For an agency that is not familiar with spreadsheet capabilities, it may take some time to learn how to enter data into a spreadsheet and use spreadsheet techniques, such as sorting functions. In this case, if a prioritization effort is very simple and only involves a small number of locations, it may be preferable to implement the prioritization framework by hand.

		Stakeholder Input	Safety	Demand	
ID	LOCATION	Number of Requests/Comments	Total Bike Crash	Population Density	Proximity to Attractor 1
1	CENTRAL AVE	15	8.0	9539.0	3.0
2	WASHINGTON/JEFFERSON CORRIDOR	10	3.0	9068.0	2.0
3	3RD ST	23	5.0	4664.0	4.0
4	12TH ST	2	7.0	3018.0	4.0
5	15TH AVE	1	5.0	4505.0	4.0
6	ENCANTO BLVD	15	5.0	6586.0	0.0
7	OSBORN RD	21	6.0	8924.0	7.0
8	OAK ST	9	6.0	7426.0	7.0
9	20TH ST	5	8.0	7115.0	8.0
10	3RD/5TH	3	1.0	7084.0	8.0
11	DEER VALLEY DR	8	8.0	8382.0	6.0
12	UNION HILLS DR	12	3.0	9459.0	0.0
13	19TH AVE	14	3.0	6766.0	7.0
14	32ND ST	21	1.0	7858.0	3.0
15	40TH ST	8	4.0	4678.0	5.0

Figure 5. Example spreadsheet prioritization application.

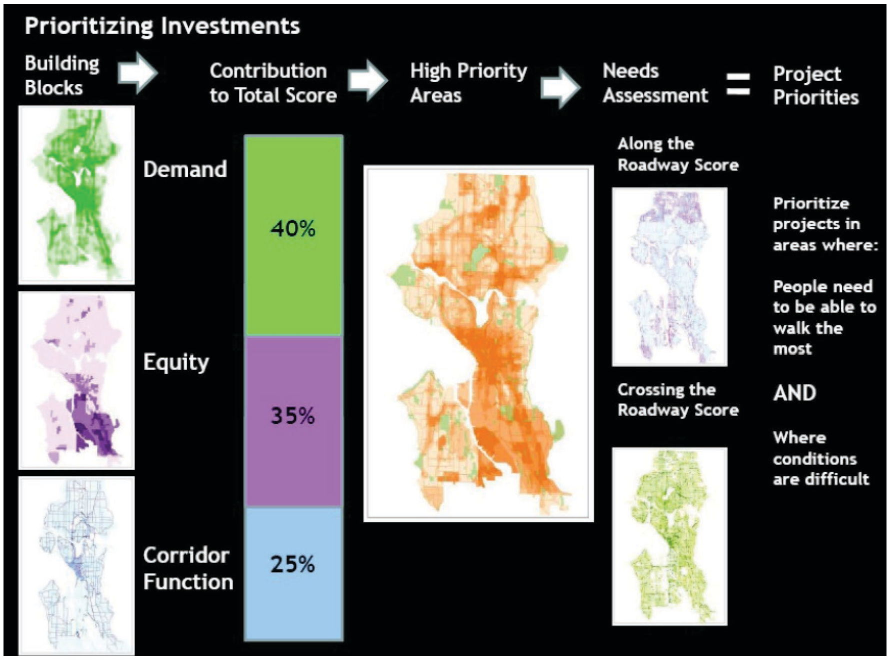
- Using a spreadsheet allows users to perform calculations and functions that may not be readily transparent to a public audience.
- On its own, a spreadsheet may not communicate top priorities as quickly and clearly as a map.

Geographic Information Systems

GIS is a tool that can be used to organize data, conduct spatial analysis, and create maps that display data and prioritization results. With these capabilities, GIS can improve the prioritization process by making data collection, measurement, organization, and analysis more efficient, particularly for large datasets and complex analyses. GIS has the added value of enabling the user to run multiple analyses and to change the parameters of an analysis easily. Because of this, many planning departments at the local, regional, and state level are familiar with GIS.

GIS is useful for organizing and measuring data and spatial variables. For example, all of the intersections within a council district can be grouped together, or street segments can be numbered from west to east. Many prioritization variables can also be created in GIS because they have a spatial dimension. For example, the density of employment within a 0.25-mile radius of each improvement location, the distance between each improvement location and the closest rail station, and the number of retail stores within a 0.25-mile radius of each improvement location are variables that require spatial measurement. GIS can measure distances, measure areas, create buffers at a certain distance from an improvement location, count the number of points within buffers, and do other spatial calculations that are helpful in prioritization processes. Further, GIS can do spatial measurements for an entire set of prioritization locations at once. The results of these measurements can be entered into a GIS database simultaneously rather than one by one, saving significant time.

GIS can be an effective tool for presenting individual components and results of the prioritization process. GIS maps help make the prioritization approach easier to visualize and understand. For example, individual maps can be created to show spatial relationships between high and low values of individual prioritization variables. For example, one map may show locations near key destinations, and another map may show socioeconomic factors (Figure 6). Viewing the maps



Source: City of Seattle, 2009

Figure 6. Example GIS prioritization application.

side-by-side can help illustrate why those two variables lead to top-priority sidewalk retrofit projects near high concentrations of employment.

GIS also has several disadvantages:

- GIS software is required and can be expensive, both in terms of the cost of the software and the cost of a GIS specialist who has the skills to use the software.
- Data used to measure variables in the prioritization process must be in GIS format or geocoded into a GIS-compatible format. Basic roadway and transit route data are often available in GIS, but other types of data such as curb ramp locations, sidewalk widths and conditions, and bicycle facility widths and pavement conditions are less common. Entering this kind of data into a GIS database can be time intensive if the number of locations is large.
- Locations that are being considered for prioritization may not be divided into discrete elements in the same way that the GIS data are organized. For example, an agency may want to prioritize several one-mile corridors, but the existing roadway data are divided into separate segments at each intersection. These individual roadway segments need to be aggregated to the corridor level. Therefore, using a GIS framework for prioritization may require manipulating existing GIS files and geocoding new data files into GIS format.
- Although GIS software allows users to manipulate data using mathematical formulas, it does not store the formulas themselves. As a result, it may be difficult for agencies to review calculations for important steps in the prioritization process, such as scaling and weighting, if the calculations for these steps are performed using GIS software.

Spreadsheets tend to be easier than GIS databases for calculating weights, sorting the final list of projects, and producing tables of prioritized locations for reports. Spreadsheets also retain a record of the formulas used to make mathematical calculations, which can be useful when reviewing prioritization calculations. Fortunately, most agencies with GIS capabilities can convert between spreadsheet and GIS database formats easily.

Appendix B offers additional guidance on using GIS when applying the APT.

Hybrid

It is possible to include elements of different technological approaches in a single prioritization process. For example, some data may be collected manually and then entered into a spreadsheet or GIS database for further analysis. Or, it is possible to collect and organize all of the data needed for a prioritization process in a GIS database and then export the database to a spreadsheet for analysis. This allows an agency to take advantage of the spatial organization capabilities of GIS and the computational analysis capabilities of a spreadsheet.

Examples of Use of Other Tools to Measure Variables

As discussed above, spreadsheet and GIS platforms can be used to measure and create new variables during a prioritization process. There are a number of other tools available for free online and from professional sources that may be useful to measure variables (see Step 7 of the prioritization process). Several of these tools can be used to measure individual variables, while others produce a single output that can be used to summarize the influence of a set of variables.

Google Earth

Google Earth is a free tool that is available to anyone with a computer and Internet to access it. It provides aerial imagery of the entire planet as well as a measuring tool that can be used to obtain dimensional data. The images have sufficient resolution in most urban areas of the

United States to allow users to measure the width of streets, sidewalks, lanes, and other features to the nearest foot (in some cases, the nearest half-foot). In addition, it is possible to measure distances between prioritization locations and other visible features, such as libraries, schools, parks, and transit stations. Therefore, agencies can use Google Earth to identify the presence of facilities like sidewalks and bicycle lanes, measure facility widths, and measure other distances and enter this information into a prioritization database. The aerial imagery in certain locations may be several years old, so it may not show roadway changes or new pedestrian and bicycle facilities that have been added recently. For more information on this tool, see http://www.google.com/earth/index.html.

Google Street View

Google Street View provides images of nearly all streets in the United States from the perspective of cameras mounted on top of cars that capture panoramic shots of the street environment. This tool does not have measurement capabilities, but it allows users to see the presence of features along the roadway. For example, signs, traffic signals, and curb ramps can be identified in specific images. Information about these features can be entered into the prioritization database. Note that this particular tool may work well for collecting specific information about a few locations, but it is time-consuming to view many different roadway segments and intersections. In addition, the Street View images may be several years old, so they may not show roadway changes or new pedestrian and bicycle facilities that have been added recently. For more information on this tool, see http://maps.google.com/intl/en/help/maps/streetview/#utm_campaign=en&utm_medium=van&utm_source=en-van-na-us-gns-svn.

Walk Score®

Walk Score is an online tool that computes an index representing the "walkability" of a location in terms of proximity to local amenities. The walkscore.com website can be used to provide the walkability for any address in the United States, Canada, and many other countries. It can also generate a map showing Walk Score values for an entire community. The locations of amenities used to calculate Walk Score values come from sources such as Google, Education.com, Open Street Map, and Localeze, so the values are updated as the locations of amenities change. Therefore, the accuracy of a Walk Score value depends on the information available from these sources.

Agencies that choose to use Walk Score in a prioritization process should not include separate variables for proximity to activities such as commercial retail and parks, since this would cause them to be double-counted (i.e., counted once as a part of the Walk Score value and counted again as individual variables). It should be noted that the specific algorithms for standard Walk Score or Street Smart Walk Score are not described in detail on the Walk Score website at this time. Therefore, the outcomes cannot be adjusted, or fully explained to stakeholders. In addition, the standard algorithm has changed in the last few years and could change again.

Bike Score™

Bike Score is an online tool developed by the same team who developed Walk Score and measures whether a location is good for biking on a scale from 0 to 100 based on four equally weighted components:

- Presence of bike lanes.
- Presence of hills.
- Destinations and road connectivity.
- Bike commuting mode share.

Unlike Walk Score, Bike Score is currently not widely available. Bike Score is being developed for more locations and its development for specific locations can be requested for a fee. See http://www.walkscore.com/bike-score-methodology.shtml.

Professional Planning and Engineering Tools

There are a number of existing planning and engineering tools that can be integrated into the prioritization framework. For example, *NCHRP Report 616* (Dowling et al. 2008) provided pedestrian level of service (LOS) and bicycle LOS models to evaluate the suitability of urban street segments, intersections, and midblock crossings. These LOS models have been adopted in the 2010 HCM. They use several variables included in the Existing Conditions factor category in this methodology to express pedestrian or bicycle suitability on an A (best) through F (worst) scale. Both of these methods provide an assessment of a pedestrian or bicyclist's feeling of comfort or safety given the existing condition of the roadway (methods also exist to measure delay, however these are not frequently used except in extremely congested conditions). While these LOS models provide a way to quantify the effects of a combination of several variables (e.g., number of lanes, automobile volume, sidewalk width, and bicycle lane width) rather than assessing each variable individually, they require collecting and organizing a large amount of data. The initial multimodal LOS developed for *NCHRP Report 616* may also be updated in the future to provide greater sensitivity to certain roadway design variables.

The list below provides examples of professional planning and engineering tools that could be used to create summary variables in particular factor categories:

Safety

- FHWA Crash Modification Factors (FHWA 2014).
- *Pedestrian Environmental Quality Index*, San Francisco Department of Public Health (San Francisco Department of Public Health 2008).
- *Bicycle Environmental Quality Index*, San Francisco Department of Public Health (San Francisco Department of Public Health 2007)

Existing Conditions

- Pedestrian Segment Level of Service, Developed from *NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets* (Dowling et al. 2008)
- Pedestrian Intersection Level of Service, Developed from *NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets* (Dowling et al. 2008)
- Bicycle Segment Level of Service, Developed from *NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets* (Dowling et al. 2008)
- Bicycle Intersection Level of Service, Developed from *NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets* (Dowling et al. 2008)
- Uncontrolled Midblock Crossing Level of Service, Developed from *NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets* (Dowling et al. 2008)
- Low-stress Bicycling and Network Connectivity, MTI Report 11-19 (Mekuria et al. 2012)
- Pedestrian Environmental Quality Index, San Francisco Department of Public Health (San Francisco Department of Public Health 2008)
- Bicycle Environmental Quality Index, San Francisco Department of Public Health (San Francisco Department of Public Health 2007)

Demand

- Local Pedestrian Demand Model Spreadsheets: e.g., San Francisco, CA (Schneider et al. 2012); San Diego County, CA (Jones et al. 2010); Alameda County, CA (Schneider et al. 2009a)

- Local Bicycle Demand Model Spreadsheets: e.g., San Diego County, CA (Jones et al. 2010); Alameda County, CA (Griswold et al. 2011)
- Pedestrian Environmental Quality Index, San Francisco Department of Public Health (San Francisco Department of Public Health 2008)
- Bicycle Environmental Quality Index, San Francisco Department of Public Health (San Francisco Department of Public Health 2008)

Constraints

- BikeCost Tool, Developed from *NCHRP Report 552: Guidelines for Analysis of Investments in Bicycle Facilities* (Krizek et al. 2006)
- Costs for Pedestrian and Bicycle Infrastructure Improvements (Bushell et al. 2013)

The advantage of using an existing, accepted model is that it already incorporates specific weights that reflect the relative importance of each variable, as identified through empirical research.

Phase I: Conclusion

The first six steps of this process (Phase I) are intended to guide agencies and reduce the time needed in setting up an effective prioritization process. These six steps are considered iteratively, which allows agencies to identify factors and variables that are suitable for the data and technical resources available, and vice versa. The initial scoping steps performed in Phase I are implemented in Phase II, which is described in the next section. By the end of Phase I, an agency should be able to:

- Clarify the purpose of the prioritization effort.
- Know the type and number of improvement locations that will be considered for analysis.
- List the variables within each general factor that will be analyzed to determine priorities.
- Identify the data sources that will be used as inputs during the prioritization process.
- Select the type of the technological platform (e.g., text file, spreadsheet, GIS) that will be used to input data and calculate prioritization rankings in Phase II.

ActiveTrans Priority Tool Phase II: Prioritization

The goal of Phase I was to identify a project purpose and consider community/agency values, the availability of data, and technical resources. In Phase I, factors relevant to the identified purpose and variables to represent the applicable factors were also chosen. The goal of Phase II is to apply a prioritization framework that incorporates selected factors and variables and accomplishes the purpose identified in Phase I.

Prioritization is the process of scoring and ranking improvement locations based on identified criteria or variables. Prioritization is sometimes accomplished through an iterative process (Figure 7).

Iterative prioritization processes like these may save time and resources by limiting the data or inputs needed for each successive round. Agencies should evaluate how best to structure the prioritization process given their prioritization purpose, available staff time and resources, and other considerations. However the process is structured, it is likely to include the following key steps:

Step 7: Set Up Prioritization Tool.

Step 8: Measure and Input Data.

Step 9: Scale Variables.

Step 10: Create Ranked List.

These steps are discussed in greater detail below.

Step 7: Set Up Prioritization Tool

Having established the improvement locations, factors, variables, and required data, the next step is to set up a tool to implement the prioritization method. This tool will likely use one of the technological platforms discussed in Step 6 or a combination of these approaches. Regardless of what technological platform is used, the structure of the prioritization tool will be the same: all information is organized in a tabular form.

Starting with a blank table, agencies should set up the prioritization tool using these steps:

1. List all of the improvement locations down the left side of the table. Each improvement location should be given a unique identification number (typically the furthest-left column) and a unique name. For street segments, a unique name may be expressed across three columns: the actual street name in the first column, the intersecting street where the segment starts in the second column, and the intersecting street where the segment ends in the third column. For intersections, a unique name may be expressed in a single column (e.g., Main Street &

Figure 7. Iterative prioritization.

1st Street) or in a separate column for each intersecting street (e.g., Main Street in the first column and 1st Street in the second column).

2. List all of the variables across the top of the table, starting to the right of the unique name column. Each variable should be given a name that is easy to interpret (e.g., "NumCrashes" for the number of crashes, "PedVol" for pedestrian volume). Note that it is good practice to create a separate document (data dictionary) that relates the short variable names to detailed descriptions of the variables. The data dictionary should provide information about what each variable represents, how it was measured, measurement units, and any numeric codes used to represent qualitative characteristics (e.g., 1 = "Good," 2 = "Average," 3 = "Poor"). For each variable, there are likely to be two columns: one for the raw variable data value and one for the scaled variable data value (see Step 9). Variable columns may be grouped under headings for the associated factor category. For example, population density, employment density, and number of bus stops should be grouped together under the Demand factor.
3. If weighting will be applied at the factor level, add columns for the unweighted factor score, the factor weight, and the weighted factor score for each factor. The unweighted factor score is the sum of the scaled variable values divided by the number of variables for the factor. The weighted factor score is the unweighted factor score multiplied by the weight (see Step 3).
4. If weighting will be applied at the variable level, add columns for the variable weight, and the weighted variable value. The weighted variable value is the scaled variable value multiplied by the variable weight.
5. Add two final columns at the right side of the table for the prioritization score and prioritization ranking. The prioritization score will be calculated from the variable values entered for each improvement location. The final prioritization ranking is based on the sorted prioritization scores.

Once the prioritization table is organized it is possible to proceed to Step 8, which entails measuring and/or inputting data into the tool (Figure 8).

Tip: Programmed Spreadsheet

The programmed spreadsheet developed to accompany the APT illustrates the structure described in this section. Built-in factor and variable menus, relational functions, scaling formulas, and sorting capabilities of the spreadsheet make it easier for the user to accomplish much of what is needed in setting up a spreadsheet-based prioritization tool.

Step 8: Measure and Input Data

Once the scoping phase is complete and the prioritization tool has been set up, the next step is to input the data to be used in the prioritization process. Some variables have already been measured and can be imported directly into the spreadsheet from another source. For example, the number of travel lanes on all street segments may be available from an existing roadway network database, so these values can be entered directly into the spreadsheet for each street segment being considered during the prioritization process.

Other variables may need to be measured before they can be inputted into the spreadsheet. For example, an agency may wish to include "proximity to schools" as a variable under Demand. In this case, the agency would know

Tip: Data Completeness

A data value is needed for each variable (the value may be zero) and in some cases it may be necessary to "clean" data as it is inputted, for example, to ensure that blank values (missing data) are addressed in a consistent and appropriate manner.

		Stakeholder Input	Safety	Demand	
ID	LOCATION	Number of Requests/Comments	Total Bike Crash	Population Density	Proximity to Schools
1	CENTRAL AVE	15	8.0	9539.0	3.0
2	WASHINGTON/JEFFERSON	10	3.0	9068.0	2.0
3	3RD ST	23	5.0	4664.0	4.0
4	12TH ST	2	7.0	3018.0	4.0
5	15TH AVE	1	5.0	4505.0	4.0
6	ENCANTO BLVD	15	5.0	6586.0	0.0
7	OSBORN RD	21	6.0	8924.0	7.0
8	OAK ST	9	6.0	7426.0	7.0
9	20TH ST	5	8.0	7115.0	8.0
10	3RD/5TH	3	1.0	7084.0	8.0
11	DEER VALLEY DR	8	8.0	8382.0	6.0
12	UNION HILLS DR	12	3.0	9459.0	0.0
13	19TH AVE	14	3.0	6766.0	7.0
14	32ND ST	21	1.0	7858.0	3.0
15	40TH ST	8	4.0	4678.0	5.0

Figure 8. Example prioritization tool structure with inputted data.

school locations but would need to calculate the distance between each improvement location and the nearest school in order to determine the proximity.

The location type of the improvement locations is a key consideration when measuring variables. For example, if the location type is an intersection or crossing and the variable is "number of crashes," the variable would most likely be measured as the number of crashes within a certain distance of the intersection or crossing. If, on the other hand, the location type is a roadway corridor, it may be necessary to normalize the data by the length of the corridor in order to avoid giving more weight to longer corridors simply because they are longer. In this example, the variable would likely be measured as the number of crashes within a certain distance of the corridor divided by the length of the corridor.

The level of effort required for measuring data will depend on the complexity of data and the technological platform being used. For example, the task of counting pedestrian crashes within 50 feet of each intersection can be done quickly using GIS, but it takes much longer to do by hand. In general, spatial measurement tasks can be done most efficiently using a GIS platform. However, there are a variety of other tools that can be used to measure variables (see Step 6).

If there are very few improvement locations and/or variables, the task could simply require manually entering data into a spreadsheet. If existing datasets will be used, it may be possible to sort and then "cut and paste" data into one central location. If using GIS, data entry typically involves joining different datasets together through the use of an identification field or "common key." The common key is an attribute that two data sets have in common, such as a street segment ID number. Using a common key ensures that the data order and integrity are maintained as several sources are combined.

Step 9: Scale Variables

The purpose of Step 9 is to ensure variables, which are represented by different units, are comparable. Step 9 involves converting non-numeric values to numeric values, selecting a common numeric scale, and adjusting raw values to fit the common scale. Scaling should not be confused with weighting. Scaling is a more objective, technical function, while weighting is based on

Table 23. Example of converting non-numeric values to numeric values.

Non-Numeric Value	Numeric Value
Excellent	4
Good	3
Fair	2
Poor	1

community/agency values. In other words, agencies should not attempt to increase or decrease the influence of variables through scaling.

Scaling is necessary so that variables have a comparable impact on the prioritization score in the absence of weighting. Consider, for example, a prioritization process that includes both "Speed" and "Number of Transit Stops Within ¼ Mile" as variables. A typical value range for speed might be 15 to 70, while a typical value range for transit stops might be 0 to 6. In the absence of scaling, the top end of the "Speed" variable is 11 times greater than the top end of the "Transit Stops Within ¼ Mile" variable, which would result in the "Speed" variable having a far greater impact on the prioritization score than the "Transit Stops Within ¼ Mile" variable.

Assign Numeric Values to Non-Numeric Variables

Variables with non-numeric values must be converted to numeric values before they can be incorporated into the prioritization framework. Examples of non-numeric values include categories such as "yes" and "no"; "compliant" and "non-compliant"; "high," "medium," and "low"; or "excellent," "good," "fair," and "poor." Converting these values requires ranking them and assigning numeric values by rank. The highest numeric value should go to the non-numeric value with the highest rank, the next highest numeric value to the non-numeric value with the next highest rank, and so on. Table 23 illustrates this process.

Select a Common Scale

There are many potential considerations that go into selecting a common scale; however, the main consideration is likely to be ease of calculation. For this reason, it is recommended that agencies select a common scale that is 0 to 1 or 0 to 10.

Tip: Adjusting the Common Scale for Specific Variables

For some variables, using a common scale may overemphasize the difference between the highest and lowest raw values for that variable. For example, consider an agency that is prioritizing improvements along arterial roadways and wants to consider 85th percentile speed as part of their analysis. The lowest 85th percentile speed in this dataset may still be quite high. Should an agency assign it a scaled value of 0? In such cases, it may be appropriate to establish a variable-specific scale with the same maximum scaled value as the common scale but with a minimum value that is higher, for example, 3 or 5 instead of 0.

Table 24. Common scaling methods.

Appropriate If Range of Raw Data Values *Does Not Include* Outliers	Appropriate If Range of Raw Data Values *Includes* Outliers
• Proportionate Scaling and Inverse Proportionate Scaling • Non-linear Scaling and Inverse Non-linear Scaling	• Quantile Scaling and Inverse Quantile Scaling • Rank Order Scaling and Inverse Rank Order Scaling • Jenks Natural Breaks Scaling and Inverse Jenks Natural Breaks Scaling

Adjust Values to Fit the Common Scale

Once a common scale is selected, it is necessary to adjust the raw values for each variable to fit the common scale. There are several ways to do this, depending on the distribution and relative importance of the values associated with each variable. Some common methods are shown in Table 24, which divides the methods into two categories based on their appropriateness for addressing outliers (i.e., minimum or maximum values that are much larger or much smaller than other values).

Whatever method is chosen, it should be evenly applied to all data values based on a consistent rule or formula, and the rule or formula should be documented.

Additional details regarding these methods and the issue of outliers is provided below.

Tip: Programmed Spreadsheet Scaling Formulas

The programmed spreadsheet that accompanies the APT allows users to select from a menu of scaling options, including:

- Proportionate scaling.
- Inverse proportionate scaling.
- Quantile scaling (4 quantiles).
- Inverse quantile scaling (4 quantiles).
- Quantile scaling (10 quantiles).
- Inverse quantile scaling (10 quantiles).
- Rank order scaling.
- Inverse rank order scaling.

Proportionate Scaling and Inverse Proportionate Scaling

If the range of values does not include outliers, then it is appropriate to adjust the raw numeric values proportionately to fit the common scale. Proportionate scaling involves assigning the highest value in the common scale to the maximum raw value for a particular variable and assigning the lowest value in the common scale to the lowest scaled value. Other raw values are scaled proportionately based on their relationship to the highest and lowest raw values. Inverse proportionate scaling is similar but involves assigning the lowest scaled value to the maximum raw value and the highest scaled value to the lowest raw value. The formula for proportionate scaling is:

$Y = (X - MIN)/(MAX - MIN) \times S$, where Y is the scaled value, X is the raw value, MIN is the minimum raw value, MAX is the maximum raw value, and S is the scale.

The formula for inverse proportionate scaling is:

$Y = (((X - MIN)/(MAX - MIN) \times S) - S)\ X - 1.$

In Table 25, the maximum raw value is 5, the scale is 0 to 10, and the raw values are adjusted using proportionate scaling.

Table 26 is the same as Table 25, except that the raw values are scaled using inverse proportionate scaling. An example for which inverse proportionate scaling might be applied is implementation costs: projects with lower implementation costs may be assigned higher scaled values if the prioritization purpose is to implement a greater number of lower cost projects.

Table 25. Example of proportionate scaling for a scale of 0 to 10.

Raw Value	Scaled Value
4	8
0	0
3	6
4	8
5	10
3	6
2	4
0	0
5	10
1	2

Note: *In this example, the minimum raw value is 0 and the maximum raw value is 5. Each of the raw values has been adjusted proportionately to fit a scale 0 to 10, and the resulting scaled values are shown in the right-hand column.*

Proportionate scaling and inverse proportionate scaling may not be appropriate if the range of values to be scaled includes outliers. In this case, proportionate scaling may result in a maximum or minimum scaled value that is much higher or lower than the next highest or lowest scaled value, which may be undesirable for a variety of reasons. One key reason is that it diminishes the level of differentiation between the majority of values and may skew the final prioritization rank for the outlier improvement location. There are several methods for addressing outliers when they are a concern, including quantile scaling and rank order scaling.

Quantile Scaling and Inverse Quantile Scaling

If the range of values includes outliers, it may be more appropriate to calculate scaled values based on quantiles. Quantile scaling involves assigning each raw value to a quantile (i.e., equal groups containing the same number of values) and scaling the quantile values proportionately to fit the selected scale. In Table 27, raw values for a variable are divided into six equal groups. Then, the quantile values are scaled proportionately to fit on a 0 to 10 scale. Note that there are two data values for each quantile. Most spreadsheet tools contain functions that allow computation of quantiles.

Table 26. Example of inverse proportionate scaling for a scale of 10.

Raw Value	Scaled Value
4	2
0	10
3	4
4	2
5	0
3	4
2	6
0	10
5	0
1	8

Note: *In this example, the minimum raw value is 0 and the maximum raw value is 5. Each of the raw values has been adjusted proportionately.*

Table 27. Example of quantile scaling using 6 quantiles.

Raw Value	Quantile	Scaled Value
16	1	0
17	1	0
22	2	2
24	2	2
26	3	4
32	3	4
33	4	6
36	4	6
37	5	8
41	5	8
48	6	10
150	6	10

Note: *In this example, the minimum raw value is 16 and the maximum raw value is 150. 150 is also an outlier, since it is more than three times larger than the next highest raw value. To address this, the raw values are sorted from low to high and divided into 6 quantiles of 2 values each. The quantile values are then adjusted.*

Table 28 is the same as Table 27 except that the raw values are scaled using inverse quantile scaling.

Please note that quantile scaling is not appropriate when multiple instances of the same data value would have to be separated into more than one quantile. For example, if there are 20 data values for a variable and 10 of them are 0, dividing the data into 10 quantiles results in two 0s being classified in the first quantile, two 0s being classified in the second quantile, and so on through the fifth quantile. In such cases, the methods described below may be more appropriate.

Rank Order Scaling and Inverse Rank Order Scaling

Rank order scaling is another method for addressing outliers. Rank order scaling involves calculating the rank of each value in the range and then scaling the rank values proportionately

Table 28. Example of inverse quantile scaling using 6 quantiles.

Raw Value	Quantile	Scaled Value
16	1	10
17	1	10
22	2	8
24	2	8
26	3	6
32	3	6
33	4	4
36	4	4
37	5	2
41	5	2
48	6	0
150	6	0

Note: *In this example, raw values are scaled using deciles. There are 20 raw values and breaking these values into deciles involves dividing them into ten equal groups. Consequently, there are two records per decile.*

Table 29. Example of rank scaling.

Raw Value	Rank	Scaled Value
0	1	0
0	1	0
0	1	0
0	1	0
5	2	2
7	3	4
9	4	6
10	5	8
32	6	10

Note: *In this example, the minimum raw value is 0 and the maximum raw value is 32. 32 is also an outlier, since it is more than three times larger than the next highest raw value. To address this, the values are ranked from low to high (i.e., the lowest value gets a rank of 1, next lowest value gets a rank of 2, and so on). The ranked values are then scaled proportionately.*

to fit the selected scale. In Table 29, the raw values for a variable are ranked from low to high. Then the ranked value is adjusted proportionately to fit a 0 to 10 scale.

Table 30 is the same as Table 29 except that the raw values are scaled using inverse rank scaling.

There are several other scaling methods that agencies may wish to consider if they are confronted with the issue of outliers. One possible approach is to give the outlier either the maximum or minimum scaled value, and then to scale the remaining values proportionately based on a range that excludes the outlier. Another approach is to use Jenks natural breaks. Jenks natural breaks are determined using a mathematical formula that assigns classes so that the average deviation from the class mean average is minimized while each class's deviation

Table 30. Example of inverse rank scaling.

Raw Value	Rank	Scaled Value
0	1	10
0	1	10
0	1	10
0	1	10
5	2	8
7	3	6
9	4	4
10	5	2
32	6	0

Note: *In this example, the minimum raw value is 0 and the maximum raw value is 32. 32 is also an outlier, since it is more than three times larger than the next highest raw value. To address this, the values are ranked from low to high. The ranked values are then scaled inverse proportionately.*

Table 31. Example of non-linear scaling.

Raw Value	Scaled Value
20	0
25	1
30	2.5
35	5
40	10

Note: *In this example, raw values are scaled in a non-linear fashion to represent the relationship between motor vehicle speed and the risk of pedestrian death in collisions involving pedestrians and motor vehicles.*

Table 32. Example of inverse non-linear scaling.

Raw Value	Scaled Value
20	10
25	5
30	2.5
35	1
40	0

from the means of other classes is maximized. The number of classes assigned depends on the chosen scale.

Non-linear Scaling and Inverse Non-linear Scaling

Finally, for some variables the importance of the raw numeric values may increase in a non-linear fashion. For example, the risk that a pedestrian will be killed in collision with a motor vehicle is 7 to 9 times higher at 30 mph than at 20 mph. Agencies may wish to incorporate this relationship in their scaling process, as in Table 31.

Table 32 is the same as Table 31 except that the raw values are scaled using inverse non-linear scaling.

Step 10: Create Ranked List

The goal of Step 10 is to create a prioritized list of projects. This involves summing the weighted values for each factor (or variable) to derive a prioritization score for each improvement location. The improvement locations are then ranked based on the prioritization score. Completion of Step 10 includes reviewing the calculations and clearly communicating the results and the process.

Calculate Prioritization Scores

At the beginning of Step 10, each variable should be scaled to a common scale and each factor should have a designated weight. To calculate the prioritization scores, follow the steps below for each improvement location:

- Calculate the *unweighted* score for each factor by summing the scaled variable values and divide by the number of variables used to get the factor score (Table 33).

Table 33. Example of calculating unweighted factor score for three improvement locations and two variables.

Improvement Location	Scaled Variable Value 1	Scaled Variable Value 2	Sum of Scaled Variable Values	Unweighted Factor Score
Location 1	3	5	8	4
Location 2	2	4	6	3
Location 3	6	4	10	5

Table 34. Example of calculating weighted factor score for three improvement locations.

Improvement Location	Factor 1 Score	Factor 1 Weight	Factor 1 Weighted Score
Location 1	4	8	32
Location 2	3	8	24
Location 3	5	8	40

Table 35. Example of calculating prioritization score for three improvement locations and two factors.

Improvement Location	Factor 1 Weighted Factor Score	Factor 2 Weighted Factor Score	Prioritization Score
Location 1	32	12	44
Location 2	24	10	34
Location 3	40	18	58

- Calculate the *weighted* score for each factor by multiplying the *unweighted* factor score by the factor weight (Table 34).
- Sum the *weighted* factor scores to get the prioritization score for each improvement location (Table 35).

Develop Ranked List

Once the prioritization scores have been calculated, the improvement locations can be ranked based on their score. The simplest approach is to give the improvement location with the highest

Tip: Scale Prioritization Scores

It can be helpful to scale the final prioritization scores using proportionate scaling to better understand the relationships between them. For example, if a common scale of 0 to 10 is selected, the improvement location with the highest prioritization score would get a scaled prioritization score of 10, and the improvement location with the lowest prioritization score would get a scaled prioritization score of 0. It's much easier to understand the significance of an improvement location that scores a 9.0 on a 10 point scale than it is to understand the significance of an improvement location that scores a 238 on scale of 135 to 250.

Table 36. Example of developing ranked list for three improvement locations.

Improvement Location	Prioritization Score	Rank
Location 3	58	1
Location 1	44	2
Location 2	34	3

score a rank of 1, the improvement location with the next highest score a rank of 2, and so on (Table 36). However, this should be done with an awareness of the relationships between prioritization scores (see *Tip: Scale Prioritization Scores*) and an understanding that small differences in prioritization scores can be the result of measurement errors.

Review Ranked List

It is important for practitioners to review the results of any prioritization scoring and ranking process carefully to understand how weighting, scaling, correlation of variables, and other issues may affect the results. The level of review should be proportional to the level of complexity of the process (i.e., the more factors and variables used, the more scrutiny the process demands). Recommended review steps include:

- Review the ranked list and/or a visual representation of the ranked list on a map. Do some improvement locations rank unexpectedly high or unexpectedly low? If so, do the raw data values make sense? Have the weighting and scaling calculations been done correctly?
- Review the scaled values for each variable to understand the impact of scaling and verify that data values are scaled appropriately.
- Review the unweighted and weighted scores for each factor to understand the impact of weighting and verify that weighting is having the intended effect.
- Review the factors and variables used. Are key policy objectives or community values being fully represented by the chosen factors or variables? Agencies have the ability to use factors and variables that are not presented in this methodology.

Communicate Results

Agencies can build confidence among stakeholders by clearly communicating the prioritization results and the process that led to them. Graphics are a highly effective form of communication. For example, pie charts can be used to show the respective weights of selected factors or variables (as in Figure 2). Maps can also effectively communicate results, allowing stakeholders to better understand how results correspond to locations of the improvement locations. Maps may also be used to further explain the prioritization process. For example, each factor category can be mapped separately and then combined into a composite map (Figure 9), giving stakeholders a better sense of how each factor category influences the prioritization results. The same can be done for individual variables.

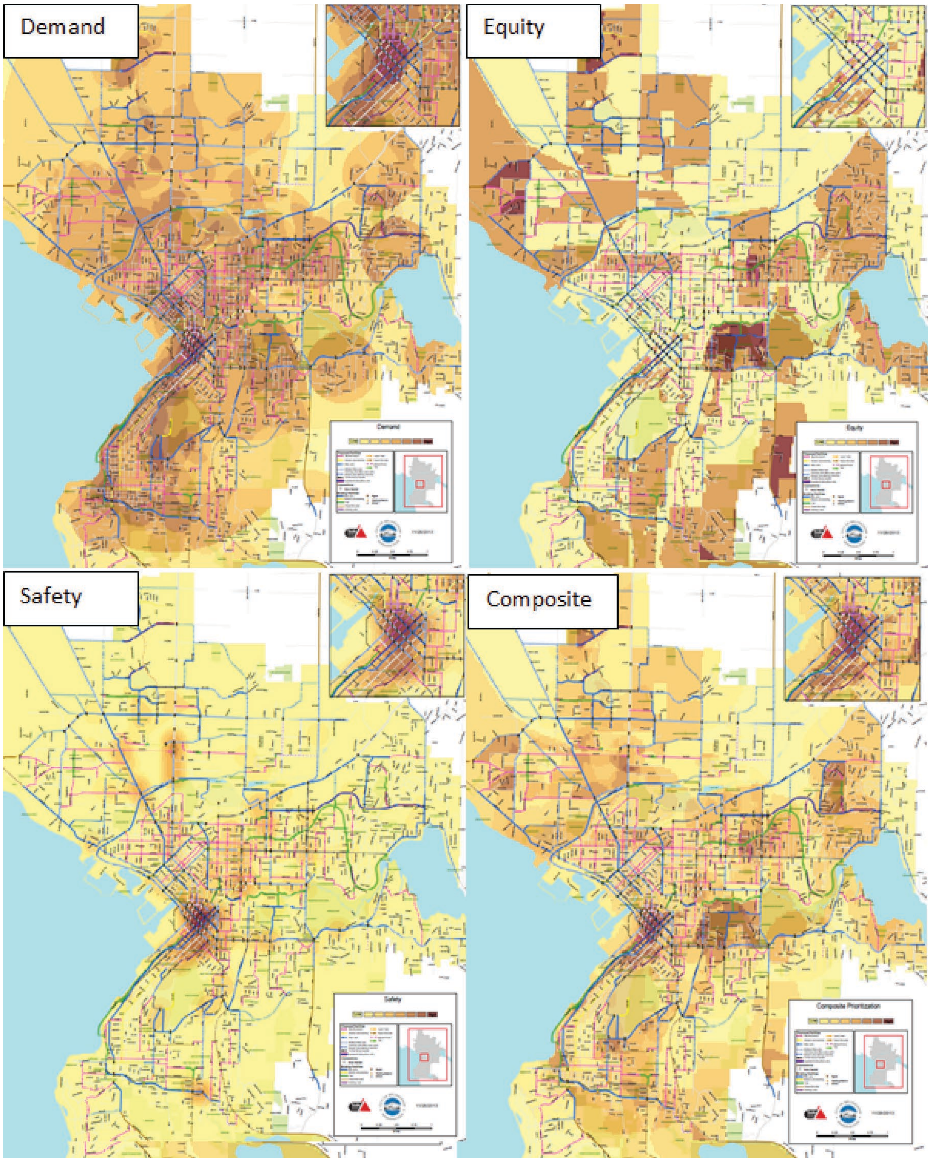


Figure 9. Communicating prioritization process by mapping selected factors—example from City of Bellingham, Washington, bicycle master plan.

Conclusion

This guidebook describes the ActiveTrans Priority Tool, a flexible, rational, data-driven methodology for prioritizing bicycle and pedestrian improvements along existing roads. The ActiveTrans Priority Tool is divided into two phases and ten discrete steps to facilitate understanding and communication of the prioritization process in a transparent manner. It is designed to work for agencies at all levels of government with different prioritization purposes and different levels of technical capacity and experience.

The ultimate product of applying the APT is a ranked list of priority pedestrian or bicycle improvement locations. The priorities on this list may differ somewhat from the intuitive priorities of decision makers and public stakeholders, which often incorporate information from personal experience or familiarity that cannot be wholly accounted for in an objective, data-driven analysis. However, if the prioritization process successfully includes the values of the community, the prioritized list will provide defensible, data-driven guidance for the implementation of pedestrian and bicycle improvements along existing roads.

Additional resources for agencies using (or considering) the APT are available on the Transportation Research Board website (TRB.org) and/or the Pedestrian and Bicycle Information Center website (pedbikeinfo.org).

- *Online Guide*—each individual step of the APT has been divided into separate files allowing users to more easily access information they are interested in.
- *Programmed Excel Spreadsheet*—this spreadsheet tool, and the User Guide (included as Appendix A to this document) steps users through the APT and incorporates functions for selecting factors and variables, weighting, and scaling that are intended to save the user time.
- *Screencast*—a brief screencast that provides instructions and tips for using the programmed Excel spreadsheet.
- *NCHRP Project 07-17 Final Report*—the Final Report of NCHRP Project 07-17 contains background information and the research approach and findings that informed development of the APT.

APPENDIX A

Programmed Spreadsheet User Guide

Introduction

The ActiveTrans Priority Tool (APT) was developed based on previous research, transportation agency input, professional guidelines and reports, and practical experience, which is described in detail in the NCHRP Project 07-17 Final Report.

This appendix explains how to use the programmed spreadsheet, which is built around the APT methodology. The programmed spreadsheet is intended to facilitate prioritization based on the APT methodology; however, the APT can be implemented independently of the programmed spreadsheet using a variety of technological tools.

The programmed spreadsheet includes worksheets for all steps in the APT. Figure A-1 shows the relationship of these steps schematically. Users are encouraged to read through the APT Guidebook prior to using this tool.

In the programmed spreadsheet, the steps are arranged in order from left to right as individual worksheet tabs. In general, users should go through these steps in sequential order; however, it may be necessary to revisit Step 2: Select Factors and Step 4: Select Variables based on data availability and technical resources.

The spreadsheet includes code allowing users to adjust factor and variable selections prior to Step 9: Scale Variables. Users wishing to adjust factors and variables after completing Step 9 should open a new iteration of the programmed spreadsheet and work through the spreadsheet again from Step 1. Improvement locations may be copied and pasted to save time.

Tip

Be sure to enable macros when opening the programmed spreadsheet by clicking "Enable Content" when the yellow security warning comes up (See Figure A-2). If this warning does not appear, then go to Excel options and confirm that macros are enabled.

Step 1: Define Purpose

This worksheet (Figure A-3) corresponds to Step 1 of the APT. On this sheet, users must indicate the mode and location type being prioritized. For mode, the user must select "pedestrian" or "bicycle." For location type, the user must select "intersection or crossing," "roadway segment," "roadway corridor," or "neighborhood/area."

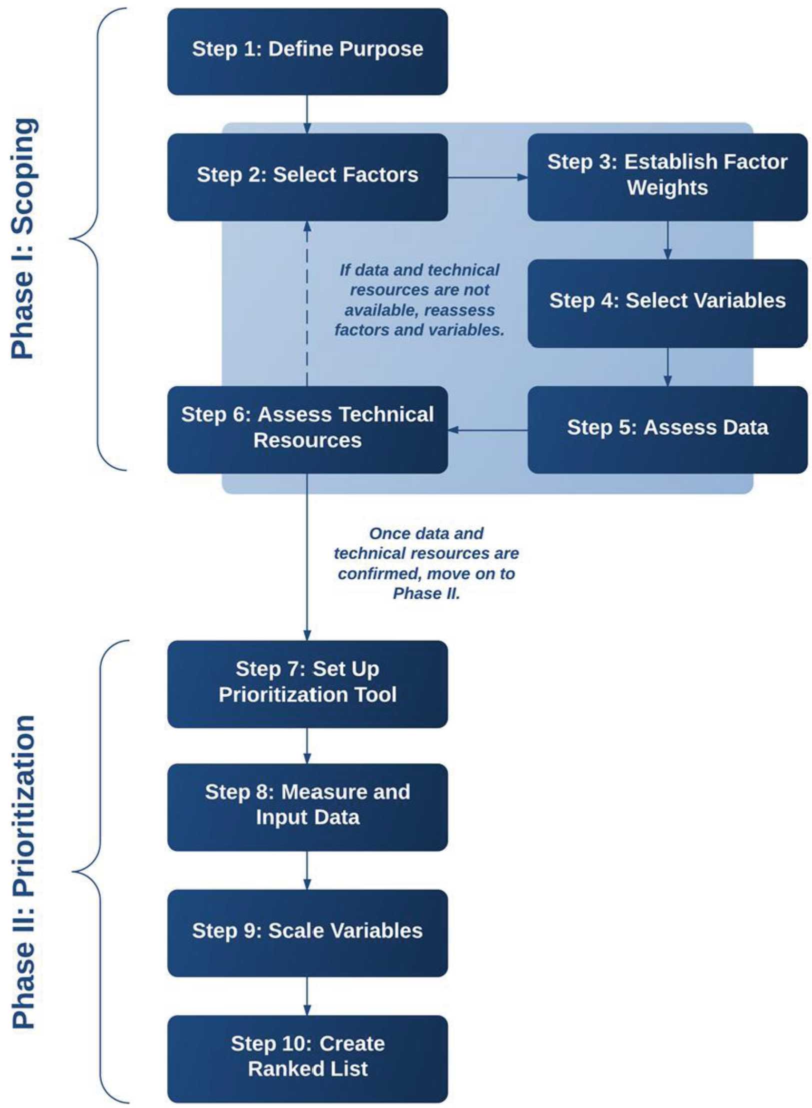


Figure A-1. APT methodology.

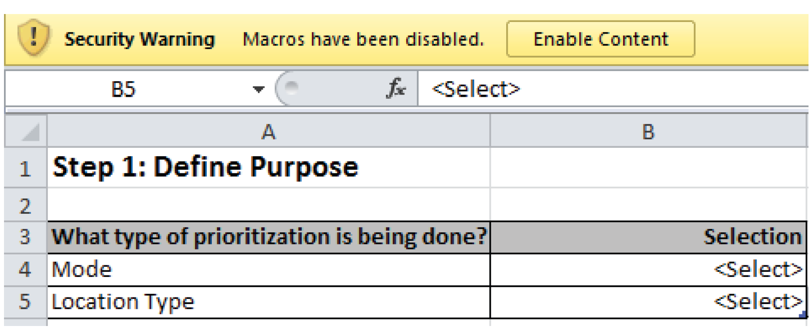


Figure A-2. Security warning with "enable content" button in Excel 2010/2013.

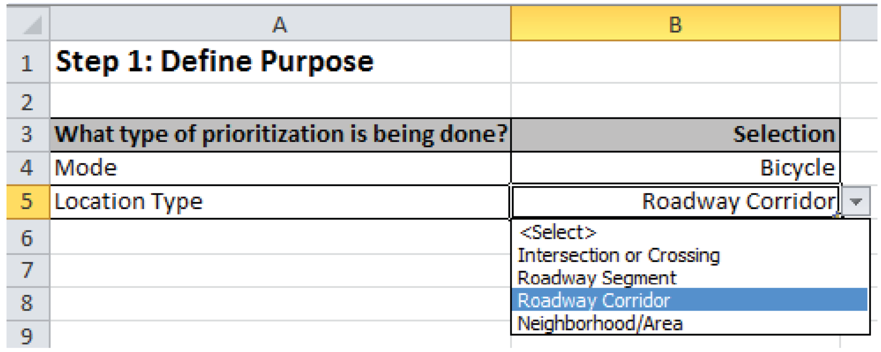


Figure A-3. View of Step 1: Define Purpose worksheet.

The four location types are defined in general below. Transportation agencies can make these definitions more specific for their own prioritization purposes.

Location Types

Intersection or Crossing

An intersection or crossing occurs where two roadways intersect, where a multi-use trail and a roadway intersect, or at a designated mid-block pedestrian crossing. When considering intersections, many agencies also include a certain distance (e.g., 50 feet) away from the intersection along each approach leg as a part of the intersection study area.

Roadway Segment

A roadway segment is any length of roadway between intersections. Some agencies may analyze the full distance between intersections as a segment, while others may choose to divide segments at regular intervals (e.g., every 0.1 miles). Some agencies may also choose to divide segments at mid-block crossings. Both sides of roadway segments may be considered separately (e.g., sidewalk presence on the north versus south side).

Roadway Corridor

A roadway corridor is a length of roadway that includes more than one segment or intersection. Agencies often analyze the attributes of both intersections and roadway segments when analyzing roadway corridors.

Tip

If the prioritization purpose is focused on identifying high-priority intersection locations or high-priority segment locations, then the respective location type should be selected. However, agencies may also be interested in prioritizing corridors or neighborhoods as a first step before prioritizing specific locations. For example, it may be important to select high-priority multimodal corridors in a regional plan in order to dedicate funding for further prioritization analysis within those corridors. In this case, the "roadway corridor" location type should be selected. Similarly, if the prioritization purpose is to identify areas or neighborhoods in which to focus funding or field assessments before identifying specific improvements, then the "neighborhood/area" location type is appropriate.

Neighborhood/Area

A neighborhood/area is a geographic region that is not constrained to a single roadway or roadway corridor. Agencies often analyze the attributes of both intersections and roadway segments when analyzing neighborhoods or areas.

Step 2: Select Factors

This worksheet (Figure A-4) corresponds to Step 2 in the APT. Users must select the factors that will be considered as part of the prioritization process by switching values in the "Select" column from "No" to "Yes." "Yes" means the factor is selected and related variables will be displayed on subsequent sheets and included in the calculation of priorities.

> **Tip**
>
> The factors listed on the Step 2 worksheet are the nine factors identified in the APT. Users are encouraged to read Step 2: Select Factors in the APT to understand how each of these factors is defined.
>
> The factor names can be edited, if necessary, and any edits will carry forward to subsequent sheets. However, it is not possible to add factor rows, i.e., the programmed spreadsheet is limited to nine factors.

Step 3: Establish Factor Weights

This worksheet (Figure A-5) corresponds to Step 3 of the APT. The purpose of Step 3 is to assign weights to each factor. Only the factors that were selected in Step 2 will appear on this sheet. The maximum and default weight is 10.

Step 2: Select Factors

Factor	Select?
Stakeholder Input	Yes
Constraints (Cost and Legal)	Yes
Opportunities (Upcoming Projects)	No
Safety	No
Existing Conditions	No Yes
Demand	No
Connectivity	No
Equity	No
Compliance	No
Number of Factors Selected	**2**

Figure A-4. View of Step 2: Select Factors worksheet.

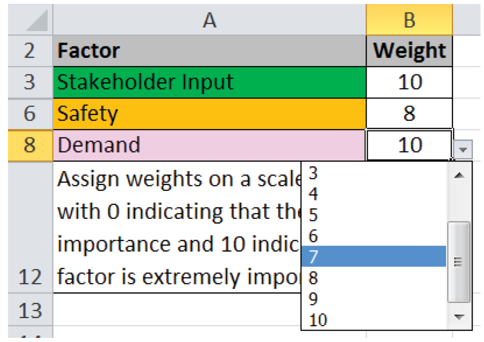


Figure A-5. View of Step 3: Factors Weight worksheet.

Tip

Factor weights will depend on the prioritization purpose and community values. There are many reasons to weight factors differently and there is no single "right" way to weight any particular set of factors. However, the process should be transparent, and opportunities for public input on the proposed weighting strategy should be provided. Existing research and public input should be incorporated into weighting decisions where possible and applicable. Existing plans and policies can also provide a strong and defensible rationale for weighting decisions. Finally, the rationale should be carefully documented, so it can be explained to stakeholders.

Step 4: Select Variables

This worksheet (Figure A-6) corresponds to Step 4 of the APT. On this sheet, users select variables for the prioritization. The variables shown depend on the mode and improvement location type selected in Step 1 and the factors selected in Step 2.

To include a particular variable, change the value in the "Select" column from "No" to "Yes." "Yes" means the variable is selected and will be displayed on subsequent sheets and included in the calculation of priorities.

Variable names can be edited, and any edits will carry forward to subsequent sheets. Each factor also includes one or more generic variables. Generic variables have names like "Variable 1" and "Variable 2." These generic variable slots provide space for additional variables, if needed, since it is not possible to add new variable rows.

For some factors (e.g., Existing Conditions) there are a large number of variables, some of which are relevant for many different prioritization purposes and some of which may be most relevant for very specific purposes. Users should review Step 4: Select Variables in the APT Guidebook for the factors they selected in Step 2: Select Factors before selecting variables on this sheet. Users will also need to consider in Step 5 whether the data required to measure each variable is currently available or can be collected. If the data is not currently available and cannot be collected, the variable should not be selected.

	A	B	I	J	AO	AP
1	**Step 4 Select Variables**					
2	Stakeholder Input (All)	Stakeholder Input Select	Safety (Bike, ALL)	Safety (Bike, ALL) Select	Demand (Bicycle, Corridor)	Demand (Bicycle, Corridor) Select
3	Number of Requests/Comments	Yes	Total Bike Crash	Yes	Presence of Bicycle Facility	No
4	Included in Adopted Plan or Approved List	No	Fatal & Severe Bike Crash (	No	Slope of Roadway on Intersection Approach	No
5	Recommended by Advisory Committee	No	Bicycle Crash Rate	No	Proximity to Retail	No
6	Variable 4	No	Variable 4	No	Population Density	Yes
7	Variable 5	No	Variable 5	No	Employment Density	No
8					Proximity to Schools	Yes
9					Proximity to Attractor 2	No
10					Proximity to Attractor 3	Yes
11					Proximity to Attractor 4	No
12					Variable 10	No
13					Variable 11	No

Figure A-6. View of Step 4: Select Variables worksheet.

Tip

Using more variables to express a particular factor will not increase the weight of that factor. As additional variables are added to a factor, each of the variables will contribute a smaller proportion to that factor's overall score. The process for weighting factors is described in Step 3: Establish Factor Weights in the APT.

Variable Weighting

The programmed spreadsheet is set up to apply weights at the factor rather than variable level. However, variable weights can be applied by adjusting the formulas on the Step 10: Calc Priority Score tab to incorporate variable weights.

For reasons of simplicity and transparency, it is generally recommended that agencies choose between assigning weights at the factor level and assigning weights at the variable level rather than trying to apply weights at both levels. For additional information about the advantages and disadvantages of variable weighting, see Tip: Variable Weighting in Step 3: Establish Weights of the APT.

Step 5: Assess Data

This worksheet (Figure A-7) corresponds to Step 5 in the APT. This sheet is included as a reminder that determining the availability of the data needed to measure the variables selected in Step 4 is an important step. Users should review Step 5: Assess Data in the APT Guidebook for guidance regarding the types of data that may be used to express the variables identified in Step 4 and sources for these data.

Step 6: Assess Technical Resources

This worksheet (Figure A-8) corresponds to Step 6 in the APT. This sheet is included as a reminder that users will need to assess their existing technical resources and capabilities to determine whether they are sufficient to measure the variables selected in Step 4, since the programmed spreadsheet itself does not calculate measures. Users should review Step 6: Assess Technical Resources in the APT Guidebook for guidance regarding technologies and tools that may be used to measure variables they have selected.

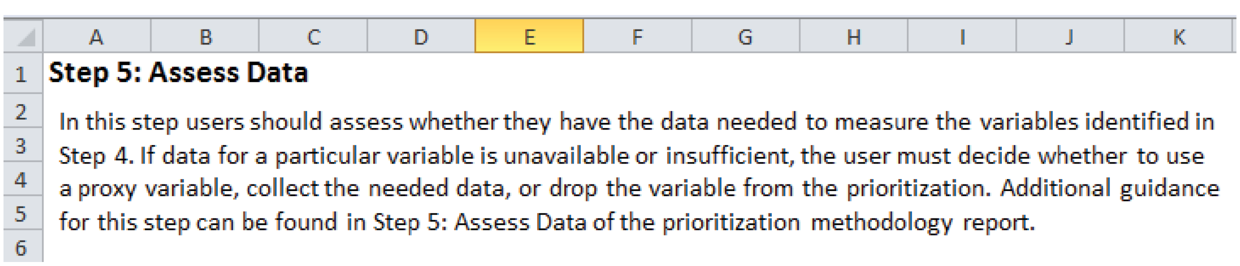


Figure A-7. View of Step 5: Assess Data worksheet.

Step 6: Assess Technical Resources

In this step users should assess whether they have the technical resources needed to measure the variables identified in Step 4. If the technical resources necessary to measure a particular variable are not available, the user must decide whether to use a proxy variable, collect the needed data, or drop the variable from the prioritization. Additional guidance for this step can be found in Step 6: Assess Technical Resources the prioritization methodology report.

Figure A-8. View of Step 6: Assess Technical Resources worksheet.

Step 7: Set Up Prioritization Tool

This worksheet (Figure A-9) corresponds to Step 7 in the APT. The programmed spreadsheet is already set up, so there should be nothing for users to do during this step.

Step 8: Measure and Input Data

This worksheet (Figure A-10) corresponds to Step 8 of the APT. This step is the first step in which rows of the worksheet are used to represent individual improvement locations (i.e., intersections/crossings, roadway segments, roadway corridors, or neighborhoods/areas).

Step 7: Set Up Prioritization Tool

This worksheet corresponds to Step 7 in the prioritization methodology. The programmed spreadsheet is already set up, so there should be nothing for users to do during this step.

Figure A-9. View of Step 7: Set Up Prioritization Tool worksheet.

Scoring Method:

		Stakeholder Input	Safety	Demand	
ID	LOCATION	Number of Requests/Comments	Total Bike Crash	Population Density	Proximity to Schools
1	CENTRAL AVE	15	8.0	9539.0	3.0
2	WASHINGTON/JEFFERSON	10	3.0	9068.0	2.0
3	3RD ST	23	5.0	4664.0	4.0
4	12TH ST	2	7.0	3018.0	4.0
5	15TH AVE	1	5.0	4505.0	4.0
6	ENCANTO BLVD	15	5.0	6586.0	0.0
7	OSBORN RD	21	6.0	8924.0	7.0
8	OAK ST	9	6.0	7426.0	7.0
9	20TH ST	5	8.0	7115.0	8.0
10	3RD/5TH	3	1.0	7084.0	8.0
11	DEER VALLEY DR	8	8.0	8382.0	6.0
12	UNION HILLS DR	12	3.0	9459.0	0.0
13	19TH AVE	14	3.0	6766.0	7.0
14	32ND ST	21	1.0	7858.0	3.0
15	40TH ST	8	4.0	4678.0	5.0

Figure A-10. View of Step 8: Measure and Input Data worksheet.

Before entering any other data, users should fill in the location identification field ("ID"), or common key, in Column A with unique numbers (e.g., 1, 2, 3, . . . or other specific ID numbers already used by the agency) and the "Location" field in Column B with the name of each improvement location (Figure A-10). This will ensure that each row corresponds to exactly one improvement location.

After the improvement locations are identified, users must import the raw variable values for the variables selected in Step 4 for each improvement location. This data will be carried over to subsequent sheets automatically.

Raw variable values may be *numeric*, representing:

- Counts of features (e.g., number of lanes, number of public requests).
- Measurements of features (e.g., length of a pedestrian crossing in feet, posted speed limit in miles per hour, duration of pedestrian crossing interval in seconds).
- Proportions (e.g., percentage of neighborhood households without access to an automobile).

Raw variable values may also be *non-numeric (categorical)*, representing:

- User-defined categories (e.g., "low," "medium," or "high").
- Binary values ("yes" or "no").
- Other types of qualitative data.

Tip

Using a unique identification field or common key in Column A ensures that the data order and integrity is maintained as raw variable values from several sources are combined together in the worksheet in Step 8: Measure and Input Data.

Users must input a value for each improvement location and variable combination. In some cases when data are transferred from another existing source, it may be necessary to "clean" data as it is inputted. This may require users to correct data that does not make sense (e.g., a posted speed limit of 250 mph on a residential street probably has an extra "0" on the end) and to ensure that missing data (blank values) are reviewed and converted to 0s or other numerical values, as necessary. This can be done by filtering the ID column to remove blanks and then filtering each variable column in turn to show only the improvement locations with blank values in that column. The blank values can then be reviewed and an appropriate numerical value entered before removing the filter for that variable and moving onto the next one. In some cases, field checks or inquiries to other agencies may be necessary. Bulk edits can be accomplished using the spreadsheet's "Find and Replace" function.

Step 9: Scale Variables

This worksheet (Figure A-11) corresponds to Step 9 of the APT, which involves converting non-numeric values to numeric values, selecting a common numeric scale, and adjusting raw values to fit the common scale. Scaling is necessary so that variables have a comparable impact on the prioritization score in the absence of weighting.

Scaling should not be confused with weighting. Scaling is a more objective, technical function, while weighting is based on community/agency values. In other words, agencies should not attempt to increase or decrease the influence of variables through scaling.

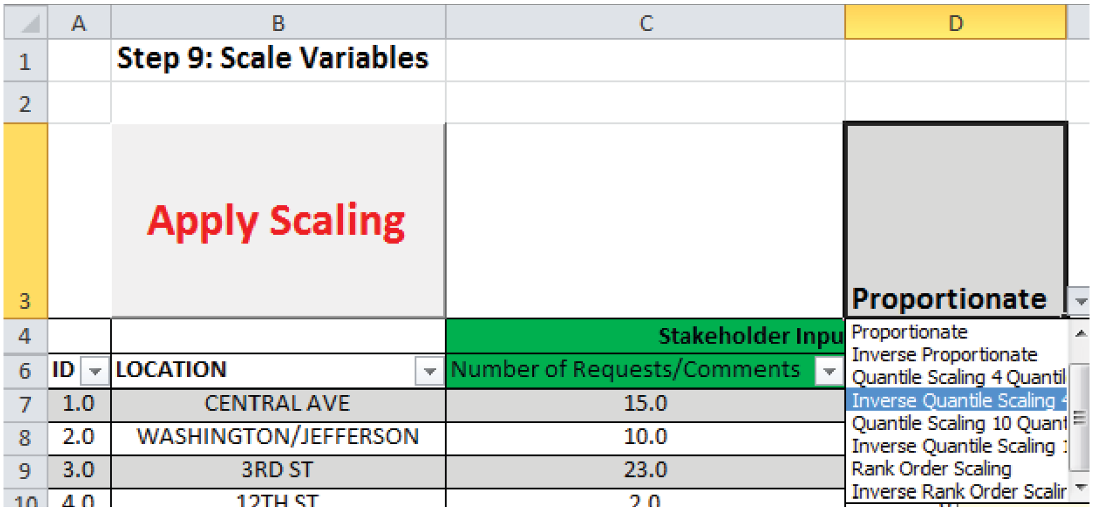


Figure A-11. View of Step 9: Scale Variables worksheet.

Tip

Users wishing to adjust factors and variables after completing Step 9 should open a new iteration of the programmed spreadsheet and work through the spreadsheet again from Step 1. Improvement locations may be copied and pasted to save time.

It is important for users to understand that the process of scaling will have an impact on the final prioritization rankings, so it should be done thoughtfully and transparently. Table A-1 shows how different scaling methods can produce different scaled values.

Scaling in the Programmed Spreadsheet

The programmed spreadsheet includes default formulas for adjusting the raw variable values entered in Step 8 to a common scale of 0 to 10. To apply one of the default formulas, click the Select Scaling Method box at the top of the scaling column for each variable, select the appropriate scaling method, and then click “Apply Scaling.” Users can also enter custom scaling formulas manually by copying the custom formula to the appropriate cells for each variable.

Selecting the Appropriate Scaling Method

There are several ways to adjust the raw variable values to the common scale, depending on the distribution and relative importance of the values associated with each variable. Methods for scaling numeric values will be discussed first, followed by methods for scaling non-numeric values. Each method includes both an option that assigns the maximum scaled value to the highest raw value and an “inverse” option that assigns the maximum scaled value to the lowest raw value. *Users should carefully consider which of these options is appropriate for each variable given their prioritization purpose, recognizing that a higher scaled value will result in a higher prioritization score.*

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Table A-1. Example showing how scaled variable values can vary depending on the chosen scaling method.

Raw Variable Value	Scaled Variable Value with Proportionate Scaling	Scaled Variable Value with Quantile Scaling (4 Quantiles)	Scaled Variable Value with Rank Order Scaling
16	0.0	0.0	0.0
17	0.1	0.0	1.4
22	0.4	3.3	2.9
24	0.6	3.3	4.3
26	0.7	6.7	5.7
32	1.2	6.7	7.1
33	1.3	10.0	8.6
150	10.0	10.0	10.0

Tip

Normal scaling (assigns maximum scaled value to the highest raw value) and inverse scaling (assigns maximum scaled value to the lowest raw value) can be applied to any variable, depending on the overall prioritization purpose. The key to scaling appropriately is to understand that improvement locations with higher scaled values will be given higher priority in the final prioritization ranking. For example, bicycle facility coverage (0% = no bicycle facilities; 50% = half of segments within corridor have facilities; 100% = all segments within corridor have facilities) may be used as a Connectivity variable for prioritizing corridors for new bicycle lanes. If an agency is interested in providing continuous bicycle facilities along a few important corridors, it may use normal scaling to give the highest value to corridors that already have some facilities, allowing it to fill small gaps and provide continuous bikeway connections in those corridors. In contrast, if an agency is interested in increasing the presence of designated bicycle facilities in more parts of their community, it may use inverse scaling to give the highest value to corridors that currently have few facilities.

Methods for Scaling Numeric Values to the Common Scale

Proportionate Scaling and Inverse Proportionate Scaling

If the range of values does not include outliers (i.e., minimum or maximum values that are much larger or much smaller than other values), then it is appropriate to adjust the raw numeric values proportionately to fit the common scale.

- **Proportionate scaling** involves assigning the highest value in the common scale to the maximum raw value for a particular variable and assigning 0 to the lowest raw value.

- **Inverse proportionate scaling** involves assigning 0 to the maximum raw value and the highest value in the common scale to the lowest raw value.

In Table A-2, the maximum raw value is 5, the scale is 0 to 10, and the raw values are adjusted using **proportionate scaling**.

Table A-3 is the same as Table A-2 except that the raw values are scaled using **inverse proportionate scaling**.

To scale raw numeric values in the programmed spreadsheet using **proportionate scaling**, users should select the "Proportionate Scaling" option from the "Select Scaling Method" drop-down. To scale raw numeric values in the programmed spreadsheet using **inverse proportionate scaling**, users should select the "Inverse Proportionate Scaling" option.

Proportionate scaling and inverse proportionate scaling may not be appropriate if the range of values to be scaled includes outliers. In this case, proportionate scaling may result in a maximum or minimum scaled value that is much higher or lower than the next highest or lowest scaled value, which may be undesirable because it diminishes the level of differentiation among the majority of values and may skew the final prioritization rank for the outlier improvement location. There are several methods for addressing outliers when they are a concern, including quantile scaling and rank order scaling.

Quantile Scaling and Inverse Quantile Scaling

If the range of values includes outliers, it may be more appropriate to calculate scaled values based on quantiles. Quantile scaling involves assigning each raw value to a quantile (i.e., equal groups containing the same number of values) and scaling the quantile values proportionately to fit the selected scale. In Table A-4, raw values for a variable are divided into four equal groups. Then, the quantile values are scaled proportionately to fit on a 0 to 10 scale. Note that there are two data values for each quantile.

Table A-2. Example of proportionate scaling for a scale of 10.

Raw Value	Scaled Value
4	8
0	0
3	6
4	8
5	10
3	6
2	4
0	0
5	10
1	2

Table A-3. Example of inverse proportionate scaling for a scale of 10.

Raw Value	Scaled Value
4	2
0	10
3	4
4	2
5	0
3	4
2	6
0	10
5	0
1	8

Table A-5 is the same as Table A-4 except that the raw values are scaled using inverse quantile scaling.

To scale raw numeric values in the programmed spreadsheet using **quantile scaling**, users should select either the "Quantile Scaling 4 Quantiles" or "Quantile Scaling 10 Quantiles" options from the "Select Scaling Method" dropdown. To scale raw numeric values in the programmed spreadsheet using **inverse quantile scaling**, users should select the "Inverse

Table A-4. Example of quantile scaling using 4 quantiles.

Raw Value	Quantile	Scaled Value
16	1	0
17	1	0
22	2	3.3
24	2	3.3
26	3	6.7
32	3	6.7
33	4	10
150	4	10

Table A-5. Example of inverse quantile scaling using 4 quantiles.

Raw Value	Quantile	Scaled Value
16	1	10
17	1	10
22	2	6.7
24	2	6.7
26	3	3.3
32	3	3.3
33	4	0
150	4	0

Tip

Quantile scaling is not appropriate when multiple instances of the same data value would have to be separated into more than one quantile. For example, if there are 20 data values for a variable and 10 of them are 0, dividing the data into 10 quantiles results in two 0s being classified in the first quantile, two 0s being classified in the second quantile, and so on through the fifth quantile. In such cases, methods such as rank order scaling may be more appropriate.

Quantile Scaling 4 Quantiles" or "Inverse Quantile Scaling 10 Quantiles" options. The choice between 4 or 10 quantiles depends on the number of improvement locations and how the data is distributed.

Rank Order Scaling and Inverse Rank Order Scaling

Rank order scaling is another method for addressing outliers. Rank order scaling involves calculating the rank of each value in the range and then scaling the rank values proportionately to fit the selected scale. In Table A-6, the raw values for a variable are ranked from low to high. Then the ranked value is adjusted proportionately to fit a 0 to 10 scale.

Table A-7 is the same as Table A-6 except that the raw values are scaled using inverse rank scaling.

To scale raw numeric values in the programmed spreadsheet using **rank order scaling**, users should select the "Rank Order Scaling" option from the "Select Scaling Method" dropdown. To scale raw numeric values in the programmed spreadsheet using **inverse rank order scaling**, users should select the "Inverse Rank Order Scaling" option.

Table A-6. Example of rank order scaling.

Raw Value	Rank	Scaled Value
0	1	0
0	1	0
0	1	0
0	1	0
5	2	2
7	3	4
9	4	6
10	5	8
32	6	10

Scaling Non-Numeric Values to the Common Scale

Variables with non-numeric values must be converted to numeric values as part of the scaling process. Converting these values requires users to rank the non-numeric values and convert the ranked values to the common scale. The highest numeric value should go to the non-numeric value with the highest rank, the next highest numeric value to the non-numeric value with the next highest rank, and so on. A higher ranking (i.e., a higher numeric value) will result in a higher prioritization score, and a lower ranking will result in a lower prioritization score.

Table A-7. Example of inverse rank order scaling.

Raw Value	Rank	Scaled Value
0	1	10
0	1	10
0	1	10
0	1	10
5	2	8
7	3	6
9	4	4
10	5	2
32	6	0

Table A-8. Example of converting non-numeric values to numeric values.

Non-Numeric Value	Numeric Value
Excellent	4
Good	3
Fair	2
Poor	1

Table A-8 illustrates this process for a case in which the non-numeric values to be scaled are "excellent," "good," "fair," and "poor."

In the programmed spreadsheet, non-numeric values can be converted to the common scale by copying and pasting them into the "SCALED" column and using the spreadsheet's "Find and Replace" feature to convert them to numeric values. Table A-9 provides guidance for this type of conversion based on the number of discrete non-numeric values, how the discrete non-numeric values are ranked, and a scale of 0 to 10. For example, a variable with two discrete values (e.g., "Yes" or "No") would be assigned the value of 10 for "Yes" and 0 for "No." A variable with five discrete values (e.g., "Very Good," "Good," "Average," "Poor," "Very Poor") would be assigned the values of 10, 7.5, 5, 2.5, and 0, respectively. Users should record the details of this conversion above the "SCALED" column.

Step 10: Create Ranked List

This step is divided into two sheets. The first sheet is labeled "Step 10A: Calculate Priority Score" (Figure A-12). The second sheet is labeled "Step 10B: Rank Priority Scores" (Figure A-13). Together, these sheets correspond to Step 10 of the APT methodology. The goal of Step 10 is to create a ranked list. This involves summing the weighted values for each factor (or

Table A-9. Conversion of non-numeric values to scaled numeric values.

	Scaled Value for Non-Numeric Values					
Number Discrete Non-Numeric Values	Highest Rank	2nd-Highest Rank	3rd-Highest Rank	4th-Highest Rank	5th-Highest Rank	6th-Highest Rank
2	10	0				
3	10	5	0			
4	10	6.67	3.33	0		
5	10	7.5	5	2.5	0	
6	10	8	6	4	2	0

	A	B	C	D	I	J	M	N	U
1		**Step 10A: Calculate Priority Score**							
3									
4									
5	ID	GAP LOCATION	Stakeholder Input SCORE	Stakeholder Input WEIGHTED SCORE	Safety SCORE	Safety WEIGHTED SCORE	Demand SCORE	Demand WEIGHTED SCORE	Prioritization Score
7	1	CENTRAL AVE	6.3	62.5	0.0	0.0	8.1	32.5	95.0
8	2	WASHINGTON/JEFFERSON CORRIDOR	4.2	41.7	7.1	57.1	8.4	33.6	132.4
9	3	3RD ST	9.6	95.8	4.3	34.3	3.8	15.0	145.2
10	4	12TH ST	0.8	8.3	1.4	11.4	2.5	10.0	29.8
11	5	15TH AVE	0.4	4.2	4.3	34.3	3.6	14.6	53.0
12	6	ENCANTO BLVD	6.3	62.5	4.3	34.3	7.7	30.9	127.7
13	7	OSBORN RD	8.8	87.5	2.9	22.9	5.2	20.6	131.0
14	8	OAK ST	3.8	37.5	2.9	22.9	4.0	16.0	76.4
15	9	20TH ST	2.1	20.8	0.0	0.0	3.1	12.6	33.4
16	10	3RD/5TH	1.3	12.5	10.0	80.0	3.1	12.5	105.0
17	11	DEER VALLEY DR	3.3	33.3	0.0	0.0	5.4	21.5	54.8
18	12	UNION HILLS DR	5.0	50.0	7.1	57.1	9.9	39.8	146.9
19	13	19TH AVE	5.8	58.3	7.1	57.1	3.5	14.0	129.5
20	14	32ND ST	8.8	87.5	10.0	80.0	6.8	27.3	194.8
21	15	40TH ST	3.3	33.3	5.7	45.7	3.1	12.6	91.6

Figure A-12. View of Step 10A: Calculate Priority Score worksheet.

variable) to derive a prioritization score for each improvement location. The improvement locations are then ranked based on the prioritization score.

All calculations on "Step 10A: Calculate Priority Scores" and on the "Step 10B: Rank Priority Score" are done automatically in the spreadsheet (unless the user wishes to apply individual variable weights). The "Step 10A: Calculate Priority Score" sheet includes columns for the unweighted scores for each factor, columns for the weighted score for each factor, and a column for the prioritization score. The "Step 10B: Rank Priority Scores" sheet includes a column for prioritization score and prioritization rank. Users can use the dropdown menu in the prioritization rank column header to sort this column from smallest to largest, so that the top ranked improvement location appears at the top of the list.

	A	B	C	D
1	**Step 10B: Calculate Priority Rank**			
4				
5				
6	ID	Location	Prioritization Score	Prioritization Rank
7	1	CENTRAL AVE	95.0	25
8	2	WASHINGTON/JEFFERSON	132.4	11
9	3	3RD ST	145.2	7
10	4	12TH ST	29.8	37
11	5	15TH AVE	53.0	35
12	6	ENCANTO BLVD	127.7	16
13	7	OSBORN RD	131.0	13
14	8	OAK ST	76.4	31
15	9	20TH ST	33.4	36
16	10	3RD/5TH	105.0	21
17	11	DEER VALLEY DR	54.8	33
18	12	UNION HILLS DR	146.9	6
19	13	19TH AVE	129.5	15
20	14	32ND ST	194.8	2
21	15	40TH ST	91.6	26

Figure A-13. View of Step 10B: Calculate Priority Rank worksheet.

Tip

It is important for practitioners to review the results of any prioritization scoring and ranking process carefully to understand how weighting, scaling, correlation of variables, and other issues may affect the results. The level of review should be proportional to the level of complexity of the process (i.e., the more factors and variables used, the more scrutiny the process demands). Recommended review steps include:

- Review the ranked list and/or a visual representation of the ranked list on a map. Do some improvement locations rank unexpectedly high or unexpectedly low? If so, do the raw variable values make sense? Have the weighting and scaling calculations been done correctly?
- Review the scaled values for each variable to understand the impact of scaling and verify that data values are scaled appropriately.
- Review the unweighted and weighted scores for each factor to understand the impact of weighting and verify that weighting is having the intended effect.
- Review the factors and variables used. Are key policy objectives or community values being fully represented by the chosen factors or variables? Agencies have the ability to use factors and variables that are not presented in the APT methodology.

APPENDIX B

Guidance for Utilizing GIS with the ActiveTrans Priority Tool

This appendix addresses two questions associated with using GIS to implement the ActiveTrans Priority Tool (APT) methodology.

1. How can GIS complement the APT?
2. What are some key considerations associated with using GIS to complement the APT?

How Can GIS Complement the APT?

GIS can complement the APT in the following ways:

- To spatially define the improvement locations (Step 8).
- To measure variables that include spatial relationships (Step 8).
- To represent prioritization outcomes spatially so that they can be more easily reviewed and communicated to the public and other stakeholders (Step 10).

GIS can be used for other aspects of the method, including scaling variables (Step 9), applying factor weights (Step 3), and calculating prioritization scores (Step 10); however, doing so may compromise the transparency of the prioritization process. While GIS systems can typically perform the calculations needed for scaling, factor weighting, and calculating prioritization scores, they usually do not retain a readily accessible record of the formulas used, making it difficult to check or adjust the calculations after the fact. Consequently, it is recommended that the scaling, weighting, and prioritization calculations be performed in a spreadsheet tool, which is capable of retaining a record of formulas and can be accessed and reviewed by people who are unfamiliar with GIS or do not have it on their computers.

What Are Some Key Considerations Associated with Using GIS to Complement the APT Method?

A variety of issues must be considered when using GIS to implement aspects of the APT. Key considerations are discussed below:

- Choosing a clear process.
- Documenting the process.
- Checking data for accuracy.
- Defining the improvement location extents.
- Setting up the GIS database.
- Selecting buffer sizes.
- Normalizing calculations.
- Double-checking calculations.
- Communicating results.

Choosing a Clear Process

Any calculations performed in GIS will likely need to be communicated to people who are unfamiliar with GIS. As a result, it is probably better to opt for simpler GIS procedures that can be more easily communicated rather than more complex procedures that may be more difficult to explain and understand. For example, there might be a legitimate case for using raster analysis for some prioritization calculations; however, the potential benefits of this type of analysis must be weighed against the difficulty of explaining it.

Documenting the Process

It is important to keep a thorough, written record of all calculations performed in GIS as part of the APT methodology. For example, if buffers are used to calculate a particular variable, it is important to record the buffer size and the rationale for selecting it. If raw variable values are normalized, then details regarding the normalization should be recorded, and so on.

Keeping a detailed, written record is critical for transparency, so that others can understand how the calculations were derived, and is also valuable for reproducing the process, which may be necessary for a variety of reasons. For example, it is not uncommon for additional improvement locations to be added to a prioritization process after the calculations for an initial set of prioritization locations are complete. Calculations for the additional improvement locations should be handled in the same way as the initial calculations for consistency, in which case a thorough written record can be extremely helpful. Also, if an agency has established a process for prioritizing improvement locations, and that process is regarded as successful, it will likely want to follow the same procedure in the future. Having a written record of the process, including detailed GIS notes, will help the agency duplicate it even in cases where there have been personnel changes.

Checking Data for Accuracy

It is important to double-check the accuracy of any datasets that will be the basis for GIS calculations before the GIS calculations are performed. Datasets that do not accurately reflect the intended conditions may result in significant calculation errors. For example, if proximity to schools is selected as a variable but the dataset used does not include private schools or schools built in recent years, then improvement locations near schools not reflected in the data may receive lower prioritization scores by mistake. Another example may be crash data, which may have been transcribed from hard copy reports. It is often good practice to conduct an accuracy scan by randomly selecting data points and comparing them to the reports. If inaccuracies are uncovered, the agency must consider appropriate next steps which, depending on the nature and extent of the inaccuracies, might include correcting the inaccuracies; using a different, more accurate dataset; or dropping variables if accurate data cannot be found to represent them.

Defining the Geographic Extents of Improvement Locations to Facilitate Comparison

Defining the geographic extents of improvement locations is something that will likely be done as part of Step 7: Set Up Prioritization Tool. GIS can be used to define the geographic extents of improvement locations so that they are more comparable, something that may be particularly important in the case of roadway segments, corridors, and neighborhoods/areas, since in these cases geographic extent can have a significant impact on the final prioritization score. It is not necessary that geographic extents be exactly equal, only that they be roughly equivalent, avoiding extreme differences that can result in counterintuitive prioritization results.

Setting Up the GIS Database

Setting up the GIS database is something that should be accomplished in Step 7: Set Up Prioritization Tool. As previously mentioned, in order to maintain transparency in the prioritization process GIS should generally not be used for scaling variables, applying factor weights, and calculating prioritization scores. These calculations should instead be done in a spreadsheet tool. Consequently, it is recommended that the GIS database be set up to facilitate conversion between spreadsheet and GIS database formats easily. The GIS database should generally include the following columns or fields:

- Common key field. A common key is an attribute that two data sets have in common, such as a street segment ID. Using a common key ensures that the data order and integrity is maintained as several sources are combined.
- Fields for important improvement location descriptors. Needed descriptors will depend on the prioritization purpose and future filtering needs. For example, an agency may wish to filter improvement locations by street or neighborhood, in which case fields should be added for the street and neighborhood names.
- Fields for raw variable values. These are the fields that will accommodate the unscaled value of each variable after the necessary spatial calculations have been performed.
- Fields for scaled variable values. The purpose of these fields would be to facilitate transfer of scaled variable values calculated in a spreadsheet tool for display on a map.
- Fields for weighted factor (or variable) values. The purpose of these fields would be to facilitate transfer of weighted factor (or variable) values calculated in a spreadsheet tool for display on a map.

Selecting Buffer Sizes

The selection of buffer sizes will likely occur in conjunction with Step 8: Measure and Input Data. Buffers are commonly used in GIS prioritization calculations; however, it is important to select buffer sizes carefully, since the choice of buffer size can have a significant impact on prioritization scores.

Figure B-1 and Figure B-2 show how the choice of buffer size can make a difference. Both figures show corridors X and Y and both figures show a series of stars representing locations for the variable. In Figure B-1 the buffers around Corridor X and Corridor Y are comparatively small, and both buffers contain four stars. In Figure B-2 the buffer is larger. As a result, the buffer around Corridor X includes 11 stars, while the buffer around Corridor Y includes only five stars, meaning that the raw score for Corridor X is now more than twice as large as the raw score for Corridor Y.

Given the impact of buffer sizes, it is very important to be clear about what the buffer is intended to capture. If the improvement location type is intersections and crossings, and the variable being calculated is "number of crashes involving pedestrians," then the buffer is likely intended to gauge the relative current safety of the intersection or crossings. The choice of buffer size should reflect this intention, i.e., it should only include crashes at or very near the intersection or crossing rather than crashes that are further afield, since such crashes are unlikely to suggest anything about the relative safety of the intersections or crossings being prioritized.

Similarly, if the improvement location type is a corridor and the variable being calculated is "proximity to park," then the buffer is likely intended to gauge the relative potential demand for bicycling along each corridor as a means of accessing parks. In cases like this, it might be tempting to consider how far people are generally willing to bicycle to parks, but this would

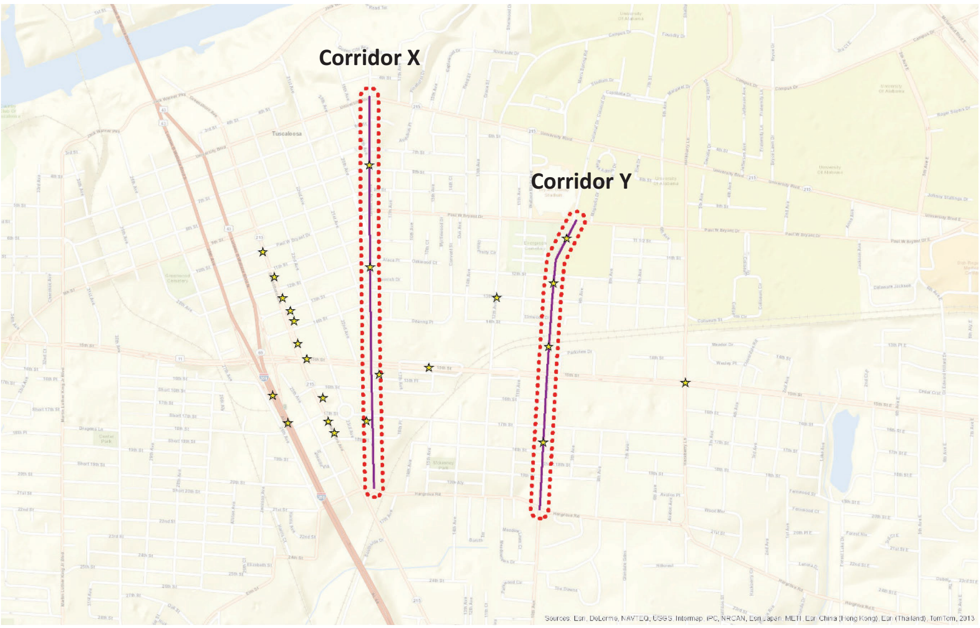

Figure B-1. Corridor X and Corridor Y with small buffer.

reflect a mistaken understanding of what the buffer is intended to capture. The question in this case is not, "How far would the average person be willing to ride a bicycle to a park?" but rather, "Would the average person use this corridor to access a given park if the park were X distance away from the corridor?" Thus, the way the question is framed has a significant impact on the chosen buffer size, with the former question seeming to justify a much larger buffer than the latter question.

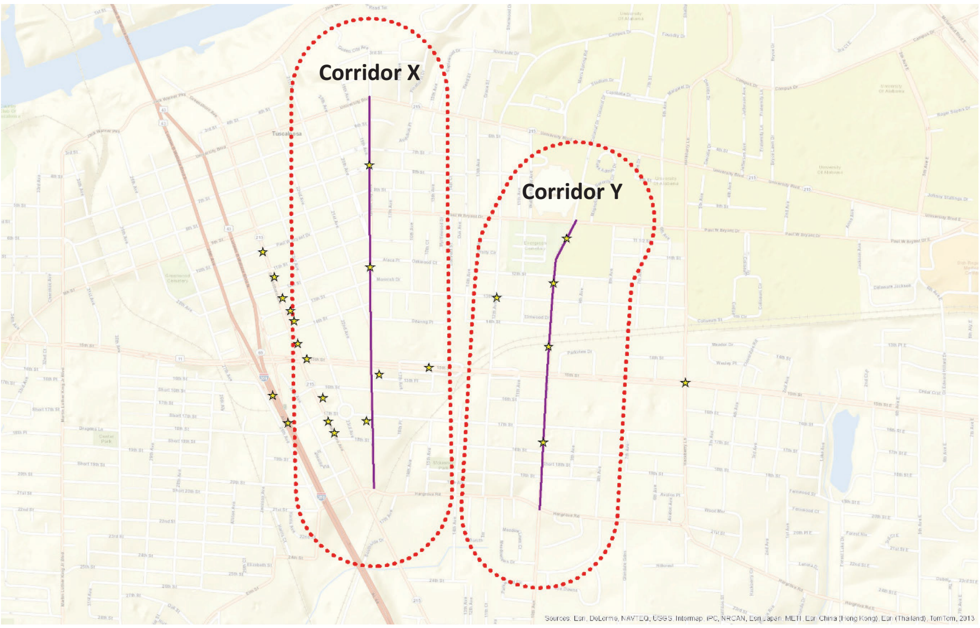

Figure B-2. Corridor X and Corridor Y with larger buffer.

In addition to understanding what the buffer is intended to capture, it is also important to consider whether the variable layer used in the calculations is represented by points, lines, or polygons, since the type of geographic representation can affect whether particular locations are included in the buffer. For example, it makes a difference whether parks are represented as points or polygons, since although the boundaries of a park may be within the buffer distance, a point representing the location of the park may not be within the buffer.

Finally, given the sensitivity of the buffer size choice and the number of factors that must be considered, it is recommended that buffer sizes be confirmed with others involved in the prioritization process before being used in GIS calculations.

Normalizing Calculations

The process of normalizing calculations is typically part of Step 8: Measure and Input Data. In many cases raw variable values involving roadway segments, roadway corridors, and neighborhoods/areas should be normalized in GIS before being transferred to a spreadsheet for scaling and other prioritization calculations. The reason is that the relative size of these location types will likely have an unintended influence on the raw variable value. For example, a larger neighborhood might have a larger number of community facilities simply because it is larger. Should it receive a higher prioritization score on this account alone? Normalization removes size from the equation. In the case of segments and corridors, this will likely mean dividing the segment or corridor variable raw value by the length of the segment or corridor in feet or miles, while in the case of neighborhoods/areas the divisor will likely be the area in acres or square miles. Table B-1 provides an example of how normalization works. In this example, the normalized variable value is calculated by dividing raw variable value for the corridor by the length of the corridor in miles.

Double-Checking All Calculations

All GIS calculations should be double-checked to make sure that they were performed correctly. Strategies for double-checking GIS calculations related to the APT include:

- Look at the high and low values for each variable. Are they unexpectedly high or low?
- Use an improvement location you know well as a test case. Do the values for this improvement location make sense?
- For each variable, create a heat map to symbolize the values. Do you notice anything unusual or unexpected when the data is displayed this way?

Table B-1. Example of normalizing variable values by corridor length.

Raw Variable Value	Corridor Length	Normalized Variable Value
30	1.5 miles	20
20	2 miles	10
45	3 miles	15

If the answer to any of these questions is yes, then the reasons why should be investigated, and if necessary the operations should be re-performed.

Communicating Results

Maps created in GIS are an excellent way to communicate and cross-check the final prioritization calculations, including scaled variable values, unweighted factor scores, weighted factor scores, and prioritization scores. Since it is recommended that these calculations be done in a spreadsheet tool rather than in GIS, they will likely have to be imported back into GIS in order to be mapped.

Several types of maps can be created. Examples include heat maps (Figure B-3) and phasing maps (Figure B-4).

Heat Maps

Heat maps can be used to display the relative magnitude of scaled variable values, unweighted factor scores, weighted factor scores, and prioritization scores for public review. They can also serve as the basis for further prioritization efforts, such as the identification of priority pedestrian or bicycle routes within the study area by a stakeholder group.

Phasing Maps

One result of a prioritization process may be to determine project phasing. In such cases, a phasing map can be used to communicate the prioritization process. A phasing map shows project routes or spot locations using a symbolic scheme to demonstrate a time frame for improvements. The example below shows short-, medium-, and long-term prioritized projects for the Bellingham, WA, Bicycle Master Plan.

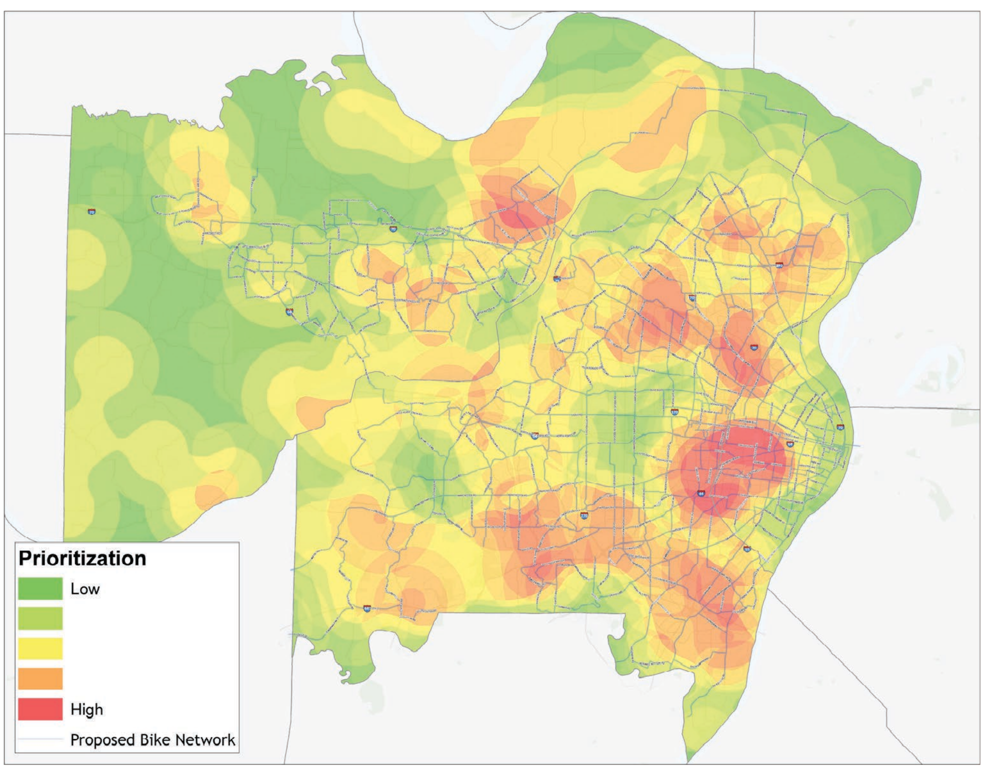

Figure B-3. Heat map.

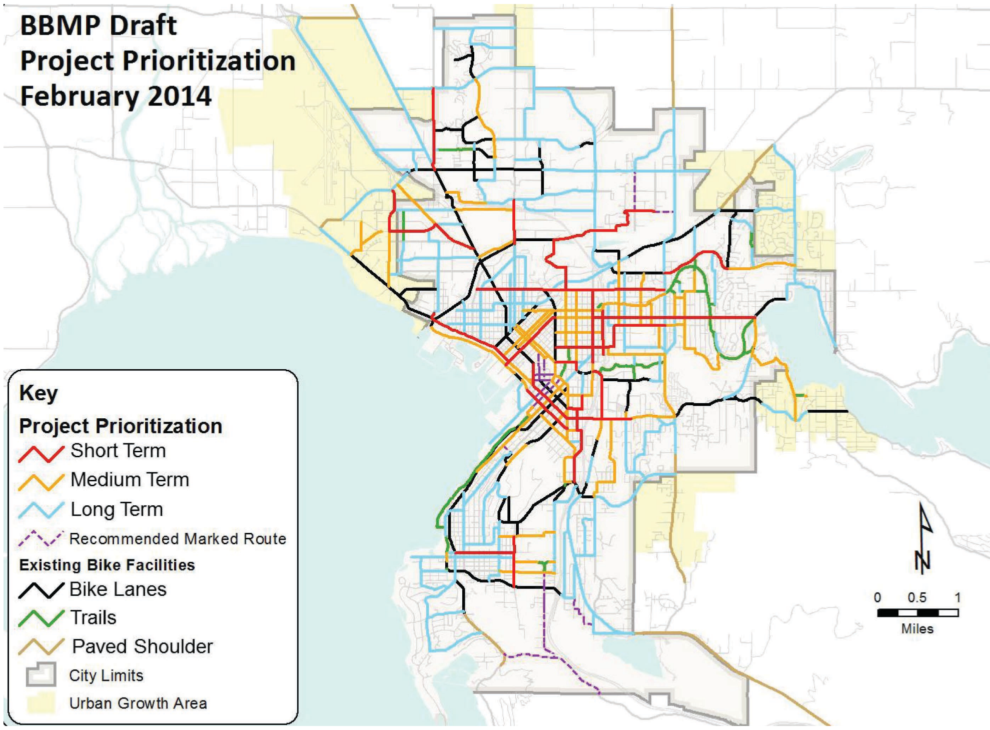

Figure B-4. Phasing map.

APPENDIX C

Existing Condition and Demand Variable References

Table C-1. Variables used in pedestrian suitability analysis tools.

Variable	Pedestrian Level of Service (LOS) (Segment)	Pedestrian Level of Service (LOS) (Uncontrolled Crossing)	Pedestrian Level of Service (LOS) (Signalized Intersection)	FHWA Crosswalk Guidelines	Pedestrian Intersection Safety Index (ISI)	Pedestrian Crash Modification Factors	Notes
Traffic speed in the parallel direction of travel or roadway being crossed	X	X	X	X	X		
Traffic volume and composition (proportion heavy vehicles) in the parallel direction of travel or roadway being crossed	X	X		X	X		
Right-turn-on-red restricted/allowed			X			X	
Signal timing (e.g., leading pedestrian interval, pedestrian clearance time, pedestrian and bicycle delay)						X	
Presence/type of traffic control (e.g., traffic signal, stop sign)					X		
Presence of crosswalk warning signs or beacons (e.g., in-street crossing signs, rectangular rapid flashing beacons, pedestrian hybrid beacon)		X				X	
Number of general-purpose (through) lanes in the parallel direction of travel or being crossed	X		X	X	X		
Number of designated right-turn lanes in the parallel direction of travel or roadway being crossed							See Schneider et al. (2010)
Total crossing distance		X					
Curb radius (for right-turn vehicles)							See AASHTO Pedestrian Guide (2004) and FHWA PedSAFE (2013)
Presence of median or crossing island				X		X	
Presence and utilization of on-street parking	X						

Table C-1. (Continued).

Variable	Pedestrian Level of Service (LOS) (Segment)	Pedestrian Level of Service (LOS) (Uncontrolled Crossing)	Pedestrian Level of Service (LOS) (Signalized Intersection)	FHWA Crosswalk Guidelines	Pedestrian Intersection Safety Index (ISI)	Pedestrian Crash Modification Factors	Notes
Presence and width of bicycle lanes	X						
Presence and width of the paved outside shoulder	X						
Frequency of driveway crossings							See Schneider (2011)
Presence and width of buffer between sidewalk and motorized traffic	X						
Presence and width of sidewalk	X						
Presence of traffic calming measures							See Zein, et al. (1997), AASHTO Pedestrian Design Guide (2004), and FHWA PEDSAFE (2013)
Sidewalk condition							See AASHTO Pedestrian Design Guide (2004) and FHWA PEDSAFE (2013)
Source	Multimodal Level of Service for Urban Streets (Dowling et al., 2008, p. 88)	Multimodal Level of Service for Urban Streets (Dowling et al., 2008, p. 88-91)	Multimodal Level of Service for Urban Streets (Dowling et al., 2008, p. 88)	Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations, Final Report and Recommended Guidelines (Zegeer et al., 2005, p. 54)	Pedestrian and Bicyclist Intersection Safety Indices, Final Report (Carter et al., 2006, p. 38)	Crash Modification Factor Clearinghouse (FHWA, 2014, http://www.cmfclearinghouse.org/)	

Table C-2. Variables used in bicycle suitability analysis tools.

Variable	Bicycle Level of Service (LOS) (Segment)	Bicycle Level of Traffic Stress (LTS)	Bicycle Compatibility Index (BCI)	Bicycle Level of Service (LOS) (Signalized Intersection)	Bicycle Level of Traffic Stress (LTS)	Bicycle Intersection Safety Index (ISI)	Bicycle Crash Modification Factors	Notes
Traffic speed in the parallel direction of travel or roadway being crossed	X	X	X		X			
Traffic volume and composition (proportion heavy vehicles) in the parallel direction of travel or roadway being crossed	X		X			X		
Right-turning traffic volume			X					
Right-turn-on-red restricted/allowed								See *NACTO Urban Bikeway Design Guide* (2012)
Presence/type of traffic control (e.g., traffic signal, stop sign)						X		
Presence of crosswalk warning signs or beacons (e.g., in-street crossing signs, rectangular rapid flashing beacons, pedestrian hybrid beacon)						X		
Number of general-purpose (through) lanes in the parallel direction of travel or being crossed	X	X			X	X	X	
Number of designated right-turn lanes in the parallel direction of travel						X	X	
Total crossing distance				X				
Curb radius (for right-turn vehicles)					X			
Presence of median or crossing island					X		X	
Presence and utilization of on-street parking	X		X					
Presence and width of bicycle lanes	X	X	X				X	
Presence and width of the paved outside shoulder	X	X						
Degree of separation/buffer width between bicycle and motorized traffic							X	Also see Dill and McNeil (2012) and Lusk et al. (2013)
Frequency of driveway crossings	X						X	
Presence of traffic calming measures								See Zein, et al. (1997), AASHTO Pedestrian Design Guide (2004), and FHWA BIKESAFE (2014)
Width of the outside through lane	X		X					
Pavement condition	X							
Source	Multimodal Level of Service for Urban Streets (Dowling et al., 2008, p. 83)	Low-Stress Bicycling and Network Connectivity (Mekuria et al., 2012, Tables 2 to 6)	Bicycle Compatibility Index, Implementation Manual (FHWA, 1999, Table 1)	Multimodal Level of Service for Urban Streets (Dowling et al., 2008, p. 83-84)	Low-Stress Bicycling and Network Connectivity (Mekuria et al., 2012, Tables 5 to 8)	Pedestrian and Bicyclist Intersection Safety Indices, Final Report (FHWA, 2006, p. 34)	Crash Modification Factor Clearinghouse (FHWA, 2014, http://www.cmfclearinghouse.org/)	

Table C-3. Variables used in pedestrian demand model studies.

Variable	Maryland Meso-Scale Model of Pedestrian Demand	Charlotte, NC, Signalized Intersection Pedestrian Volume Model	Alameda County, CA, Intersection Pedestrian Volume Model	San Francisco Intersection Pedestrian Volume Model (1)	Santa Monica, CA, Pedestrian Volume Model	San Diego, CA, Pedestrian Volume Model	Montreal, QC, Signalized Intersection Pedestrian Volume Model	San Francisco Intersection Pedestrian Volume Model (2)	Portland, OR, Pedestrian Index of the Environment	WalkScore®	Notes
Population or housing unit density	X	X	X	X		X	X	X	X		
Employment density	X	X	X	X	X	X		X	X		
Commercial retail property density/proximity/accessibility	X		X		X	X	X	X		X	
Transit station or stop density/proximity/accessibility		X	X	X	X	X	X	X	X		
Density/proximity/accessibility of attractors (grocery stores, restaurants, coffee shops, banks, parks, schools)							X		X	X	
Land use mix		X		X							
Proximity to college/university campus								X			
Bicycle facility density/proximity/accessibility (e.g., multi-use trail, bicycle lane, cycle track, bicycle boulevard)				X		X					
Number of boardings at transit stops						X					
Proportion of residents living in poverty or without access to an automobile	X					X					
Roadway slope				X				X			
Distance from downtown/central business district							X				
Source	A Meso-Scale Model of Pedestrian Demand (Clifton et. al, 2008)	Assessment of Models to Measure Pedestrian Activity at Signalized Intersections (Pulugurtha and Repaka, 2008)	Pilot Model for Estimating Pedestrian Intersection Crossing Volumes (Schneider et al., 2009a)	Pedestrian Volume Modeling: A Case Study of San Francisco (Liu and Griswold, 2009)	GIS Based Bicycle and Pedestrian Demand Forecasting Techniques (Haynes and Andrzejewski, 2010)	Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and its Relationship to Land Use, Transportation, Safety, and Facility Type (Jones et al., 2010)	Modeling of Pedestrian Activity at Signalized Intersections: Land Use, Urban Form, Weather, and Spatiotemporal Patterns (Miranda-Moreno and Fernandes, 2011)	Development and Application of the San Francisco Pedestrian Intersection Volume Model (Schneider et al., 2012)	The Pedestrian Index of the Environment (PIE): Representing the Walking Environment in Planning Applications (Singleton et al., 2014)	www.walkscore.com (Note: The details of the WalkScore calculation methodology are not available publicly. The methodology has been changed in the past and could be changed again. Public users can also update data.)	

Table C-4. Variables used in bicycle demand model studies.

Variable	Cambridge, MA, Space Syntax Bicycle Volume Model	Santa Monica, CA, Bicycle Volume Model	San Diego, CA, Bicycle Volume Model	Alameda County, CA, Bicycle Volume Models	Montreal, QC, Signalized Intersection Bicycle Volume Model	Portland, OR, Bicycle Route Choice Model	San Francisco Bicycle Route Choice Model	Bike Score™	Notes
Population or housing unit density	X								
Employment density	X		X		X				
Commercial retail property density/proximity/accessibility				X				X	
Transit station or stop density/proximity/accessibility		X			X				
Density/proximity/accessibility of attractors (grocery stores, restaurants, coffee shops, banks, parks, schools)								X	
Land use mix		X			X				
Proximity to college/university campus				X					
Bicycle facility density/proximity/accessibility (e.g., multi-use trail, bicycle lane, cycle track, bicycle boulevard)		X	X	X	X	X	X	X	Also significant in Dill and Voros (2007) Portland survey.
Proportion of residents living in poverty or without access to an automobile					X				Also significant in Dill and Carr (2003) bicycle commuting study and Dill and Voros (2007) Portland survey.
Density/proximity/accessibility of number of bike share docking stations									Strauss and Miranda-Moreno (2013) recommend for future research
Roadway slope				X		X	X	X	
Roadway density/connectivity	X			X	X				
Distance from downtown/central business district									Significant in Dill and Voros (2007) Portland survey.
Source	The Applicability of Space Syntax to Bicycle Facility Planning (McCahill and Garrick, 2008)	GIS Based Bicycle and Pedestrian Demand Forecasting Techniques (Haynes and Andrzejewski, 2010)	Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and its Relationship to Land Use, Transportation, Safety, and Facility Type (Jones et al., 2010)	Pilot Models for Estimating Bicycle Intersection Volumes (Griswold, Medury, and Schneider, 2011)	Spatial Modeling of Bicycle Activity at Signalized Intersections (Strauss and Miranda-Moreno, 2013)	Understanding and Measuring Bicycling Behavior: A Focus on Travel Time and Route Choice (Dill and Gliebe, 2008)	A GPS-based bicycle route choice model for San Francisco, California (Hood, Sall, and Charlton, 2011)	http://www.walkscore.com/bike-score-methodology.shtml (Note: The methodology could be changed in the future. Public users can also update data.)	

APPENDIX D

Guidebook References and Resources

Association of American State Highway and Transportation Officials (AASHTO). *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities*, First Edition, 2004.

AASHTO. *Guide to the Development of Bicycle Facilities,* Fourth Edition, 2012.

Aultman-Hall, L., F. L. Hall, and B. B. Baetz. Analysis of Bicycle Commuter Routes Using Geographic Information Systems: Implications for Bicycle Planning, *Transportation Research Record 1578*, TRB, National Research Council, Washington, D.C., pp. 102–110, 1997.

Aultman-Hall, L., and J. LaMondia. *Developing a Methodology to Evaluate the Safety of Shared-Use Paths: Results from Three Corridors in Connecticut*, Connecticut Department of Transportation, May 2004.

Barnes, G. *The Benefits of Bicycling in Minnesota*, Minnesota Department of Transportation, December 2004.

Bicycle Federation of Wisconsin. *The Economic Impact of Bicycling in Wisconsin*, prepared for the Governor's Bicycle Coordinating Council by the Bicycle Federation of Wisconsin in conjunction with the Wisconsin Department of Transportation, 2006.

Bushell, M. A., B. W. Poole, C. V. Zegeer, and D. A. Rodriguez. *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*, UNC Highway Safety Research Center, prepared for the Federal Highway Administration and supported by the Robert Wood Johnson Foundation through its Active Living Program, October 2013.

Carter, D. L., W. W. Hunter, C. V. Zegeer, J. R. Stewart, and H. F. Huang. *Pedestrian and Bicyclist Intersection Safety Indices: Final Report*, Federal Highway Administration, Report Number FHWA-HRT-06-125, November 2006.

Clifton, K. J., C. V. Burnier, R. J. Schneider, S. Huang, and M. W. Kang. A Meso-Scale Model of Pedestrian Demand. Prepared by The National Center for Smart Growth Research and Education, University of Maryland, College Park for ACSP-AESOP 4th Joint Congress, Chicago, IL, 2008.

Dill, J., and T. Carr. Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them, *Transportation Research Record: Journal of the Transportation Research Board, No. 1828*, Transportation Research Board of the National Academies, Washington, D.C., pp. 116–123, 2003.

Dill, J., and J. Gliebe. *Understanding and Measuring Bicycling Behavior: A Focus on Travel Time and Route Choice, Final Report*, Oregon Transportation Research and Education Consortium, OTREC-RR-08-03, December 2008.

Dill, J., and N. McNeil. Four Types of Cyclists? Testing a Typology to Better Understand Bicycling Behavior and Potential, Working Paper, Portland State University, Oregon Transportation Research and Education Consortium, 2012.

Dill, J., and K. Voros. Factors Affecting Bicycling Demand: Initial Survey Findings from the Portland, Oregon Region. *Transportation Research Record: Journal of the Transportation Research Board*, *2031*, pp. 9–17, 2007.

Dowling, R., D. Reinke, A. Flannery, P. Ryus, M. Vandehey, T. Petritsch, B. Landis, N. Rouphail, and J. Bonneson. *NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets*, Transportation Research Board of the National Academies, Washington, D.C., 2008.

East Florida Regional Planning Council. *Economic Impact Analysis of Orange County Trails*, 2011.

Federal Highway Administration. *The Bicycle Compatibility Index: A Level of Service Concept, Implementation Manual*, FHWA-RD-98-095, 1999.

Federal Highway Administration. Crash Modification Factors Clearinghouse, available online, http://www.cmfclearinghouse.org/, 2014.

Federal Highway Administration. National Household Travel Survey, available online: http://nhts.ornl.gov/, 2009.

Federal Highway Administration. *Report to the US Congress on the Outcomes of the Nonmotorized Transportation Pilot Program*, SAFETEA-LU Section 1807, submitted by the Federal Highway Administration with the assistance of the U.S. Department of Transportation's Volpe National Transportation Systems Center, April 2012.

Federal Highway Administration, Pedestrian and Bicycle Information Center, *Benefit-Cost Analysis of Bicycle Facilities*, available online, http://www.bicyclinginfo.org/bikecost/, 2006.

Federal Highway Administration, Pedestrian and Bicycle Information Center, *Bicycle Safety Guide and Countermeasure Selection System (BIKESAFE)*, Available online http://www.pedbikesafe.org/BIKESAFE/, 2014.

Federal Highway Administration, Pedestrian and Bicycle Information Center, *Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE)*, Available online http://www.pedbikesafe.org/PEDSAFE/, 2013.

Google Earth. Available online, http://www.google.com/earth/index.html, 2014.

Google Street View. Available online, https://www.google.com/maps/views/streetview?gl=us, 2014.

Gotschi, T. "Costs and Benefits of Bicycling Investments in Portland, Oregon," *Journal of Physical Activity and Health*, Volume 8, Supplement 1, pp. S49–S58, 2011.

Gotschi, T., and K. Mills. *Active Transportation for America: The Case for Increased Federal Investment in Bicycling and Walking*, Rails-to-Trails Conservancy and Bikes Belong, 2008.

Griswold, J. B., A. Medury, and R. J. Schneider. "Pilot Models for Estimating Bicycle Intersection Volumes," *Transportation Research Record: Journal of the Transportation Research Board, No. 2247*, Transportation Research Board of the National Academies, Washington, D.C., pp. 1–7, 2011.

Handy, S. L., Y. Xing, and T. J. Buehler. Factors Associated with Bicycle Ownership and Use: A Study of 6 Small U.S. Cities, *Transportation*, Volume 37, Issue 6, pp. 967–985, 2010.

Harkey, D. L., S. Tsai, L. Thomas, and W. W. Hunter. "Pedestrian and Bicycle Crash Analysis Tool (PBCAT) Version 2.0," Federal Highway Administration, FHWA HRT–06–090, 2006.

Haynes, M., and S. Andrzejewski. GIS Based Bicycle and Pedestrian Demand Forecasting Techniques. Travel Model Improvement Program Webinar. Available online, http://media.tmiponline.org/webinars/2010/fehr_and_peers.pdf, April 29, 2010.

Hood, J., E. Sall, and B. Charlton. A GPS-Based Bicycle Route Choice Model for San Francisco, California, *Transportation Letters: The International Journal of Transportation Research*, Volume 3, pp. 63–75, 2011.

Jones, M. G., S. Ryan, J. Donlan, L. Ledbetter, L. Arnold, and D. Ragland. *Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and Its Relationship to Land Use, Transportation, Safety, and Facility Type*, Alta Planning and Design and Safe Transportation Research and Education Center, University of California, Berkeley, available online, 2010.

Krizek, K. J., G. Barnes, G. Pointexter, P. Mogush, K. Thompson, D. Levinson, N. Tilahun, D. Loutzenheiser, D. Kidston, W. Hunter, D. Tharpe, Z. Gillenwater, and R. Killingsworth. *NCHRP Report 552: Guidelines for Analysis of Investments in Bicycle Facilities*, Transportation Research Board of the National Academies, Washington, D.C., 2006.

Lawrie, J., T. Norman, M. Meletiou, and S. W. O'Brien. *Bikeways to Prosperity: Assessing the Economic Impact of Bicycle Facilities*, prepared for the North Carolina Department of Transportation, 2006.

Liu, X., and J. Griswold. Pedestrian Volume Modeling: A Case Study of San Francisco, *Association of Pacific Coast Geographers Yearbook*, Vol. 71, 2009.

Lusk, A. C., P. Morency, L. F. Miranda-Moreno, W. C. Willett, and J. T. Dennerlein. Bicycle Guidelines and Crash Rates on Cycle Tracks in the United States, *American Journal of Public Health*, Volume 103, Number 7, pp. 1240–1248, 2013.

McCahill, C. T., and N. Garrick. The Applicability of Space Syntax to Bicycle Facility Planning. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2074*, pp. 46–51, 2008.

Mekuria, M. C., P. G. Furth, and H. Nixon. *Low-Stress Bicycling and Network Connectivity.* Mineta Transportation Institute, College of Business, San José State University, 2012.

Miranda-Moreno, L. F., and D. Fernandes. Modeling of Pedestrian Activity at Signalized Intersections: Land Use, Urban Form, Weather, and Spatiotemporal Patterns, *Transportation Research Record: Journal of the Transportation Research Board, No. 2264*, pp. 74–82, 2011.

National Association of City Transportation Officials. *NACTO Urban Bikeway Design Guide*, 2nd Edition, 2012.

New Zealand Transport Agency. *Economic Evaluation Manual*, Volume 1, available online, January 2010.

Pulugurtha, S. S., and S. R. Repaka. Assessment of Models to Measure Pedestrian Activity at Signalized Intersections, *Transportation Research Record: Journal of the Transportation Research Board, No. 2073*, pp. 39–48, 2008.

Rosén, E., H. Stigson, and U. Sander. Literature Review of Pedestrian Fatality Risk as a Function of Car Impact Speed, *Accident Analysis and Prevention*, Volume 43, pp. 25–33, 2011.

San Francisco Department of Public Health. *Bicycle Environmental Quality Index*, 2007.

San Francisco Department of Public Health. *Pedestrian Environmental Quality Index*, 2008.

Schneider, R. J. Understanding Sustainable Transportation Choices: Shifting Routine Automobile Travel to Walking and Bicycling, University of California, Berkeley dissertation, http://www.uctc.net/research/UCTC-DISS-2011-01.pdf, 2011.

Schneider, R. J., L. S. Arnold, and D. R. Ragland. A Methodology for Counting Pedestrians at Intersections: Using Automated Counters to Extrapolate Weekly Volumes from Short Manual Counts, *Transportation Research Record: Journal of the Transportation Research Board, No. 2140*, Transportation Research Board of the National Academies, Washington, D.C., pp. 1–12, 2009b.

Schneider R. J., L. S. Arnold, and D. R. Ragland. A Pilot Model for Estimating Pedestrian Intersection Crossing Volumes, *Transportation Research Record: Journal of the Transportation Research Board, No. 2140*, Transportation Research Board of the National Academies, Washington, D.C., pp. 13–26, 2009a.

Schneider, R. J., M. C. Diogenes, L. S. Arnold, V. Attaset, J. Griswold, and D. R. Ragland. Association between Roadway Intersection Characteristics and Pedestrian Crash Risk in Alameda County, California, *Transportation Research Record: Journal of the Transportation Research Board, Volume 2198*, pp. 41–51, 2010.

Schneider, R. J., T. Henry, M. F. Mitman, L. Stonehill, and J. Koehler. Development and Application of the San Francisco Pedestrian Intersection Volume Model, *Transportation Research Record: Journal of the Transportation Research Board, No. 2299*, Transportation Research Board of the National Academies, Washington, D.C., pp. 65–78, 2012.

Schneider, R., R. Patten, J. Toole, and C. Raborn. *Pedestrian and Bicycle Data Collection in United States Communities: Quantifying Use, Surveying Users, and Documenting Facility Extent*, prepared for the Federal Highway Administration by the Pedestrian and Bicycle Information Center, available online, January 2005.

Singleton, P. A., R. J. Schneider, C. D. Muhs, and K. J. Clifton. The Pedestrian Index of the Environment: Representing the Walking Environment in Planning Applications, Presented at 93rd Annual Meeting of the Transportation Research Board, Washington, D.C., 2014.

Stinson, M. A., and C. R. Bhat. Commuter Bicyclist Route Choice: Analysis Using a Stated Preference Survey, In T*ransportation Research Record: Journal of the Transportation Research Board, No. 1828*, pp. 107–115, 2003.

Strauss, J., and L. F. Miranda-Moreno. "Spatial Modeling of Bicycle Activity at Signalized Intersections," Journal of Transport and Land Use, Volume 6, Number 2, pp. 47-58, 2013.

Stutts, J. C., and W. W. Hunter. "Police-reporting of Pedestrians and Bicyclists Treated in Hospital Emergency Rooms," In *Transportation Research Record: Journal of the Transportation Research Board, No. 1635*, TRB, National Research Council, Washington, D.C., pp. 88–92, 1998.

Highway Capacity Manual 2010. Transportation Research Board of the National Academies. Washington, D.C., 2010.

United States Census Bureau. American Community Survey, available online, http://www.census.gov/acs/www/, 2013.

Walk Score. Bike Score Methodology, available online, http://www.walkscore.com/bike-score-methodology.shtml, 2014.

Walk Score. Walk Score, available online, http://www.walkscore.com/, 2014.

World Health Organization, Regional Office for Europe. Health Economic Assessment Tool, available online, http://www.heatwalkingcycling.org/, 2011.

Zegeer, C. V., J. R. Stewart, H. Huang, and P. Lagerwey. *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations*, U.S. Department of Transportation, Federal Highway Administration, FHWA-RD-04-100, 2005.

Zegeer, C. V., J. Stutts, H. Huang, M. J. Cynecki, R. Van Houten, B. Alberson, R. Pfefer, T. R. Neuman, K. L. Slack, and K. K. Hardy. *National Cooperative Highway Research Program Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 10: A Guide for Reducing Collisions Involving Pedestrians*, Transportation Research Board of the National Academies, Washington, D.C., 2004.

Zein, S. R., E. Geddes, S. Memsing, and M. Johnson. Safety Benefits of Traffic Calming, In *Transportation Research Record Volume 1578*, pp. 3–10, 1997.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation