Pedestrian and Bicycle Information Center

White Paper Series

Bicycle and Pedestrian Forecasting Tools: State of the Practice

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Introduction

Transportation forecasting models predict levels of activity, and help inform decisions on issues such as future facility use and the prioritization of projects. Travel and demand forecasting methods have long been used to estimate the number of vehicles traveling on a specific street or network and to estimate ridership for mass transit. Many jurisdictions and metropolitan planning organizations use forecasting methods to determine the potential impact of new development, changes to roadway capacity, or projected ridership for new transit.

However, these methods have traditionally excluded pedestrian and bicycle activity. For communities seeking to support walking and bicycling activity, quantifying the use and potential demand of facilities that support active transportation is increasingly important. To meet this need, bicycle and pedestrian forecasting models are being developed and integrated into planning projects focusing on facilitating mobility, managing resources, and improving health and safety.

These emerging forecasting approaches vary widely in the amount of data and level of effort required. The type, specificity, and reliability of data also vary between different forecasting approaches. For example, data used in forecasting models can range from readily available U.S. Census data to large sets of cell phone data. Simple forecasting techniques can be useful for basic estimating exercises, while more labor-intensive modeling tools can provide fine-grained analysis on future demand, network connectivity, collision rates and a number of other topics.

This paper summarizes the state of the practice of bicycle and pedestrian forecasting tools, and suggests potential next steps to improve them. The forecasting tools discussed in this paper differ in geographical application as well as the accessibility of the tools and data required to complete the analysis. The objectives of this paper are to evaluate the state of bicycle and pedestrian forecasting tools to better inform their use and to contribute to an ongoing conversation about opportunities for development of future forecasting methods. All tools were evaluated based on the resources necessary to complete analysis, as well as the practical application of the resulting information. The evaluation found that though many forecasting tools and required data are publicly available, the more sophisticated tools often require high levels of experience, extensive amounts of time and sometimes costly software. To better forecast bicycle and pedestrian activity in the future, accurate and regularly-collected public and private data and accessible analysis platforms are essential. It is also important to note that while this paper is organized by geographic scope, the analyst or model developer should carefully consider the scale of influence, scale of infrastructure, problem definition, and available data when choosing a forecasting tool instead of assuming a "one-size-fits-all" approach for modeling pedestrian and bicycle activity.

This paper is organized into the following sections:

- Definition and Purpose
- Bicycle and Pedestrian Forecasting Applications
- State of the Practice
- Conclusions and Next Steps

Definition and Purpose

A common phrase in transportation planning is that ***if it isn't counted, it doesn't count***, meaning true multi-modal planning is limited when data is missing or of poor quality. While many jurisdictions have had policies supporting multimodal transportation for at least a decade, transportation conditions are often measured using vehicle delay-based level-of-service. This results in transportation improvements focused on moving autos more efficiently. Because more traditional forecasting tools do not account for walking and bicycling, new forecasting tools are being created and used that can account for and address active transportation.

Regions and cities spend significant time, effort, and resources on travel demand forecasting. Many legislative requirements, such as congestion management process monitoring, regional transportation plan development, and statewide project development, require auto or transit trip forecasting. However, no similar equivalents are in place for bicycle and pedestrian forecasting. Currently, the amount of funding and resources allocated to bicycle and pedestrian forecasting pale in comparison to other modes, despite active transportation being an area of emphasis in most regions, and bicycle and pedestrian mode share around 11% nationwide and 14% for large cities (Alliance for Biking and Walking, 2014).

Bicycle- and pedestrian-specific forecasting allows planners and engineers to understand, quantify, and plan for the demand for bicycle and pedestrian infrastructure. The following sections outline various types of forecasting tools with case studies highlighting recent project examples.

Table 1. Popular Terms and Descriptions

Big Data	Large datasets that require advanced processing, data synthesis techniques, and integration with other datasets to produce meaningful metrics and support decision making.
Civic Technologies	Web apps, mobile apps, and APIs developed to address community issues and improve communication between governments and their constituents, often by volunteers and non-profit organizations.
Crowdsourcing	The process of obtaining information, insight, and knowledge from user-generated data provided through web and mobile applications, often to address a specific issue or solve a problem.
Forecasting	Using models to determine the future demand or use of a facility.
Regression	A statistically-based process for estimating the relationship between variables.

Forecasting Tool Types

Bicycle and pedestrian forecasting tools vary in their inputs, methods, and outputs. These tools can be categorized by their fundamental structure, by their purpose, or by their geographic scope. This paper examines two types of model structure for forecasting bicycle and pedestrian demand: aggregate and disaggregate. While geographic scope, structure, and purpose are not mutually exclusive, describing tools by their structure provides a useful framework for discussing forecasting tools for planners.

Table 2. Categories of Forecasting Tools

Structure	**Aggregate:** Aggregate forecasting tools analyze a collective or "aggregated" set of data on existing travel choices to predict travel choices. As an example, this may include using Census Journey-to-Work data for an area to determine what the mode split would be for a new school. **Disaggregate:** Disaggregate forecasting tools analyze travel choices at the individual level and then make assumptions about how many different types of individuals are represented in the population in order to forecast travel choices across the population. Using travel surveys to determine what demographic is most likely to bicycle is an example of a disaggregate forecasting approach.
Purpose	Another way to categorize forecasting tools is based on their purpose: demand estimation versus project prioritization [2]. **Demand:** Demand estimation tools seek to predict specific aspects of activity, including volumes, length, time of day, travel direction, origin and destination. This information is then used to plan and refine design for bicycle and pedestrian facilities. For example, a demand estimation tool would generate an estimated number of users for a new trail facility. **Project Prioritization:** Project prioritization tools do not necessarily aim to forecast demand, but inform our understanding of relative levels of usage in order to make more strategic decisions (i.e., how to prioritize improvements). For example, prioritization tools could use distances to schools, parks, and colleges to determine whether a new trail, separated bike lane, or bike lane should be built first.
Geographic Scope	Forecasts are typically performed at one of three geographic levels: (1) regional planning, (2) corridor and subarea planning, and (3) community, project and facility planning level. The tools discussed in this white paper generally support planning at the local area or corridor level, which is the most appropriate geographic scope for bicycle and pedestrian forecasting as average trip lengths by bicycle are typically under three miles. However, these tools are versatile enough that they can be enhanced to support broader or finer geographic scopes.

Forecasting models are different than simulation models. Simulation models create a representation of a built environment and recreate the real world to determine how users interact within that environment, i.e. how much delay occurs at an intersection. These models are not the subject of this paper but are discussed briefly.

Bicycle and Pedestrian Forecasting Tools

The National Cooperative Highway Research Program (NCHRP) Study 08-78 produced an interim report, "Estimating Bicycling and Walking for Planning and Project Development" (08-78 (Report 770 and technical background document), (March 2011) in which the authors categorized forecasting tools available by the geographic scope they cover. The report provided a comprehensive review of the various tools, which informs is summarized in much of this section.

An overview of each tool is provided along with its advantages and shortcomings. Figure 1 illustrates which tools are most appropriate for different geographic levels. Table 3 provides an overview of tools suitable for forecasting pedestrian and bicycle activity, including the advantages and disadvantages of each. The distinction between these different approaches generally has more to do with the sphere of their application rather than the actual processes themselves, which can often overlap between these methodologies.

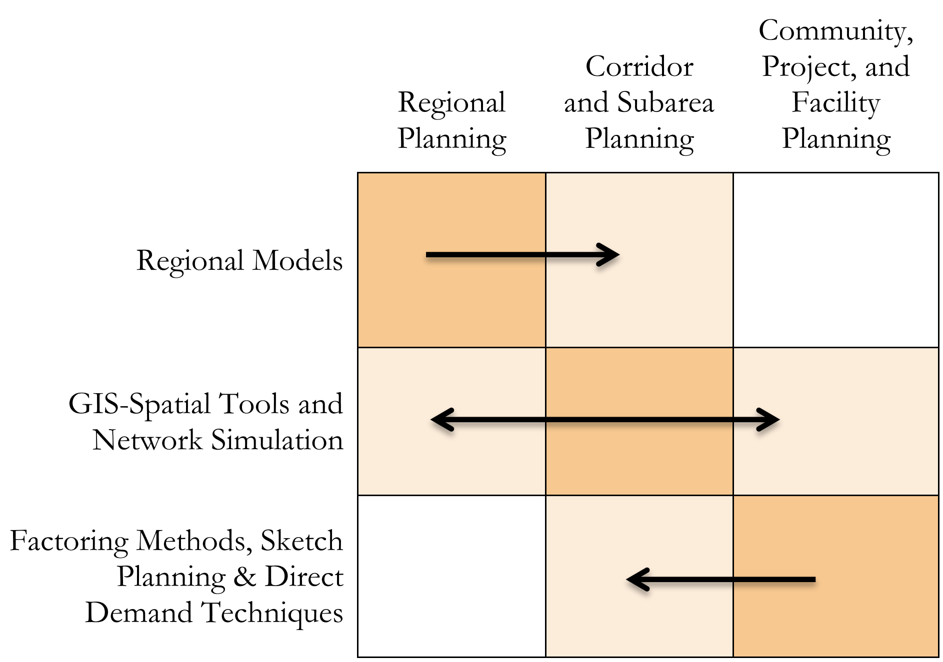

Figure 1. Geographic Framework for Bicycle and Pedestrian Modeling Methods (NCHRP 08-78, 2011)

Table 3. Summary of Forecasting Model Tools

Method	Description	Advantages	Disadvantages
Local Level			
Factor Methods and Sketch Planning Tools *(see Table 4 for more information on these methods)*	Methods use existing bicycle and pedestrian count data, elasticities (or rules of thumb) to determine projections for new facilities	• Generally rely on data that already exist or can be collected with relative ease • Can be produced with limited software, relying mainly on spreadsheets • Suitable for practical day-to-day needs such as grant applications	• Can be difficult to validate forecasts because these tools are generally based on broad data sets or may not account for enough contextual factors
Aggregate Demand Models	Typically regression models that create an equation based on an existing data set, which would include bicycle/pedestrian data and influencing attributes such as population density, land uses, etc.	• Software requirements are usually limited to spreadsheets or standard statistical software packages • Can be created largely using existing data	• They do not take into account individual trip choices and factors • They may inaccurately correlate activity levels with adjacent land use • They are not always validated against count data not included in the model development
Bike Share Forecasting	Combine elements of Aggregate Demand Models, GIS and other spatial tools. The models apply GIS and other spatial tools to the areas surrounding existing bike share stations to compile demographic data and spatial relationships between bike share stations. These factors are then analyzed to develop a regression equation that describes observed ridership levels of existing bike share stations as indicated by station-level activity data collected by the system software.	• Existing ridership data is readily available • Demographic data is publicly accessible	• Demographic data may not reflect characteristics of "tourist" users, who frequently use bike share systems • Demographics of bike share users may not reflect broader community • Validity across data sets may not be adequate

Method	Description	Advantages	Disadvantages
Corridor and Sub-area Level			
Network Simulation Tools	Uses a constructed network of links and nodes layered with other data to determine bicycle and pedestrian demand	• Adds greater sophistication to modeling efforts	• Data collection efforts can be arduous • May be time and resource-intensive to build model
GIS and Spatial Tools	Spatial modeling of built environments and proximities to determine activity levels	• Easy to update once the structure is built • Can be created using attributes like land use and population densities instead of existing count data	• Require specialized software and analysis knowledge such as ArcGIS, special extensions within ArcGIS like network or spatial analyst, and a working knowledge of tools within ArcGIS
Regional Level			
Regional Travel Demand Forecasting Models	Detailed, sophisticated models that typically employ the traditional four step process (trip generation, trip distribution, mode choice, trip assignment) to determine pedestrian and bicycle activity levels along corridors	• Regional models have been developed for all major urban areas (and thus existing travel survey data, population and employment estimates, and land uses have already been collected and analyzed) and can be modified. • Data/output from these models can be used as inputs for other models and can reduce the amount of new data and analysis that needs to be collected/ conducted.	• Conversion of existing vehicular-focused models to a pedestrian/ bicycle-scale may require significant effort. • Most regional models do not consider a "recreation" trip purpose, which comprises a significant number of pedestrian and bicycle trips. • These models require specialized software packages and expertise.
Activity and Tour-Based Models	Travel demand forecasting models that determine travel choice based on an individual's daily activity pattern in the form of trip "tours"	• Can account for effects of the built environment and travel behavior. • Output from these models can be used as inputs for others and can reduce the amount of new data or analysis that needs to be collected or conducted.	• Creation of these models is resource-intensive. • These models require specialized software packages and expertise.

Factor Methods and Sketch Planning Techniques

Overview

Factor methods and sketch planning techniques comprise a number of relatively simple methods. These techniques include using activity levels at one facility (such as a multi-use path or bike lane) to predict demand at a new facility, using census data or surveys to model relationships between activity levels and contextual factors, and using rules of thumb to estimate demand. A number of different approaches can each address a specific planning question or need. Several examples are summarized in Table 4.

Table 4. Summary of Quick Forecasting Model Tools

Approach and Purpose	Description	Data/Level of Effort Required	Outcome/Example
Estimate Future Demand using American Community Survey (ACS) and Census Data	Estimates are derived using data from the US Census and the American Community Survey (ACS). Multiplying ACS mode-share by total Census population produces an estimate for the total number of pedestrians and bicyclists. These can be scaled proportionally to the square mileage within a project area and forecasted into the future using a population growth estimate.	Very low level of effort—requires basic statistical analysis	Estimating number of users that would benefit from a proposed project. Grant applications for improvements often request this information.
Estimate Demand Based on Traffic Volumes on Adjacent Streets	These estimates are derived through use of American Community Survey: Means of Transportation to Work data and existing traffic counts to estimate potential demand for a proposed bike facility.	Existing counts are required	Facility demand estimates adjacent to existing facilities
Estimating Demand for an Improved Roadway based on Level of Traffic Stress (LTS)	Estimates can be derived using existing count data on a facility for which LTS data is also available. LTS classifies road segments into four levels of traffic stress, (low to high). Using multipliers for types of bicyclists and their corresponding LTS score, future activity can be estimated for a segment or network where improvements in the LTS score are made.	Existing LTS data and counts are required	Future ridership based on existing facility safety and access improvements
Extract Short Trips within a Travel Demand Model	Short trips from within a travel demand model could be defined by a maximum travel distance, such as five miles for bicycling and one mile for walking. These trips could then be described as potential bicycle and pedestrian demand regardless of what mode they use in the model itself. Each trip in a regional transportation demand model has a given distance from its origin to destination. This process filters those trips to meet these assumptions.	Requires access to and knowledge of a travel demand model.	A list of trips to/from a project area, filtered by a defined trip distance maximum. List of can be used as a proxy for potential bicycle and pedestrian demand.

Because these techniques can be relatively simple in nature, they typically require less data or resources for analysis. These types of models can be used to:

- Prioritize active transportation projects
- Predict the amount of bicycling or walking in one area, based on data collected in another area
- Determine differences in demand volumes at facilities
- Develop bicycle and pedestrian trip generation rate estimates
- Estimate reduced vehicle miles traveled (VMT) and emissions reductions associated with new bicycle/pedestrian infrastructure

Factor methods and sketch planning techniques can rely on spreadsheets and do not require sophisticated software. Data typically used for these methods have included Census and household travel survey data, land use data, and pedestrian/bicycle infrastructure data. While Census data is available nation-wide, availability of other data sources will depend on individual jurisdictions and may be available online. Other data used such as bicycle, pedestrian, and vehicle counts may be available through public agencies and/or consultants, but otherwise require resources to collect.

Although factor methods and sketch planning tools have not generally been perceived as being sophisticated enough to capture travel behavior decisions relating to connectivity, streetscape, and land use mix, these models can be modified to include these factors. An overarching gap exists in the suitability of available models to forecast activity levels with enough sensitivity to inform project planning, from spot locations to city-wide projects (Ridgway, 1995) (Schwartz, 1998) (NCHRP, 2011).

Advantages

- Generally rely on data that already exists or can be collected with relative ease
- Can be produced with limited software, relying mainly on spreadsheets
- Can be produced relatively quickly
- Can use publicly available data to substantiate comparative use estimates
- Offer a "right-sized" level of effort for standard requirements in grant applications

Disadvantages

- Forecasts can be difficult to validate because these techniques are not generally robust enough to account for location- or design-specific attributes
- Accuracy and transferability may be limited due to location-specificity and high variability of supporting data
- Resources allocated to the development of these models are generally limited, and thus the scope of these models tends to be limited

- Results are typically rough estimates based on existing use of a similar facility
- Most facilities are difficult to directly compare, leading to inaccurate use forecasts

Data Needs/Costs

These models generally rely on land use/zoning, population, and journey-to-work data. Bicycle and pedestrian travel patterns, including origin and destination information and key routes may also be useful. These methods are easy to understand and inexpensive to use. Geographic calibration is not needed. For more information about sketch-planning tools, refer to NCHRP Report 255 and NCHRP Report 765.

Case Study

Researcher Stuart Goldsmith used sketch planning methods to estimate the impact of a new bicycle facility on reducing vehicle miles traveled in Seattle, Washington (Goldsmith, 1997). Goldsmith first determined the boundaries of the travel shed accessible by bike surrounding the new facility and the percent of people already commuting by bike (based on Census Journey to Work data) within those boundaries. Goldsmith then estimated the impact of the new facility on generating new bicycle commuters, average trip lengths and potential diversion from single-occupancy vehicle (SOV) trips. This study does not consider the impact of facility design on travel demand. However, proximity to other bicycle routes is a factor in determining travel shed limits. Using those factors, Goldsmith determined new bicycle commute and non-work trips per day, the number of SOV trips eliminated and the reduction in VMT (see Figure 2).

For more information, visit www.fhwa.dot.gov/publications/research/safety/pedbike/98166/sec2.3.cfm.

	Average Round Trip Length	Projected New Bicycle Trips	SOV Trips Eliminated	VMT Avoided
Daily Commute Trips = (a)	3.56	144	72	244
Daily Non-work Trips = (b)	1.78	381	127	217
Total Daily Reductions = (a) + (b)		525	199	461
Total Annual Reductions = 250 * (a) + 365 * (b)		175,065	64,355	140,205

Figure 2. Results from a sketch-planning tool used in Seattle, WA (FHWA, 1999)

Aggregate Demand Models

Overview

Aggregate Demand Models are typically regression models that create an equation using activity level data and influencing attributes such as population density, land use diversity, design, and distance to transit to determine demand for active transportation. After the model is created, the user enters a set of inputs specific to the facility or area in question to yield a forecasted activity level. In this way, the models are fairly quick and easy to use.

Aggregate models can be used to:

- Identify which factors influence overall levels of bicycling or walking in an area
- Predict the change in levels of bicycling and walking
- Predict the amount of bicycling or walking in other areas, based on data collected in one area
- Develop data for use in a travel demand model [5]
- Can be used for a range of geographic scopes from intersections to metropolitan areas

GIS and other spatial tools can be used to develop and display aggregate demand models. GIS and spatial tools offer a range of capabilities from producing heat maps of walking/biking activity to forecasts of activity levels. A heat map presents stratified colors based on activity levels. Walk Score and Bikeability Index are two well-known examples of indicators that reflect the attractiveness of an area or location for walking or biking based on land uses and facilities within a certain distance, and which can be incorporated into GIS and spatial models. However, these indices do not account for actual activity levels.

Other, more data-intensive aggregate demand tools may use population density, land use mix, pedestrian friendly design, and other attributes at the parcel or grid level to create bikeability or walkability indices which become inputs for transportation demand equations. When combined, these indices could be used to predict bike share ridership or determine infrastructure design to accommodate bicyclists and/or pedestrians. This emerging blended analysis is discussed further in Section 3 – State of the Practice.

Advantages

- Software requirements are usually limited to spreadsheets or standard statistical software packages
- Can be created largely using existing data
- Most necessary data is typically publicly available and can be found at a variety of geographic levels
- Network connectivity can be estimated, but requires additional time/ resources to quantify

Disadvantages

- They do not take into account individual trip choices and factors
- Activity level (count) data is costly to collect, depending on geographic scale

- They may inaccurately correlate activity levels with adjacent land uses
- Validity between datasets may not be satisfactory
- Datasets typically used (i.e. U.S. Census Data) are not frequently updated

Data Needs/Cost

A wide variety of data can be used in these models. Data used should ideally be at the same unit of analysis to ensure consistency in the analysis. For instance, regional population densities should generally not be used with tract level auto ownership levels. The greatest constraint to this type of model is what data can be easily obtained from available sources or collected with little additional effort. Potential data sources are:

- Census or American Community Survey data: population, socioeconomic, demographic, journey-to-work
- Land uses/ zoning maps
- Topography
- Roadway network, including multimodal volumes and road characteristics

Geographic calibration is not necessary, but can be accomplished if count data are available. Accuracy of regression models will be determined by inputs and can be determined through statistical processes.

Case Study

Aggregate models have been used in bicycle and pedestrian planning efforts in several areas, including Salt Lake City, UT; San Diego and Santa Monica, California; pedestrian crossing models in San Francisco and Alameda, California and Charlotte, North Carolina; and in research to determine influencing factors of bicycling. The Massachusetts Institute of Technology has recently developed a "between-ness" computation that addresses some of the network attributes that are commonly cited as a disadvantage of this type of model such as presence of pedestrian-oriented facilities and connectivity.

The Utah Collaborative Active Transportation Study (UCATS) (Utah Department of Transportation, 2013) was a multi-jurisdictional study in the Salt Lake City area between the local Transit Authority, Department of Transportation, County, and Metropolitan Planning Organizations. The study's main focus was to create a regional bicycle network and improve pedestrian and bicycle connections to transit. To determine walking and bicycling routes with the highest demand/usage, a GIS-based latent demand model was created. This latent demand model used population and employment densities, distance to major destinations, land use mix, and network connectivity to create a demand-assigned bicycle and pedestrian network. This GIS model was used to prioritize projects based on the relative demand of a particular corridor, so that areas with the highest bicycling and pedestrian activity would receive investment first. The model can be easily updated periodically when new population and land use data become available. For more information about UCATS, see http://www.ucatsplan.com.

Bike Share Forecasting

Overview

Bike Share Forecasting Models combine elements of Aggregate Demand Models (described above) and GIS and Spatial Tools (described below). The models apply GIS and other spatial tools to the areas surrounding existing bike share stations to compile data such as:

- Population and employment density
- Land use mix
- Network or intersection density
- Transit proximity and frequency
- Other demographic and built environment variables.

The spatial relationships among bike share stations are also correlated with bike share ridership. These factors are then analyzed to develop a regression equation that describes observed ridership levels of existing bike share stations as indicated by station-level activity data collected by the system software.

Once the model has been estimated it can be applied to generate heat maps that indicate expected popularity of bike share stations across a broad geographic area. Heat maps may be based on intuitive factors that support bike share ridership (Delaware Valley Regional Planning Commission, 2009) or, ideally, based on a forecasting model calibrated to actual bike share ridership data.

Models can also be applied to estimate ridership at the station level for a specific network of proposed new or relocated bike share stations. The model can be applied within the same geographic area from which its inputs were drawn, to inform efforts to expand or relocate bike share stations within an existing system, or applied to a new area that does not yet have a bike share system to estimate potential ridership. Some inferences can also be drawn about the overall level of bike activity in an area based on the observed or predicted bike share ridership activity.

Although bike share models to date (Mauer, 2012) (Rixey, 2013)have focused on the origin of the bike share trip ("check-outs" or "rentals"), models that consider both the origin and destination of the trip can be estimated with available data.

Advantages

- Relies on ridership data that is usually collected continuously at each station by a bike share systems' software. Bike share operators are increasingly making this ridership data publicly available
- Demographic and built environment variables are also typically publicly available
- Can be estimated based on data at both the origin and destination of a bike share trip

Disadvantages

- Requires specialized software and analysis knowledge
- Validity between datasets may not be satisfactory
- Datasets typically used (i.e. U.S. Census Data) are not frequently updated
- Demographic data may not reflect characteristics of out of town visitor (i.e. tourists) users

Data Needs/Cost

Bike share ridership data are generally available from existing bike share systems. As with Aggregate Demand Models, a wide variety of data can be used as model inputs. Data used should ideally be at the same unit of analysis to ensure consistency and model applicability; particular attention should be paid to data collected from one geographic area for application in another geographic area. The greatest constraint to this type of model is what data can be easily obtained from available sources or collected with little additional effort. Potential data sources are:

- Census data, or American Community Survey: population, socioeconomic, demographic, journey-to-work
- Land uses/ zoning maps
- Topography
- Roadway network, including multimodal volumes and road characteristics
- Station locations

Bike share models do not need to be geographically calibrated. Accuracy of regression models will be determined by inputs and can be determined through statistical processes. Bike share forecasting has been shown to be statistically significant, as described in this TRB paper: http://docs.trb.org/prp/13-1862.pdf.

Case Study

Bike Share Forecasting Models have been estimated from bike share ridership data in Washington, D.C.; Minneapolis, Minnesota; Denver, Colorado; and the San Francisco Bay Area. Heat maps not validated to bike share ridership data have been applied in communities across the U.S., including Philadelphia, Pennsylvania; Providence, Rhode Island; Raleigh, North Carolina; and Eugene, Oregon, among others. More information about station-level bike share forecasts are discussed in this TRB paper: http://docs.trb.org/prp/13-1862.pdf

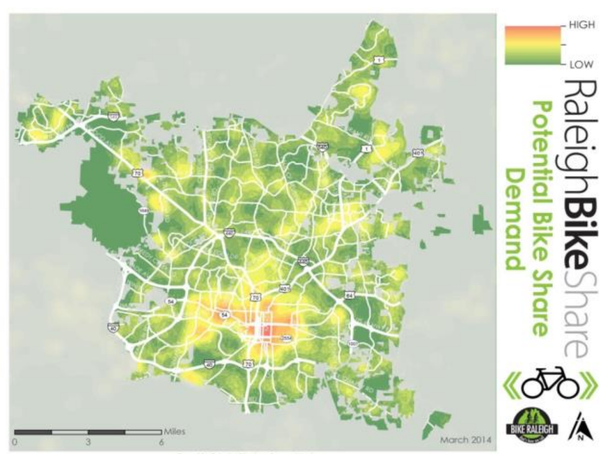

Figure 3. Potential Bike Share Demand Heat Map, Raleigh, NC

Network Simulation Tools

Overview

Network simulation tools use a representation of a network, complete with links and nodes, integrated with other data, such as street network density, block size, and local attractions, to determine activity levels and travel times. Network simulation tools can also account for how collisions may affect pedestrian volumes. However, building a developed network can be arduous, especially for complex systems. Previous studies have taken into account:

- Regional transportation
- Block size
- Street directionality
- Roadway type
- Attraction locations
- Collision data

Network simulation, GIS, and spatial tools require more sophisticated skills and software (GIS) to simulate a network with links and nodes and to populate them with contextual variables that are ultimately used to estimate a likelihood level of users traveling on each link by bicycle or foot. Depending on the scope of the subject network, this could be time-intensive; however, using road centerline files in GIS can reduce the effort of creating the network. Thus, network simulation tools benefit from having Census, network, count, and land use data available in GIS format or readily convertible into a GIS format.

To minimize the data collection effort, some studies have focused counts at spot locations during peak hours or even smaller time increments and used multipliers to estimate period or daily volumes. One of the biggest challenges is that bicycle and pedestrian activity can sometimes be low enough that is can be difficult to extrapolate the data into meaningful or reliable information.

Advantages

- Adds greater sophistication to modeling efforts by accounting for the pedestrian/bicycle network in trip decision making
- Models can be calibrated using pedestrian counts from previous planning studies

Disadvantages

- Data collection efforts can be arduous
- Activity level data is costly to collect, depending on geographic scale
- May be time-intensive to build model
- May mistakenly correlate activity with network attributes, such as correlating small block sizes in an industrial area with high pedestrian activity

Data Needs/Cost

Simulation tools require a network as the base of a model. Depending on the software being used, the network can be based on an existing GIS-based network data. Otherwise, a network will need to be coded within the tool and may require additional data collection to determine, among others, roadway locations and number of lanes. These models also require pedestrian and bicycle count data, land use data, and population/employment data.

These models should be geographically calibrated. Accuracy can be improved by calibrating the model with count data. Previous models, such as the Space Syntax model described below, have been useful in predicting bicycle volumes.

Case Study

The Space Syntax model, which is widely used in Europe and Asia for pedestrian network planning, is one type of simulation tool in which network variables such as connectivity, distance, and accessibility are layered on top of the existing pedestrian and/or bicycle network to determine relative route attractiveness (Space Syntax). This metric is then correlated with count data, which allows demand to be predicted in other locations using interpolation. A Space Syntax analysis for the City of Berkeley's *Pedestrian Master Plan* analyzed pedestrian safety based on built environment factors, count volumes and the Statewide Integrated Traffic Records System (SWITRS) data to identify corridors with high pedestrian exposure (Safe Transportation Education and Research Center, 2010). Pedestrian exposure calculations were based on the forecasted level of pedestrian activity and SWITRS collision data.

For more information, visit http://www.ci.berkeley.ca.us/pedestrian/.

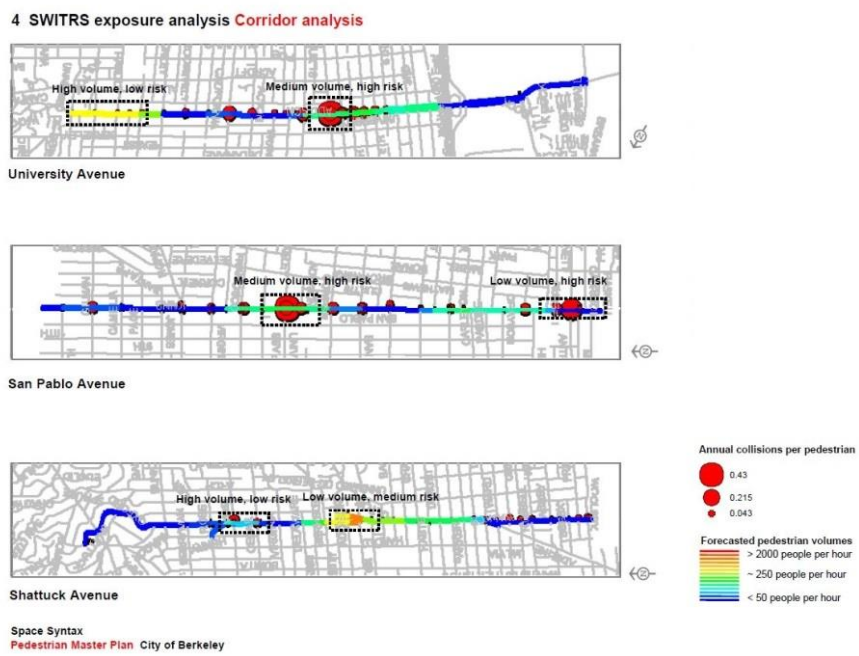

Figure 4. Pedestrian Collision Exposure Analysis (Space Syntax), City of Berkeley, CA

Regional Travel Demand Forecasting Models

Overview

Regional travel demand forecasting models are detailed models which employ the traditional four-step process typically used for vehicle traffic and transit analysis:

- Trip generation (estimates number and types of trips for households)
- Trip distribution (correlates trips originating in a traffic analysis zone with trips destined to another traffic analysis zones)
- Mode choice (proportion of trips for each origin-destination pair into mode categories (pedestrian, bicycle, transit, auto, truck)
- Traffic assignment (assigns trips to routes on the road network).

Regional demand forecasting models are typically used to plan and forecast roadway and transit networks. Modifying these models to incorporate bicycle and pedestrian modes can provide consistency through the planning process; however, these models have significant drawbacks for pedestrian and bicycle planning purposes. These drawbacks include:

- Traffic analysis zones (TAZs) are relatively large and may not capture internal bicycle/pedestrian trips
- These models do not commonly depict the quality of the pedestrian and bicycle networks across a region, an important factor in determining the likelihood of pedestrian and bicyclist activity.
- These models have typically excluded non-motorized trips from the latter steps (trip distribution and route selection) which are necessary to achieve a prediction of activity levels by location.
- In many models, transit trips represent a very small component and can be less than the margin of error of model validation. This issue is even more relevant for bicycle and pedestrian trips.

As a result, these models likely require modification including changing the structure or process in the model (for example, reducing the size of traffic analysis zones), as well as obtaining and incorporating new data inputs (for example, using auto ownership to distinguish between household types and their likelihood of using non-motorized transportation).

Despite these limitations, one creative way to use travel demand models to forecast bicycle and pedestrian trips is to extract the short distance trips from the model to generate an estimate of existing and potential bicycle and pedestrian trips. For example, trips less than two miles will likely have a higher existing bicycle mode share and will have greater potential to shift a portion of SOV trips to bicycling.

Advantages

- Regional models have been developed for all major urban areas and this structure can provide an integrated framework for analyzing choices between modes.
- Strong fiscal and regulatory pressures affect the accuracy of these models, since they are used as the basis to justify funding requests for transportation investments and to demonstrate environmental compliance.
- Data/output from these models can be used as inputs for other models, including sketch planning models. This is particularly useful if resources are limited, because using data/outputs from regional demand models can replace the need to collect new data, and travel demand models, as they become more accommodating of parcel-level data, are a good source of localized future population and employment forecasts.

Disadvantages

- Existing models are usually developed on a scale more appropriate for auto travel and converting these tools to a pedestrian/bicycle scale may require significant effort.
- Most regional models do not consider a "recreation" trip purpose, a key consideration in bicycle and pedestrian trip rates.
- These models require specialized software packages and substantial expertise.

Data Needs/Cost

To accurately build a travel demand forecasting model that adequately accounts for bicycle and pedestrian trips, a robust data set is needed. A household travel survey is typically the basis of existing travel demand models. Pedestrian and bicycle counts on the corridor-level also feed into calibration of the model. Multi-modal transportation network, land use, population, and employment data are other key components.

Regional travel demand models need to be geographically calibrated. Accuracy of the models is determined by the robustness of the network built in the model and thoroughness and quality of count data used for calibration.

Case Study

Researchers at Bucknell University developed a four-step travel demand model to predict pedestrian volumes on campus walkways. The model applies each of the four model steps using inputs unique to the nature of pedestrian travel in a campus setting. Trip generation uses a database of campus land uses and person trip generation rates by trip purpose calibrated to each land use type. Trip distribution applies the gravity model[1] with locally calibrated impedance factors. Because very few bicycling trips are made to/from/on campus, the model's mode share component assumes that all person trips are made by walking. This data was used to inform campus roadway and path infrastructure developments to serve increasing pedestrian volumes as a result of changes in land use.

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[1] The gravity model analyzes migration based on distances from the point of origin to the destination. The model assumes that the interaction between two places declines with increasing distance between two points but the model positively associates the amount of activity at each location.

Activity and Tour-Based Models

Overview

Activity and tour-based models are considered superior to traditional four-step models because of their ability to reflect the complexity of household types in the population and their trip choices. These models use an individual's daily activity, as recorded in a travel diary, to develop a relationship between the transportation system (including levels of congestion and network connectivity) and demand for travel. These individuals or households and their travel activities are then extrapolated to the larger population. One drawback to these types of models is the intense data and skills required to develop them.

Advantages

- Can account for effects of the built environment and travel behavior
- May be more appropriate for activity at a more refined geographic area than regional travel demand models
- Address nuances such as distribution of household responsibilities and opportunities for multi-stop trip chaining which can allow them to better assess opportunities to bicycle or walk
- Are based on household surveys, which demand accurate accounting for and detail on individual trips and their linkages

Disadvantages

- Underlying processes introduce variability from analysis to analysis which can overwhelm relatively small amounts of non-motorized travel within a region, producing imprecise estimates and inaccurate comparisons among planning alternatives
- Creation and application of these models is resource-intensive

Data Needs/Cost

Household profiles are constructed through Census data, surveys, and other factors. The travel network is typically created by the type of pedestrian or bicycle facility. For pedestrian networks this can be difficult as most jurisdictions do not have GIS layers of sidewalk networks or the condition of these facilities.

Regional travel demand models need to be geographically calibrated. Accuracy of the models is determined by the robustness of the network built in the model and thoroughness and quality of count data and travel diaries used for calibration.

Case Study

The San Francisco Chained Activity Modeling Process (SF-CHAMP) predicts future travel patterns based on observed travel patterns, the existing transportation network, population and employment, transit boardings, roadway volumes and the number of vehicles per household (for more information see: http://www.sfcta.org/modeling-and-travel-forecasting). The integration of annual bicycle counts at locations throughout San Francisco enables the model to forecast the quantity of bicycle trips. Additionally, a smartphone app "CycleTracks" has been used to track trip distribution across the existing bicycle network (for more information see: http://www.sfcta.org/modeling-and-travel-forecasting/cycletracks-iphone-and-android). The integration of bicycle counts, trips distribution and built environment and behavior factors allow the model to predict bicycle trip distribution in future street network scenarios.

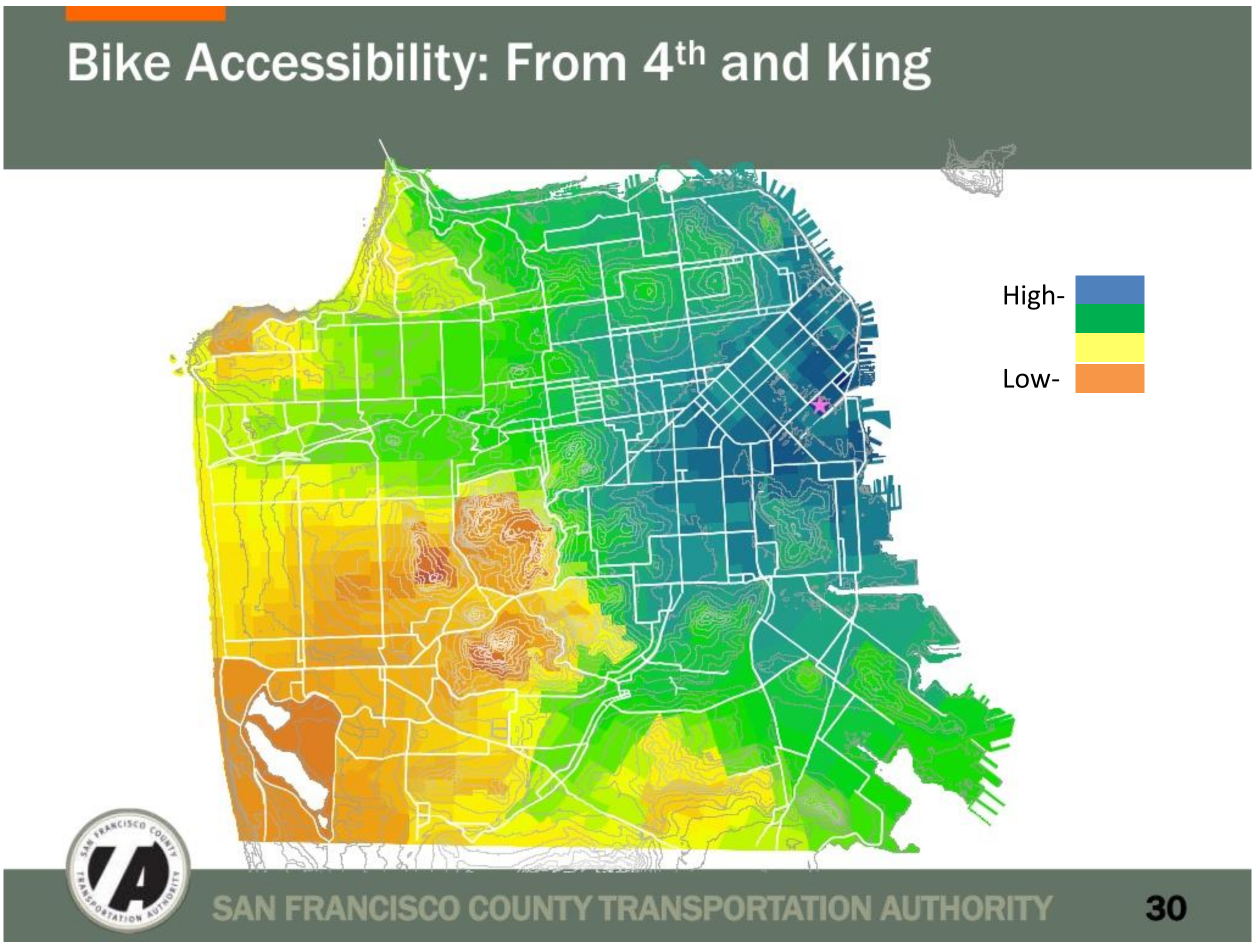

Figure 5. Map Illustrating Data from SFCTA's CycleTracks Smartphone App, San Francisco CA

State of the Practice

Pedestrian and bicycle demand forecasting is an evolving field with many opportunities for improvement. Strengthening the interaction between forecasting tools to refine forecasts is one potential way to address deficiencies discussed in this report. For example, combining regression analysis with GIS to create a spatially-driven method for forecasting pedestrian volumes is a key opportunity. This section outlines several examples of emerging tools or tools under development that begin to address the gaps in current modeling practice:

- Spatial models with forecasting capabilities
- Fine-grained simulation models
- Regional models with enhanced non-motorized transportation forecasting
- NCHRP 08-78 Planning Tools
  - Tour Generation/ Mode Split
  - GIS Accessibility Model
  - Trip Based Model Enhancements

These recent efforts seek to create more detailed and meaningful information to improve planning for pedestrians, bicycles, and transit.

Spatial Models with Forecasting Capabilities

NCHRP 08-78 (NCHRP, 2011) identified GIS-Spatial tools and Network Simulation as having the most potential to address the gaps in meeting practitioner needs (see Figure 1). These tools generally support planning at the local area or corridor level, which is the most appropriate geographic scope for bicycle and pedestrian forecasting. However, these tools are versatile enough that they can be enhanced to support broader or finer geographic scopes. Several examples of GIS spatial tools blended with aggregate demand models are described in the Applications section.

One example of a spatial tool that can also forecast bicycle and pedestrian trips is Active+, an objective, GIS-based tool for project prioritization within bicycle and pedestrian planning. Originally created for Sacramento's Pedestrian Master Plan, the tool assesses various geographic areas (i.e. street segments, intersections) in terms of their potential to attract a specific level of walking or bicycling activity. Recently, the Active+ model was adapted in a joint project with UC Berkeley SafeTREC, SFMTA, and SFCTA into a pedestrian exposure (demand) model for the City of San Francisco. The San Francisco pedestrian volume modeling process refined the methodology used to develop previous intersection-based models and incorporated variables that estimate walking activity in the local urban context.

The San Francisco methodology included two main steps. First, manual and automated pedestrian counts were taken at a sample of 50 study intersections with a variety of characteristics. A series of factor adjustments were applied to produce an annual pedestrian crossing estimate at each intersection. Second, log-linear regression modeling was used to identify statistically-significant relationships between the annual pedestrian volume estimate and land use, transportation system, local environment, and socioeconomic characteristics near each intersection. Twelve alternative models were considered, and the preferred model had a good overall fit (adjusted-R2 = 0.804). As identified in other communities, pedestrian volumes were positively associated with the number of households and the number of jobs near each intersection. The San Francisco model also found significantly higher pedestrian volumes at intersections in high-activity zones with metered on-street parking, in areas with fewer hills, near university campuses, and controlled by traffic signals. The model was based on a relatively small sample of intersections, so the number of significant factors was limited to six. Results are being used by public agencies in San Francisco to better understand pedestrian crossing risk and to inform citywide pedestrian safety policy and investment. The full results are available in the Transportation Research Record journal article here: http://docs.trb.org/prp/12-4224.pdf.

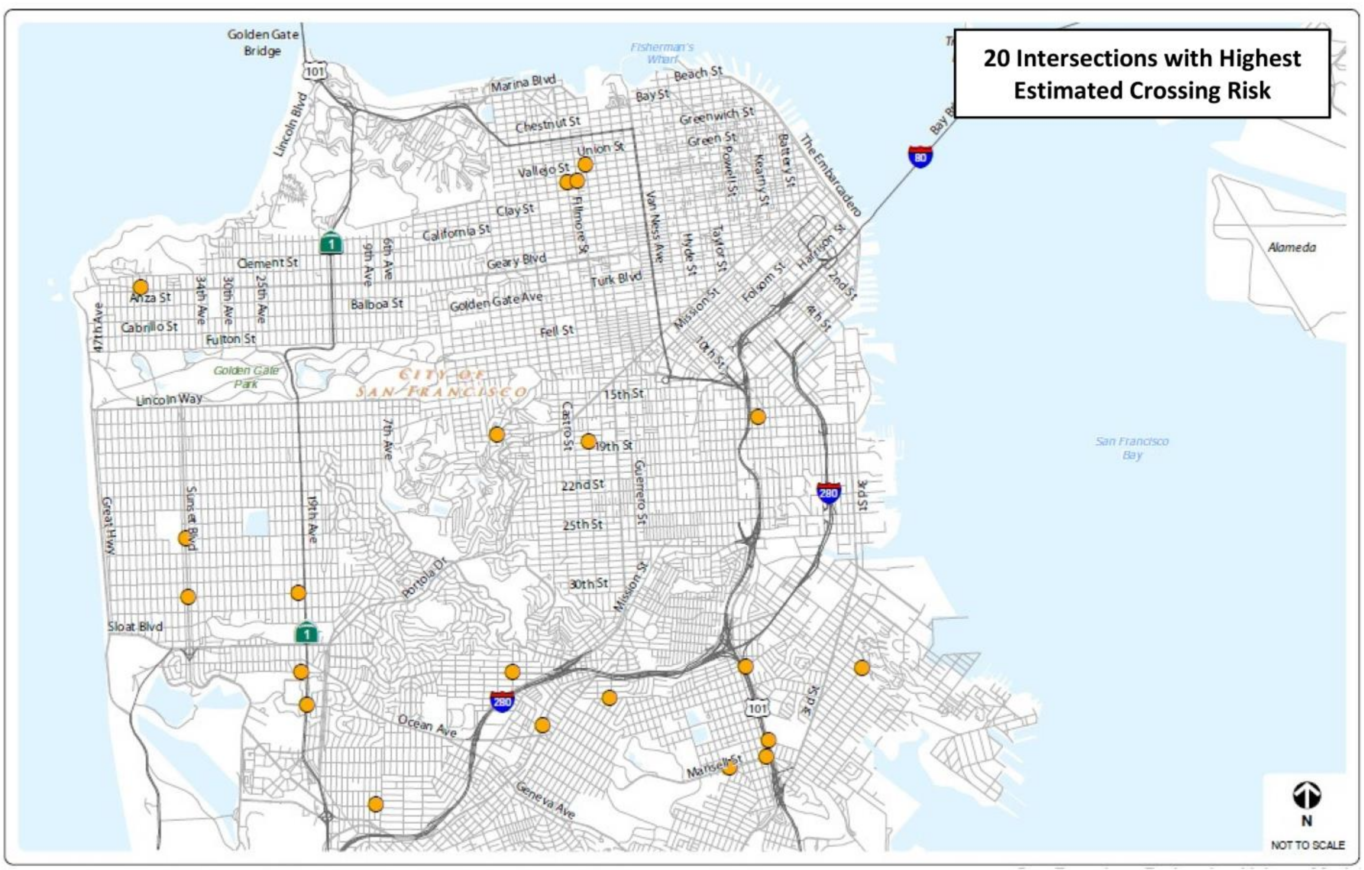

Figure 6. Intersections with Highest Estimated Crossing Risks in San Francisco

Fine-Grained Simulation Models

MoPeD (Model of Pedestrian Demand) is an example of a simulation tool that was developed by Professor Kelly Clifton and her team at the University of Maryland (Clifton, 2008). MoPeD is a GIS-based model which analyzes pedestrian travel by geographic zones, known as pedestrian analysis zone (PAZ) which is the block or street level. Similar to the four-step model, MoPeD uses parcel-level data to estimate trip generation from each PAZ, assigns the trips to destinations, and routes the trips on the network e.g. by the minimum travel time. The end result is a 24-hour simulation of pedestrian movements on sidewalks and crosswalks.

To build the pedestrian network in GIS, US Census TIGER files (spatial representations of roads, railroads, rivers, legal boundaries, etc. from the Census Bureau) were used with aerial photographs to verify existing pedestrian paths, sidewalks, and crosswalks. Parcel data was used to define pedestrian analysis zones by the street block, or by each block face if the street block is large. Each PAZ was associated with attributes of the pedestrian network, land use mix, and transportation system. This process is explained in detail for users in the model manual which can be found at http://kellyjclifton.com/products/moped. (Clifton, 2008).

Figure 7. A sample output of the MoPeD assignment program (Clifton, 2008)

Regional Models with Enhanced Non-Motorized Transportation Forecasting

Metro, Portland, Oregon's metropolitan planning organization, uses a travel demand forecasting model in which bicycle and walk trips are determined in the mode choice step in the four-step process. This means that once trip generation and distribution are predicted, whether users will walk, bike, drive alone, carpool, or take transit for trips is determined based on variables. Some of the data upon which these variables are based include:

- number of local intersections within one half mile of each zone
- households within one half mile of each zone
- retail employment within one half mile of each zone
- total employment within one half mile of each zone
- door-to-door travel time
- zone-to-zone travel time
- auto ownership

Bicycling is included as a mode choice option for trips under ten miles; walking is included for trips under five miles. Metro is currently collaborating with Portland State University to use bike path data derived from GPS to better understand how bicyclists choose their routes and to incorporate this relationship into the route assignment step of the travel demand model (Kim, 2008) (Oregon Metro). More detail can be found at: http://library.oregonmetro.gov/files/transportation_modeling_overview_sept09.pdf.

NCHRP 08-78 Planning Tools

Research performed as part the NCHRP 08-78 project include three pilot forecasting efforts, which are summarized in Table 5. Two of the projects were performed using data from the Puget Sound Regional Planning Commission (PSRC) in the Seattle area, while the third focused on Arlington County, VA using data from the Metropolitan Washington Council of Governments (MWCOG).

Table 5. Bicycle/Pedestrian Planning Tools Included in NCHRP 08-78 Guidebook

Modeling Approach	Source	Characteristics
Tour Generation/ Mode Split	NCHRP 08-78 (Seattle/PSRC data)	• Simple/complex tour generation for trip purposes (sociodemographics, land use, local & regional accessibility) • Mode choice (walk, bike, transit, auto) for trip purposes (sociodemographics, land use, local & regional accessibility) • Fully detailed walk and bicycle networks, physical attributes affect impedance
GIS Accessibility Model	NCHRP 08-78 (Arlington, VA/MWCOG data)	• Uses GIS layering to create accessibility scores for walk, bike, transit, and auto. • Links mode choice with accessibility scores at trip origin and destination • Estimates mode share at block level for various trip purposes • Builds walk trip table (but does not assign) • Highly visual presentation
Trip Based Model Enhancements	NCHRP 08-78 (Seattle/PSRC data)	• Strategic changes to traditional four-step TAZ model to improve sensitivity to land use and non-motorized travel • Sensitizes auto ownership and trip generation to land use characteristics • Performs pre-mode choice to distinguish inter- vs. intra-zonal trips • Performs mode choice separately for intra zone (drive alone, shared ride, walk) and inter-zone (drive, shared-ride, transit, walk, bike) travel

Conclusions and Next Steps

As the desire for more robust pedestrian and bicycle planning tools increases, the field of forecasting methods has expanded significantly. Despite the variety of tools and levels of effort to choose from, every approach requires tradeoffs. Developing or using the most appropriate models can be constrained by resources, such as available data, budget, or skill sets required. The best available model may also be within reach, but may still fall short of forecasting the desired metric, or providing the level of accuracy needed. Despite these limitations, practitioners require better guidance on how and why to select a specific approach based on their needs and resources available.

While linking forecasting approaches and developing new tools promises to improve bicycle and pedestrian planning, a number of issues remain unresolved. Below are several recommendations for future research needs from NCHRP 08-78 to further advance the state of the practice in bicycle and pedestrian planning:

- Continue ongoing application, testing and validation of existing models
- Validate models by comparing them to observed activity levels (i.e., counts)
- To overcome small sample sizes, enhance bicycle modeling efforts with additional data collection and research
- Enhance travel models by more clearly distinguishing between pedestrian and bicycle trips, and perform trip generation collectively for all modes and then separate out pedestrian and bike trips during the distribution and mode choice phases.
- Perform additional study on pedestrian path choice, similar to efforts made in understanding bicycle route preferences

FHWA is presently investing heavily in improving bicycle and pedestrian data collection. Notable efforts include expansion of the Traffic Monitoring Analysis System to receive bicycle and pedestrian data in the format described in FHWA's Traffic Monitoring Guide, technical support and pilot studies to improve the quality and coverage of bicycle and pedestrian count programs, and collection of information on available bicycle and pedestrian networks.

In addition, the Institute for Transportation Engineers is currently considering moving away from traditional vehicle-focused trip generation toward person trip generation. This move could trigger the development of a robust database that would help bring non-motorized forecasting practices on par with what is common for auto trips. Although this approach would not be as sophisticated as some other methods, it would provide greater depth than sketch planning techniques and be less resource intensive than a regression model.

Addressing these issues with ongoing refinements to existing and new approaches will bring the state of the practice forward in meaningful ways.

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