CHAPTER 3.

LITERATURE REVIEW

The Highway Capacity Manual (HCM) is the traffic engineering and planning industry standard in conducting pedestrian level of service (LOS) analysis. The HCM pedestrian LOS analysis has many advantages. It provides a standardized methodology for data collection and for quantifying congestion in pedestrian facilities. However, there are many studies which recommend various amendments to the HCM methodology or propose new methods of pedestrian LOS analysis altogether.

The purpose of this chapter is to explore existing pedestrian literature in order to identify best practices in pedestrian data collection, analysis, and measurement as well as areas where additional research is warranted.

A. Introduction

The measurement of pedestrian level of service is a tool which ensures that pedestrian facilities are balanced with vehicular facilities and other land uses. As discussed earlier, the HCM provides two components in its level of service calculation: a quantitative measure of pedestrian flow rate and a table that helps planners derive an LOS grade from that flow rate. The HCM's pedestrian LOS grade is designed to be an objective measure of congestion on a pedestrian facility. It also provides a set of empirical data that highlights the limitations of this basic method and suggests ways to localize the LOS calculation based on various factors: pedestrian trip purpose, age, and group size, for example.

Since the HCM pedestrian LOS methodology was published, researchers inside and outside the United States have published studies on ways to better measure pedestrian LOS in their regions, given local conditions. They have focused on three primary areas: the sidewalk environment, pedestrian characteristics and flow characteristics. Relationships among these categories have emerged in pedestrian literature. For example, researchers have explained how elements in the sidewalk environment – such as land use and proximity to transit – influence pedestrian and flow characteristics. They have also sought to explain how pedestrian characteristics shape the speed and density characteristics of flow. These relationships are illustrated in Figure 3.1. below.

While a great deal of research has been published to describe how the pedestrian LOS calculation may be tailored to local environments, the HCM has remained consistent in its generic, location-independent approach. The limitations of this approach in its applicability to New York City, as defined in the HCM, are discussed below.

In the following sections existing literature is reviewed to understand how planners and researchers in other regions are collecting, analyzing, and applying pedestrian data in order to develop better LOS measurement tools. A detailed summary of each publication cited in the literature review is included in Appendix A.

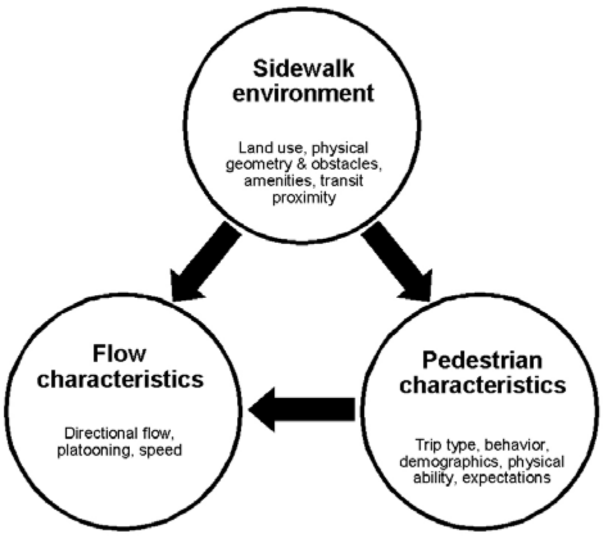

Figure 3.1. Relationship between the Sidewalk, Pedestrians, and Flow

B. Analysis of Pedestrian Characteristics

1. Personal Characteristics

Researchers have documented that normal pedestrian speeds are a function of a large number of factors: age, gender, and group size are frequently cited (Bowman, 1994; Knoblauch, 1996; Fruin, 1971; Whyte, 1988; Puskharev, 1995). While the HCM refers to these differences and recommends taking them into account when, for example, a large number of elderly pedestrians are expected on a facility, these differences are not incorporated into the standard LOS calculation.

Person size is a factor that has been widely discussed in pedestrian literature as it relates to personal space requirements (Fruin, 1971). But sidewalk widths have not kept pace with American waistlines over the last decade. Because personal space requirements are tightly coupled with the speed-space relationships used to interpret the HCM LOS from the flow rate calculation, it may be necessary to revisit these assumptions.

2. Trip Purpose and Expectations

Varying pedestrian expectations—especially as a function of a pedestrian's trip purpose—are also ignored by the HCM. At lunchtime, many sidewalks in Lower Manhattan have a diverse mix of users, from financial sector executives to tourists. Even if these pedestrians have everything else in common, their expectations of sidewalk crowding may vary widely. A pedestrian on his way to lunch may not mind the same delay faced by the person behind him, on her way to a meeting. Other pedestrian perceptions such as comfort, safety and convenience are not addressed by the HCM.

The HCM uses a single LOS scale for all pedestrians, but recommends that planners take the predominant trip purpose into account when evaluating local facilities. However, researchers have found that pedestrians' perceptions of the walking environment can affect pedestrian behavior significantly (Sarkar, 1993; Khisty, 1994; Miler, 1993). Hoogendoorn found that pedestrians predict the "cost" of each sidewalk facility in terms of the convenience and speed to reach a destination and that the cost is based on their personal expectations (2004a).

In Benz's time-space level of service methodology, trip purpose plays a key role. He uses it to identify the preferred walking speed of a pedestrian subgroup (commuters, for example), determine the mix of subgroups on a sidewalk, and prioritize the subgroups with the greatest speed expectations (1986).

3. Behavior

Devices such as mobile phones and portable music players have become ubiquitous in urban areas. Writers in the popular press have lampooned the ability of people to walk and use cell phones at the same time (Belson, 2004). But researchers have nothing more than anecdotal evidence to suggest the impact these devices have on pedestrians in the aggregate.

C. Analysis of Environmental Characteristics

1. Usable Sidewalk Space and Obstacles

The only characteristic of a midblock location that the Highway Capacity Manual's pedestrian LOS takes into account is the effective width of the walkway. This measurement is determined by reducing the total walkway width by the width of obstacles in the amenity strip and along the building line.

The HCM reiterates a recommendation made by AASHTO that the effective sidewalk width should not be under 5 feet on any facility (2000). Even 5 feet may be a conservative minimum width. After observing groups of pedestrians trying to get past one another in Midtown Manhattan, Pushkarev and Zupan (1975) suggest that 7.5 feet is a better minimum width when a large number of groups are expected on a pedestrian facility.

A simple example illustrates the wisdom of a 5 foot or 7.5 foot minimum width. Using the standard pedestrian LOS calculation, a moderately traveled 3-foot-wide sidewalk (1,080 people/hour with platooning) will achieve an acceptable LOS of C according to the HCM. In Fruin's (1971) work, upon which the HCM methodology was based, it states that the average male pedestrian would occupy an area of approximately 1.5 ft^2 . By this measure, a sidewalk with a 3-foot effective width would likely require passing pedestrians to slow down and twist their bodies to get around each other. And with 1,080 people/hour, there will be up to 9 passing events (18 impeded pedestrians) per minute.

The Highway Capacity Manual also recommends decreasing the effective sidewalk width by 12-18 inches on each side to account for the buffer space between pedestrians and obstacles. The empirical origin of this distance is difficult to confirm, but many researchers also advocate a so-called "shy distance", "buffer zone", or "cushion" and have attempted to measure what those distances should be. Pushkarev and Zupan, while cited by the HCM as the origin of "shy distance" did not, in fact, invent the term or the distance. Based on their observation of Midtown Manhattan pedestrians, they state that, "the exact effect of the various obstacles on pedestrian capacity and flow is a good subject for further study." The closest the authors come to providing a "shy distance" (a term used by HCM, not Pushkarev and Zupan) is by suggesting a standard distance of 2.5 feet between the curb next to an obstacle and a pedestrian walking adjacent to the obstacle (1975).

How pedestrians negotiate obstacles on New York City sidewalks, whether they are transit entrances, vendor stands, bus shelters, newspaper boxes, or security devices, is still not understood. The HCM classifies walkway obstructions in the following categories: street furniture, public underground access, landscaping, commercial uses and building protrusions. And, according to the HCM, these obstructions (and the shy distance alongside them) should be taken into account when calculating a walkway's effective width.

Literature on the distance that people walk away from obstacles is scarce. Weidmann synthesized data from a number of other studies and then used that data into determining average distance values for different obstacles (1993). Mauron compiled data on the distances people walk from a curb on a straight sidewalk in order to calibrate his simulation methods (2002). More recently, Hoogendoorn conducted an experiment in an indoor pedestrian space and found that pedestrians require about 10 cm (≈ 4 inches) of lateral spacing (2004b). For obvious reasons, these results cannot be assumed to be valid on New York City sidewalks without confirmation.

While Benz does not address the question of shy distance, he proposes a completely different unit of space for level of service analysis—the entire length and width of a sidewalk segment minus obstacles and a "cushion" near obstacles and the edges of buildings and curbs (1986).

In order to determine when pedestrians choose to walk on narrow street beds in Japan, Kwon et al. (1989) created overhead video recordings of a walkway marked in a 10cm. X 20cm. grid. They used the video to record the location of each pedestrian over time. However, they did not create a general shy distance based on these findings.

Thambiah et al. (2004) predicted that obstacles are important to pedestrians' perception of a sidewalk level of service and used conjoint analysis to attempt to show this. They did find the number of obstacles on a sidewalk influences pedestrian perceptions, but did not seek to observe how pedestrians actually behave around these obstacles.

Stucki et al. (2003) synthesized the work of Ulrich Weidmann (1993) to come up with shy distances for different types of obstacles. For example, pedestrians walk 0.45m (~1.5 ft.) from walls, 0.35m (~1.14ft.) from fences, and 0.30m (~1 ft.) from small obstacles such as street lights, trees, and benches.

These studies indicate that there is consensus about the fact that a shy distance exists and that a good measure of these shy distances is needed. But there is no consensus on what those distances should be.

2. Land Use / Amenities

In addition to the need for a better understanding of the relationship between a sidewalk's capacity and its obstacles, researchers have found that pedestrians tend to judge the LOS of a sidewalk based on additional, qualitative factors. For example, some researchers have found that the sidewalk's separation from vehicular travel lanes, the speed of traffic, and the attractiveness of the location are more important to pedestrians than pedestrian congestion (Dixon, 1996; Khisty, 1994). While it is unlikely New York City pedestrians have exactly the same set of preferences given differences in land use and intensity, these environmental factors are not considered in the HCM's LOS methodology.

Phillips et al. (2001) push this concept the farthest. They surveyed pedestrians at segments of a predetermined route through Pensacola, FL, asking them, "How safe / comfortable they felt as they traveled each segment." They used the pedestrian ratings along with measurements of each segment to create a regression model incorporating everything from the percent of on-street parking to the average speed of traffic to the width of the sidewalk. While this is an innovative approach in a suburban location with low to moderate pedestrian volumes, wide and fast commercial streets, and frequent curb cuts, it is not particularly applicable to New York City CBDs. But there are sidewalk amenities in New York City that may warrant attention: bus stops, vendor carts, newsstands, subway entrances, security devices, and sidewalk cafes.

D. Analysis of Flow Characteristics

1. Platooning

The HCM's pedestrian LOS calculation accounts for pedestrian platooning by assigning worse LOS grades at lower flow rates on facilities where platooning is expected. This is an important consideration as Pushkarev and Zupan observed that most pedestrian traffic in New York City travels in platoons (1975). In fact, researchers find that pedestrian platooning – rather than random, even flow – may be a general characteristic of urban life due to density, rates of transit use, and signalized intersections (Virkler, 1998; Chilukuri, 2000).

2. Directional Flow

A second flow characteristic that researchers have sought to understand in its relation to pedestrian level of service is friction created as a result of bi- and multi-directional pedestrian flows. In other words, holding all other variables constant, do differences in the ratio of flow in opposing directions result in different levels of service depending on the direction of travel?

Several researchers have attempted to answer this question. John Fruin (1971) found that when neither opposing flow dominates, the speed in both directions tends to be equal, but a strong flow tends to impede weaker flow. William Whyte (1988) and Pushkarev and Zupan (1975) observed the same phenomenon. Researchers studying pedestrian behavior in transit stations also found discrepancies in directional flow under different circumstances (Blue & Adler, 2000).

The HCM includes Fruin's finding that highly lopsided bi-directional flow may result in a lower level of service for flow in the weaker direction. However, the standard LOS calculation does not take these differences into account: a single LOS is calculated for the entire facility based on the sum of pedestrians walking in both directions.

E. Data Collection Techniques

Three predominant methodologies for collecting pedestrian data were identified: direct observation, video observation, and surveys. For a more comprehensive review of pedestrian and bicycle data collection techniques in the United States, Schneider et al. have published an excellent guide (2005).

1. Direct Observation Methodologies
Virtually all pedestrian studies and models, including the HCM LOS methodology, rely on direct observation of pedestrians for data collection. Direct observation has been applied indoors (Hoogendoorn, 2004b) and outdoors (Whyte, 1971), with experimental (Phillips, 2001) and non-experimental studies (Chilukuri, 2000).

2. Video Techniques
Increasingly, researchers are using video to observe and collect data about pedestrians. Video has plenty of advantages over direct observation: you can collect data from the video carefully back in the office or lab, you can easily share video with others to illustrate a point, and there are tools available to automate data collection. On the other hand, it is difficult to collect video data in an unobtrusive way and identifying pedestrian characteristics—even gender—can be difficult on a video monitor.

Whyte (1988) pioneered the use of film to record pedestrian behavior in urban environments, using a combination of ground level and overhead cameras to collect data. He and his team analyzed some of the video methodically to create objective, quantitative comparisons between locations (the number of people using each location by time of day, for example). They also used video for more qualitative—almost ethnographic—analysis.

Birrel et al. (2001) did not use video to capture pedestrians, but used techniques that may be useful to pedestrian researchers. They filmed in-line skaters at grade level and devised a methodology to measure their lateral motion.

Mauron (2002) and Kwon et al. (1989) placed video cameras directly overhead in order to get a clear picture of pedestrian movement and lateral spacing on the two-dimensional plane of the sidewalk.

As part of their PEDFLOW simulation model, Willis et al. created an computer-based application that improved the ability to collect video data (2001).

3. Survey Methodologies
Transportation planners face a difficult task in assigning levels of service grades because perceptions vary widely among drivers, cyclists, and walkers.

Surveys are sometimes used to help establish a level of service scale. Thambiah et al. (2004) used an entirely survey-based methodology, simply having participants rate pictures of sidewalks with varying conditions. The results of these surveys were processed through a conjoint analysis, a statistical modeling method available in SPSS (a statistical software), to determine what sidewalk "features" resulted in the high and low scores. This method has a high degree of internal validity, but its external validity is limited.

Phillips et al. (2001) used a combination of field observation and survey. During their FunWalk for Science, they set up checkpoints along the route where they asked participants to rate the segment they had just walked. Unlike the method used by Thambiah et al., this has the advantage of testing real conditions rather than those imagined based on a picture. On the other hand, there are some minor external validity problems due to self-selection of participants and the uniformity of trip purposes.

Although Willis et al. (2001) used computer-aided video analysis for their PEDFLOW simulation model, they conducted interviews in order to understand how individual pedestrians make decisions as they walk.

4. Experimental vs. Non-Experimental Design

Most pedestrian studies are non-experimental. Researchers simply visit a location, observe pedestrian behavior and collect data, and analyze that data without interfering in the pedestrian environment. While this ensures that studies are externally valid, it becomes nearly impossible to draw definitive causal conclusions since a typical sidewalk is a complex system, with dozens of interrelated factors that change level of service perceptions.

Hoogendoorn's (2004b) study of pedestrian bottlenecks is among the few pedestrian studies with an experimental design. Hoogendoorn set up three different bottleneck conditions in order to determine how pedestrians behave in each one. By reducing the number of uncontrolled variables, he was able to draw causal conclusions that are not possible in most pedestrian studies.

F. Data Analysis and Simulation Models

If the HCM's LOS model is to be critiqued, it is critical that the alternatives and the general techniques that may be used to create a modified pedestrian LOS model are understood. The HCM LOS model is a macroscopic pedestrian model based on the relationship between space, walking speed, and flow. The input is a pedestrian count, a time period, and sidewalk's effective width. The output is the flow rate and a corresponding grade.

The broadest discussion of pedestrian modeling can be found in Bierlaire et al. (2003). They provide a survey of microscopic and macroscopic models and discuss their applicability to different types of problems.

1. Regression Analysis / Modeling

After conducting their FunWalk for Science survey, Phillips et al. created a regression model to explain what sidewalk characteristics result in a higher survey score by participants (2001). This allows transportation planners to easily assess their own pedestrian facilities based on the factors in the regression model.

Thambiah et al. (2004) used conjoint analysis, a statistical method by SPSS in "how individual product attributes affect consumer and citizen preferences," to come up with a pedestrian LOS. Basically, they propose that every sidewalk has a set of features. The conjoint analysis process allows researchers to assess the value of these features to pedestrians based on a survey.

2. Microscopic Pedestrian Models

The conjoint analysis and regression models above—and the HCM pedestrian calculation, in fact—are applied to an entire location based on the results of many pedestrians taken together. Other researchers—especially those optimizing evacuation planning and procedures—have focused on microscopic pedestrian models in which each pedestrian's behavior is considered independently of all other pedestrians. The advantage of this type of model is that it is potentially more realistic and fine-grained than the macroscopic models. On the other hand, the model is only as good as the data collected (which can be intensive) and may actually be overkill when then question to be answered is simply: what is the LOS for this sidewalk segment? Bierlaire et al. discuss microscopic modeling, its advantages and disadvantages in much greater detail (2003).

Researchers have used microscopic pedestrian models to attempt to answer LOS-related questions. For example, Stucki et al. have applied a microscopic model to try to determine how individual pedestrians behave around obstacles (2003). Blue and Adler use a microscopic model to predict complex, multi-directional pedestrian flows in Grand Central Station (2000).

Other researchers use microscopic models to predict how pedestrians make larger decisions about the routes they take. Mauron proposes a model in which each pedestrian chooses the fastest— though not necessarily the shortest—route (2002). Similarly, Hoogendoorn suggests a simulation model in which individual pedestrians predict the relative "cost" of each route based on their preferences and choose the one with the lowest cost (2004a).

G. Conclusion

As the TD has seen, there is a significant body of research featuring new ways of evaluating pedestrian service levels on urban sidewalks. These studies recommend everything from small amendments to the HCM's LOS calculation to completely new LOS methodologies, depending on local needs and characteristics.

The studies cited in this Chapter suggest that the current tool for measuring pedestrian LOS prescribed by the Highway Capacity Manual may not take into account important differences in pedestrian characteristics, location characteristics, and flow characteristics when evaluating New York City sidewalks. If that is the case, the LOS used to evaluate New York City's sidewalks does not serve the city's pedestrians.

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