

PEDESTRIAN LEVEL OF SERVICE FOR MID-BLOCK STREET CROSSINGS

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ABSTRACT

This paper describes the results from a research project that developed a level of service methodology for pedestrians crossing streets at mid-block locations. To the best of the knowledge of the authors, there are no known methodologies for evaluating pedestrian level of service for street crossing at either mid-block locations or intersections based on pedestrian perceptions. The methodology developed and described within is capable of providing a measure of effectiveness that indicates pedestrians' perceived quality of service in crossing roads at mid-block locations. One of the project's objectives was to determine what variables are correlated with pedestrians' perceived quality of service for mid-block crossings. A statistical calibration and validation process involved the collection of actual site characteristics and stated levels of quality of service by a sample of persons at a sample of mid-block crossing locations. The variables included those that are most important to the Florida Department of Transportation and local governments for the purpose of improving pedestrian mobility, safety, and livability. Results showed that the levels of crossing difficulty tend to increase with the width of painted medians, signal spacing, and turning movements. They also showed that both the presence of pedestrian-signals and cycle length are statistically significant though they were hypothesized to be un-determinate. Finally, the results further indicated that people tend to find the presence of pedestrian-signals lowers their levels of crossing difficulty.

Keywords: Pedestrian, Level of Service, Mid-Block, Traffic, and Crosswalk

INTRODUCTION

The Florida Department of Transportation (FDOT) recently initiated a Multi-modal Quality of Service Program to improve the methodologies used to evaluate arterial level of service from a multi-modal perspective. This initiative was motivated by two primary factors. At the national level, the Transportation Equity Act for the 21st Century (TEA-21) and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) led to a national desire to know the levels of service for automobile users and for users of transit and bicycles and pedestrians as well. At the state level, the Florida legislature passed the Urban Infill and Redevelopment Act that required local governments to use professionally accepted methodologies for measuring multi-modal level of service. The Act also required that the FDOT develop these accepted methodologies and provide technical assistance to localities when being applied.

The FDOT has already developed a preliminary methodology for evaluating public transit level of service at the generalized planning level. This public transit level of service methodology evaluates public transit service for route segments on an hourly or daily basis. The basic measure of effectiveness is transit frequency (headways) along the route segments. For daily transit level of service, it also takes into account the span of service for daily transit operations. For either hourly or daily analysis, it further considers three pedestrian variables including pedestrian level of service along route segments, sidewalk connections to transit stops, and pedestrian crossing difficulty. Both transit service span and the three pedestrian variables are proposed as multiplicative adjustment factors, which have not been subjected to field calibration. The adjusted service frequency will then be converted to a level of service designation based on some numerical thresholds.

The FDOT has proposed to use a methodology developed by Landis et al. (1) to evaluate bicycle level of service for riding along roadways (2). This bicycle level of service is based on five variables: average effective width of the outside through lane, motorized vehicle volumes, motorized vehicle speeds, large truck volumes, and pavement conditions. As is obvious, the methodology for measuring bicycle level of service is also based on a number of variables. Unlike the transit level of service methodology that is based on actual frequency, the basic measure of effectiveness in the bicycle level of service methodology is perceived safety and comfort levels by bicyclists. Furthermore, the bicycle level of service methodology weighs the multiple variables by importance through statistical calibration with actual field data. The weights are then used to convert the variables into a numerical index. Just like the public transit level of service methodology, the numerical index score is finally changed to a level of service designation, based on numerical thresholds.

The FDOT has also proposed the use of a methodology developed by Landis et al. (3) to evaluate pedestrian level of service for walking along roadways (2). Again, it is based on five variables: lateral separation of pedestrians from motor vehicle traffic, presence of physical barriers and buffers, outside lane traffic volume, motor vehicle speed, and vehicle mix. Just like the bicycle level of service methodology, the basic measure of effectiveness is perceived safety and comfort levels by pedestrians. The variables are also weighted by importance through statistical calibration using field data. The weights are then used to convert the variables into a numerical index. The numerical index score is finally changed to a level of service designation, based on numerical thresholds.

To determine pedestrian level of service for crossing streets at various locations, the FDOT has proposed separately considering street crossing at both mid-block locations and intersections. This paper reports on a project that developed a level of

service methodology for the crossing of streets by pedestrians at mid-block locations. The methodology from this project can be combined with those for the pedestrian level of service methodologies that focus on pedestrians walking along a roadway segment and crossing at intersections to determine pedestrian level of service for an entire roadway segment.

LITERATURE REVIEW

Based on a review of literature, there is a large body of work that has been completed dealing with pedestrian level of service issues. However, much of that work is limited to pedestrian level of service on uninterrupted pedestrian facilities and the level of crowding on these facilities. The work being reported on in this paper parallels the work that has been done on measuring automobile level of service. Much of this work is summarized in the pedestrian chapter of the 1997 update of the *Highway Capacity Manual* (4).

On the other hand, there were a few studies related to determining pedestrian level of service for crossing streets. First, there is the transit level of service methodology that has been developed as part of the FDOT's Multi-Modal Quality of Service Program. As mentioned earlier, the transit level of service methodology does incorporate a street crossing difficulty variable for pedestrians. However, this methodology is designed to generate an adjustment factor for considering pedestrian quality of service for street crossing in the transit level of service methodology. It is not designed to lead to a numerical score that can then be changed to a level of service designation, nor has it been tested with actual field data. Finally, it also does not distinguish street crossings at mid-block locations from street crossings at intersections.

Second, there have been studies measuring pedestrian crossing difficulty in terms of pedestrian delays or lack of crossing opportunities for mid-block locations (5, 6, 7). Some of these studies are based on field observations of pedestrian crossings or the supply of traffic gaps, while others are based on analysis of hypothetical situations. They typically are not based on pedestrians' perception of delays or crossing opportunities. They are also narrow in what aspects of pedestrian quality of service for mid-block crossing are considered. Much of the work on measuring pedestrian quality of service for street crossing in terms of pedestrian delays is summarized by Rouphail et al. (8).

Third, there are three studies closely related to pedestrian level of service for crossing streets at intersections. A study by Palamarthy et al. (9) develops models of pedestrian crossing behavior at signalized intersections. The motivation of this study was to get a better understanding of pedestrians' crossing behavior so that new strategies to deal with non-compliance of pedestrians with signals can be evaluated. It is based on a theory about pedestrians' decision to cross a street (i.e., the gap-acceptance theory). It was calibrated with field data from Austin, Texas. This study resulted in the identification of determinants of pedestrian crossing behavior at signalized intersections. The gap-acceptance theory used also provides a foundation to develop methodologies of pedestrian level of service for crossing streets. This study does not, however, lead to numerical scores that can be changed to specific level of service designations.

Another one related to street crossing at intersections is a proposed study by the Federal Highway Administration (10). The purpose is to develop mathematical models that can be used to identify engineering improvements to reduce pedestrian involvement in crashes with motor vehicles at intersections. Calibration will be based on reported statistics of pedestrian crash involvement rather than perceived levels of crossing safety.

As a result, this methodology is inconsistent with those for evaluating bicycle level of service or pedestrian level of service along roadways.

The last study related to street crossing at intersections is summarized by Wellar (11). The purpose of this study is to develop an index to represent the level of safety, comfort, and convenience expected by pedestrians crossing streets at signalized intersections. A preliminary formation of the index is based on the amount of interaction between motor vehicles and pedestrians, which is further adjusted by six multiplicative variables: number of through lanes, number of turning lanes, street angles, street grade, number of legs, and number of channels at the intersection.

While what this index tries to measure is similar to what was considered in the mid-block crossing project, both the intended purpose and the approach to developing this index differ from it. The index is intended for ranking intersections rather than for determining the pedestrian level of service for individual intersections. Selection of variables is based on opinion surveys of elected officials, professionals, and citizens. No data collection or statistical calibration is involved in developing this index.

The next section summarizes the thought process behind the selection of independent variables and the methodology used to collect data about what variables are important and how they may affect the needs of pedestrians when crossing streets at mid-block locations.

DETERMINANTS OF PEDESTRIAN QUALITY OF SERVICE

One difficulty that the research team faced in understanding what determines pedestrian quality of service for mid-block crossing was the lack of a framework provided in the literature to guide in the selection of determinants. During the course of the project, a component approach was taken, as illustrated in Table 1. Specifically, the research team first examined the components of pedestrian quality of service for mid-block crossing and then sought to understand what determines these components. Unfortunately, this approach turned out not to be as fruitful as originally thought. The team then turned to examining the components of pedestrian crossing behavior at mid-block locations and once again sought to understand what determines these components. This second approach proved to be more helpful in identifying a set of potential determinants for measuring pedestrian quality of service at mid-block crossing locations. Since the first approach proved to be less suitable, only the second approach is briefly discussed in the following paragraphs.

Components of Pedestrian Crossing Behavior

In the second approach pedestrian crossing behavior and its major components were decomposed and then used as a vehicle for selecting the determinants. Fortunately, gap-acceptance theory for pedestrian crossing behavior was available to provide guidance.

Gap-acceptance Theory

Pedestrian crossing behavior is largely governed by the gap-acceptance theory (11). Gap-acceptance theory states that each pedestrian has a critical gap to cross the street. Upon arriving at the curb, the pedestrian would check if the current traffic gap was greater than the critical gap and decide whether to accept the traffic gap. If the current one was rejected, the next one will be considered and so on. This process continues until the pedestrian accepts a traffic gap or gives up entirely and decides not

to cross. The critical gap consists of two parts. One part is the required crossing time and the other part is a safety margin. The safety margin is the difference between the time a pedestrian crosses the traffic and the time the next vehicle arrives at the crossing point. It is what is beyond the minimum crossing time for a traffic gap to be acceptable. The crossing time is what it takes a pedestrian to cross a particular street. Therefore, this theory indicates that pedestrian crossing behavior is governed largely by three components: the supply of gaps, crossing time, and safety margin.

Supply of Traffic Gaps

It is no doubt that the supply of traffic gaps is the key determinant of pedestrian quality of service for street crossing at mid-block locations. There were two arguments, however, against using it as a variable for this particular project. Data for this variable will not be readily available or easily collected when the result of this project was to be applied. While data collection would not be a significant effort if the application were to only a few blocks, it will be if an entire region was involved. In addition, the supply of traffic gaps was not a direct policy variable such as cycle length, crossing facilities, medians, or speed limits.

Instead of directly applying it as a determinant, the team used the variables that influence the supply of traffic gaps as potential determinants of pedestrian quality of service for mid-block crossings. The supply of traffic gaps, including both the frequency and duration of gaps, was determined by traffic volume and its patterns. Traffic patterns indicated both the spatial and temporal distributions of traffic. Spatially, it indicated, for example, whether vehicles arriving at a given crossing point were evenly distributed across the traffic lanes and traffic directions. Temporally, it indicated how vehicles arriving at a given crossing point were distributed in time. In general, the more uniform the traffic pattern, the fewer the large gaps that allow people to safely cross a street.

While traffic volume was relatively easy to measure, it was not as easy to measure traffic patterns, especially temporal patterns. As a result, it would be desirable to determine what characteristics of a street influence its traffic pattern. Once these were determined, it could be used as predictors of pedestrian quality of service for mid-block crossing. A review of the literature and discussion with FDOT staff indicated that there were six major variables influencing traffic patterns: signal cycle, signal spacing, turning movements, crossing facilities, median treatments, and directional distribution of traffic.

Three of these variables (cycle length, signal spacing, and turning movement) influence traffic patterns through their effects on the platooning of traffic. When traffic is light there is an ample supply of traffic gaps. As a result, there was little difficulty for pedestrians with no physical disabilities to wait for a suitable gap and cross the road. When traffic was heavy, however, the supply of traffic gaps depended on traffic platooning (7). With interrupted traffic, which was being dealt with in this project, platooning resulted from traffic signal cycles at intersections. Platooning was positive for street crossing because it was easier for pedestrians to cross traffic that were bunched into platoons separated with long time gaps than traffic that was more uniformly distributed.

An alternative approach to measuring the effects of traffic platooning may be the use of traffic arrival types (4). The 1997 update of the *Highway Capacity Manual* uses six arrival types to represent the quality of progression. Quantitatively, arrival types may be approximated by the ratio between the proportion of all vehicles in movement arriving during green phase and the effective green time ratio.

The other three variables influence traffic patterns either by creating gaps (crossing facilities) or by taking advantage of what gaps are available in the traffic stream that would otherwise be much less acceptable without the effects of such variables (median treatments and directional distribution of traffic).

Crossing Time

The time a pedestrian takes to cross a street was determined by the distance to be crossed, the walking speed of the pedestrian, and whether the median treatments allow the pedestrian to cross the street in two stages. When medians allowed pedestrians to have a two-stage crossing, more traffic gaps become acceptable because the required crossing time was cut in half. Walking speed determines how much time a pedestrian takes to cover a given distance. It could be measured in the field if the participating pedestrians actually cross the street.

It appears that personal attributes such as age are good indicators for walking speeds, on average (12, 13). The presence of disabilities certainly affected how fast one can walk. In addition, median treatments, crossing location, group size of pedestrians, weather such as snow and ice, being encumbered by parcels, and trip purpose appeared to influence walking speed as well. According to Bowman and Vecellio (14), the average walking speed is higher for roads with two-way-left-turn lanes than for undivided roads; and pedestrians tend to walk faster at mid-block locations than at signalized intersections. According to Dipietro and King (15), individual pedestrians crossed a street at mid-block locations at higher speeds than groups. Finally, according to a review by Puchkarev and Zupan (16), commuters and students walk at higher speeds than shoppers.

Safety Margin

It appears that the size of the safety margin is largely determined by certain personal attributes such as age and gender (15, 17). It may also depend on some other variables, including whether the pedestrian was walking or standing still before stepping into the street (18), the expected pedestrian delays before the next gap comes (9), the relative supply of traffic gaps in the two directions of traffic (19), the group size of pedestrians (15, 17), and the presence of children (17). Finally, several other variables could also influence pedestrians' choice of safety margin and perception of crossing quality of service. These included traffic speed at mid-block locations, the presence of large vehicles in traffic, sight distance, and lighting conditions.

Determinants of Perception

Pedestrian quality of service for mid-block crossing reflects not only the objective quality of service provided by roadway segments for mid-block crossing but also pedestrians' perception of these objective quality of service. By definition, personal attributes determine how one perceives. How pedestrians perceive the lack of crossing opportunities depends on their safety margin. The perception of pedestrians on their individual delays is likely to be related to how urgent they are, how long the entire trip is, etc. How a pedestrian perceives the lack of safety depends on how much personal risk he or she is willing to assume. How a pedestrian perceives the quality of service for street crossing is also likely to depend on the amount experience crossing streets.

METHODOLOGY

Identify Sample of Mid-Block Crossing Locations

Databases of roadway facilities and roadway blocks for both Hillsborough and Pinellas Counties were obtained to assist in the selection of the final sample of mid-block crossing locations to be used in the collection of data. These databases were extracted from the Roadway Characteristics Inventory archived by District Seven of the FDOT, which oversees both Hillsborough and Pinellas Counties. In addition, a list of signalized and un-signalized mid-block crosswalks was obtained from the Hillsborough County Transportation Department, City of Tampa Public Works Department, and City of Clearwater Public Works Department. The research team used information from these sources to identify 20 mid-block locations in Tampa and 13 in and around Downtown St. Petersburg.

Mid-blocks were defined on the basis of traditional blocks, i.e., roadway sections between two consecutive intersections regardless of signalization. It was important that the selected mid-block crossing locations have wide variation with regard to a host of static (unchanging) characteristics.

Dynamic characteristics at each mid-block crossing location such as traffic volume, speed, and turning movements were collected concurrently with the field study. In order to capture these dynamic characteristics, traffic counters were used for 24 hours at each location. In conjunction with the use of traffic counters, the research team used video cameras to capture both far side and nearside turning movements. In addition to the use of video cameras, the research team also manually tabulated turning movements within each roadway segment.

Data Collection

The final sample of participants was obtained by using a temporary staffing agency. This resulted in a total of 96 participants. Due to more than one participant showing up for more than one day of data collect, certain participants took part in the more than one day of actual data collection. The participants were diverse in nature ranging in age from 18 to 77 years and were composed of 68 percent females and 32 percent males. The average age of participants was 42.7 years. Any person 13 years of age or older was included as a participant.

The collection of data took place on Tuesday, April 17, in South Tampa, Thursday, April 19, in the Downtown St. Petersburg area, and Tuesday, April 24, 2001 in North Tampa from approximately 9 AM to 2:30 PM, depending on the day of data collection.

Prior to departing the central location each day, participants were read a set of briefing instructions by the research team that made it clear what was expected of them as well as some basic logistical issues such as the sites to be covered and other issues pertinent to that day's data collection. It was also explained to participants what the research team means by crossing difficulty. For this project, crossing difficulty was explained to participants as the risk of being hit by a vehicle, the amount of time to wait for a suitable gap in traffic, presence of a median or other refuge, parked cars, lack of an acceptable (wide enough) traffic gaps, or anything else that may affect crossing safety.

It was emphasized to participants that the research team is only interested in their perception of the level of difficulty if they were to cross the road. The research team did not want their perception of the level of difficulty for other persons crossing the same road at the same point.

When it was their turn at any given site, three participants were instructed to approach the curb and observe traffic conditions for three minutes. They were instructed not to enter or cross the street. In each case, a research team member kept the time for each group of participants. Based on observations by the research team, three minutes was more than enough time for each group to observe any major changes in traffic conditions such as traffic signal cycles and vehicle speeds prior to making an assessment about the site. When observing traffic conditions, participants were instructed to continuously scan the roadway segment (block) by looking left, then right, then across the street as many times as they could during the allotted three minutes. It was stressed to each participant that it was critically important for them to take into account all of the static and dynamic roadway characteristics that were present at each site prior to making an assessment or grading the site. Participants were told to be mindful that all of the dynamic characteristics are likely to continuously change during the three-minute observation window and that their perception of the level of crossing difficulty should not be based on the least favorable condition, the most favorable condition, or any single moment. Rather, they should base their perception on the summation of conditions, including any variations that they observed.

Once the three-minute observation window closed, participants were asked to record their perception of crossing difficulty on the survey form before leaving the curb. The survey form contained either 5 or 6 rows of letters depending on the survey day, with each row representing a mid-block crossing location. A copy of the survey form can be found in Figure 1. To simplify the matter of providing an assessment, the survey form was designed to parallel a grading system, ranging from A through F. An "A" indicated no difficulty in crossing the road at a mid-block location and an "F" indicated extreme difficulty. Participants were instructed to think of the letter grades that they were to assign to each site as identical to those used in school. For each site, participants recorded their grade by simply circling the letter grade (A through F) on the appropriate row of the survey form. Table 2 shows the average grade by gender assigned by participants.

In all, 767 observations were recorded during the three days of data collection and the final dataset contained 26 variables. Table 3 shows summary statistics for the collected data.

RESULTS

Table 4 shows the results from the analysis using the ordinary least squares statistical method. The four columns of Table 4 list the independent variables, coefficients, standardized coefficients, and t-statistics. The bottom two rows show the adjusted R-square and the number of observations used in the estimation. The model is specified according to the research design discussed earlier.

The overall fit of the final model is reasonable as indicated by the adjusted R-square of 0.333. However, its overall fit may have been influenced by several variables, some by design and others as the result of resource constraints. One example of the former is those variables that are potential determinants of traffic patterns. Another example of the former is the use of a cross-sectional sample, which typically leads to lower values of R-square. Further, one example of the latter is the limited number of sites used in the sample. The limited number of sites in the sample was a direct result of a lack of financial resources.

The statistical analysis started with a basic model that had several features:

- It used all characteristics that were hypothesized to be important in the research-design process
- It used directional measures for four characteristics
- All variables were in linear form
- The full data set was used for estimation.

In addition to specifying the basic model, many alternative model forms were considered as well. One set of alternatives used one of the four groups of characteristics: personal, traffic, roadway, and control characteristics. One alternative combined the two directional measures for each of the four directionally measured characteristics. Yet another alternative considers non-linear forms of the variables. The fourth alternative re-estimated the basic model with a part of the full data set that excludes observations from one site with stop-sign control and two sites with one-way traffic. However, it was determined that the four alternative models were not more suited for predictive purposes than basic model, which became the final model.

Alternative model forms that include interactions between variables were considered but not estimated. It is reasonable to hypothesize that certain site characteristics become important only if some of the other site characteristics reach certain levels. For example, the presence of pedestrian signals may start to reduce the perceived difficulty for mid-block crossing once traffic volume is very high. Such interactions are not included for several reasons. First, there are potentially a large number of interactions. Second, it is unknown where the breakpoints are for each interaction. Determining these breakpoints for the large number of potential interactions would mean almost endless mining of the data. Third, the range of variation, particularly traffic volume, is very limited in the sample due largely to the fact that the field surveys occurred mostly during the mid-day period.

Table 4 shows the results for the final model. To discuss the fit of the final model, several aspects are covered including the R-square and estimation issues.

R-square

The R-square reflects how well the model fits the data and measures the proportion of variation in the reported level of difficulty across the sample that is explained by the explanatory variables in the model. One property of the R-square is that it increases with the number of explanatory variables. It is customary to report the adjusted R-square that accounts for the number of explanatory variables. The adjusted R-square for the basic model was 0.34. While this value is reasonable for a cross-sectional analysis of individual responses, it is low relative to several similar studies related to the Department's Multi-modal Quality of Service Program. For example, Landis et al. (18) report an unadjusted R-square value of 0.85. With adjustment, the value reported by Landis et al. would still have been more than double what is being reported from this analysis.

Estimation Issues

Two estimation issues are discussed related to the final model. The first is related to the presence of multicollinearity across the explanatory variables. The second is related to the use of repeated observations from the same individuals in the sample.

Multicollinearity

Some multicollinearity appeared to be present in the data, particularly between each pair of directional measures of the same characteristic. Specifically, the correlation coefficients between the two directional measures are 0.77, 0.71, 0.82, and 0.99 for traffic volume, turning movements, crossing width, and signal cycle, respectively. The correlation was particularly strong for signal cycle. However, correlation between different characteristics was relatively low and did not appear to be a concern.

The consequence of multicollinearity is that the coefficients of the highly correlated variables are not precisely estimated. This consequence becomes a serious problem if the objective of estimating the model was to test hypothesis on the individual variables. When the coefficients are not precisely estimated, any hypothesis testing based on these coefficients is unreliable. If, however, the model was estimated for predictive purposes, imprecision in the individual coefficients need not be a serious concern as long as two conditions were reasonably satisfied. One condition was that the correlated variables as a group are precisely estimated. The other condition that the correlation pattern was expected to prevail in the situations to be predicted (19). Because the final model satisfies with all these conditions, multicollinearity was not used as a reason to reject the final model.

Repeated Observations

Like previous modeling efforts of pedestrian or bicyclist perceived quality of service, repeated observations were used in this research. In reporting the results, especially the t-statistics, repeated observations were assumed to be statistically independent from one another. In reality, the repeated observations from the same person are likely to be correlated. This correlation results from certain characteristic of the person that influences his or her reported level of difficulty but was unobserved. Not accounting for such correlation would inflate t-statistics and overstate the statistical significance of individual variables.

One ad hoc but conservative adjustment for such correlation is to divide the reported t-statistics by the square root of the average number of repeated observations per participant (20). In this case, the adjustment factor is 2.83 or the square root of the average number of responses per participant. Of the 15 variables in the model, 13 are significant without adjustment but only 6 are with adjustment. Similarly, the adjustment factor would be 4.58 or the square root of 21 for the study reported by (18). With this adjustment, only lateral separation elements were significant; neither motor vehicle volume nor traffic running speed was significant.

Equation Format for Application

To apply the final model for planning studies, it may take one of two forms as discussed in the following paragraphs.

Side-of-Roadway Specific

If a planning study calls for levels of crossing difficulty that are side specific, especially because the four directionally-measured characteristics are asymmetric between the two sides, the original form of the final model would be used as shown in Table 4. It would be applied twice for each street block. In an equation format, the model takes the following form:

Directional Level of Crossing Difficulty =

$$\begin{aligned}
 &-2.4778 \\
 &+0.4937 * \text{Share 65 Years or Older} \\
 &-0.1159 * \text{Nearside Total Volume (1000 vehicles / hour)} \\
 &+0.2674 * \text{Far-side Total Volume (1000 vehicles / hour)} \\
 &+0.0018 * \text{Nearside Turning Movements (vehicles / hour)} \\
 &+0.0013 * \text{Far-side Turning Movements (vehicles / hour)} \\
 &+0.0107 * \text{Running Speed (miles / hour)} \\
 &-0.0852 * \text{Nearside Crossing Width (feet)} \\
 &+0.1241 * \text{Far-side Crossing Width (feet)} \\
 &-0.0661 * \text{Width of Restricted Median (feet)} \\
 &-0.0712 * \text{Width of Painted Median (feet)} \\
 &-0.2762 * \text{Crosswalk (1 if present; 0 otherwise)} \\
 &-0.4930 * \text{Pedestrian-Signal (1 if present; 0 otherwise)} \\
 &-0.0326 * \text{Nearside Cycle Length (seconds)} \\
 &+0.0610 * \text{Far-side Cycle Length (seconds)} \\
 &+0.0007 * \text{Signal Spacing (feet)}
 \end{aligned}$$

Combined

If the street block is largely symmetric in the four directionally measured characteristics, however, there is no need to estimate side-specific levels of crossing difficulty. In that case, the two directional measures for each of the four directionally measure characteristics may be combined and a simplified model format may be used as follows in equation format:

Combined Level of Crossing Difficulty =

$$\begin{aligned}
 &-2.4778 \\
 &+0.4937 * \text{Share 65 Years or Older} \\
 &+0.0758 * \text{Combined Total Volume (1000 vehicles / hour)} \\
 &+0.0016 * \text{Combined Turning Movements (vehicles / hour)} \\
 &+0.0107 * \text{Running Speed (miles / hour)} \\
 &+0.0195 * \text{Combined Crossing Width (feet, excluding} \\
 &\quad \text{medians)} \\
 &-0.0661 * \text{Width of Restricted Median (feet)} \\
 &-0.0712 * \text{Width of Painted Median (feet)} \\
 &-0.2762 * \text{Crosswalk (1 if present; 0 otherwise)} \\
 &-0.4930 * \text{Pedestrian-Signal (1 if present; 0 otherwise)} \\
 &+0.0284 * \text{Average Cycle Length (seconds)} \\
 &+0.0007 * \text{Signal Spacing (feet)}
 \end{aligned}$$

Example Calculations

One example is used below to illustrate how the predicted level of crossing difficulty may be calculated from the preferred model and how the corresponding level of service may be determined from the predicted difficulty. This is done separately for the side-specific model form and the combined model form.

Side-of-Roadway Specific

Table 5 illustrates how the side-specific model may be used in planning studies to predict crossing difficulty and determine the corresponding level of service. The variables in the model are shown in the first column. The values of the variables for this sample site are shown in the next column. Please note that the value for the Constant is 1 and the value for 65 Years or Older Dummy variable is percentage. The conversion column is there to put the values in units appropriate for the model. In this case, only the percent of pedestrians who are 65 years or older is converted to get a share value. In real applications, some of these variables may be measured on a daily basis. If that is the case, these variables also need to be converted appropriately. If total volume is measured as average annual daily traffic, for example, an appropriate conversion factor is required to get a particular hourly rate. The last column is the product of the coefficients and conversion columns.

To get the predicted level of difficulty for this site, one simply needs to add the last column up. In this case, it is 6.06. Each row in the last column may be interpreted as the contribution of each variable to the overall level of difficulty.

To determine the predicted level of service for this site, one needs a mechanism to convert this predicted level of difficulty into a particular level of service designation. Following previous practices and the breakpoints used in the sensitivity analysis, the level of service is "F," since the predicted level of difficulty is in the range of at least 5.5.

Taking into account prediction errors would not change the predicted level of service in this case. Using an average standard error of predictions of 0.188 and a 95 percent confidence level, the lower bound of the confidence interval would be 5.7, which is still higher than the breakpoint for level of service "F".

Combined

Finally, Table 6 shows a similar illustration for the combined model. In terms of calculation, the difference is in the four characteristics that were measured by direction. For cycle length, the value is the average of the two directions. For the other three, the value is the sum of the two directions. The result is the same in this case because the directions are assumed to be symmetrical in terms of these four characteristics.

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FIGURE 1 Data Collection Form

TABLE 1 Potential Determinants

TABLE 2 Descriptive Sample Statistics

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TABLE 4 Final Model with Full Sample

TABLE 5 Illustration of Site-Specific Model

TABLE 6 Illustration of Combined Model

FIGURE 1

Site ID	Without actually crossing it, how do you perceive the level of difficulty for you to cross this street at this point under current conditions?					
	 No Difficulty (Please circle only one letter per row) Extreme Difficulty					
9	A	B	C	D	E	F
2	A	B	C	D	E	F
3	A	B	C	D	E	F
4	A	B	C	D	E	F
1	A	B	C	D	E	F

TABLE 1

<i>Determinants</i>	<i>Measurement for Calibration</i>	<i>Measurement for Application</i>	<i>By Direction</i>	<i>Function Form</i>	<i>Data for Calibration</i>	<i>Data for Application</i>
<i>Personal Characteristics</i>						
Age 16-64	1 if age 16-64; 0 otherwise	Share 16-64	No	/	Concurrent question	Not in ART_PLAN
<i>Traffic Characteristics</i>						
Traffic volume	Vehicles per hour per lane (VPH)	VPH from AADT	Yes	/	Concurrent taping	Available in ART_PLAN
Turning movements	Vehicles per hour from turning points	Same	Yes	/	Concurrent taping	Not in ART_PLAN
Traffic speed	Mid-block running speed	Same	No	/	Concurrent taping	Available in ART_PLAN
<i>Roadway Characteristics</i>						
Crossing distance	Feet from curb center	Same	Yes	∩	Pre-survey	Not in ART_PLAN
Restrictive medians	Width in feet	Same	No	∪	Pre-survey	Not in ART_PLAN
Non-restrictive medians	Width in feet	Same	No	/	Pre-survey	Not in ART_PLAN
Crosswalks	1 if crosswalks present; 0 otherwise	Same	No	/	Pre-survey	Not in ART_PLAN
Pedestrian signals	1 if signals present; 0 otherwise	Same	No	/	Pre-survey	Not in ART_PLAN
<i>Control Characteristics</i>						
Signal cycle	Full cycle length in seconds	Same	Yes	—	Pre-survey	Available in ART_PLAN
Signal spacing	Feet between nearby signalized intersections	Same	No	/	Pre-survey	Available in ART_PLAN

Function Form: Refers to linear and non-linear relationships.

ART-PLAN: ART_PLAN is the Florida DOT's software tool that determines LOS for detailed planning of interrupted facilities in urbanized areas. (ART is likely to represent arterial, while PLAN represents planning.)

TABLE 2

<i>Gender</i>	<i>Age</i>	<i>Average Grade (1-6)¹</i>	<i>Observations</i>	<i>Std. Deviation</i>
Female	18-24	2.66	119	1.463
	25-64	2.92	345	1.736
	65+	3.57	60	1.721
	Total	2.94	524	1.692
Male	18-24	2.93	56	1.616
	25-64	2.96	165	1.51
	65+	2.55	22	1.262
	Total	2.92	243	1.514
Total	18-24	2.75	175	1.514
	25-64	2.94	510	1.665
	65+	3.29	82	1.667
	Total	2.93	767	1.636

¹ Grade of 1 indicates no difficulty and grade of 6 indicates extreme difficulty.

TABLE 3

<i>Variable</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Median</i>	<i>Mean</i>	<i>Standard Deviation</i>
65 years or older	0	1	0.50	0.96	0.18
Male	0	1	0.50	0.32	0.47
Nearside volume in vehicles per hour	0	15	7.50	4.43	3.79
Far-side volume in vehicles per hour	0	11	5.50	3.67	2.42
Total volume	0	25	12.32	8.10	5.85
Nearside turning movements in vehicles per hour	0	840	420.00	137.00	183.26
Far-side turning movements in vehicles per hour	0	560	280.00	127.22	149.72
Total turning movements	0	1,400	700.00	264.22	309.06
Average speed in miles per hour	23	45	34.00	32.12	5.26
Nearside crossing width in feet	14	54	34.00	26.73	7.38
Far-side crossing width in feet	14	54	34.00	28.54	9.25
Total width in feet	28	108	68.00	55.27	15.97
Width of restricted median in feet	0	40	20.00	7.47	13.11
Width of painted median in feet	0	20	10.00	3.52	5.82
Crosswalk present	0	1	0.50	0.51	0.50
Pedestrian-signal present	0	1	0.50	0.23	0.42
Nearside cycle length in seconds	0	165	82.50	27.31	49.30
Far-side cycle length in seconds	0	150	75.00	25.82	45.96
Total cycle in seconds	0	158	78.75	26.56	47.55
Signal spacing	484	5,000	2,742.00	4,075.55	1,613.72

TABLE 4

Variables	Coefficients	Standardized Coefficients	t-statistics
Constant	-2.4778		-3.2120
(+) 65 Years Or Older Dummy (0-1)	0.4937	0.0933	3.1133
(+) NS Total Volume (1000 vehicles / hour)	-0.1159	-0.2682	-4.1854
(+) FS Total Volume (1000 vehicles / hour)	0.2674	0.3957	6.8259
(+) NS Turning Movements (vehicles / hour)	0.0018	0.2033	3.5434
(+) FS Turning Movements (vehicles / hour)	0.0013	0.1224	2.5595
(+) Average Speed (miles / hour)	0.0107	0.0344	0.7618
(+) NS Crossing Width (feet)	-0.0852	-0.3846	-4.3901
(+) FS Crossing Width (feet)	0.1241	0.7015	6.1663
(-) Width Of Restricted Median (feet)	-0.0661	-0.5300	-5.5726
(-) Width Of Painted Median (feet)	0.0712	0.2531	7.2010
(-) Crosswalk Dummy (0-1)	-0.2762	-0.0844	-1.5645
(±) Pedestrian-Signal Dummy (0-1)	-0.4930	-0.1265	-3.1598
(±) NS Cycle Length (seconds)	-0.0326	-0.9823	-3.3957
(±) FS Cycle Length In (seconds)	0.0610	1.7144	5.4797
(±) Signal Spacing (feet)	0.0007	0.6464	7.6269
Adjusted R Square		0.34	
Std. Error Of The Regression		1.328	
Sample		767	

Notes: "+" ("−") indicates that an increase in the explanatory variable would increase (decrease) the level of difficulty "±" indicates that the direction of the net effect of the explanatory variable is analytically unknown and needs to be empirically determined. The abbreviations "NS" and "FS" represent nearside and far side, respectively. The dummy variables take one when the characteristic as described in the name of the variable is present and zero otherwise. The standardized coefficients represent the change in the level of difficulty from a change of one standard deviation in an explanatory variable. The t-statistics assumes that the repeated observations from the same participant were statistically independent.

TABLE 5

Variables	Coefficients	Values	Conversion	Difficulty
Constant	-2.4778	1	1	-2.48
Share 65 Years Or Older	0.4937	25	0.25	0.12
Nearside Total Volume (1000 vehicles / hour)	-0.1159	6.0	6.0	-0.70
Farside Total Volume (1000 vehicles / hour)	0.2674	6.0	6.0	1.60
Nearside Turning Movements (vehicles / hour)	0.0018	180	180	0.32
Farside Turning Movements (vehicles / hour)	0.0013	180	180	0.23
Average Speed (miles / hour)	0.0107	55	55	0.59
Nearside Crossing Width (feet)	-0.0852	36	36	-3.07
Farside Crossing Width (feet)	0.1241	36	36	4.47
Width Of Restricted Median (feet)	-0.0661	0	0	0.00
Width Of Painted Median (feet)	0.0712	0	0	0.00
Crosswalk Dummy (0-1)	-0.2762	0	0	0.00
Pedestrian-Signal Dummy (0-1)	-0.4930	0	0	0.00
Nearside Cycle Length (seconds)	-0.0326	150	150	-4.89
Farside Cycle Length In (seconds)	0.0610	150	150	9.15
Signal Spacing (feet)	0.0007	1,000	1,000	0.70
Predicted Difficulty for Sample Site		6.06		
95 Percent Confidence Interval		5.69 – 6.43		
Predicted Level of Service		F		

TABLE 6

Variables	Coefficients	Values	Conversion	Difficulty
Constant	-2.4778	1	1	-2.48
Share 65 Years Or Older (0-1)	0.4937	25	0.25	0.12
Total Volume (1000 vehicles / hour)	0.0758	12.0	12	0.91
Turning Movements (vehicles / hour)	0.0016	360	360	0.56
Average Speed (miles / hour)	0.0107	55	55	0.59
Crossing Width (feet)	0.0195	72	72	1.40
Width Of Restricted Median (feet)	-0.0661	0	0	0
Width Of Painted Median (feet)	0.0712	0	0	0
Crosswalk Dummy (0-1)	-0.2762	0	0	0
Pedestrian-Signal Dummy (0-1)	-0.4930	0	0	0
Average Cycle Length (seconds)	0.0284	150	150	4.26
Signal Spacing (feet)	0.0007	1,000	1,000	0.70
Predicted Difficulty for Sample Site		6.06		
95 Percent Confidence Interval		5.69 – 6.43		
Predicted Level of Service		F		