Why People Cross Where They Do

The Role of the Street Environment

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ABSTRACT

This paper models the role of the street environment in how people cross roads in urban settings. Respondents were placed in real traffic conditions at the curbside of street blocks in the Tampa Bay area for a three-minute observation of the street environment. Without crossing the blocks, each respondent stated his crossing preference at each of six blocks. The origin and destination of each crossing were hypothetically set and varied across the blocks. So were the options available: two options for crossing at an intersection and up to four options for crossing at mid-block locations. Within the framework of discrete-choice models, the stated preferences are explained with the street environment, including traffic conditions, roadway characteristics, and signal-control characteristics. All three components of the street environment are considered: mid-block locations, intersections, and the roadside environment. The paper describes the data; estimates a nested logit model of pedestrian street-crossing behavior; and discusses its implications to researchers and practitioners.

INTRODUCTION

Street crossing is a critical element of the urban transportation environment for pedestrians. A large body of work already exists on street crossing by pedestrians, including the following by subject area:

- Crossing delays (*1*),
- Crossing opportunities (*2*),
- Pedestrians' behavioral parameters (*3-4*),
- Pedestrian compliance (*5*),
- Pedestrian perceptions toward specific treatments (*6*),
- Determination of level of service (*7-10*),
- Engineering parameters such as pedestrian clearance intervals (*11*),
- Evaluation of treatments (*12-13*),
- Drivers' perspective (*14-15*),
- Safety (*16*), and
- Empirical modeling (*17-19*).

However, little research exists that can help answer questions related to pedestrian planning, engineering solutions to pedestrian crossing safety, and research methods for modeling street-crossing behavior. Below are a few examples of these questions:

Planning Questions
- How can existing planning tools for determining pedestrian level of service for street crossing at mid-block locations and intersections be integrated to determine pedestrian level of service at the block level?

Engineering Questions
- How and when might a pedestrian go to a crosswalk at mid-block locations?
- How and when might a pedestrian go to an intersection?
- Where should transit bus stops be located so that transit users are more likely to choose safe crossing options to access them?

Research Methodology Questions
- What statistical models are most appropriate for modeling the street-crossing behavior of pedestrians so that these planning and engineering questions can be answered?
- What and how should data be collected in order to estimate such statistical models?

This paper models the role of the street environment in how pedestrians cross roads in urban settings. Specifically, 86 participants placed in real traffic conditions at the curbside of 48 street blocks in the Tampa Bay area observed the street environment for three minutes. Without crossing the street blocks, the participants stated their crossing preferences at each of six blocks. The origin and destination for each crossing were hypothetically set and varied across the blocks. So were the options available: two options for crossing at intersections and up to four options for crossing at mid-block locations. Within the framework of discrete choice models, the stated preferences are explained by traffic conditions, roadway characteristics, and signal-control characteristics.

The paper focuses on the street environment so that variables are readily measured for model applications. As an alternative, one could model the role of the direct attributes, such as safety and time, that pedestrians may trade off in choosing a crossing option. By focusing on the street environment, the paper assumes that the indirect attributes that characterize the street environment determine the direct attributes and that the street crossing behavior can be modeled with these indirect attributes equally well. As another alternative, one could include the street environment as well as pedestrians' personal characteristics. It is recognized here that these characteristics are potentially important in how pedestrians cross roads. They are excluded solely because data on them are not readily available for model applications. The impacts of these two alternative specifications on model results are reported elsewhere (*20*) and are briefly described in this paper when its research implications are discussed.

The rest of the paper has four sections. They describe: 1) the design of the stated-preference survey, 2) data collection efforts, 3) model estimation results, and 4) the implications of the study to pedestrian planning, engineering solutions to pedestrian crossing safety, and research, respectively.

DATA

The data are described here in terms of the steps used in survey design, the selection of potential determinants, data collection, and the final database.

Design

A stated-preference approach was chosen for several reasons. It resulted in wide ranges of variation in the street environment. It allowed solicitation of preferences in real traffic conditions. It also resulted in a manageable number of crossing options for modeling. The design process involved four steps:

1. Identify potential determinants of pedestrian street-crossing behavior;
~~1.~~2. Determine levels of key determinants through the selection of street blocks;
~~1.~~3. Formulate crossing scenarios by defining crossing origins and destinations, crossing options, and temporary mid-block crosswalks; and
~~1.~~4. Develop instruments for individual crossing scenarios.

These reasons and design steps differ from those for a standard stated-preference survey (*21*).

Determinants

Two steps were used to select potential determinants that describe the street environment. The first step identified the direct attributes that pedestrians may trade off in making a choice: comfort, safety, time, and predictability. Predictability refers to the uncertainty in the amount of time an option may take a pedestrian to cross. The second step identified the indirect factors that may determine the direct attributes.

Comfort and Predictability

Differences in comfort result largely from differences in exposure to unpleasantness (e.g., hot weather) and personal traits that influence comfort sensitivity (e.g., poor health). Such differences are captured with roadside walking and crossing distance. Roadside walking could vary significantly across options. Crossing distance varies when jaywalking is involved or when the choice involves intersections and mid-block locations that have different width. Variation in predictability results from the presence or absence as well as the spacing of traffic signals.

Safety and Time

The amount of time spent walking along a street is determined by the distance involved and speed of walking. Distance is already identified as a potential factor in the paragraph above. The potential factors for safety, crossing time, and waiting time are discussed below for crossing at mid-block locations, crossing at intersections, and roadside walking separately.

Mid-block. Chu and Baltes (*22*) identify potential determinants for pedestrian crossing behavior at mid-block locations, based on supply of gaps, crossing time, and safety margin, which form the three components of the gap-acceptance behavior of pedestrians (*17*). Safety margin is the difference between the time a pedestrian takes to cross the traffic and the time the next vehicle arrives at the crossing point.

Intersections. Crider et al. identify potential determinants for pedestrian crossing behavior at intersections (*8*). These are done separately for safety and delays. Safety consists of conflicts with road users and pedestrian's exposure to these conflicts. Vehicle movements at an intersection that cross the crosswalk represent conflict volumes. Exposure consists of crossing distance, presence of crosswalks, and presence of curb or sidewalk, and median type. For pedestrian delays, the potential determinants differ between signalized and un-signalized intersections. At signalized intersections, pedestrian crossing delay depends on cycle length for crossing with a pedestrian signal and on the facility's green ratio for crossing without a pedestrian signal. At un-signalized intersections, pedestrian crossing delay is a function of the conflict volumes described above in relation to pedestrian safety.

Roadside. Landis et al. identify potential determinants for pedestrians walking along roadsides (*23*). Through a step-wise regression process, the authors identify factors describing the roadside environment, including the various components of lateral separation between sidewalks and traffic lanes.

Collection

The data were collected from a sample of 86 respondents and 48 street blocks in the Tampa Bay area in Florida in spring of 2002. The participants were recruited by using a temporary staffing agency. The initial target sample size was 96 so that a total of 24 would participate on each of the four survey days with 12 on each bus. Ten did not show up for all four days combined. This approach to selecting participants gave much certainty in the number of recruited participants who actually showed up. Given the fact that completing the field surveys for any given participant took between five and six hours, recruiting volunteers through random sampling of residents in the study area would not have been possible to get the same number of participants.

The respondents were placed in real traffic conditions at the curbside of these street blocks. After observing the street environment at each street block for three minutes, they were asked to state preferred location choices for crossing the street. In addition, they were also asked to provide perceived direct attributes (safety, time, and predictability of time) of each crossing option available at the street block. The perceived attributes were on a scale from 1 to 10 with 10 being the most desirable. Each respondent provided these data for two crossing scenarios at each of six street blocks. Once all six street blocks were finished, the respondents were asked to provide background information, including their age, gender, and household income ranges.

A crossing scenario consisted of these elements: the street environment, the start and end points of the crossing, and the options available. The street environment for a particular scenario is determined through pre-selecting a large set of indirect attributes describing the street environment and through selecting street blocks that vary in wide ranges in these indirect attributes.

The selection of blocks for the field survey determined the values for most aspects of the street environment and the combinations of these values. Ideally stratified random sampling should have been used with stratification by key variables such as road width and signalization. The lack of a computerized database for individual street blocks prevented such a random approach. Instead, a non-random but systematic approach was taken. Specifically, the following criteria were used. First, the blocks were from four different areas of the Tampa Bay region: northeast Tampa, South Tampa, Clearwater, and St. Petersburg. In order to facilitate survey logistics, the selection was further limited to a circle of 5-mile radius within each area. Second, a number of potential determinants were considered, including number of lanes, presence and type of medians, signalization and crosswalk marking at intersections, pedestrian signal heads at intersections, sidewalks, lateral separation between sidewalks and traffic lanes, and block length. Third, a wide range of combinations of the values of the considered determinants was included. For example, it is desirable to have blocks on a 6-lane road with medians and blocks on a 6-lane road without medians. Fourth, a total of 48 blocks were selected with 12 from each sub-area. The number 48 was chosen because it was affordable and better facilitated field surveys.

To select a start and end combination for a scenario, five potential locations for either the start or end point were considered with equal distance between them. For either the start or end point, two potential locations were at the intersections. These potential locations allowed a total of 25 different start-end combinations. Two combinations of start and end points were randomly selected for each street block. The nearside for a scenario is where the start point is.

For a given start-end combination, a set of up to six discrete options was defined that can approximate most of the potentially infinite number of crossing options. These options are labeled as A through F for ease of reference and defined as follows (left and right are relative to the nearside):

- A = Crossing at the left intersection
- B = Crossing at a mid-block start point at a right angle
- C = Crossing with a jaywalk between the start and end points
- D = Walking on the nearside to the opposite side of a mid-block end point and crossing there at a right angle
- E = Crossing at the right intersection
- F = Crossing at a mid-block crosswalk that is away from a start or end point

The exact options depend on the particular start-end combination. Consider a case where the start point is located at the second potential location and the end point is at the forth potential location (counted from the left). In this case, options A-B-C-D-E would be available. If the start point is at the left intersection instead, for example, option B would disappear and option A would no longer involve walking along the nearside of the street. If the start point is opposite of the end point instead, as another example, both options C and D disappear and option B would involve no walking along the street. In general, there are a total of five possible sets of options from the 25 possible start-end combinations discussed earlier. These are: A-E, A-C-E, A-B-E, A-C-D-E, A-B-C-E, and A-B-C-D-E. On the other hand, option F is available only when a mid-block crosswalk is present and located away from a start or end point.

Figure 1 shows an example of an instrument. In this case, all options are available. Chu provides details on the design of the reality-based stated-preference survey, and the collection of the data (*21*). The database is briefly described below.

Database

A dataset was developed from the survey scenarios, static data, dynamic data, and stated preferences. It contained a total of 1,028 observations (out of 1,032 possible observations) and 38 independent variables. Among the variables, 6 are trip characteristics, traffic characteristics, roadway characteristics for crossing, and traffic control characteristics, respectively. Seven are roadside characteristics that are measured separately for each side of the blocks. The first two columns of Table 1 explain these variables.

The 48 blocks had a range of combinations of the potential determinants considered. The average length was 188 meters with a minimum of 71 meters, a maximum of 396 meters, and a standard deviation of 96 meters. There were 15 blocks on a 2-lane road, 16 on a 4-lane road, and 17 on a 6-lane road. Sixteen of these blocks were undivided; 20 were with restrictive medians (raised or grassy); and 12 were with painted medians. Crosswalk marking was present at both intersections for 7 blocks, at one intersection for 24 blocks, and at none of the intersections for 17 blocks.

The participants had more females than males but had a reasonable spread by age and household income. The 65+ age group crossed far fewer roads than the younger groups on the day before survey, ranging from one third of the average crossing by the 25-44 group to one half of the average by the other groups. On the day before survey, the female participants crossed roads one and half times versus three and quarter times by the male participants. Few of the participants perceived themselves having difficulty with walking at normal speed. These were evenly distributed between the two genders. Far more of them perceived having difficulty with walking at higher walking speeds, however, especially with the 45-64 group. Every one of the 13 participants who reported no difficulty at normal walking speed but reported difficulty at higher walking speeds was female.

All potential independent variables were examined for correlation. For example, traffic volume is positively correlated with green time and crossing distance for each intersection option with a correlation coefficient slightly over 0.5. This information was then used later in model estimation. In addition, individual independent variables were examined for the reasonableness of their mean, standard deviation, maximum value, and minimum value.

ESTIMATION

Hypotheses

Hypotheses were formulated for a statistical model and expected directions of effects of the independent variables.

Statistical Model

It was hypothesized that the most appropriate statistical model is the nested logit model (*24*). It is natural to view the six potential options for street crossing as two distinctive groups: those related to crossing at intersections and those related to crossing at mid-block locations. That is, the nested logit model has a two-level structure. The top level has two branches: intersections (I) and mid-block locations (M). The bottom level has two options in the intersection branch (A and E) and up to four options in the mid-block branch (B, C, D, F).

Independent Variables

The hypothesized direction of effects of independent variables was based on a basic specification of the utility functions. This specification involved two aspects. First, all variables were to be entered linearly to reduce the complexity of the model. Second, the specific utility functions to which a particular independent variable may enter were determined. Several criteria were used for this purpose.

- Whether an independent variable is constant across the options (e.g., roadside walking varies but not total traffic volume).
- Whether an independent variable is defined for each crossing option (e.g., signalization is defined for intersections only).
- Whether a specific direction of effects could be hypothesized (The width of shoulders or bike lanes is likely to increase the probability that pedestrians choose options that require roadside walking but is likely to decrease the probability that they choose options that do not require such walking).

Based on this specification, hypotheses were formulated for each independent variable. Table 1 also shows the specification and hypotheses.

Model Estimation

Model estimation was a complex process because of the large number of variables and multiple utility functions involved. Model estimation followed two stages and multiple steps.

The first stage resulted in a basic model that included only those characteristics that were explicitly shown in the instruments: traffic signals, pedestrian signals, crosswalks, relative crossing distance, relative roadside walking distance, and the location of the start and end points. These characteristics were highly significant and showed the hypothesized direction of effects in the basic model. This stage followed three steps: 1) Estimated a nested logit model of our initial specification; 2) Deleted variables one at a time that were significant but contradicted our hypothesis; and 3) Deleted variables one at a time that were consistent with our hypothesis but were insignificant.

One example of the variables that were significant but contradicted our hypotheses was driveway frequency for each roadside. As indicated in Table 1, it is reasonable to expect that people would be more likely to take options that do not require walking along a roadside that has higher driveway frequency. That is, the coefficients for driveway frequency should be positive as specified. However, they were consistently significant and negative. It is difficult to determine the exact reason for this contradiction. One possible explanation is that driveway frequency is positively correlated with block length. People are less willing to walk along roadsides if there are many driveways. When block length is not used as an independent variable, the coefficients of driveway frequency may reflect the effects of block length rather than its own effect.

The second stage resulted in our preferred model that included three additional variables: traffic volume, width of a shoulder or bike lane on the nearside, and width of a shoulder or bike lane on the farside. This stage took an opposite approach from the first stage. This was done by starting with the basic model from the first stage and adding one variable at a time that was not already in the basic model. This stage also involved making tradeoffs between certain variables. Signal cycle, for example, made traffic volume become insignificant when both were present although traffic volume worked alone. Since the presence of traffic signals was already in the basic model, it was decided to keep traffic volume rather than signal cycle.

Table 2 presents our preferred model. It contains 10 variables descriptive of the street environment. The model also includes several alternative-specific constants and two inclusive values for the two branches. Note that the columns of coefficients are not in the same order as the options. The coefficients for the two intersection options, A and E, are placed next to each other first. They are followed by the coefficients for the mid-block options. The same order is used in the discussion below. The t-statistics are reported in the parentheses below the coefficients.

The model is well behaved. First, all variables are significant and have the hypothesized direction of effects. Second, it fits the data well. The $ñ^2$ adjusted for the number of variables is 0.452. In contrast, it is common to see an adjusted $ñ^2$ below 0.3 in discrete choice models such as mode choice models. Third, the model is consistent with utility maximization (*25*). The scale parameter at the bottom level of the nested logit model was scaled to 1. The estimated coefficients of the inclusive values fall between 0 and 1. Third, the estimated coefficients of the inclusive values are significantly different from 1, indicating that the nested logit model fits the data better than the logit model.

One way to understand the model is to look at the implied elasticities, which measure how responsive the choice probabilities are to changes in continuous variables. The model has three of these: crossing distance, roadside walking distance, and traffic volume.

- With respect to crossing distance, the elasticity is -0.099 (A-left intersection), -0.117 (E-right intersection), -0.050 (B-cross first and walk later), -0.584 (C-jaywalk), -0.057 (D-walk first and cross later), and -0.025 (F-midblock crosswalk). None of the options is responsive to changes in crossing distance. Option C (jaywalk), however, is far more responsive than the other options. That is, pedestrians are far less likely to jaywalk than to take other options when crossing distance increases.
- With respect to roadside walking distance, the elasticity is -1.547 (A-left intersection), -1.853 (E-right intersection), -0.243 (B-cross first and walk later), -0.345 (D-walk first and cross later), and -0.232 (F-midblock crosswalk). The probability of an intersection being chosen is highly responsive. An increase of 10 percent in roadside walking could reduce the probability by 15 to 18 percent. In contrast, the probability of any mid-block option being chosen is irresponsive.
- With respect to traffic volume, the elasticity is -0.197 (B-cross first and walk later), -0.273 (C-jaywalk), -0.134 (D-walk first and cross later), and -0.059 (F-midblock crosswalk). Pedestrians are less likely to choose mid-block options when traffic volume increases. This impact, however, is irresponsive. Furthermore, the elasticity values for options B (cross first and walk later), D (walk first and cross later), and F (mid-block crosswalk) are several times higher in magnitude than those with respect to crossing distance but lower in magnitude than those related to roadside walking distance. For option C (jaywalk), however, the elasticity with respect to traffic volume is only half of that in magnitude as crossing distance.

To present the formula for probability calculations, let U_O (O = A, E; B, C, D, F; I, M) be the sum of the products of all variables in the first column with the corresponding parameter values for option O on the right side columns in Table 1. Note that the inclusive values are $V_I = \mathrm{Ln}(e^{U_A} + e^{U_E})$ and $V_M = \mathrm{Ln}(e^{U_B} + e^{U_C} + e^{U_D} + e^{U_F})$ for the intersection and mid-block branches, respectively. The probability of a crossing option being chosen is the product of its marginal and conditional choice probabilities. The conditional probability represents the probability of choosing a particular crossing option once the choice has been made between intersections or mid-block options. With intersections being chosen (I), for example, the conditional probability of intersection k (k = L, R) being chosen is given by $P(k / I) = e^{U_k} / e^{V_I}$. With mid-block options being chosen (M), similarly, the probability of mid-block option m (m = B, C, D, F) being chosen is given by $P(m / M) = e^{U_m} / e^{V_M}$. The marginal probability represents the probability of choosing intersections or mid-block options. Specifically, the probability of either being chosen (J = I, M) is $P(J) = e^{U_J} / e^{V}$ where $V = \ln(e^{U_I} + e^{U_M})$.

DISCUSSION

Limitations

Before discussing potential implications, it is critical to understand the simplifications made as part of the research. One simplification is that the model does not account for the dynamics of traffic conditions and pedestrian's street crossing behavior. The model relates the average traffic conditions during a three-minute period with how a pedestrian may have chosen to cross a street block under such average conditions. Whether safe traffic gaps are available can change quickly over time and across locations along a street block. Such temporal and spatial dynamics in traffic conditions lead to dynamics in the street crossing behavior of pedestrians as well. This simplification falls short for understanding certain crossing behavior, such as mid-block dash, i.e., situations where the pedestrian unexpectedly appeared in front of a motorist while the pedestrian was running and the motorist's view was not obstructed (*26*). Another simplification is that it ignores the role of time constraints. Relative to other direct attributes, time and its predictability would become far more important to a pedestrian when he has a tight time constraint. As a result, he may take riskier crossing options. By excluding time constraints, the usefulness of the model is reduced in understanding the behavior of transit users in trying to catch a coming bus on the other side of the road. The exclusion is made partly because of the difficulty in modeling time constraints.

Implications

Implications relating to research, planning tools, and engineering solutions are discussed.

Research Methods. A number of implications can be drawn that have both current and lasting value to researchers. These include:

1. The results show that pedestrian street-crossing behavior can be reasonably modeled with indirect factors that can be directly measured in practice. In this case, the indirect factors describe the street environment. However, an otherwise similar model based on direct factors alone fits the reported pedestrian street-crossing behavior better. In fact, the adjusted ρ^2 increased from 0.453 to 0.552. The direct factors measure perceived safety, time, and predictability on a scale from 1 (least favorable) to 10 (most favorable). The data were collected from the respondents in the field just after they stated their crossing preference for each crossing scenario.

~~1.~~2. Excluding personal attributes from the preferred model appears to have small impacts on the model. An alternative model with added personal attributes was estimated. The addition improved the preferred model with an increase in the adjusted ρ^2 to 0.471. The elasticity with respect to roadside walking was compared, for example, and it increased from –1.547 to –1.593 for the left intersection and from –1.853 to –1.901 for the right intersection.

~~1.~~3. The reported results earlier show that the nested logit model fits the stated pedestrian street-crossing behavior better than the conditional logit model.

~~1.~~4. The quasi-stated preference approach provides an alternative to the standard stated-preference approach.

~~1.~~5. The survey design provides an example of modeling the continuum of street crossing options in real life with discrete methods.

Planning Tools. The existing tools for determining pedestrian level of service are based on simple regression models that predict pedestrian perceptions of quality of service with the street environment. The estimated model from this research could provide a new approach that is based on pedestrians' overall satisfaction with street crossing. Specifically, the estimated utility functions can be combined to provide a meaningful measure of the overall satisfaction from crossing specific blocks: $V = \ln(e^{U_I} + e^{U_M})$. This concept is similar to using the denominator of a logit destination choice model as an accessibility measure (*27*). More important, this new approach to determining pedestrian level of service is also a behaviorally sound way to measure level of service across different modes equally. The National Corporate Highway Research Program has planned a research project to look for a unified approach for equal measurement of level of service across modes (*28*).

Engineering Solutions. The estimated model may be used to simulate how certain engineering solutions may influence how pedestrians cross streets.

1. The model can be used to determine the circumstances under which pedestrians are more likely to go to an intersection or a mid-block crosswalk. With some basic assumptions, curves may be developed to show how different combinations of selected aspects of the street environment influence the likelihood that a typical pedestrian would choose an intersection or a mid-block crosswalk in daytime conditions.

~~1.~~2. The model can also be used to determine how marking a mid-block crosswalk may discourage pedestrians from taking risky options.

~~1.~~3. Transit stops are often the destination of pedestrians crossing a street. When these stops are located inappropriately, transit users may be more likely to take risky options for crossing. For given origins, the model can help understand how the destination within a block can influence the likelihood of pedestrians to take risky options. The same implication also applies to locating walkways from major activity centers, newspaper boxes, vending machines, etc.

The actual simulation requires additional space to explore and is currently being researched.

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Table 1. Variables and Hypotheses

Variables		Hypotheses							
		Individual Options						Branches	
Description	Unit	A	E	B	C	D	F	I	M
Trip									
Walking distance	Feet along roadsides	-	-	-	-	-	-		
Crossing distance	Feet on travel lanes	-	-	-	-	-	-		
Start and end at mid-block locations	1 if true; 0 otherwise								+
Start at mid-block & end at intersection	1 if true; 0 otherwise								+
Start at intersection & end at mid-block	1 if true; 0 otherwise							+	
Start and end at intersections	1 if true; 0 otherwise							+	
Traffic									
Traffic volume	Vehicles per hour			-	-	-	-		
Mid-block running speed	Miles per hour			-	-	-	-		
Vehicle mix	Percent trucks			-	-	-	-		
Driveway volumes	Vehicles per hour			-	-	-	-		
Mid-block U-turns	Vehicles per hour			-	-	-	-		
Intersection turnings	Vehicles per hour	-	-						
Roadway- Crossing									
Right-turn lane	1 if present; 0 otherwise	-	-						
Left-turn lane	1 if present; 0 otherwise	-	-						
Acceleration lane	1 if present; 0 otherwise	-	-						
Crosswalk marking	1 if marked; 0 otherwise	+	+	+	+	+	+		
Restrictive medians	Width in feet	+	+	+	+	+	+		
Non-restrictive medians	Width in feet	-	-	-	-	-	-		
Roadway- Roadside									
Driveway frequency (nearside)	Number			+	+				
Sidewalk (nearside)	1 if present; 0 otherwise			-	-				
Buffer (nearside)	1 if present; 0 otherwise			-	-				
Barriers in buffer (nearside)	1 if present; 0 otherwise			-	-				
Curbed roadside (nearside)	1 if curbed; 0 otherwise			-	-				
Width of outside lane (nearside)	Feet			-	-				
Width of shoulder / bike lane (nearside)	Feet			-	-				
Driveway frequency (farside)	Number				+	+			
Sidewalk (farside)	1 if present; 0 otherwise				-	-			
Buffer (farside)	1 if present; 0 otherwise				-	-			
Barriers in buffer (farside)	1 if present; 0 otherwise				-	-			
Curbed roadside (farside)	1 if curbed; 0 otherwise				-	-			
Width of outside lane (farside)	Feet				-	-			
Width of shoulder / bike lane (farside)	Feet				-	-			
Control									
Traffic signal	1 if present; 0 otherwise	+	+						
Signal cycle length	Seconds	-	-						
Signal spacing	Feet to next signal	-	-						
Pedestrian signal	1 if present; 0 otherwise	+	+						
Green time	Seconds	-	-						
Green ratio	Unit-less	-	-						

Note: Please refer to hypothesis formulation in the section for Estimation. A = (left intersection); B = (cross first and walk later); C = (jaywalk); D = (walk first and cross later); E = (right intersection); and F = (mid-block crosswalk). I = Intersections; M = Mid-block. Left and right are determined in terms of the nearside. The nearside of a block is where the start point is.

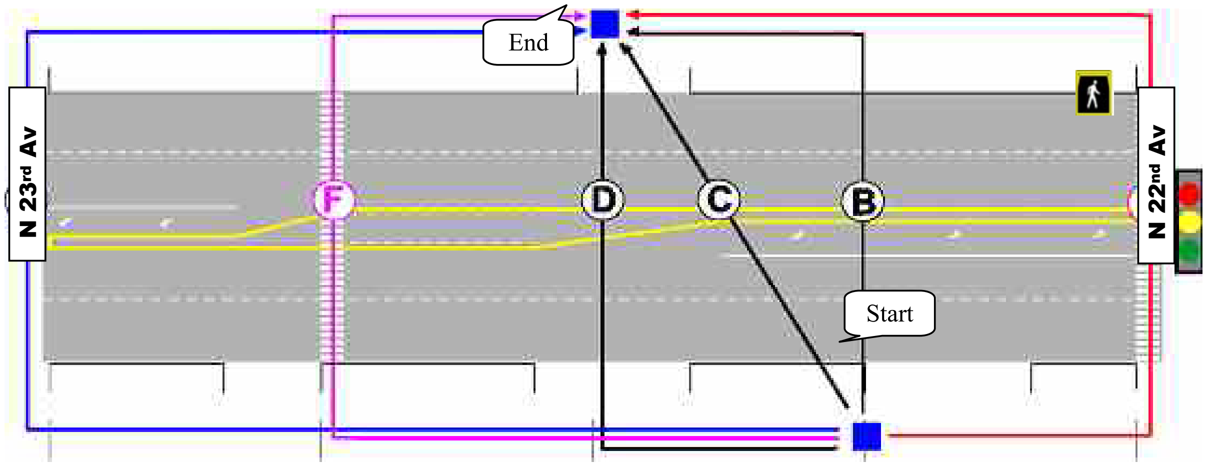
Table 2. Nested Logit Model of Pedestrian Street Crossing Behavior (t-statistics in parentheses) [1]

Variable	Definition	Coefficient							
		Individual Options						Branches	
		Intersections		Mid-block				Inter-sections	Mid-block
		A	E	B	C	D	F	I	M
Alternative-specific constant	1			2.2079 (7.34) [2]		1.7266 (5.55)	1.3875 (3.44)	2.2332 (4.20)	
Walking distance	Feet along roadsides	-0.0034 (-11.65)	-0.0034 (-11.65)	-0.0034 (-11.65)	-0.0034 (-11.65)	-0.0034 (-11.65)	-0.0034 (-11.65)		
Crossing distance	Feet on travel lanes	-0.0027 (-2.31)	-0.0027 (-2.31)	-0.0027 (-2.31)	-0.0027 (-2.31)	-0.0027 (-2.31)	-0.0027 (-2.31)		
Start and end at mid-block locations	1 if true; 0 otherwise								1.5722 (3.14)
Start at mid-block & end at intersection	1 if true; 0 otherwise								0.8415 (2.32)
Traffic volume	Vehicles per hour			-0.0003 (-1.77)	-0.0003 (-1.77)	-0.0003 (-1.77)	-0.0003 (-1.77)		
Crosswalk marking	1 if marked; 0 otherwise	1.0002 (4.30)	1.0002 (4.30)	0.7891 (4.02)	0.7891 (4.02)	0.7891 (4.02)	0.7891 (4.02)		
Width of nearside shoulder/bike lane	Feet if present; 0 otherwise			-0.0728 (-1.22)	-0.0728 (-1.22)				
Width of farside shoulder/bike lane	Feet if present; 0 otherwise				-0.0923 (-1.42)	-0.0923 (-1.42)			
Traffic signal	1 if present;0 otherwise	0.7502 (3.42)	0.7502 (3.42)						
Pedestrian signal	1 if present; 0 otherwise	1.2350 (4.34)	1.2350 (4.34)						
Inclusive value: Intersections	$J_I \equiv Ln(e^{U_A} + e^{U_E})$							0.7585 (7.05)	
Include value: Mid-block	$J_M \equiv Ln(e^{U_B} + e^{U_C} + e^{U_D} + e^{U_F})$								0.8342 (5.87)
Utility function	Σ (Variable * Coefficient)	U_A	U_E	U_B	U_C	U_D	U_F	U_I	U_M

Number of Observations	1,028
Number Cases	4,334
Log likelihood with constants only	-1769.605
Log likelihood at convergence	-963.728
Unadjusted ρ^2	0.455
Adjusted ρ^2	0.453

[1] NLOGIT 3.0 of Econometric Software, Inc. was used to estimate this model with full information maximum likelihood. The RU1 normalization was used for the scale parameters. The nested logit model has two levels with variable options across observations. The top level has two branches: intersections and mid-block locations. The bottom level has two options in the intersection branch (A and E) and up to four options in the mid-block branch (B, C, D, F). A = Crossing at the left intersection (left intersection); B = Crossing at a mid-block start point at a right angle (cross first and walk later); C = Crossing with a jaywalk between the start and end points (jaywalk); D = Walking to the opposite of a mid-block end point and crossing there at a right angle (walk first and cross later); E = Crossing at the right intersection (right intersection); and F = Crossing at a mid-block crosswalk (mid-block crosswalk). I = Intersections; M = Mid-block. Left and right are determined in terms of the nearside. The nearside of a block is where the start point is.

[2] It is appropriate to determine the significance of the coefficients with a one-sided test because the null hypothesis for each coefficient is either being positive or negative rather than zero. A coefficient would be significant at the 10 percent, 5 percent, and 1 percent level if its t-statistic is at least 1.282, 1.645, and 2.326, respectively. These reported t-statistics do not correct for potential overestimation due to the repeated observations from individual respondents.



Please stand at your start point and observe the block characteristics and traffic conditions for 3 minutes. Based on your observation of the block and evaluation of the options during these 3 minutes, please tell us your choice for crossing this street by selecting **one** from below:

A **F** **D** **C** **B** **E**