Crossing Locations, Light Conditions, and Pedestrian Injury Severity

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This paper assesses the role of crossing locations and light conditions in the severity of pedestrian injuries through a multivariate regression analysis to control for many other factors that also may influence pedestrian injury severity. Crossing locations include midblock and intersections, and light conditions include daylight, dark with street lighting, and dark without street lighting. The paper formulates a theoretical framework on the determinants of pedestrian injury severity and specifies an empirical model accordingly. The paper applies the ordered probit model to the KABCO severity scale of pedestrian injuries that occurred while attempting street crossing in the years 1986–2003 in Florida. In terms of crossing locations, the probability of a pedestrian dying when struck by a vehicle is higher at midblock locations than at intersections for any light condition. The odds of sustaining a fatal injury are 49% lower at intersections than at midblock locations under daylight conditions, 24% lower under dark-with-street-lighting conditions, and 5% lower under dark-without-street-lighting conditions. Relative to dark conditions without street lighting, daylight reduces the odds of a fatal injury by 75% at midblock locations and by 83% at intersections, whereas street lighting reduces the odds by 42% at midblock locations and by 54% at intersections.

In 2003, 4,749 pedestrians were killed and about 70,000 were injured by motor vehicles in the United States (*1*). The average pedestrian fatality rate in the United States in 2003 was 1.63 deaths per 100,000 population (*1*). The situation is even more severe in Florida, which had the second highest rate in the country at 2.94 fatalities per 100,000 population.

One serious problem with pedestrian safety in Florida relates to crossing locations. According to data from 1986 through 2003, the ratio of pedestrian fatalities to the total number of pedestrians involved in crashes while attempting street crossing is higher at midblock locations than at intersections under any light condition (Figure 1). No existing research was found that compares pedestrian injury severity risks associated with midblock and intersection locations. In a recent study, Lee and Abdel-Aty (*2*) analyzed pedestrian crashes at intersections in Florida for 1999–2002, but they did not perform any comparative study between locations.

Another serious problem with pedestrian safety in Florida relates to light conditions. On the basis of data for 1986–2003, about 37% of all pedestrian crashes occurred while the pedestrians were attempting to cross streets under dark conditions versus daylight conditions. Although dark conditions do not represent a large share of pedestrian crashes, the differential risk across light conditions is significantly higher than that across crossing locations. Stated as the probability of a pedestrian getting killed once struck by a vehicle, the fatal injury risk on average is several times higher under dark conditions than under daylight conditions (Figure 1). Earlier studies mentioned that fatal pedestrian crashes are more likely to occur during nighttime hours and nonfatal pedestrian crashes are more likely to occur during daytime hours (*3*). Previous studies found that the probability of a pedestrian getting killed increases at least three times when the person is involved in a nighttime crash compared with a daytime crash (*4, 5*). A large body of research ascertains the reasons behind the high nighttime fatality risk (*6*), but previous work has not looked at light conditions and crossing locations jointly.

This paper assesses the role of crossing locations and light conditions in pedestrian injury severity through a multivariate regression analysis to control for many other factors that also may influence pedestrian injury severity. One may not attribute the differential risks in Figure 1 simply to the differences in locations or light conditions. Many other factors that differ across locations or light conditions are likely to have played a role in the observed differential average risks.

THEORETICAL FRAMEWORK

Direct Determinants

Three sets of factors directly determine the injury severity of a pedestrian once struck by a motor vehicle:

- Impact speed. The most important factor is the impact speed, which is the speed of the vehicle upon striking the pedestrian (*2, 5, 7–9*). The chance of survival by the pedestrian drops quickly between an impact speed of 20 mph and an impact speed of 40 mph (*10*).
- Impact configuration. Besides impact speed, one set of determinants relates to impact configuration between the pedestrian and the vehicle (*11*). This impact configuration includes several aspects, such as the angle at which the vehicle strikes the pedestrian (e.g., frontal versus side), the angle at which the pedestrian is struck (i.e., front, back, side), and the height of the impact on the pedestrian.
- Pedestrian attributes. The final set of determinants relates to the characteristics of the pedestrian. Two pedestrian age groups, the very young (*7, 12–14*) and the very old (*2, 7, 12–15*), are most vulnerable to suffering from severe injuries. Also, male pedestrians, being physically stronger and bigger on average than their female counterparts, may be less likely to sustain severe injuries.

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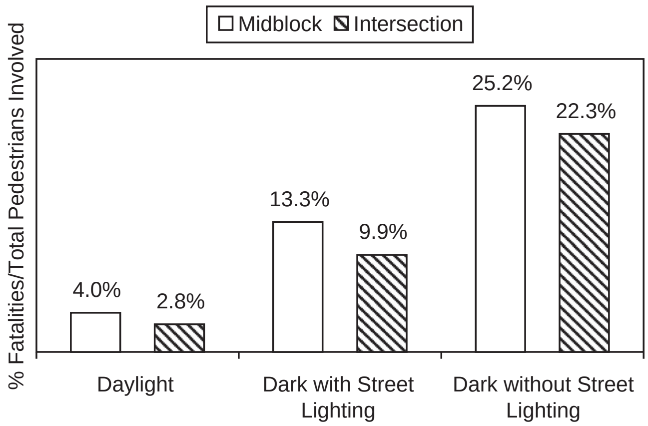

FIGURE 1 Pedestrian fatality risk by crossing location and light condition.

These three sets of direct determinants are presented in boldface in Figure 2. Although, the mass of an involved vehicle is an important determinant of injury severities to its own occupants and occupants of the other vehicles involved, it is unlikely to be a significant factor in determining the injury severity of a pedestrian.

Indirect Determinants

Policy analysis of pedestrian safety, however, often requires an understanding of indirect determinants of pedestrian injury severity that go beyond the direct determinants. This paper, for example, focuses on the role of crossing locations and light conditions on pedestrian injury severity. But crossing locations and light conditions do not directly affect pedestrian injury severity. These indirect determinants play a role in pedestrian injury severity through their effects on the direct determinants (Figure 2):

- Vehicle attributes may affect both impact configuration and impact speed. High-profile vehicles, such as sport utility vehicles, are more likely to increase the height of the impact on a pedestrian. Holding other factors constant, on the other hand, heavy vehicles are harder to stop, resulting in a higher impact speed.
- In addition to vehicle attributes, several sets of other factors affect the impact speed of a vehicle. These factors include the moving speed of the vehicle, driver attributes, road attributes, and pedestrian visibility to the driver.
- Both driver attributes and road attributes affect the moving speed and pedestrian visibility to the driver.
- Pedestrian attributes, such as wearing reflective clothing at night, affect pedestrian visibility to the driver.
- The environment in terms of weather and light conditions can affect both the moving speed of the vehicle and pedestrian visibility to the driver.

In this theoretical framework, crossing locations are part of road attributes, and light conditions are part of the environment. Crossing locations affect pedestrian injury severity most likely through their indirect effects on moving speeds, which in turn affect impact speed. Light conditions, on the other hand, affect pedestrian injury severity largely through their indirect effects on pedestrian visibility to drivers. The following discusses the link between light conditions and impact speed in more detail.

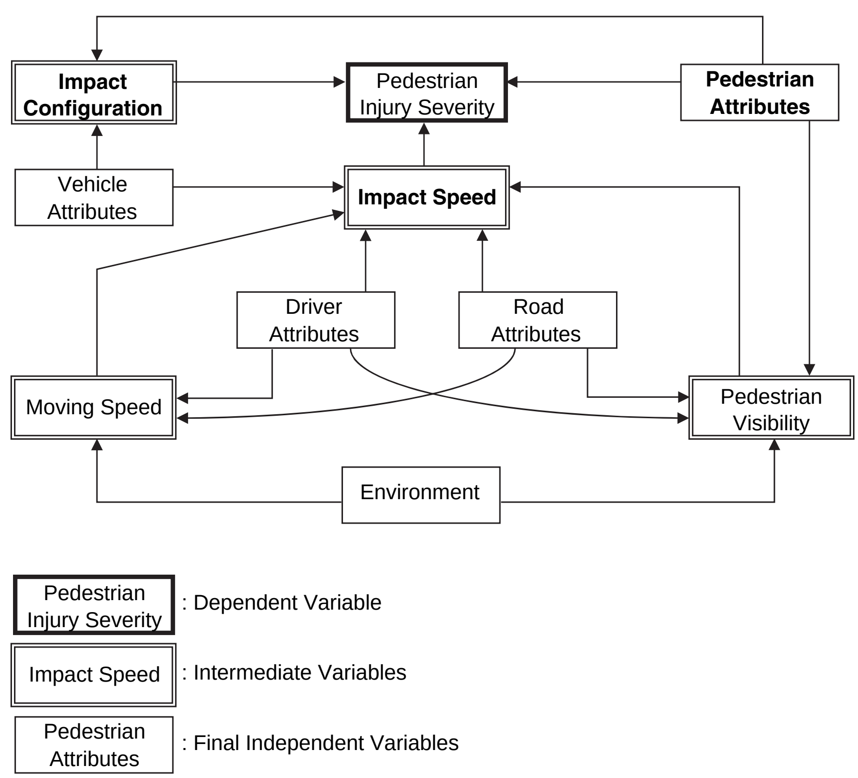

FIGURE 2 Framework of determinants of pedestrian injury severity.

The constraints faced by drivers in recognizing pedestrians at night can be understood by the two types of visual systems used by the eyes. One is the focal vision controlled by the central retina, which helps in recognizing objects, and another is the ambient vision controlled by the peripheral retina, which helps in guiding movements. Although focal vision degrades rapidly at night, the ambient system is relatively independent of any errors (*16–19*). Proper functioning of the guidance mode combined with the rare appearance of pedestrians at night makes it hard for drivers to realize the degradation in their recognition mode. Also, the visible distance ahead is always constant regardless of the driving conditions because of the use of fixed headlights. This distance is further reduced with the use of low beams. Consequently, at night, often the distance available to drivers to avoid crashing with a pedestrian is shorter than the total stopping sight distance required (*20, 21*).

Visual degradation at night affects pedestrians as well. The pedestrian's ability to find a proper gap for crossing roads at night is affected by the indistinctness of the vehicle's position and the pedestrian's inability to judge the vehicle's approaching speed. Also, pedestrians do not realize the visual challenge experienced by drivers, resulting in them overestimating drivers' observation abilities (*16, 21, 22*). Allen (*6*) found that the distances at which pedestrians thought they were visible to drivers were far greater than the distance at which they were actually visible to drivers (*6*).

METHODOLOGY

Data

This paper uses an electronic database of all 160,119 pedestrian crashes in the state of Florida reported on its long-form police accident reports (PARs) in the period 1986–2003. It does not include pedestrian crashes reported on Florida's short-form PARs. The only relevant change over this period is in what is considered a fatal injury. Before 1999, a fatality was a person who died within 90 days of a crash. Since then, a 30-day criterion has been used.

The database uses the KABCO scale for injury severity: no injury, possible injury, nonincapacitating injury, incapacitating injury, and fatal injury. In addition to information on injury severity, the database includes a large number of characteristics about the crash, the vehicle, the driver, and the pedestrian. In particular, light conditions are described in five categories: daylight, dusk, dawn, dark with street lighting, and dark without street lighting. Furthermore, a variable describing pedestrian action at the time of a crash provides information on whether the pedestrian was crossing the road and the location of crossing the road in terms of midblock locations versus intersections.

A total of 101,917 pedestrian crashes were excluded because they did not serve the purpose of the paper. Among the excluded crashes, 77,297 were non-street-crossing crashes, 2,817 were crashes in dusk or dawn conditions, and 986 were on freeways; the rest were excluded because of data problems. These exclusions result in a total of 58,202 pedestrian crashes for analysis.

Econometric Model

This paper used the ordered probit model. The dependent variable, injury severity, is an ordinal scale, where the relative difference between different injury severities is not well defined. For example, the difference between a possible injury and a nonincapacitating injury is not the same as the difference between an incapacitating injury and a fatal injury. Previous researchers have used the ordered probit model to analyze crash severity and injury severity of vehicle occupants (*23–28*). More recently, researchers have also used the ordered probit model to analyze pedestrian injury severity (*2, 15*).

The ordered probit model is built around a latent regression as follows (*29*):

$$y_i^* = x_i\beta + \epsilon_i$$

where

y_i^* = unobserved injury severity for observation *i,*
x_i = row vector of independent variables with 1 in the first column to denote the constant for observation *i,*
β = column vector of coefficients with the first row being the constant intercept, and
ϵ_i = error term that is normally distributed across observations with mean 0 and variance 1.

What the researcher observes is the pedestrian injury severity scale *y* as follows:

$$y = \begin{cases} 0 \text{ if } y^* \le 0 & (\text{no injury}) \\ 1 \text{ if } 0 < y^* \le \mu_1 & (\text{possible injury}) \\ 2 \text{ if } \mu_1 < y^* \le \mu_2 & (\text{nonincapacitating injury}) \\ 3 \text{ if } \mu_2 < y^* \le \mu_3 & (\text{incapacitating injury}) \\ 4 \text{ if } \mu_3 < y^* & (\text{fatal injury}) \end{cases}$$

where μ_i values are unknown thresholds to be estimated with β. Let $\Phi(\cdot)$ be the cumulative standard normal distribution and let X be the matrix of independent variables with 1 in the first column, and the probability (Pr) of a pedestrian suffering each of the injury severities is as follows:

$$\Pr(y=0) = \Phi(-X\beta)$$

$$\Pr(y=1) = \Phi(\mu_1 - X\beta) - \Phi(-X\beta)$$

$$\Pr(y=2) = \Phi(\mu_2 - X\beta) - \Phi(\mu_1 - X\beta)$$

$$\Pr(y=3) = \Phi(\mu_3 - X\beta) - \Phi(\mu_2 - X\beta)$$

$$\Pr(y=4) = 1 - \Phi(\mu_3 - X\beta)$$

Unlike the commonly used linear regression model, the ordered probit model is nonlinear, and its coefficients do not reflect the marginal effect on the dependent variable from one unit change in any one independent variable. To help interpret the results of the ordered probit model, one common practice is to estimate the marginal effects of the independent variables and to interpret the ordered probit model through these marginal effects. For a dummy variable, the marginal effect of an independent variable shows the difference in the probability with that variable taking a value of 1 versus 0. For a continuous independent variable X_k and fatal injuries, for example, the marginal effect at the mean of the sample $\overline{X}$ is computed as follows:

$$\frac{\partial \Pr\left(y=4 \,\middle|\, \overline{X}\right)}{\partial X_k} = \beta_k\left[\phi\left(\mu_3 - \overline{X}\beta\right)\right]$$

where $\phi(\cdot)$ is the standard normal density function.

Model Specification

This section describes what variables are included in the row vector of independent variables in the previously stated model and how they are included. The objective is to have a specification that would allow one to estimate the differential effects between crossing locations and between light conditions on the probability of pedestrians suffering specific injury severity levels once involved in a motor vehicle crash. The theoretical framework described earlier is used to guide the selection of control variables as well as the approach in which crossing locations and light conditions enter the model.

Guidance

The theoretical framework has important implications for model specification. If the objective were to determine the role of impact configuration, or any of the pedestrian characteristics, or impact speed on pedestrian injury severity, one would need to consider only the direct determinants in a model of pedestrian injury severity. However, both crossing locations and light conditions are indirect determinants. A focus on these two indirect determinants requires that the model of pedestrian injury severity exclude impact speed and other intermediate variables (vehicle configuration, moving speed, and pedestrian visibility) and include only final independent variables. In addition to pedestrian attributes, these final independent variables include driver attributes, vehicle attributes, road attributes (including crossing locations), and the environment (including light conditions). Whereas impact speed needs to be excluded, posted speed limit as a part of road attributes needs to be included because it is an important determinant of moving speeds. In mathematical terms, the framework in Figure 2 represents a structural model of pedestrian injury severity, and the focus on the effects of crossing locations and light conditions requires estimation of the reduced form of the structural model.

Location and Light Conditions

To measure the effects of crossing locations and light conditions on the probability of any injury severity, this paper includes the following five interactive variables between the two locations (midblock and intersection) and the three light conditions (daylight, dark with street lighting, and dark without street lighting):

1. Intersection–dark with street lighting,
2. Intersection–dark without street lighting,
3. Midblock–daylight,
4. Midblock–dark with street lighting, and
5. Midblock–dark without street lighting.

This specification takes the interaction between intersections and daylight conditions as the base of comparison for all included interactions. Some descriptive statistics of these five interactive variables are presented at the bottom of Table 1.

Once the overall model is estimated and the marginal effects of individual variables are determined, one can determine the effects of crossing locations and light conditions on the probability of an injury severity. Assuming that α_i represents the marginal effect of a fatal injury with respect to the *i*th interactive variable mentioned earlier, one can determine the effects of crossing locations and light conditions on the probability of a fatal injury. Holding other factors constant, for example, the probability of a fatal injury is expected to be lower at intersections by $-\alpha_3$ for daylight conditions, by $\alpha_1 - \alpha_4$ for dark-with-street-lighting conditions, and by $\alpha_2 - \alpha_5$ for dark-without-street-lighting conditions. Similarly, changes in the probability of a fatal injury at midblock locations or intersections can also be determined between different light conditions. At midblock locations, daylight reduces the probability of a fatal injury by $\alpha_3 - \alpha_5$, and street lighting reduces the probability of a fatal injury by $\alpha_4 - \alpha_5$. At intersections, daylight reduces the probability by $-\alpha_2$, and street lighting reduces the probability by $\alpha_1 - \alpha_2$.

Once determined, these differences in the probability of a fatal injury can then be used along with the data from Figure 1 to show the percentage differences in the odds of a fatal pedestrian injury between midblock and intersection locations as well as between light conditions. The odds of something happening is the ratio of the probability of that happening to the probability of that not happening. Figure 1, for example, indicates that the average probability of a fatal injury under daylight conditions is 4.0% at midblock locations and 2.8% at intersections. That is, the odds of a fatal injury under daylight conditions is 4.0/(100 − 4.0) = 0.042 at midblock locations and 2.8/(100 − 2.8) = 0.029 at intersections. Therefore, the odds of a fatal injury is 100(0.029 − 0.042)/0.042 = 31% lower at intersections than at midblock locations. For intersections, the probability of a fatal injury for each light condition is assumed to be as indicated in Figure 1. For midblock locations, the probability for each light condition is that for intersections plus the preceding differences. Percent differences in odds are just another useful way to look at the effects of crossing locations and light conditions on pedestrian injury severity.

Control Variables

Besides crossing locations and light conditions, all other final independent variables in the framework presented in Figure 2 are considered control variables. They include all vehicle attributes, all driver attributes, and all pedestrian attributes. With the exception of crossing locations and light conditions, they also include all other road attributes and all weather attributes. The top portion of Table 1 presents some descriptive statistics of all control variables that are available from the original database and are included in the model.

Pedestrian and Driver Attributes

Two pedestrian age groups, very young (*7, 12–14*) and very old (*2, 7, 12–15*), are considered because they are the most vulnerable to high-severity crashes. Young and male drivers, being typically more aggressive, are likely to be involved in more severe pedestrian

TABLE 1 Ordered Probit Model Estimate of Pedestrian Injury Severity Along with Descriptive Statistics and Expected Direction of Effect of Variables

Variable	Description	Mean	S.D.	Exp. Sign	Coeff.	*t*-Stat.
ONE	Constant				1.0032	27.64
AGEGP1_P	1 if pedestrian is under 10; 0 otherwise	0.2007	0.4005	+	0.0686	4.07
AGEGP2_P	1 if 11 years ≤ pedestrian age ≤ 24 years; 0 otherwise	0.2397	0.4269	±	–0.0705	–4.94
AGEGP5_P	1 if pedestrian is over 64; 0 otherwise	0.1477	0.3548	+	0.3793	22.34
MALE_P	1 if pedestrian is male; 0 otherwise	0.6058	0.4887	–	0.0146	1.31
BLACK_P	1 if pedestrian is black; 0 otherwise	0.2949	0.4560	±	–0.1281	–9.54
HISPNC_P	1 if pedestrian is Hispanic; 0 otherwise	0.0881	0.2834	±	–0.0152	–0.72
DISABIL_P	1 if pedestrian has any physical disability; 0 otherwise	0.0422	0.2011	+	0.0631	2.36
UI_P	1 if pedestrian was under influence; 0 otherwise	0.1629	0.3692	+	0.1546	9.07
AGEGP1_D	1 if driver is under 25; 0 otherwise	0.2502	0.4331	+	0.0890	7.09
AGEGP4_D	1 if driver is over 64; 0 otherwise	0.1118	0.3151	+	0.0212	1.21
MALE_D	1 if driver is male; 0 otherwise	0.6227	0.4847	+	0.0211	1.88
BLACK_D	1 if driver is black; 0 otherwise	0.2411	0.4278	±	–0.0008	–0.06
HISPNC_D	1 if driver is Hispanic; 0 otherwise	0.0757	0.2645	±	0.0526	2.35
DISABIL_D	1 if driver had any physical disability; 0 otherwise	0.0149	0.1210	+	0.1339	3.04
UI_D	1 if driver was under influence; 0 otherwise	0.0319	0.1758	+	0.2778	8.91
LANES	Number of lanes	3.4778	1.5657	+	0.0238	5.25
UNDIV	1 if undivided road; 0 otherwise	0.6173	0.4861	+	–0.0056	–0.43
US	1 if U.S.-owned; 0 otherwise	0.0659	0.2482	+	0.2520	10.17
STATE	1 if state-owned; 0 otherwise	0.3223	0.4674	+	0.0695	4.73
COUNTY	1 if county-owned; 0 otherwise	0.1908	0.3929	+	0.0902	5.38
RURAL	1 if road in area with population ≤ 2,500; 0 otherwise	0.3443	0.4752	+	0.0421	3.13
POST_SP	Posted speed limit in mph	35.2435	8.1990	+	0.0204	24.77
RAINY	1 if raining; 0 otherwise	0.0577	0.2332	±	–0.0134	–0.59
FOGGY	1 if foggy; 0 otherwise	0.0024	0.0491	±	0.2101	1.93
BIG_VEH	1 if vehicle is truck, bus, or all-terrain; 0 otherwise	0.1450	0.3521	+	0.0984	6.35
YR92TO98	1 if crash occurred between 1992 through 1998; 0 otherwise	0.4028	0.4905	±	–0.0608	–4.88
YR99TO03	1 if crash occurred between 1999 through 2003; 0 otherwise	0.2594	0.4383	±	–0.1111	–7.85
MBDAY	1 if midblock and daylight; 0 otherwise	0.4452	0.4970	+	0.2036	14.05
MBDRKSL	1 if midblock and dark with street lights; 0 otherwise	0.1736	0.3788	+	0.4623	24.93
MBDRKNSL	1 if midblock and dark without street lights; 0 otherwise	0.0913	0.2881	+	0.6850	28.88
ISDRKSL	1 if intersection and dark with street lights; 0 otherwise	0.0656	0.2475	+	0.2929	12.08
ISDRKNSL	1 if intersection and dark without street lights; 0 otherwise	0.0166	0.1277	+	0.6183	14.05
Observations				40,512		
Restricted log likelihood				–54,292		
Unrestricted log likelihood				–51,451		

crashes. Male pedestrians, being physically stronger than their female counterparts, are less likely to sustain severe injuries. Pedestrians having any physical disability are more likely to be injured when struck by a vehicle. Drivers having any physical disability may take longer to react, resulting in a higher impact speed. Ethnicities of the pedestrian and the driver have also been included in the model as control variables to avoid any bias arising from their omission. One cannot help but notice the unusually high involvement of blacks both as pedestrians and as drivers relative to the share of blacks in the general population. In fact, blacks represent more than 29% of the involved pedestrians and more than 24% of the involved drivers.

Consumption of alcohol by drivers and pedestrians is considered an important contributor to higher-severity pedestrian crashes. Previous studies have found that alcohol consumption by pedestrians considerably increases the probability of getting injured severely or of being killed once involved in a crash (*2, 4, 12, 14, 15, 30, 31*). It is said that "pedestrians who drink have the judgment skills of a child and the mobility skills of a senior" (*32*) and are not only more likely to get involved in a crash but also to sustain more severe injuries once involved. By the same reasoning, a drunk driver's ability to react to an obstacle (pedestrian) in the available time is affected adversely and contributes to higher-severity crashes (*15*).

Road Attributes

Vehicular speeds are usually higher on wider roads. Rural roads are associated with higher vehicle speeds and emergency medical services are less accessible, as they are in rural areas. Earlier studies also found that rural roads are typically associated with more severe pedestrian crashes (*2, 4*). Functional classification of roads is unavailable in the data; instead, the roadway system has been classified on the basis of ownership and has been used as a substitute. As pointed out already, posted speed limit is an important determinant of average vehicle moving speeds.

Environment

Rainy and foggy conditions are included for weather conditions. Adverse weather conditions may force drivers to slow down, which is a positive effect on moving speeds. Adverse weather conditions may also make it harder for them to stop, which is a negative effect on impact speed, and harder for them to see pedestrians, which is a negative effect on their visibility.

Vehicle Attributes

The type of vehicle involved in a crash is also an important determinant of how severely a pedestrian is injured in a crash. Examples are the stiffness and shape of the vehicle front, such as the bumper height, hood height and length, and windshield frame (*11*). Trucks of all sizes, all-terrain vehicles, and buses have been grouped into a category of "big" vehicles and the rest are grouped into the category "smaller vehicles." These big vehicles also require a longer distance to stop, resulting in a higher impact speed.

Temporal Attributes

Two dummy variables are included to capture temporal effects on pedestrian injury severity. One covers the period from 1992 to 1998, and the other from 1999 to 2003, with the period from 1986 to 1991 as the basis of comparison. These variables are included to capture changes in the transportation system that help reduce pedestrian injury severity but are not controlled for through other control variables. They also are designed to capture any effect of the definitional change of a fatality, made in 1999.

RESULTS

The results are presented in three forms: the estimated model, the derived marginal effects of individual variables for fatal injuries, and the location and light-condition effects on pedestrian injury severity in terms of probabilities and odds of fatal injuries.

Estimated Model

The maximum likelihood estimation of the ordered probit model is presented in Table 1. For each variable, the table shows the estimated coefficient and its *t*-statistic along with its mean and standard deviation in the sample and also the expected sign. In general, a positive sign of the coefficient indicates that an increase in the variable would lead to an increase in pedestrian injury severity. A plus-or-minus sign indicates that, although these variables are expected to affect injury severity, there is no proposition of the direction of its effect. The model is well behaved in general. All variables that have specific expected directions of effects are statistically significant and have the expected signs. More important, all five interactive variables on crossing locations and light conditions are statistically significant and have the expected direction of effects. Holding other factors constant, pedestrian injuries under all other combinations of location and light conditions are more severe relative to injuries at intersection locations under daylight conditions.

Marginal Effects of Control Variables

The marginal effects of the control variables on the probability of fatal injuries along with their *t*-statistics are presented in the top portion of Table 2. The marginal effects of crossing locations and light conditions are discussed in the next subsection. To save space, only the marginal effects for fatal injuries are shown.

Among the control variables, the largest risk factors for fatal injuries facing pedestrians, in decreasing order, are being at least 65 years old, being hit by a driver who is driving under the influence of alcohol or drugs, being involved in a crash on the U.S. road system, walking in foggy conditions, walking under the influence of alcohol or drugs, being struck by a driver with a physical disability, and being struck by a large vehicle. Holding other factors constant, the probability of getting killed once involved in a crash is 5.8 percentage points higher for elderly pedestrians than for pedestrians aged between 25 and 64 years. Although not shown, this is equivalent to an increase of 68% in the odds of being killed when struck by a vehicle. A driver being under the influence is a greater fatality risk for pedestrians than a pedestrian being under the influence. The probability of a pedestrian getting killed once involved in a crash is 4.5 percentage points higher when being hit by a driver under the influence than when hit by a sober driver. This is equivalent to an increase of 60% in the odds of being killed when struck by a vehicle. On the other hand, the probability is 2.1 percentage points higher between a pedestrian who is under the influence and a pedestrian who is sober. This is equivalent to an increase of 40% in the odds of being killed. Also, walking in foggy conditions increases the odds of being killed when struck by a vehicle by 42% compared with walking in nonfoggy conditions. On the other hand, crossing in the rain and crossing undivided roads do not appear to be risk factors for pedestrians to be fatally injured once involved in a crash.

Location and Light Conditions

The marginal effects of the five interactive variables between crossing locations and light conditions on the probability of pedestrian fatal injuries are presented at the bottom of Table 2. To facilitate the discussion, these marginal effects have been translated into the location effects and the light-condition effects in Tables 3 and 4. The determination of the information in Tables 3 and 4 was explained in the subsection on model specification.

The probability of a pedestrian dying from being hit by a vehicle is lower at intersections than at midblock locations for any light condition (Table 3). The differences are 2.6 percentage points under daylight conditions, 2.8 percentage points under dark-with-street-lighting conditions, and 1.0 percentage points under dark-without-street-lighting conditions. Whereas the difference in probability is the largest under dark-with-street-lighting conditions, the odds of sustaining a fatal injury is reduced by 49% under daylight conditions versus 24% under dark-with-street-lighting conditions and 5% under dark-without-street-lighting conditions.

TABLE 2 Marginal Effects on Probability of a Fatal Injury

Variable	Description	Marginal Effect	*t*-Statistic
AGEGP1_P	1 if pedestrian is under 10; 0 otherwise	0.0088	8.03
AGEGP2_P	1 if 11 years ≤ pedestrian age ≤ 24 years; 0 otherwise	–0.0085	–6.18
AGEGP5_P	1 if pedestrian is over 64; 0 otherwise	0.0575	68.69
MALE_P	1 if pedestrian is male; 0 otherwise	0.0018	1.51
BLACK_P	1 if pedestrian is black; 0 otherwise	–0.0153	–10.06
HISPNC_P	1 if pedestrian is Hispanic; 0 otherwise	–0.0019	–1.49
DISABIL_P	1 if pedestrian has any physical disability; 0 otherwise	0.0082	7.29
UI_P	1 if pedestrian was under influence; 0 otherwise	0.0208	21.70
AGEGP1_D	1 if driver is under 25; 0 otherwise	0.0114	10.89
AGEGP4_D	1 if driver is over 64; 0 otherwise	0.0027	2.24
MALE_D	1 if driver is male; 0 otherwise	0.0026	2.23
BLACK_D	1 if driver is black; 0 otherwise	–0.0001	–0.08
HISPNC_D	1 if driver is Hispanic; 0 otherwise	0.0068	5.95
DISABIL_D	1 if driver had any physical disability; 0 otherwise	0.0183	17.94
UI_D	1 if driver was under influence; 0 otherwise	0.0418	47.47
LANES	Number of lanes	0.0029	5.15
UNDIV	1 if undivided road; 0 otherwise	–0.0007	–0.56
US	1 if U.S.-owned; 0 otherwise	0.0368	41.78
STATE	1 if state-owned; 0 otherwise	0.0088	8.16
COUNTY	1 if county-owned; 0 otherwise	0.0117	11.07
RURAL	1 if road in area with population ≤ 2,500; 0 otherwise	0.0053	4.65
POST_SP	Posted speed limit in mph	0.0025	19.58
RAINY	1 if raining; 0 otherwise	–0.0017	–1.32
FOGGY	1 if foggy; 0 otherwise	0.0305	32.51
BIG_VEH	1 if vehicle is truck, bus, or all terrain; 0 otherwise	0.0129	12.28
YR92TO98	1 if crash occurred between 1992 through 1998; 0 otherwise	–0.0075	–5.43
YR99TO03	1 if crash occurred between 1999 through 2003; 0 otherwise	–0.0132	–9.00
MBDAY	1 if midblock and daylight; 0 otherwise	0.0258	31.88
MBDRKSL	1 if midblock and dark with street lights; 0 otherwise	0.0720	79.30
MBDRKNSL	1 if midblock and dark without street lights; 0 otherwise	0.1267	91.76
ISDRKSL	1 if intersection and dark with street lights; 0 otherwise	0.0439	50.97
ISDRKNSL	1 if intersection and dark without street lights; 0 otherwise	0.1168	93.48

TABLE 3 Effects of Light Conditions

Effects of	Light Condition	Probability (percentage points)	Odds
Intersection locations	Daylight	–2.6%	–49%
	Dark with lighting	–2.8%	–24%
	Dark without lighting	–1.0%	–5%

NOTE: The effect of daylight is calculated as the difference in marginal effects between daylight and dark without street lighting. The effect of street lighting is calculated as the difference in marginal effects between dark with street lighting and dark without street lighting.

TABLE 4 Effects of Location

Effects of	Location	Probability (percentage points)	Odds
Daylight	Midblock	–10.1%	–75%
	Intersection	–11.7%	–83%
Street lighting	Midblock	–5.5%	–42%
	Intersection	–7.3%	–54%

In terms of the probability of a fatal injury, light conditions have a larger effect than location (Table 4). Daylight reduces the probability of a fatal injury by 10.1 percentage points at midblock locations and by 11.7 percentage points at intersections, whereas street lighting reduces the probability of a fatal injury by 5.5 percentage points at midblock locations and by 7.3 percentage points at intersections. In terms of the odds of a fatal injury, however, the difference is less clear cut. Daylight has a larger effect on the odds of a fatal injury than the effect of location under any lighting condition. The effect of street lighting is larger than the effect of location under dark conditions but is comparable to the effect of location under daylight conditions.

The effect of street lighting is smaller than the effect of daylight (Table 4). Street lighting reduces the probability of a fatal injury by 5.5 percentage points at midblock locations and by 7.3 percentage points at intersections. In comparison, the reductions from daylight are 10.1 percentage points at midblock locations and 11.7 percentage points at intersections. Similarly, street lighting results in a reduction in the odds of a fatal injury around 50% versus a reduction of around 80% in daylight.

The effect of light conditions is greater at intersections than at midblock locations (Table 4). Daylight reduces the probability of a fatal injury by 11.7 percentage points at intersections versus 10.1 percentage points at midblock locations. In terms of the odds of a fatal injury, the reductions are 83% at intersections and 75% at midblock locations. Similarly, street lighting reduces the probability of a fatal injury by 7.3 percentage points at intersections and by 5.5 percentage points at midblock locations. The effect of street lighting in terms of the odds of a fatal injury is a reduction of 54% at intersections and 42% at midblock locations.

CONCLUSIONS

Applying the ordered probit model to crash data for 1986–2003 in Florida, this paper assesses the role of crossing locations and light conditions in the injury severity of pedestrians after being struck by motor vehicles while crossing roads. The empirical model is well behaved. It includes pedestrian attributes, driver attributes, road attributes, vehicle attributes, and weather conditions as control variables. All control variables having specific expectations are statistically significant and have the expected signs. All five interactive variables on crossing locations and light conditions are found to be statistically significant and also have the expected direction of effects.

The empirical model provides insights about the role of various control variables on pedestrian injury severity. The largest risk factors for fatal injuries facing pedestrians when struck by a vehicle, in decreasing order, are being at least 65 years old, being hit by a driver who is driving under the influence, being involved in a crash on the U.S. road system, walking in foggy conditions, walking under the influence, being hit by a driver with a physical disability, and being hit by a large vehicle. For example, holding other factors constant, the odds of getting killed when struck by a vehicle is 68% higher for elderly pedestrians than for 25- to 64-year-old pedestrians. A driver under the influence is a greater fatality risk for pedestrians than if the pedestrian is under the influence. The odds of a pedestrian getting killed is 60% higher when struck by a driver under the influence than when struck by a sober driver. On the other hand, the odds of being killed are 40% higher for a pedestrian who is under the influence than for a sober pedestrian. Also, walking in foggy conditions increases the odds of being killed when struck by a vehicle by 42% compared with nonfoggy conditions. However, crossing in the rain and crossing undivided roads do not appear to be risk factors for pedestrians to be fatally injured once involved in a crash.

The results provide new insights into the role of crossing locations and light conditions on pedestrian injury severity. In terms of crossing locations, the probability of a pedestrian dying when struck by a vehicle is higher at midblock locations than at intersections for any light condition. In fact, the odds of sustaining a fatal injury at intersections is 49% lower than at midblock locations under daylight conditions, 24% lower under dark-with-street-lighting conditions, and 5% lower under dark-without-street-lighting conditions. Relative to dark conditions without street lighting, daylight reduces the odds of a fatal injury by 75% at midblock locations and by 83% at intersections, whereas street lighting reduces the odds by 42% at midblock locations and by 54% at intersections.

Like most previous work, this paper relies on electronic data from accident reports completed by investigating officers at the time of a crash. It is well established that traffic accident reports have inconsistencies and inaccuracies due to judgmental and reporting discrepancies, including the injury severity of the pedestrians involved (*33*). Lighting conditions from street lights under dark conditions do not reflect the quantity and quality of light. Additional errors may be introduced when information from accident reports is entered into electronic databases. Furthermore, some pedestrian crashes are either unreported or reported but not made electronically available.

Like most previous work, this paper focuses on the resulting injury severity of pedestrians after a crash has already occurred. To assess the overall roles of crossing locations and light conditions in pedestrian safety for street crossing, the relative probability of a pedestrian getting involved in crashes at different crossing locations under different light conditions also needs to be considered. Such a broader consideration would require data on pedestrian exposure to vehicle traffic while crossing streets. One good measure would be pedestrian crossing volumes at the locations where pedestrian crashes occurred and at the times when these pedestrian crashes occurred. However, such exposure data are unavailable, and the probability of a pedestrian getting involved in a crash has not been incorporated in this study.

This paper has several advantages over previous work. One theoretical advantage of the paper is its use of a reduced-form model of pedestrian injury severity to guide model specification, resulting in unbiased estimates of the effects of crossing locations and light conditions on pedestrian injury severity. One empirical advantage is the use of data for 17 years, resulting in reliable estimates of the effects of crossing locations and light conditions on pedestrian injury severity. This is important because of the relatively small number of pedestrian crashes reported each year, the potential errors in traffic accident reports, and the need to estimate the effects of crossing locations and light conditions interactively.

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