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Yue Ke

Konstantina Gkritza

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Safety ramifications of a change in pedestrian crosswalk law: A case study of Oregon, USA

Yue Ke [*], Konstantina Gkritza

Lyles School of Civil Engineering, Purdue University, 550 Stadium Dr., West Lafayette, IN 47906, United states

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ABSTRACT

Pedestrians are some of the most vulnerable road users as they are not protected by safety devices, and must also share the road with vehicles traveling at dangerous speeds, particularly during road crossings. In 2011, the state of Oregon changed their traffic laws to be more accommodating to pedestrians by giving right of way to pedestrians using a crosswalk, regardless if whether the crosswalk is marked or unmarked. This paper estimates a panel logit model to evaluate the efficacy of the law in preventing pedestrian fatalities. Pedestrian fatalities are shown to decrease over time, with smaller likelihood of a fatality outcome in the years following the change in pedestrian crossing laws. To the authors' knowledge, it is the first time panel logit models have been used in evaluating pedestrian safety. Results indicate that panel logit models are an alternative to using Box-Tiao intervention models to analyze the long term effects of policy changes, as they allow for the consideration of crash exposure factors as well as temporal effects.

1. Introduction

As federal and state departments of transportation across the country increasingly embrace vision-zero policies (e.g., zero transportation-related fatalities), a large body of research has evolved examining traffic crashes, particularly for passenger vehicles, motorcycles, and commercial vehicles, since these crashes account for the majority of roadway fatalities. However, the National Highway Safety Administration (NHTSA) estimates that 4884 pedestrians were killed in motor vehicle crashes in the United States (U.S.) in 2014 (14.9% of total traffic crash fatalities). Pedestrians represent some of the most vulnerable road users, as they are not protected by airbags, seatbelts, or other safety devices, and must also at times share the road with vehicles traveling at dangerous speeds.

Unlike motor vehicle crashes though, pedestrian-related crashes are prone to additional factors difficult to model, such as jaywalking behavior, a failure to look both ways, and blind spots caused by parked vehicles. Additionally, inadequate pedestrian lighting, difficulty in judging safe crossing gaps in traffic particularly when drivers may be speeding, volume of pedestrians crossing at a particular point, and inadequate spacing of safe crossing opportunities alongside roadways also contribute to pedestrian-related crashes (Sarkar, 1995; Leden, 2002; Ebrahim and Nikraz, 2012; Elhamy, 2012; Rizaldi et al., 2017). Furthermore, while driving norms tend to be roughly consistent between states and municipalities, pedestrian

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[*] Corresponding author.

E-mail addresses: ke10@purdue.edu (Y. Ke), nadia@purdue.edu (K. Gkritza).

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safety laws may vary more dramatically. These include right-of-way policies, which dictate when oncoming traffic should stop, or yield to pedestrians, as well as the presence of laws that penalize reckless and distracted drivers. In the U.S., drivers are required to either (a) stop in any portion of a roadway when pedestrians are crossing (i.e., Minnesota), (b) stop within one lane of the vehicle's lane (e.g., Oregon) (c) stop upon the same half of the roadway (e.g., Washington), (d) yield in any portion of the roadway (e.g., California), (e) yield if the pedestrian is in the same half of the roadway (i.e., Louisiana), (f) yield in only the lane the pedestrian is actively crossing (i.e., Nebraska), or (g) yield if pedestrians are within 10 feet of the vehicle (i.e., Massachusetts) (Shinkle, 2016).

In 2011, Oregon's pedestrian law was changed to be more accommodating to pedestrians, by giving right-of-way to pedestrians using a crosswalk, which is defined as any location in which two roads intersect regardless of markings (Thomas, 2013). Under Oregon law, drivers must stop and remain stopped for pedestrians until they have cleared the lane in which drivers are traveling and the next lane, unless the pedestrian is blind and using a white cane or a guide dog, in which case the pedestrian must be completely across the roadway. Crosswalks may be marked (i.e., striped) or unmarked. Regardless of markings however, the law, ORS 811.028, is consistently applied. Before 2011, the law was ambiguous on how pedestrians could trigger their right of way, as they had to be "crossing the roadway in a crosswalk" before the law granted them a legal right of way to safe passage. However, as it feels unsafe to walk in front of speeding traffic, pedestrians did not reliably trigger their right of way. The 2011 amendment to the crosswalk law changed the way in which right of way is triggered: rather than hoping for good will on behalf of drivers, a pedestrian crossing the roadway is specified as the moment that any part of the pedestrian's body, wheelchair, cane, or crutch moves onto the roadway. In other words, this meant that traffic must stop when a pedestrian's foot (or cane, wheeled mobility device, etc.) leaves the curb and enters a roadway. While this policy may reduce fatalities in pedestrian crashes as it may force drivers to be more cautious when entering an intersection, it may also perversely induce a higher crash rate by allowing for riskier pedestrian behaviors, such as pedestrians crossing without looking knowing the law is on "their side".

In view of the above, the main objective of this paper is to examine the effectiveness of this policy change with respect to pedestrian safety using Oregon Department of Transportation (ODOT)-maintained crash data from 2007 to 2014. The analysis has a practical value in that it will assist decision makers in identifying problematic roadways and exposure factors that may contribute to pedestrian crash injury severities, as well as potentially identify a low-cost policy change that can address location-specific pedestrian safety problems. Furthermore, the results can contribute to understanding the heterogeneous efficacy of region-wide policies in reducing pedestrian-related fatalities across different spatial geographies. Finally, this study extends the methodological techniques of examining pedestrian crash severities by proposing an alternative estimation technique.

The rest of this paper is organized as follows: the next section contains a brief summary of existing literature on pedestrian safety interventions, as well as a review of methods others have used in the past, and presents a description of the data. Section 3 provides an explanation of the methodology used. Section 4 discusses the results of the model, while Section 5 offers some concluding remarks and identifies areas where additional research is required.

2. Material and methods

2.1. Literature review

Partially due to the heterogeneity amongst pedestrians, as well as under-reporting of data, the existing literature for pedestrian safety is not as rich as that for the other transportation users. The following section is a review of previous research on this topic focusing on the methodology adopted.

Generally, pedestrian crash studies examined injury severity due to exposure factors using state-level crash databases, similar to those for vehicle and bicycle crashes' these studies use primarily logistic regression techniques. Kim et al. (2008b), for instance, used police reported crash data from 1997 to 2000 in North Carolina to examine the injury severity of pedestrians in motor-vehicle crashes using a heteroskedastic logit model. The authors demonstrated that pedestrian age induces heteroscedasticity, which affects the probability of fatal injury. This was attributed to the greater variance in health conditions among older pedestrians than younger pedestrians. As the presence of heteroscedasticity violates the independently and identically distributed errors assumption in multinomial logit models, the heteroskedastic model provided a better fit than a multinomial logit model.

In a follow-up paper, Kim et al. (2010) explored the use of a mixed logit model using the same dataset. They argued that a mixed logit model was an improvement on the heteroskedastic model as it accounted for unobserved heterogeneity between pedestrians. This was particularly important as unobserved health, strength, and behavior can significantly affect individual injury outcomes. Using the mixed logit model, the effect of pedestrian age was normally distributed across observations; thus, the authors argued that there was no heteroscedasticity.

Rather than examining exposure factors found in crash databases, Ewing et al. (2003) analyzed the effect of the built environment on pedestrian fatalities. Specifically, the authors found urban sprawl to be directly related to pedestrian fatalities. The authors developed an index to rank urban sprawl across 448 counties in the U.S. and found that pedestrian fatality rates significantly declined as sprawl declined. It is important to note that despite analyzing different factors, Ewing et al.'s (2003) conclusions were consistent with those of exposure studies (e.g., Kim et al., 2010).

While fatality risks may be lower in dense urban areas, pedestrians are paradoxically most at risk of crashes in these areas. This is due to the large amount of automobile activity as well as the higher numbers of pedestrians, especially when compared to rural areas and the suburbs (Zegeer and Bushell, 2012). Internationally, this is an even larger problem, particularly in countries where traffic laws are poorly enforced. However, one solution may be to design urban landscapes that can naturally provide safe and accessible facilities to reduce pedestrian crashes. This may include physical improvements, such as wider sidewalks, tighter intersection turning radii, and refuge islands (Zegeer and Bushell, 2012). Alternatively, traffic control devices could be optimized to allow pedestrian input during peak hours of pedestrian volumes. In another study, Zegeer (2005) estimated Poisson and negative binomial regression models and found that the efficacy of marked crosswalks at uncontrolled intersections largely depended on the physical limitations of a particular location. Interestingly, multilane roads with traffic volumes above 12,000 vehicles per day were associated with higher pedestrian crash rates when the crosswalk was marked. This could be due to the marked crosswalks giving pedestrians a false sense of a security when walking onto the roadway and into fast-moving oncoming traffic.

Additionally, the legal system may choose to favor pedestrians in the event of a conflict. This can be seen in changes in federal and state laws governing crosswalk behaviors, pedestrian right of way, as well as additional roadway markings, signal technologies, and striped crosswalks, particularly for unsignalized intersections (Fitzpatrick et al., 2015). In a national study, Turner et al. (2006) evaluated engineering solutions for improving pedestrian safety in marked crosswalks. The authors found that the red signal was the most effective means of forcing drivers to yield to pedestrians.

Interested in the short run effects of a change in crosswalk law, Kim et al. (2008a) observed traffic violations in Hawaii. The authors estimated binary logistic regression models to examine the patterns of violation of and compliance with a changed pedestrian crosswalk law in Hawaii (Kim et al., 2008a). In 2005, Hawaii changed their pedestrian crosswalk laws such that vehicles had to come to a full stop when faced with pedestrians at crosswalks; previously, motorists only had to yield. Using 2006 data, the authors found that proportionately, motorists were more likely to ignore the new pedestrian crosswalk law and were the source of the majority of violations. The authors concluded that in order to protect pedestrians, additional driver education is needed. Kweon et al. (2009) took an alternate approach to examining the impact of a law requiring drivers to stop for pedestrians in marked crosswalks in four U.S. states, Washington, Georgia, Minnesota, and Oregon. The authors applied three methods—a before-after analysis, time series analysis, and a cross-sectional analysis. They found no statistically significant reduction in pedestrian-involved fatal crashes attributable to the changed law, but note that their findings were not definitive as the study omitted relevant exposure data. Further, the Oregon data considered in that study contained only two years of the treatment (“after”) effect. Therefore, this paper may be considered an extension of the Kweon et al. (2009) study by examining the impact of a legal change in Oregon, albeit using a different methodology.

Last, Serhiyenko et al. (2014) examined monthly pedestrian crash counts on urban roads in Connecticut from 1995 to 2009, using a vector autoregressive model. The authors reported a decrease in incapacitating injuries, and an increase in major and minor injuries, but no statistically significant changes in the number of monthly fatal crashes.

2.2. Data

The data used in this study comes from the Oregon Department of Transportation (ODOT) maintained crash databases, spanning from 2007 to 2014. These data draw heavily from police reports of crash scenes, and thus, may not include complete descriptions of the intersection at which a crash occurred. As this study is only interested in pedestrian-involved crashes occurring at intersections, non-intersection crashes were filtered out. A total of 3559 pedestrian-involved crashes at intersections occurred during the study period.

The eight-year span of the Oregon crash database contains every crash that occurred on federal, state, and local roads between 2007 and 2014. ODOT also provided GIS files of their roadway network, which was used to confirm crash locations, as indicated in the crash database. As crosswalk laws only apply to pedestrians using a crosswalk, the crash database is geocoded and filtered such that midblock crashes that occur during a pedestrian jaywalk is omitted from analysis. This process involved using GIS to first identify all intersections in Oregon creating a 20-foot radius (i.e., buffer) around each intersection point to signify crosswalk space, and mapping crash incidents from the crash database to assess whether pedestrians were jaywalking or legally within the bounds of a crosswalk. Although the crash database includes whether or not crashes occurred at an intersection, this additional data cleaning step was necessary as some records may have been inappropriately coded/entered into the database.

Although every intersection is a crosswalk according to the new Oregon law, not every intersection is built the same way. Thus, intersection geometry is included in the analysis. Some intersections may be in a cross configuration, while others may involve several roads coming together at various angles. These angles affect driver sight lines and their ability to detect pedestrians. For instance, a driver seeking to make a right turn at an intersection may find it harder to notice a crossing pedestrian approaching from his right side, particularly if the pedestrian is approaching from an oblique angle, which then increases the likelihood for a pedestrian-involved crash.

Exposure factors including weather, lighting, and roadway surface conditions are included as they have been shown to affect crash outcomes and thus, should be controlled for. Weather and lighting conditions affect driver behavior as well as their physical abilities to detect pedestrians crossing the road. Poor weather and poor lighting conditions may lead a driver to behave more cautiously, while good lighting and clear weather may be associated with more reckless driving (e.g., Edwards, 1998; Eisenberg, 2004; Tefft, 2016). Additionally, poor weather may also discourage pedestrian traffic, while clear

Table 1
Variable description

Variable	Description
Crash Outcome	Dependent variable: Outcome of crash following KABCO standards (fatal, injury a, b, c, pdo). For the purposes of this research, crash outcomes have been simplified to fatal and non-fatal outcomes
Year	The year the crash occurred in; included to control for environmental effects that may change from year to year, such as macroeconomic shocks that can affect the transportation sector
Month	The month the crash occurred in; included to capture seasonal effects not otherwise controlled for in the crash exposure variables.
Intersection Geometry	Indicates if the intersection consists of 2, 3, 4, 5, or 6 legs, or if the intersection is in the cross configuration
Weather	Exposure factor: weather conditions at time of crash; includes cloudy, clear, fog, rain, sleet, smoke, and snow
Road Surface	Exposure factor: road surface conditions at time of crash; includes dry, icy, snow, and wet
Natural Lighting Conditions	Exposure factor: Amount of natural light available at time of crash; includes dark, dawn, day, dim, and dusk
Population	Estimated number of persons living in the incorporated area in which the crash occurred expressed as 10 sets of ranges, from "1 to 500" persons to "Over 200,000" persons

Table 2
Number of pedestrians involved in crashes over time.

Year	Total Pedestrian Count	Total Pedestrian Fatal Count	Total Pedestrian Injury Count	Total Pedestrian Property Damage Only (PDO) Count
2007	302	16	281	5
2008	328	14	311	3
2009	382	10	361	11
2010	483	11	469	3
2011	515	12	500	3
2012	584	20	556	8
2013	532	15	505	12
2014	600	20	575	5

weather conditions may be more amenable for pedestrians. Roadway surface conditions affect drivers' ability to react to stimulus in the roadway, and may therefore lead to changes in behavior. Icy roads, for instance, typically cause motorists to drive at a rate lower than the posted speed limit.

In addition to the standard set of variables, such as descriptions of the causes of crashes, intersection type, functional class of roadway, weather and lighting conditions, types of vehicle(s) involved, number of participants and the most serious injury type sustained, ODOT's crash data also includes information on the population of the location, based on annual estimates published by Portland State University, at which the crash occurred. Ewing et al. (2003) demonstrated that the degree of urban sprawl plays a significant role in pedestrian injury severity in the event of a motor vehicle and pedestrian collision. Thus, in order to account for spatial differences (i.e., differing geographies and land use practices that may arise on various sides of state lines), the estimated population of crash locations is also controlled for. The population variable includes 10 population ranges: 1-500; 501-1,000; 1,001-2,500; 2,501-5,000; 5,001-10,000; 10,001-25,000; 25,001-50,000; 50,001-100,000; 100,001-200,000; over 200,000. Table 1 provides a brief description of the variables considered in this study.

Table 2 provides information on pedestrian crash outcomes over the study period. PDO, and injury A, B, and C outcomes have been aggregated into a single crash outcome for the purposes of performing a panel logit analysis. It is important to note that although 3559 pedestrian-involved crashes occurred, some crashes involved more than one pedestrian. Overall, the number of pedestrians involved in crashes has increased over time. While total pedestrian fatalities appear to also increase between 2007 and 2014, no clear trend line emerges from the data.

Individual participant-level data were also included in the ODOT crash database. However, to stay consistent with the existing body of pedestrian crash safety research, the crash-level data was used. While this means that individual injury outcomes are obscured, due to the physics of pedestrian-involved crashes, it is safe to assume the most severe injury occurred to the pedestrian in pedestrian-involved vehicle crashes.

As the research question poses to answer whether or not the change in crosswalk definitions affected pedestrian safety over time, one cannot treat the crash data as cross-sectional data. Rather, time could play an important role, as drivers and pedestrians become aware of the new law and react to it. However, the crash database reports discrete crash outcomes. The next section will describe the modeling choices made to overcome these challenges.

3. Theory

In order to evaluate the various pedestrian safety-oriented policies and interventions, many methodological approaches have been used in the past. Kim et al. (2010), McFadden and Train (2000), Train (2009), and Hensher and Greene (2003) estimated a random parameters model, as unobserved heterogeneity between pedestrians can significantly affect injury severity, to analyze exposure factors contributing to crash outcomes. Pedestrian safety-oriented policies as a means of lowering fatalities have been examined using mixed logit models (Kim et al., 2008b; Kim et al., 2010) and count models (Zegeer, 2005). Much of these modeling decisions arise from the data available: the logistic regression-based models were chosen by the aforementioned authors as they had only cross-sectional data, while Zegeer (2005) chose Poisson and negative binomial models as crash data were interpreted as counts.

As indicated in previous sections, this study is interested in the longer term effects the change in crosswalk definitions had on pedestrian safety. As drivers and pedestrians alike adapt behavior over time, it was important that the temporal aspect be captured in the modeling. Thus, the cross-sectional logistic and probit types of regression models were deemed inappropriate, as they would result in biased and inefficient estimates. A before-after-control-impact (BACI) model could not be used, as the policy change was statewide; the differing state laws as well as state-specific driving characteristics (e.g., as a result of drivers' education programs) of neighboring states meant there were no clear control groups. An uncontrolled before-after (BA) analysis approach was considered inappropriate, as it could not adequately account for changes in behavior over time. The BA approach treats data collected as independent samples which are compared using a two-sample test. Any difference found is attributed to the intervention. However, in addition to introducing heteroscedasticity by ignoring the panel aspect of the data set, causal inference can be difficult to establish as trends may be due to unobservable or confounding factors.

Intervention analysis research typically relies on Box-Tiao autoregressive integrated moving average (ARIMA) approaches. This allows for one to control for the noise using ARIMA and at the same time allow for the causal specification of the intervention. However, this approach calls for time series data rather than panel data, and was therefore not considered a viable solution—particularly as independent variables (i.e., exposure factors) could not be included (see Kweon et al., 2009 for an extended discussion).

Because of the temporal aspect of the research question as well as the discrete outcomes inherent in crash outcomes, an unbalanced fixed effects panel logistic regression using the maximum likelihood estimator is the most appropriate method as it allows one to account for the time as well as satisfy the assumptions of logit models. The dependent variable is defined as whether or not a pedestrian-involved crash resulted in a fatal outcome. The regressors are meant to capture the various exposure factors that can impact crash outcomes, as outlined in the previous section. The model comprises a reduced form formulation where the coefficient estimates of the regressors reflect the net effects that the regressors have on the probability of whether or not fatal crashes would occur. For instance, clear weather conditions indicate improved visibility to drivers, corresponding to a decrease in likelihood that collision with a pedestrian would result in a fatality, but may also mean drivers are more careless in driving—the coefficient estimates represent the total effect of these exposure factors. Because not every intersection experienced a crash, the data is unbalanced in nature.

As seen in Baltagi (2008), the panel logistic model takes the form of

$$\Pr[y_{it} = 1 \ = \frac{e^{\mu_i + x'_{it}\beta}}{1 + e^{\mu_i + x'_{it}\beta}} \tag{1a}$$

$$\Pr[y_{it} = 0 \ = \frac{1}{1 + e^{\mu_i + x'_{it}\beta}} \tag{1b}$$

By conditioning on y_{i1}+y_{i2}, μ_i, can be swept away. The product of terms gives the conditional likelihood function, which can be maximized with respect to β using maximum likelihood. In the case of two time periods ($T = 2$),

$$\Pr[y_{i1} = 1, y_{i2} = 0 | y_{i1} + y_{i2} = 1] = \frac{1}{1 + e^{(x_{i2} \ \ x_{i1})'\beta}} \tag{2a}$$

$$\Pr[y_{i1} = 0, y_{i2} = 1 | y_{i1} + y_{i2} = 1] = \frac{e^{(x_{i2} \ \ x_{i1})'\beta}}{1 \quad e^{(x_{i2} \ \ x_{i1})'\beta}} \tag{2b}$$

This procedure is then generalized for $T > 2$. The maximum likelihood estimator is solved using the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm found in R's base function `optim()`. BFGS is a quasi-Newton hill-climbing optimization method often used for solving unconstrained nonlinear optimizations. As BFGS iteratively approximates the second order Hessian matrix rather than finds the true Hessian, a necessary condition for convergence is that the gradient is zero. This optimization technique was chosen as it is considered to have good performance for non-smooth optimizations (Lewis and Overton, 2009).

The next section shows the model estimation results and corresponding inferences.

4. Results and discussion

The results of the panel logit model with the best fit are shown in Table 3. Additional specifications were estimated, but resulted in higher AIC values. All variables shown are statistically significant to the 90th percentile or better. Overall, the month of year, intersection geometry, weather, lighting conditions, and population were found to be statistically significant and associated with the likelihood of a pedestrian fatality. Year dummies were included to try to control for additional year

Table 3

Fixed effects panel logit model estimation results

Maximum likelihood estimation			
	Estimate	t value	Pr (>t)
(Intercept)	0.1555	0.217	0.828
Months of year			
January	0.330	2.739	0.006
March	0.230	1.714	0.087
June	0.398	2.596	0.009
July	0.279	1.879	0.060
August	0.360	2.496	0.013
Year Dummies			
Y2009	0.268	2.218	0.027
Y2010	0.331	2.829	0.005
Y2011	0.312	2.748	0.006
Y2012	0.313	2.805	0.005
Y2013	0.347	3.061	0.002
Y2014	0.237	2.182	0.029
Intersection geometries			
3-LEG	0.716	1.779	0.075
CROSS	0.789	1.968	0.049
Weather conditions			
Clear	0.297	3.777	0.000
Road conditions			
Ice	0.686	1.661	0.097
Population			
25,001 to 50,000 persons	0.316	2.288	0.022
Over 200,000 persons	0.190	1.694	0.090
BFGS maximization	182 iterations		
Log-Likelihood at convergence	1386.75		
AIC	1356.75		

effects, and were all found to be significant with the exception of Year 2008. All year estimates are in relation to Year 2007, as Year 2007 was omitted to avoid collinearity issues. The month of February was omitted for the same reason. Although one may suspect additional multicollinearity between year and month dummies, examination of variance inflation factors found no evidence of multicollinearity.

Compared to 2-legged intersections, 3-legged and 4-legged intersections arranged in a cross configuration geometries included in the model were all less likely to result in a pedestrian fatality should a crash occur at the respective intersections. It is suspected that drivers' sight lines are impeded in 2-legged intersections and 4-legged intersections with non-ninety degree angled cross roads, and may be less likely to detect and respond to pedestrians in a reasonable amount of time. However, because the ODOT data did not include data on incidence angle, aside from distinguishing whether 4-legged intersections were in a cross configuration or not, it is difficult to draw further conclusions.

Clear weather was associated with a decreased likelihood of a pedestrian-involved crash fatality, likely due to drivers' improved visibility on clear days. Compared to dry road conditions, icy roads were positively associated with pedestrian fatalities. This is likely due to a reduction in friction on pavement surfaces due to the presence of ice, and drivers' inability to reduce speed at the time of collision. Crashes in the summer months, June, July, and August, and January and March were more likely to result in fatal crashes involving pedestrians compared to crashes involving pedestrians that occur February. It has been widely shown that drivers drive faster and less carefully when roads are dry (e.g., Edwards, 1998; Eisenberg, 2004; Tefft, 2016). Moreover, summer time is also when many households go on vacation, leading to visiting pedestrians in unfamiliar environments. These factors may help explain why crashes in summer were more likely to result in pedestrian fatalities. However, it is interesting to note that pedestrian-involved crashes in January and March were more likely to result in a fatality; more research is needed to better understand these results.

Consistent with Ewing et al. (2003), land use, proxied by the population range variable, does impact crash outcomes. Compared to rural places (population ranging from 1 to 25,000 persons), crashes in small towns (pop 25,001 to 50,000) and urban centers (pop over 200,000) are less likely to result in pedestrian fatalities. This may be due to the speed at which vehicles are traveling: vehicle speeds in large cities may be low due to stop and go traffic and the traffic signal topology, while drivers in small towns may be more accustomed to pedestrians crossing the streets. Intermediate intervals of population ranges were not found to be statistically significant from the base case, rural places with population ranging from 1 to 25,000 persons. This result could be in part due to similar relative speed limits as well as an increase in the number of pedestrians, which may in turn increase the likelihood that a vehicle-pedestrian collision results in a fatal outcome.

The year dummies were included with the intention that they could capture some of the variation between years that was not included in the crash database, such as macroeconomic conditions that could impact statewide driving patterns, as well as monthly vehicle miles traveled data. Thus, the estimated coefficients for these variables should be interpreted with caution. Compared to the base year, 2007, each year, except for 2008 which was not significant, correspond to a lowered likelihood that a crash would result in a pedestrian fatality. While this is a promising result, it could be due to any number of things, including a change in crosswalk law, improved driver education programs, or vehicle technologies that can assist the driver in stopping in time for a pedestrian. The largest effect occurs in 2013, and could be a culmination of these things as well as drivers becoming used to the idea of pedestrian rights of way.

5. Conclusions

The main objective of this paper was to examine if a change in pedestrian crosswalk laws would make it safer for pedestrians to cohabitate with vehicles and other transportation modes in Oregon, U.S. Results were inconclusive over what effect this specific law has had on pedestrian safety, although the general trend seems to be that the likelihood of pedestrian fatalities in a pedestrian-involved crash is decreasing over time, even though descriptive statistics indicate that the number of pedestrians involved in crashes is increasing. Exposure factors revealed to be associated with pedestrian fatalities include clear conditions, wet roads, and daytime driving. Crashes in urban areas were less likely to result in pedestrian fatalities than those in rural areas.

Unlike previous crash outcome studies, an unbalanced fixed effects panel logit model was estimated using ODOT crash databases. While these models have been used extensively in other fields such as economics and political science, they have received little attention in the transportation safety realm and to the authors' knowledge, none in the area of pedestrian road safety. This paper suggests that there is value in using panel models, as they allow for the study of changes in crash outcomes over time due to changing driver and pedestrian behaviors in the face of legal or environmental changes. As the changes in the legislation were applied statewide in this case, the methodology followed in this paper is appropriate as it allows for studying the impacts at the same level as the changes.

However, it is important to note that, while crash event exposure is helpful in understanding the physical factors leading up to a crash, the human factors and decision making processes are also important. Specifically, pedestrians' and drivers' attitudes towards risk-taking may play a big role in pedestrian-involved crashes: pedestrians must decide what an acceptable gap between vehicles is, while drivers have to estimate where a pedestrian will be and how much deceleration is required. Furthermore, the amount of exposure to vehicles, such as the average annual daily traffic of intersections, can have a significant impact on the likelihood of a crash and the resulting injury severity. This information was not included in the crash database either.

Further work should seek to combine additional data sources, such as behavioral traits, such as attitudes towards risk, or demographics, with traditional crash databases to overcome some of these issues. Further work should also explore the use of panel multinomial logistic regression models, although the computational requirements for such models may be challenging.

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