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The built environment and the determination of fault in urban pedestrian crashes: Toward a systems-oriented crash investigation

Jonathan Stiles
Department of Geography
The Ohio State University
jes2403@columbia.edu

Harvey J. Miller
Department of Geography and Center for Urban and Regional Analysis
The Ohio State University
miller.81@osu.edu

Abstract: This study identifies built environmental factors that influence the determination of fault in urban pedestrian crashes in the United States, with implications for both safety and equity. Using data from Columbus, Ohio, we apply regression modeling, spatial analysis, and case studies, and find pedestrians are more likely to be found at fault on fast, high-volume arterial roads with bus stops. We also observe that better provision of crossings leads to more marked intersection crashes, which are less likely to be blamed on pedestrians. In addition, large differences in both the provision of crossings and fault exist between neighborhoods. We interpret findings through the lenses of the systems-oriented safety approaches Safe Systems and Vision Zero. The conclusion argues that the designation of individual responsibility for crashes preempts collective responsibility, preventing wider adoption of design interventions as well as systemic changes to the processes that determine the built environment of US roadways.

Keywords: Pedestrian, traffic crashes, Safe Systems, Vision Zero, transportation equity

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1 Introduction

The emergence of systems-oriented frameworks for addressing traffic safety in recent decades has drawn attention to the role of perceptions of fault in our collective responses to traffic crashes. The Safe Systems perspective identifies how particular environmental conditions can induce human errors (Dumbaugh et al., 2020), while the Vision Zero framework aims to broaden responsibility for crashes to include system designers (Belin et al., 2012). The determination of fault in traffic crashes can be a judgment of individual responsibility but can also point to collective responsibility and the need for design or policy interventions to prevent further crashes. Yet when fault is neatly assigned only to individual participants in a crash without awareness of the environment, it limits possibilities for such collective action, representing what Lee (2014) denotes as "cumulative irresponsibility" towards road safety. The challenging task of creating a

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more systems-oriented response to crashes would benefit from an understanding of how fault is presently being assigned by existing processes of investigating road crashes. When police officers respond to serious traffic crashes, these judgments of fault are shaped and bounded by crash reporting forms, as well as state and local traffic ordinances. Furthermore, fault for crashes may be distributed unevenly across a city along built environmental or socioeconomic lines, contributing to unjust inequalities in outcomes of not just injury, but also blame.

This paper seeks to inform these challenges by presenting an analysis of the factors related to the outcome of who, if anyone, is determined to be at fault by reporting officers for traffic crashes involving pedestrians. We analyze five years of data on pedestrian crashes in Franklin County, Ohio, the site of its state capital and largest city, Columbus. We fit a multinomial logistic regression model to indicate factors associated with different fault outcomes, with an interest in those related to the built environment such as speed limit, road class, pedestrian connectivity, and land uses, as well as the location of the pedestrian at the point of the crash. We also conduct a spatial analysis and case study of arterial road segments in four high crash communities—Downtown Columbus, South Linden**,** University District, and Hilltop. Our findings indicate that the built environment influences determination of fault in pedestrian crashes on two levels. Firstly, better provision of signalized and marked intersections on arterials in some neighborhoods leads to a higher proportion of marked intersection crashes, which are less likely to be blamed on pedestrians. Secondly, independent of pedestrian location, pedestrians are more likely to be found at fault in areas with faster arterial roads, bus stops, and fewer crossings. We interpret our findings through Safe Systems theory and in light of the recent launching of a Vision Zero initiative by the City of Columbus.

2 Background

2.1 Pedestrian crash risk in Safe Systems

A Safe Systems approach to road safety aims to create a transportation system that accommodates human behavior, including error, and that mitigates harm from kinetic energy of travel (Naumann et al., 2020). In a systems perspective, risk is derived from the interactions of all system components, rather than merely human decision-making (Leveson, 2004). For road crashes, Hauer (2016) draws a distinction between a backward-looking perspective that emphasizes immediate causes like human error, and a more forward-looking perspective that seeks to prevent future crashes by considering error in relation to road design and speed limits. Thus, Safe Systems challenges the longstanding belief that driver error is the overwhelming cause of crashes (Singh, 2015). Instead, a systemic analysis identifies unsafe corridors, determines multiple underlying environmental risk factors, and plans appropriate countermeasures (Thomas et al., 2018). Research has explored various sources of pedestrian risk that inform Safe Systems, including speed, exposure to risk through adjacent land uses, and elements of road design and the built environment, also considering how they shape interactions between drivers and pedestrians.

Higher vehicle speeds are associated with increased severity of pedestrian crashes. An analysis of crash data in Australia finds that a speed of 25mph or less (40km) is needed to limit pedestrian fatal crash risk on impact to 1 in 100 outcomes (Doeke at al., 2018). Using US data Tefft (2013) estimates the risk of severe pedestrian injury reaches 75% at a speed of 39 mph, and that the risk of death reaches 75% at 50 mph, and also show that elderly pedestrians experience higher risks in relation to speed. In a review encompassing studies from the US, Asia and Europe, Rosen et al. (2011) found that all studies show higher speeds related to greater risk of fatality and injury. In a Safe Systems approach, the management of speed through limits, enforcement, and speed reducing design is central to the goal of mitigating harm from the kinetic energy of travel (Kumfer et al., 2019). In practice, countermeasures in urban areas vary but include curb extensions and road diets, however standard practices such as allowing speed limits to be determined by observed traffic flow hamper efforts to set lower limits (Sanders et al., 2019).

The concept of exposure refers to the extent that pedestrians are in proximity to moving vehicles based on their location and daily activities such as walking, working, or shopping. Exposure creates opportunities for pedestrian crashes and is distinct from factors that increase crash likelihood and severity (Corben, 2020). In a review paper, Merlin et al. (2020) consider factors that directly affect exposure such as traffic levels and population, and factors that directly affect crash risk after exposure such as speed and intersection design; they also allow for factors that may have mixed or indirect effects on both exposure and risk, such as land use, density, and the presence of low-income populations. Numerous studies have especially found commercial land uses associated with increased pedestrian crashes (Loukaitou-Sideris et al., 2007; Schneider et al., 2021; Ukkusuri, 2012; Yu & Xu, 2017). Recently Al-Mahameed et al. (2019), use structural equation modeling to distinguish the effects of exposure variables—traffic, area employment, walking and biking levels—from road design variables, finding that the exposure group had the largest positive effect on crash frequency, while road design had a smaller negative effect. Finally, low income populations are more exposed to crash risk due to lower vehicle ownership, contributing to higher levels of transit use, since transit stops are often located along major roadways (Cotrill & Thakuria, 2010; Loukaitou-Sideris et al., 2007; Noland et al., 2013).

Road design in a safe system considers the interactions of the built environment with human behavior. Dumbaugh et al. (2020) show how environmental conditions induce human error leading to increased crashes, such as complex intersections, commercial land use, and bus stops, especially along urban arterial class roads. These wider and faster roads, accompanied by “big box” retail are a source for severe pedestrian traffic crashes (Dumbaugh & Rae, 2009; Dumbaugh & Zhang, 2013). In a national study of fatal crash hotspots, Schneider et al. (2021) similarly identify wide, high speed, and high-volume road segments with commercial land uses as producing more crashes. On the contrary, denser urban areas with high levels of transit access and frequent crossings have been found less risky for pedestrians, contributing to less severe crashes (Clifton et al., 2009). Based on a review of the literature, Ewing and Dumbaugh (2009) argue that dense urban environments with narrower and slower roads, have better traffic safety outcomes, including for pedestrians.

The built environment further shapes pedestrian safety by influencing crossing behavior. Severe midblock crashes are more frequent on wider roads with longer crossing distances but are less frequent in cases where a wider median provides a refuge (Gooch et al., 2022). Medians were also found to reduce pedestrian crash risk in a recent North Carolina analysis (Gayah, 2022). Yannis et al. (2007) use assessments of crossing difficulty and distance to model crossings. Observing others or acting as part of a group may also influence crossing decisions (Faria et al., 2010). Tao et al. (2010) consider how in the Chinese cities, wide roads, short pedestrian green signals, and large superblocks contribute to prevalence of midblock crossings. The installation of a marked crosswalk where one had not been previously, attracted more crossings and created perceptions of greater safety (Havard & Willis, 2012). In deciding their walking routes pedestrians consider the presence of traffic signals, traffic speed, and the duration of waiting to cross (Weinstein Agrawal et al., 2008). However, young pedestrians are more motivated to cross quickly and less deterred by illegality, or a lack of pavement or signals (Bernhoft & Carstensen, 2008).

2.2 Fault and bias in pedestrian crash reporting

Historian Peter Norton (2011) shows how in the mid-20th century, user error became the dominant frame for understanding traffic safety. Amidst efforts to restrict vehicle speeds, automobile manufacturers and advocates promoted individual responsibility—both of drivers and pedestrians—in part to draw attention away from vehicles and the safety of automobility broadly (Norton, 2011). This frame now manifests in enforcement practices and media coverage of crashes. In terms of enforcement, few studies have considered factors that contribute to the determination of fault for a pedestrian crash, with a focus on individual behavior. In Hawaii, Kim et al. (1998) find younger and older drivers more likely to be found at fault, while Kim at al. (2008) identifies subgroups of pedestrians‒drunk and young men‒and drivers‒male commuters‒

as more likely to be indicated at fault. Spainhour and Woooton (2007) study fault assignment of fatal pedestrian crashes in Florida, finding that mental state was an important factor, as well as number of lanes, visibility, and weather. Ulfarsson et al. (2010) analyze pedestrian crashes in North Carolina, finding drivers are more found at fault when turning or backing up, and pedestrians are more found at fault when crossing; both groups are more found at fault while intoxicated.

The topic of bias and underreporting of crashes has been taken up by scholars. The role of police departments in recording crash data leads to bias that can mislead analysts (Abay, 2015). In San Francisco, Sciortino et al. (2005) identifies the underreporting of pedestrian and cyclist crashes by comparing crash records with hospital records, finding that injuries were under reported by 21%. In a university neighborhood, Medury et al. (2019) highlight underreporting by comparing areas perceived as hazardous with reported crashes. In terms of media coverage, a study of editorial patterns reveals how pedestrian and cyclist crashes were treated more often as isolated occurrences and tended towards blaming non-drivers (Ralph et al., 2019). Additionally, the role of driver-oriented media coverage of crashes can shape individual perceptions of fault, contributing to a wider societal bias (Goddard et al., 2019).

2.3 Vision Zero: Beyond individual fault

The applied systems-oriented approach, Vision Zero, was developed in Sweden in the late 1990s. Its ambition is to achieve zero fatalities or severe injuries in a transportation system, in large part by broadening responsibility for crashes from individuals to system characteristics such as road designs (Tingvall & Haworth, 1999; Belin et al., 2012). This conception of fault represents a fundamental shift from the backward-looking perspective on crashes that blames particular agents, towards a forward-looking perspective which also considers the role of designers in being responsible for preventing future crashes (Fahlquist, 2006). The implementation of Vision Zero in Sweden, which reduced fatalities by nearly 20% over ten years, focused largely on speed reduction and barriers to keep pedestrians separated from vehicles in areas where speeds are higher (Johansson, 2009). In the United States, Vision Zero programs in US cities are mostly local and state governmental multi-agency coalitions of stakeholders created through political support with a focus on collaborative plan development (Naumann et al., 2019). The city of Columbus, Ohio enacted its Vision Zero policy in March 2020. As of January 2022, the US National Road Safety Strategy advocates for a Safe Systems approach and asks local governments to commit to a goal of “zero roadway fatalities” (USDOT, 2022).

Broadening the way administrators perceive pedestrian crash responsibility is central to the success of Safe Systems and Vision Zero implementations. Yet equity is also a concern since a focus on individual responsibility in crashes supports the continuation of inequities by preventing collective action towards creating a more just transportation system (Lee, 2014). This paper’s findings can add to the literature on pedestrian crashes in a Safe Systems perspective by prompting a reconsideration of the criteria we use to evaluate crashes, as well shine a light on equity concerns related to the current determination of fault in pedestrian crashes.

2.4 Data and methodology

This paper presents an analysis of five years of pedestrian traffic crashes in Franklin County, Ohio augmented by a case study of the built environment on key urban arterial roads of four Columbus communities. When a crash occurs in Ohio, the responding officer completes a standardized form that asks for detailed information about the participants, vehicles, and events of the crash, including numerous categorical questions as well as space for a short narrative and diagram (Appendix A). One of the categorical fields is labeled “Unit in Error,” with instructions in the reporting manual to “enter the unit number of the motorist/non-motorist which had the most causative bearing on the crash,” and an option to enter “99” for other cause (Ohio Department of Public Safety, n.d.). Other categorical fields apply to each unit involved in the crash, such as the action being taken at the moment of the crash. For pedestrians without vehicles this is limited to choices labeled "entering or crossing," "walking, running, jogging, playing," or "standing" (Ohio Traffic Safety Office, n.d.). Additionally, for pedestrians a key piece of information collected is their location in relation to the roadway at the point of the crash, including whether or not they were in a crosswalk. This is especially important given the existence of a Columbus ordinance that prohibits walking in the road where sidewalks are provided or crossing in places where crosswalks are not "an unreasonable distance apart"—a distance that is not quantified (Furbee & Overking, 2018). Additionally, Ohio state law gives the right of way to drivers except for "within a crosswalk" in specific circumstances (Motor vehicles-aeronautics-watercraft, 2018). Notably, no categorical information is collected by crash reporting forms concerning pedestrian infrastructure beyond pedestrian location, or any elements beyond the roadway. Crash reports are aggregated by the Ohio Department of Public Safety and a quantitative dataset is made available. The resulting dataset contains information on type of crash, location, road type, and the actions of crash participants based on each department's completion of the forms but does not contain all the information collected by reports.

There were 2757 pedestrian crashes in Franklin County between 2015 and 2019 according to the dataset (Table 1). In over half of crashes during the study period the driver was found at fault, compared to over a third of crashes for which the pedestrian was found at fault. Officers found no individual fault for just one in ten crashes. Severity of injury is approximately normally distributed among these pedestrian crashes; this differs from the typical distribution for non-pedestrian crashes which is more biased towards lower severity outcomes. In a majority of crashes, neither the pedestrian nor the driver was facing a control such a red light or a stop sign. In over 30% of crashes, the pedestrian was either crossing midblock or in a car travel lane at the time of collision. A substantial percent of crashes (16.1%) have unknown driver, which represents more than one in seven drivers leaving the scene after the collision. Over 60% of pedestrian crashes for which road class was identified occurred on major or minor arterial roads, which are higher capacity functional road classes that may also contain commercial land uses.

We introduce additional variables about the surrounding built environment not available in crash records. These include data on sidewalks and crosswalks, which were measured at a buffer distance of 100 meters to reflect wider pedestrian connectivity based on a hypothesis that neighborhood walkability is influential. These data were available through the Ohio Department of Transportation. We also include points of interest and bus stops measured within a 50-meter buffer, to reflect the immediate proximity of elements that attract traffic and necessitate street crossings. Points of interest data was accessed through the City of Columbus data portal, and bus stop point locations were accessed from the Central Ohio Transit Authority. Finally, we join each crash to Census tract data from the 2018 American Community Survey five-year estimates based on its location, to create socio-demographic variables for population density, household income, race, and primary commuting mode.

Table 1. Summary statistics for pedestrian crashes in Franklin County, Ohio, 2015 to 2019

		ALL (n=2757)		**IN MODEL (n=1518)**	
		% Crashes	**Mean**	**% Crashes**	**Mean**
Dependent Variable					
Assignment of Fault	Driver Found at Fault	53.6		49.3	
	No Fault Found	10.0		11.5	
	Pedestrian Found at Fault	36.4		39.2	
Individual Characteristics	Pedestrian Age (years)		34.1		34.3
	Pedestrian Male	59.2		56.3	
	Driver was Distracted	2.9		3.7	
	Driver was Speeding	3.8		3.1	
	Driver is Unknown (Hit Skip)	16.1		n.a	
	Alcohol Use Indicated	8.1		n.a	
Crash Characteristics	Vehicle Turning	28.0		37.5	
	Pedestrian No Traffic Control	68.7		65.8	
	Driver No Traffic Control	62.8		53.8	
	Posted Speed Limit (mph)		32.1		32.0
Crash Severity	No Injury	5.4		4.6	
	Possible Injury	24.3		24.4	

	Non-Incapacitating	49.7		51.5	
	Incapacitating	16.7		16.4	
	Fatal	3.9		3.1	
Pedestrian Location	Marked Intersection	34.5		39.3	
	Unmarked Intersection	14.4		14.8	
	Midblock / Travel Lane	30.8		32.8	
	Other	20.4		13.1	
	Road Width (lanes)		3.2		3.3
Road Functional Class	Local	21.7		19.0	
	Collector	10.9		10.9	
	Arterial	64.5		69.4	
	Highway or Interstate	2.9		1.6	
	Daylight	54.1		61.3	
	Clear Weather	64.6		63.9	
	Dry Road	77.4		77.3	
Area and Time Characteristics	Unmarked Crosswalks (in 100m)		2.9		3.0
	Marked Crosswalks (in 100m)		1.8		2.1
	Sidewalk Density (dam per 100m)		85.9		93.1
	Retail Stores (in 50m)		0.54		0.56
	Bus Stops (in 50m)		0.46		0.52
	Population Density (ppl. per sqm)		5.94		5.49
	Median Household Inc. (1000s of $)		47.6		48.2
	White Population (percent)		58.4		58.7
	Drive for Commute (percent)		82.43		82.9
	Weekend	24.2		20.9	

Our analytic method consists firstly of a multinomial logistic regression model of the determination of fault recorded by the crash reporting framework, which has three possible outcomes: driver found at fault, no fault found, or pedestrian found at fault. This modeling approach for nominal dependent outcome variables has its origins in travel demand mode choice estimation (McFadden, 1974). The model uses a subset of 1518 observations (Table 1), excluding 445 unknown driver crashes because none were blamed on pedestrians, which created a problem with multicollinearity. We additionally excluded 224 alcohol cases for which it was unclear which parties used the alcohol. However alternate specifications tried with these observations did not change any of our major findings. The 47 crashes that occurred in unincorporated parts of the county were also left out of the modeling, and the remaining exclusions were because of missing data on road, crash conditions, or participants. Our hypotheses are based in the theory and practice of Safe Systems and Vision Zero. In the model analysis, we expect to find non-crosswalk crossings associated with pedestrians being blamed. This has important implications for the role of the built environment since according to Safe Systems theory, these risky crossings are environmentally induced—a connection we explore further in our secondary analyses. We expect the model to show the driver behaviors of speeding and distraction associated with drivers being blamed. Yet we are also interested in the variables related to road speed, road type, land use, and pedestrian connectivity. We hypothesize that crashes on faster, higher volume arterial roads will be associated with pedestrians being blamed, while better pedestrian connectivity will be associated with less pedestrian blame, with the underlying theory that pedestrians are found at fault more frequently in areas less designed to accommodate their presence. We expect land uses to play the role of attracting pedestrians to environments where they may be more likely to be found at fault for crashes. Finally, the model includes time and spatial fixed effects to control for variations across year and district.

We augment our modeling with spatial analysis and four area case studies of urban arterials to show variations in the prevalence of pedestrians being found at fault between districts and arterial road segments across Franklin County. We construct a district dataset that combines the boundaries of Columbus city neighborhoods with other Franklin County municipalities. Neighborhood boundaries were available through the city data portal and are used by city agencies for planning and reporting (City of Columbus, 2018). We then calculate the proportion of crashes for which pedestrians were found at fault in each district that contained at least ten crashes during the study period, thereby excluding low population, industrial, and special districts such as the airport, and depict this distribution in a map. We do the same calculation based on road network data from the Ohio Department of Transportation for crashes on arterial road segments than contained at least two crashes, thereby excluding segments with no possibility of variation. Arterial class roads are considered central to this study based on their prevalence among pedestrian crashes (64.5%) and because of their discussion in the literature as sources of crashes, especially Dumbaugh and Rae (2009), Dumbaugh et al. (2020), and Schneider et al. (2021). Note that the spatial analysis draws on the full dataset and does not exclude unknown driver crashes in the Columbus metropolitan area, which represent a sizable proportion (16.1%), and for which drivers were indicated at fault. Nor does it exclude alcohol crashes or other crashes with missing data where possible.

The case studies examine arterial roads and crash characteristics in four Columbus neighborhoods with the goal of observing built environmental conditions that contribute to area differences in both fault outcomes and pedestrian location at the point of the crash. Case selection was based on two factors. Firstly, we identified the highest crash communities in terms of total crashes, crashes per area, or both. These communities also correlated with the "high injury network" identified by the Columbus Vision Zero initiative (Vision Zero Columbus, 2021a). Secondly, from among these high crash communities, we selected four that highlight differences in the prevalence of pedestrians being found at fault: Downtown Columbus and University District are among the top three communities both for total pedestrian crashes and density of crashes, Hilltop has the highest total pedestrian crashes of any community, and South Linden is a smaller community with the fourth highest density of crashes. Case studies have been previously used to augment modeling and spatial analysis in planning-oriented road safety research to compare demographic and built environmental characteristics between areas (Loukaitou-Sideris et al., 2007). For each case study neighborhood, a researcher visited and both walked and drove along a primary urban arterial, and documented the street design with photographs. The researcher also examined crossings at two locations and recorded the type of crossing, including whether the pedestrian signal was automatic or required pressing a button. Additionally, the distance between crossings along the length of a high crash arterial road was both observed in person as well as calculated using Google Street View. The researcher also learned the history of street improvements for each area, in part aided by Google Street View timelines, Finally, characteristics of arterial road crashes in case study communities were compared using Wilcoxon Signed Rank testing to crashes in other districts so that statistically significant differences could be identified.

3 Results

3.1 Modeling assignment of fault in pedestrian crashes

Table 2 shows results of the multinomial logistic regression model of the fault determination in pedestrian crashes, including odds ratios for which a value greater than 1 indicates increased odds of an outcome, while a value below 1 indicates decreased odds. The model has moderately good fit as indicated by a McFadden's R^2 of 0.413. The base category of the dependent variable for our modeling was the driver being found at fault. We first review the factors that affect the outcome of the pedestrian being found at fault in comparison to this base category. Older pedestrians are less likely to be found at fault for a crash, while pedestrian gender had no effect. The driver being found distracted has a strong negative effect on likelihood of the pedestrian being found at fault, decreasing odds by 94%. Surprisingly, the driver being found speeding was not associated with a lower likelihood of the pedestrian found at fault. However, driver turning movements decrease the odds of pedestrian fault. As we expected, the pedestrian being located in the middle of the block or in a travel lane increases the likelihood of their being found at fault, and this is the strongest effect of any variable in the model. Being in an unmarked intersection also greatly increases that likelihood compared to a marked intersection. The absence of traffic controls behaves as expected, with no pedestrian control decreasing the likelihood of pedestrians being found at fault, and no driver controls increasing that likelihood.

Among variables directly related to the built environment, higher speed limits are associated with a higher likelihood of pedestrians being found at fault, with each additional mile per hour increasing odds by 9%. Number of lanes has no effect of who is found at fault, however arterial roads are associated with higher likelihood of pedestrian fault compared to the base of local roads, increasing odds by 99%. This class of roads are designed wider to handle higher volumes, yet unlike highways, they may have more numerous and diverse connections and adjacent land uses. The density of nearby retail did not have any effect on fault outcomes; however, the presence of bus stops increased the odds of the pedestrian being found at fault, with each one increasing odds by 30 percent. A higher number of unmarked crosswalks in the surrounding area lowered the likelihood of the pedestrian being found at fault, with each additional unmarked crosswalk decreasing the odds of the pedestrian being found at fault by 10%. There were no effects seen in any socio-demographic variable for the outcome of the pedestrian being found at fault.

Table 2. Results from multinomial logistic regression of assignment of fault by reporting officer in Franklin County pedestrian crashes 2015-2019 (n=1,518)

	Base: Driver Fault Found	**No Fault Found**				**Pedestrian Fault Found**			
		Coef.	**S.E.**	**Sig.**	**O.R.**	**Coef.**	**S.E.**	**Sig.**	**O.R.**
Individual Characteristics	Pedestrian Age	0.32	0.19			0.18	0.18		
	Pedestrian Male	0.00	0.00			-0.02	0.00	***	0.98
	Driver was Distracted	-1.02	0.54	*	0.36	-2.88	0.82	***	0.06
	Driver was Speeding	0.82	0.53			0.76	0.53		
Crash and Road Characteristics	Vehicle Turning	-0.33	0.24			-2.16	0.23	***	0.12
	Pedestrian No Controls	-0.69	0.31	**	0.50	-1.03	0.29	***	0.36
	Driver No Controls	0.16	0.31			0.72	0.29	**	2.05
	Posted Speed Limit	0.01	0.01			0.09	0.02	***	1.09
	Crash Severity	0.09	0.12			0.30	0.11	***	1.35
Pedestrian Location	Base: Marked Intersection								
	Unmarked Intersection	1.22	0.33	***	3.38	2.25	0.31	***	9.45
	Midblock / Travel Lane	1.29	0.36	***	3.63	3.09	0.31	***	21.90
	Other	0.17	0.37			-3.67	0.78	***	0.03
	Road Width (Lanes)	0.12	0.11			0.11	0.10		
Road Class	*Base: Local*								
	Highway or Interstate	-0.07	0.86			-2.28	1.15	**	0.10
	Arterial	0.22	0.31			0.69	0.30	**	1.99
	Collector	0.25	0.36			0.61	0.35	*	1.83
Area and Time Characteristics	Daylight	-0.16	0.20			0.19	0.20		
	Clear Weather	-0.09	0.25			0.04	0.24		
	Dry Road	0.18	0.30			-0.21	0.28		
	Unmarked Crosswalks	-0.06	0.04			-0.10	0.04	**	0.90
	Marked Crosswalks	-0.15	0.07	**	0.86	-0.05	0.07		
	Sidewalk Density	0.003	0.002	*	1.003	0.003	0.002		
	Retail Stores Adjacent	0.07	0.09			0.04	0.08		
	Bus Stops Adjacent	-0.03	0.14			0.26	0.12	**	1.30
	Population Density	-0.05	0.04			0.00	0.04		
	Median HH Income	0.01	0.01			0.00	0.01		
	White Population	-1.57	0.82	*	0.21	-0.01	0.78		
	Drive for Commute	-1.79	1.64			-0.82	1.53		
	Weekend	-0.34	0.24			-0.33	0.22		
				McFadden's R2 = 0.413					

*Note: Stars indicate significance: * p< 0.10; ** p< 0.05; ***p< 0.01; Fixed year and district effects are not shown;*

There are far fewer variables that influence the outcome of neither driver nor pedestrian being found at fault. Again, the pedestrian being midblock or in an unmarked intersection has a strong positive effect, increasing the odds of neither party being found at fault, compared to the outcome of the driver being found at fault. A higher number of marked crosswalks in the immediate area decreased the likelihood of no fault being found. Each additional marked crosswalk decreased the odds of no fault being found by 14%. Sidewalk density alternately is found to increase the likelihood of no fault being found, but this effect was only significant at the 10 percent level. Finally, it is only for the outcome of no fault that the racial makeup of the area has any influence in the model, by decreasing the likelihood of no fault being found, although again this effect is only significant at the 10 percent level.

3.2 Spatial analysis and neighborhood case studies

Results from our descriptive analysis and modeling point to arterial roads as both a source of pedestrian crashes and a factor influencing the determination of fault, which we hypothesize to be through crossing location. We therefore engaged in a spatial analysis and four case studies to show how environmental conditions on arterials contribute to different locations of crashes on the roadway and different fault outcomes. Our spatial analysis in Figure 1 shows that the prevalence of pedestrians being found at fault on arterial roads in the Columbus metropolitan area differs by area and road segment. The downtown district core leading north and the wealthier Northwestern suburbs have lower rates of pedestrians at fault, while the lower income western and near-northeastern areas have higher rates. Figure 1 also shows road segments with at least two crashes during the study period, highlighted based on the percentage of those crashes that were deemed to be the pedestrian's fault according to aggregated police reports. The central downtown core of Columbus, which is located slightly south and west of the center of the map, is notable for the lower likelihood that pedestrians are to blame. Using these maps we identified four high crash areas that showed different tendencies towards or against finding pedestrians at fault for crashes, which became the basis for our case studies–Downtown Columbus, University District, Hilltop, and South Linden.

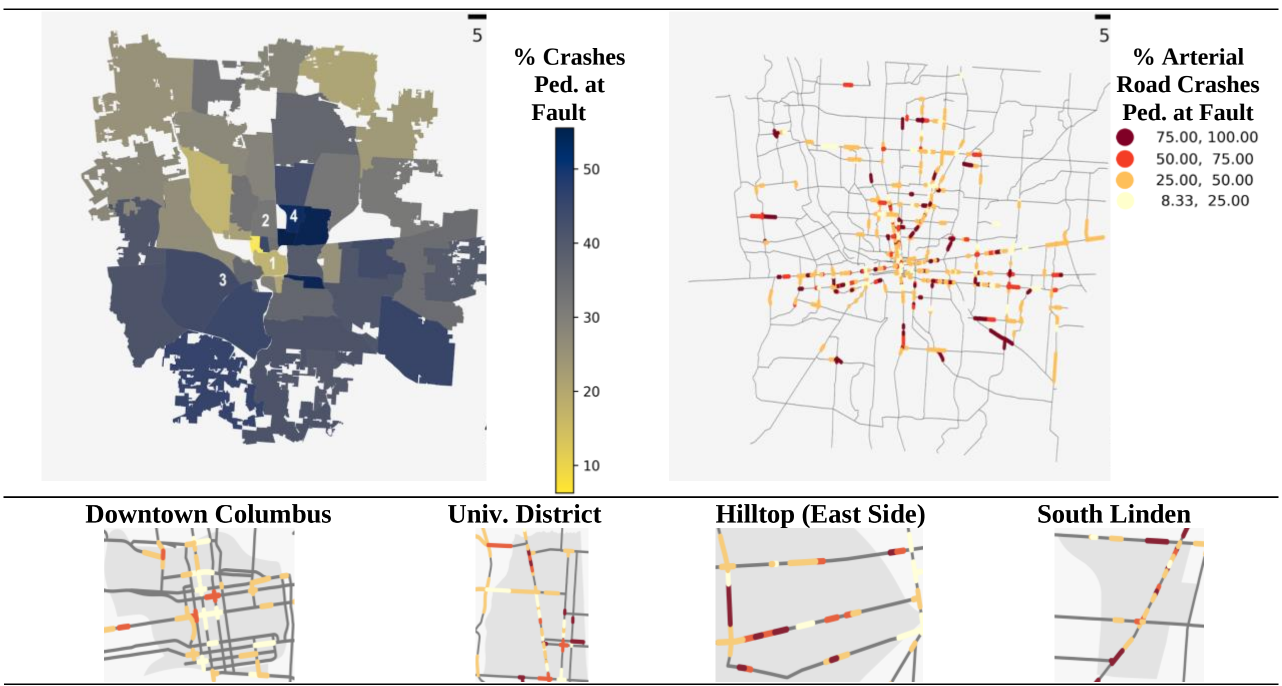

Figure 1. Spatial distribution of fault for pedestrian crashes in Columbus metro communities 2015-2019

All four selected communities are areas with a large number of arterial crashes compared to other parts of the Columbus Metropolitan area. Table 3 compares the crash characteristics in these neighborhoods against all 1697 arterial crashes for which a neighborhood could be determined, using Wilcoxon Signed Rank tests. Downtown has the largest number of arterial crashes. Hilltop is by far the largest community by area; however, the majority of its crashes took place in its eastern portion. There are differences in the percentage of crashes in which the driver vs. the pedestrian is found at fault between these communities, as well as notably large differences by neighborhood in the pedestrian location at the time of the crash and the distance between signalized intersection crossings on arterials.

3.3 Downtown Columbus

Downtown Columbus consists of wide arterials, several of which are one-way. Despite these wide streets with speeds often appearing above the 25-mph limit, there is widespread pedestrian-friendly street design and infrastructure. There are automatic pedestrian traffic controls at most intersections, and these intersections are generally well marked (Figure 2). The predominance of signalized intersections and relatively short blocks means the distance to a crossing point is minimal, with an average distance of 161 meters between signalized crossings on High Street. There are also signs at many intersections that instruct turning drivers to "YIELD to pedestrians." According to Table 3, downtown Columbus had the largest number of arterial road crashes. However, with the pedestrian friendly street design of downtown, the majority of crashes occurred within marked intersections (70%). The driver was found to be at fault by the reporting officer for over three quarters of downtown arterial crashes, while in only 17.5% of crashes was the pedestrian found responsible. All these differences were statistically significant at the 1 percent level (Table 3).

Table 3. Comparison of Columbus communities arterial crashes in case study areas 2015-2019

All Columbus Metro Communities		**Downtown**		**University Dist.**		**Hilltop**		**South Linden**	
Area (Sq. Km.)		6.3	n.a.	7.5	n.a.	40.1	n.a.	4.1	n.a.
Arterial Ped. Crashes (n)	1697	183	n.a.	132	n.a.	154	n.a.	54	n.a.
Crash Assignment of Fault									
Driver Found at Fault (%)	51.1	75.4	***	56.8		46.1		38.8	*
No Fault Found (%)	9.8	7.1		6.8		7.8		5.5	
Pedestrian Found at Fault (%)	39.0	17.5	***	36.4		46.1	*	55.5	**
Crash Pedestrian Location									
Marked Intersection (%)	42.6	70.3	***	55.8	*	30.9	***	12.5	***
Unmarked Intersection (%)	12.8	8.7	*	12.5		17.3	*	27.1	***
Midblock / Travel Lane (%)	29.7	16.0	***	26.7		35.3		37.5	
Other (Shoulder, Sidewalk)	14.9	5.2	***	5.0	***	16.5		22.9	
Median HH Inc (Mean 1000s of $)	47.2	51.2	***	29.7	***	31.9	***	25.5	***
White Population (Mean %)	58.2	67.3	***	76.4	***	69.5	***	17.9	***
Retail Stores Adjacent (Mean n)	0.70	0.91	***	2.39	***	0.47	*	1.13	***
Avg. Dist. Btw. Signal Crossings (m)		161	n.a.	253	n.a.	418	n.a.	429	n.a.

Note: n.a. = not applicable for Wilcoxon Signed Rank testing; Stars indicate significance: * p< 0.10; ** p< 0.05; ***p< 0.01; Calculated distance between crossings is for High St. (two sections), Sullivant Ave., and Cleveland Ave; Communities exclude unincorporated areas

3.4 University District

Just over half of the 132 arterial pedestrian crashes in the University District occurred on its primary arterial, North High Street, which is lined with high density commercial uses. The pedestrian infrastructure on this part of High Street is similar to downtown in that there are well-marked signalized intersections an average distance of 253 meters apart. While there are longer distances between them in some locations, there are several marked midblock crossings in which cars are expected to yield to crossing pedestrians to compensate. According to Table 3, just over half of crashes in University District occurred in marked intersections—a significant difference from the rest of Columbus, with over one quarter occurring midblock and over one in ten occurring in an unmarked intersection. The driver was found at fault for 57% of district crashes, while in 36% of crashes was the pedestrian found responsible, yet these differences from the rest of Columbus were not statistically significant. Finally, it is notable the arterial crashes in the University District tended to occur adjacent to more retail outlets on average than elsewhere in Columbus, and more than in the other case study areas.

3.5 Hilltop

Greater Hilltop to the west of Downtown Columbus. has two main east/west arterial roads, which accounted for nearly half of the arterial pedestrian crashes, Broad Street (38 crashes) and Sullivant Avenue (37 crashes). Both roads have concentrations of retail, although not as dense as in the previous neighborhoods, as well as bus stops. Broad Street is a five-lane arterial with sparsely located signalized crossings. It is a daunting road to cross with or without a signal in Hilltop, and distances to signalized crossing areas can be several blocks. Sullivant Avenue is a four-lane arterial. Signalized intersections are rare with an average of 418 meters between them on the eastern part of Sullivant Ave. As such there are long stretches of blocks without a marked crossing. Pedestrian signals on both roads are by request. As shown in Table 3, more than half of arterial crashes in Hilltop occurred outside of an intersection, and just over 30% occurred within a marked intersection, a significant difference at the 1 percent level. For 46% of arterial crashes in Hilltop, the pedestrian was found at fault—the same percent as drivers—and for 8% of crashes neither the driver nor pedestrian was found at fault, yet these were not significantly different than the rest of Columbus.

Downtown Columbus | University Dist. | Hilltop (East side) | South Linden

S. High Street | *N. High Street* | *Broad St.* | *Cleveland Ave.*

Figure 2. Examples of built environment on urban arterials in case study neighborhoods

3.6 South Linden

South Linden is a predominantly Black neighborhood to the northwest of Downtown Columbus. The primary arterial road is Cleveland Avenue, which has four travel lanes, two in each direction. As in Hilltop, signalized crossings are far apart in some locations with an average distance of 429 meters. Some busy areas are well above this average, including one which lacks signalized crossings over a distance of 640 meters. This stretch has a mix of residences, retail, daycare, religious facilities, a library and bus stops. As a diagonal road, many of the cross street intersections on Cleveland Avenue do not line up, which further challenges crossings and design. As shown in Table 3, only 12.5% of South Linden arterial crashes occurred within a marked intersection. Over one in four crashes occurred in an unmarked intersection, while the remaining 60% were midblock or on the shoulder. In South Linden during the study period, pedestrians were found to be at fault for more than half of pedestrian crashes (55.5%), and this difference was statistically significant compared to the rest of Columbus (Table 3).

4 Discussion

The results from the multinomial logistic regression model showed firstly that pedestrian location at the point of the crash is the strongest predictor of fault outcome. The pedestrian being in a marked intersection greatly increased the likelihood of the driver being found at fault for a crash, whereas a pedestrian either being midblock or in an unmarked intersection greatly increased the likelihood of the pedestrian being found at fault, or of the outcome of no fault being designated. Relatedly, the number of nearby marked intersections was associated with less likelihood of no fault being found, indicating that their presence reduced ambiguity of fault. Together this indicates that pedestrian location is the dominant factor of fault determination within the current process. Secondly, the modeling showed that faster roads as well as higher-volume arterial roads were correlated with pedestrians more likely being found at fault for crashes. This suggests that in these driver-oriented spaces there is some bias towards finding pedestrians at fault, although from an officer perspective this may seem in the interest of public safety to find pedestrians at fault on busy, high speed, apparently dangerous roads. Additional research is needed to confirm this understanding. Yet notably, speeding as a behavior surprisingly did not show any effect on fault outcomes in our models. The only effects related to driver-behavior to decrease the likelihood of a pedestrian being found at fault were driver distraction and vehicle turning. A third finding is that the number of nearby bus stops were associated with increased likelihood of pedestrians being found at fault. These bus stops in Columbus are often located on busy arterials which suggests both that bus stops are sources of risky arterial crossings, and also that transit users are devalued in these fast arterial road environments.

The connection between the model results and the spatial analysis and case studies lay in the relationship between the built environment and the location of the pedestrian at the point of the crash on arterial roads, which we assumed is largely related to crossing. According to the case studies, there were considerable differences in the provision of signalized intersections and marked crossings on arterial roads between neighborhoods. Additionally, these differences correlated with observed statistically significant differences in the percentage of marked intersection crashes between neighborhoods, with more in Downtown Columbus and fewer in the lower income Hilltop and South Linden neighborhoods. Thus, according to these case studies, one mechanism of disparities in fault between communities is the provision of crossing infrastructure on arterial roads. In downtown Columbus, with frequent signalized intersections and automatic pedestrian signals, fewer crossings occur outside of marked intersections, and fewer pedestrians are found at fault. Conversely, in Hilltop and South Linden, with less frequent intersections, more crossings occur both midblock and at unmarked intersections, and more pedestrians are found at fault. Yet because these differences depend on infrastructure, they are not behavioral, but rather are built environmental.

4.1 Limitations and future directions

While more research is generally needed on pedestrian crashes to inform their prevention, two limitations of this study point to areas for continuing research on fault finding. Firstly, we were limited to the variables in the crash data collected and made available by the Ohio Department of Public Safety and Ohio Department of Transportation, in particular lacking officer-level variables that could indicate individual-level bias or differences in perceptions of events and environments between officers. Nor did this study conduct a textual analysis of reports to understand the police rationale for their decisions. Based on findings we theorize that while officers are guided through the reporting process to have a greater focus on actions over environment, they are largely acting with public safety in mind when they find more pedestrians at fault in what they observe as more dangerous situations on faster, wider roads and in compliance with ordinances. Yet the lack of an effect of speeding behavior on fault outcomes may also indicate bias in favor of drivers in cases where both parties committed errors according to prevailing traffic regulations. Future research at a precinct or departmental level could study to what extent officer differences explain variations in fault outcomes. Furthermore, additional research can explore differences in reporting forms between states. The training of officers in the use of forms could also be of interest.

Secondly, there were findings from our modelling regarding the influence of the built environment on fault that we could not fully explain. For example, the influence of nearby crosswalks and sidewalk density—which may evidence greater pedestrian exposure—on fault determinations was unclear. Our results showed that more unmarked crosswalks were associated with less pedestrian fault, while higher sidewalk density was associated with more fault. This may point to how sidewalks alone, without crossability, do not create pedestrian friendly or safe environments. However more extensive research, including observational research, should confirm and deepen this understanding. Additionally, a better understand of access control could shed additional light on sources of inequities of fault between neighborhoods. Finally, knowledge of how countermeasures such as pedestrian islands and traffic calming design interventions influence both crossing behavior and the determination of fault would be especially useful for informing policies that seek to reduce inequities in both crashes and fault.

4.2 Implications for road safety policy and planning

We conclude that differences in blame between areas are largely caused by different built environments, including allocations of pedestrian-friendly street design such as signalized and marked crossings—as well as by the prevalence of faster and wider arterial roads with bus stops. These findings have implications for equity and safety policy, especially related to the Safe Systems perspective and the Vision Zero policy framework, which was adopted by the City of Columbus in March 2020. In terms of equity, blame is an additional burden on top of injury and fatality for pedestrians walking in neighborhoods with lower pedestrian connectivity and that are underserved with pedestrian infrastructure. Environmental conditions in some neighborhoods induce pedestrians to make midblock crossings to avoid long detours to sanctioned crossings. In light of this, individual responsibility is an incomplete frame for understanding and addressing the sources of pedestrian crashes. When the determination of fault in pedestrian crashes fails to take into consideration the unequal distribution of pedestrian connectivity and pedestrian-friendly infrastructure between neighborhoods, it reinforces an undue burden on pedestrians in some areas. Additionally, it creates inequity within neighborhoods between those who primarily drive and those who primarily walk or use transit, with that latter more exposed to crash risk. Transit is an important consideration because in many cities, including Columbus, bus stops are located along the very sorts of urban arterial roads that contain the majority of pedestrian crashes.

In terms of safety policy, our analyses of Franklin County crash data reflect on the very instrument of that data's assemblage—standardized crash investigation and reporting. This raises the question: what would a systems-oriented crash response and reporting framework look like? As imagined by Hauer (2016) it would be forward thinking and encompassing a wider scope beyond events and actions of individuals. This entails redesigning reporting frameworks to allow for more complex understandings of fault with a greater allowance for the role of environmental risk and differential exposure. Redesigned forms should consider aspects of the built environment found particularly important by our research. Suggested new data points related to midblock pedestrian crashes are distance to the nearest crossing, purpose of crossing, type of crossing, type of signal system, average pedestrian wait times, the condition of any pedestrian signal system, and the presence of medians and buffers. Related to drivers and intersection crashes, suggested new data are the visibility and prominence of yield and speed signage, as well as an indicator of whether traffic in the area on average fails to yield to pedestrians or exceeds lawful speed limits. At a local level we recommend that every pedestrian crash be examined critically through an ongoing process that includes these environmental factors that shaped its outcomes. If such a process were followed we believe more crashes would be found to be related to built environmental conditions as well as speed and speeding, all of which could lead to potentially life-saved redesigns of streets.

Yet there are significant state and local institutional challenges to establishing systems-oriented crash evaluation. The collection of data may be coordinated at the state level through standardized forms and process requiring political support to fundamentally change. In cities with district-based representation some neighborhoods may oppose changes they perceive as disadvantaging drivers. And in most localities both the enforcement of traffic and the investigation of crashes are embedded within police departments, which could be resistant to changes. Yet in practice, to realize greater recognition of the role of the built environment in fault finding and crashes generally, police officers need to be trained like planners, or else planners need to do work currently done by police officers. The adoption of city Vision Zero initiatives is an opportunity—locally at least—to have the challenging discussions needed to put these ideas into practice, especially in how it demands collaboration and shifting of responsibilities between agencies. The city of Columbus released its Vision Zero Action Plan in March 2021, which includes a "Rapid Response team" to evaluate the built environment of every fatal crash (Vision Zero Columbus, 2021b). This is the right sort of local policy change. Yet it should also be done with an eye to the inequality of pedestrian-friendly environment, infrastructure, and finding of fault, which entails recognizing that a midblock crossing is not the same in every neighborhood. Finally, because street designs are tied to urban development initiatives, we consider Vision Zero an opportunity to confront the political and economic processes that produce unequal distributions of safety and blame.

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Appendix

An appendix is available as a supplemental file at https://jtlu.org/index.php/jtlu/article/view/2335.

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