CHARACTERISTICS OF THE BUILT ENVIRONMENT SURROUNDING PEDESTRIAN-MOTOR VEHICLE COLLISIONS

By

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CERTIFICATE OF APPROVAL

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Abstract

Context: Pedestrian fatalities account for a disproportionate number of overall traffic fatalities. In 2009, 12.1% of all traffic fatalities nationwide were pedestrian fatalities. Research on how the built environment can minimize pedestrian injury is essential to creating safe communities and promoting active lifestyles.

Objective: To identify characteristics of the built environment associated with pedestrian-motor vehicle collision (PMVC) locations along primary arterials.

Study Population: Clark County, Washington PMVCs, 2007-2009.

Methods: Retrospective sampling and logistic regression analysis allowed comparison of characteristics of the built environment surrounding PMVC locations to comparable locations without nearby collisions.

Results: Locations on primary arterials with greater average monthly transit utilization (boardings and alightings) had significantly greater odds of having a nearby collision (OR = 1.24, 95% CI: 1.06-1.43 for 10,000 passenger increase per month). Areas with sidewalks, high-traffic volume intersections, and supermarkets were also associated with collision locations. Walkability of the surrounding environment was not predictive of PMVC locations in the multivariate model.

Conclusion: Areas on primary arterials near highly utilized transit stops have more PMVCs. After adjustment, transit stops with lower walkability scores did not have more PMVCs, although overmatching may have masked a possible association. Future research should gather prospective data on pedestrian activity and look to areas with greater variation in walkability score.

Research Questions and Specific Aims:

1. Are locations with greater nearby transit stop usage (i.e., more boardings and alightings) more likely to be sites of pedestrian-motor vehicle collisions (PMVCs)?

   Specific Aim 1: Describe and compare characteristics of the built environment surrounding collision locations and non-collision locations.

   Specific Aim 2: Determine whether sites with greater nearby transit stop usage are more likely to be sites of PMVCs. We hypothesize that locations along primary arterials with greater nearby transit stop usage are more likely to be sites of PMVCs.

2. If locations with greater transit stop usage are more likely to be sites of PMVCs, how are transit stops with nearby pedestrian-motor vehicle collisions unique compared to stops without nearby collisions?

   Specific Aim 3: Describe and compare characteristics of the built environment surrounding transit stops with and without nearby collisions.

Background and Significance:

Impact of Pedestrian Injury

Pedestrian fatalities account for a disproportionate number of overall traffic fatalities. In 2009, 12.1% of all traffic fatalities nationwide were pedestrian fatalities.[1] Transportation safety and public health agencies are often tasked with reducing the incidence of pedestrian injury. Traditionally, these efforts have aimed to reduce morbidity and mortality specifically related to these acute injuries.

However, with the incidence of lifestyle-related chronic disease increasing, public health agencies have developed broader motivation that also seeks to promote more active lifestyles. A comprehensive review by the Environmental Protection Agency reported that human health could be significantly affected by our built environment.[2] The use of "active transportation" (e.g., walking, running, or bicycling not merely for exercise, but also as a method of transportation) may be a component of an active lifestyle, and various positive indicators of health have repeatedly been found to be associated with choosing active transportation.[3-5] Given both the beneficial health and environmental impacts of such human-powered transportation, communities are focusing efforts on promoting walking and bicycling.[6-8]

However, there are significant barriers to choosing to use active transportation. Among these, safety and risk of injury and death are often-cited concerns for people when choosing their method of travel.[3, 9] In 2009, there were 4,092 pedestrian fatalities nationally (1.3 fatalities per 100,000 population), 61 of which occurred in the State of Washington (0.92 fatalities per 100,000 population), and 1 of which occurred in Clark County, Washington (0.23 fatalities per 100,000 population). These pedestrian fatalities accounted for 12.4% of all traffic fatalities in Washington, compared to 12.1% nationwide. Between 2005 and 2009, pedestrians accounted for 13.9% of all traffic fatalities in Clark County, compared to 11.5% for Washington.[10]

Additionally, the incidence of injury to pedestrians may dissuade individuals from choosing non-motorized methods of transport.[3, 9] An estimated 69,000 injuries to pedestrians occurred nationwide in 2008.[11] Naturally, there is fear that injuries and mortalities will increase with increased promotion of walking as transportation. However, studies have found that the "dose-response" relationship between pedestrian activity and pedestrian-motor vehicle collisions is not linear. Rather, several studies have shown that with substantial increases in pedestrian and bicyclist traffic, the incidence of pedestrian-motor vehicle and bicyclist-motor vehicle collisions is reduced.[12-14]

Thus, there may be a two-fold benefit to building communities that promote pedestrian and bicyclist activity: expected decreases in chronic health conditions due to improved activity levels, as well as possible decreases in the incidence of pedestrian and bicyclist injury due to the "safety in numbers" phenomenon that has been described in the literature. Although this relationship cannot be defined as causal, and not all research has demonstrated this effect,[15] the potential for a "safety in numbers" effect should not be discounted.

Over the past decade, research has more closely examined features of our built environments that may increase risk of pedestrian injury, the focus of our analysis. Better understanding of these associations can aid urban planners and policymakers in planning healthier communities. Some approaches have looked at area characteristics on the census tract level, finding that traffic volume, arterial streets without transit, land area, land use, and population characteristics (socioeconomic and demographic factors) were all significant predictors of pedestrian injury.[16] Additionally, studies have found that PMVC risk is higher around schools,[17-19] and risk of collision near schools is further increased among non-white populations.[18, 20]

Other studies have looked at smaller geographical areas. Hess and colleagues examined traffic corridors in King County, Washington found that increased usage of transit stops along state routes was associated with more pedestrian-motor vehicle collisions,[21] while an analysis of pedestrian collision points in New Zealand found significant associations between both traffic volume and curb parking in relation to pedestrian-motor vehicle collisions.[22]

Walkability, a measure of how conducive an environment is to walking, is another measure of the built environment that may affect pedestrian injury. Research studies by Frank have developed a validated measure of "walkability" (Appendix A) that incorporates measures of land use mix, residential density, street connectivity, and nearby retail floor area ratio ("retail FAR").[23] Land use is measured by an entropy index that indicates the degree of heterogeneity of land use within the given area.[24] Residential density is a measure of the number of housing units relative to the area zoned as residential. Connectivity describes how well connected streets are, and therefore how easily different destinations may be accessed. Retail FAR is a measure of the amount of actual retail space relative to the area zoned for retail, as an indicator of the relative ease of access to the storefront by foot (e.g., a location with large parking lots that need to be walked through before reaching the storefront would have a low retail FAR).

Need for Research

Human behavior is affected by the environments in which we live. In a review of eleven studies assessing the effect of neighborhood walkability on one's choice to walk, Sallis and colleagues found that those in highly walkable neighborhoods were consistently at least two times more likely to choose to walk to their destination than those in less walkable neighborhoods.[8] Additionally, other studies within the fields of both urban planning and public health research have found that various neighborhood characteristics are associated with whether a person chooses to walk or bike as a method of transportation (i.e., use "active transportation").[1] As public health seeks to reduce the physical inactivity inherent in today's society, attention needs to be given to improving the walkability of our communities to promote better health outcomes.

Researchers are aware that features of the built environment can affect the level of pedestrian demand, and have found correlations between these features and pedestrian injury, but have not completely assessed whether the "walkability" of the environment can influence pedestrian injury. For example, in areas where walkability is high, people may be more encouraged to walk to their destination. With higher pedestrian volume, we might expect that pedestrian injury from motor-vehicle collisions will go down due to the safety-in-numbers phenomenon.

Alternatively, we might expect less injury from pedestrian-motor vehicle collisions in areas with low walkability, where people are dissuaded from walking.

Hess's aforementioned study of King County, Washington used "case-control" methods to compare collision locations to non-collision locations along state routes. The Hess study reported that frequent collision locations were associated with proximity to transit stops with greater numbers of boardings and alightings.[20] This finding raises important questions. Were these pedestrians also transit users, or was this finding simply indicative of overall higher pedestrian volume? Since state routes are high-volume roadways not typically designed to act as pedestrian facilities, one might expect that these individuals were largely transit users, as other pedestrians would not likely be drawn to using these facilities.

Inclusion of a walkability measure would help inform whether other pedestrians were attracted to these roadways because of deficits in the pedestrian facility network, or whether these were pedestrians on the roadway because they were accessing transit. Unfortunately, the Hess study did not include a measure of walkability of the surrounding environment in their analysis. While Hess's study accounted for variables similar to those included in Frank's walkability index, Hess's variables were simplified and accounted for only a relatively small area surrounding the collision and control sites.[21]

Similar to the Hess study, our preliminary analysis (see below) found that most PMVCs in Clark County were occurring on primary arterials. However, primary arterials are not designed to provide local community access, but rather to facilitate major traffic movement through the area.[25] Pedestrian activity along these primary arterials should then hypothetically be largely limited to pedestrians boarding or alighting from transit. However, in areas like Clark County that were designed around a high dependence on automobile transportation, pedestrians may be forced to use primary arterials if street connectivity within the community is limited.

We seek to improve upon Hess's methods by including Frank's composite measure of walkability as a potential predictor of PMVC locations. This approach will help determine whether locations have greater odds of being a PMVC site not only in the presence of high nearby transit usage, but also when other pedestrians are drawn to the roadway for local access purposes. Additionally, this research may inform future research about the suitability of Frank's walkability index as a measure of pedestrian risk of injury.

Preliminary Analysis of Pedestrian-Motor Vehicle Collision Features

This analysis is limited to factors of the built environment that do not vary temporally. However, factors such as time-of-day, month-of-year, road conditions, lighting conditions, etc. are undoubtedly operating and, if unevenly distributed, these factors could confound our findings. Prior to analysis of features of the built environment, we evaluated variance of these factors.

Collision Characteristics

Overall, there were 60 collisions along primary arterials in Clark County, Washington during 2007-2009 that involved both a pedestrian and a motor vehicle. Of these, 42 occurred within the City of Vancouver, and the other 18 occurred within unincorporated Clark County. Detailed data for two collisions in the City of Vancouver were missing.

Temporally Varying Characteristics of Collisions (Table 1)

Collisions occurred throughout the year, though there were marked increases in collisions during the winter months of December (19%) and January (12%). This might be expected because these months have fewer daylight hours and a higher likelihood of inclement weather. However, lighting conditions at the time of collisions were typically daylight (62%). Road condition data were available for only 34 of the 60 collisions. Of these, 27 collisions (79%) occurred with dry road conditions (Table 2). Most collisions occurred during the afternoon hours of 2:00-8:00 PM. More collisions occurred on Mondays than any other day (24%), while the fewest collisions occurred on Sundays (5%).

Table 1: Temporal variations in collision occurrence*

Feature		Count (%)
Month		
	January	7 (12%)
	February	3 (5%)
	March	4 (7%)
	April	4 (7%)
	May	1 (2%)
	June	6 (10%)
	July	3 (5%)
	August	6 (10%)
	September	4 (7%)
	October	5 (9%)
	November	4 (7%)
	December	11 (19%)
Hour of collision occurrence		
	12:00-5:59	0 (0%)
	6:00-9:59	7 (12%)
	10:00-1:59	10 (18%)
	2:00-7:59	32 (56%)
	8:00-11:59	8 (14%)
Day of collision occurrence		
	Sunday	3 (5%)
	Monday	14 (24%)
	Tuesday	5 (9%)
	Wednesday	8 (14%)
	Thursday	11 (19%)
	Friday	10 (17%)
	Saturday	7 (12%)

*Data for two collisions were missing

Table 2: Lighting and roadway conditions at time of collision*

Lighting conditions		
	Daylight	36 (62%)
	Dark with streetlights	17 (29%)
	Dark without streetlights	3 (5%)
	Dusk	2 (4%)
Road conditions		
	Dry	27 (79%)
	Wet	5 (15%)
	Snowy/slushy	1 (3%)
	Icy	1 (3%)

*Data for two collisions were missing

Individual Characteristics

Demographic information (Table 3) about individuals involved the collisions were available only for collisions occurring in the City of Vancouver (n = 42). Pedestrians were on average 36.9 years old (range: 12-88, SD = 22.9) and motor vehicle drivers were on average 45.2 years old (range: 16-77, SD = 16.3). Drivers were more often female than male (57% vs. 43%), while pedestrians were more often male than female (54% vs. 46%). Most collisions resulted in some form of injury, with disabling injuries occurring in 16% of collisions, and death resulting in 14% of collisions (Table 4). Only 9% of collisions resulted in no injury. Race and ethnicity data were not available. Additionally, data describing negligence (i.e., whether the driver or pedestrian were considered at-fault in the collision) were not available.

Table 3: Demographic characteristics of collision participants

Characteristic	Driver	Pedestrian
Gender		
Male	15 (43%)	22 (54%)
Female	20 (57%)	19(46%)
Age, years		
Mean (Range)	45 (16-77)	37 (12-88)

Table 4: Injury severity

Severity of injury	
No injury	5 (9%)
Possible injury	19 (33%)
Non-disabling injury	17 (29%)
Disabling injury	9 (16%)
Dead at scene or dead on arrival	8 (14%)

Methods

Overview

This study analyzed the built environment surrounding 60 pedestrian-motor vehicle collision (PMVC) sites and 120 "control" sites (locations where collisions had not occurred). We measured features of the built environment within "walking distance" (250 feet) of each location and compared differences between collision locations and control locations using logistic regression. We then narrowed our analysis to only the area surrounding transit stops. Using a matched case-control design for this transit-specific analysis, we attempted to identify possible predictors of "safe" and "unsafe" transit stops to help inform future research.

Study Sample

This case-control analysis used data from Clark County, Washington to assess whether an association between nearby transit stop usage and pedestrian collision locations is exhibited, as has been previously reported in other jurisdictions.

Unlike typical case-control studies, which compare individuals with (case) and without (control) a particular disease (outcome), this case-control study compared locations where collisions occurred (case locations) to locations where no reported collisions occurred (control locations) during the study period, 2007-2009. This method of using locations rather than individuals has been used previously by Hess and colleagues to analyze relationships between the built environment and pedestrian injury.[21]

Control Selection

Control sites were selected to be representative of the same geographical area and roadway type from which collision sites arose. As such, control locations were limited to occurring on primary arterials, and were frequency matched by data source. Of the 60 total collisions, 42 occurred within the City of Vancouver and were reported by the City of Vancouver Police. The remaining 18 collisions occurred in unincorporated Clark County, and were reported by the Clark County Sherriff.

By frequency matching by data source, we sought to minimize various potential biases. For example, less serious collisions may go unreported more often in unincorporated areas where law enforcement is not as readily available. Additionally, there may have been differences in how collisions were reported between the two agencies. Ultimately, locations within the City of Vancouver vs. unincorporated Clark County may simply possess differences not measured by variables within our dataset.

Within the constraints of locations along primary arterials, and frequency matched by data source, control locations were randomly generated along the network of primary arterials using ArcGIS software. These points were generated through a multi-step process. First, a one-inch buffer was created around each primary arterial. These buffers were then merged into one buffer, thereby forming a polygon that contained the entire network of primary arterials. The polygon was then cut into two polygons using the City of Vancouver boundary to allow for frequency matching. Using the "random point generation" function in ArcGIS, we then created control locations at a 2:1 ratio of controls to cases.

Figure 1 illustrates the case and control locations for our analysis of characteristics of the built environment surrounding PMVCs (Specific Aims 1 and 2). Figure 2 illustrates case and control transit stops for our analysis of characteristics of the built environment specifically surrounding transit stops with nearby collisions (Specific Aim 3). Areas not included in either analysis included Battle Ground, Camas, Woodland, La Center, Yacolt, Ridgefield and Washougal. Collisions in these municipalities are reported to their respective authorities, and were therefore not represented by the data from the City of Vancouver Police or Clark County Sherriff. Further, it should be noted that primary arterials located in these municipalities were not included as potential locations during control selection.

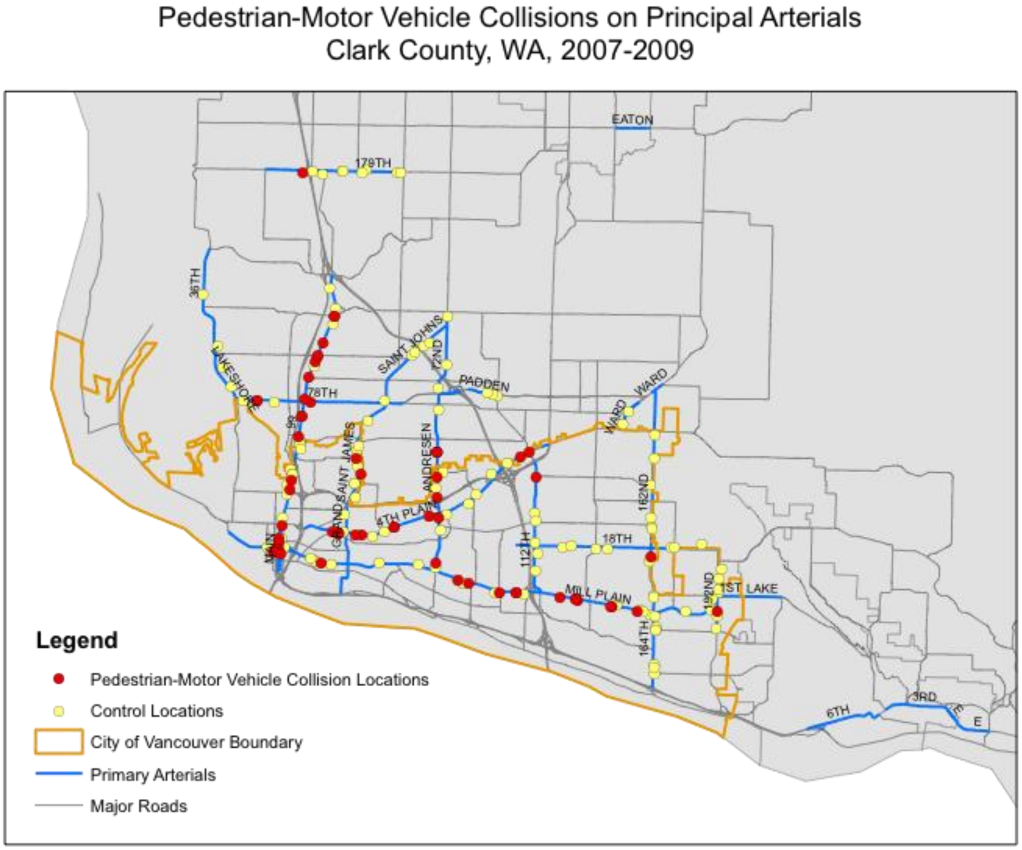

Figure 1: Pedestrian-motor vehicle collision locations and control locations (specific aims 1 and 2)

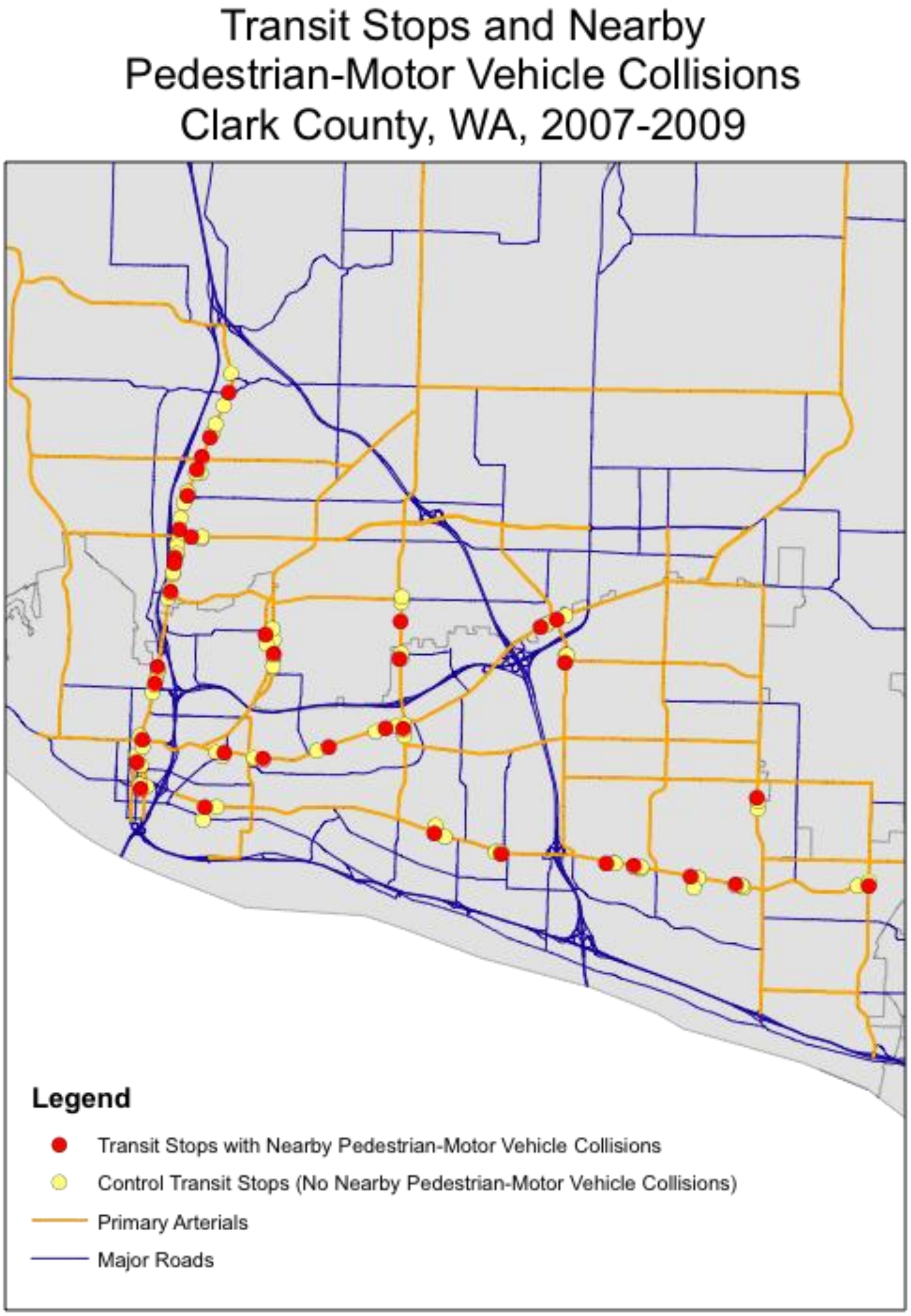

Figure 2: Transit stops with nearby collisions and their matched control locations (specific aim 3)

Inclusion and Exclusion Criteria

Collisions were eligible for inclusion in the study according to the criteria described in Table 3. Our final dataset included 60 PMVCs. The exclusion algorithm is outlined in Figure 3.

Table 5: Inclusion and exclusion criteria for collisions

Inclusion Criteria	Exclusion Criteria
At least one pedestrian and one motor vehicle must have been involved	Nearby construction
Collision must have occurred on primary arterial	
Occurrence during 2007-2009	

Because preliminary analyses showed a strong correlation between road type and the occurrence of a pedestrian-motor vehicle collision, collision sites were restricted to those occurring on principal arterials. All other road types were excluded from this analysis.

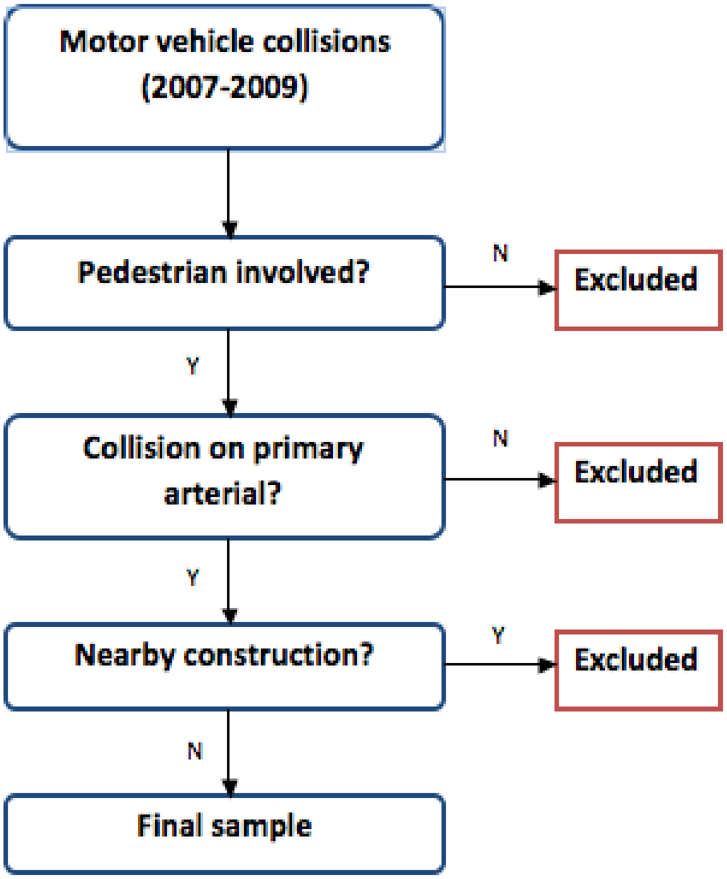

Figure 3: Algorithm for identifying collisions eligible for inclusion in the analysis

Additionally, some aspects of the built environment at the time of a collision may have been transient, such as nearby construction work. Therefore, any collisions with noted nearby construction were to be excluded from the analysis. Collision reports were inspected and news reports for Clark County were searched to reveal any mention of nearby construction, but none were found. Therefore, no collisions were excluded because of this criterion.

We elected not to exclude any particular population of individuals involved in collisions, such as the disabled, elderly, or children. These populations, though they may be at increased risk of injury, are also populations that are high users of transit services. Inclusion of these subgroups in the analysis will better inform this research on how to make areas surrounding transit facilities safer.

Variables

Variables included in the primary analysis (i.e., Specific Aims 1 and 2) are described in Table 7. Variables for the transit-specific analysis (i.e., Specific Aim 3) are described in Table 8. Data sources for all variables are described in Appendix B.

Primary Outcome Variables

The outcome variable – "collision" – indicates whether a collision involving a pedestrian and a motor vehicle occurred at the specified location during the three-year period, 2007-2009. Case data (collision data) were obtained from the City of Vancouver Police Department for collisions occurring within the City of Vancouver boundary. For collisions occurring within unincorporated Clark County, data were obtained from the Clark County Sherriff's Office.

Primary Predictor Variables

The predictor variable of interest is that of nearby transit stop usage. Transit stop locations were obtained as a shapefile from the local mass transit provider, C-TRAN. Monthly passenger counts were provided as separate Excel documents. Because data specifically describing our entire study period (2007-2009) were not available, data from 2010 were used. Because the transit network was largely unchanged between our study period and the time of the passenger count data collection, these data should provide an adequate picture of transit stop usage for our study period.

However, there have been some small changes in the transit network in Clark County. Only stops that were present for the entire study period were included in this analysis. All of the stops excluded for this reason were very low-volume stops and exclusion of these stops should not substantially influence our generalizabilty to the entire study area.

Monthly passenger counts were combined to generate a monthly average for each transit stop. These counts were then spatially attributed to each stop using ArcGIS 9.3. A 250-foot network buffer was created surrounding each collision point and control point. The size of the buffer was chosen both to correspond with a one-block radius and to align our methods with those of Hess[21] so that our results can be compared more readily. A spatial join then captured all of the stops within the buffer for each case/control location, and passenger counts were summed to provide the total number of boardings and alightings occurring within 250 feet of each location.

Covariates

Most covariates describing the built environment were compiled using ArcGIS 9.3. A 1-kilometer network buffer was created surrounding each collision point and control point, as this is the distance typically used within urban planning as "walking distance." Various attributes of the built environment will be spatially joined to these "walking-distance" buffers. These included both point features (park access points, high traffic volume intersections) and polygon features (schools, alcohol outlets, supermarkets).

Other built environment characteristics were calculated using GIS software, as well. These included street connectivity, residential density, retail floor area ratio, and an entropy index (used as an indicator of the heterogeneity of the land use within the buffer). These were used to create a composite variable considered to represent "walkability." This measure was developed by Frank and colleagues and has been accepted for use in research regarding health and the built environment.[23] Higher walkability scores indicate a more walkable environment.

Other road characteristics were assessed for inclusion in the analysis. These included the presence of sidewalks on either or both sides of the street using data from Clark County GIS and the City of Vancouver.

Various demographic measures of the area population – age, gender, ethnicity and race – were obtained from the Census Bureau. These variables were included in the analysis to control for confounding.

Statistical Analysis

Statistical analyses were performed using Stata (v. 11) and PASS (v. 11).

<u>Descriptive Analysis</u>

(1) *Built Environment Characteristics Surrounding PMVC and Control Locations*

Included in this study are 60 case locations and 120 control locations, for a total sample size of 180 locations. Because of the method by which the dataset was compiled, there were no missing values for our primary predictor variable or any of the covariates. Descriptive statistics were prepared for all variables. Continuous variables were described in terms of frequency, mean, and standard deviation. Frequencies and percentages were calculated for categorical variables.

(2) *Built Environment Characteristics Surrounding Transit Stops*

For the period 2007-2009, 480 transit stops were located along principal arterials within the C-TRAN network. For each pedestrian-motor vehicle collision occurring during this period that was within 250 ft of a transit stop, the stop closest to the collision was selected as a case site. This resulted in 36 case stop locations. Case sites were matched to controls at a 1:2 ratio. Case-control matching was performed by pairing case sites with the two nearest transit stops that were at least 250 feet away from a collision. This yielded a total sample size of 108.

Logistic Regression

(1) *Identifying Predictors of PMVC Locations (Specific Aim 2)*

Univariate analyses were conducted using contingency tables (Pearson's chi-square) to analyze categorical variables and t-tests to analyze continuous variables. Independent variables associated with the outcome at the $p < 0.20$ level were considered for inclusion in the model. Additionally, variables that were suspected of being confounders were considered.

We used a forward stepwise selection procedure to narrow the list of candidate independent variables further. During this procedure, a statistical significance < 0.20 was required for addition to the model, while a statistical significance > 0.15 resulted in elimination from the model. Because the volume of passengers boarding and alighting from nearby transit was our predictor of interest, this variable was forced into the model and not subjected to the stepwise selection procedure.

Variables remaining after the stepwise selection procedure were then evaluated for their necessity in the overall model. We manually removed the variable with the highest p-value from the model and compared the resulting model using a likelihood ratio test. If the likelihood ratio test indicated that the resulting model was not significantly different than the preliminary main effects model, the variable was removed, and the variable with the next highest p-value underwent the same procedure until the likelihood ratio test indicated that all variables were significant.

The resulting variables were evaluated for possible interactions, specifically focusing on possible interactions between the predictor of interest and the other variables. We then assessed scaling of continuous variables.

(2) *Identifying Transit Stops That May be More Likely to Have Nearby PMVCs (Specific Aim 3)*

The model-building process for Specific Aim 3 differed from the analysis used to address Specific Aim 1 because cases and controls were specifically matched (1:2) in the transit-specific analysis, whereas those in the prior analysis were frequency matched by jurisdiction. Therefore, conditional logistic models were used in the transit-specific portion. Conditional logistic models allow analysis of predictors where observations are not independent because they are matched, while also allowing matching of 1:k sets ($k = 2$ in this analysis). To determine whether an independent variable may be valuable in a multivariate model, univariate conditional logistic regression models were first created between the outcome and each independent variable. Variables were considered for inclusion in the multivariate model when they were found to be associated with the outcome at the $p < 0.20$ level. By spatially matching cases and controls, we attempted to control for unmeasured and unknown confounders.

We used a forward stepwise selection procedure to narrow the list of candidate independent variables further. During this procedure, a statistical significance < 0.20 was required for addition to the model, while a statistical significance > 0.15 resulted in elimination from the model. Because this was an exploratory analysis that was designed to be hypothesis-generating for future research, no variables were forced into the model.

Variables remaining after the stepwise selection procedure were then evaluated for their necessity in the overall model. We manually removed the variable with the highest p-value from the model and compared the resulting model using a likelihood ratio test. If the likelihood ratio test indicated that the resulting model was not significantly different than the preliminary main effects model, the variable was removed, and the variable with the next highest p-value underwent the same procedure until the likelihood ratio test indicated that all variables were significant.

The resulting variables were evaluated for possible interactions. We then assessed scaling of continuous variables.

<u>Power</u>

A power analysis was conducted a priori using PASS software v. 11, which indicated that the present study would have approximately 82% power at $\alpha = 0.05$ to detect a change in the probability of a collision occurring from the value of 0.33 at the mean number of nearby transit stops to 0.43 when the number of transit stops is increased to one standard deviation above the mean. This corresponds to an odds ratio of 1.5. Further, this study would have more than 95% power to detect an odds ratio of 1.7, and more than 99% power to detect an odds ratio of 1.9.

Results

Built Environment Characteristics Surrounding PMVC and Control Locations (Specific Aim 1)

Descriptors of the built environment surrounding collision locations and control locations are presented in Table 6. On average, collisions were located within walking distance (1 km) of three park access points, approximately 13 licensed alcohol outlets, two schools, and two high traffic volume intersections. More than 90% of collisions occurred in locations with sidewalks on both sides of the street, compared to just over 60% for control locations. Additionally, census demographics indicated that collision locations had, on average, a greater Hispanic population, but smaller White and youth populations when compared to control locations. Walkability of the areas surrounding collision locations was typically higher than control locations. Transit stop usage was also higher on average surrounding collision locations compared to control locations, with more than 17,000 additional boardings and alightings per month on average.

Table 6: Descriptive statistics of the built environment characteristics surrounding collision (case) locations and control locations

Variable Name	Definition	Cases (n = 60)	Controls (n = 120)
		Mean (range) or Frequency (percent)	Mean (range) or Frequency (percent)
Jurisdiction	0 = Unincorporated Clark County 1 = City of Vancouver	0 = 18 1 = 42	0 = 36 1 = 84
Parks	Number of park access points within 1 km walking distance	2.9 (0-11.0)	2.4 (0.0-11.0)
ETOH	Number of alcohol outlets within 1 km walking distance	13.6 (1-44)	6.5 (0.0-43.0)
Schools	Number of schools within 1 km walking distance	2.0 (0.0-5.0)	1.4 (0.0-6.0)
Income	Median household income	$39,352 ($6,985 - $86,197)	$48,272 ($13,300-$100,449)
NoVehicle	Percentage of households without motor vehicle(s)	10.4% (0.0% - 49.5%)	5.8% (0.0% -35.7%)
Female	Proportion of population that is female	51.0% (32.7%-57.1%)	50.6% (47.0% - 57.1%)
Hispanic	Proportion of population that is Hispanic	8.5% (1.5%-29.6%)	5.3% (1.4% - 29.6%)
White	Proportion of population that is White	84.5% (68.1%-94.0%)	87.0% (64.8% - 94.4%)
Youth	Proportion of population that is 14 years old or younger	21.5% (4.2%-30.7%)	23.4% (4.2% - 33.3%)
Speed	Posted speed limit (miles per hour)	25 = 8 (13.3) 30 = 7 (11.7) 35 = 27 (45.0) 40 = 18 (30.0) 45 = 0 50 = 0	25 = 5 (4.2) 30 = 10 (8.3) 35 = 40 (33.3) 40 = 53 (44.2) 45 = 9 (7.5) 50 = 3 (2.5)
Sidewalk	0 = no sidewalks present 1 = sidewalk present on one side of the road 2 = sidewalks present on both sides of the road	0 = 4 (6.7) 1 = 1 (1.7) 2 = (91.7)	0 = 38 (31.7) 1 = 8 (6.7) 2 = 74 (61.7)
Transit	Average monthly boarding and alightings at transit stop	30,086 (0-136,522)	12,688 (0 – 138,918)
Supermarkets	Number of supermarkets within 1 km walking distance	0 = 28 (46.7) 1 = 32 (53.3)	0 = 85 (70.8) 1 = 35 (29.2)
Traffic	Number of high traffic intersections within 1 km walking distance buffer; high traffic = greater than 38,000 daily volume as defined by RTC	2.4 (0-7)	1.7 (0-6)
Walkability	Composite measure: Walkability = 2 * [Z(entropy) + Z(residential density) + Z(retail FAR) + Z(connectivity)]	1.8 (-3.4-11.2)	0.49 (-3.8 – 8.3)

Identifying Predictors of PMVC Locations (Specific Aim 2)

Only one independent variable was eliminated after conducting univariate analyses nearby access to parks (p = 0.25). All other variables were significantly associated with the outcome at the 0.20 level. Because the number of variables remaining under consideration was still large and we sought the most parsimonious model, we utilized a forward stepwise selection procedure. Our predictor of interest, transit volume, was forced into the model and did not undergo stepwise selection for inclusion in the model. The stepwise procedure yielded two additional significant built environment variables: sidewalk presence and presence of nearby supermarkets. The stepwise procedure also identified various demographic features that were associated with collision locations: areas with Hispanic populations in the top quartile, as well as areas with White populations in the second and third quartiles.

The plausibility of any interaction terms was then individually assessed using likelihood ratio tests. After Bonferroni adjustment for multiple comparisons, no interaction terms were found to add significantly to the model. We examined the lowess curve of Transit (transit boardings and alightings) to assess whether the variable should have alternate scaling. After testing quartiles, tertiles and a dichotomous split at the median, we found that only a dichotomous split at the median produced significant results. We then compared the model with transit passenger volume as a continuous variable to the model with transit passenger volume split at the median, and found that the original, ungrouped model was still preferable because it maximized the log likelihood of the model. Additionally, AIC and BIC values of the two models both indicated that the model with ungrouped transit passenger volume was a better fit for the data, as this model minimized the AIC and BIC.

In our final model (Table 7), the volume of passengers boarding and alighting from nearby transit stops was significantly associated with the occurrence of a pedestrian-motor vehicle collision ($p = 0.02$). After adjustment for nearby supermarkets, the presence of sidewalks at the location, nearby high traffic volume intersections, and the proportion of the residential population identifying as white, the odds of a location being the site of a PMVC increased by more than 32% for every 10,000 increase in monthly passenger volume (OR = 1.32, 95% CI: 1.02 – 1.71).

Table 7: Univariate and multivariate analyses of characteristics of the built environment surrounding pedestrian-motor vehicle collisions

Variable		Univariate p-value*	Multivariate OR (95% CI)
Parkaccess	(# nearby park access points)	0.25	*NS*
Alcohol	(#nearby licensed alcohol outlets)	< 0.01	*NS*
Schools	(# nearby schools)	0.01	*NS*
Speed	(posted speed limit of road)	< 0.01	*NS*
Sidewalk		< 0.01	
	None present		*Reference*
	Present on one side of road		0.26 (0.02-3.55)
	Present on both sides		4.27 (1.16-15.8)
Supermarkets		< 0.01	
	No nearby supermarkets		*Reference*
	One nearby supermarket		4.09 (1.71 – 9.79)
Fast_food	(# nearby fast-food restaurants)	< 0.01	*NS*
Traffic	(# nearby high traffic volume intersections)	< 0.01	1.32 (1.02 – 1.71)
Income	(median)	0.02	*NS*
Females	(proportion of population)	0.04	*NS*
Hispanic	(proportion of population)	< 0.01	*NS*
Non-White	(proportion of population)	< 0.01	
	Highest quartile		*Reference*
	3rd quartile		4.35 (1.42-13.3)
	2nd quartile		8.37 (2.69-26.1)
	Lowest quartile		0.41 (0.11 – 1.50)
Youth	(proportion of population)	0.06	*NS*
No_vehicle	(proportion of residents without motor vehicle)	< 0.01	*NS*
Walkability	(index)	< 0.01	*NS*
Transit	(10,000 monthly nearby passenger boardings and alightings)	< 0.01	1.24 (1.06-1.43)

*Categorical variables tested by chi square test; continuous variables tested by t-test
NS = not significant

The fit of the model was evaluated using the Hosmer and Lemeshow goodness-of-fit statistic, which indicated that the model fits the data well (chi-square = 4.18, 8 d.f., p = 0.84). The optimal cut-point was determined to be 0.33, which maximized the sensitivity (71.67%) and specificity (78.33%) of our model, thereby resulting in 76.11% of the data being correctly classified. The ROC curve for our model is shown in Figure 4. The area under the curve was 0.83, indicating that our model has excellent discriminative ability.

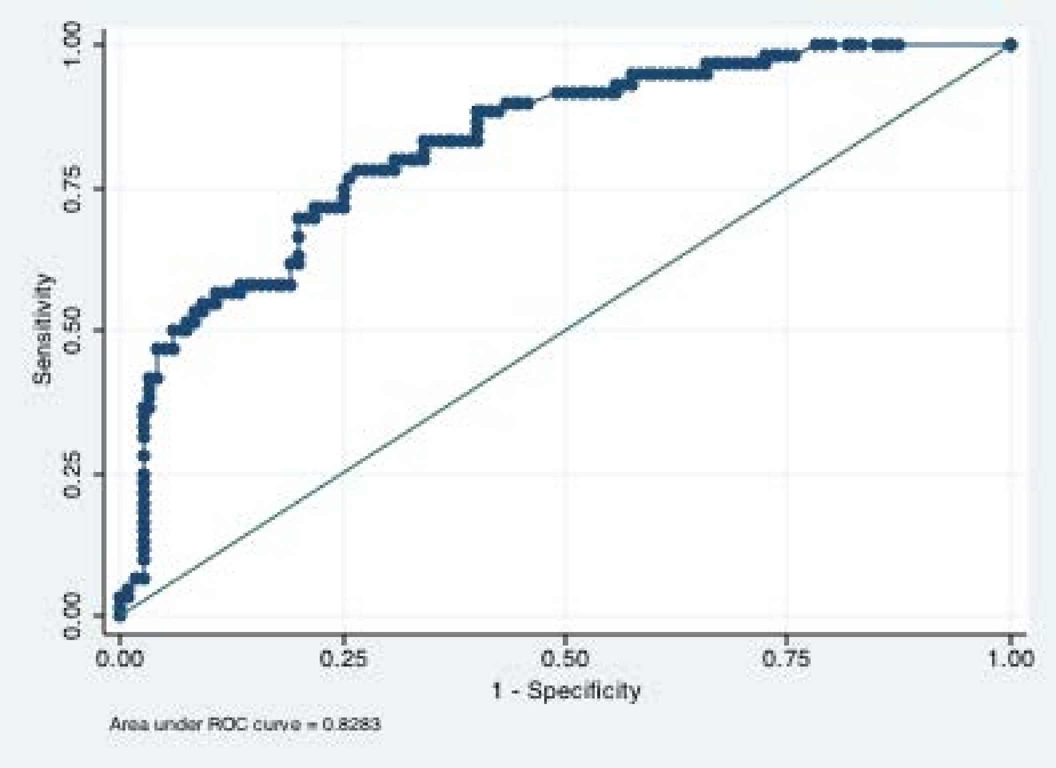

Figure 4: ROC curve of final model to predict odds of pedestrian-motor vehicle collision

Identifying Transit Stops That May be More Likely to Have Nearby PMVCs (Specific Aim 3)

Table 8 presents characteristics for transit stops with nearby collisions (cases) and matched control transit stops. Initial analysis of the built environment specifically surrounding transit stops indicated that stops with nearby collisions were those that had greater utilization. A similar difference was observed between the case and control stops. Mean monthly alightings and boardings were 1,388 at case stops and 858 at control stops (Table 8). Approximately 8.3% of stops with nearby collisions were within one block of a school, compared to 5.6% of control locations. Both case and control transit stops were typically on roads with posted speed limits greater than 35 miles per hour. Similar to our initial analysis, most collision locations had sidewalk on both sides of the roadway. Average walkability scores between case locations and control locations differed only very slightly, with case locations having slightly higher walkability scores on average. The greatest differences between case locations and control locations were those of transit utilization at the stop, and proximity to at least one high traffic volume intersection.

Table 8: Descriptive statistics of the built environment characteristics surrounding transit stops with nearby collisions (cases) and matched control transit stops

Variable Name	Definition	Cases (n = 60)	Controls (n = 120)
		Mean (range) or Frequency (percent)	Mean (range) or Frequency (percent)
ID	Unique identifier	N/A	N/A
Parks	Number of park access points within 250 ft walking distance	0 = 35 (97.2) 1 = 1 (2.8)	0 = 71 (98.6) 1 = 1 (1.4)
ETOH	Number of alcohol outlets within 250 ft walking distance	0 = 25 (69.4) 1 = 10 (27.8) 2 = 1 (2.8) 3 = 0 (0.0) 4 = 0 (0.0)	0 = 53 (73.6) 1 = 13 (18.1) 2 = 4 (5.6) 3 = 0 (0.0) 4 = 2 (2.8)
Schools	Number of schools within 250 ft walking distance	0 = 33 (91.7) 1 = 3 (8.3)	0 = 68 (94.4) 1 = 4 (5.6)
Speed	Posted speed limit (MPH)	10 = 2 (5.6) 20 = 0 25 = 3 (8.3) 30 = 4 (11.1) 35 = 18 (50.0) 40 =9 (25.0)	10 = 1 (1.4) 20 = 1 (1.4) 25 = 12 (16.7) 30 = 7 9.7) 35 = 32 (44.4) 40 = 19 (26.4)
Sidewalk	0 = no sidewalks present 1 = sidewalk present on one side of the road 2 = sidewalks present on both sides of the road	0 = 2 (5.6) 1 = 2 (5.6) 2 = 32 (88.9)	0 = 8 (11.3) 1 = 4 (5.6) 2 = 59 (83.1)
Transit	Average monthly boarding and alightings at transit stop	1388 (5-16550)	858 (0-8219)
Supermarkets	Number of supermarkets within 250 ft walking distance	0 = 31 (86.1) 1 = 1 (13.9)	0 = 62 (86.1) 1 = 10 (13.9)
ADT_big	0 = no nearby high traffic volume intersection 1 = at least one nearby high traffic volume intersection high traffic = greater than 38,000 daily volume as defined by RTC	0 = 23 (63.9) 1 = 13 (36.1)	0 = 62 (86.1) 1 = 10 (13.9)
Walkability	Composite measure: Walkability = 2 * [Z(entropy) + Z(residential density) + Z(retail FAR) + Z(connectivity)]	1.69 (-3.03-8.33)	1.82 (-3.03-8.33)

Eight independent variables were eliminated after conducting univariate analyses: parks (p = 1.0), schools (p = 0.43), supermarkets (p = 1.0), sidewalks (p = 0.21), speed limit (0.90), alcohol (p = 0.62), fast food (p = 0.62), and walkability (p = 0.57).

Two variables, adt_big (p = 0.01) and transit (0.15) were significantly associated with the outcome at the 0.20 level (Table 9). The stepwise selection procedure was unnecessary because only two independent variables were eligible for inclusion in the model. Likelihood ratio tests indicated that the model including both adt_big and transit had the best predictive value (p = 0.046 compared to reduced model with only adt_big).

Table 9: Univariate and multivariate analyses of characteristics of the built environment surrounding transit stops with and without nearby collisions

Variable	Univariate p-value*	Multivariate OR (95% CI)
Parkaccess (# nearby park access points)	1.0	*NS*
Alcohol (#nearby licensed alcohol outlets)	0.62	*NS*
Schools (# nearby schools)	0.43	*NS*
Speed (posted speed limit of road)	0.90	*NS*
Sidewalk	0.21	*NS*
Supermarkets	1.0	*NS*
Fastfood (# nearby fast-food restaurants)	0.62	*NS*
Traffic	0.01	
No nearby high-volume traffic intersections		Reference
At least one high-volume intersection		4.53 (1.47-13.93)
Walkability (index)	0.57	*NS*
Transit (1,000 monthly nearby passenger boardings and alightings)	0.15	1.52 (0.88-2.65)

*Categorical variables tested by chi square test; continuous variables tested by t-test
NS = not significant

The plausibility of an interaction term between ADT_big and transit was then also assessed using a likelihood ratio test, which indicated that the interaction did not significantly add to the model (p = 0.83 compared to the reduced model). We examined the lowess curve of transit to assess whether the variable should have alternate scaling. We compared models that split transit ridership into quartiles, tertiles and a dichotomous split at the median. Although models approached significance at the alpha = 0.05 level, none reached significance. The most promising of these was the model including transit boardings and alightings split into tertiles (p = 0.058). However, we found that the model with transit as a continuous variable remained preferable because it maximized the log likelihood of the model. Additionally, AIC and BIC values of the continuous-transit model and the tertile-transit model both indicated that the model with transit passenger volume was a better fit for the data.

The fit of the model was evaluated by comparing the model to an intercept-only model. Both AIC and BIC values suggested that the intercept-only model was a better fit as it minimized both values, which indicated that the built model was an overall poor fit for the data.

Discussion

Identifying Predictors of PMVC Locations (Specific Aims 1 and 2)

Transit stop usage was a significant predictor of the presence of a PMVC site. This finding, which agrees with Hess,[21] may be interpreted a number of ways. Because we had no direct measure of pedestrian volume, part of this finding may be attributed to the possibility that transit stops are located closer to areas with more pedestrian generators. However, our analysis did control for the number of nearby supermarkets. Because supermarkets act as pedestrian generators, the supermarkets variable acts as a crude proxy for the pedestrian volume within the area, thereby controlling for pedestrian volume to a certain extent. Since transit stop usage was significant even after adjustment for nearby supermarkets, this may suggest that transit passengers have increased odds of being in a PMVC over other pedestrians.

Perhaps unexpectedly, our analysis also found that roadway locations with an immediately adjacent sidewalk have higher odds of being a PMVC site (OR = 4.27, 95% CI: 1.16 – 15.8, p = 0.015). This finding's wide confidence interval indicates a lack of precision. However, the magnitude of the point estimate is considerable. Because sidewalks are protective features of the built environment that contribute to pedestrian safety, this finding is counterintuitive. This finding raises questions regarding Clark County's sidewalk network, utilization of these facilities, along with potential inadequacies in our study design. Various measures were not included in our analysis, such as the contiguity of the sidewalk network along primary arterials or the visibility of pedestrians on sidewalks. However, such factors could alter the risk of pedestrian-motor vehicle collisions.

Another issue to consider may be how the presence of sidewalks correlates with the presence of adequate bicycle lanes in the roadway. If bicycle facilities on the roadway are lacking, some cyclists may feel safer on the sidewalk, putting both cyclists and pedestrians at higher risk for collision and injury.[26-28] However, while any of these factors may explain the positive association of sidewalks and PMVC sites in part, it is most likely that the analysis simply did not control well enough for pedestrian activity.

Additionally, our analysis identified one demographic characteristic that was predictive of our outcome measure. In areas where the proportion of non-Whites was between the 25th and 75th percentiles, the odds of being a PMVC site increased. For decades, previous research has suggested that socioeconomic disparities are associated with increased risk of pedestrian injury, particularly among children.[1] In areas with more crowding, where disadvantaged populations disproportionately reside, individuals spend more time outside. The sidewalk or roadway may act as the front yard for families living in such dense areas, thereby increasing their exposure. Additionally, individuals of lower socioeconomic status are less likely to own a vehicle and more likely to rely on public transportation for utilitarian (commuting) and recreational travel. The National Highway Traffic Safety Administration noted in their 2008 National Pedestrian Collision Report that minorities have a higher incidence of pedestrian injury.[1] Consistent with our findings, the NHTSA report notes that the incidence of pedestrian injury is higher among non-Whites than Whites.[1]

Identifying Transit Stops That May be More Likely to Have Nearby PMVCs (Specific Aim 3)

Our transit-specific analysis found that transit stops with higher transit passenger volume and nearby high-volume traffic intersections were more likely to be near sites of pedestrian-motor vehicle collisions. These findings are not particularly surprising because they capture measures of pedestrian and motor vehicle exposure at the location. However, because we matched case transit stops to nearby collision-free control transit stops, it is possible that nearby control stops also had a significant amount of traffic volume on the adjacent roadway.

From this analysis, it is difficult to ascertain whether this finding suggests that proximity to an intersection, or whether high traffic volume increases the likelihood of a pedestrian motor vehicle collision occurring near a transit stop. Traffic counters are typically placed at well-traveled intersections, but if one roadway had significantly less traffic than the intersecting roadway, traffic counts may be the same (if on the high traffic roadway) or significantly lower (if on the intersecting, lower traffic roadway) at a nearby midblock location. Although traffic counts were not available for mid-block locations, the 250-foot buffer was chosen because it encompasses slightly more than a one-block radius. Therefore, nearby intersections should have been captured in this buffer. This supports the interpretation that proximity to high traffic volume, not solely proximity to an intersection, increases the likelihood of a PMVC occurring near a transit stop.

Our finding that the transit-specific model was a poor fit for the data was not surprising. The pseudo R^2 from the best model indicated that variation in our predictors accounted for only roughly 14% of variation in the outcome. There are clearly other factors that play an important role in collision occurrence near transit stops, including both unmeasured environmental factors and human factors.

Walkability of area surrounding transit stops was not found to be a significant predictor in either of the analyses. The transit-specific analysis matched case transit stops to the next closest control transit stops, so it is quite possible that there was not enough variation in the walking environments to identify a change. However, the more randomized sampling used in the initial analysis identified locations with a wide range of walkability scores, yet walkability was not significantly statistically associated with the outcome in the multivariate model.

Since control sites were selected in the analysis of transit stops by selecting the next closest stop, cases and controls may have been overmatched. Selection of a more distant control stop would have introduced more variation in walkability scores allowing differences to be detected more easily. We performed a post hoc comparison of the control sites used to those that would have been selected if the third and fourth closest stops had been selected as controls and found a mean increase of 0.76 units in control location walkability score. However, matching to more distant locations may also diminish the underlying value of matching methodology, i.e., to help control for any unmeasured confounders, assuming they are evenly spatially distributed.

Ultimately, our findings do not support use of Frank's walkability index as a stand-alone indicator of relative pedestrian safety. There are other factors that could be integrated into a pedestrian safety index, such as crime rate, street lighting, pedestrian crossings, etc.

The population of Clark County is characterized by its reliance on motor vehicle transportation, particularly for commuting. In 2010, there were 2.75 registered vehicles per household, and 78.0% of employed individuals drove alone to work. Additionally, mean travel time to work has steadily increased among Clark County residents, rising from 21.2 minutes in 1990 to 24.9 minutes in 2009.[29]

Geographically, the county lies in southwestern Washington, along the Washington-Oregon border. The county seat, Vancouver, is the largest city and is situated across the Columbia River from Portland, Oregon. As such, the Clark County economy is closely linked with that of the Portland metropolitan area, and more than one third (35.2%) of Clark County residents work outside the county. The use of active transportation among County residents for commuting is lower than national estimates. The Census Bureau reports that 2.8% of the population nationally walks to work, but only 1.2% of Clark County residents do so. Similarly, use of public transit for commuting is lower in Clark County than the national average (2.4% in Clark County vs. 4.9% nationally).

In 2008, 64% of adults in Clark County were overweight or obese.[30] Despite the geoeconomic challenges of Clark County, where many residents work outside of the county, opportunities for active living should be maximized. This includes ensuring that residents feel safe enough to walk or bike to work without fearing injury. Given the relatively low proportion of individuals who do choose active transportation to work, there is room for improvement. However, active transportation is not limited to commuting practices. It also encompasses the modes of travel people choose for day-to-day activities, including trips to school, the grocery store, or recreational destinations. For individuals who must use motor vehicle transportation to their work site, encouraging active transportation for non-work trips is especially important.

Strengths and Limitations

Several potential limitations must be considered in the interpretation of these findings. As with any case-control study, there is a potential for selection bias. This bias may occur from differential selection of cases, controls, or both. In this study, this may have manifested as case selection bias if our cases were not representative of all pedestrian injuries occurring in Clark County. While any location with a collision including both a motor vehicle and a pedestrian during 2007-2009 in Clark County met our inclusion criteria, the source of our data was likely limited to only more serious collision locations. Our data came from law enforcement reports, so any collisions that were less severe may not have been reported to law enforcement. In such an instance, this bias may produce either an overestimate or underestimate of the association, depending on the situation. For example, if it is the culture in some communities to notify police in emergency situations, these areas may appear to have fewer environmental risk factors than they really do because of small-collision underreporting. However, in more disjointed communities, there may be more cultural tension and a propensity to report any collision to the police. Since all collision sites were weighted equally, regardless of severity of injury, such inherent selection bias may have ultimately created a confounding effect.

Similarly, selection of the controls in our primary analysis may have introduced bias. Cases and controls were frequency matched by jurisdiction (City of Vancouver vs. unincorporated Clark County), but were not matched on other factors. It is possible that locations were selected as controls that were not representative of the population that produced the cases. For example, since we have no direct measure of pedestrian activity, control sites may have been selected where there is essentially no pedestrian traffic. Environmental features of these sites would be erroneously categorized as resilience factors that make the environment at that location appear safer than it actually is.

Public Health Implications and Future Studies

Findings from our analysis support the hypothesis that locations with greater nearby transit boardings and alightings are more likely to have a PMVC. Using supermarkets as a proxy to control for pedestrian volume, this suggests that transit riders may be at a higher risk for collision with a motor vehicle than other pedestrians. Our analysis of transit stops provided supportive evidence, finding that transit stops with more passengers boarding or alighting were more likely to have nearby collisions than stops with fewer boardings and alightings.

Numerous questions are raised by these findings regarding pedestrian and driver behavior. While we do not know whether pedestrians involved in the collisions were also utilizing transit facilities, there is a clear possibility that were, particularly given the higher prevalence of transit usage over walking for commuting purposes (4.9% of the population commute by transit vs. 2.8% who walk). There is also a reasonable possibility that non-transit riders are at increased risk near transit stops. If drivers are swerving, speeding, or driving more aggressively to get around a bus, nearby pedestrians would be at increased risk of collision.

Future research should consider whether individuals who have recently alighted or intend to board transit are truly at higher risk of a collision. Although this study does not provide definitive evidence that transit riders are at higher risk, policymakers may choose to preemptively invest in transit rider education. Additionally, further emphasis on safe driving practices near busses may be warranted.

The high proportion of PMVCs occurring on primary arterials in Clark County remains an important concern. We had hypothesized that the incidence of PMVCs may be higher in areas with lower walkability, where individuals may be drawn to walking along roadways designed to function as high-traffic thoroughfares, rather than walking along safer, smaller streets. Although our analysis detected a significant difference in the walkability of environments surrounding PMVC and control locations, the association was not significant in the multivariate model.

Future studies looking at the built environment may be improved by including other environmental characteristics that were not used in this analysis. These characteristics include the presence of lamp posts, speed bumps, crosswalks, medians, street parking, and crime rates. There remains confounding potential in this study because of these and other unmeasured or unknown factors. Additionally, future studies that include more precise traffic counts as well as direct measures of pedestrian activity, rather than proxy measures, will provide a higher level of evidence and more specific estimates of risk.

Injury, like other health events, has both environmental and individual component causes. While this analysis sought to identify characteristics of the built environment that may be associated with pedestrian-motor vehicle collisions, it is essential to understand that individual characteristics also act as risk and resilience factors. Both pedestrian and driver behaviors can affect the risk of collision in any environment. While the importance of individual behavior cannot be overemphasized, one must also acknowledge the challenges associated with trying to change human behavior.

From a public health perspective, it is often more feasible to change environmental factors than to change human behavior. By focusing on the built environment's contributions to pedestrian motor vehicle collision occurrence, this study provides researchers and policymakers with information that may help build safer and ultimately more active communities.

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Appendix A: Components of the walkability measure

Measure	Definition	Source
ResDens	Residential density: (number of residential units within buffer) / (area designated for residential use within buffer)	Clark County Assessor
RetailFAR	Retail floor area ratio: (retail building square footage within buffer) / (retail land square footage within buffer)	Clark County Assessor
Connectivity	Number of intersections with at least 3 nodes / area of walking network buffer (*1,000,000)	Clark County Public Health
Entropy	Measure of land use mix in 1 km walking distance buffer area: $\frac{-\sum \text{[illegible]}}{\text{[illegible]}}$ where N = number of different land uses within the walking distance buffer area P = the proportion of square feet of the nth land use within the walking distance buffer area	Clark County Assessor

Appendix B: Data sources

Variable Name	Definition	Source
ID	Unique identifier	N/A
Jurisdiction	0 = Unincorporated Clark County 1 = City of Vancouver	N/A
Collision	0 = Control 1 = Case	N/A
Parks	Number of park access points within 1 km walking distance	Clark County GIS
ETOH	Number of alcohol outlets within 1 km walking distance	Washington State Liquor Control Board
Schools	Number of schools within 1 km walking distance	Clark County GIS
Income	Median household income	Census Bureau
NoVehicle	Number of households without vehicles	Census Bureau
Female	Proportion of population that is female	Census Bureau
Hispanic	Proportion of population that is Hispanic	Census Bureau
White	Proportion of population that is White	Census Bureau
Youth	Proportion of population that is 14 years old or younger	Census Bureau
Speed	Posted speed limit (MPH)	Clark County GIS
Sidewalk	0 = no sidewalks present 1 = sidewalk present on one side of the road 2 = sidewalks present on both sides of the road	Clark County GIS; City of Vancouver
Transit	Average monthly boarding and alightings at transit stop	C-TRAN
Supermarkets	Number of supermarkets within 1 km walking distance	Clark County Environmental Health
Traffic	Number of high traffic intersections within 1 km walking distance buffer; high traffic = greater than 38,000 daily volume as defined by RTC	Southwest Washington Regional Transportation Council
Walk	Composite measure: Walkability = 2 * [Z(entropy) + Z(residential density) + Z(retail FAR) + Z(connectivity)]	Composite measure using other variables