Factors driving intersection pedestrian crash risk in concentrated urban environments

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Abstract

Concentrated urban environments are known to be pedestrian crash clusters. An in-depth understanding of pedestrian crash risk is a key to identifying the appropriate distribution and focus of safety interventions. This research focuses on the assessment of the risk of pedestrian crashes at the Melbourne Central Business District (CBD) intersections. Intersection pedestrian casualty crashes reported to police that occurred within the Melbourne CBD during a 10-year period from 2000 to 2009 were used. Pedestrian road crossing counts and Annual Average Daily Traffic (AADT) at intersections were used as the measures of exposure. The characteristics of the built environment (land use, roads, public transport and environmental features) and the socioeconomic environment were used as independent predictors. Count data regression methods (Poisson and Negative Binomial) were employed to investigate the association between pedestrian crashes and predictor variables during weekday daytime hours (07:00-18:59) and hours of darkness (19:00-06:59). The three most important categories of predictors of intersection pedestrian crashes during daytime hours were land uses surrounding the intersection (shops; entertainment areas), road factors (hierarchy of roads; divided vs. non-divided; percentage of left turn lanes) and public transport factors (bus stops; distance from railway station), respectively. Similarly, during hours of darkness, pedestrian crashes were highly correlated with the characteristics of surrounding land uses (entertainment; gaming; cinema/theatre; accommodation) and road factors (hierarchy of roads; divided vs. non-divided). The findings of this research provided a better understanding of the unique factors that are likely to influence pedestrian crash risk at intersections in concentrated urban environments.

Introduction

Pedestrians behave differently at intersections versus midblocks (Sisiopiku and Akin 2003) and therefore, may suffer different crash risks. Intersection density (the number of intersections within a specific area) is relatively higher in concentrated urban environments, and possibly therefore, intersection crashes compose a major part of pedestrian crashes in such areas. Pedestrian crash statistics reported by the police show that 56.4% of pedestrian crashes in the Melbourne CBD (2000-2009) occurred at intersections.

Pedestrian crashes tend to cluster in the form of high pedestrian crash zones (Pulugurtha et al. 2007). Identifying these zones helps pedestrian safety practitioners to focus interventions on problematic areas more effectively and efficiently (Vasudevan et al. 2007). Concentrated urban environments are reported to be high pedestrian crash zones (Pulugurtha et al. 2007). For instance, the Melbourne Central Business District (CBD) composes less than 0. 02 per cent of the land area of the Melbourne Metropolitan area, but 6.6 per cent of all the police reported pedestrian crashes in Melbourne (2000-2009) occurred in the CBD.

Lack of in-depth knowledge, particularly regarding pedestrian exposure and crash risk, may result in crude estimations, expert opinions and in some cases, as Lyons et al. (2006) reported, political imperatives displacing rigorous scientific evidence in developing pedestrian safety countermeasures.

Thus, this research focused on pedestrian crash risk at intersections in concentrated urban environments. It was attempted to identify risk factors impacting pedestrian safety at intersections in the Melbourne CBD.

Study design

The study analysed all intersection pedestrian casualty crashes reported to police in Victoria, Australia that occurred within the Melbourne CBD during a 10-year period from 2000 to 2009.

The spatial framework of the analyses was intersections (84 locations). In this research, those segments of the crossing roads that are within 15 metre of the intersection are also considered as a part of the intersection, as these segments are observed to be influenced by the intersection traffic lights and conditions.

With regards to the temporal framework of the analyses, a survey of Melbourne central city users (Ognjanov and Maddern 2008) suggested that the characteristics of pedestrian activities differ considerably on different hours of the day and on different days of the week. The purpose of trips and the origin/destination of trips, and the demographic characteristics, particularly age of pedestrians, have also been shown to change during different times of the day and days of the week (Ognjanov and Maddern 2008). This study concentrated on the assessment of pedestrian crash risk on weekdays. The weekend days were excluded from the study due to time and budget limitations. Adopting the approach described by Priyantha Wedagama et al. (2006), two mutually exclusive but collectively exhaustive time periods were defined: daytime hours (or working hours: 7-18) and hours of darkness (or non-working hours: 0-6 & 19-23).

Data

Dependent variable and exposure measures

Some previous studies have used pedestrian crash frequency, rather than the pedestrian collision rate (crashes/exposure), as the dependent variable. The main rationale for this approach is to address the non-linearity between crash counts and pedestrian exposure (Shankar et al. 2003). In this study, both pedestrian crash frequency and collision rate were used in the modelling process. The possibility of a nonlinear relationship between pedestrian crashes and exposure was also examined by assuming a polynomial relationship between these variables. Using these two approaches, the role of pedestrian exposure in estimating pedestrian crash risk was examined in two different ways: as an independent variable (IV) in the model, and as the denominator in forming collision rate to be used as the outcome variable.

The influence of different exposure measures on pedestrian crashes was tested in this research. Previous research has shown that different measures represent pedestrian exposure to risk in different contexts; for example, some studies have shown that the volume of vehicular traffic is positively associated with pedestrian crashes (LaScala et al. 2000; Lyon and Persaud 2002; Shankar et al. 2003; Lee and Abdel-Aty 2005; Torbic et al. 2010; Daniels et al. 2010; Miranda-Moreno et al. 2011), while others report that pedestrians volume is positively associated with pedestrian crashes (Lyon and Persaud 2002; Sebert Kuhlmann et al. 2009; Torbic et al. 2010; Daniels et al. 2010; Pulugurtha and Sambhara 2011).

Three micro-level exposure measures were used in the modelling process for this study: (1) pedestrian road crossing counts within the modelling space-time; (2) Annual Average Daily Traffic (AADT) through intersections; and the product of pedestrian volumes by AADT (P×V).

Independent variables

With regards to the independent variables used in the modelling process, the likely multi-factorial nature of pedestrian crashes was considered. Table 1 summarises the factors included in this research. The majority of broad categories in the study framework were represented. A small number of specific factors could not be included due to data unavailability or financial limitations of the study. Most notably, "human factors" such as the demographic characteristics of road users and their physical health status were not included in the model since no relevant data could be found and collection of these measures was not feasible.

Table 1: Factors used as independent variables in modelling intersection pedestrian crash risk in the Melbourne CBD

Factors	Attributes
Human	None
Vehicle	Percentage of trucks in the total traffic volume
Physical Environment	Land use ▪ Density* of floor space area and capacity of various land uses Road ▪ Functional class and type (Class of roads and posted speed) ▪ Geometric design ▪ Traffic control and management ▪ Clutter Public transport ▪ Public transport access (distance to the main railway stations, and the density of the number of bus/tram stops and routes) Environmental conditions ▪ Light conditions (Number of street lights)
Socioeconomic (Area Level)	Density of residential population Density of the number of employments
Exposure	Estimates of pedestrian road crossing volumes (P) Estimates of vehicular traffic (AADT) P×AADT

* Density of land uses and public transport facilities were calculated for various buffer zones around the respective intersection.

Data collection

Pedestrian crash data was sourced from the Road Crash Information System (RCIS) held by VicRoads, the state road and traffic authority in the state of Victoria, Australia. This data set is based on Police crash records.

Four hundred and eighty eight intersection pedestrian crashes (353, 72.3%, during the daytime, 135, 27.7%, during the hours of darkness) occurred in the Melbourne CBD during 2000-2009. Crashes rather than pedestrian injuries were used as the dependent variable to ensure independence of the observations.

Vehicle fleet data for truck traffic was obtained from the Sydney Coordinated Adaptive Traffic System (SCATS) database, which covers 3,200 sets of traffic signals, controlled and managed through a central monitoring computer at the VicRoads' Traffic Management Centre. The number of trucks expressed as a percentage of total traffic volume at the CBD intersections was used as the independent variable (mean, 5.52%, variance, 1.67 %).

Physical environment variables in the form of the density of the capacity and floor space area of land uses surrounding each intersection in the CBD were obtained from the Census of Land Use and Employment (CLUE) data set, hosted by the City of Melbourne. The data set contains data for every building by accumulating all floor space area, capacity, and employment elements. Using the GIS software, the respective land-use data can be extracted for each intersection in the CBD according to relevant buffer areas and their associated building blocks. Equation 1 defines the computation used for estimating the density of the capacity or floor space area of a specific land use surrounding each study site.

Density of capacity or floor space area = (Capacity or floor space area of the intended land use within the intended buffer zone) / (Area of the intended buffer zone) Eq. 1

Fourteen different buffer zones were defined to extract the data and estimate the density of land uses with the radii of the buffers being 25, 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, and 1,000 meters. The reason for this is that pedestrian crossing activities at a specific intersection are not only created by the immediate surrounding land-uses and public transport facilities, but potentially also, by some other land-uses and facilities that are located in a walkable distance of the location of interest. Table 2 shows the variables used to represent the variety of land uses surrounding the CBD intersections.

Table 2: Variables representing the density of various land uses surrounding the CBD intersections

Land use feature	Variable	Unit
Capacity (density)	Amusement and gaming centre	Machines/m^2
	Bar, tavern, pub, night club	Persons/m^2
	Cinema, theatre, concert hall, stadium	Seats/m^2
	Commercial accommodation, hostel, backpacker	Beds/m^2
	House, townhouse, residential apartment, serviced apartment, student apartment	Dwellings/m^2
	Café, restaurant, bistro, food court	Seats/m^2
Floor space area (density)	Office	m^2/m^2*
	Entertainment/ recreation (indoor/outdoor)	m^2/m^2
	House, institutional accommodation, residential apartment, student apartment	m^2/m^2
	All retails	m^2/m^2

* Square meters of floor space per square meters of land space.

Variables representing the physical characteristics of the road system, i.e. road geometry, class of roads, geometric design variables, traffic management/control variables and clutter, were also used to assess the risk of a pedestrian being involved in traffic crash. The data was collected through a series of field surveys especially conducted for this study purposes. The variables used are shown in **Error! Not a valid bookmark self-reference.**.

The data on public transport access was sourced from the Department of Transport (DoT). The geographical map of the public transport system was analysed to extract the number of public transport (trams and buses) stops and routes in vicinity of each intersection in the Melbourne CBD. The density of the above-mentioned variables within a surrounding buffer of a location was calculated using Equation 2:

Density of stops and routes = (Number of stops and routes within the intended buffer zone) / (Area of the intended buffer zone) Eq. 2

The same buffer zones used for land use densities were used. The density of the product of the number of public transport (trams and buses) stops and routes in the vicinity of intersections was also used as an independent variable. It was assumed that the product of the number of stops and routes may give a better measure of public transport access than the number of stops and routes, separately.

Table 3: Characteristics of the roads system at the CBD intersections (2000-2009)

Group	Variable	Attribute	Variable type
Class of roads	Major or minor intersection*	Minor Major	Categorical
Geometric design variables	Total number of ways	-	Continuous
	Total number of lanes	-	Continuous
	Total number of lanes at main road over minor road	-	Continuous
	Percentage of left turn movements	-	Continuous
	Percentage of right turn movements	-	Continuous
	Average grade of the intersecting roads (%)	-	Continuous
	Road division	Any combination of refuge, median, car park, or tram tracks Just tram tracks	Categorical
	Tram tracks**	No Yes	Categorical
	Average distance of on-street parking clearance – towards intersection	-	Continuous
	Average distance of on-street parking clearance – from intersection	-	Continuous
Traffic management/control	Posted speed	-	Continuous
	Hook-turn possibility	No Yes	Categorical
	Exclusive bicycle lane or bicycle box	Yes No	Categorical
	Exclusive bus lane	Yes No	Categorical
	Number of street lights	-	Continuous
Visual clutter***	Number of traffic control devices	-	Continuous
	Number of legs with shops	-	Continuous

* A major intersection is the intersection of two main roads and a minor one is the intersection of a main road and a minor street.
** Trams run down the centre of the road and share traffic space in the Melbourne CBD.
*** A number of factors mentioned within the other groups influence visual clutter as defined by Edquist (2008), such as "total number of lanes", "exclusive lanes" etc. However, these factors were deemed to be more relevant to their current groupings rather than visual clutter.

Finally, the distance of the intersection to the nearest main railway station in the CBD was measured and used as an independent variable.

Area-wide socioeconomic characteristics of the areas surrounding the CBD intersections in terms of the density of the number of residents (population) and the quantity of employments in the vicinity of the locations were used. The densities were calculated in a similar way to the density of land uses and public transport access.

Pedestrian road crossings (P), vehicular traffic (AADT) and their product (P×AADT) at the CBD intersections were used as the exposure measures. The data on vehicular traffic was extracted from the SCATS database.

Modelling methods

Pedestrian crash data at CBD intersections is a series of random non-negative integer counts (0, 1, 2, 3...): "count data." The intersection pedestrian crash data are highly skewed and not well represented by the normal distribution. Count data are commonly represented by the Poisson or Negative Binomial, distributions (Cameron and Trivedi 1998) for statistical analysis. The Poisson distribution is often assumed for count data. A property of the Poisson distribution is that its mean (μ) and variance are equal (equi-dispersion). If the variance exceeds or is less than the mean, termed over-dispersion or under-dispersion, respectively, the standard Poisson distribution is not appropriate to be used to represent the data. In case of over-dispersion, the negative binomial distribution is potentially more appropriate to use that the Poisson distribution. The variance of the negative binomial is related to the mean of the distribution, μ, by $Variance = \mu + \alpha.\mu^2$ (Equation 3); where, α: dispersion parameter.

Over-dispersion is a phenomenon often caused by latent heterogeneity, meaning that the sample arises from a population consisting of different subpopulations. A stringent test of over-dispersion is to test if the parameter α in the Equation 3 is significantly greater than zero. For seeing the general equations for the standard discrete models, refer to Tabachnick and Fidell (2001).

Results

Intersections crashes during the daytime hours on weekdays – modelling results

The modelling of pedestrian crashes that occurred at the CBD intersections during the daytime hours showed that the model that describes the association between the collision rate (with the AADT being the denominator variable) and the independent regressors is the best model. The results of the Vuong's test and goodness-of-fit of the Poisson and ZIP models showed that there was no need to use the zero-inflated version. Table 4 shows the estimated regression parameters with standard errors, significance values and confidence intervals.

Table 4: Estimated regression parameters for the intersections daytime model

IVs	Type		Coefficient	Standard error	Z	P>lZl	95% confidence interval	
lt-p	Continuous		0.0064	0.00375	1.72	0.085	-0.00089	0.01382
leg-shops	Ordinal	1 (ref*)						
		2	0.2110	0.0506	4.17	0.000	0.1117	0.31023
		3						
		4						
hook-turn	Categorical	Yes	0.3502	0.1217	2.88	0.004	0.1116	0.5889
		No (ref)						
division	Categorical	Yes	- 0.4261	0.1237	-3.44	0.001	-0.6685	-001837
		No (ref)						
maj-min	Categorical	Major	- 0.8889	0.167	-5.32	0.000	-1.216	-0.561
		Minor (ref)						
S-Enter-800	Continuous		6.58e-6	1.83e-6	3.60	0.000	3.0 e-6	10.2e-6
Bus-R-500	Continuous		0.0115	0.0043	2.62	0.009	0.0028	0.0201
dis-rail	Continuous		- 0.0009	0.0004	-2.26	0.024	-0.0017	-0.0001

* Reference category

The definitions of the variables introduced in Table 7 are:

left – p: The percentage of left – turn movements to total number of possible movements

leg – shops: Number of legs with shops

hookturn: Hook – turn possibility at the intersection (binary – 1:yes, 0:No)

division: Division of the intersecting roads (binary – 1: roads divided by refuges or medians, 0:roads divided by only tram tracks maj − min: Major or minor intersection (binary − 1:major, 0:minor)

S − Enter − 800: Density of floor space area of entertainment areas (indoors and outdoors) within a 800-m buffer

Bus − R − 500: Density of bus routes within a 500 − m buffer

dis − rail: Distance of the intersection from the nearest main railway station

Table 8 shows the correlates of pedestrian crash risk in the order of the importance of their contribution to the model.

Table 5: Importance ranking of the regressors

Variable	Intersections – daytime hours Sign in the model	AIC of the model excluding the variable	Importance ranking
maj-min	-	362.714	1
leg-shops	+	351.317	2
S-Enter-800	+	345.780	3
division	-	344.534	3*
hook-turn	+	341.230	4
Bus-R-500	+	340.018	4
dis-rail	-	338.132	5
left-p	+	335.841	6

* Variables with close respective AIC are tie-ranked.

As can be seen, the density of entertainment land uses, the hierarchy of the intersection (major or minor), and the density of bus routes have the highest impact on the percentage change in the number of crashes, respectively.

Intersection crashes during the hours of darkness on weekdays – modelling results

The modelling of pedestrian crashes that occurred at the CBD intersections during hours of darkness showed that the model that describes the association between the collision rate (with the AADT being the denominator variable) and the independent regressors is the best model. Although the Vuong's test statistic was greater than 1.96, the goodness-of- fit of the ZIP model was shown to be inferior to the Poisson model. The 'straight' Poisson model was therefore selected as the best model. Table 6 shows the estimated regression parameters with standard errors, significance values and confidence intervals.

Table 6: Estimated regression parameters for the intersections the hours of darkness model

IVs	Type		Coefficient	Standard error	Z	P>|Z|	95% confidence interval	
C-Cine-Theat-300	Continuous		2.18e-5	8.54e-6	2.55	0.011	5.05e-6	3.85e-5
S-Enter-100	Continuous		2.02e-6	3.65e-7	5.54	0.000	1.31e-6	2.74e-6
C-All-Accom-150	Continuous		2.69e-5	1.06e-5	2.53	0.011	6.07e-6	4.77e-5
C-Amu-Gam-900	Continuous		5.25e-4	2.06e-4	2.54	0.011	1.19e-4	9.3e-4
maj-min	Categorical	Yes No (ref)	-0.4985	0.2060	-2.42	0.016	-0.902	-0.0946
division	Categorical	Yes No (ref)	-0.4837	0.1887	-2.56	0.010	-0.8536	-0.1138

The definitions of the variables introduced in Table 6 are:

C − Cine − Theat − 300: Density of capacity of cinema, theatres, concert halls and stadiums within a 300-m buffer

S – Enter – 100: Density of floor space area of entertainment areas (indoors and outdoors) within a 100-m buffer

C – All – Accom – 150: Density of capacity of all commercial and non – commercail accommodations within a 150 – m buffer

C – Amu – Gam – 900: Density of capacity of amusement and gaming areas within a 900 – m buffer

maj – min: Major or minor intersection (binary – 1: major, 0: minor)

division: Division of the intersecting roads (binary – 1: roads divided by refuges or medians, 0: roads divided by only tram tracks

Table 7 shows the correlates of pedestrian crash risk in the order of the importance of their contribution to the model.

Table 7: Importance ranking of the regressors

Intersections – Hours of darkness			
Variable	Sign in the model	AIC of the model excluding the variable	Importance ranking
S-Enter-100	+	274.340	1
C-Amu-Gam-900	+	253.488	2
division	-	253.345	2
maj-min	-	253.220	2
C-Cine-Theat-300	+	253.088	2
C-All-Accom-150	+	253.041	2

Discussion

The primary focus of this research was to identify factors predicting pedestrian crash risk at intersections in the CBD of Melbourne. The crash risk models identified several factors associated with pedestrian crash risk that are discussed in detail in relevant categories below.

Correlates of pedestrian crashes at intersections – daytime

The most important correlate with pedestrian collision rate was the class of the intersecting roads as defined by “major or minor intersection.” Minor intersections were associated with a higher pedestrian crash risk (collision rate) than the major ones. In the Melbourne CB, the number of lanes at a main intersection is generally greater than at a minor intersection. This finding contradicts the findings of the literature that the number of lanes at an intersection is positively associated with pedestrian crashes (Lee and Abdel-Aty 2005; Torbic et al. 2010; Ukkusuri et al. 2011). The difference in findings may be explained by a higher rate of jaywalking at minor intersections as reported by Pelosi and Goddard (2006). Similarly, during the field observation for the exposure modelling component of the thesis, it was noted that pedestrians were more likely to ignore the “Do Not Walk” light at minor intersections than at major intersections. Moreover, several of the major intersections in the Melbourne CBD receive more attention by the Police which would arguably lead to higher compliance with light phases compared with minor intersections.

The next most important factors were the land use characteristics, that is, the number of legs with shops and the density of indoor and outdoor entertainment areas, which were positively associated with pedestrian collision rate. Previous research corroborates this finding (Kim et al. 2010; Torbic et al. 2010; Miranda-Moreno et al. 2011; Schneider et al. 2011; Ukkusuriet al. 2011). One plausible explanation for this finding is that these variables create a relatively high level of visual clutter and are likely to attract younger pedestrians.

Other road factors were also found to be associated with pedestrian collision rates at intersections.

Unsurprisingly, the collision rate was found to be lower where the intersecting roads were divided by medians, refuges or middle-of-the-road car parks. This may be because pedestrians can cross the road in two stages and do not to deal with the traffic coming from both directions, simultaneously. The literature supports this conjecture (Lee and Abdel-Aty 2005; Oxley et al. 2005; Schneider et al. 2010).

Two particularly novel findings were made in this project; firstly, the intersections at which a so-called hook-turn was possible witnessed a higher collision rate; secondly, the percentage of left-turn manoeuvres of vehicles to total possible manoeuvres was positively associated with the collision rate. With respect to hook-turns, it is likely that these manoeuvres are confusing for road users and cause both drivers and pedestrians to make unsafe decisions and precipitate vehicle-pedestrian conflicts. Left-turning vehicles crossing the path of pedestrians are legally obliged to give way to pedestrians. However, it was noticed during the field observations that pedestrian right-of-way is frequently ignored by drivers. This potential pattern of non-compliance for left turns might explain the higher likelihood of pedestrian conflicts during these manoeuvres.

Public transport factors influencing the pedestrian collision rate included the number of bus routes and distance from the nearest railway station. Previous studies have also reported a positive association between the number of bus routes and pedestrian collision rate (Diogenes and Lindau 2010; Kim et al. 2010; Torbic et al. 2010; Miranda-Moreno et al. 2011; Ukkusuriet al. 2011). This may be attributed to unsafe actions of pedestrians running to catch a bus. Alternatively, the occurrence of pedestrian crashes may be related to difficulty in driving a heavy and large bus at intersections. The finding relating to proximity to railway stations was unique to the present study; the further the intersection from the main railway stations, the lower the collision rate. This finding can be explained in the light of a higher clutter level around the railway stations and a possibly more hasty pedestrian population.

Correlates of the pedestrian collision rate at the intersections – hours of darkness

Prominent amongst those factors that were associated with pedestrian collision rate at night were land use variables. The presence of entertainment areas, amusement and gaming centres, cinemas, theatres, concert halls and stadiums, and commercial and non-commercial accommodation were associated with higher pedestrian collision rate during the hours of darkness. This finding corroborates previous findings (Kim et al. 2010; Torbic et al. 2010; Miranda-Moreno et al. 2011; Schneider et al. 2011; Ukkusuri et al. 2011). One exception to this general finding is that residential accommodation has been reported to be associated with reduced pedestrian crashes (Pulugurtha and Sambhara 2011; Ukkusuri et al. 2011). Few studies have considered the effect of aggregate entertainment area on pedestrian crashes. One possible explanation for the findings may be that younger people frequent these types of settings during non-working hours and with a high likelihood of alcohol use. Two road factors were also found to negatively correlate with the pedestrian collision rate: notably major intersections and the division of intersecting roads. They variables affect both the day and darkness models in the same way. The underlying reasons for their influence are discussed in the previous section.

Conclusions

A diverse range of factors was used as the predictor variables in the modelling process for the selection of potential factors influencing pedestrian crash risk.

A unique aspect of the risk assessments was an exclusive focus on concentrated urban environments. A further refinement of the modelling approach in this research was the comparison of pedestrian crash risk across different hours of the day. Moreover, an attempt was made to differentiate between weekday and weekend day, with specific attention given to risk factors associated with weekdays only.

The spatial focus of the work was also honed to investigate and compare pedestrian crashes at intersections. This concentration is proposed to provide a better understanding of risk factors associated with different locations, i.e. intersections vs. midblocks.

The findings of this research provided a better understanding of the unique factors that influence pedestrian crash risk at intersections in concentrated urban environments. Land uses surrounding the intersection, road factors and public transport factors, respectively, were the most important categories of predictors of pedestrian collision rate during daytime hours. During hours of darkness, collision rates were highly correlated with the characteristics of surrounding land uses and road factors.

References

1. Cameron, M. H. (1982). "A method of measuring exposure to pedestrian accident risk." Accident Analysis & Prevention 14(5): 397-405.
2. Cameron, M. H. (2000). Statistical evaluation of road trauma countermeasures. Department of Mathematics and Statitics. Melbourne, Monash University. Doctor of Philosophy.
3. Daniels, S., T. Brijs, et al. (2010). "Externality of risk and crash severity at roundabouts." Accident Analysis & Prevention 42(6): 1966-1973.
4. Diogenes, M. C. and L. A. Lindau (2010). Evaluation of pedestrian safety at midblock crossings, Porto Alegre, Brazil. Transportation Research Record: 37-43.
5. Edquist, J. (2008). The effects of visual clutter on driving performance. Accident Research Centre. Melbourne, Monash University. Doctor of Philosophy: 226.
6. Kim, J.-K., G. F. Ulfarsson, et al. (2010). "A note on modeling pedestrian-injury severity in motor-vehicle crashes with the mixed logit model." Accident Analysis & Prevention 42(6): 1751-1758.
7. LaScala, E. A., D. Gerber, et al. (2000). "Demographic and environmental correlates of pedestrian injury collisions: a spatial analysis." Accident Analysis & Prevention 32(5): 651-658.
8. Lee, C. and M. Abdel-Aty (2005). "Comprehensive analysis of vehicle-pedestrian crashes at intersections in Florida." Accident Analysis and Prevention 37(4): 775-786.
9. Lyon, C. and B. Persaud (2002). Pedestrian collision prediction models for urban intersections. Transportation Research Record: 102-107.
10. Lyons, R. A., S. J. Jones, et al. (2006). "The influence of local politicians on pedestrian safety." Injury Prevention 12(5): 312-315.
11. Miranda-Moreno, L. F., P. Morency, et al. (2011). "The link between built environment, pedestrian activity and pedestrian-vehicle collision occurrence at signalized intersections." Accident Analysis & Prevention.
12. Ognjanov, B. and C. Maddern (2008). Central city users survey, City of Melbourne.
13. Oxley, J., M. Lenne, et al. (2006). "The effect of alcohol impairment on road-crossing behaviour." Transportation Research Part F: Traffic Psychology and Behaviour 9(4): 258-268.
14. Priyantha Wedagama, D. M., R. N. Bird, et al. (2006). "The influence of urban land-use on non-motorised transport casualties." Accident Analysis and Prevention 38(6): 1049-1057.

15. Pulugurtha, S. and S. Repaka (2008). "Assessment of Models to Measure Pedestrian Activity at Signalized Intersections." Transportation Research Record: Journal of the Transportation Research Board 2073(-1): 39-48.
16. Pulugurtha, S. S. and V. R. Sambhara (2011). "Pedestrian crash estimation models for signalized intersections." Accident Analysis & Prevention 43(1): 439-446.
17. Pulugurtha, S. S., V. K. Krishnakumar, et al. (2007). "New methods to identify and rank high pedestrian crash zones: An illustration." Accident Analysis and Prevention 39(4): 800-811.
18. Schneider, R., L. Arnold, et al. (2009). "Methodology for Counting Pedestrians at Intersections." Transportation Research Record: Journal of the Transportation Research Board 2140(-1): 1-12.
19. Schneider, R., M. Diogenes, et al. (2010). "Association Between Roadway Intersection Characteristics and Pedestrian Crash Risk in Alameda County, California." Transportation Research Record: Journal of the Transportation Research Board 2198(-1): 41-51.
20. Sebert Kuhlmann, A. K., J. Brett, et al. (2009). "Environmental characteristics associated with pedestrian-motor vehicle collisions in Denver, Colorado." American Journal of Public Health 99(9): 1632-1637.
21. Shankar, V.N., G.F. Ulfarsson, R.M. Pendyala, M.B. Nebergall (2003). “Modeling crashes involving pedestrians and motorized traffic.” Safety Sci., 41 (7) (2003), pp. 557–640.
22. Shankar, V.N., J. Milton, F. Mannering (1997). “Modeling accident frequencies as zero-altered probability processes: an empirical inquiry.” Accident Analysis and Prevention, 29 (6) (1997), pp. 829–837.
23. Sisiopiku, V. P. and D. Akin (2003). "Pedestrian behaviors at and perceptions towards various pedestrian facilities: an examination based on observation and survey data." Transportation Research Part F: Traffic Psychology and Behaviour 6(4): 249-274.
24. Tabachnick, B. G. and L. S. Fidell (2001). Using multivariate statistics, Allyn & Bacon.
25. Torbic, D.J., Harwood, D.W., Bokenkroger, C.D., Srinivasan, R., Carter, D.L., Zegeer, C.V., Lyon, C., 2010. Pedestrian Safety Prediction Methodology for Urban Signalized Intersections. Transportation Research Board 89th Annual Meeting Compendium of Papers DVD, Washington, DC.
26. Ukkusuri, S., L. F. Miranda-Moreno, et al. (2012) "The role of built environment on pedestrian crash frequency." Safety Science, Volume 50, Issue 4, Pages 1141-1151.
27. Vasudevan, V., S. Pulugurtha, et al. (2007). "Methods to Prioritize Pedestrian High-Crash Locations and Statistical Analysis of Their Relationships." Transportation Research Record: Journal of the Transportation Research Board 2002(-1): 39-54.