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15-09 Impact of Access Management Practices to Pedestrian Safety

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Impact of Access Management Practices to Pedestrian Safety

FINAL REPORT

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16. Abstract

This study focused on the impact of access management practices to the safety of pedestrians. Some of the access management practices considered to impact pedestrian safety included limiting direct access to and from major streets, locating signals, limiting the number of conflict points and separating conflict areas, removing turning vehicles from through traffic lanes, using nontraversable medians to manage left-turn movements and providing a supporting street and circulation system. The study evaluated through statistical modeling the correlation between access management practices to pedestrian crashes. Focused on the impacts of access management on pedestrian crashes, eight (8) major roadway corridors were selected and utilized for analysis. Utilizing Negative Binomial, the correlation between roadway features and pedestrian crashes were modeled. Four variables including AADT, access density, percentage of trucks and the presence of TWLT were found to be positively associated with the pedestrian crash frequency. Variables such as the presence of median, presence of crosswalk, presence of shoulders, presence of sidewalk and high speed limit had negative coefficients hence their increase or presence tends to decrease pedestrian crashes. It could therefore be concluded that though these variables had some influence on the pedestrian crashes, access density, crosswalk, sidewalk and speed limit were the most statistically significant variables that determined the frequency of the pedestrian crashes.

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CHAPTER 1: INTRODUCTION

1.1. Overview

Studies have shown that significant population of Americans indulge in walking for recreational purpose and exercise with 3.9 million workers walking to work daily in United States as of 2009 [1]. Walking also has its advantage of improving and maintaining healthier environment by creating safer neighborhoods, reducing automobile pollution, noise and pavement depletion. This has propelled experts (especially of public health and environmental protection agencies) to encourage public walking; therefore anticipate transportation professionals to plan more walkable communities. However, in some situations increased walking can lead to increased risk of road traffic crashes and injury. Due to the dramatic growth in the number of motor vehicles and the frequency of their use around the world – as well as the general neglect of pedestrian needs in roadway design and land-use planning – pedestrians are increasingly susceptible to road traffic injury. According to statistical records from the Enhanced Tennessee Roadway Information (E-trims), it is observed that pedestrians are the most vulnerable road users to both fatal and incapacitated crashes in Tennessee. While notable improvements are noticed for vehicle crashes, pedestrian crash rates recorded a rise in the past 10 years (Figure 1.1). Therefore, the thrust of this work falls under the desperate need to reduce pedestrian crash rates in order to ensure livability of communities through safe and efficient transportation. The study attempts to identify/analyze vital access management features and practices and its impacts on pedestrian crashes.

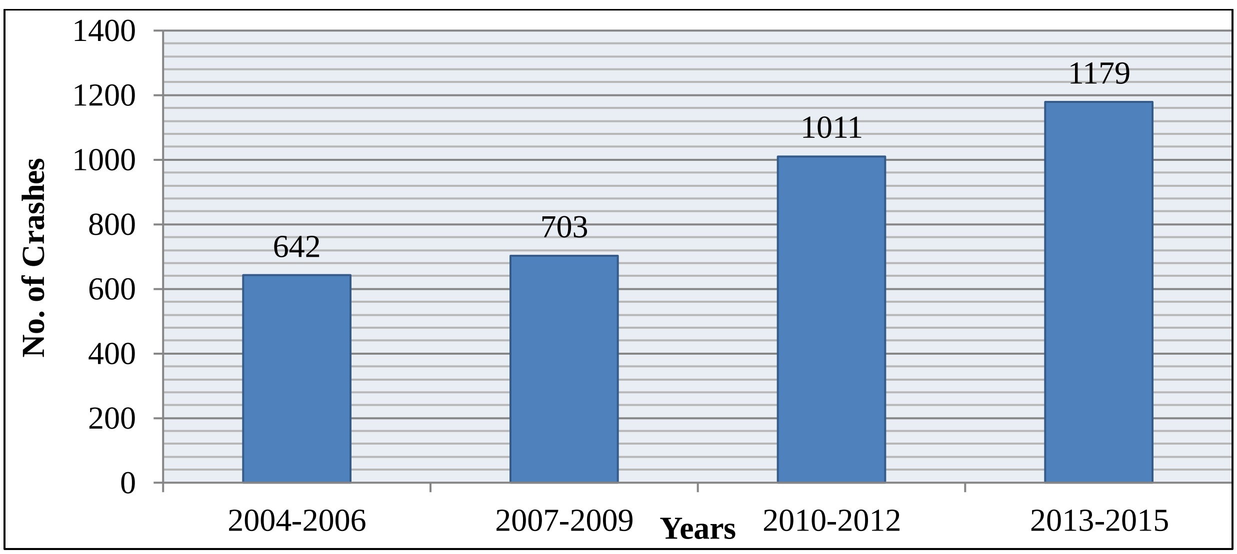

Figure 1: Tennessee Pedestrian reported crash trend (2004-2015)

1.2. Scope

In order to achieve the primary aim of the study several primary tasks were involved: Literature review was done to identify the approach and findings from similar studies. Study data gathered included access management roadway features, traffic data and crash information. These data were merged to form a base file which served as source of data for statistical analysis of the access management features with significant impact on the crash frequency.

CHAPTER 2: LITERATURE REVIREW

2.1. Introduction

Researchers are of the opinion that an average of 22% of global road deaths involve pedestrian [2]. That is each year, over 270,000 pedestrians die as a result of interaction with vehicles, with a far higher number of reported severe injuries which often lead to permanent disabilities. This has given rise to the significance of access management, particularly in the US since the early 1970's. While some authors have slightly different definition of access management, an underlining agreement between them is that it is the efficient spacing of driveways, median openings, placements and road interconnectivity primarily aimed at maintaining access mobility function and pedestrian safety. This literature review is well-structured to identify past and present significant studies on access management, pedestrian safety and their inter-relationship adopting the funnel classification method as shown in Figure 2.1. [3]

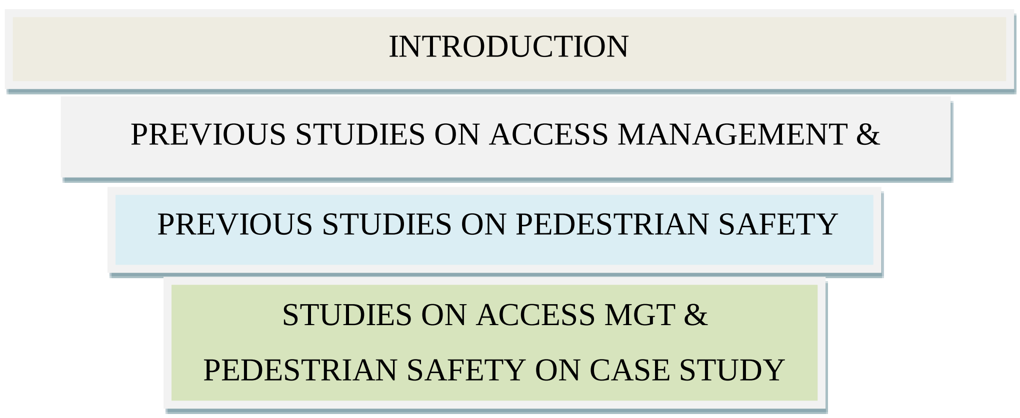

Figure 2.1: Literature Review Structural Representation

Source: [3]

2.2. Access Management and Practices

Increase in urban settlement globally has directly brought about a direct increase in urban population and automobile use, with vehicle sales reaching an all-time record of 85M in 2014 for urban dwellers, it is projected to attain 100M by 2018 [2]. Though some authors have suggested methods for adequate management/reduction of congestion, traffic light management technique which could be adopted and applied for different major intersections similar to the focus of this work was identified and studied [4]. The study tried to combine a Wireless Sensor Network (WSN) and multiple fuzzy logic controllers for the assessment of vehicle movement and density for each road lanes. Data were ascertained twice; first by sorter module and by fuzzy logic controller. These data were then analyzed using the MATLAB and TRUETIME (for WSN) software. Simulation results obtained revealed that this approach is perfectly ideal as it greatly reduced vehicle waiting times in queues especially under heavy traffic. Further researchers insisted that while signal, traffic and road maintenance are necessary, a pivotal aspect of access management is the evaluation of urban space for pedestrians and cyclists [5]. Their work attempted to support and validates different peer-reviewed access management performance indicators (Table 2.1). It validates these indicators by utilizing them in the assessment of pedestrians in two subway train stations of Rio de Janeiro by the use of survey questionnaires. Results obtained revealed that pedestrians experience great difficulty during walk to train stations. Issues such as lack of safe-crossing signs, lack of bike lanes, uneven sidewalks etc. were highlighted. The success of this study therefore validates the selected criteria. Furthermore, it was also determined that adequate access management process must take cognizance of the access density and weight and their impact on crash rates especially on roads with major intersections like those of the case study of this work [6]. The study proposed a new method of ascertaining access density by utilizing a case study of Temple Terrace and M.N Dale Mabry Highway in Florida, with each divided into 14 sections. Data were collected from 2002 to 2006 and simulated using a microscopic traffic simulation software package (TSIS-CORSIM). Access density here was then compared with the proposed access density in existing studies by analyzing each correlation with crash rates. Results (Table 2.2 and 2.3) reveals a correlation crash rate coefficient of 0.728 (for existing research) and 0.764 (for proposed methods) were obtained after the correlation for the 14 sections of Temple Terrace Highway while 0.809 (existing) and 0.846 (proposed) for N. Dale Mabry Highway.

Table 2.1: Summary of variables used for the analysis of pedestrian spacing

ISSUES	VARIABLES	REFERNCES
Density	Population density, residential density, households, employment density, pedestrian flow.	[7]; [8]; [9]; [10]
Diversity of Land Use	Land use parceling, proximity of residence and services, convenience, connectivity of origin to destination point	[7]; [9] [11]
Urban Design	Road width; traffic flow separation between the modes, visual design, system coherence, conflict between pedestrian and vehicles, accessibility to public transport, urban ambiance, urban form.	[9]; [12]; [11]; [13]; [10]
Facilities for Pedestrians	Overall width of the sidewalk; Effective width of sidewalk, pavement type, rate barriers; rate of green area; Number of parked vehicles, obstructions at intersections; Attractiveness, Comfort, Continuity of the system	[10]; [12]; [13]; [8]; [11]
Safety and Security	Possibility of falls and injuries; Perception of security; Personal Security	[12]; [11]
Characteristics of Pedestrian	Speed of walk	[8]; [9]

Source: [5]

Table 2.2: Summary at Temple Terrace Highway

No	Milepost Start	Milepost End	AADT	No. of lane	Speed Limit	Land use	No. of crashes	Crash rate (10^6 VMT)	Access Density (existing)	Access Density (Proposed)
1	0	0.5	10,000	4	45	Urban	9	4.93	29	186.9
2	0.5	1	34,500	4	45	Urban	5	0.79	19	94
3	1	1.5	34,500	4	45	Urban	16	2.54	15.6	175.6
4	1.5	2	34,500	4	45	Urban	20	3.18	14.8	129.8
5	2	2.5	34,500	4	45	Urban	20	3.18	19.6	175.7
6	2.5	3	44,500	4.6	45	Urban	21	2.59	19.6	141.0
7	3	3.5	44,500	6	45	Urban	25	3.08	14	103.6
8	3.5	4	34,500	6	45	Urban	6	0.95	12.8	89.5
9	4	4.5	34,500	6	45	Urban	5	0.79	9.2	87.1
10	4.5	5	34,500	6	45	Urban	7	1.11	10.4	124.7
11	5	5.5	34,500	6	45	Urban	12	1.91	3.6	109.3
12	5.5	6	32,000	5	45	Urban	6	1.03	10.8	88.9
13	6	6.5	35,000	4	45	Urban	11	1.72	11.6	70.4
14	6.5	7	35,000	4	45	Urban	0	0.00	5.2	91.8
						Average			14	119
						Correlation coefficient			0.728	0.764

Source: [6]

Table 2.3: Summary at N Dale Mabry Highway

No	Milepost Start	Milepost End	AADT	No. of lane	Speed Limit	Land use	No. of crashes	Crash rate (10^6 VMT)	Access Density (existing)	Access Density (Proposed)
1	0	0.5	27,000	6	45	Suburban	6	1.22	21	150.4
2	0.5	1	27,000	6	45	Suburban	9	1.83	13	110.4
3	1	1.5	27,000	6	45	Suburban	18	3.65	21.2	180.9
4	1.5	2	27,000	6	45	Suburban	18	3.65	24.8	135.8
5	2	2.5	27,500	6	45	Suburban	23	4.58	22.3	176.9
6	2.5	3	27,500	6	45	Suburban	21	4.18	21	170.3
7	3	3.5	27,500	6	45	Suburban	8	1.59	14	128.5
8	3.5	4	27,500	6	45	Suburban	5	1.00	11.2	95.1
9	4	4.5	33,500	6	45	Suburban	6	0.98	11.6	92.2
10	4.5	5	33,500	6	45	Suburban	11	1.80	11.5	115.3
11	5	5.5	33,500	6	45	Suburban	10	1.64	13.5	113.4
12	5.5	6	33,500	6	45	Suburban	8	1.31	16	96.4
13	6	6.5	31,000	6	45	Suburban	9	1.59	9.1	75.2
14	6.5	7	31,000	6	45	Suburban	0	0.00	6.8	48.2
						Average			16	121
						Correlation coefficient			0.809	0.846

Source: [6]

2.3. Pedestrian Safety

Another relevant study focused on the management of crowd pedestrian movement during the "Eidengenossisches Scwinger-and Alperfest" (ESAF) in Burgdorf Switzerland in 2013 [14]. Though the focus slightly differs from the main objective of this work, its final identification of potential pedestrian 'hot spots' (that is, points of congestions and/or frequent interaction) is an essential/integral part in the identification and development of safety performance functions (SPF) for pedestrian safety improvement. Utilizing the PedGo software, simulations were performed at different points for departing pedestrian flow. Findings revealed that though the arrival of pedestrians at the pedestrian tunnel was relatively free (in support of the prognosis predicted), the train platform experienced some measure of congestion. A similar trend was also experienced at the pedestrian departure flow (defying the prognosis) with congestions observed only at the entry of train station. However, this was as a result of the fact that only certain percentage of the crowd left immediately after the event with others remaining for the award ceremony. It was furthermore argued that the study of drivers' behavior and/or tolerance especially in major metropolitan roads is a major determinant of pedestrian-vehicle interaction [15]. This was further reiterated by the research which focused on pedestrian gestures and drivers' yielding rate at uncontrolled mid-block crosswalks [16]. Firstly, adopting the four gestures displayed in Figure 2.2 (G1, G3, G6 and G11) with a baseline (no gesture), researchers did a random survey of drivers at 5 different roads in Beijing to ascertain their response to these pedestrian gestures if driving. An average yield rate (i.e. slow down + stop) of over 80% was achieved. However, the practical experiment for same five roads was carried out by three participants (1 pedestrian crossing road at specific distance and 2 observers) on 100 vehicles for each road. Findings revealed a great decline in vehicle yield rate to an average 4.2% (Table 2.4). Each gesture yield rate was further correlated against the baseline gesture using Mann-Whitney quantitative analysis and it was concluded that on Gesture 3 (G3: L-bent level) significantly increased drivers' yield rate (to slow down or stop for pedestrian) with values (Z: -3.45, p: 0.01). They further suggested with support from findings of Underwood [17] that pedestrian gesturing is usually more 'prominent' than road signs and markings.

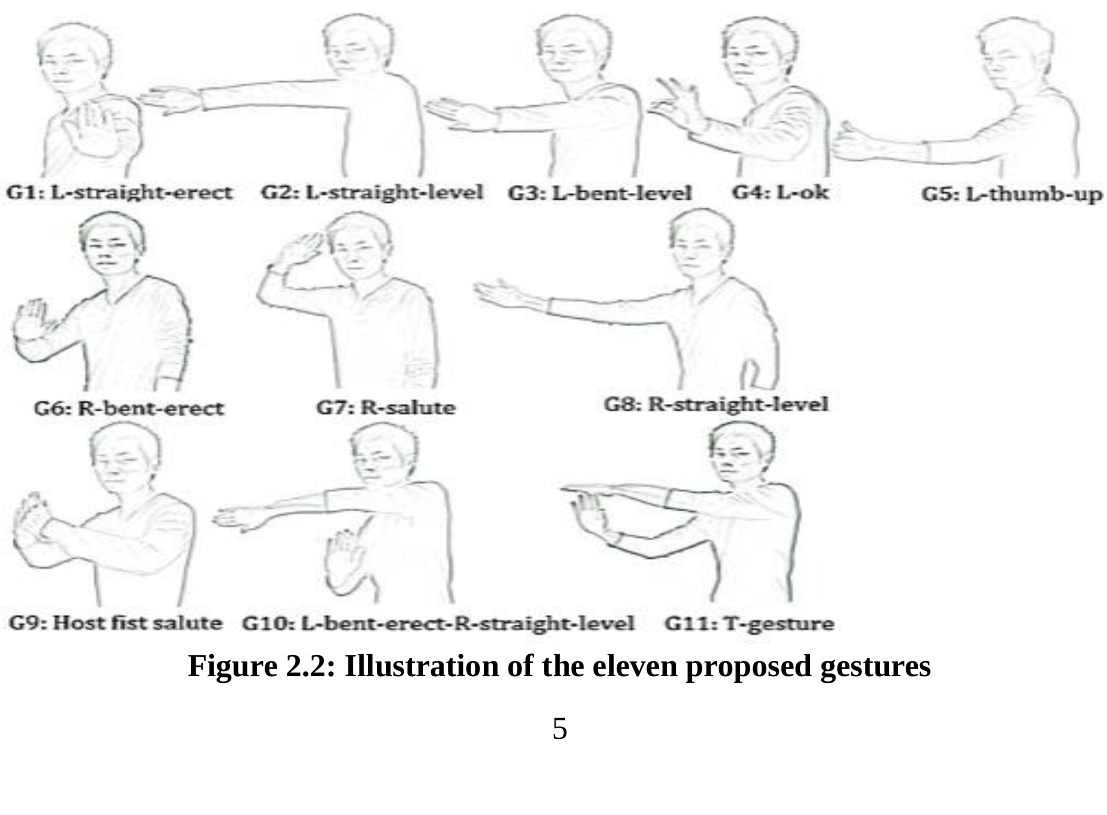

Figure 2.2: Illustration of the eleven proposed gestures

Table 2.4: Drivers' response to selected gestures

Gestures/Responses (%)	No Change	Pass (Slow down)	Yield (Slow down)	Yield (Stop)	Use Horn	Change Lane
Baseline (no gesture)	63.5	32.9	2.4	1.2	15.3	5.9
R-straight erect	51.8	42.2	1.2	4.8	24.1	9.6
Time-out	55.7	32.9	5.1	6.3	19.0	8.9
L-Straight erect	46.6	44.3	4.5	4.5	18.2	12.5
L-bent level	38.8	48.2	4.7	8.2	12.9	10.6

Source: [15]

Similarly some studies were of the opinion that road/street design is also an integral factor that influences vehicle-pedestrian interactions [18]. The study focused on the development of behavioral criteria for the analysis of pedestrian and vehicle when they interact. Utilizing video recording/observation method, data was obtained from an 800-metre road in West London over time (before and after its redevelopment). Results obtained (Table 2.5) showed a great decline in the frequency of occurrence of Steady-Car Pedestrian (SCP) interaction (defined as the vehicle-pedestrian interaction when the vehicle is at a steady pace)

Table 2.5: Results before and after roadway redevelopment

	LOCATION						TOTAL	
	L1		L2		L3			
	Before	After	Before	After	Before	After	Before	After
SC-P	241	196	207	192	231	0	679	388
ESS	8	75	174	136	24	8	206	291
TOTAL	249	271	381	328	255	8	885	607

This opinion was further reiterated by the research which suggested that pedestrian-vehicle collision is greatly influenced by the specific built in environment such as road width, street connectivity and general public transit layout [19]. The study attempted to determine the impact of the implementation of streetcar right of way (ROW) on pedestrian motor-vehicle crashes (PMVC) at St. Claire Avenue West of Toronto, Canada. Data from an 11 year records of all reported PMVC were collected and analyzed. A zero-inflated Poisson regression data analysis method was utilized to analyze these data to ascertain variations in PMVC, pre and post ROW implementation. Research finding validates author's opinion that access designs is an essential determinant of pedestrian safety as it revealed a great decline of 48% in rate of PMVC on St. Clair Street with this decline notable among the different sections (adults and children). Table 2.6 reveals further studies, summaries and conclusion/findings of similar works.

Table 2.6: Studies of similar work

AUTHOR	FOCUS	METHODOLOGY	CONCLUSION/FINDINGS
[20]	Pedestrian-vehicle crash frequency at intersections in Florida (1999-2002)	N.B model/Ordered Logit Model (for data categorization)	Higher average volume of intersection increases no. of crashes.
[21]	Comparative analysis of N.B and Artificial Neural network in the a analysis of the relationship between accident record frequency and the Built-in Environment (Highway geometric variables)	N.B model vs Artificial Neural Network	Artificial Neural Network model is a standard option for the NB model as findings revealed significant relationship between the built-in environment and accident frequency.
[22]	The Non-linearity of risk associated with pedestrians	Equations from literature was adopted: No. of accident = $\alpha(Q_{MV})^{\beta_1} (Q_{PED})^{\beta_2}$ Q_{MV} = Vol. of motor vehicles. Q_{PED} = Vol. of pedestrians α = scaling parameter β_1 & β_2 = shape & relationship between traffic volume and number of accidents	*Safety in Numbers*: increase in number of pedestrians as a result of reduction in traffic volume will bring about a decline in pedestrian-vehicle crash
[23]	Relationship between built-in Environment (B.E), pedestrian activity and pedestrian collision frequency at signalized intersection	N.B models used to analyze the proposed equation: $P = f(\alpha; BE, \Sigma_{1i})$ $\Theta = f(\beta; V, P, x, \Sigma_{2i})$ Where P = Pedestrian activity Ɵ = pedestrian-vehicle collision frequency	B.E characteristics like population density, no. of bus-stops, street length, % of major arterials are significantly associated with pedestrian activity (with elasticities that vary from 0.16-0.46) B.E characteristics on pedestrian-vehicle collision frequency is significantly associated with pedestrian activity & traffic volume (with elasticity of 0.45-1.1 respectively)
[24]	Analyze the relationship btw pedestrian safety and Built-in Environment (like land use patterns, population, transit characteristics) at the Census tract and Zip code level using New York City as case study.	• N.B model • N.B with heterogeneity in dispersion parameter. • Zero-inflated N.B Model	• B.E characters like multilane is greatly associated with pedestrian-vehicle crashes. • Census tract data sample provides better and more in-depth result details than the zip code
[25]	Introduction of a multivariate, area-level regression model of vehicle-pedestrian injury collision as influenced by B.E Case study: San Francisco, California county (Census tract data, 2001-2005)	Multivariate, Area Regression Model	Consistent with previous study: Traffic volumes, road width, employee/resident population, arterial streets without public transit are all significant determinants of vehicle-injust collision. Thus, validates the methodology.

CHAPTER 3: METHODOLOGY

3.1. Corridor Selection

The study of the impacts of access management on pedestrian safety could serve as an example of a broad analysis requiring diverse studies encompassing numerous roadways [26]. This has therefore necessitated the need for a case study research for this work. Previous studies have shown that a case study allows researchers carry out evaluations on holistic issues/problems within certain specific boundaries so long as they exhibit common issues/problems and are influenced by similar factors [26]. This study utilized arterial and local roads which are the main pathways for commercial activities and pedestrian movement in Nashville area. The selected arterials were considered because they feed into the freeways and are characterized with speed limits between 35-50mph. This roadway class was therefore most suited for the actualization of the aim of this study. The local streets on the other hand usually support access to residential areas (homes) and are therefore designed for low vehicle speeds. They possess less commercial activities, fewer commercial access points and prone to fewer vehicle-pedestrian interaction. For proper and precise analysis, representative sample corridors/roadways were selected from the Nashville arterial roadway class randomly [27]. Based on this sampling, eight (8) arterial access corridors /roadways with the following similar characteristics were selected for analysis: Two or more business areas within 1-2 mile, high AADT and high number of access points. The selected corridors included:

1. Charlotte Pike (SR024) – Log mile (3.648 – 10.298)
2. Nolensville Pike (SR011) – Log mile (0.54 – 6.49)
3. Hillsboro Pike (SR106) – Log mile (3.67 – 6.40)
4. Jefferson Street (03258) – Log mile (0.055 – 2.265)
5. Harding Pike / West end (SR001) – Log mile (10.98 – 16.00)
6. Lebanon Pike (SR024) – Log mile (15.05 – 22.56)
7. Murfreesboro Pike (SR001) – Log mile (22.84 – 28.15)
8. Bell Road (01011) – Log mile (1.63 – 5.53)

3.2. Data Collection

The use of primary and secondary data collection methods was employed in assembling data required for analysis of this study. These primary data include information such as traffic records (AADT, lane width, median width, speed limit etc.) and geometric data. However, difficulties in logistics like police approval, limited funds and time constraints were major barriers to field data collection. This therefore necessitated the use of the Enhanced Tennessee Roadway Information Management System (E-trims), Google Earth and simple on-field data collection.

3.3. Google Earth Data

It is an advanced geo-browser which accesses satellite and aerial imagery, ocean bathymetry and other geographic data over the internet to represent the earth as a three dimensional globe. On this software, the search engine was used to identify each roadway which was further divided into different segments of signalized intersection. However, distances greater than 0.5 miles with no signalized intersection was subdivided for a more precise analysis (except roadways with no major access point e.g. SR024). Furthermore, utilizing the line/path measurement tool, each segment length, lane width, median width and shoulder width were measured several times and the average figure recorded.

3.4.Database Data

The Enhanced Tennessee Roadway Information Management System (E-trims) is an online data base owned and managed by Tennessee Department of Transport (TDOT). In this study, this database served as a source for several traffic, geometric and crash data.

1. Traffic Data: E-trims provided access to online advanced query which was utilized to gather traffic data for each roadway. Some of the relevant information obtained includes beginning and end log miles, AADT, DHV%, Peak Hour %, Directional Distribution, Passenger Car %, Truck %.
2. Crash data: Historic crash data (involving pedestrian) was used to obtain crash frequency patterning to the selected roadways. In order to obtain pedestrian crash trend within a precise time frame, pedestrian crashes were obtained from 2000 – 2015.

3.5. Merging Data

Each of the roadways selected possessed beginning log mile (BLM) and end log mile (ELM). These were easily identified from the traffic data search from E-trims. The need for identification of access management features for each roadway segment and corresponding pedestrian crash trend necessitated the need for identification of specific BLM and ELM for each roadway segment. Utilizing the Google Earth, the start point (beginning) and end point (end) of each roadway was identified and represented the corresponding BLM and ELM of E-trims. For easier identification during statistical analysis, segments were issued Unique Identification (Unique ID).

3.6. Data Summary and Description

A total of 165 segments were identified in the case study area and utilized for this study. Each segment were coded and allotted a ROUTE ID and UNIQUE ID for easier identification and location at base file. Each Route ID was obtained by the addition of sequential numbers 001, 002, 003 to the original route ID (for E-trims) while the unique ID were sequential numbers of 1000, 2000, 3000, 165,000. Several researchers are of the opinion that vehicle crashes are characterized as random, rare, and countable and of positive numbers [20]. This implies that vehicle crashes cannot be easily predicted and for roadways with good level-of-service (LOS), its occurrence is seldom. Since the focus of this study is on pedestrian, other crash types (vehicle-vehicle, vehicle-to-property, vehicle-to-bicycle etc.) were ignored. A total of 341 pedestrian crashes were recorded for the duration in the selected roadways with Harding/West End Pike (SR001), Charlotte Pike (SR024) and Murfreesboro Road (SR001) having the highest frequency of 76, 60 and 49 crashes respectively (Table 3.1). Since roadway division was dependent on distance between signalized/unsignalized major intersections, therefore, summation of segment length and number of segments vary for the different roadways. Further descriptive summary of the entire pedestrian crash by total segments revealed that pedestrian crash frequency appear to reduce as the number of segments increase (Figure 3.1). Though 60 different segments recorded no crash for the 15-year duration, the highest crashes per segments were observed in Charlotte Pike (SR024) and Hillsboro Pike with 13 pedestrian crashes each, Figure 3.2.

Table 3.1: Summary of Crash Data by roadway (2000-2015)

Road Name (Road ID)	No. of segments	∑ Segment length (Miles)	No. of Crashes
Bell Road (01011)	19	3.9	9
Jefferson Street (03258)	10	2.2	40
Harding Pike/West-end (SR001)	27	5.02	76
Murfreesboro Pike (SR001)	21	5.31	49
Nolensville Pike (SR011)	23	5.95	39
Charlotte Pike (SR024)	26	6.65	60
Lebanon Pike (SR024)	24	7.51	34
Hillsboro Pike (SR106)	15	2.73	34
TOTAL	165	39.27	341

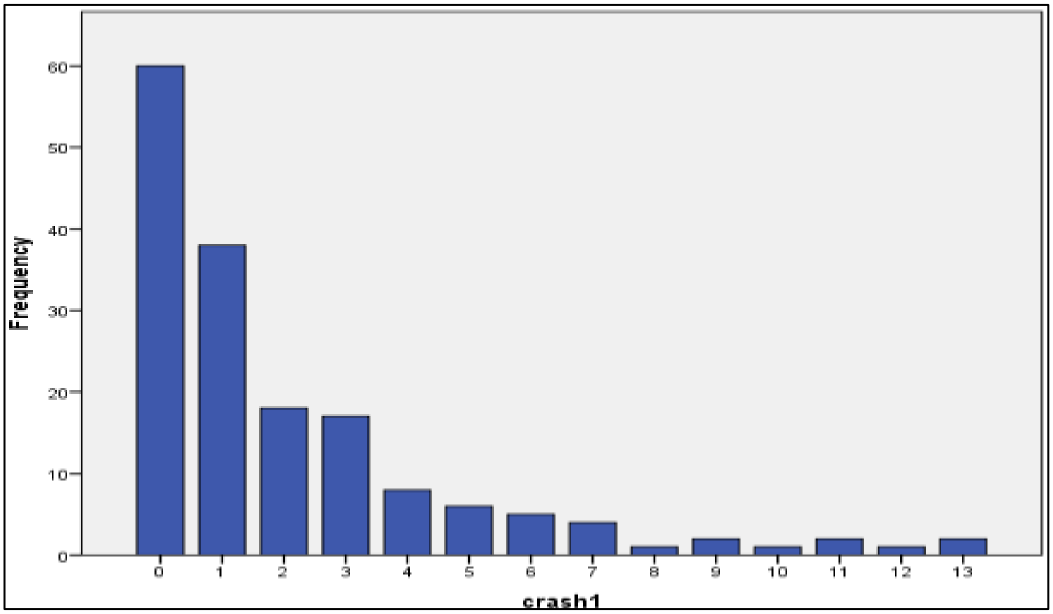

Figure 3.1: Crash Frequency Summary

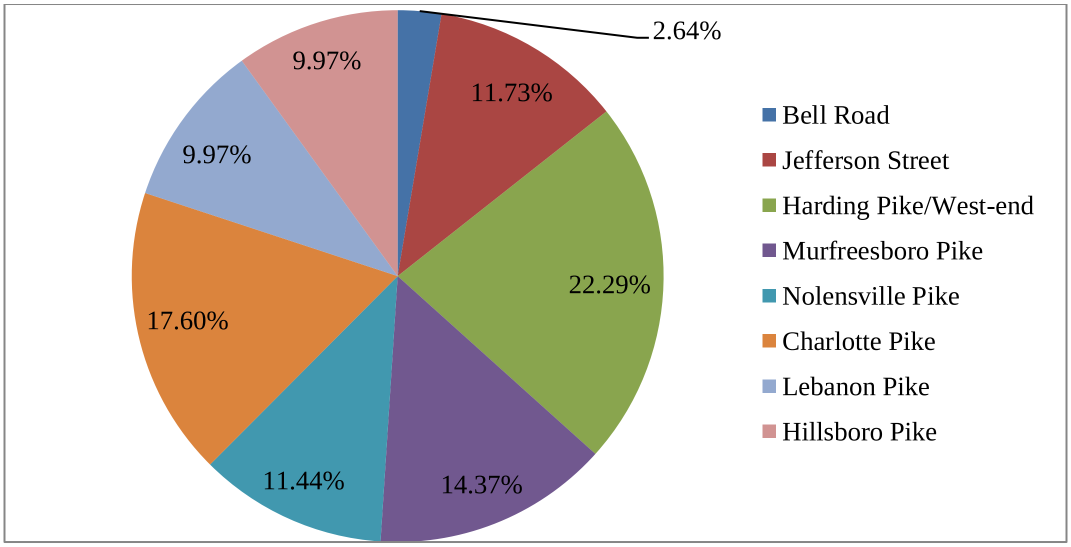

Figure 3.2: Roadway Crash distribution by Percentage

3.7.Crash Prediction Model

Crash prediction models are various statistical/mathematical equations which identifies the relationship between crash frequencies and access management features [28]. While several researchers refer to it as Safety Performance Functions, the Highway Safety Manual identifies two main types of SPF's which could be developed, namely:

1. LEVEL 1 SPF's : determines crash frequencies based on traffic volume (AADT) and segment length only
2. LEVEL 2 SPF's: determines crash frequency from different variables like access management features and various socio-demographic features.

Safety Analyst software developed by Federal Highway Authority (FHWA) determines only level 1 SPF's [29]. Since the objectives of this study is to determine the relationship between crash frequency and various access management features, level 2 SPF's were considered for analysis.

3.7.1. Model Selection Criteria

It is worthy of note that existing crash models developed for analysis has evolved from the ordinary linear form to the generalized linear model form [30, 31]. According to standard requirement from the SPF guide, some major issues considered for model selection include;

Variable Selection: For the objective of this study, various variables were meant to be used in the analysis. However, the addition of too many variables could lead to overfitting and inclusion of correlated variables, and therefore poor analysis result. In order to prevent this, variables were examined according to standard requirements.

Variable Correlation: Two variables are said to be correlated when the knowledge of one enables for the prediction of the other with known degree of accuracy. The use of correlated variables in most statistical models could result in error, displaying existence of multicollinearity, therefore posing a problem for this study. The correlation test was done between variables and it was realized that certain variables are correlated. Therefore only one of the correlated variables was utilized in statistical modeling analysis.

Overdisposition Parameter: overdispersion is the condition where data is characterized with variance greater than its mean value while underdispersion is its direct opposite where variance is less than the mean. For Poisson regression analysis, equidispersion (the condition of equal variance and mean) is assumed whereas overdispersion is the predominant condition found in crash data frequency. Therefore to determine the appropriate statistical model suited for the crash data obtained, there was a need to ascertain the mean, variance and overdispersion of the crash data. Utilizing a descriptive summary of total pedestrian crashes of the selected roadways, mean of 2.067 and variance of 7.697 were obtained. Since the mean and variance of the pedestrian crash frequency are not equal, the Poisson regression seemed to be unsuitable for accurate data analysis. This was also further reiterated by the best-fit graph (Figure 3.3) to the observed crash and it was observed that the Negative Binomial model seemed best suited for the data analysis (Figure 3.3), with its plot also best fitted with the actual observed proportion as compared with the Poisson probability.

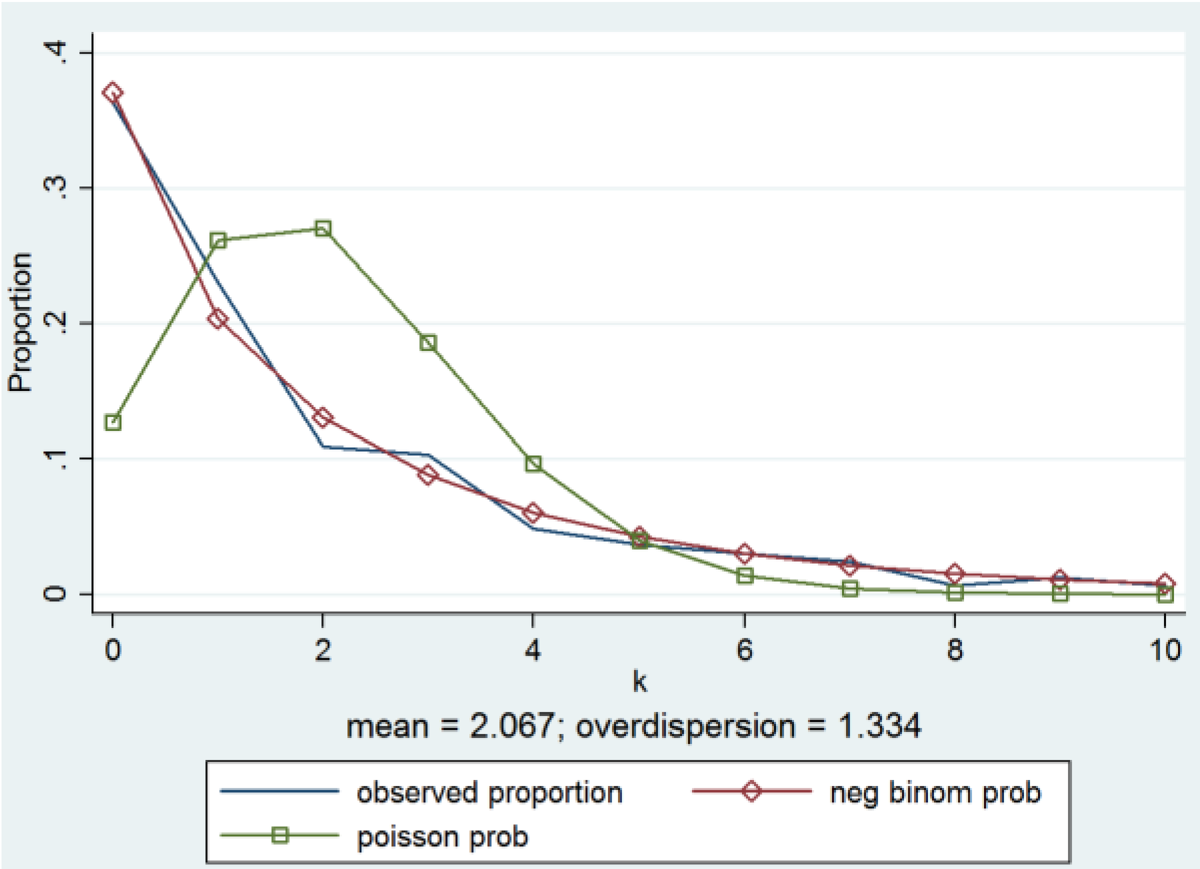

Figure 3.3: Poisson probability vs Negative Binomial test

3.7.2. Negative Binomial (NB) Model

The Negative Binomial is an enhanced form of the Poisson model best suited for crash data with these characteristics. In this study, Negative Binomial was utilized to model the correlation between the access management variables for the selected roadways and corresponding pedestrian crash frequency. In its application, segment length was considered as offset. This implies that there is no possibility of pedestrian crash for roadways with zero segment length. The Negative Binomial is given by 3.1 [32].

For crash data:

- mean ≠ Variance
- VAR *(yi)* > *E (yi)*
- *E (yi)* = expected no. of crashes at a period

$$P(y) = \frac{\tau(y+\alpha^{-1})}{\tau(\alpha^{-1})\tau(y+1)}\left[\frac{1}{1+\alpha\mu}\right]^{1/\alpha}\left[\frac{\alpha\mu}{1+\alpha\mu}\right]^{y} \qquad (3.1)$$

Where

$\mu = E(yi) = e^{(Xi\,\beta)}$

μ = overdispersion factor

□ = mean of crashes

X_i = value of variable being evaluated

CHAPTER 4: MODEL RESULTS AND CONCLUSIONS

4.1. Model Results

Prior to statistical model analysis with the selected model (Negative Binomial), a correlation test was utilized to ascertain variables which were somewhat correlated (see chapter 3). Correlation test was run to determine which variables were highly correlated to avoid variable redundancy. Access management variables such as AADT, access density, percent of trucks, presence of TWLT, presence of median, presence of shoulder, presence of crosswalk, presence of sidewalk and posted speed limits served as independent variables with segment length utilized as offset.

Table 4.1 shows the Negative Binomial model results, also represented in equation (4.1):

$$C = e^{0.778+0.000015A+0.043AD+0.036T+0.206TW-0.266M-0.422C-0.130S-0.064Si-0.584SL} \quad (4.1)$$

Where
C = Predicted number of Pedestrian crashes

Table 4.1: Negative Binomial Regression results

Variables	**Coefficient**	**Z- factor**	**P(Z)**
AADT (A)	1.51E-05	0.43	0.67
Access Density (AD)	0.043	2.37	0.02
Percent of Trucks (T)	0.036	1.47	0.14
Presence of TWLT (TW)	0.206	0.84	0.40
Presence of Median (M)	-0.266	-0.78	0.44
Presence of Crosswalk (C)	-0.422	-1.93	0.05
Presence of Shoulder (S)	-0.13	-0.54	0.59
Presence of Sidewalk (Si)	-0.064	-2.93	0.00
Speed Limit 30-40 mph (SL)	-0.584	-2.87	0.00
Constant (β)	0.778		
Length	**(offset)**		

4.2. Result Interpretation and Discussion

It was observed that a unit increase in variables with negative coefficient will result in a decrease in the number of pedestrian crashes and vice versa [29]. P-value of 0.1 (90% confidence level) was utilized as the acceptable significance level. Variables such as access density, presence of crosswalk, presence of sidewalk and speed limit were found to significantly influence the frequency of pedestrian crashes at the referenced confidence level. Only the access density returned positive coefficient among the significant variables, indicating a positive association with pedestrian crashes. That is, an increase in the number of access density of these roadways will result in corresponding increase in pedestrian crash frequency. This implies that for the analyzed corridors, segments with fewer access densities (fewer business/commercial access points) were safer for pedestrians than those with more access points. The findings is consistent with existing studies which suggest that corridors with high access densities such as commercial/business areas are characterized with higher number of pedestrian and vehicle crashes. The presence of crosswalk has negative coefficient showing presence of crosswalks result in the reduction of pedestrian crashes. The variable is also significant which is consistent with previous findings which showed marked crosswalks alert drivers to reduce speed or sometimes stop to allow pedestrian crossing, [33]. Similarly, the presence of sidewalk has significant negative coefficient indicating that roadway segments with sidewalks experienced less pedestrian crashes compared to those without sidewalks. This finding could resolve the contradict results of previous studies in which some showed presence of sidewalks to increase pedestrian-vehicle interactions hence high probability of related crashes. Others are of the opinion that roadways with sidewalks are safer especially those with guardrails as they provide a clear and distinct path for vehicle and pedestrian movement.

For the posted speed limit variable, the study found that roadways with lower posted speed limits between 30 – 40 mph as compared with the referenced speed of 45–55mph tend to decrease crash frequency. That is, with a coefficient of -0.584 and P- value of 0.004, increase in posted speed limit increase the likelihood of pedestrian crashes. Previous studies have concluded that posted speed limit is a statistically significant determinant of all forms of crashes as well as injury severities. AADT, present of rucks and the presence of TWLT all had positive coefficients in the model, showing their increase or presence increase likelihood of pedestrian crashes. However these variables were not significant in the model. For roadway sections with TWLT, it eliminates the median which could serve as a ‘safe’ resting point for pedestrian during crossing. This is also evident in the reverse result found for the ‘presence of median lead to decrease in pedestrian crashes. Presence of shoulders also tends to lower pedestrian crashes and shown by negative coefficient in Table 4.1.

4.3. Conclusions

Overall, the study found that pedestrian safety is affected by accesses management practices especially the distribution of access points. Though critical to commercial and business access, if not planned well, access points may lead to severe pedestrian crashes. Therefore, access density can be reduced by re-routing the entrance/exit point to and from the business areas to minimize conflicts. In addition, divided roadways with raised medians are much safer than TWLT or undivided roadways for the pedestrian safety. Speed limits along commercial areas with significant pedestrian movements should be kept not above 40 mph as beyond that the risk to pedestrian safety increases.

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