A Methodology to Measure Pedestrian Crash Rates against Statewide Averages for Roadways and Intersections in Central Florida

Hatem Abou Senna[1]*, Negaar Minaei[2], Azza Alisawi[3] and Youssef Elsebaie[4]

[1]*Associate Professor, Department of Civil, Environmental and Construction Engineering (CECE), University of Central Florida, Orlando, Florida, USA*

[2]*Travel Demand Modeler, CDM Smith Consulting Engineering, Maitland, Florida, USA*

[3]*MS Student, University of Central Florida, Orlando, Florida, USA*

[4]*MS, University of Central Florida, Orlando, Florida 32816, USA*

*Corresponding author: Hatem Abou Senna, Associate Professor, Department of Civil, Environmental and Construction Engineering (CECE), University of Central Florida, Orlando, Florida, USA

Abstract

To date there are no clear or uniform standards for a method to measure pedestrian crash rates and compare it against a statewide average. In this paper, a novel methodology to measure pedestrian crash rates along roadways and intersections is presented. The main objective is to identify critical pedestrian crash locations that are operating above its corresponding statewide average. It was crucial to address the pedestrian-vehicular conflict as the State of Florida currently tops the list in the "Dangerous by Design" report as having the highest four pedestrian incident locations in the Country. The main challenge was to identify a practical and accurate exposure measure. In most cases, the exposure measure is either a surrogate or impractical. The proposed approach focuses on the potential conflict between pedestrians and motor vehicles expressed in the amount of walking while at risk of being involved in a vehicle crash. The main parameters used in calculating pedestrian crash rates along roadways and intersections included roadway, pedestrian volume and crash data. The pilot studies conducted for the roadways and intersections revealed several critical safety locations within District 5 when compared to the developed statewide average rates which required further investigation to identify main causes and emphasize mitigation improvements. It is recommended that an annual statewide pedestrian count program be initiated for the intersections as well as roadways which would increase the sample size and help in validating the assumptions provided in this study.

Keywords: Pedestrian Safety; Pedestrian Crash Rates; Statewide Crash Rate Averages; Pedestrian-Vehicle Conflict; Exposure Measures

Introduction

Pedestrian safety has become more predominant for governmental agencies to address and prioritize. With the transition to the mobility of people, to date there are no clear or uniform standards for a method to measure pedestrian incidents against a statewide average. However, the Florida Department of Transportation (FDOT) has developed vehicular crash rates that resulted in hypothesis that geometric and traffic characteristics influence vehicle incidents and corresponding crash rates. Therefore, research is needed to evaluate / identify crash rates for pedestrians that would result in the ability to identify locations within regions for higher than or above a statewide average on pedestrian crash rates.

Between 2006 and 2009, pedestrian fatalities in the United States declined from 4795 to 4109. However, the downward trend had halted and there were 4302 pedestrian deaths in 2010, increasing to 4457 in 2011 and 4743 in 2012 [1]. Recently, the 7,388 pedestrian fatalities in 2021 represented approximately 13-percent increase from 6,565 pedestrian fatalities in 2020 [2]. Although pedestrian deaths were two percent lower in 2021 than in 1975, they have increased 80 percent since reaching their lowest point in 2009. It is the highest since 1981, when 7,837 pedestrians died in traffic crashes. The state of Florida has consistently ranked as one of the worst states in terms of pedestrian crashes, injuries and fatalities according to the National Highway Traffic Safety data [2]. Ernst (2021) also indicated that four metro areas in Florida (Orlando-Kissimmee, Tampa-St. Petersburg-Clearwater, Jacksonville, Miami-Fort Lauderdale-Pompano) were considered the most dangerous for pedestrians among all the United States [3]. Therefore, pedestrian safety is of particular concern to Florida. Several studies used several methods and surrogate measures to estimate pedestrian crashes. In general, population, pedestrian volumes, time and distance are examples of the most studied surrogate measures for pedestrian exposure. The methods used in estimating pedestrian hot spot crash locations included density methods, clustering methods and other GIS-related methods. However, the main challenge in analyzing pedestrian crashes is to identify a practical and correct exposure measure as in the case with vehicular crashes. In most cases, the exposure measure is either unavailable, unpractical or can be obtained at a great cost. In this paper, statewide averages for pedestrian crash rates were quantified to identify critical pedestrian crash locations, thus evaluating locations that are operating beyond statewide averages and therefore emphasizing mitigation improvements.

Literature Review

There have been numerous studies that were devoted to investigating and evaluating pedestrian safety at the national level as well as Statewide and local levels. Several studies also attempted to identify significant factors related to pedestrian crashes. The main factors discussed in this section include environmental factors, roadway characteristics factors, human factors, and vehicle characteristics factors.

Ernst et al. (2021) in the "dangerous by design" national report conducted for the Transportation for America examined the pedestrian fatalities for each state from 2011 to 2021 to identify the common thread on the roads. Using ten years of pedestrian fatality data, they used a Pedestrian Danger Index (PDI) to rank the country's largest metropolitan areas according to their relative risk to walkers. The analysis concluded that Orlando tops the list of most dangerous places due to its high pedestrian fatality rate of 3 per 100,000 people, followed by Tampa, Jacksonville and Miami areas [3]. Chang (2008) utilized the Fatality Analysis Reporting System (FARS) to analyze the trends in pedestrian fatalities and identify the probability of different contributing factors [4]. He found that 26% of pedestrian crashes occurred from 3 p.m. to 6 p.m. in Chicago, which was the period with most occurrences. However, NHTSA found that 24.7% percent of pedestrian deaths were between 6

p.m. and 9 p.m. which was the highest number of pedestrian deaths during the whole day. Weather and lighting condition factors were also of common concern. Clifton (2009) and Mohamed et al. (2013) showed that poor lighting conditions lead to increase the likelihood of pedestrian injuries [5,6]. However, weather was not a significant factor in Dai (2012) findings [7]. Ukkusuri et al. showed that a greater fraction of residential land use decreased pedestrian crashes compared to the industrial, commercial and open land use types in New York City [8]. They also found that more pedestrian crashes were associated with larger road width. Other similar studies concluded that low density residential areas were more dangerous than compact areas [9,10].

Lee and Abdel-Aty (2005) used four years of vehicle-pedestrian crashes data from 1999 to 2002 in Florida to identify roadway characteristics that were correlated with high pedestrian crashes using a log-linear model [11]. They found that undivided roads with a greater number of lanes were more dangerous than divided roads with fewer lanes. Hanson (2013) also studied roadway characteristics which included the presence of sidewalks, buffers between the road and the sidewalk, number of travel lanes and presence of medians, traffic control at intersections, and posted speed limits with a database of pedestrian casualties [12]. The results showed that lack of buffers between the road and the sidewalk and higher speed limits were found to be associated with higher pedestrian severe causalities and fatality rates. Chidester and Isenberg (2001) developed the Pedestrian Crash Data Study (PCDS) in 1994. The data were collected through on-scene crash investigations (or within 24 hours) of pedestrian crashes using two techniques, video camera recording and contour gauge, to collect 521 pedestrian crashes at six sites which were selected from around the nation [13]. The study concluded that 68% of the involved vehicles were passenger cars and 32% were other light vehicles, including light trucks, vans, and utility vehicles.

Brustman (1999) utilized two main databases to analyze pedestrian and bicyclist crash rates [14]. One was "Hospitalizations Due to Bicyclist and Pedestrian Injuries" from the Department of Health (DOH), which was more reflective of the actual injury situation. The other was "Summary of Bicycle and Pedestrian Crashes on State Highways" from the Department of Transportation (DOT), which looked for clusters of crashes on state highway routes. They found that municipal streets had a higher probability of crashes involving a pedestrian compared to state roads, county roads, town roads and limited access highways. Thomas et al. (2009) used five years of state crash data and the perception data from 400 intercept survey respondents to identify the general trends in characteristics of people and the high-risk locations in North Carolina [15]. They used kernel density analysis method through GIS to identify high risk locations and exploited Ripley's K-function test to decide whether crashes were clustered randomly. An age-specific study of death rates due to pedestrian-car crashes in the city of Montreal was   conducted in which the inner city was compared to the outer parts of the cities in four contiguous areas. They found that the rates are highest in downtown and decrease progressively in the outlying areas [16]. Dumbaugh et al. (2012) mainly focused on the

relationship between the built environment and pedestrian crashes in Texas [17]. Negative binomial regression models were fitted to the data and it was concluded that the environmental factors associated with a vehicle-pedestrian crash were a combination of traffic conflicts and the vehicle speed. Dewey et al. (2003) pointed out why pedestrian fatality rates in Florida were higher than other states [18]. A multivariate regression model was used to analyze specific factors that could relate to the pedestrian fatality, including environmental factors and crash locations. They found that Florida residents walk more often in places that are exposed to traffic compared to other U.S. residents because of warm winters and the natural timing of summer and winter sunlight. Besides, there were millions of tourists visiting Florida every year, which led to more exposure to traffic. In another FDOT pedestrian safety study, Alluri et al. (2013) analyzed 6434 pedestrian crashes on roads during 2008-2010 in Florida [19]. A mixed logit model was developed to identify factors contributing to pedestrian injury severity at signalized and non-signalized locations. Several countermeasures at both non-signalized and signalized locations were suggested to reduce pedestrian crash frequency and severity. Abou-Senna et al. (2016-2022) investigated reasons attributing to pedestrian crashes in Central Florida using categorical principal component analysis (CATPCA) and identified several parameters including sidewalk gaps that ends abruptly along roadway segments [20-24].

Based on the literature review and previous studies, it can be seen that majority of the exposure measures used are either in an aggregate form and not accurate enough to represent a clear picture of the safety situation, or not practical enough to collect the data needed or do not indicate an overall level of the transportation activity. Very few studies in previous research that incorporated the product of P × V (pedestrian and vehicular traffic) as a measure of exposure. Others included the pedestrian miles travelled. The proposed approach focuses on the level of pedestrian activity and the potential conflict between pedestrians and motor vehicles expressed in the amount of walking while at risk of being involved in a motor vehicle crash. Majority of the pedestrian-vehicle crashes occur while crossing the street whereas insignificant percentage of crashes occur while walking along the street. Therefore, it is believed that the pedestrian miles crossed (PMC) parameter is more representative of the risks associated with pedestrian exposure. Furthermore, since the exposure measure should directly reflect the amount of walking in areas shared with vehicles, the vehicular traffic volume is another significant factor that should be included in the equation. Based on that, the three (3) main significant parameters that were used in the exposure measure calculations in this paper are:

a. Pedestrian traffic

b. Distance crossed

c. Vehicular traffic

The proposed methodology in this paper is considered detailed, practical and provide a broad depiction of the main factors that directly contribute to pedestrian crashes.

Methodology

The methodology was designed to arrive at the statewide averages for pedestrian crash rates involving two types of analyses: roadways and intersections. Statewide roadway characteristic inventory (RCI) data was collected from the GIS layers and classified according to their functional classification, area type and number of lanes as well as their annual average daily traffic (AADT) and total lengths. Intersection data was classified according to several parameters including their total entering traffic, total crossing distance, total daily pedestrians and type of control. Furthermore, the total statewide number of crashes over the 5-year period (June 2016 to May 2021) was identified for all the roadways and intersections. In addition to the intersection GIS data, sample intersection data was collected based on a pilot study within the nine [9] counties of FDOT District Five. The purpose of the pilot study is to identify the critical pedestrian safety locations within the district and correlate this against safety locations based on statewide averages. The methodology is summarized into the following steps:

A. Roadways:

i. Identify statewide roadway categories and characteristics

ii. Assemble statewide pedestrian crashes along roadways

iii. Develop statewide average pedestrian crash rates along roadways

iv. Determine critical segment locations within District 5

B. Intersections:

i. Identify statewide intersections and characteristics

ii. Identify pedestrian crashes at signalized intersections

iii. Pilot study for District 5 intersections

iv. Estimation of intersection pedestrian volume

v. Intersection classification

vi. Establish statewide average pedestrian crash rates at intersections

vii. Determine critical hotspot locations within District 5

Pedestrian Crash Rates for Roadways

Identify Statewide Roadway Categories and Characteristics

FDOT roadway GIS layers were spatially joined to categorize the roadways according to their functional classification, area type, AADT, number of lanes and total lengths. Functional classification layer included 7 different roadway classes; Principal Arterial-Interstate, Principal Arterial-Expressway, Principal Arterial-Other, Minor Arterial Major Collector, Minor Collector and Local roads Area type included 2 types (urban and rural). The number of lanes layer included 12 categories and was further split based on the roadway side value for divided and undivided roadways. A total of 135 different categories resulted from these combinations (83 for divided and 52 for undivided). The last 5-year AADT data (2016-2021) was then overlaid on top of the roadway categories and the

average AADT values were calculated for each roadway type. The total length for each roadway category was also calculated. The total length of the undivided roadways was about 29,400 miles while the divided roadways length was about 15,400 miles.

Assemble Statewide Pedestrian Crashes along Roadways

The GIS layer from Signal Four Analytics database for the most recent 5-year period (June 2016-May 2021) was utilized to identify statewide pedestrian crashes along the roadways [25]. The statewide data showed a total of 35,287 pedestrian related crashes. The crash layer was spatially joined with the roadways layer and a 15 feet buffer was used to identify the crashes that occurred specifically on the roadway segments. A total of 14,451 pedestrian related crashes were located along roadways involving the state highway system. There were 9,552 pedestrian crashes on the divided roadways while 4,899 crashes on the undivided roadways.

Develop Statewide Average Pedestrian Crash Rates along Roadways

The exposure measure used to calculate pedestrian crash rates along the roadways included the total length in miles, total number of crashes and the AADT for each roadway category over the 5-year study period. The average number of daily pedestrians for each roadway category is not applicable in this case due to the fact that pedestrians are less confined to paths of travel than motor vehicles and they often travel in closely spaced groups in specific areas. There will be numerous locations along the roadway with no pedestrians or no designated crossings except at intersections or midblocks which are addressed in the intersections' section. Therefore,

it is difficult to define an average number of pedestrians that are always using a 2-lane urban major arterial or 4-lane rural minor collector and generalize it statewide for the entire roadway type. Reliable data is necessary for measuring trends in facility use and for putting crash data into context. Accordingly, the equation used in calculating average pedestrian crash rates along roadways is: 4

$$APCR = \frac{\#PC_5 * 10^8}{5 * 365 * L_i * ADT_i} \quad (1)$$

Where:

APCR = Average Pedestrian Crash Rate per 100 million vehicle miles.

$\#PC_5$ = Number of Pedestrian Crashes over 5-year period

L_i = total length of the roadway category

ADT_i = Average daily traffic for the roadway category

Using the above formula, statewide averages for pedestrian crash rates along roadways were established. Tables 1a & 1b summarize all the divided and undivided roadway data respectively, exposure measure and average crash rate for each category. It should be noted that few roadway categories had total lengths of less than one mile and others exhibited zero pedestrian crashes. Therefore, these categories were eliminated from the database. The analysis resulted in a total of 70 different roadway categories with 70 different statewide average rates. The divided roadways had 45 categories while the undivided roadways had 25 categories.

Table 1a: Statewide Average Pedestrian Crash Rates for Divided Roadways.

Divided Roadway Category	5-YR Number of Ped Crashes	5-YR AADT	Total Length (mile)	Statewide Crash Rate per 100 MVM
2-Lane - Divided Local - URBAN	89	7443	108.04	6.064
2-Lane - Divided Major Collector - RURAL	5	4380	78.5	19.922
2-Lane - Divided Major Collector - URBAN	967	9647	1153.97	4.76
2-Lane - Divided Minor Arterial - RURAL	15	4051	114.29	44.382
2-Lane - Divided Minor Arterial - URBAN	511	13124	575.79	3.705
2-Lane - Divided Minor Collector (Fed Aid) - URBAN	152	8289	239.61	4.193
2-Lane - Divided Principal Arterial-Other - RURAL	31	9118	152.42	30.558
2-Lane - Divided Principal Arterial-Other - URBAN	199	14652	228.05	3.263
3-Lane - Divided Local - URBAN	3	7367	10.14	3.667
3-Lane - Divided Major Collector - URBAN	108	11173	101.66	5.21
3-Lane - Divided Minor Arterial - URBAN	68	16686	73.03	3.058
3-Lane - Divided Minor Collector (Fed Aid) - URBAN	17	11320	14.05	5.857
3-Lane - Divided Principal Arterial-Other - RURAL	2	8071	102.99	8.24
3-Lane - Divided Principal Arterial-Other - URBAN	21	16482	35.89	1.945
4-Lane - Divided Local - RURAL	1	3850	12.03	29.58
4-Lane - Divided Local - URBAN	49	20295	73.45	1.801
4-Lane - Divided Major Collector - RURAL	2	10025	116.64	5.858
4-Lane - Divided Major Collector - URBAN	748	15434	1089.63	2.437

4-Lane - Divided Minor Arterial - RURAL	4	7451	101.66	9.042
4-Lane - Divided Minor Arterial - URBAN	2043	23835	1858.32	2.527
4-Lane - Divided Minor Collector (Fed Aid) - URBAN	92	13185	187.98	2.034
4-Lane-Divided Principal Arterial-Expressway- RURAL	4	29706	350.22	0.658
4-Lane-Divided Principal Art-Fwy and Expwy-URBAN	77	49155	519.58	0.165
4-Lane - Divided Principal Arterial-Interstate - RURAL	8	37999	762.82	0.378
4-Lane - Divided Principal Arterial-Interstate - URBAN	10	51122	508.62	0.527
4-Lane - Divided Principal Arterial-Other - RURAL	30	10755	1264.34	3.022
4-Lane - Divided Principal Arterial-Other - URBAN	1382	28393	2308.33	1.155
5-Lane - Divided Major Collector - URBAN	15	19333	10.14	4.192
5-Lane - Divided Minor Arterial - URBAN	81	30298	66.05	2.218
5-Lane-Divided Principal Art-Fwy and Expwy- URBAN	1	28250	21.27	0.456
5-Lane - Divided Principal Arterial-Interstate - URBAN	5	92502	18.03	0.164
5-Lane - Divided Principal Arterial-Other - URBAN	81	41642	65.92	1.617
6-Lane - Divided Local - URBAN	10	38853	1.91	7.372
6-Lane - Divided Major Collector - URBAN	60	30640	35.1	3.057
6-Lane - Divided Minor Arterial - URBAN	371	34409	308.23	1.917
6-Lane - Divided Minor Collector (Fed Aid) - URBAN	10	19248	2.14	13.309
6-Lane-Divided Principal Art-Fwy and Expwy- URBAN	42	96328	136.53	0.175
6-Lane - Divided Principal Arterial-Interstate - RURAL	7	48554	520.98	0.379
6-Lane - Divided Principal Arterial-Other - URBAN	1154	45934	910.85	1.511
7-Lane-Divided Principal Art-Fwy and Expwy- URBAN	6	80900	22.37	0.182
7-Lane - Divided Principal Arterial-Interstate - URBAN	7	183571	28.2	1.852
7-Lane - Divided Principal Arterial-Other - URBAN	37	51604	23.4	1.679
8-Lane-Divided Principal Art-Fwy and Expwy- URBAN	6	138421	39.42	1.506
8-Lane - Divided Principal Arterial-Other - URBAN	57	49186	46.29	1.372
9-Lane - Divided Principal Arterial-Interstate - URBAN	2	110250	7.21	0.344

Table 1b: Statewide Average Pedestrian Crash Rates for Undivided Roadways.

Undivided Roadway Category	5-YR Number of Ped Crashes	5-YR AADT	Length (mile)	Statewide Crash Rate per 100 MVM
1-Lane - Undivided Major Collector - URBAN	5	5500	16.92	2.944
1-Lane - Undivided Minor Collector (Fed Aid) - URBAN	5	6240	5.65	7.776
1-Lane - Undivided Principal Arterial-Other - URBAN	1	33000	5.31	1.565
2-Lane - Undivided Local - RURAL	39	7017	4203.49	1.811
2-Lane - Undivided Local - URBAN	260	5207	1443.28	1.896
2-Lane - Undivided Major Collector - RURAL	79	3131	5231.34	6.608
2-Lane - Undivided Major Collector - URBAN	1464	6664	5273.38	2.283
2-Lane - Undivided Minor Arterial - RURAL	69	5342	2578.46	6.862
2-Lane - Undivided Minor Arterial - URBAN	470	10758	1688.91	1.417
2-Lane - Undivided Minor Collector - RURAL	55	2439	4087.43	7.559
2-Lane - Undivided Minor Collector (Fed Aid) - URBAN	349	5009	1813.1	2.106
2-Lane - Undivided Principal Art-Frwy and Expwy - URBAN	1	5925	22	2.102
2-Lane - Undivided Principal Arterial-Other - RURAL	77	7153	1740.54	8.473

2-Lane - Undivided Principal Arterial-Other - UR-BAN	160	12705	730.2	0.945
3-Lane - Undivided Local - URBAN	3	7300	2.73	13.727
3-Lane - Undivided Major Collector - URBAN	75	9620	49.77	8.583
3-Lane - Undivided Minor Arterial - URBAN	102	11590	54.61	8.83
3-Lane - Undivided Minor Collector (Fed Aid) - URBAN	5	3867	5.08	13.945
3-Lane - Undivided Principal Arterial-Other - UR-BAN	164	19348	63.4	7.325
4-Lane - Undivided Local - RURAL	1	14400	2.35	40.48
4-Lane - Undivided Local - URBAN	5	5981	4.9	9.354
4-Lane - Undivided Major Collector - RURAL	1	10267	3.49	38.23
4-Lane - Undivided Major Collector - URBAN	132	9782	111.8	6.614
4-Lane - Undivided Minor Arterial - URBAN	337	16457	115.43	9.721
4-Lane - Undivided Minor Collector (Fed Aid) - URBAN	18	11285	13.1	6.673
4-Lane - Undivided Principal Arterial-Other - UR-BAN	160	20184	46.89	9.265

Area Type Adjustment Factor (ATAF)

From the analysis, it was found that the statewide average rates for rural roads exhibited very low values especially when compared with the urban rates. This could be attributed to the effect of averaging over the entire state and also due to the fact that rural roadway categories have very different characteristics compared to urban roadways. They were less than the urban categories but have longer lengths since they connect between urban areas and usually have less AADT volumes than urban roads and with extremely low number of pedestrian crashes. In order to account for the pedestrians at risk on rural roads, an Area Type Adjustment Factor (ATAF) was considered in the exposure measure for the rural areas. The analysis showed that out of the 21,434 miles of rural roads only 431 pedestrian crashes were recorded over the 5-year period. On the other hand, there were 12,233 pedestrian crashes recorded on the 23,145 miles of urban roads. Therefore, an ATAF of 0.04 was calculated by dividing the rural crashes per mile over the urban ones, to adjust for the pedestrians at risk in rural areas when compared to urban areas. Accordingly, the statewide average rates were revised to include the ATAF for rural roads as shown on Tables 1a & 1b. Other criteria were also required to disqualify segments with extremely low number of pedestrian crashes over the 5-year period. Therefore, the analysis was revised to include a minimum threshold of 5 crashes over the 5-year period to be considered in the analysis and compared to the statewide averages. Hence, the revised equation used to calculate average pedestrian crash rates along the roadways is:

$$\text{APCR} = \frac{\#PC_5 * 10^8}{5 * 365 * L_i * ADT_i * ATAF} \quad (2)$$

Where ATAF is (1) for urban roads and (0.04) for rural roads.

Determine Critical Segment Locations within District 5

A random sample of 10 segments located within FDOT district 5 jurisdiction were selected to identify critical safety concerns along these facilities and whether they are considered high crash locations. This should be determined by comparing the actual pedestrian crash rates to the developed statewide averages. As shown in Table 2, the sample included different roadway types and categories from Central Florida Counties (Orange, Osceola, Seminole and Lake Counties). Roadway segment data included the length measured from aerial maps as well as the average daily traffic over the 5-year period between 2016 and 2020 based on the latest FDOT traffic data. The 5-year pedestrian crash data was obtained from Signal 4 Analytics database from June 2016 till May 2021. The results showed that majority of the urban roadway segments within District 5 sample have the actual pedestrian crash rates greater than their corresponding statewide averages which qualifies them to be considered hazardous segments. It should be noted also that, although the number of crashes on some roadway segments seemed low, they exceeded the statewide average rate based on their exposure measure which takes into consideration traffic volume and length of the roadway segment. Since the length of the roadway segment plays a major role in the exposure measure, it is recommended to consider the maximum length of the studied segment that corresponds to the number of crashes. For example, if the studied roadway segment is two miles and has four crashes, then the analyst should consider the maximum length of this roadway segment that contains those four crashes by extending the segment from both sides just before the next crash, excluding the crashes at the intersections within 250 feet radius.

Table 2: Actual Crash Rates versus Statewide Averages for Roadway Pilot Study.

No	Roadway Name	segment	Roadway Category	AADT (5-YR Avg)	Length (miles)	No of Ped Crashes (5-YR)	Exposure	Actual Ped Crash Rate per 100MVM	Statewide Avg Rate per 100 MVM	Hazardous Segment
1	US 17/92 (OBT)	Oak Bridge Rd to Holden Ave	6 Ln Div Principal Arterial- Other Urban	58,500	1.50	14	160,143,750	8.74	1.51	YES
2	SR 434 (Alafaya TI)	SR 50 to McCull-och Rd	6 Ln Div Principal Arterial- Other Urban	59,400	3.12	22	338,223,600	6.50	1.51	YES
3	SR 436 (Semo-ran Blvd)	SR 528 to SR 408	6 Ln Div Principal Arterial- Other Urban	45,992	5.54	59	464,998,072	12.69	1.51	YES
4	SR 551 (Golden-rod Road)	Lake Underhill to SR 50	4 Ln Div Minor Arterial- Urban47,800	33,300	2.00	5	121,545,000	4.11	2.53	YES
5	SR 50 (Colonial Dr)	Dean Rd to Alafaya TI	4 Ln Div Principal Arterial- Other Urban	47,800	2.27	14	198,023,450	7.07	1.16	YES
6	SR 15 (Hoffner Ave)	Conway Rd to Goldenrod Rd	2 Ln Div Principal Arterial- Rural	21,060	2.61	4	100,314,045	3.99	6.86	NO
7	US 27	CR 747 to Lake Lousia Rd	4 Ln Div Principal Arterial- Other Rural	20,920	8.52	2	325,285,080	0.61	3.02	NO
8	US 192	Holopaw Rd to Deer Park Rd	4 Ln Div Principal Arterial- Other Rural	5,800	11.38	3	120,457,300	2.49	3.02	NO
9	SR 415	Celery Ave to Reed Ellis Rd	2 Ln Undiv Minor Arterial- Rural	16,920	2.48	2	76,579,920	2.61	6.86	NO
10	CR 419 (Chuluo-ta Rd)	SR 50 to Lake Pickett Rd	2 Ln Undiv Minor Arterial- Urban	12,000	1.93	1	42,267,000	2.37	3.59	NO

Pedestrian Crash Rate for Intersections

Identify Statewide Intersections and Characteristics

Several FDOT intersection GIS layers were utilized in order to gather all the relevant information associated with each intersection. The intersection layer included all types of intersections such as signalized and unsignalized. Furthermore, the GIS Traffic Signal Locations feature class layer provided spatial information on locations of traffic signals in the RCI database. The signal locations layers included 5 types of signalized intersections as follows: Flashing Beacon, Standard Traffic Signal, Mid-block Pedestrian Control, Emergency Signal and School Signal.

Identify Pedestrian Crashes at Signalized Intersections

To identify statewide pedestrian crashes that are related to signalized intersections, a 250 feet buffer radius was created around each of the signalized intersections. The GIS layer for Pedestrian crashes was spatially intersected with the 250' buffer to isolate pedestrian crashes located at signalized intersections (within 250 feet) from those located along the roadway segments. Data associated with the resulting pedestrian crashes at signalized intersection was then extracted and exported to a spreadsheet. Due to the overlapped traffic signal buffers at adjacent signalized intersections that are spaced less than 500 feet apart, some crashes associated with more than one signalized intersection were duplicated. Therefore, those duplicated crashes were eliminated from the analysis. A total of 6,684 statewide pedestrian crashes were located within the signalized intersections area of influence. Out of the 10,500 signalized intersections in the State of Florida, 3,492 signalized intersections experienced one or more pedestrian crash during the five-year study period. Crashes ranged from 1 to 20 crashes per intersection.

Pilot Study for District 5 Intersections

A pilot study was necessary to collect intersection specific data. FDOT District 5 was selected for this purpose out of the 6 districts in Florida due to its relatively high number of crashes compared to other districts. A sample of 52 intersections located within FDOT district 5 jurisdiction were selected to represent sufficient parameter variations to be utilized in the statewide analysis. The process for selecting these intersections is explained in the following sections.

a. Selection criteria

The FDOT GIS intersections layer within District 5 and the pedestrian crash layer were spatially joined. Based on the dataset, a total of 2,166 crashes were located within 250 feet diameter surrounding the intersections for the 5-year period between June 1st, 2016, and May 31st, 2021. The intersections were further divided into 2 categories (urban intersections and rural intersections). There were 1,760 crashes within the vicinity of urban intersections and 406 crashes within the vicinity of rural intersections. It was found that more than 85% of the rural intersections have only one crash while 90% of the urban intersections have crashes ranging from 1 to 5.

b. Sample Size

A reasonable statistical sample size should include more than 30 intersections; therefore 52 intersections were randomly selected using the random number generator. About third of the intersections were selected to be in rural areas (15 intersections). The remaining intersections were in urban areas (37 intersections).
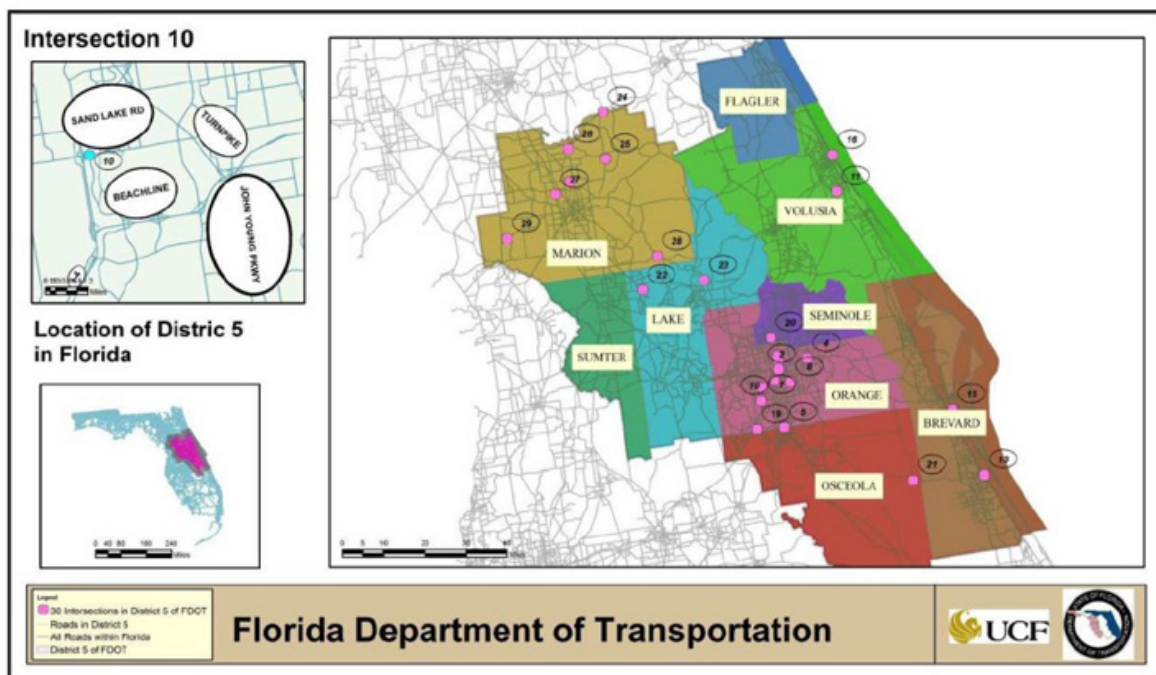
FIGURE 1: Candidate intersection locations within District 5.

c.   Sample Refinement

Since the sample size was randomly selected, therefore visual inspection of the selected intersections was necessary to ensure proper locations and correct number of crashes within the vicinity of the intersection. The visual inspection utilized the Signal 4 Analytics crash database [20]. The selected sample was further refined to include major intersections at appropriate locations with reasonable number of crashes that would trigger a reasonable amount of pedestrian activity. The intersections were then plotted on District 5 map to ensure an appropriate distribution. The selected intersections were distributed over 7 Counties out of the 9 Counties within District 5 as shown on Figure 1.

d.   Data Collection

The 52 intersections were videotaped for 24 to 48 hours. Then the following data was extracted from viewing and analyzing the recorded tapes in increments of 15 minutes:

i.   Number of daily vehicles at each directional approach (ADT)

ii.   Number of daily pedestrians crossing each directional approach (ADP)

In addition, distances crossed (DC) at each directional approach was measured from the aerial maps.

e.   Pedestrian Crash Rates

As explained earlier, three (3) main significant parameters were required to calculate the exposure measure:

i.   Average Daily Pedestrian traffic (ADP)

ii.   Distance Crossed (DC)

iii.   Average Daily Vehicular traffic (ADT)

The following formula is used to calculate the actual pedestrian crash rate at intersections:

$$APCR = \frac{\#PC_5 * 5280 * 10^6}{5 * 365 * \sum_{i=1}^{n} ADP_i * DC_i * ADT_i} \quad (3)$$

Where: (3)

APCR = Actual Pedestrian Crash Rate

$\#PC_5$ = Number of Pedestrian Crashes over 5-year period

$\sum_{i=1}^{n} ADP_i * DC_i * ADT_i$ = Sum of cross product of the average daily pedestrians * distance crossed in feet * average daily traffic for each directional approach (1 to 8).

It was more appropriate to use the sum of the product of the pedestrian miles crossed (PMC) and entering volume (ADT) for each entering and departing approach separately instead of using the cross product of the aggregate sum of each parameter along all approaches as depicted on Figures 2a & 2b. The above parameters were extracted from the sample intersections and pedestrian crash rates per million pedestrian miles crossed per entering vehicle (MPMC/EV) was calculated for each intersection as shown in Table 3.

Figure 2a: Pedestrian exposure at eight (8) intersection crossings.

Table 3: Pedestrian Crash Rates at Sample Intersections.

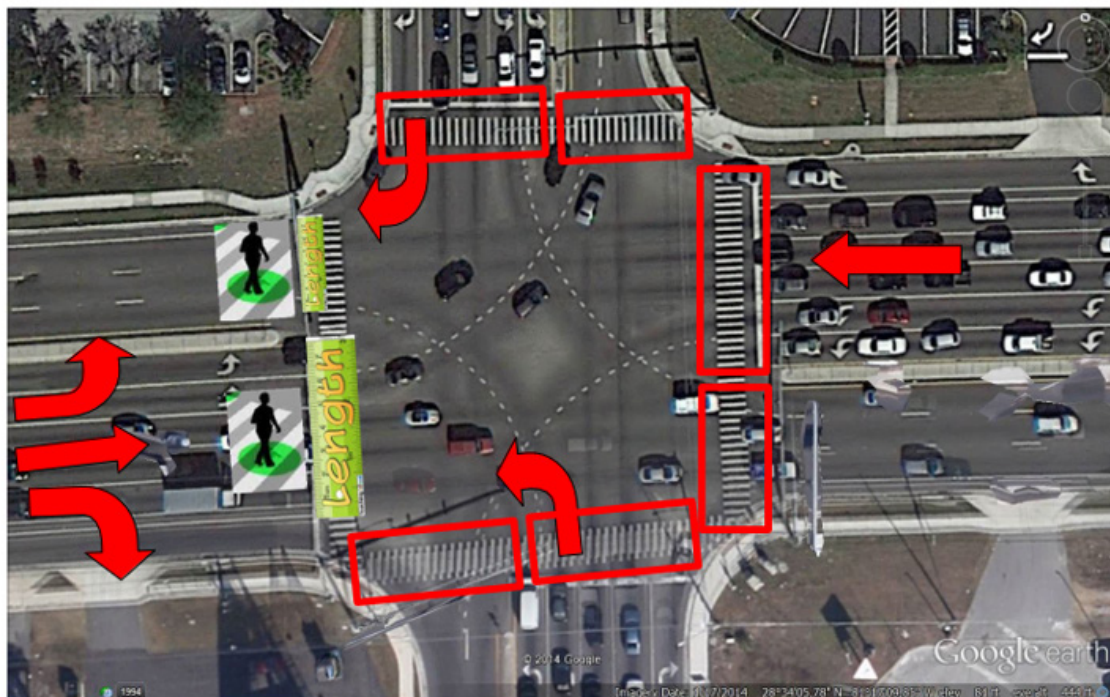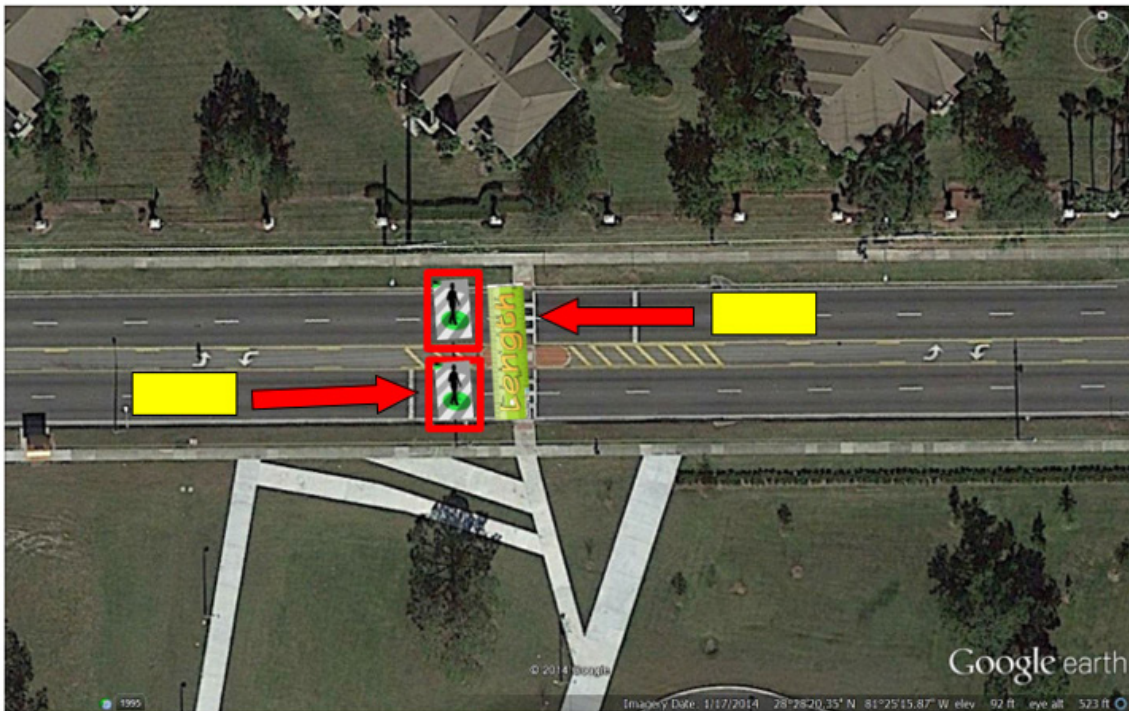| Int ID	Intersection Name	West Approach				East Approach				South Approach				North Approach				West Approach	East Approach	South Approach	North Approach	Exposure Measure (PFC-EV)	Number of Crashes (250 ft Radius)	APCR per MPMC per EV
		EB ADT	WB ADT	EB Dist	WB Dist	WB ADT	EB ADT	WB Dist	EB Dist	NB ADT	SB ADT	NB Dist	SB Dist	SB ADT	NB ADT	SB Dist	NB Dist	ADP	ADP	ADP	ADP			
1	Orange Ave @ Central Blvd	1,600	1,600	12	24	1,600	1,600	24	12	0	16,041	0	36	16,041	0	36	0	3,321	4,217	2,117	1,514	2,531,004,156	7	0.008
2	Primrose Dr @ Colonial Dr	23,500	25,500	48	36	25,500	23,500	48	36	4,540	2,756	24	24	1,553	1,056	24	24	192	52	122	227	536,048,520	9	0.049
3A	Lee Rd @ I-4 WB Off Ramp	21,500	21,000	48	36	17,500	18,000	48	36	0	13,000	0	50	12,000	0	84	0	0	0	114	51	125,508,000	3	0.069
3B	Lee Rd @ I-4 EB Off Ramp	21,500	21,000	36	48	17,500	18,000	60	24	11,500	0	65	0	0	12,500	0	20	0	0	57	57	56,857,500	3	0.153
4	Dean Rd @ Colonial Dr	28,000	28,500	77	36	24,500	23,000	65	55	11,000	10,500	60	24	10,500	11,000	60	24	114	43	67	40	582,484,500	3	0.015
5	Ridgewood Ave @ OBT	862	877	12	12	43	41	12	12	15,000	15,500	36	36	15,500	15,000	36	36	45	14	153	3	5,531,172	5	2.615
6	IY9 @SR 50	20,000	19,000	72	55	16,000	16,000	72	36	24,000	21,000	72	77	21,500	22,000	77	36	59	59	203	110	897,844,000	7	0.023
7	Silver Star @ Hiawassee Rd	14,500	16,500	65	36	18,500	20,000	60	36	16,500	16,000	48	24	16,500	17,500	48	24	261	226	203	310	1,429,054,500	13	0.026
8	Pershing Ave @ Semoran	4,500	4,500	48	12	11,000	10,000	48	24	28,000	25,500	65	50	25,500	28,000	50	77	115	98	139	100	879,619,000	4	0.013
9	41 st St @ OBT	164	680	12	12	2,016	0	0	0	29,453	29,453	48	36	29,453	29,453	36	36	260	2	40	37	180,058,152	7	0.112
10	Sand Lake Rd @ I-Drive	24,500	26,500	60	36	22,500	22,000	53	24	11,627	11,627	48	24	8,375	8,375	48	24	945	1,608	741	572	6,022,483,704	4	0.002
11	Dunlawton Ave @ Clyde Morris Blvd	21,000	24,500	60	60	15,000	13,500	60	36	4,500	4,500	48	15	4,500	4,500	48	24	12	38	35	19	95,868,000	8	0.241
12	Kirkman Rd @ Conroy-Windemere Rd	16,500	18,500	48	36	18,000	17,500	73	40	28,237	28,237	77	75	29,708	29,708	75	60	208	197	157	317	2,556,559,448	8	0.009
13	Palm Bay Rd @ Babcock St	12,500	13,500	70	55	13,500	12,500	70	55	18,500	15,000	77	70	13,938	14,162	70	40	25	20	37	36	206,286,040	5	0.070
14	SR 426 @SR 436	22,000	22,000	72	36	18,500	18,500	72	36	26,500	24,000	60	24	27,000	24,500	72	36	58	115	142	66	902,562,000	6	0.019
15	Courtenay Pkwy @ Lucas Rd	1,200	1,300	12	12	1,300	1,200	24	12	17,500	17,500	48	24	17,500	17,500	48	36	55	42	41	174	311,005,200	8	0.074
16	Martin Luther King @ US 92	13,000	13,000	36	24	11,000	11,000	36	24	1,450	1,450	15	15	1,450	1,450	24	15	149	192	108	136	256,738,200	4	0.045
17	Michigan St @ SR 527	16,000	13,000	48	24	13,000	16,000	48	24	18,404	17,712	60	24	16,500	16,500	48	24	116	125	157	107	608,228,496	5	0.024
18	Orlando Central Pkwy @ US 17-92	2,400	1,400	24	24	1,400	2,400	12	12	25,855	25,855	48	48	27,642	27,642	48	60	166	210	117	85	540,677,280	12	0.064
19	Vineland Rd @ Apopka- Vineland Rd	24,000	24,500	48	36	7,200	7,300	48	24	10,000	10,000	60	36	10,000	10,000	48	24	158	3	9	126	422,294,400	5	0.034
20	Lake Mary Bv @ US 17-92	6,700	5,000	60	24	5,700	6,300	60	24	18,000	18,500	48	36	18,902	18,875	60	60	13	148	18	5	119,143,200	4	0.121
21	Science Dr @ Alafaya Dr	4,440	4,440	24	12	4,072	4,179	24	12	27,500	26,000	48	36	27,500	27,500	48	36	165	44	115	128	578,784,144	4	0.020
22	Holopaw Rd @ US 192	4,358	4,302	48	24	3,000	3,100	36	24	1,100	1,100	24	24	17	23	12	12	0	0	6	0	237,600	1	12.177
23	Picciola Rd @ US 27	0	0	0	0	3,000	3,000	56	60	12,000	11,500	48	36	15,000	14,500	48	36	0	16	1	33	47,544,000	3	0.183
24	Dixie Ave @ US 441	13,000	14,000	24	36	14,000	13,000	24	24	2,900	2,900	12	12	2,900	2,900	0	0	4	0	5	3	2,940,000	2	1.968
25	US-441/US 301 @ CR 329	850	900	24	12	900	900	24	12	11,500	11,000	48	48	11,000	11,500	48	12	1	7	4	0	4,050,000	1	1.429
26	NE 52nd CT @ E Silver Springs Bv	10,381	9,613	18	18	9,613	10,381	18	18	634	634	0	0	620	620	12	12	81	4	0	22	30,921,876	1	0.094
27	NE Jacksonville Rd (CR 200A) @ US 301	0	3,800	72	36	3,800	3,700	36	24	13,500	14,000	36	24	13,500	13,500	36	24	0	2	0	0	451,200	1	6.412
28	Howland Blvd @ SR 415	5,100	5,100	30	10	1,050	1,050	20	10	7,500	7,700	24	12	3,400	3,100	12	12	2	0	4	9	2,158,800	2	2.680
29	Howland Blvd @Courtland Bv	9,900	10,500	60	24	10,500	9,900	36	12	2,700	2,700	24	24	2,700	2,700	24	12	23	29	26	38	34,621,200	2	0.167
30	Airport Av @ Sanford Ave	2,100	2,000	60	24	2,000	2,100	48	24	6,800	8,200	48	48	8,200	6,800	48	36	20	8	25	8	22,185,600	2	0.261
31	Howland Blvd @ Belvedere Rd	12,874	12,402	36	24	12,402	12,874	36	24	375	400	12	12	623	1,326	12	12	4	27	3	4	24,158,292	3	0.359
32	SR 50 @ Chuluota Rd	19,500	17,500	48	36	12,402	21,000	48	24	3,548	2,973	36	24	6,000	6,000	36	24	168	1	19	3	268,854,792	3	0.032
33	US441 @ Osceola Pkwy	17,000	17,000	60	36	21,000	21,000	60	36	12,500	19,500	72	36	17,000	15,000	72	24	6	18	27	37	154,602,000	1	0.019
34	Lake Nona Blvd @ SR 417 SB Ramp	0	3,635	65	0	2,016	1,236	0	24	4,894	3,064	36	24	2,700	1,861	24	36	19	5	1	1	5,473,345	0	0.000
34A	Lake Nona Blvd @ SR 417 NB Ramp	1,785	0	36	0	0	1,236	0	24	2,683	5,111	36	36	1,861	1,861	36	36	2	6	0	2	531,648	0	0.000
34B	US 27 @ Hartwood Marsh	797	418	24	12	6,100	4,200	36	36	12,000	12,000	70	77	14,500	15,000	48	12	25	0	6	2	12,052,000	0	0.000
35	University Blvd @ Dean Rd	23,500	23,000	72	36	30,000	32,000	60	36	8,300	8,400	48	24	8,400	8,300	60	24	5	60	31	10	215,352,000	1	0.013
36	SR436 at Old Cheney Hwy	16,500	18,500	30	24	18,000	17,500	20	10	20,000	21,000	48	36	21,000	20,000	48	36	61	155	91	117	394,688,500	10	0.073
37	SR 436 & Curry Ford Rd	25,000	24,500	60	24	16,000	16,500	36	24	28,000	26,500	72	36	26,500	30,500	72	36	30	141	123	46	648,934,000	5	0.022
38	SR 50 & Alafaya Trail	17,000	19,500	60	36	20,500	19,500	60	36	26,500	26,500	72	36	26,500	26,500	60	36	92	117	73	68	836,401,500	1	0.003
39	SR 438 (Silver Star Rd) & CR 431 (N. Pine Hills Rd)	18,000	18,000	60	24	13,000	13,000	36	24	17,000	16,500	60	36	18,500	19,500	60	36	150	69	129	184	924,904,500	11	0.034
40	US 92 (Int. Speedway Blvd) & SR SA (Nova Rd)	200	200	24	24	200	200	24	24	17,000	16,000	60	36	15,000	15,000	60	36	53	44	61	111	378,312,000	2	0.015
41	US 1 (N. Ridgewood Ave) & Madison Ave	21,500	24,000	36	24	21,000	23,000	48	24	13,500	14,000	60	36	14,500	12,000	48	36	272	148	108	69	227,691,600	5	0.064
42	US 1 (S. Harbor City Blvd) & US 192 (E Strawbridge Ave)	17,500	17,500	48	36	17,500	17,000	48	38	14,500	15,500	50	45	19,000	20,500	50	45	26	17	24	47	113,940,400	4	0.102
43	US 192 (Vine Street) & US 17/92	16,500	24,000	52	24	24,000	23,000	75	47	18,000	18,000	33	50	19,000	20,500	33	90	86	132	135	180	957,918,000	3	0.009
44	US 424 at SR 423	11,500	11,000	24	24	17,500	17,000	48	30	18,000	18,000	50	87	27,500	29,000	90	60	36	21	27	6	110,896,500	4	0.104
45	SR 435 at Conroy Rd	16,500	18,500	64	52	18,000	17,500	75	47	29,000	27,500	87	66	25,668	29,000	80	90	72	0	30	72	578,916,000	8	0.040
46	SR 436 at Hoffner Ave	8,800	9,700	48	24	9,900	9,900	48	30	24,177	25,668	72	40	25,668	24,177	80	30	54	57	30	18	224,925,480	1	0.013
47	SR 436 at Oxford Rd	19,500	16,000	36	36	36,000	34,000	36	36	4,700	4,200	36	12	4,200	4,700	36	36	153	57	24	21	485,202,600	4	0.024
48	US 17-92 at 1st St	8,800	8,600	24	24	8,600	8,800	36	12	11,500	11,500	36	22	5,400	5,500	36	30	24	0	51	60	66,670,800	1	0.043
49	US 192 at Budinger Ave	19,500	20,500	50	44	20,000	18,500	50	42	2,300	2,300	45	20	700	700	24	22	12	9	9	15	40,345,500	0	0.000

Figure 2b: Pedestrian exposure at two (2) midblock crossings.

Estimation of Intersection Pedestrian Volume

In order to arrive at the statewide averages for the intersections, the 3 main parameters mentioned above are required. Since statewide pedestrian counts at each intersection are not available and not feasible to collect, it needs to be estimated from existing data. Estimating the intersection pedestrian volume using the collected sample data was one of the most challenging tasks of this methodology. The 52 sample intersections, where pedestrian count data were collected, were utilized for this analysis. Several attempts were performed to find correlations between pedestrian volumes and intersection data, i.e., distance crossed in feet and daily traffic volume. It was also essential to include population size around each intersection due to its known correlation to the magnitude of pedestrian volume. Population size around each of the statewide intersection within a quarter mile (0.25) distance were obtained using the census population block GIS layer and included in the statistical analysis.

Statistical Analysis

JMP statistical model (version 16), a module from SAS software, was used in this investigation. The 3 independent variables ADT, distance crossed (DIST), and population (POP). The response variable was the pedestrian volume (ADP). Preliminary analysis was conducted for the 52 intersections of sample data using JMP's forward stepwise regression approach with all main effects and interactions as candidate effects according to the effect hierarchy principle. Stepwise regression is a very basic way of handling variable inclusion issues. An initial model was developed but the fit was poor due to the presence of 5 data points that were considered outliers. Therefore, they were eliminated from the dataset. Different data transformations were applied to the parameters and the highest correlation was found between the Distance (DIST), square root of the daily traffic volume (SQRTADT), natural logarithm of Population (LNPOP) and the natural logarithm of pedestrian volume (LNADP). This improved form of the model included the 3 significant main effect parameters along with other 2 two-way factor interaction terms with an adjusted coefficient of determination (R2) of 72.08% which means that 72% of the data were

explained by the model:

$$Ln(ADP)=a_1+a_2\ Ln(POP)+a_3\ sqrt(ADT)-a_4\ Ln(POP)*sqrt(ADT)-a_5\ DIST+a_6\ DIST*sqrt(ADT) \quad (4)$$

The model results and the prediction profiles for the significant factors selected by the model are displayed on Figure 3 showing the actual values of the response variable (Ln ADP). The prediction profilers are dynamic and interactive. A separate prediction equation for each dependent variable is fitted to the observed responses on the respective dependent variable. The developed model was applied to the statewide data where pedestrian volumes were estimated using the AADT at each approach, total distance crossed as well as the population size surrounding each intersection within 0.25-mile radius.
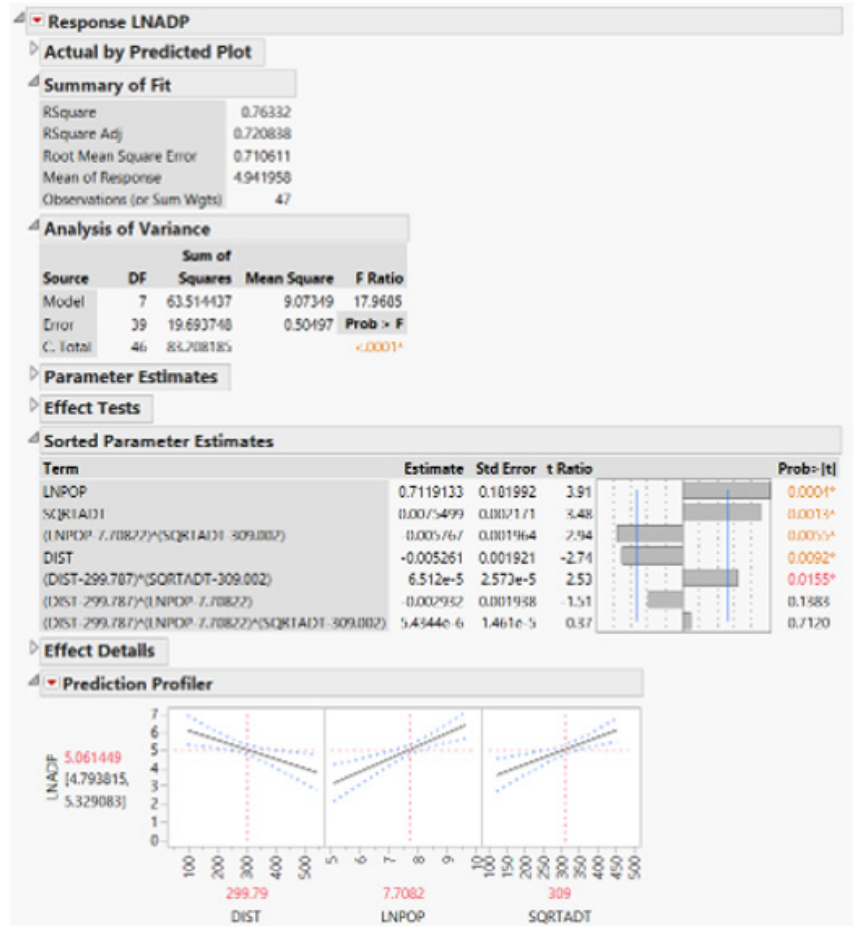
Figure 3: Statistical results & pedestrian volume estimation model.

Intersection Classification

The 3 main parameters required to calculate the exposure measure at intersections are now available especially after applying the above model for estimating pedestrian volume. The next step in the process demanded the classification of the intersections based on these 3 parameters. The sample intersection data was used to examine distributions of total crossed distances as well as the total daily number of pedestrians at each intersection. Based on the total distance crossed for all the approaches, Intersections were classified as:

i.   Intersections with total crossing distance less than 200 ft (11 intersections)

ii. Intersections with total crossing distance between 200 ft and 300 ft (17 Int)

iii. Intersections with total crossing distance between 300 ft and 400 ft (17 Int)

iv. Intersections with total crossing distance greater than 400 ft (7).

This classification provided similar number of intersections at each crossed distance category as shown in parenthesis from the pilot intersection data. Similarly, intersections were classified based on the total daily number of pedestrians crossing the intersection approaches to provide similar number of intersections at each pedestrian category as shown in parenthesis from the pilot intersection data:

a. Intersections with total daily pedestrians less than 100 pedestrians per day (16 Int)

b. Intersections with total daily pedestrians between 100 and 300 pedestrians per day (17)

c. Intersections with total daily pedestrians more than 300 pedestrians per day (19 Int)

On the other hand, statewide total daily number of vehicles at every intersection in the State of Florida was obtained from the data associated with the traffic monitoring sites along with the AADT GIS layer as explained earlier. The distribution of the total number of vehicles for all approaches was examined for the 3,492 intersection that experienced crashes. The following   classification based

on the total daily number of vehicles provided similar number of intersections at each AADT category as shown in parenthesis from the statewide intersection data:

a. Intersections with total AADT less than 20,000 vehicles per day (836 Int)

b. Intersections with total AADT between 20,000 and 30,000 veh per day (827 Int)

c. Intersections with total AADT between 30,000 and 40,000 veh per day (772 Int)

d. Intersections with total AADT between 40,000 and 50,000 veh per day (537 Int)

e. Intersections with total AADT more than 50,000 vehicles per day (518 Int)

Based on the above classifications, there existed 5*4*3 = 60 different combinations for average values for crash rates at the intersections.

Establish Statewide Average Pedestrian Crash Rates at Intersections

The same methodology for calculating the exposure measure for the sample intersections was used to calculate the exposure measure at all the statewide intersections using the 3 main parameters; AADT at each approach, distance crossed and the estimated daily pedestrians. Based on the intersection classifications and combinations of the different ranges, the statewide averages for pedestrian crash rates at intersections were established. It was found that 47 different averages out of the 60 were generated. The remaining averages for the 13 combinations were not found in the database. Table 4 summarizes the developed statewide averages for the intersection crash rates.

Table 4: Statewide Averages for Pedestrian Crash Rates at Intersections.

No	Intersection Classification & Ranges	Statewide Average Rate per MPMC/EV
1	< 20,000 vpd & < 100 ped & < 200 ft Average	6.822
2	< 20,000 vpd & < 100 ped & 200 - 300 ft Average	3.371
3	< 20,000 vpd & < 100 ped & 300 - 400 ft Average	1.808
4	< 20,000 vpd & < 100 ped & > 400 ft Average	
5	< 20,000 vpd & 100 - 300 ped & < 200 ft Average	2.682
6	< 20,000 vpd & 100 - 300 ped & 200 - 300 ft Average	0.726
7	< 20,000 vpd & 100 - 300 ped & 300 - 400 ft Average	
8	< 20,000 vpd & 100 - 300 ped & > 400 ft Average	
9	< 20,000 vpd & > 300 ped & < 200 ft Average	0.196
10	< 20,000 vpd & > 300 ped & 200 - 300 ft Average	0.174
11	< 20,000 vpd & > 300 ped & 300 - 400 ft Average	
12	< 20,000 vpd & > 300 ped & > 400 ft Average	
1	20,000 - 30,000 vpd & < 100 ped & < 200 ft Average	5.578
2	20,000 - 30,000 vpd & < 100 ped & 200 - 300 ft Average	1.693
3	20,000 - 30,000 vpd & < 100 ped & 300 - 400 ft Average	2.104
4	20,000 - 30,000 vpd & < 100 ped & > 400 ft Average	
5	20,000 - 30,000 vpd & 100 - 300 ped & < 200 ft Average	0.948
6	20,000 - 30,000 vpd & 100 - 300 ped & 200 - 300 ft Average	0.673
7	20,000 - 30,000 vpd & 100 - 300 ped & 300 - 400 ft Average	0.653
8	20,000 - 30,000 vpd & 100 - 300 ped & > 400 ft Average	
9	20,000 - 30,000 vpd & > 300 ped & < 200 ft Average	0.159
10	20,000 - 30,000 vpd & > 300 ped & 200 - 300 ft Average	0.129
11	20,000 - 30,000 vpd & > 300 ped & 300 - 400 ft Average	0.139
12	20,000 - 30,000 vpd & > 300 ped & > 400 ft Average	
1	30,000 - 40,000 vpd & < 100 ped & < 200 ft Average	1.88
2	30,000 - 40,000 vpd & < 100 ped & 200 - 300 ft Average	1.469
3	30,000 - 40,000 vpd & < 100 ped & 300 - 400 ft Average	1.212
4	30,000 - 40,000 vpd & < 100 ped & > 400 ft Average	1.165
5	30,000 - 40,000 vpd & 100 - 300 ped & < 200 ft Average	0.433

6	30,000 - 40,000 vpd & 100 - 300 ped & 200 - 300 ft Average	0.457
7	30,000 - 40,000 vpd & 100 - 300 ped & 300 - 400 ft Average	0.424
8	30,000 - 40,000 vpd & 100 - 300 ped & > 400 ft Average	
9	30,000 - 40,000 vpd & > 300 ped & < 200 ft Average	0.106
10	30,000 - 40,000 vpd & > 300 ped & 200 - 300 ft Average	0.118
11	30,000 - 40,000 vpd & > 300 ped & 300 - 400 ft Average	
12	30,000 - 40,000 vpd & > 300 ped & > 400 ft Average	
1	> 50,000 vpd & < 100 ped & < 200 ft Average	2.322
2	> 50,000 vpd & < 100 ped & 200 - 300 ft Average	0.62
3	> 50,000 vpd & < 100 ped & 300 - 400 ft Average	0.582
4	> 50,000 vpd & < 100 ped & > 400 ft Average	0.387
5	> 50,000 vpd & 100 - 300 ped & < 200 ft Average	0.213
6	> 50,000 vpd & 100 - 300 ped & 200 - 300 ft Average	0.154
7	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft Average	0.195
8	> 50,000 vpd & 100 - 300 ped & > 400 ft Average	0.167
9	> 50,000 vpd & > 300 ped & < 200 ft Average	0.055
10	> 50,000 vpd & > 300 ped & 200 - 300 ft Average	0.051
11	> 50,000 vpd & > 300 ped & 300 - 400 ft Average	0.05
12	> 50,000 vpd & > 300 ped & > 400 ft Average	0.053

Notes:

Vpd: Total entering vehicles per day at the intersection (AADT for all approaches/2)

Ped: Total pedestrian counts for all intersection approaches

Ft: Total crossing distance for all intersection approaches

Determine Critical Hotspot Locations within District 5

The final step in the process included the application of the developed statewide average rates to the sample data for the purpose of identifying critical hotspot locations within District 5. As can be seen in Table 5, the 52-sample intersection actual crash rates based on the data collected from the field were compared against the statewide average rates. The data showed several intersections with extremely low number of pedestrian crashes over the 5-year period. In order to disqualify intersections with extremely low crash occurrences over the 5-year period, other criteria were required. At minimum, 5 crashes over the 5-year period are required to qualify for the analysis. Therefore, the analysis was revised to include the minimum threshold of 5 crashes over the 5-year period which was compared to the statewide averages. The results showed that few of the intersections within the urban boundary of District 5 triggered safety concerns as critical locations which require further investigation to identify main causes and emphasize mitigation improvements.

Conclusions & Recommendations

To date there are no clear or uniform standards for a method to measure pedestrian incidents against a statewide average. In this study, statewide averages for pedestrian crash rates along the roadways as well as the intersections were quantified. The main objective is to identify critical pedestrian crash locations, thus evaluating locations that are operating beyond or above statewide averages, identifying main causes and developing a prioritization tool to em-

phasize mitigation improvements. It was crucial to address the pedestrian-vehicular conflict as the State of Florida currently tops the list in the "Dangerous by Design" report as having the highest four (4) pedestrianincident locations in the Country. The main challenge in analyzing pedestrian crashes is to identify a practical and correct exposure measure. In most cases, the exposure measure is either unavailable or can be obtained at a greater cost. The methods and procedures explained in this paper are considered detailed, practical and provide a broad depiction of the main factors that directly contribute to pedestrian crashes. The main parameters used in calculating pedestrian crash rates along the different roadway categories which combine the functional classification, number of lanes and area type together were the AADT and the total length of the roadway category. Conversely, the main parameters used for computing pedestrian crash rates for the different intersection classifications were the daily pedestrian volumes, distance crossed and the AADT in addition to the number of pedestrian crashes either along the studied roadways or intersections. The pilot studies conducted for the roadways and intersections revealed several critical safety   locations within District 5 when compared to the developed statewide average rates which require further investigation to identify main causes and emphasize mitigation improvements. It is recommended that an annual statewide pedestrian count program be initiated for the intersections as well as roadways which would increase the sample size and help in validating the assumptions provided in this study. The purpose and duration of data collection are essential pieces of information for determining the appropriate data.

Table 5: Actual Crash Rates versus Statewide Averages for Intersection Pilot Study.

Int ID	Intersection Name	Number of Crashes (250 ft Radius)	APCR per MPMC per EV	Total ADT	Total Dist Crossed	Total ADP	Intersection Category	Statewide Average Crash Rate	Hazardous Intersection
1	Orange Ave @ Central Blvd	7	0.008	38,482	144	11,169	30,000 - 40,000 vpd & > 300 ped & < 200 ft	0.106	NO
2	Primrose Dr @ Colonial Dr	9	0.049	107,905	264	593	> 50,000 vpd & > 300 ped & 200 - 300 ft	0.051	NO
3A	Lee Rd @ I-4 WB Off Ramp	3	0.069	103,000	302	165	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.195	NO
3B	Lee Rd @ I-4 EB Off Ramp	3	0.153	102,000	253	114	> 50,000 vpd & 100 - 300 ped & 200 - 300 ft	0.154	NO
4	Dean Rd @ Colonial Dr	3	0.015	147,000	401	264	> 50,000 vpd & 100 - 300 ped & > 400 ft	0.167	YES
5	Ridgewood Ave @ OBT	5	2.615	62,823	168	64	> 50,000 vpd & < 100 ped & < 200 ft	2.322	NO
6	JYP @SR 50	7	0.023	159,500	456	381	> 50,000 vpd & > 300 ped & > 400 ft	0.053	NO
7	Silver Star @ Hiawassee Rd	13	0.026	136,000	341	1,000	> 50,000 vpd & > 300 ped & 300 - 400 ft	0.050	NO
8	Pershing Ave @ Semoran	4	0.013	137,000	374	452	> 50,000 vpd & > 300 ped & 300 - 400 ft	0.050	YES
9	41 st St @ OBT	7	0.112	118,656	180	339	> 50,000 vpd & > 300 ped & < 200 ft	0.055	NO
10	Sand Lake Rd @ I-Drive	4	0.002	135,504	317	3,866	> 50,000 vpd & > 300 ped & 300 - 400 ft	0.050	YES
11	Dunlawton Ave @ Clyde Morris Blvd	8	0.241	92,000	336	104	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.195	NO
12	Kirkman Rd @ Conroy-Windemere Rd	8	0.009	186,390	464	879	> 50,000 vpd & > 300 ped & > 400 ft	0.053	NO
13	Palm Bay Rd @ Babcock St	5	0.070	113,600	482	118	> 50,000 vpd & 100 - 300 ped & > 400 ft	0.167	YES
14	SR 426 @SR 436	6	0.019	183,000	420	381	> 50,000 vpd & > 300 ped & > 400 ft	0.053	NO
15	Courtenay Pkwy @ Lucas Rd	8	0.074	75,000	216	312	> 50,000 vpd & > 300 ped & 200 - 300 ft	0.051	NO
16	Martin Luther King @ US 92	4	0.045	53,800	198	585	> 50,000 vpd & > 300 ped & < 200 ft	0.055	YES
17	Michigan St @ SR 527	5	0.024	125,116	300	505	> 50,000 vpd & > 300 ped & 200 - 300 ft	0.051	NO
18	Orlando Central Pkwy @ US 17-92	12	0.064	114,594	264	578	> 50,000 vpd & > 300 ped & 200 - 300 ft	0.051	YES
19	Vineland Rd @ Apopka- Vineland Rd	5	0.094	103,000	324	296	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.195	NO
20	Lake Mary Bv @ US 17-92	5	0.121	97,977	348	184	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.195	NO
21	Science Dr @ Alafaya Dr	4	0.020	124,131	240	452	> 50,000 vpd & > 300 ped & 200 - 300 ft	0.051	NO
22	Holopaw Rd @ US 192	1	12.177	17,000	204	6	< 20,000 vpd & < 100 ped & 200 - 300 ft	3.371	NO
23	Picciola Rd @ US 27	3	0.183	59,000	284	50	> 50,000 vpd & < 100 ped & 200 - 300 ft	0.620	NO
24	Dixie Ave @ US 441	2	1.968	59,500	132	12	> 50,000 vpd & < 100 ped & < 200 ft	2.322	NO
25	US 441/US 301 @ CR 329	2	1.429	48,550	240	12	40,000 - 50,000 vpd & < 100 & 200 - 300 ft	0.960	NO
26	NE 52nd CT @ E Silver Springs Bv	1	0.019	41,242	96	107	40,000 - 50,000 vpd & 100 - 300 ped & < 200 ft	0.394	NO
27	NE Jacksonville Rd (CR 200A) @ US 301	1	6.412	62,500	180	2	> 50,000 vpd & < 100 ped & < 200 ft	2.322	NO
28	Howland Blvd @ SR 415	2	2.680	31,900	96	15	30,000 - 40,000 vpd & < 100 ped & < 200 ft	1.880	NO
29	Howland Blvd @Courtland Bv	2	0.167	51,600	180	116	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.213	NO
30	Airport Av @ Sanford Ave	2	0.261	38,200	300	61	30,000 - 40,000 vpd & < 100 ped & 200 - 300 ft	1.469	NO
31	SR 50 @ Belvedere Rd	3	0.359	53,276	180	38	> 50,000 vpd & < 100 ped & < 200 ft	2.322	NO
32	SR 50 @ Chuluota Rd	3	0.032	80,797	276	191	> 50,000 vpd & 100 - 300 ped & 200 - 300 ft	0.154	NO
33	US 441 at Osceola Pkwy	1	0.019	140,000	408	88	> 50,000 vpd & > 300 ped & > 400 ft	0.387	NO
34A	Lake Nona Blvd @ SR 417 SB Ramp	0	0.000	19,009	233	26	< 20,000 vpd & 100 - 300 ped & 200 - 300 ft	3.371	NO
34B	Lake Nona Blvd @ SR 417 NB Ramp	0	0.000	14,537	180	10	< 20,000 vpd & < 100 ped & < 200 ft	6.822	NO
35	US 27 @ Hartwood Marsh	0	0.000	65,515	324	33	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.582	NO
36	University Blvd @ Dean Rd	1	0.013	141,900	360	106	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.195	NO
37	SR436 at Old Cheney Hwy	10	0.073	86,200	250	424	> 50,000 vpd & > 300 ped & 200 - 300 ft	0.051	YES
38	SR 436 & Curry Ford Rd	5	0.022	175,500	348	340	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.154	NO
39	SR 50 & Alafaya Trail	1	0.003	205,000	384	350	> 50,000 vpd & > 300 ped & 300 - 400 ft	0.050	NO
40	SR 438 (Silver Star Rd) & CR 431 (N. Pine Hills Rd)	11	0.034	147,000	384	532	> 50,000 vpd & > 300 ped & 300 - 400 ft	0.050	NO
41	US 92 (Int. Speedway Blvd) & SR 5A (Nova Rd)	2	0.015	126,000	336	269	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.195	NO
42	US 1 (N. Ridgewood Ave) & Madison Ave	5	0.064	52,300	336	597	> 50,000 vpd & > 300 ped & 300 - 400 ft	0.050	YES
43	US 1 (S. Harbor City Blvd) & US 192 (E Strawbridge Ave)	4	0.102	99,000	288	114	> 50,000 vpd & 100 - 300 ped & 200 - 300 ft	0.154	NO
44	US 192 (Vine Street) & US 17/92	3	0.009	165,000	348	533	> 50,000 vpd & > 300 ped & 300 - 400 ft	0.050	NO
45	SR 424 at SR 423	4	0.104	122,500	325	90	> 50,000 vpd & < 100 ped & 300 - 400 ft	0.582	NO
46	SR 435 at Conroy Rd	8	0.040	183,500	541	174	> 50,000 vpd & 100 - 300 ped & > 400 ft	0.167	NO
47	SR 436 at Hoffner Ave	1	0.013	141,790	382	159	> 50,000 vpd & 100 - 300 ped & 300 - 400 ft	0.195	NO
48	SR 436 at Oxford Rd	4	0.024	132,300	294	255	> 50,000 vpd & 100 - 300 ped & 200 - 300 ft	0.154	NO
49	US 17-92 at 1st St	1	0.043	68,700	226	135	> 50,000 vpd & 100 - 300 ped & 200 - 300 ft	0.154	NO
50	US 192 at Budinger Ave	0	0.000	84,500	297	45	> 50,000 vpd & < 100 ped & 200 - 300 ft	0.620	NO

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: Hatem Abou-Senna; data collection: Azza Alisawi and Negaar Minaei; analysis and interpretation of results: Hatem Abou-Senna, Negaar Minaei and Azza Alisawi; draft manuscript preparation: Hatem Abou-Senna, Azza Alisawi and Negaar Minaei. All authors reviewed the results and approved the final version of the manuscript.

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