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A new access density definition and its correlation with crash rates by microscopic traffic simulation method

Bing Huang[a,*], Yu Zhang[b], Linjun Lu[c], Jian John Lu[b]

[a] Century Engineering, Inc., 10710 Gilroy Road, Hunt Valley, MD 21031, United States
[b] Department of Civil and Environmental Engineering, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620, United States
[c] School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, 800 Dong Chuan Road, Min Hang District, Shanghai 200240, China

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ABSTRACT

Better access management can improve highway safety by reducing potential crashes and conflicts. To make adequate access management decisions, it is essential to understand the impact of different access types on roadway safety, usually represented by the crash rate of a roadway segment. The objective of this paper is to propose a new access density definition reflecting the impact of traffic speed variation of different access types. The traffic speed variation was obtained from a microscopic traffic simulation software package TSIS-CORSIM. A sample roadway Temple Terrace Highway was selected to perform traffic simulation. Access Weight was obtained from traffic speed variation, and access density was obtained from access weight. The proposed access density was then compared with the existing definition by analyzing their correlations with crash rates on one suburban street in Temple Terrace, Florida. The comparison demonstrates that crash rates are more highly correlated with the proposed access density than that in the previous study, which is helpful for Federal Highway Administration (FHWA), United States Department of Transportation (USDOT), and transportation consulting companies to regulate the construction, management and design of roadway segments.

1. Introduction

Access density is a widely-accepted measurement that has been extensively applied to studies related to crash modeling, operational impact, and planning (Saxena, 2009). Previous research has shown that accident rates increase with the increase of the total number of access points or access point density (Peng, 2004; Chimba, 2004; Eisele and Frawley, 2005). In those studies, access density was defined as the number of access points divided by the length of the roadway segment. Other studies found that driveway density, unsignalized minor street density, and different median types are significantly correlated with crash frequency (Drummond et al., 2002; Eisele and Frawley, 2005). Deng et al. (2006) defined access density as the number of driveways and minor intersections and found that different access types (according to land use) had different impacts on crash severity. Saxena (2009) compared three distinct methods for calculating access density and proposed a weighting methodology for determining the access density for 10 types of access points. According to her study, dependent on the geometric layout and condition, each access type has a particular number of diverging, merging, crossing, and weaving conflicts. She standardized the total number of conflicts for each access type and used the values as weights in calculating the access density.

However, as one of the characteristics of access points, traffic speed variation has not been considered while computing access density. Crash rates were observed to be highly related to traffic speed variation (Graves et al., 1993). Major traffic speed reduction and recovery usually occur at access points. Dependent on the types of access points, traffic speed reduction and recovery distributions are different. These distributions are key features of various access types and should be considered in defining access density. Thus, this study proposes a new weighting method of capturing traffic speed variations into calculating access density. To demonstrate the effectiveness of the new method, correlation analysis between access density and historical crash rates was conducted for a roadway segment in Temple Terrace, Florida. The outcomes of the correlation analysis are compared with those following existing weighting method in previous study.

Besides the literatures that listed above, access management and safety was talked about in some other literatures. An article provides an overview of the safety benefits of access management based on case studies in the Denver, Colorado metropolitan area. It notes that a typical four-lane road with a high level of

* Corresponding author. Tel.: +1 443 589 2400; fax: +1 443589 2401.
E-mail addresses: bhuang@centuryeng.com, hb19821203@gmail.com (B. Huang).

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Table 1
CORSIM default parameters.

Driver type	1	2	3	4	5	6	7	8	9	10
Driver type percentage (%)	17	12	12	11	10	10	9	7	7	5
Acceptable deceleration (fpss)	21	18	15	12	9	7	6	5	4	4
Acceptable Gap–Cross (s)	5.6	5.0	4.6	4.2	3.9	3.7	3.4	3.0	2.6	2.0
Acceptable gap–left (s)	7.8	6.6	6.0	5.4	4.8	4.5	4.2	3.9	3.6	2.7
Acceptable gap–right (s)	10.0	8.8	8.0	7.2	6.4	6.0	5.6	5.2	4.8	3.6

access control can serve 10,000 more vehicles per day at double the average speed and with 50% fewer accidents than a similar road with a low level of access control (Public Works, 1995). Dart and Mann (1970) found the strong relationship between an increasing density of access points and traffic accidents. A doubling of access points (driveways or curb cuts per mile) leads to a 20–40% increase in the accident rate. Gattis (1996) compared the accident and other characteristics of three arterial segments within a single small city (Muskogee, Oklahoma). He found all three segments had four lanes with some sort of median treatment and turning lanes, but differing amounts of access management in place. The segment with the highest level of access control experienced 40% lower property damage and injury accident rates than the two with less access control. Stover et al. (1994) compared the accident experience with raised medians and continuous left turn lanes (CLTL). It was concluded that left turns entering and exiting driveways account for the majority of total driveway crashes and also generate a substantial amount of motorist delay.

A detailed "before and after" collision analysis with many collision diagrams for five corridors was conducted in Florida. The non-traversable medians were installed on the corridors.

The remainder of this paper is organized as follows: Section 2 presents the access types considered in this study and traffic speed variation phenomena observed in microscopic simulation; Section 3 proposes the methodology for computing access weight and access density; Section 4 describes the correlation analysis of the proposed access density and crash rates and comparison with the previous method, followed by conclusions in Section 5.

2. A new method of calculating access density

In our study, access density is defined as the sum of the access weights of different access points on one road segment divided by the length of that roadway segment. The access weight is determined by traffic speed variation and the length of speed fluctuation area for a given combination of access type, number of lanes, speed limit, and traffic volume level, which will be discussed later. The simulation software Traffic Software Integrated System–Corridor Simulation (TSIS-CORSIM) was used for obtaining the measurements of traffic speed variation. Because the access weights sought in this study are for general conditions, called theoretical access weights, the traffic simulation model uses the default parameters from TSIS-CORSIM, which reflect normal driver behaviors, as shown in Table 1. CORSIM is operational under the Windows 95/98/NT/2000/XP/7 operating system. The model runs under a shell software called TSIS, and includes the TRAFVue software for graphic displays and animation. The computer run time depends on the network size, number of vehicles processed, output options and control features been simulated. There are ten driver types in CORSIM (from 1 = least aggressive to 10 = most aggressive). The driver type is randomly assigned when each vehicle is generated.

As shown in Table 2, nine access types in the *Access Management Manual* (Schneider et al., 2003) are considered in this study. Some access types listed in the manual are not considered, such as Michigan shoulder bypass, continuous two-way left-turn lane, indirect left turn, etc., because they are not common and cannot easily be found in the field for simulation calibration purposes.

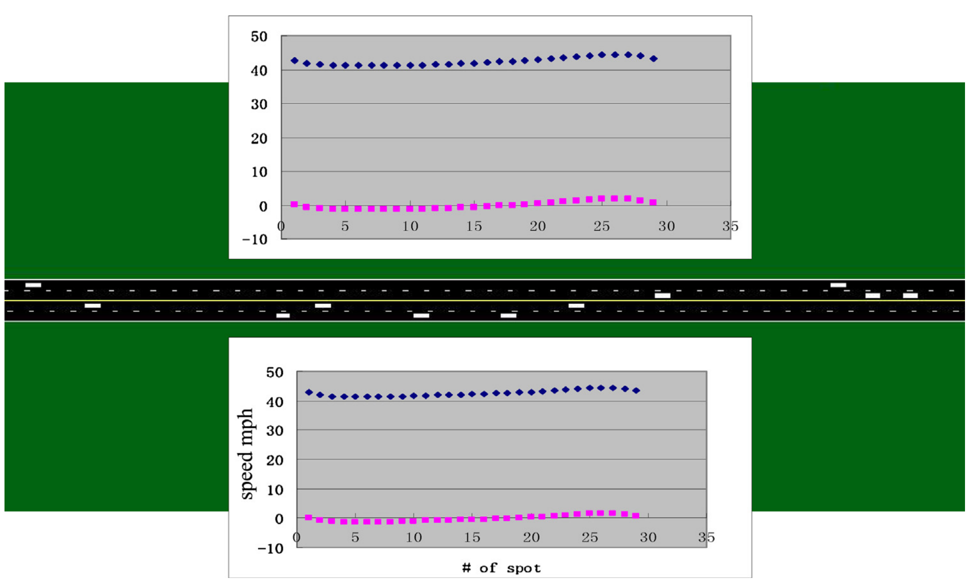
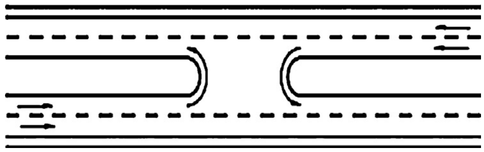
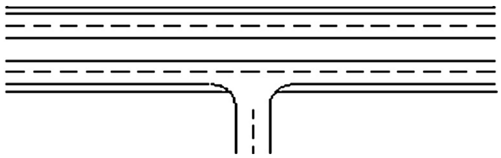
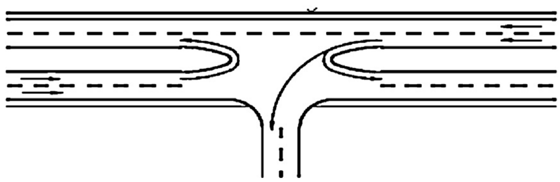
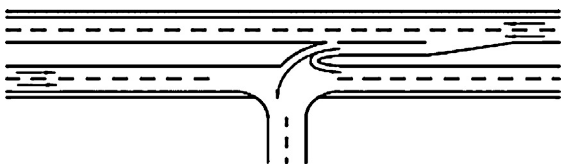
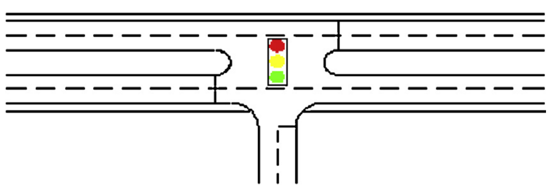
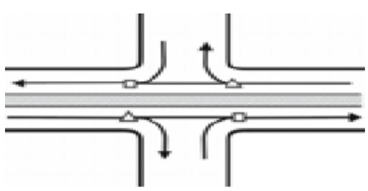
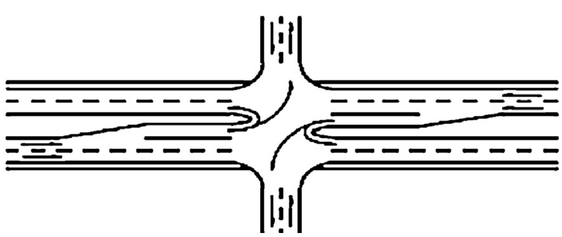
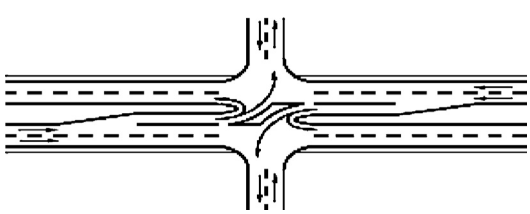
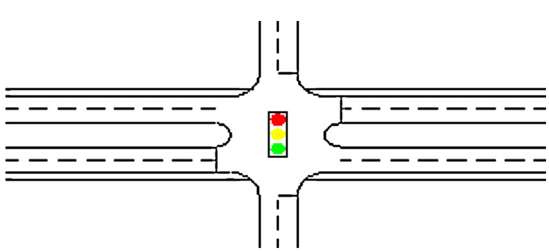


Fig. 1. Curve of speed fluctuation without intersection, the dotted blue lines at the top of both plots in the figures represent the operating speeds of traffic, and the dotted red lines at the bottom represent the difference between operating speeds and posted speeds.

Table 2
Nine access types used for obtaining theoretical access weight.

Type 1		Midblock median opening
Type 2		Three leg intersection (no median opening)
Type 3		Three leg intersection (full median opening)
Type 4		Three leg intersection (directional median opening)
Type 5		Three leg intersection (signalized)
Type 6		Four leg intersection (no median opening)
Type 7		Four leg intersection (full median opening)
Type 8		Four leg intersection (directional median opening)
Type 9		Four leg intersection (signalized)

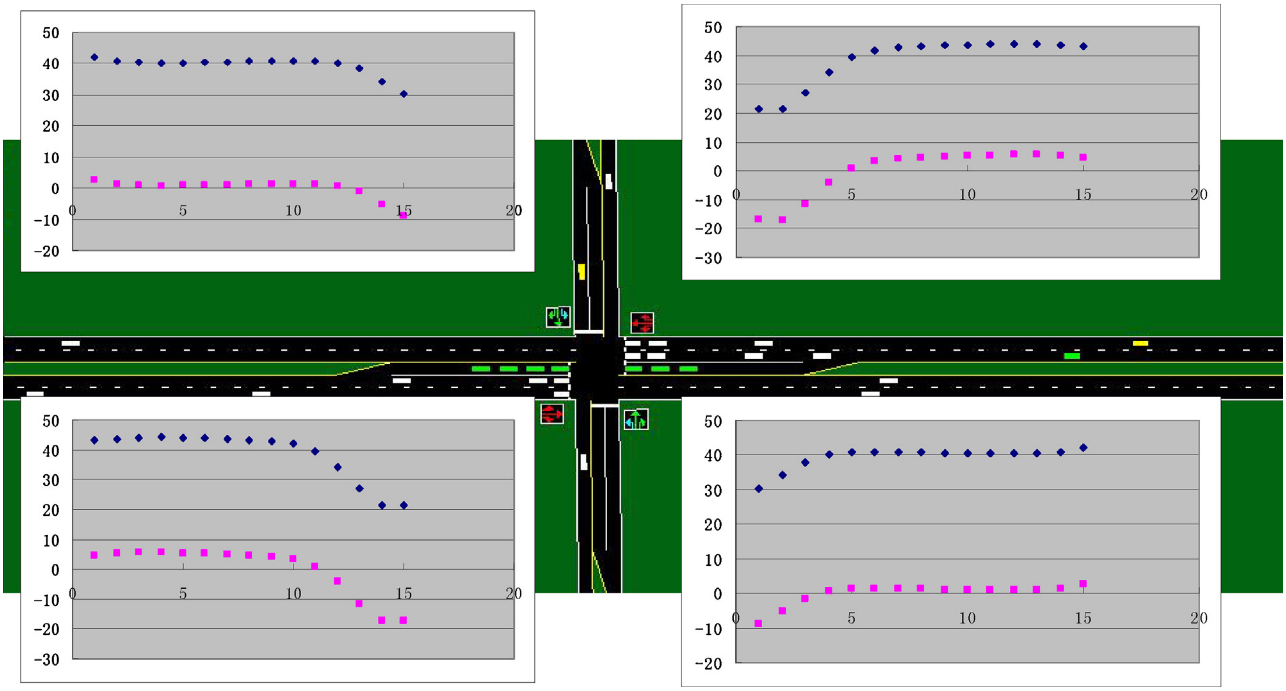


Fig. 2. Curve of speed fluctuation with intersection, the dotted blue lines at the top of both plots in the figures represent the operating speeds of traffic, and the dotted red lines at the bottom represent the difference between operating speeds and posted speeds.

2.1. Speed fluctuation area

Traffic speed varies largely while approaching/leaving an access point. Fig. 1 shows the CORSIM (CORridor SIMulator) simulation results of traffic speed variation for a roadway segment without any access points, while Fig. 2 shows the results with an access point, for instance, a signalized intersection. The *X*-axis represents the number of spot sites. The *Y*-axis represents the traffic speed in miles per hour (mph), combining all lanes in one direction. The dotted blue lines at the top of both plots in the figures represent the operating speeds of traffic, and the dotted red lines at the bottom represent the difference between operating speeds and posted speeds. Comparing Figs. 1 and 2, it is easy to draw a conclusion that traffic speeds fluctuate largely due to the interference of access points.

A speed fluctuation area is defined as an area in which traffic speed varies significantly due to an access point. It is different for each access type and could be different for various directions at a same access point. Generally, the further the detection spot from the access point, the less fluctuation the traffic speed will have. The starting point of a speed fluctuation area is set as the center of an access point. The end point of a speed fluctuation area is the closest spot site where the speed standard deviation (SSD) of that site is less than 0.5% of the speed limit. For instance, given the speed limit of a major arterial roadway is 50 mph, the end point of the speed fluctuation area is the spot site with SSD less than $50 \times 0.5\% = 0.25$ mph. If there are multiple spot sites with SSDs less than the threshold, the end point of the speed fluctuation area is the one closest to the starting point.

2.2. Speed standard deviation

Multiple-run simulations were conducted for different combinations of access type, number of lanes, speed limit, and volume level. The number of lanes (two ways) includes three categories: 4, 6 and 8 lanes. The speed limit includes four categories: 45, 50, 55, and 60 mph. Volume level includes three categories: high, medium and low, which are derived from signal warranty in the *Manual on Uniform Traffic Control Devices* (MUTCD) (AASHTO, 2009) for unsignalized intersections, and road segment level of service (LOS) in the Highway Capacity Manual (2000) for signal-controlled access points.

The curves in Fig. 3 (signal warranty in MUTCD) show the maximum service flow rate combinations for major and minor streets of unsignalized intersections with different numbers of lanes. For intersections suitable for unsignalized control, the traffic volumes on major and minor streets for a particular lane combination should be on or below the curves. In this study, we were interested only in major and minor roads with two or more lanes. Table 3 shows the thresholds of the three levels of traffic volumes for unsignalized intersections derived from the upper curve in Fig. 3 (major street with 2 or more lanes and minor road with 2 lanes). For example, if the traffic volume of one approach on the major street is between 350 vph and 600 vph, the volume is classified as Low; if the traffic volume of one approach on the major street is between 600 vph and 800 vph, the volume level is Medium; if the traffic volume of one approach on the major street is more than 800 vph, the volume level is High. Here, the traffic volume is same for both directions on the major street, which is eastbound direction and westbound direction.

Traffic volume levels for signal-controlled access points are defined based on the LOS of roadway segments categorized in the HCM (see Table 4). In the HCM, the LOS of a roadway is categorized into five levels (A–E), each with a corresponding traffic volume threshold. To simplify the volume classification for data input into the simulation, these five levels (A–E) are combined into three levels (low, medium, and high); traffic volumes in LOS A and LOS B belong to the low volume level, traffic volumes in LOS C belongs

Table 3
Traffic volume levels for unsignalized access points.

Classification	Traffic volume (vph)		
	Low	Medium	High
Major Street (each direction)	350–600	600–800	800+

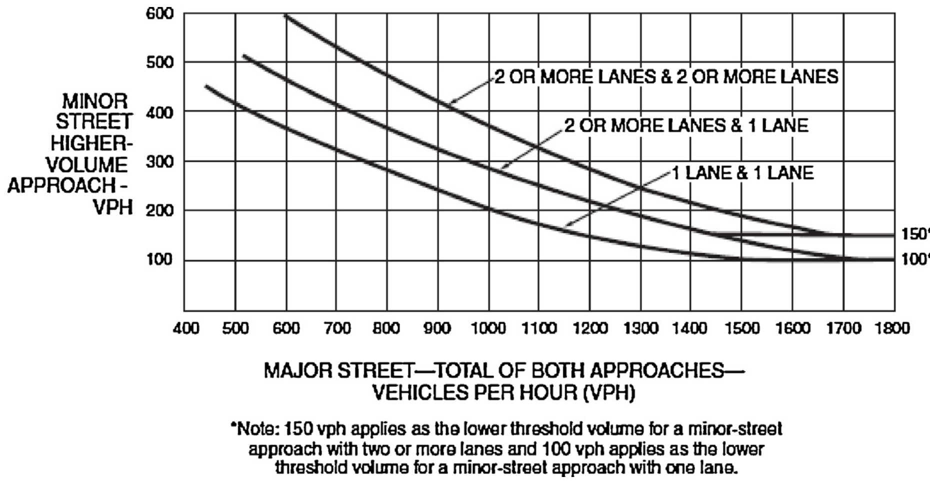


Fig. 3. Maximum service flow rate for major and minor streets with different number of lanes.

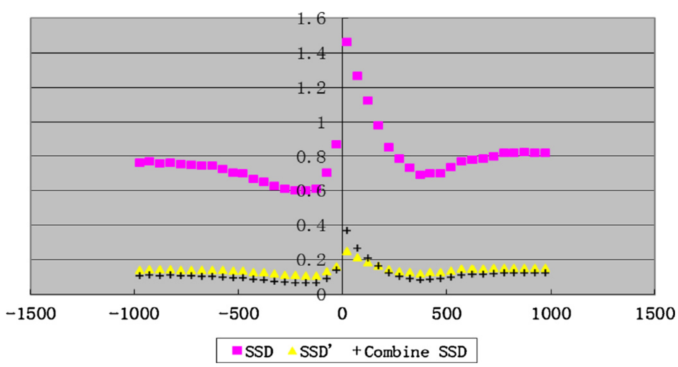


Fig. 4. Example of SSD, SSD′ and combined SSD for access type 4 with 4 lanes, speed limit 45 mph, and low level of traffic volume.

to a medium volume level, and traffic volume in LOS D and LOS E belong to a high volume level.

According to the traffic volume levels defined for unsignalized and signalized access points, the traffic volumes in the simulation are generated by adding a constant increment to the lower thresholds of the traffic volume levels. For instance, the low level volume at an unsignalized access driveway is between 350 vph and 600 vph for each major road direction, so the traffic volumes generated in the simulation are 350, 400, 450, 500, 550, and 600 vph (50 vph is taken as the increment) for the each major road direction. The outcomes of the simulation with different traffic volumes in the same level are averaged and considered as the simulation outcome of the selected traffic volume level.

2.3. Access weight

Access weight is defined by considering traffic speed variations around access points. It is assumed that the larger the traffic speed variations at spot sites of the access point, the more likely that a crash will occur. In addition, the larger the traffic speed differences between one spot site and the consecutive one, the more likely a crash will occur. Given this hypothesis, the following mathematical formulas are proposed to calculate the access weight.

$$SSD_i = \sqrt{\frac{\sum_{n=1}^{N}(v_i^n - \bar{v}_i)^2}{N-1}}$$

$$SSD'_i = \sqrt{\frac{\sum_{n=1}^{N}(v_{i+1}^n - v_i^n)^2}{N-1}}$$

$$SSD_i^c = \sqrt{SSD_i \times SSD'_i}$$

$$AW = \frac{1}{L_d}\sum_{i=1}^{I} SSD_i^c$$

where AW, access weight; SSD_i, speed standard deviation at spot site i; SSD'_i, speed standard deviation variance between spot site i and consecutive spot site $i+1$; SSD_i^c, combined speed variation measurement; v_i^n, traffic speed at spot site i in the nth running of the simulation; $\bar{v}_i$, average traffic speed at spot site i of all runs of simulation; I, total number of detected spot sites in the length of speed fluctuation area; N, total number of simulation runs; L_d, length of speed fluctuation area (assumed as 100 ft in the simulation).

As shown in Appendix I, the first 144 of 324 sample access weights are listed. Each weight corresponds to one scenario with a specific access type, number of lanes, speed limit, and traffic volume level. For instance, the access weight of access type 4 on a roadway segment with 4 lanes, speed limit 45 mph, and low traffic volume is 6.70. Fig. 4 illustrates the traffic speed variation metrics for this particular scenario. The upper square-dashed purple line

Table 4
Traffic volume levels for signalized access points.

Traffic levels for signalized access points		Low		Medium	High	
Free-flow speed (mph)	LOS in HCM	*A*	*B*	*C*	*D*	*E*
60	Maximum service flow rate (pc/h/ln)	660	1080	1550	1980	2200
55	Maximum service flow rate (pc/h/ln)	600	990	1430	1850	2100
50	Maximum service flow rate (pc/h/ln)	550	900	1300	1710	2000
45	Maximum service flow rate (pc/h/ln)	490	810	1170	1550	1900

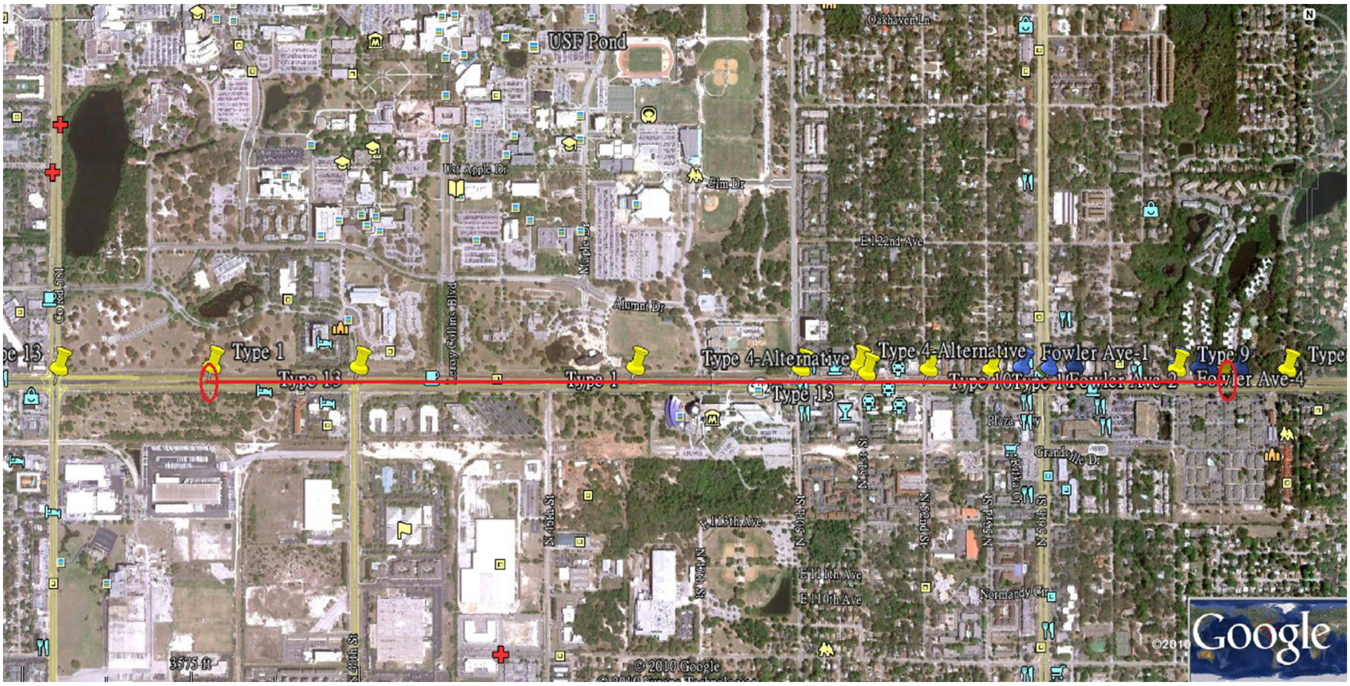


Fig. 5. Study area of case study.

represents the SSD, which is Speed Standard Deviation at spot site i; the triangle-dashed yellow line represents the SSD′, which is speed standard deviation variance between spot site i and consecutive spot site $i+1$; and the cross-dashed black line represents the SSD^c, which is combined speed variation measurement. SSD^c equals to the square root of Speed Standard Deviation at spot site I (SSD) and speed standard deviation variance between spot site i and consecutive spot site $i+1$ (SSD′). It is normally believed that SSD^c is always less than SSD and SSD′. But unexpected situation also exists, as shown in Fig. 4. For all of 40 detectors of access types 4 with 4 lanes, speed limit 45 mph, and low level of traffic volume, SSD^c values are all less than SSD values, but greater than SSD′ values. In this study, access type 4 is Three Leg Intersection (directional median opening).

2.4. Access density

Access density is defined as the sum of access weights of different access points on one road segment divided by the length of the roadway segment.

$$AD = \frac{\sum_{m=1}^{M} AW_m}{L}$$

where AD, access density; AW_m, access weight of access point m; M, total number of access points in the roadway segment; L, length of the road segment.

3. Traffic simulation, calibration and validation

3.1. Concept

Traffic simulation analysis was used to collect speed data. Thus, on the test sites, speed data was collected in field through radar gun. Additionally, simulation models, which were calibrated and validated by the collected field data, was developed by traffic simulation software TSIS/CORSIM package for collecting speed data. The main objective to perform simulation analysis is to promote support the analysis findings to be obtained through field speed analysis. Since data collection and reduction were completed, traffic data analysis was implemented to achieve the objectives. Meanwhile, simulation analysis was performed. Outcomes from both analyses were compared and combined together to obtain models that could characterize the impacts of access management treatments and geometric design on traffic operational speed variation. The outcomes of the data analysis were used for the development of guidelines for access management design for the objectives of minimizing operational speed variations. Simulation and calibration are the two important steps to do traffic simulation analysis. Calibration method normally divides into two categories: single parameter calibration method and multiple parameter calibration method. Calibration parameters can be travel time, adjusting parameters include amber interval response, distribution of multiplier for discharge headway percentage, start-up lost time, cross traffic, mean startup delay and mean discharge headway and etc. Finally, calibration target is to make fitness factor smaller than 15%. Finally, the validation is performed by comparing the simulated data and calibrated data. There are no standards for simulation runs, 5, 10, 20, 50 are all applicable. In this study, the simulation was run 10 times.

3.2. Case study

The study area of case study was located on E Flower Ave (Bruce B Downs Boulevard → N 60th Street) in Tampa, Florida. The intersection of E Fowler Ave and Bruce B Downs Blvd is a four-leg signalized intersection. The intersection of E Fowler Avenue and N 60th Street is a four-leg full median opening intersection. Fig. 5 shows the study area of case study.

Traffic volume, operation speed, turn bay length, signal timing plan and travel time were collected. After all filed data were prepared well, a base model was built and simulated in CORSIM to generate the simulated data, as shown in Fig. 6. For travel time, field and simulated data were compared, as Table 5 below shows.

In Table 5, the results show that for eastbound of E Fowler Ave (Bruce B Downs Boulevard → N 60th Street), the simulation data of travel time is longer than the field data. For westbound of E Fowler Avenue (Bruce B Downs Boulevard → N 60th Street), the simulation

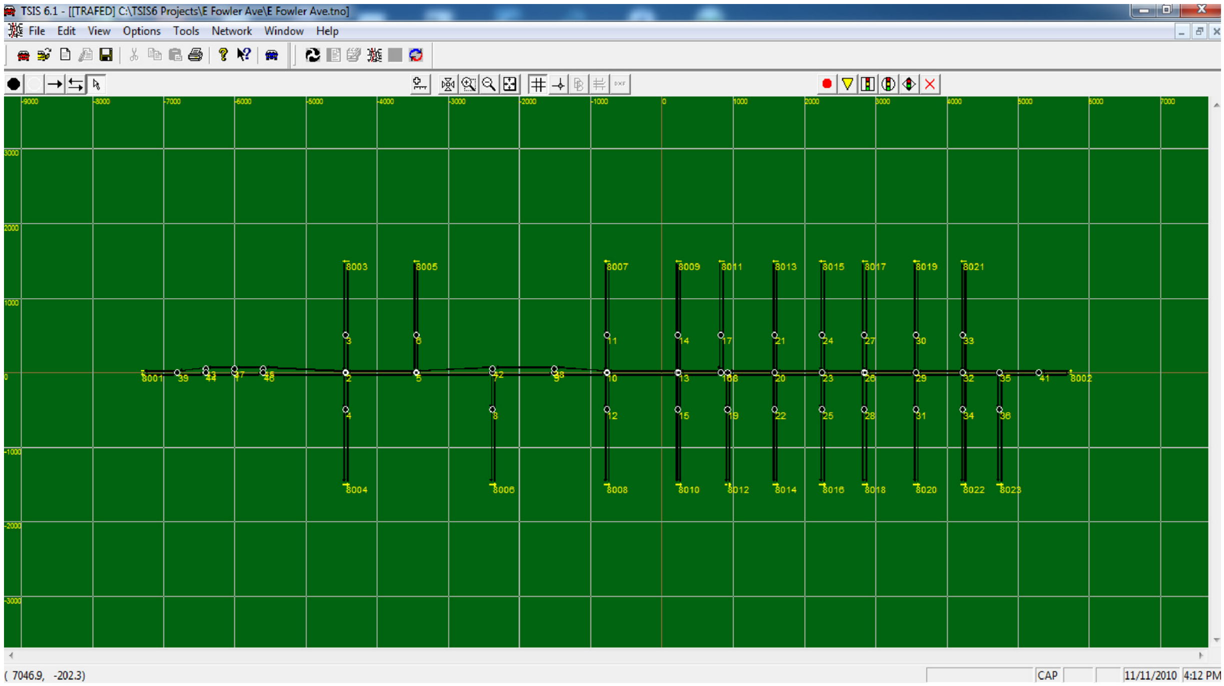


Fig. 6. Simulation model of case study.

Table 5
Comparison of field travel time and simulated travel time.

Direction	Travel time (field test)	Travel time (simulation)	Fitness factor
Eastbound	258.5	298.5	15.47%
Westbound	303.6	274.5	−9.58%

data of travel time is shorter than the field data. To decrease the simulation data of travel time of eastbound to match the field data and also increase the simulation data of travel time of westbound to match the filed data, calibration is needed.

The multiple parameter calibration method was used for this study. The calibration parameter is travel time, and the adjusting parameters include amber interval response, distribution of multiplier for discharge headway percentage, start-up lost time, cross traffic, mean startup delay, and mean discharge headway. Figs. 7–11 demonstrate the calibration process. The calibration target is to make the fitness factor smaller than 15%. The equation below shows the calculation of fitness factor.

$$Fitness\quad Factor = \left| \frac{Value_{sim} - Value_{field}}{Value_{field}} \right| \leq 15\%$$

Table 6 shows the comparison of field travel time and calibrated travel time. The calibrated travel times of both the eastbound and westbound directions are close to field travel times. The fitness factor of both the eastbound and westbound directions by comparing the calibrated travel time with the field travel time are 2.59 and −1.71%, respectively. It is much better than the fitness factor of both the eastbound and westbound directions (15.47%, −9.58%) by comparing the simulated travel time with the field travel time. 2.59

Table 6
Comparison of field travel time and calibrated travel time.

Direction	Travel time (field test)	Travel time (calibrated)	Fitness factor
Eastbound	258.5	265.2	2.59%
Westbound	303.6	298.4	−1.71%

and −1.71% of fitness factor meet the calibration target. So, there is no need to do further calibration.

4. Correlation between crash rates and access density: a case study

4.1. Site selection

Two roadways were selected: Temple Terrace Highway and N Dale Mabry Hwy. Temple Terrace Highway is an urban arterial in Temple Terrace near Tampa, Florida. The length of the entire selected arterial is 7 miles. The posted average speed limit is 45 mph. The geometry of the access points for the selected roadway was obtained from Google Earth. As shown in Fig. 12, the selected roadway segment is primarily straight, which avoids unpredictable safety impacts due to geometry curves.

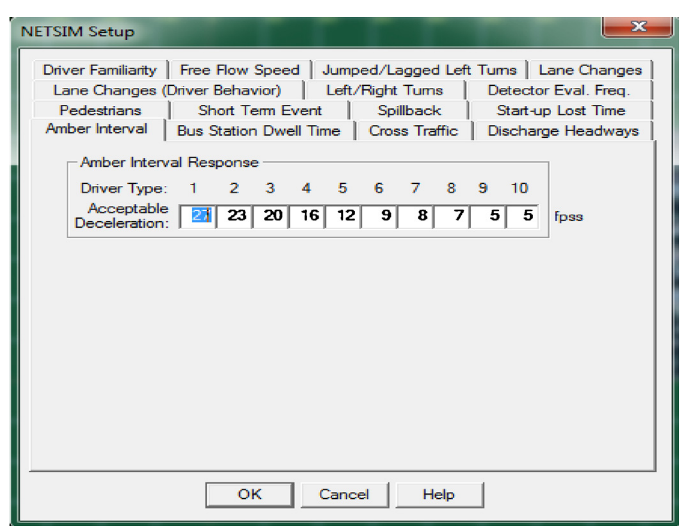


Fig. 7. Adjust amber interval response +30%.

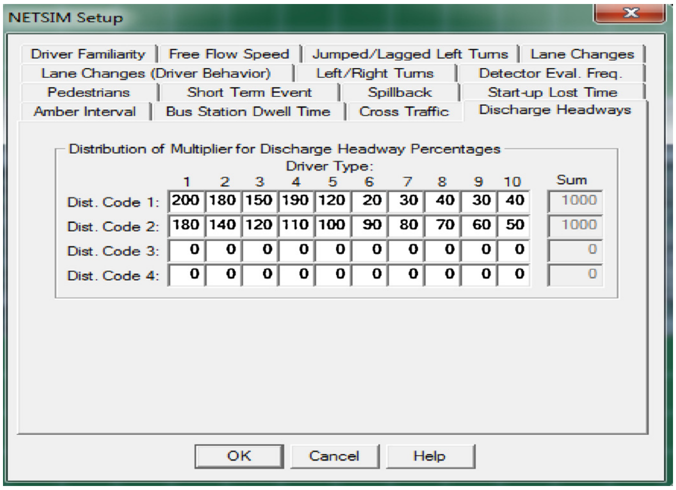


Fig. 8. Adjust discharge headways.

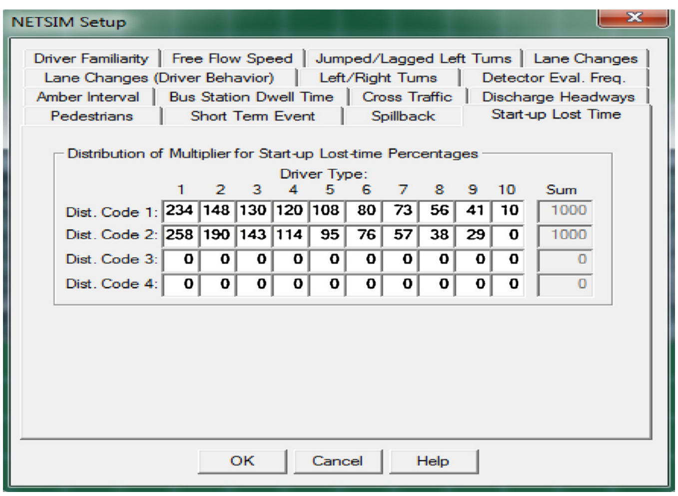


Fig. 9. Adjust start-up lost time.

As shown in Fig. 13, N Dale Mabry Hwy is a suburban roadway in Tampa, Florida. It is also known as State Road 597 (SR 597). The length of the entire selected arterial is 7 miles. The posted average speed limit is 45 mph. The geometry of the access points for the selected roadway was obtained from Google Earth.

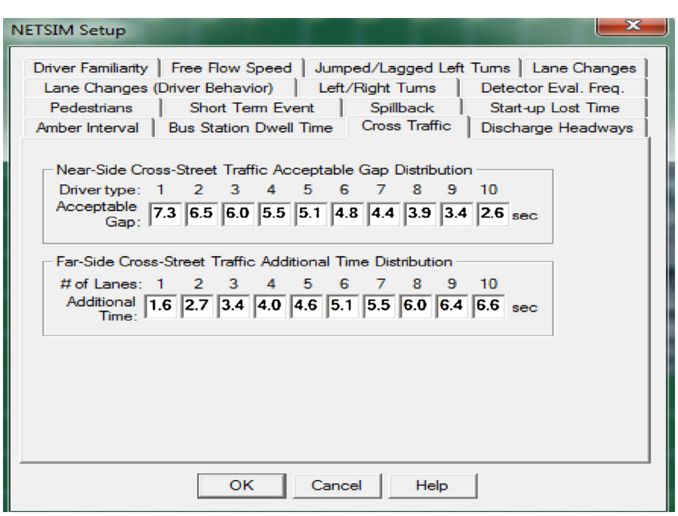


Fig. 10. Adjust cross traffic +30%.

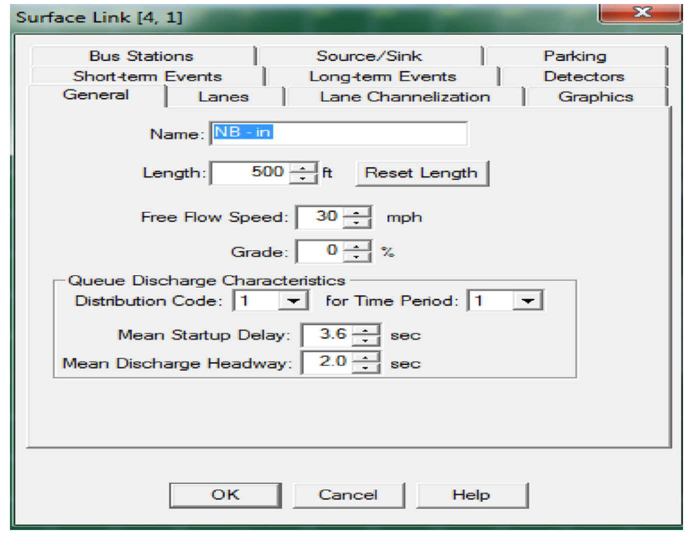


Fig. 11. Adjust mean startup delay and mean discharge headway.

4.2. Crash rates

The crash information on the selected roadway segment was extracted from the Florida Crash database for the years 2002 to 2006. No crashes occurred in the selected roadway segment after 2006, so the crash data were selected only from 2002 to 2006. The crash rate definition used in this study is crashes per million vehicle miles traveled (MVMT). It is a function of the number of crashes, the traffic volume, and the length of roadway segment, as shown below.

$$R = \frac{1,000,000 \times A}{365 \times T \times V \times L}$$

where R, crash rate for the section (in crashes per MVMT); A, number of reported crashes; T, time frame of data (years); V AADT (average annual daily traffic) of roadway segment; L, length of roadway segment (miles).

4.3. Statistical analysis

The first selected roadway segment of Temple Terrace Hwy was divided into 14 sections to obtain more data points for the correlation analysis. Table 7 shows the crash rate for each section, calculated access density for each section given the proposed method and the existing method, and the correlation between the crash rate and the calculated access density. All the 14 sections are 0.5 miles, located in urban area. The AADT of 14 sections ranged from 10,000 to 44,500. The number of lanes of 14 sections divides into four categories: 4; 5; 6 and 4, 6. Due to higher crashes occurred in ID#6 section (Milepost 2.5–Milepost 3), adding traffic lanes can split traffic flow and reduce traffic accidents. The speed limits of 14 sections are all 45 mph. 25 crashes occurred in ID#7 section, which is the highest among all 14 sections. No crashes occurred in ID#14 section. However, ID#1 is the highest crash rates section. Similarly, ID#1 is the highest access density section compared with other 13 sections following both the existing access density method and proposed access density method. As shown in Table 7, for existing access density method, the correlation coefficient is estimated between crash rates and access density calculated following the existing method of 14 sections, which is 0.728. The same method is applied to the estimation of correlation coefficient between crash rates and access density calculated following the proposed method of 14 sections. The correlation coefficient used in this study is Pearson product-moment correlation coefficient,

Table 7
Crash rate, access density, and correlation coefficients of temple terrace Hwy.

No.	Milepost		AADT	No. of lanes	Speed limit	Land use	No. of crashes	Crash rate (10 million VMT)	Access density (existing)	Access density (proposed)
	Start	End								
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	94.0
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

also known as r, R, or Pearson's r, a measure of the strength and direction of the linear relationship between two variables that is defined as the (sample) covariance of the variables divided by the product of their (sample) standard deviations.

Similar information is presented in Fig. 14 with linear trend lines for both methods. The X-axis represents the access density, and the Y-axis represents the crash rate. When the access density increases, the crash rate increases as well. The correlation coefficient of calculated access density and crash rate following the proposed method is 0.764. It is higher than the correlation efficient of calculated access density and crash rate following the existing method, which is 0.728. Also, the R square value of mathematical model of calculated access density and crash rate following the proposed method is 0.583. It is higher than the R square value of mathematical model of calculated access density and crash rate following the existing method, which is 0.5299. Both correlation coefficient analysis and R square value analysis of this case study show that the access density calculated following the proposed method has a high correlation with the crash rates.

Similarly, the second selected roadway segment of N Dale Mabry Hwy was divided into 14 sections to obtain more data points for the correlation analysis. Table 8 shows the crash rate for each section, calculated access density for each section given the proposed method and the existing method, and the correlation between the crash rate and the calculated access density. All the 14 sections are 0.5 miles, located in suburban area. The AADT of 14 sections are 27,000, 27,500, 31,000 and 33,500. Only one category of 6 is applied to all 14 sections. The speed limits of 14 sections are all 45 mph. 23 crashes occurred in ID#5 section, which is the highest among all 14 sections. No crashes occurred in ID#14 section. However, ID#5 is the highest crash rates section. Similarly, ID#4 is the highest access density section compared with other 13 sections following the existing access density method. But ID#3 is the highest access density section compared with other 13 sections following

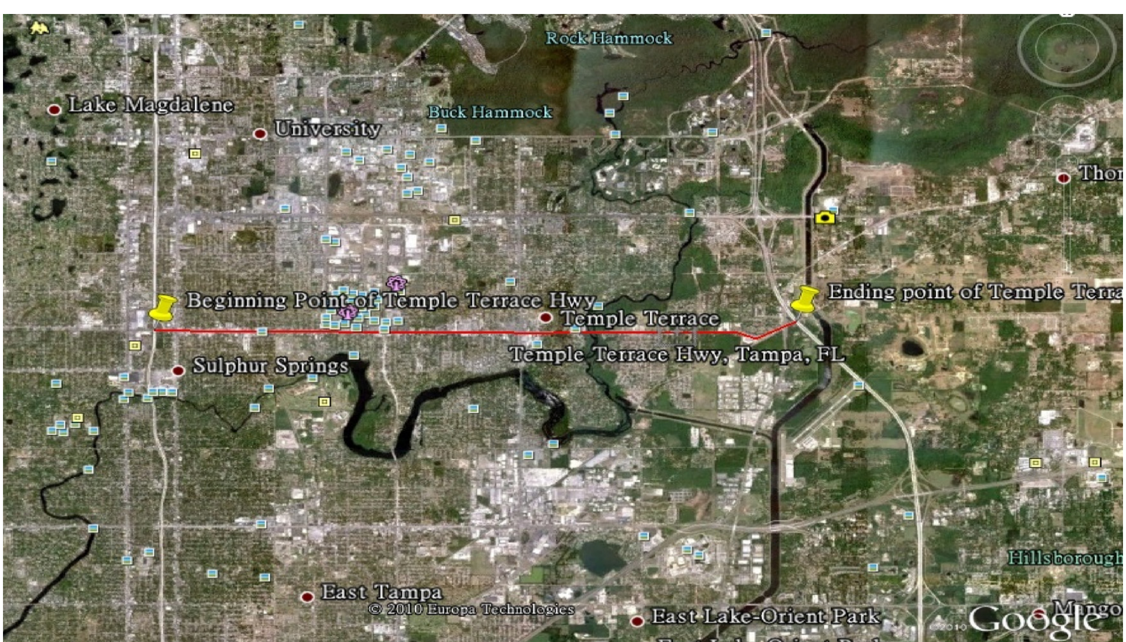


Fig. 12. Location of first selected roadway.

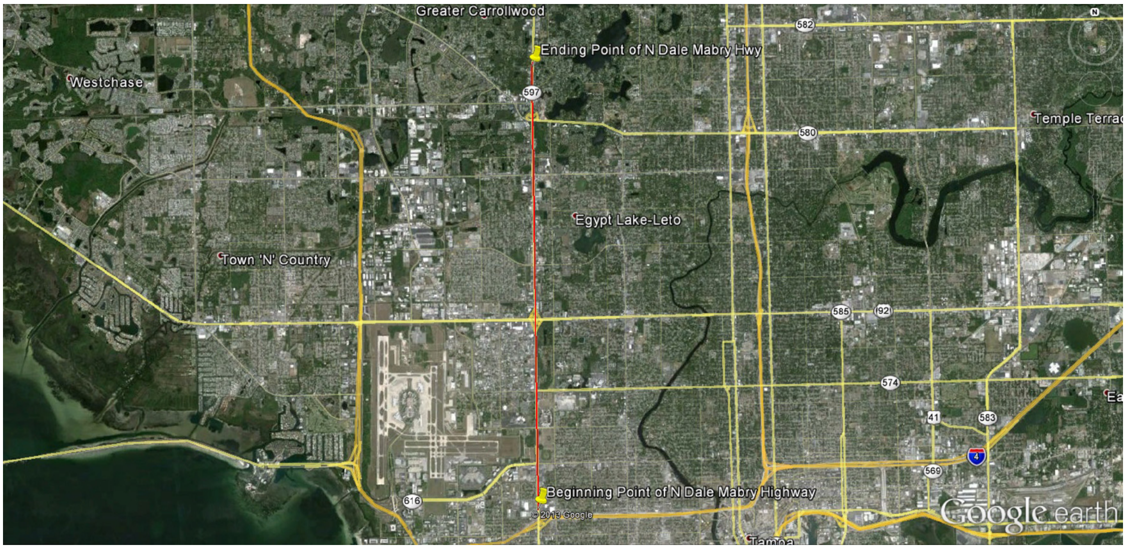


Fig. 13. Location of second selected roadway.

the proposed access density method. As shown in Table 8, for existing access density method, the correlation coefficient is estimated between crash rates and access density calculated following the existing method of 14 sections, which is 0.809. The same method is applied to the estimation of correlation coefficient between crash rates and access density calculated following the proposed method of 14 sections. The correlation coefficient between crash rates and access density calculated following the proposed method of 14 sections, which is 0.846.

Fig. 15 shows the comparison of crash rate versus access density of N Dale Mabry Hwy following the existing method and proposed method. The *X*-axis represents the access density, and the *Y*-axis represents the crash rate. The correlation coefficient of calculated access density and crash rate following the proposed method is 0.846. It is higher than the correlation efficient of calculated access density and crash rate following the existing method, which is 0.809. Also, the *R* square value of mathematical model of calculated access density and crash rate following the proposed method is 0.7164. It is higher than the *R* square value of mathematical model of calculated access density and crash rate following the existing method, which is 0.655. Both correlation coefficient analysis and *R* square value analysis of this case study show that the access density calculated following the proposed method has a high correlation with the crash rates.

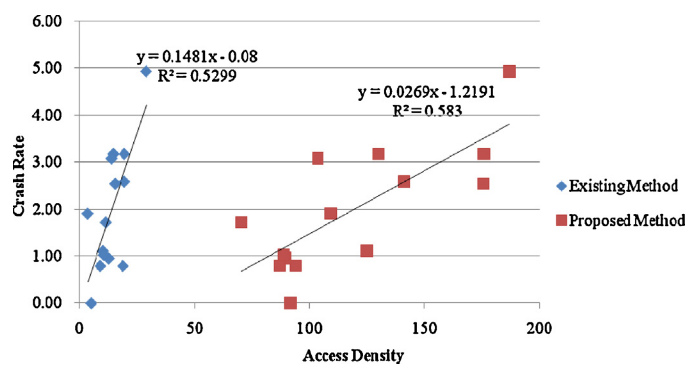


Fig. 14. Crash rate vs. access density of Temple Terrace Hwy.

Table 8
Crash rate, access density, and correlation coefficients of N Dale Mabry Hwy.

No.	Milepost		AADT	No. of lanes	Speed limit	Land use	No. of crashes	Crash rate (10 million VMT)	Access density (existing)	Access density (proposed)
	Start	End								
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

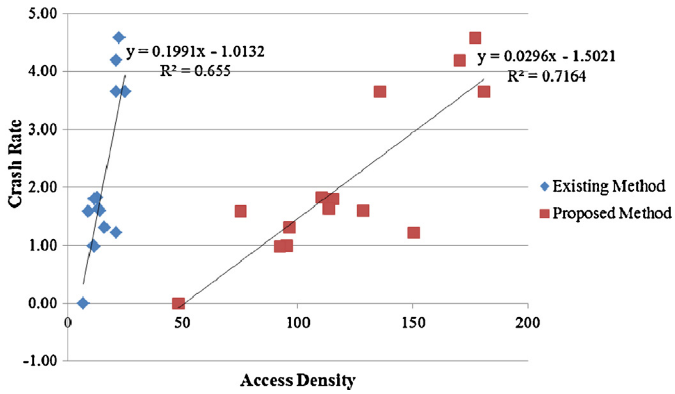


Fig. 15. Crash rate vs. access density of N Dale Mabry Hwy.

5. Conclusions and suggestions

This study proposes a new method for calculating access density considering traffic speed variation and the length of the speed fluctuation area. Given default traveler behavior, a microscopic traffic simulation software package, TSIS-CORSIM was used to simulate traffic operations and provide traffic speed variation metrics for different combinations of access type, number of lanes, speed limit, and traffic volume level. Access densities were calculated for 14 sections using the existing method and proposed method for two roadway segments in Temple Terrace, Florida and Tampa, Florida. The conclusions and suggestions are summarized as follows:

1. The correlations between access densities and crash rates were analyzed, and the outcomes were compared with those following the method in a previous study. It is verified that the access densities calculated using the new method demonstrates a somewhat higher correlation with the crash rates than existing method.
2. Simulation outputs of different access weights under ideal traffic conditions are listed in Appendix I, which shows diverse impact of speed variance.
3. The proposed method can be further improved by considering the overlapping of the speed fluctuation areas if two successive access points are close enough to each other.
4. Additional roadway segments need to be analyzed for obtaining a more general conclusion.
5. The outcome of this study can be used for providing guidelines on access management so as to improve corridor safety. The guideline will be developed to help Federal Highway Administration (FHWA), United States Department of Transportation (USDOT), and transportation consulting companies to regulate the construction, management and design of roadway segments.
6. To improve roadway safety design and set higher standards of roadway access control, the access weights are suggested more than the number of access.

Appendix I.

First 144 sample access weights by access type, number of lanes, speed limit, and level of service

Number	Access type	Number of lanes	Speed limit	LOS	Access weight
1	1	4	45	H	5.76
2	1	4	45	M	8.62
3	1	4	45	L	6.24
4	1	4	50	H	5.68
5	1	4	50	M	9.40
6	1	4	50	L	7.64
7	1	4	55	H	7.03
8	1	4	55	M	10.40
9	1	4	55	L	7.75
10	1	4	60	H	7.84
11	1	4	60	M	11.15
12	1	4	60	L	9.05
13	1	6	45	H	5.56
14	1	6	45	M	8.60
15	1	6	45	L	6.31
16	1	6	50	H	6.01
17	1	6	50	M	9.34
18	1	6	50	L	7.64
19	1	6	55	H	6.75
20	1	6	55	M	10.34
21	1	6	55	L	7.81
22	1	6	60	H	7.68
23	1	6	60	M	11.24
24	1	6	60	L	8.92
25	1	8	45	H	5.46
26	1	8	45	M	8.61
27	1	8	45	L	6.31
28	1	8	50	H	5.88
29	1	8	50	M	9.31
30	1	8	50	L	7.60
31	1	8	55	H	6.83
32	1	8	55	M	10.39
33	1	8	55	L	7.79
34	1	8	60	H	7.62
35	1	8	60	M	11.18
36	1	8	60	L	8.87
37	2	4	45	H	6.07
38	2	4	45	M	7.97
39	2	4	45	L	6.64
40	2	4	50	H	7.02
41	2	4	50	M	8.06
42	2	4	50	L	7.37
43	2	4	55	H	7.38
44	2	4	55	M	9.77
45	2	4	55	L	8.25
46	2	4	60	H	8.40
47	2	4	60	M	10.45
48	2	4	60	L	8.95
49	2	6	45	H	5.77
50	2	6	45	M	8.07
51	2	6	45	L	7.06
52	2	6	50	H	7.17
53	2	6	50	M	8.48
54	2	6	50	L	7.37
55	2	6	55	H	7.04
56	2	6	55	M	9.67
57	2	6	55	L	8.65
58	2	6	60	H	8.39
59	2	6	60	M	10.53
60	2	6	60	L	9.37
61	2	8	45	H	5.69
62	2	8	45	M	8.07
63	2	8	45	L	6.85
64	2	8	50	H	7.00
65	2	8	50	M	8.48
66	2	8	50	L	7.55
67	2	8	55	H	6.98
68	2	8	55	M	9.69
69	2	8	55	L	8.67
70	2	8	60	H	8.45
71	2	8	60	M	10.57
72	2	8	60	L	9.23
73	3	4	45	H	6.37

Number	Access type	Number of lanes	Speed limit	LOS	Access weight
74	3	4	45	M	8.75
75	3	4	45	L	6.82
76	3	4	50	H	7.26
77	3	4	50	M	9.57
78	3	4	50	L	7.81
79	3	4	55	H	8.02
80	3	4	55	M	11.28
81	3	4	55	L	8.74
82	3	4	60	H	8.88
83	3	4	60	M	12.19
84	3	4	60	L	8.80
85	3	6	45	H	6.15
86	3	6	45	M	8.86
87	3	6	45	L	6.79
88	3	6	50	H	7.58
89	3	6	50	M	9.60
90	3	6	50	L	7.69
91	3	6	55	H	8.16
92	3	6	55	M	10.75
93	3	6	55	L	8.62
94	3	6	60	H	10.04
95	3	6	60	M	12.02
96	3	6	60	L	10.48
97	3	8	45	H	5.83
98	3	8	45	M	9.08
99	3	8	45	L	7.21
100	3	8	50	H	7.14
101	3	8	50	M	9.70
102	3	8	50	L	8.03
103	3	8	55	H	8.33
104	3	8	55	M	11.18
105	3	8	55	L	8.46
106	3	8	60	H	9.60
107	3	8	60	M	11.51
108	3	8	60	L	8.77
109	4	4	45	H	6.12
110	4	4	45	M	8.00
111	4	4	45	L	6.70
112	4	4	50	H	6.92
113	4	4	50	M	7.33
114	4	4	50	L	7.33
115	4	4	55	H	7.72
116	4	4	55	M	9.74
117	4	4	55	L	8.23
118	4	4	60	H	8.28
119	4	4	60	M	10.61
120	4	4	60	L	8.16
121	4	6	45	H	5.92
122	4	6	45	M	8.03
123	4	6	45	L	6.53
124	4	6	50	H	6.94
125	4	6	50	M	8.60
126	4	6	50	L	7.45
127	4	6	55	H	7.53
128	4	6	55	M	9.70
129	4	6	55	L	7.84
130	4	6	60	H	8.99
131	4	6	60	M	10.41
132	4	6	60	L	10.18
133	4	8	45	H	5.69
134	4	8	45	M	8.06
135	4	8	45	L	6.75
136	4	8	50	H	6.73
137	4	8	50	M	8.63
138	4	8	50	L	7.74
139	4	8	55	H	7.41
140	4	8	55	M	9.73
141	4	8	55	L	8.36
142	4	8	60	H	8.39
143	4	8	60	M	10.14
144	4	8	60	L	8.67

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