Analysis of Safety Effects of Traffic, Geometric, and Access Parameters on Truck Arterial Corridors

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According to NHTSA, more than 400,000 truck-related crashes occurred in 2009; approximately 7,800 of those were fatal. Truck-related crashes undermine the truck's remarkable contribution to the U.S. economy. Truck safety research on arterial streets is considerably disproportionate when compared with the extensive studies of truck safety on freeways. Identifying critical factors that contribute to truck-related crashes and developing remedial and preventive strategies to reduce truck-related crashes and their consequences on arterials are imperative. Truck-related crashes can be mitigated through careful planning of the location, design, and operation of driveways, median openings, and street connections. In this study, access-related data were collected manually in addition to roadway geometric characteristics. The augmented data offered more explanation and prediction power for truck crashes. The standard deviation of commercial driveway throat width, commercial driveway throat width with flare and its standard deviation, and the proportion of divided commercial driveway, signal density, and shoulder width were significant factors for crash frequency prediction. A generalized negative binomial model was used to identify sources of data overdispersion. This study found that some previously significant variables were no longer significant after access parameters were added; this finding demonstrated the impact of access parameters on truck-related crashes on arterials. This noticeable change in the statistical models composed of different variables is a reminder that a spurious relationship can form if a causal relationship is nonexistent.

Arterial roads collect traffic from local roads and channel it to freeways, providing both mobility and accessibility. Good access management of arterial roads involves balancing the dual role of the arterial roadway: corridors for through traffic and access to adjacent properties and economic activities. Some key factors commonly identified in the literature as directly influencing safety performance of arterial highways include driveway spacing, signal density, driveway design, driveway proximity to intersections and interchanges, median configuration, geometric design elements, land use, and signal timing plan.

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Arterial safety conditions are critical because of the numerous access points, turning movements, and mixture of transportation modes, which can be complicated by various traffic control devices and strategies. For arterial movement, roadway characteristics such as lane width, shoulder width, posted speed limit, median width, horizontal and vertical curvature, and pavement surface conditions are important determinants in safety, since each of these components relates to a certain level of service when the arterial acts as a thoroughfare. From an access perspective, driveways and median opening densities are important measures related to safety; each of these factors adds to the number of conflicts for vehicles along a roadway during egress and ingress. Although it is certainly necessary to ensure movement, it is also important to accommodate access to commercial and residential properties; thus, the number, type, spacing, and location of driveways and median openings need to be planned carefully. Therefore, it is important for local governments, road authorities, and land developers to coordinate access decisions on the basis of the arterial's desired level of safety, mobility, and accessibility.

The proportion of driveway-related accidents to overall accident numbers in different states illustrates the magnitude of the problem. Driveway-related crashes amounted to more than 10% of total crashes in Iowa, Indiana, and Michigan (*1–3*). In Maine, one in six crashes occurred at driveways or entrances, and one in five persons involved in a crash was involved in a driveway- or entrance-related crash in 1996 (*4*). Rawlings and Gattis examined over 2,000 accident reports from Springdale, Arkansas, for one year to identify which crashes were driveway-related (*5*). A "driveway-related" crash was defined as a collision that occurred either directly or indirectly because of the operation of a driveway. Researchers found that the one-sixth of crashes involved left-turn egress (*5*). However, the solution to the problem is not simply limiting, reducing, or closing the access points but providing access at proper locations and designing it in a manner that is safer and more effective.

Because of the substantial truck–passenger vehicle interactions that occur on arterial streets, it is necessary to study the relationship between truck safety and arterial access management while also considering the geometric characteristics and traffic control. Therefore, the main objective of this study is to identify the safety impact of access-related phenomena on truck arterial corridors. The study began with an extensive literature review and focused on collecting data relating to access parameters. To investigate the consequences of incorporating access-related variables in a previous model, two negative binomial models were compared, and the implications of the statistically significant variables were discussed on the basis of the study context (*6*).

LITERATURE REVIEW

Arterial streets are the "last miles" for trucks when they deliver freight to commercial and residential destinations or enter the freeway system. Frequent and direct access from commercial and residential properties to an arterial road reduces capacity and creates substantial opportunities for crashes. Increasing the spacing between access points helps reduce the number and variety of events to which drivers must respond. In addition, greater access spacing gives drivers more time to perceive, react, and navigate safely. Truck crashes in many of the counties of Wisconsin have continued to increase in recent years, particularly on arterial streets (*7*). The increase in truck crashes has become a major issue for researchers and transportation officials, who frequently debate the cost-effectiveness of implementing access management techniques (e.g., raised medians or driveway consolidation) to alleviate some of the safety concerns. Application of access management best practices has benefits for motorists, transit riders, planning and government agencies, and communities.

In recent years, access management along arterial streets has started to gain attention from researchers (*8–12*). Using microscopic traffic simulation models for 11 arterial corridors, Eisele and Frawley estimated the relationship between crash rates and density of access points (driveways and public street intersections), with or without the presence of raised medians or two-way left-turn lanes (*8*). They concluded that as access point density increases, there is an increase in crash rates that is irrespective of the median type. However, the researchers also found that the relationship between access density and crash rate is higher on roadways without raised medians. Lee et al. analyzed the crashes that occurred at midblock of an urban arterial road with log-linear models to show that midblock crashes are more likely to occur on road sections with access points and a high percentage of trucks (>20%) (*11*). Results showed that median opening, driver age and gender, lighting, time of day, and day of the week are associated with different types of crashes classified by the vehicles involved. Their study shows the importance of analyzing divided urban arterial midblock crashes with high truck volume by travel direction, since the complex interaction among cars and trucks is influenced by more frequent egress and ingress driveway traffic.

Numerous studies have been conducted on the relationship between access management techniques and safety, specifically when it comes to access spacing, corner clearance, and medians (*13–17*). Schultz et al. undertook several studies on urban arterial access management and safety in order to determine the safety benefits provided by access management techniques in Utah (*14–16*). Statistical analyses showed that on roadways that included high access density, numerous signals per unit length and lack of medians were positively related to increased crash rate and severity. In particular, crash totals, crash rates, and rear-end crashes in intersection functional areas increase with the increase in commercial access density. In a follow-up study, the researchers showed that raised medians and driveway consolidation can change the crash pattern or manner of collision and the injury severity. Gluck et al. found that doubling the access frequency from 10 to 20 access points per mile would increase accident rates by 40% (*18*). A road with 60 access points per mile would triple the accident rate as compared with a density of 10 access points per mile. Each additional access point increases the accident rate by about 4%. The results suggest a generally consistent relationship: the greater the frequency of driveways and intersections, the greater the number of accidents. Gattis et al. presented six major considerations for driveway design, including maintaining or improving the efficiency and safety of the intersecting roadway and providing adequate sight distance for road and sidewalk users (*19*). Stover and Koepke indicated that two-way driveways allow for simultaneous two-way operations, and thus it is better to have separate entrance and exit lanes (*20*).

Adequate spacing and design of access to crossroads in the vicinity of freeway ramps avoids traffic backups and preserves safe and efficient traffic operation (*21*). A methodology was developed by Flintsch et al. to quantitatively evaluate the safety impacts of different access-spacing standards in Virginia (*13*). According to their analysis, shortcomings exist in the AASHTO standards, and significant safety benefits can be achieved by adopting stricter standards such as those recommended in the TRB *Access Management Manual.* For example, an increase in the minimum access spacing from 300 ft to 600 ft results in a 50% reduction in the crash rate.

In Wisconsin between 2005 and 2009, 7.4% of midblock crashes were related to access movements, and 20% of intersection crashes were related to turning left into the selected truck-preferred arterial corridors (*7*). Though numerous studies have been conducted in hope of capturing the contributing factors to crashes due to access-related variables, nevertheless the impacts of access-related variables together with traffic, geometric, and pavement variables were not specifically considered for truck-preferred corridors. Motivated by planning and design of safer corridors heavily used by trucks, this study aims to enrich the current body of knowledge through informed data collection and statistical models. The cause-and-effect relationships between crashes and presumed crash causal factors will be explored.

DATA COLLECTION AND PROCESSING

Data used in this research consisted of 5 years (2005 to 2009) of crash counts, as well as geometric, pavement, access-related, and traffic volume data. Truck crashes were retrieved from the online Wisconsin crash database through the WisTransportal system (*7*). In order to undertake the investigation of truck crashes from a corridor perspective based on arterial roads, truck corridor selection was confined to principal arterials and minor arterials. Truck corridors were identified on the basis of criteria established in a previous study (*6*). The number of corridors was changed from 100 to 74 because the current study considered the corridors with signalized intersections. Descriptive statistics for key variables used in the crash frequency model can be seen in Table 1.

As shown in Table 1, the 5-year crash total had a mean of 93 and a standard deviation of 79, with a maximum of 407 crashes. Corridor lengths vary from relatively short (1.03 mi) to very long (16.94 mi), with an average segment length of 4.88 mi. The mean corridor annual average daily traffic (AADT) was 17,825. Most access-related variables are not readily available in any geographic information system or tabular format; thus the most reliable source for collecting this information is through manual measurements of aerial photographs. Considerable effort was made to collect access-related variables such as median opening width, length of left-turn bay, length of two-way left-turn lane, driveway width, and driveway width with flare. These variables were measured from Google Earth and Google Map images, and the mean and standard deviation of each were calculated. Median opening width, left-turn bay length, minimum distance to a signalized intersection, and intersection functional area are illustrated in Figure 1. The corridor start and end points were carefully identified by matching the attributes of these corridors in the geographic information system shape file. Signal,

TABLE 1 Summary Statistics of Crash-, Traffic-, and Access-Related Variables

Variable Name	Description	Avg.	SD	Min.	Max.
Crash count	5-year crash count for each corridor	93	79	14	407
L	Length of the corridor (mi)	4.88	3.42	1.03	16.94
AADT	Annual average daily traffic	17,825	6,126	8,346	39,435
AADTT	Annual average daily truck traffic	1,126	213	796	1,892
W_Med_Op	Average width of median opening within corridor (ft)	71.16	14.41	36	97.14
Stdv_W_Med_Op	Standard deviation of median opening width (ft)	18.95	8.81	0	44.39
Med_den	Median opening density (per mile)	4.48	3.56	0	17.64
Min_Dist	Minimum distance of driveway to signalized intersection (ft)	134	252	0	1920
TWLTL	Length of two-way left-turn lane (mi)	0.70	0.79	0.06	3.58
L_LT	Average length of left-turn bay within a corridor (ft)	178	72	60	451
Stdv_L_LT	Standard deviation of length left-turn bay length (ft)	68.73	33.70	15.29	197
R_Throat_W	Average width of driveway (ft)	12.86	2.61	8	22.03
R_Stdv_Throat_W	Standard deviation of driveway width (ft)	3.91	2.35	0.70	15.80
R_Flare_W	Average width of driveway with flare (ft)	25.49	9.36	8	61
R_Stdv_Flare_W	Standard deviation of driveway width with flare (ft)	7.36	6.51	0.78	46.60
C_Throat_W	Average throat width of driveway (ft)	28.34	4.17	19.80	37.10
C_Stdv_Throat_W	Standard deviation of driveway throat width (ft)	9.27	3.15	4.16	17.87
C_Flare_W	Average width of driveway with flare (ft)	48.07	15.75	25.20	112.3
C_Stdv_Flare_W	Standard deviation of driveway width with flare (ft)	19.88	11.0	5.10	56.43
Drv_SigInt	Average number of driveways located within 0.1 mi from signalized intersection	17.38	14.36	0	40
C_Div_Drv	Proportion of divided driveway, commercial	0.33	0.18	0	0.67
Drv_den	Driveway density for corridor/mile	17.09	11.50	1.10	54.70
C_Den	Number of commercial driveways per mile	9.57	7.37	0.9	41.30
R_Den	Residential driveway density/mile	7.51	7.15	0.0	34.20
Sig_Den	Signal density (signals/mile)	1.52	1.01	0.12	4.85
PSI	Pavement serviceability index	2.86	0.81	0.88	4.35
STD (PSI)	Standard deviation of PSI	0.61	0.43	0	1.98
SHWD	Shoulder width (ft)	3.10	2.95	0	10

NOTE: Avg. = average; SD = standard deviation; min. = minimum; max. = maximum.

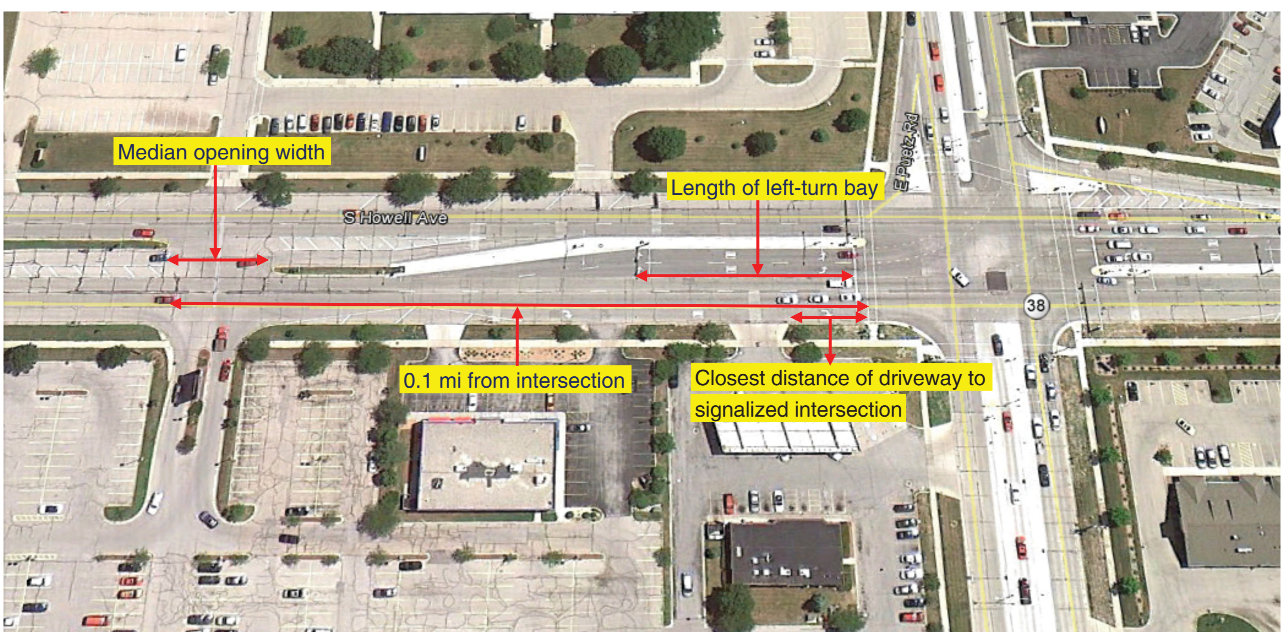

FIGURE 1 Roadway access-related components.

median opening, and driveway density were calculated by the ratio of their count to corridor length.

Driveways were categorized as either residential or commercial (commercial driveways include commercial, industrial, institutional, etc.) by counting the number of visible parking spots. Primarily, driveway turn radius, driveway throat width, driveway throat length, driveway slope, existence of dedicated turn lanes, and length of sight distance (especially for drivers exiting driveways) were considered as the key driveway design factors. However, because of time limitations and technical difficulties (e.g., driveway slope), data collection was eventually limited to three aspects: driveway throat width, driveway throat width with flare, and number of divided driveways. Figure 2 shows how measurements of throat width and throat width with flare were taken.

The maximum driveway density, 54.7, exists in a 1.17-mi-long corridor where a total of 64 driveways—30 commercial and 34 residential—were counted. Many researchers recommend 20 to 30 driveways per mile as a maximum driveway density standard; above that standard, accident rates may increase significantly. This standard applies to commercial driveways on urban, multilane arterials with a posted speed limit of 35 mph (*22*). In these data 17 corridors with an average of 45 mph posted limit have more than 30 driveways per mile. High speed limits suggest lower driveway density if the roadway is primarily functioning toward through traffic (i.e., higher movement demands are more important than the need for access). Hence, some truck-preferred arterial corridors may have safety compromises such as a high number of collision points and a high crash rate.

The functional area of an intersection includes the area beyond the physical junction of two roadways that comprises decision and maneuvering distance plus any required vehicle storage length. Limiting or, when possible, eliminating driveways within the functional area of an intersection (upstream and downstream) helps reduce crashes through an intersection and reduces possible driver errors. It is important that the influence of any driveway access be minimized at the functional area of an intersection, since driveway traffic may result in higher crash rates and increased congestion. According to the *Manual on Uniform Traffic Control Devices* (*23*), the crashes that occur within a 15-m to 152-m (50-ft to 500-ft) radius from the center point of an intersection are classified as intersection-related crashes (*24*). In order to assess the safety impact of a driveway within an intersection's functional area, two variables were collected: minimum distance of a driveway to a signalized intersection and the total number of residential and commercial driveways located within 500 ft of a signalized intersection. Figure 3 shows the number of driveways that are located within the intersection's functional area.

Generally there are three median types in use: a raised median, a painted median, and a two-way left-turn lane (TWLTL). Continuous TWLTLs are a common access management treatment when combined with driveway consolidation and corner clearance. TWLTLs provide a separate lane for vehicles turning into property access. In the current study, only 23 of 74 corridors have this kind of median treatment. Continuous raised medians with well-designed median openings are also common access management treatments and are among the most important features for a safe and efficient highway system. Median openings should generally only be provided at public road intersections or at driveways shared by several businesses. The number of median openings should be kept to a minimum since they add conflict points and detract from safety. In this study, data for median opening width and the number of median openings for a roadway segment with raised medians were collected.

METHODOLOGY

Count-data modeling (Poisson, negative binomial) techniques are widely used for crash frequency as the number of accidents (n_i) on a roadway segment per unit of time is a nonnegative integer. When the variance is larger than the mean, the data are said to be overdispersed. Overdispersed count data are usually modeled with a negative binomial distribution because the Poisson distribution has a restrictive assumption of equal variance and mean. In a Poisson

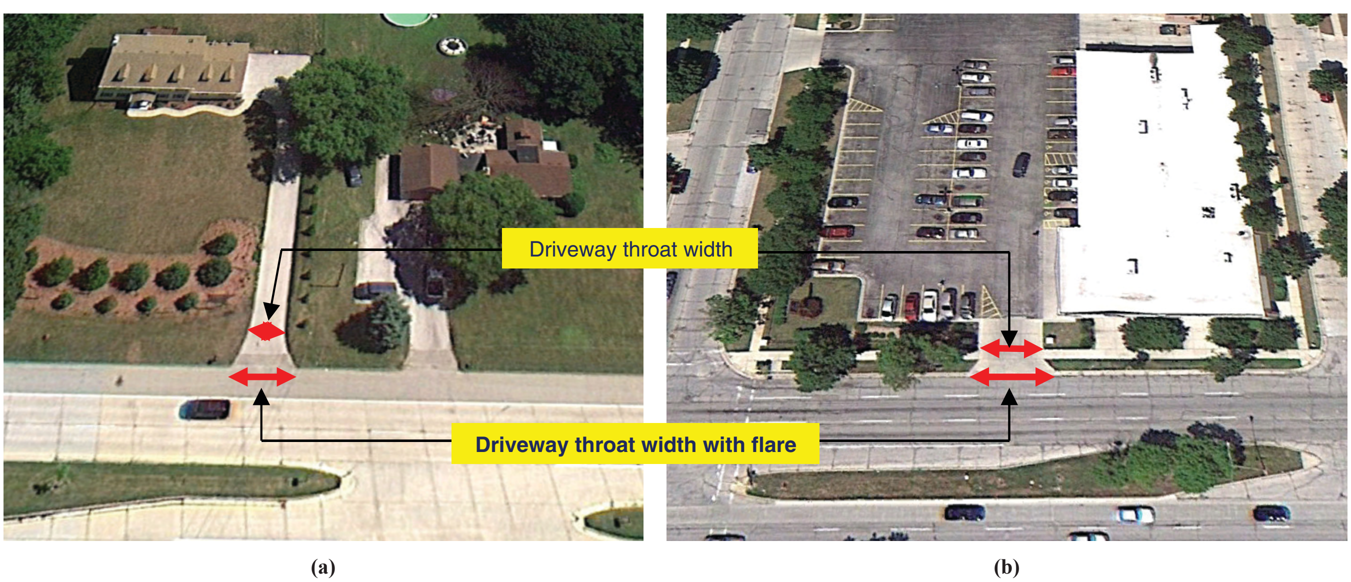

FIGURE 2 Driveway configurations: (*a*) residential and (*b*) commercial.

FIGURE 3 Functional area of intersection (S = south; ave = avenue; ln = lane).

model, the probability of the number of truck crashes for corridor i (n_i) is

$$P(n_i) = \frac{\exp(-\lambda_i)\lambda_i^{n_i}}{n_i!} \quad (1)$$

where $P(n_i)$ is the probability that corridor i will have n_i crashes and λ_i is the expected number of crashes in corridor i. The negative binomial model is an extension of the Poisson in which the Poisson parameter λ follows a gamma probability distribution. The standard log link function for the negative binomial model can be expressed as a linear model of the covariates:

$$\lambda_i = \exp(\beta_0 + \beta_1 x_{1i} + \cdots + \beta_k x_{ki})\exp(\varepsilon_i) \quad (2)$$

where the β's are coefficients of explanatory variables and $\exp(\varepsilon_i)$ is the term adjusting for overdispersion and is gamma distributed. The models were estimated by using generalized linear modeling. For this modeling, STATA was used (*25*).

The generalized negative binomial (GNB) model is a generalization of the negative binomial mean–variance structure where the over-dispersion parameter alpha (α) may also be parameterized specifically to account for the data heterogeneity. The GNB model extends the negative binomial model by allowing user-specified parameterization of the ancillary parameter, α. There are two uses of the GNB model. First, parameterization of α provides information regarding which predictors influence overdispersion. Second, it is possible to determine whether overdispersion varies over the significant predictors of α by observing the differential values of its standard errors. If the standard errors vary only a little between parameters, the overdispersion in the model can be regarded as constant (*26*).

RESULTS

Given the importance of access data for arterial street traffic safety, manually collected access data elements were added to the model link function in addition to the available geometric and traffic data. These augmented data were expected to offer more explanation and prediction power for truck crashes. The Pearson correlation test was performed before the variables were put into the statistical models. After several iterations, the statistically significant variables were as shown in Table 2. The Akaike information criterion (AIC) was used to determine statistical goodness of fit. The general formula is AIC = $2k - 2\ln(L)$, where k is the number of parameters in the statistical model and L is the maximized value of the likelihood function for the estimated model. Columns 4 and 5 represent the t-value and two-tailed p-value, which are used for testing the null hypothesis. Coefficients having p-values less than alpha (.05) are statistically significant.

The design and location of commercial driveways, which are frequently used by trucks, appear to affect the safety performance of a corridor. Significant factors in crash frequency prediction include standard deviation of commercial driveway throat width, flared commercial driveway throat width and its standard deviation, proportion of divided commercial driveways, signal density, and shoulder width. Among all statistically significant variables, flared commercial driveway throat width, shoulder width, minimum distance of a driveway to the signalized intersection, and proportion of divided commercial driveways are negatively associated with the prediction of the number of truck crashes. These variables help to provide insightful, logical, and meaningful explanation to the cause-and-effect relations of truck crashes.

The standard negative binomial model is often criticized because of its fixed overdispersion parameter α. Researchers are keen to

TABLE 2 Negative Binomial Estimates for Crash Frequency Prediction

Effect	Estimate	SE	*t*-Value	Pr > | *t* |
Intercept	3.0377	0.3119	9.74	.000
TMT (truck million miles traveled)	0.1033	0.0095	10.78	.000
Standard deviation of driveway throat width (ft)	0.0475	0.0184	2.58	.027
Average width of driveway with flare (ft)	–0.0111	0.0041	–2.70	.019
Standard deviation of driveway width with flare (ft)	0.0143	0.0057	2.48	.008
Proportion of divided driveway, commercial	–0.5748	0.2847	–2.03	.042
Shoulder width (ft)	–0.0428	0.0215	–1.99	.044
Signal density	0.3324	0.0704	4.60	.000
Dispersion	0.1611	0.0280	5.72	.000

NOTE: AIC = 726; SE = standard error; Pr = probability.

find the source of this overdispersion (*27, 28*). Heterogeneous or GNB regression is a valuable method for assessing the source of overdispersion (*26*). The GNB model can be used to differentiate sources influencing the model parameter estimates from sources influencing overdispersion. Through overdispersion factor parameterization, predictors influencing the value of α can be determined by establishing a functional relationship between them and estimated by including the function in the overall model estimation. It was hypothesized that AADT, truck million miles traveled, signalized intersection density, driveway density, and other factors may be contributing factors to α. Table 3 attempts to formulate the parameters as the source of overdispersion including signal density, proportion of divided commercial driveways, and truck miles traveled. The significant variables of the negative binomial model are statistically significant in the GNB for truck crash prediction. The AIC indicates that GNB yields a better goodness of fit than the negative binomial model.

TABLE 3 GNB Estimates for Accident Frequency Prediction

Parameter	Estimate	SE	*t*-Value	Pr > | *t* |
Effect				
Constant	2.7659	0.30204	9.16	.000
TMT	0.12508	0.01644	7.61	.000
Standard deviation of driveway throat width (ft)	0.05526	0.0171	3.23	.001
Average width of driveway with flare (ft)	–0.0086	0.00422	–2.03	.042
Standard deviation of driveway width with flare (ft)	0.01638	0.00518	3.16	.002
Proportion of divided driveway, commercial	–0.6893	0.29692	–2.32	.020
Shoulder width (ft)	–0.0588	0.01954	–3.01	.003
Signal density	0.30074	0.06639	4.53	.000
ln(α)				
TMT	0.10707	0.04503	2.38	.017
Proportion of divided driveway, commercial	–3.5114	1.43085	–2.45	.014
Signal density	0.577	0.2546	2.27	.023
Constant	–2.6737	0.63455	–4.21	.000

NOTE: AIC = 718.

ANALYSIS AND DISCUSSION

From the model results it is apparent that commercial driveway design components—not including the geometric features—are a very intriguing issue for truck-preferred arterial corridors. In the following sections an effort is made to enhance the understanding of the findings that influence the occurrence of a crash either positively or negatively.

Commercial Driveway Design

An important component of access management involves managing traffic movements into and out of commercial driveways since a large number of crashes on arterial streets involve commercial driveways. Commercial driveway width is important because it has a significant impact on the ease of entry into the driveway. A larger radius results in easier egress and ingress for passenger cars as well as commercial motor vehicles so that the driveway movement can be performed without abruptly slowing down or substantially encroaching into other roadway lanes and driveway lanes. The more quickly a vehicle can enter a driveway, the less likely there is to be a rear-end collision. According to the TRB *Access Management Manual* (*21*), simultaneous entry and exit by a single-unit truck must have a driveway throat width of 40 ft. It was estimated that 18% of corridors appear to have a higher number of crashes because they contain driveway throat widths with flare of less than 40 ft and 38% of corridors have a lower number of crashes because they contain driveway widths with flare greater than 40 ft. Varying widths (standard deviation of throat width and throat width with flare) lead to a situation in which the driver is not guided to the best position for driveway movements. In this case, pavement marking becomes vital to guide the driver toward entering the road.

Signalized Intersection Density

Although most discussions about access management focus on the management of private driveways, proper spacing of signalized

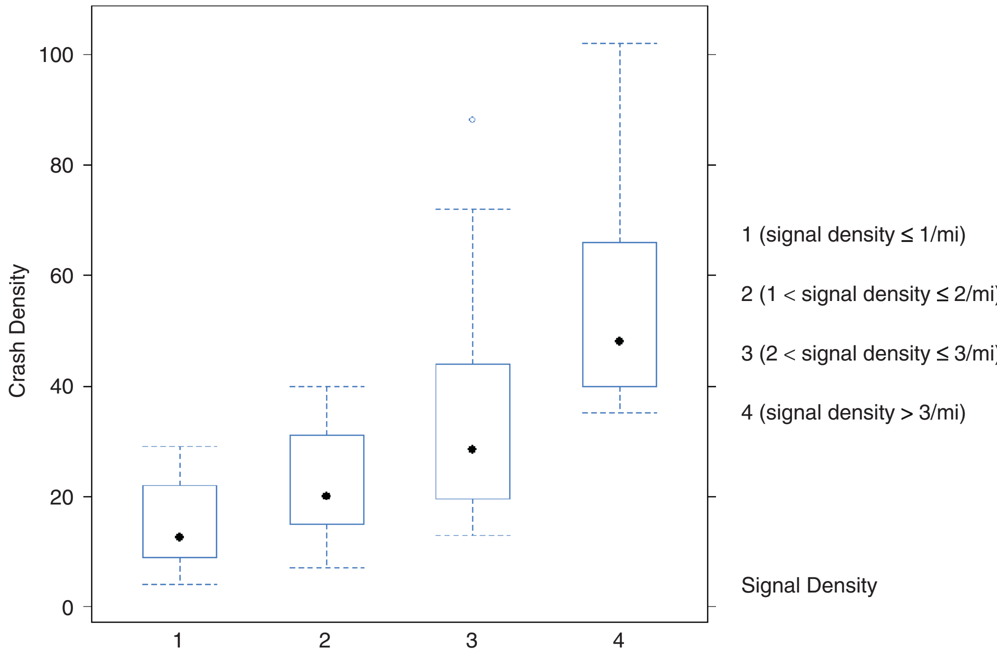

FIGURE 4 Crash density versus signal density.

intersections is an equally important issue. The importance of intersection spacing is similar to that of driveway spacing: as the number of intersections per mile increases, the opportunity for crashes increases. The existence of too many intersections per mile also increases delay and congestion. Stover (*29*) and Gluck et al. (*18*) reported that crash rates increase as the number of signalized intersections per segment increases. The average crash rate can be increased by up to 200% when the signal density along a given segment is increased from two to four signals per mile, depending on the number of unsignalized access points along the same segment (*21*). To test the findings of previous studies, a sensitivity analysis was performed to capture the impact of signalized intersection density. Figure 4 shows that crash density increases exponentially with the increase of signal density. Thus, for higher values of signal density, crash density will increase at a higher rate than for lower values of signal density.

Comparison Between Two Models

The addition of access-related variables led to different results from those for the previously selected corridors (*6*), as illustrated in Table 4. AADT and pavement serviceability index and its standard

TABLE 4 Comparison of Negative Binomial Estimates for Crash Frequency Prediction

	Estimate (*t*-value)		
Effect	Without Access Data	With Access Data	Final Model
Intercept	2.75 (11)	2.93 (7.6)	3.03 (9.74)
TMT	0.84 (10.2)	0.095 (9.36)	0.103 (10.78)
AADT	0.023 (2.54)	0.017 (1.74)	[b]
Shoulder width	−.042 (−2.24)	−0.035 (−1.67)	−0.043 (−1.99)
Pavement serviceability index (PSI)	−.212 (−3.53)	−.0363 (−0.44)	[b]
SD of (PSI)	0.26 (2.27)	0.174 (1.37)	[b]
Signal density	.186 (2.95)	0.273 (3.72)	0.332 (4.60)
SD of driveway throat width (ft)	[a]	0.045 (2.47)	0.047 (2.58)
Average width of driveway with flare	[a]	−0.011 (−2.48)	−0.011 (−2.70)
SD of driveway width with flare	[a]	0.015 (2.59)	0.014 (2.48)
Proportion of divided driveway, commercial	[a]	−0.626 (−2.14)	−0.575 (−2.03)
Dispersion	0.18 (6.67)	0.152 (5.68)	0.161 (5.72)
AIC	966	728	726

NOTE: Underlined variables are not significant in the model at 5% significance level.
[a]Results from a previous study (*6*).
[b]Final model includes only statistically significant variables.

deviation are no longer statistically significant for predicting truck crashes. One of the interesting findings of this study is that the presence of more relevant variables can nullify the effect of statistically significant variables that are less relevant. Under the guided data collection, the access variables represent a relationship between truck crashes and access design and management. This relationship not only displays the statistically significant correlation between truck-related crashes on arterials and access management but also corrects the spurious causality between crashes. An inappropriate choice can create statistical artifacts. The statistical artifact is a difficult issue to address because it can be caused by the choice of faulty variables or function misspecification. A well-designed data collection guided by the appropriate knowledge of highway safety can mitigate the negative impact of statistical artifacts.

The negative sign of the pavement serviceability index coefficient suggests that the probability of a crash occurrence becomes higher on distressed pavement. One could argue that poor pavement condition caused by rutting, potholes, failures, and cracking forces drivers to be more wary and travel more slowly, so that the result would be fewer crashes or less severe injuries. Smoother pavements may suggest faster driving conditions and consequently higher driving speeds, which increase the probability of frequency and severity of a crash. One can also argue that poor pavement condition causes drivers to swerve or stop in order to avoid damage to the vehicle, and therefore compromises safety. The dilemma exists because the variable can be confounded with other unobserved or unavailable factors such as driver behavior. The solution can be difficult without a good understanding of how the variables interact with one another. Unavailable data could be an additional difficulty. The alternative is to seek new variables without ambiguous influence on safety. In this study, the added commercial driveway design data give more insight and logical explanation to the truck crash without compromising the statistical goodness of fit.

CONCLUSION

The fundamental differences between freeways and arterials are access control and mobility. Arterial streets connect facilities and properties with freeways to ensure successful and timely deliveries. This process involves planning the location, spacing of driveways, median openings, interchanges, and street connections to an arterial street, in addition to appropriate spacing of traffic signals and efficient operation of a variety of traffic controls. Proper access management has been found to achieve significant improvements in roadway operations and safety; crash frequency has been reduced by as much as 60% (*30*). In a south Florida study, 90% of truck operators estimated that access management improvements improved safety (*31*).

The main objective of this study was to quantify the safety impact of access parameters on truck-preferred arterial corridors. In addition to existing traffic, geometric, and pavement variables, several access-related variables were collected manually to have more comprehensive and complete information about truck crash occurrence. Negative binomial regression analysis was used to establish the relationships between truck crashes and arterial street characteristics. Along with driveway design configuration, signalized intersection density and shoulder width ended up being statistically significant variables for prediction of truck crashes. On the basis of the analysis it has become obvious that improvements in the design of commercial driveways could help to improve the safety of truck-preferred arterial corridors. AADT and pavement serviceability index and its standard deviation were no longer statistically significant variables after introduction of the access-related variables (*6*).

One challenge facing the current crash model development is data heterogeneity due to the fact that crash data are usually obtained at different times across a wide range of geographical locations. In order to overcome the standard negative binomial model's fixed overdispersion parameterization, a GNB regression method was used for assessing the source of overdispersion. The same variables are statistically significant for truck crash prediction; although the magnitude changed, the signs are consistent and interpretations are also the same.

Finally, the variables that caused the overdispersion of the study data are the million miles traveled by truck, signal density, and proportion of divided commercial driveways. The AIC indicates that the GNB model yields a better goodness of fit than the negative binomial model. The addition of access-related variables appears to provide a reasonable explanation of the relationship of truck crashes, and it nullifies a few variables that were statistically correlated with the number of crashes in previous models. The change in statistical significance of these variables may suggest a statistical artifact that can be corrected by including more appropriate variables or by improving model specification.

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