Effect of Urban and Suburban Median Types on Both Vehicular and Pedestrian Safety

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Urban and suburban traffic engineers have the difficult task of providing safe roadway cross sections for all types of users. The major difficulty arises at most central business districts and at many suburban locations because of relatively high volumes of pedestrians attempting to cross roadways with minimum available traffic gaps. This is due to differences in operating characteristics between vehicles and pedestrians. Measures to increase vehicular capacity on arterials often result in potential hazards to pedestrians. It has long been recognized that medians are an effective method of increasing vehicular safety and capacity on urban and suburban arterials. Also medians are generally considered to be beneficial for pedestrian safety and operations, but their actual effects are unknown. The results of a study sponsored by FHWA on the impact of median types on the safety of vehicles and pedestrians are presented. The study included the analysis of 32,894 vehicular and 1,012 pedestrian accidents occurring in three cities on arterials with the following median types: (a) raised, (b) flush or two-way left-turn, and (c) no existing median (undivided).

Urban traffic engineers have the difficult task of providing safe and efficient traffic facilities for all roadway users. These traffic facilities must be provided at locations that often have both high vehicular and high pedestrian volumes. The difficulty arises because of the conflicting needs of motorists and pedestrians and their respective behavioral characteristics.

As an example consider the concerns that must be addressed during the selection of an optimal traffic signal timing plan. The duration of the green phase must provide sufficient time for pedestrians to cross and simultaneously to satisfy vehicular needs. In this instance the needs of pedestrians and vehicular traffic can be in conflict with each other. This often occurs at the intersection of a high-volume roadway with a relatively low-volume minor roadway. In addition the major street is often wide and the proportionate green time to the minor street is small. The pedestrians are, however, crossing the wide major roadway with the minor street green time. The selection of minimum green time on the basis of slower walking speeds in these instances can result in increased delay to the major arterial traffic.

Problems at signalized intersections are also complicated by geometric design and vehicle movement paths. Unless lead left signal phasing is used, the majority of vehicular left turn movements take place at the end of the through green phase. At this time slower-moving pedestrians may still be in the crosswalk, partially fatigued, and concerned with arriving at the far curb line. Conversely the left-turning motorist is primarily concerned with oncoming traffic and may not be aware of pedestrians in the crosswalk. The result is an increased potential for pedestrian and vehicular conflicts and subsequent accidents. Solutions to the problems include separating the paths of pedestrians and vehicles, narrowing the roadway cross section at intersections, and providing medians.

Medians are classifications of traffic control islands defined as areas between traffic lanes that separate opposing traffic flows. Medians can be designed to serve more than one purpose, including controlling or providing space for vehicular crossover or other turning movements, providing a landscape area, channelizing traffic, and providing pedestrian refuge. It has long been recognized that the use of medians is an effective method of increasing vehicular safety and capacity on urban and suburban arterials. Medians help to provide more efficient use of through traffic lanes by removing left-turning vehicles from the traffic stream. Also medians generally can be considered to be beneficial for pedestrian safety and operations, but their actual effects are unknown.

This paper presents the accident analysis results of a project sponsored by FHWA. The objective of the analysis was to determine the impact of median installation on the safety of both motorists and pedestrians. The study included medians constructed on urban and suburban arterials with unrestricted land use adjacent to the street.

DATA COLLECTION METHODOLOGY

A literature review and state-of-the-practice survey conducted as part of the project indicated that raised-curb medians and two-way left-turn (TWLT) median lanes are the predominant median types currently being installed. The efforts of the project were therefore concentrated on arterials with raised-curb medians, TWLT lane medians, and undivided (no existing median) arterials. The undivided arterials are included to provide the base or control data by which to measure the safety effects of sites with medians.

Fifteen arterial sites, each with a raised curb, TWLT median, and undivided cross sections, were randomly selected from the cities of Atlanta, Georgia; Phoenix, Arizona; and Los Angeles and Pasadena, California. Each selected arterial was inspected to verify a homogeneous roadway and median design and to establish, with the local officials, that significant changes had not occurred at the location over the accident analysis time period. These determinations resulted in final site selections and the requests for accident data.

Each selected arterial was videotaped over its entire length to obtain roadway and land use characteristics. The videotapes for each arterial were reviewed, and those variables identified from prior studies as being relevant and as potentially relevant for the

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present study were extracted. Each median type was divided into midblock segments, with a segment defined as a roadway link subtended by signalized intersections. If this process resulted in segments that were shorter than 0.16 km (0.1 mi) long, they were excluded from the midblock analysis. The variables were identified and extracted separately for midblock segments and signalized intersections. This method of extraction permitted the flexibility of analyzing midblock segments, signalized intersections, and the entire length of arterial (i.e., segments and signalized intersections) separately.

A total of 33,139 vehicle and 1,328 pedestrian accidents were initially identifed as being relevant to the study. A detailed printout of each pedestrian accident that occurred on the major road and within 46 m (150 ft) of the major road curb line was requested. Reports on all pedestrian accidents within 46 m (150 ft) of the major roadway were requested to help ensure that all relevant accidents were included. Without this type of request, accidents involving a pedestrian crossing the minor roadway (i.e., traveling along the arterial being analyzed) and being struck by a vehicle turning left from the major roadway may have been lost. The possible effects of medians on the behavior and visual search patterns of left-turning motorists would therefore have been neglected. Copies of the original pedestrian accident reports were obtained, and the verbal descriptions and accident diagrams were reviewed to determine whether the project criteria were satisfied. The scenario used in the extraction and coding of the accident data base is summarized below.

- Pedestrian accidents that occurred on the arterial, including vehicles from the minor road, and within 30 m (100 ft) of the arterial centerline and involving a major arterial vehicle were included in the analysis. The original request for reports of pedestrian accidents within 30 m (150 ft) was made to enable an inspection of the verbal accident description and the subsequent identification of erroneously located accidents.
- Vehicular accidents on the arterial segments [i.e., arterials subtended by signalized intersections 0.2 km (0.1 mi) or longer], and for signalized intersections considered separately, include only accidents that occurred on the arterial. Vehicular accidents on the minor roadway were not included.
- Traffic volume counts were obtained for each arterial. When available, these counts were summarized for each analysis year. In many instances annual counts were not available, necessitating the use of growth factors to increase or decrease the traffic volumes as appropriate.
- Pedestrian traffic accidents involve the presence of both a vehicle and a pedestrian in the same place at the same time. Estimates of vehicular presence are available to most agencies in the form of average daily traffic (ADT) counts. Pedestrian volumes are not available to most agencies, resulting in the need to develop surrogate measures of pedestrian activity. The intensity of pedestrian presence is inherently assumed to be represented by the area [i.e., central business district (CBD) or suburban area] and the type of land use.

DATA ANALYSIS

Physical Data

The data collection sheets completed during the field review of each site, the videotapes, and city maps were used to extract the physical data for each site. The data were organized into a data base that contained a city and segment identifier that permitted a merge with the accident data base.

The majority of arterial miles (84.7 percent) included in the study was found in suburban areas. This disparity is due to the relatively limited number of miles available in CBD areas compared with the large number of suburban miles within the CBD of each city. The limited size, development intensity, and city traffic engineering practices resulted in an inability to identify each median type of sufficient length for study purposes. Control over site selection was exercised to ensure that the combined arterial miles for each median type were sufficient for CBD and suburban data reliability. This was accomplished by increasing the analysis miles of deficient median types in some cities and by increasing the years of pedestrian accident analysis. The largest number of arterial miles were obtained from the Atlanta area. A total of 234.8 km (145.9 arterial mi) was analyzed for the project.

Land use was classified as residential, office, and business since land use type was suspected to influence the type and quantity of pedestrian activity. The original land use classifications included subcategories on land use type such as single-dwelling residential, high-rise residential, shopping center, and strip commercial. This subdivision of land use, however, resulted in large data stratifications that provided few useful data. Residential, therefore, indicates land use that varies from single dwellings to multistory apartment structures. Office refers to land use that does not entail large movements of customers during the business day and where employees are the primary trip makers. The commercial designation includes business activity that depends on customer visitation to the establishment. The predominant land use in the vicinity of the suburban arterials was residential, whereas only 0.5 km (0.3 mi) of CBD area was residential.

It should be noted that the land use varied drastically not only along the arterial length but also on each side of the roadway. To compensate for this variation the predominant land use was coded for each segment of the arterial (i.e., between signalized intersections). There were many instances, however, in which residential use would occupy one side of the arterial and another use such as commercial would occupy the opposite side. In these instances the land use was assigned on the basis of judgment related to the observed activity at the time of the field survey.

Minor variations in volumes were experienced at some sites because of annual volume counts and growth factors. The volumes for the majority of sites were within the range of 20,000 to 50,000 per day and remained relatively consistent during the analysis period. Since the project concentrated on CBD and subruban sites, the volumes of all the studied arterials were relatively high. Only a limited number of arterials had volumes of fewer than 15,000 vehicles per day.

Table 1 gives the number of arterial miles by traffic lane cross section for each median type. All of the raised-curb and TWLT median sites consisted of four to six through lanes. The flush center lane for TWLT arterials was not counted as a traffic lane. In the category of undivided arterials, 8.2 km (5.1 mi) of an odd number of lanes is included. These roadways consist of an unbalanced number of lanes to facilitate traffic movement during the peak hours (e.g., three lanes in one direction and two lanes in the other direction). The flush center lane is then used for reverse traffic flows during the other daily peak hour. These special cross sections are located in Phoenix.

TABLE 1 Summary of Arterial Miles by Number of Traffic Lanes

Thru Lanes	Miles of Arterials by Number of Through Lanes and Median Type										
	Raised			TWLT			Undivided				
	4	5[1]	6	4	5[1]	6	2	3[1]	4	5[1]	6
CBD	0.3	--	29.7	5.7	1.2	0.9	--	0.6	6.1	--	1.7
Suburban	13.0	3.1	5.8	26.9	11.6	8.8	2.9	--	22.1	4.5	1.0

1 mi = 1.6 km
[1]Unbalanced number of lanes to facilitate peak hour traffic flow

Accident Data

The accident data provided for each median arterial were coded into a uniform format and merged with the physical features data base. Separate data bases were maintained for vehicular and pedestrian accidents. Vehicular accidents included only those accidents that were coded as occurring on the arterial. The pedestrian data base included accidents coded as occurring on the arterial and on the minor roadway, within 30 m (100 ft) of the median arterial centerline, that involved an arterial vehicle.

Summary rates for the arterials were determined by summing the accident frequency and dividing that number by the sum of the annual volume (ADT_i) and median length (L_i) product for each median segment. The equation can be written as

$$\left(\sum_{i=1}^{n} \text{Annual accident frequency for segment } i\right) \Big/ \left(365 \sum_{i=1}^{n} ADT_i L_i\right)$$

where n = number of segments. This provides a weighted average estimate that is better than the estimate obtained by averaging the rates of each individual section for comparing rates for arterials. The rates were then multiplied by 100 million vehicles to obtain a sufficient number of significant figures for analysis of pedestrian accidents.

The accident data were tested to determine whether there were significant differences between the accident rates of selected data sets. Statistical tests were performed by using each categorized site and its respective accident rate in the data base. Because the data had been converted to rates and a large number of observations existed for each data set, the data were considered as being normally distributed between analysis groups. Student's t-test was used to determine whether a statistical difference existed between two data sets. The procedure was applied by using the SAS computer statistical analysis package (*1*). The first step in the application of the t-test was to develop an F-statistic to test for equality of the variances. This was necessary because the SAS procedure computes two t-statistics. One is based on the assumption that the variances of the two sets are equal, and the other is based on unequal variances.

Comparisons between more than two groups at a time were performed by simultaneously comparing the variability of group means about the overall mean (between estimate) relative to the variability of each observation to its respective group mean (within estimate). This procedure, known as analysis of variance, (ANOVA), established when sufficiently large differences existed between the groups to determine that a significant difference existed. The Scheffé multiple comparison test was then used to establish simultaneous confidence intervals between all possible combinations of group pairs. The means of the paired groups were considered unequal, and therefore significantly different, when the confidence interval did not contain zero. All statistical tests were conducted as two-tailed 95 percent confidence interval tests.

An initial premise of the study was that pedestrian activity and intensity in CBD areas were different from those in suburban areas. If this premise were true then different models for each area, or the inclusion of area as an independent variable, would provide enhanced accident prediction capabilities. Table 2 contains the result of the t-test performed to determine whether there is a significant difference in the accident rate between CBD and suburban areas for the different median types. Pedestrian accidents occurred

TABLE 2 Significant Difference and Mean Accident Rates Between CBD and Suburban Areas

Ho: CBD accident rate = suburban accident rate. Significance level (of t - test) = 0.05.									
Accident Category	Raised			TWLT			Undivided		
	α	Mean Rate[1]		α	Mean Rate[1]		α	Mean Rate[1]	
		CBD	Sub		CBD	Sub		CBD	Sub
vehicle	0.2463	471.64	384.02	0.0320*	475.17	611.27	0.0798	835.85	627.68
pedestrian	0.0304*	26.30	9.23	0.0027*	31.55	13.11	0.000*	95.42	28.28

*Denotes significant difference.
[1]Summary - accident rates expressed in accidents per 10^8 vehicle miles
1 mi = 1.6 km

TABLE 3 Accident Frequency and Associated Rate for Arterials

Area	Accident Category	Raised	TWLT	Undivided
CBD	Veh	1663	2019	2509
	Rate[1]	623.06	513.79	905.21
	Ped	51	162	242
	Rate[1]	19.11	41.11	87.31
SUB	Veh	7535	14828	4340
	Rate[1]	373.00	676.29	409.22
	Ped	128	282	147
	Rate[1]	6.31	12.89	13.91

[1]Arterial accident rates in 10^8 vehicle miles
1 mi = 1.6 km

at a significantly higher rate in CBD areas for all of the median types. Vehicular accidents did not exhibit as large an influence by area as did pedestrian accidents. The impact of raised medians on vehicular accidents is significantly different between CBD and suburban areas, with the average rate of vehicular accidents being higher in CBD areas.

The frequency of vehicular and pedestrian accidents occurring on the arterials and the associated summary rates are provided in Table 3. In the CBD the accident rate for undivided arterials is higher for both vehicles and pedestrians than that for arterials with raised and TWLT medians in the same type of area. Although this is not unexpected, it is also interesting to note that the vehicular accident rates in CBD areas are higher on arterials with raised-curb medians than on those with TWLT medians. In both CBD and suburban areas arterials with raised-curb medians displayed a lower pedestrian accident rate than the arterials with either a TWLT lane or no median.

The accident rates for the different median types within CBD or suburban areas were analyzed to determine whether the differences in the accident rates shown in Table 3 were sufficiently large to be significant. Statistical significance was determined by performing ANOVA on the accident rate of each categorized site for the arterials. The results of the statistical test, presented in Table 4, indicate that there were significant differences in the accident rates between arterials with raised and TWLT median types and undivided cross-sections in both the CBD and suburban areas.

TABLE 4 Statistical Difference Between Accident Rates[1] on Arterials with Raised-Curb and TWLT Medians and Undivided Cross Sections for CBD and Suburban Areas

Ho: accident rate of raised = accident rate of TWLT = accident rate of undivided
Significance level (critical α) = 0.05

	Source[2]	DF	Mean Square	F	Prob. > F	Significant
CBD						
vehicle	Between	2	1928888			
	Within	115	293918	6.56	0.0020	yes
pedestrian	Between	2	63141			
	Within	115	4508	14.01	0.0001	yes
SUBURBAN						
vehicle	Between	2	2162291			
	Within	323	204462	10.58	0.0001	yes
pedestrian	Between	2	9990			
	Within	323	2062	4.85	0.0084	yes

[1]Accident rates expressed in accidents per 10^8 vehicle miles
[2]Between is the variability of vehicle and pedestrian group means to overall mean.
Within is the variability of vehicle and pedestrian observations to their group mean.
1 mi = 1.6 km

When differences existed they were determined to be significant or not by performing the Scheffé multiple comparison test, the results of which are presented in Table 5. For vehicular accidents there was a significant difference between those on arterials with a TWLT median and those on arterials with an undivided cross section in CBD areas, and in suburban areas, there was a significant difference between accidents on arterials with a raised median, a TWLT and raised median, and an undivided cross section.

Therefore in CBD areas arterials with undivided cross sections have significantly higher vehicular accident rates than do those with TWLT medians. In suburban areas arterials with raised medians have a significantly lower vehicular accident rate than do those with TWLT medians and undivided cross sections. In addition there are significantly fewer pedestrian accidents on arterials with raised medians than on those with undivided arterials in suburban areas, and there are fewer pedestrian accidents in CBD areas for arterials with both TWLT medians and undivided cross sections.

Because of the different operational characteristics and the effects of the median on safety, the data in Table 3 were divided into midblock segment and signalized intersection accidents and are presented in Table 6. The median arterial accidents shown in Table 3 are less than the total number of accidents described in Table 6 because of data verification and editing. In a limited number of cases the median type changed for a short length of roadway between signalized arterials or sufficient data could not be reliably extracted from the videotapes because vehicles blocked the visual field or because land uses were too few for statistical reliability (e.g., industrial). In these instances the median segments were dropped from the analysis, but the intersection data were retained for use in the analysis of isolated intersections. The arterial accident data in Table 3 include the midblock and signalized intersection accidents that are appropriate for analyzing arterial lengths with specific median types. The data on midblock segment accidents in Table 6 include data for all accidents that did not occur within 30 m (100 ft) of the crossroad intersection centerline. The rates for midblock segments are based on the ADT of the arterial. The rates for the signalized intersections are based on the total number of entering vehicles.

The CBD vehicular accident rates, presented in Table 6, for arterials with raised medians, both midblock and signalized intersection locations, were higher than those for arterials with TWLT medians and undivided cross sections. This difference is very pronounced at CBD signalized intersections with raised-curb medians. The rate is more than 3 times greater than that for arterials with undivided cross-sections and almost 13 times greater than that for arterials with a TWLT median design. This disparity can be explained by considering that curbed medians concentrate left-turn maneuvers at median cross-over points and major intersections. Therefore on short median segments, as would occur within CBD areas, vehicle turning movements would be concentrated at the signalized intersections. The pedestrian accident rate for CBD areas is lower at midblock locations with raised medians than at TWLT medians or undivided cross sections.

TABLE 5 Scheffé Multiple Comparison Tests Between Median Types for Vehicular and Pedestrian Accident Rates on Arterials

VEHICLE ACCIDENTS			
	95% Simultaneous Confidence Interval		Significant[1]
CBD			
raised, TWLT	-388.7	381.6	no
raised, undivided	-735.0	6.6	no
TWLT, undivided	-631.2	-901.0	yes
SUBURBAN			
raised, TWLT	-371.8	-82.7	yes
raised, undivided	-397.5	-89.9	yes
TWLT, undivided	-176.6	143.8	no
PEDESTRIAN ACCIDENTS			
CBD			
raised, TWLT	-52.9	42.5	no
raised, undivided	-115.0	-23.2	yes
TWLT, undivided	-97.4	-30.4	yes
SUBURBAN			
raised, TWLT	-18.4	10.6	no
raised, undivided	-34.5	-3.6	yes
TWLT, undivided	-31.3	0.9	no

[1]Pairs are significantly different if confidence interval does not contain zero.

TABLE 6 Accident Frequency and Associated Rate for Midblock Median Segments and Signalized Intersections

Area	Location	Accident Category	Raised	TWLT	Undivided	Freq Totals
CBD	midblock	vehicle				
		freq	558	626	564	1748
		rate[1]	209.06	159.34	203.48	--
		pedestrian				
		freq	26	46	60	132
		rate[1]	9.74	11.71	21.65	--
	signalized inter	vehicle				
		freq[1]	1105	137	34.7	4659
		rate[2]	144.96	11.23	45.91	--
		pedestrian				
		freq	25	16	299	340
		rate[2]	3.28	1.31	4.02	--
Suburban	midblock	vehicle				
		freq	3823	6827	2241	12891
		rate[1]	189.23	311.37	211.31	--
		pedestrian				
		freq[1]	78	146	71	295
		rate	3.86	6.66	6.69	--
	signalized inter	vehicle				
		freq	4229	7507	2105	13841
		rate[2]	87.43	136.36	68.79	--
		pedestrian				
		freq[2]	47	137	71	255
		rate	0.97	2.49	2.32	--
Frequency			9,715	15,097	8,327	33,139
TOTAL vehicles, pedestrians			176	345	501	1,022

[1]Midblock accident rate per 10^8 vehicle miles
[2]Intersection accident rate per 10^8 entering vehicles
1 mi = 1.6 km

Table 7 gives the predominant vehicular accident types for CBD and suburban areas that occur on arterials with raised or TWLT medians and undivided roadways. The vehicular accident rates exhibited were unexpected, and at first they were believed to be erroneous. This resulted in a reverification of the data base. For example the rear-end accident rate on arterials with raised medians in CBD areas is higher than that on arterials with TWLT medians and undivided cross sections. The reason for this is not known with certainty, since the total miles of arterials with raised TWLT medians and undivided cross sections included in the analysis with the CBD areas were approximately equal. One possible explanation is that left turns are often prohibited from undivided roadways at midblock locations within the CBD, thereby reducing the potential for rear-end accidents. In the majority of cases the accident rates in CBD areas are less than those in suburban areas.

The determination of statistical significance of vehicular accident types between midblock median types for both CBD and suburban areas is presented in Table 8. A significant difference in rear-end, right-angle, and left-turn vehicular accident rates between the different median types was exhibited in suburban areas. This significant difference was also exhibited with right-angle accident types in CBD areas. The median types that exhibited the difference, as determined by the Scheffé multiple comparison test, are given in Table 9. Raised medians have a significantly lower midblock accident rate when comparing arterials with raised medians with those with TWLT medians for rear-end, right-angle,

TABLE 7 Summary of Predominant Midblock Vehicle-to-Vehicle Accident Types

Accident Type	Raised		TWLT		Undivided		Freq TOTAL
	CBD	Suburb	CBD	Suburb	CBD	Sub	
Rear End							
freq	269	1636	172	3061	179	1007	6324
rate[1]	100.78	80.98	43.78	139.61	64.58	94.95	--
Right Angle							
freq	70	708	73	1387	94	405	2737
rate[1]	26.23	35.05	18.58	63.26	33.91	38.19	--
Head-On							
freq	2	27	14	56	9	22	130
rate[1]	0.75	1.34	3.56	2.55	3.25	2.07	--
Left Turn							
freq	57	492	86	1151	53	232	2071
rate[1]	21.36	24.35	21.89	52.50	19.12	21.88	--
Other							
freq	160	960	281	1172	229	575	3377
rate[1]	59.95	47.52	71.53	53.45	82.62	54.22	--
FREQ TOTAL	558	3823	626	6827	564	2241	14639

[1]Accident rates expressed as accidents per 10^8 vehicle miles
1 mi = 1.6 km

and left-turn accident types and also when comparing arterials with raised medians with those with undivided medians for right-angle accident types in suburban areas. Arterials with TWLT medians have significantly higher rear-end and left-turn accident rates than undivided arterials at suburban midblock segments. There were 29 CBD and suburban head-on type accidents at midblock segments with raised medians. These accidents were analyzed to determine what driver actions contributed to the accidents and the associated severity. Ten of the 29 head-on accidents (34.5 percent) were the result of motorists traveling the wrong way and 3 (10.3 percent) occurred in the median crossover resulting from a left-turning maneuver. The majority of the raised medians where head-on accidents occurred (82.8 percent) had a width of 2.4 m (8 ft) or more. The severity rates for head-on accidents are summarized in Table 10 and indicate that midblock, head-on types of accidents at raised medians are less severe than those on arterials with TWLT medians.

A summary of accident severity by median type for midblock segments is presented in Table 11. A greater percentage of accidents occurred at raised medians but were of lower severity [property damage only (PDO)] than at TWLT medians and undivided cross-sections. The severity of accidents on arterials with TWLT medians is greater in CBD areas but is less in suburban areas in comparison with the severity of accidents on undivided arterials. Tests on the accident severity rates presented in Table 12 indicate the statistical difference between the median types for both CBD and suburban areas for accidents involving property damage only and personal injury. The lack of significant differences in the fatality rates is due to relatively small sample sizes. The multiple comparison tests summarized in Table 13 indicate that arterials with raised medians in both CBD and suburban areas have significantly lower personal injury rates than arterials with TWLT medians.

Findings and Conclusions

- It was initially assumed that pedestrian activity, and hence pedestrian accident rate, is higher in CBD areas than in suburban areas. This assumption was necessary since actual pedestrian volumes for roadway segments were not available. The assumption was tested by developing pedestrian accident rates on the basis of pedestrian accident frequency, vehicular volumes, and roadway length. Pedestrian accidents occurred at a significantly higher rate in CBD areas than in suburban areas for all three median types. CBD and suburban areas can, therefore, be used as surrogate measures of pedestrian activity. In addition the development of models to predict pedestrian accidents should be performed separately for CBD and suburban areas.
- Vehicular accidents do not exhibit as large an influence by area as do pedestrian accidents. This supports the assumption that CBD areas have more pedestrian activity than suburban areas.
- Arterials with TWLT medians located in CBD areas had lower vehicular accident rates than those with raised-curb medians and undivided cross sections. Undivided arterials had the highest vehicular accident rates in CBD areas. Comparisons between the

TABLE 8 Statistical Difference in Midblock Vehicular Accident Types Between Median Types for CBD and Suburban Areas[1]

Ho: accident type rate of raised = accident type rate of TWLT = accident type rate of undivided
Significance level (critical ∝) = 0.05

	Source	DF	Mean Square	F	Prob. > F	Significant
REAR END						
CBD	Between	2	12218	1.00	0.3681	no
	Within	578	12205			
SUBURBAN	Between	2	503609	28.39	0.0001	yes
	Within	1222	17739			
RIGHT ANGLE						
CBD	Between	2	13544	3.33	0.0365	yes
	Within	578	4067			
SUBURBAN	Between	2	104307	12.20	0.0001	yes
	Within	1222	8548			
HEAD ON						
CBD	Between	2	195	1.57	0.2084	no
	Within	578	124			
SUBURBAN	Between	2	46	0.42	0.6548	no
	Within	1222	109			
LEFT TURN						
CBD	Between	2	759	0.20	0.8168	no
	Within	578	3753			
SUBURBAN	Between	2	144226	33.24	0.0001	yes
	Within	1222	4339			

[1]Accident rates expressed as accidents per 10^8 vehicle miles
1 mi = 1.6 km
[2]Between is the variability of CBD and suburban group means to overall mean
Within is the variability of CBD and suburban observations to their group mean

three types of cross sections revealed that arterials with TWLT medians had significantly lower vehicular accident rates than undivided arterials. No significant differences were identified between comparisons of vehicular accident rates between arterials with raised-curb and TWLT medians or raised-curb medians and undivided cross sections.

- Pedestrian accident rate for CBD locations and undivided arterials was significantly higher than those for arterials with raised-curb and TWLT medians. The pedestrian accident rate for arterials with raised-curb medians was lower than those for arterials with TWLT medians and undivided cross sections in CBD locations.
- In suburban areas arterials with raised-curb medians had significantly lower vehicular accident rates than arterials with TWLT medians and undivided cross sections.
- Arterials with raised-curb medians in suburban areas had the lowest pedestrian accident rate. Arterials with raised-curb medians had a significantly lower pedestrian accident rate than arterials with undivided cross sections. There was not a significant difference between the pedestrian accident rates on arterials with raised-curb and TWLT medians.
- In suburban areas arterials with raised-curb medians had significantly lower vehicular accident rates than arterials with TWLT medians for rear-end, right-angle, and left-turn accident types. Arterials with raised-curb medians also had significantly lower accident rates than arterials with undivided cross sections for right-angle-type vehicle accidents.
- In both CBD and suburban locations arterials with raised-curb medians had lower vehicular accident rates with personal injuries than arterials with TWLT medians and undivided cross sections. The vehicular accident rates with personal injuries on arterials with raised-curb medians were significantly lower than those on arterials with TWLT medians in suburban areas. Undivided arterials had lower vehicle personal injury rates than arterials with TWLT medians in suburban areas.
- Study results indicate that, when possible, arterials with undivided cross sections should not be used in CBD areas. In CBD areas undivided arterials result in the highest accident rates for both pedestrians and vehicles.
- With one exception there is no significant difference in either pedestrian or vehicular accident rates between arterials with

TABLE 9 Scheffé Multiple Comparison Tests of Midblock Vehicular Accident Type Between Median Types in CBD and Suburban Areas

		95% Simultaneous Confidence	Interval	Significant[1]
REAR END				
SUBURBAN	raised,TWLT	-81.6	-38.1	yes
	raised, undivided	-24.2	23.3	no
	TWLT, undivided	35.4	83.2	yes
RIGHT ANGLE				
CBD	raised, TWLT	-16.54	21.83	no
	raised, undivided	-30.00	6.43	no
	TWLT, undivided	-28.92	0.06	no
SUBURBAN	raised, TWLT	-44.3	-14.2	yes
	raised, undivided	-39.0	-6.1	yes
	TWLT, undivided	-9.9	23.3	no
LEFT TURN				
SUBURBAN	raised, TWLT	-41.8	-20.3	yes
	raised, undivided	-9.8	13.7	no
	TWLT, undivided	21.2	44.8	yes

[1]Pairs are significantly different if confidence interval does not contain zero.

TABLE 10 Summary of Head-on Vehicular Accident Rates for Midblock Segments by Median Type and Area

	Raised		TWLT		Undivided	
Severity	CBD	Suburban	CBD	Suburban	CBD	Suburban
PDO						
frequency	2	12	4	26	0	5
rate[1]	0.75	0.59	1.02	1.19	0	0.47
Injury						
frequency	0	15	10	28	9	16
rate[1]	0	0.74	2.55	1.28	3.25	1.51
Fatal						
frequency	0	0	0	2	0	1
rate[1]	0	0	0	0.09	0	0.09

[1]Midblock segment rates in accidents per 10^8 vehicle miles.
1 mi = 1.6 km

TABLE 11 Summary of Midblock Vehicular Accident Severity by Median Type[1]

Severity	Raised		TWLT		Undivided	
	CBD	Suburban	CBD	Suburban	CBD	Suburban
PDO						
frequency	401	2649	266	4855	3.42	1451
rate	150.24	131.12	67.71	221.43	123.39	136.82
percent	71.9	69.3	42.5	71.1	60.6	64.8
Injury						
frequency	156	1169	360	1962	222	783
rate	58.45	57.86	91.63	89.48	80.09	78.83
percent	28.0	30.6	57.5	28.7	39.4	34.9
Fatal						
frequency	1	5	0	10	0	7
rate	0.37	0.25	0	0.46	0	0.66
percent	0.1	0.1		0.2	0	0.3

[1]Midblock segment accident rate in accidents per 10^8 vehicle miles.

TABLE 12 Statistical Difference in Midblock Vehicular Accident Severity Rates Between Median Types for CBD and Suburban Areas[1]

Ho: accident severity of raised = accident severity of TWLT = accident severity rate of undivided
Significance level = 0.05

	Source	DF	Mean Square	F	Prob. > F	Significant[2]
PROPERTY DAMAGE ONLY						
CBD	Between	2	125344	4.08	0.0174	yes
	Within	578	30743			
SUBURBAN	Between	2	1146617	24.79	0.0001	yes
	Within	1222	46260			
PERSONAL INJURY						
CBD	Between	2	73224	4.47	0.0119	yes
	Within	578	16399			
SUBURBAN	Between	2	85213	9.66	0.0001	yes
	Within	1222	8817			
FATAL						
CBD	Between	2	2.04	2.42	0.0901	no
	Within	578	0.84			
SUBURBAN	Between	2	1.51	0.11	0.8968	no
	Within	1222	13.83			

[1]Accident rates in accidents per 10^8 vehicle miles
[2]Between is the variability of CBD and suburban group means to overall mean
Within is the variability of CBD and suburban observations to their group mean
1 mi = 1.6 km

TABLE 13 Scheffé Multiple Comparison Tests of Accident Severity Between Median Types for Midblock Locations

VEHICLE ACCIDENTS				
		95% Simultaneous Confidence	Interval	Significant[1]
PROPERTY DAMAGE ONLY				
CBD	raised, TWLT	-16.5	88.9	no
	raised, undivided	-59.5	40.6	no
	TWLT, undivided	-85.5	-5.8	yes
SUBURBAN	raised, TWLT	-134.6	-64.4	yes
	raised, undivided	-71.8	4.9	no
	TWLT, undivided	27.5	104.7	yes
PERSONAL INJURY				
CBD	raised, TWLT	-85.3	-8.3	yes
	raised, undivided	-65.8	7.3	no
	TWLT, undivided	-11.5	46.7	no
SUBURBAN	raised, TWLT	-39.7	-9.1	yes
	raised, undivided	-41.1	-7.7	yes
	TWLT, undivided	-16.9	16.8	no

[1]Pairs are significantly different if confidence interval does not contain zero.

raised-curb and TWLT medians. The one exception was vehicular accident rates in suburban areas, where accident rates on arterials with raised-curb medians were significantly less than those on arterials with TWLT medians.

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REFERENCE

1. *SAS*. SAS Institute Inc., Cary, N.C., 1988.

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