An Analysis of Factors Contributing to "Walking Along Roadway" Crashes: Research Study and Guidelines for Sidewalks and Walkways

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Pedestrian & Bicycle Safety

FOREWORD

The Federal Highway Administration's (FHWA) Pedestrian and Bicycle Safety Research Program's overall goal is to increase pedestrian and bicycle safety and mobility. From better crosswalks, sidewalks, and pedestrian technologies to expanding public educational and safety programs, the FHWA's Pedestrian and Bicycle Safety Research Program strives to pave the way for a more walkable future.

The following document summarizes the results of a study that examined the safety impacts of having sidewalks and walkways along roadways. The document also provides guidelines and recommendations for providing such facilities. The sidewalk study was part of a large FHWA study "Evaluation of Pedestrian Facilities" that has produced a number of other documents regarding the safety of pedestrian crossings and the effectiveness of innovative engineering treatments on pedestrian safety. It is hoped that readers also will read the reports documenting the results of the related pedestrian safety studies.

The results of this research will be useful to transportation engineers, planners, and safety professionals who are involved in improving pedestrian safety and mobility.

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Research and Development

NOTICE

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16. Abstract

There are a variety of factors widely acknowledged to have an impact on the risk of pedestrian/motor vehicle crashes. The factors that have been most extensively researched are the geometric characteristics of the road, including the presence of sidewalks. However, in relevant epidemiological research, factors related to demographics and neighborhood characteristics have been alluded to, but not sufficiently researched. This study uses a case-control methodology and applies conditional and binary logistic models to determine the effects of cross-sectional roadway design attributes and socioeconomic and other census block group data on the likelihood that a site is a crash site. A total of 47 crash sites and 94 comparison sites are analyzed. Physical design factors found to be associated with a significantly higher likelihood of being a crash site are higher traffic volume, higher speed limit, the lack of wide grassy walkable areas, and the absence of sidewalks. When these roadway factors are controlled for, non-geometric factors associated with a significantly higher likelihood of being a crash site are high levels of unemployment, older housing stock, lower proportions of families within households, and more single-parent households. This information suggests that some neighborhoods, due to increased exposure or specific types of exposure, may be especially appropriate sites for pedestrian safety measures such as sidewalks, lower speed roadway designs, and the addition of wide grassy shoulders.

This report also documents the results of a behavioral evaluation of a new sidewalk in SeaTac, Washington (Appendix A). Recommended guidelines and priorities for sidewalks and walkways are given in Appendix B.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

NOTE: Volumes greater than 1000 l shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

(Revised September 1993)

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INTRODUCTION

The goal of a transportation system is to provide safe and efficient mobility and access to different modes of travel to a wide variety of travelers with diverse needs. Walking is the most basic form of transportation, and it is important for transportation officials to provide facilities that enhance safe movement for pedestrians along roads and streets. An individual's transportation needs, and his or her ability to meet them, are likely to vary not only according to the physical roadway environment, but also according to their socioeconomic situations and the proximity of potential attractors. Neighborhoods have their own specific patterns of transportation and travelers within those neighborhoods may be subject to different risks than encountered in other areas.

The purpose of this paper is to identify the types of risks to pedestrians who are walking along a roadway and the reasons for those risks. Factors examined in this study include both roadway factors and neighborhood factors. The sampling methodology matches crash sites where pedestrians were struck walking along a roadway to comparison sites of similar zoning, parcel size, and level of development, much like the matching done in a case-control study. Such roadway factors as vehicle volume, pedestrian volume, presence of sidewalk, shoulder width, and type of roadside are included in the analysis. Census data from the U.S. Census block group in which each site was located was attributed to that crash site in order to analyze the impact of socioeconomic and other neighborhood factors (e.g., unemployment level, age of housing, and number of parents in the household).

LITERATURE REVIEW

Hunter et al. found "walking along roadway" crashes to comprise 7.9 percent (400 of 5,073) of all pedestrian/motor vehicle crashes of a sample from six States (1). Of the 400 crashes, they found that 69 percent involved pedestrians walking with traffic and 21 percent involved pedestrians walking against traffic. Overrepresented variables of these 400 "walking along roadway" crashes included:

- Pedestrians 15 to 44 years of age.
- Alcohol involvement by the pedestrian and/or driver.
- Rural, two-lane roads.
- Dark conditions with no lights.
- Interstate and county roads.

A number of studies have applied case-control methods to questions of pedestrian safety. For example, Carlin et al. used a case-control method to examine the effects of the behavior and attributes of children in determining their propensity to be involved in bicycle crashes (2). One of the findings of this study was a disproportionate number of injuries among children in the lowest income category.

A limited number of studies have investigated roadway factors associated with "walking along roadway" pedestrian/motor vehicle crashes. In a 1996 study by Knoblauch et al. involving an analysis of pedestrian/motor vehicle crashes and exposure under various roadway situations, locations with no sidewalks were more than twice as likely to have pedestrian/motor vehicle crashes than sites where sidewalks existed. The presence of a sidewalk was found to have a particularly large safety benefit in residential and mixed residential areas. However, sidewalks had no effect on pedestrian/motor vehicle crash experiences in commercial areas (3).

A wide variety of studies have acknowledged the increased risk of pedestrian injuries in some socioeconomic groups, with a focus on children and youth. These studies have generally shown that children of minorities and low-income families tend to be disproportionately represented in groups especially prone to pedestrian/motor vehicle crashes and injuries. For example, Roberts recognized a connection between economic and ethnic differences, concentrating on the increased "exposure to risk" of children of single parents, often in lower income brackets, with regard to supervision of playing near roads and walking to school (4-5). King found that neighborhoods with high pedestrian injuries in the West Midlands (U.K.) had high proportions of immigrant heads of households (6). Epperson noted that the economic status of neighborhood residents plays an important role in the prediction of areas with high bicycle crash rates (7). He theorized that this was due to increased dependence on bicycles as a mode of transportation. It may be concluded from these studies that the overrepresentation of crash risk among some lower income people and minorities is probably the result of different travel patterns, proximity to dangerous streets, less supervision of children at play near streets, and/or the lower likelihood of large fenced-in yards, compared to higher income neighborhoods, etc.

Some of these researchers have used methods similar to those in this paper. Christie used logistic regression to determine the socioeconomic and environmental factors that increased the likelihood of individual children to have been involved in a crash (8). Bagley, on the other hand, analyzed the likelihood of neighborhoods to be sites of crashes given socioeconomic and crime data (9). He found "general" crime, the percentage of subsidized housing, population density, percentage unemployed, and low birth weights to be correlated with pedestrian crashes, and the percentage of park space to be negatively correlated with crashes (i.e., more park space correlates with a lower risk of pedestrian crashes) (10). Finally, Braddock used geographic information systems (GIS) to map out the pedestrian/motor vehicle crashes involving youth and found a non-uniform distribution, but he did not appear to have looked at the socioeconomic characteristics of these neighborhoods (11).

OBJECTIVE AND SCOPE

The first objective of this paper was to identify roadway design factors and neighborhood socioeconomic factors that distinguish "walking along roadway" crash sites from other matched sites in the same neighborhood and also in faraway neighborhoods. The second objective was to suggest measures that are likely to reduce the occurrence of such crashes.

Wake County, North Carolina, was selected as the study area because it contains a mix of urban, suburban, and rural conditions, and 4 years of crash data were easily available for research purposes. Sites could be visited and geometric data obtained for the crash and faraway comparison sites. Finally, the number of sites—141, including the crash site and both nearby and faraway comparison sites—was adequate to conduct multivariate analysis with minimal difficulties.

The 47 "walking along roadway" crashes in this 4-year sample (1993-1996) constituted 6.61 percent of the 711 pedestrian/motor vehicle crashes in Wake County during the same period. Based upon the crash reports, it was found that roughly 77 percent of the crashes involved pedestrians walking with traffic and 23 percent involved pedestrians walking against traffic. A small proportion of the pedestrians walking with traffic were hit by oncoming traffic and a small proportion of the pedestrians walking against traffic were hit from behind. These trends compare closely with the 1996 study by Hunter et al. (1), as discussed earlier.

METHODOLOGY

This paper uses the case-control method often used in epidemiology. The study analyzes variation between sites, not individuals. For this reason, the case sites were matched with nearby (same neighborhood) and faraway (other side of town) comparison sites. The comparison sites were chosen on the basis of current land use. A tax assessors' map from the Wake County Planning Department was used to match crash sites to nearby and more distant comparison sites.

Crash sites were pinpointed on the color-coded zoning map. Then, for each case site, comparison areas of the county, with the same type of zoning, covering about the same amount of area, with the same sized parcels as the crash site—but with no crashes—were identified. From this suitable comparative area of the county, a segment of roadway with the same functional class and number of lanes as the crash segment was chosen without regard to vehicle volume, sidewalk presence, or any other variables for which data were collected. The entire process was done prior to visiting the sites. Comparison site selection was done in this manner to avoid bias in the selection.

The issue of exposure was addressed in the analysis by including vehicle and pedestrian counts as independent variables in the models. Hence, the analysis controls for exposure without matching sites by traffic counts. Vehicle volumes listed in this paper refer to the number of vehicles counted in the outside lanes at the sites (i.e., the lanes closest to pedestrians walking along the roadway) over the course of 1 hour. These volume measurements, like the other site measurements, were taken at approximately the same time of day as the crash occurred. However, no counts were taken after midnight or before 6:00 a.m.

Because of the low frequency of "walking along roadway" crashes, it would take many years of observing a very large number of links before enough crashes could be observed for use in some types of experimental designs (e.g., before/after with a cohort analysis). For this reason, this study begins with known crash sites, then identifies matched nearby and faraway comparison sites. While a segment was defined as an unintersected stretch of roadway, specific measurements of segment lengths were not taken. However, because crash and comparison segments were in areas with similar levels of development and on the same functional class of roadway, they were of comparable length in all cases. These sampling strategies are appropriate, given the conceptual framework of the study and the policy questions being addressed.

This sampling method yields a set of three sites for each of the 47 crash sites (all of the "walking along roadway" crashes in Wake County from 1993 through 1996), consisting of (1) the crash site, (2) a nearby comparison site, and (3) a distant comparison site. Hence, a total of 141 sites were observed. Each crash site was the location of a single pedestrian/motor vehicle crash during the period studied (although two crashes involved two pedestrians each). Data collectors visited these matched sites generally during the same hour that the crash occurred. For example, if a crash occurred at 6:30 a.m., data collectors visited the crash and faraway comparison sites from 6:00 a.m. to 7:00 a.m. on a given morning, collecting pedestrian and vehicular volumes and making detailed measurements of cross-sectional design attributes.

Two different types of modeling analyses were conducted to quantify roadway and neighborhood effects on “walking along roadway” pedestrian/motor vehicle crashes. The first of these was a matched case-control analysis carried out using SAS PROC PHREG (explained below) that examined the geometric roadway data at all three types of sites (i.e., crash sites, nearby comparison sites, and faraway comparison sites), while the other used Statistical Packages for Social Sciences and a binary logistic regression and addressed both geometric and neighborhood demographic factors at the crash site and the distant comparison site.

SAS PROC PHREG is a procedure for survival analysis based on the Cox proportional hazards model. It has been concluded that a matched conditional logistic model has a likelihood function that is a special case of a proportional hazards model. Details can be found in Stokes et al. (11). Another reference is SAS/STAT Software Changes and Enhancements through Release 6.11 (12). SPSS for Windows, Release 7.5.1, was used to estimate the parameters of the binary logistic model.

Several of these variables differ considerably between the crash sites and faraway comparison sites. On the other hand, both the demographic variables and the roadway characteristics would have been expected to differ only slightly between the crash sites and non-crash nearby comparison sites (i.e., since non-crash nearby comparison sites were typically selected on a nearby street crossing the street of the crash site).

It was expected that the nearby locations would have been exposed to much the same population of drivers and pedestrians as the crash sites and, hence, would, to some extent, control for these factors. Yet, there was concern that street design within the same neighborhood might be so uniform that it would tend to control out the factors of interest (e.g., sidewalk present or absent). The more distant locations would not be expected to be exposed to the same distributions of motorists and pedestrians, but the matching might be expected to yield some degree of similarity. These sites should also add variability to the observed roadway designs. Therefore, the selection of both a nearby and faraway comparison site was considered desirable for each crash site.

ANALYSIS OF THE ROADWAY FACTORS USING CONDITIONAL LOGISTIC ANALYSIS

Among the data elements collected at each location, the following were the key variables used in the statistical analysis:

- Speed limit.
- Sidewalk (present or absent).
- Paved shoulder width.
- Gutter pan width.
- Pedestrian volume.
- Traffic volume in the outside lanes.
- Unpaved walkable space.

A four-way tabulation is given in Table 1 of speed limit by site type, by sidewalk presence, and by presence or absence of a paved shoulder 0.76 m (2.5 ft) in width or wider. The crash sites differed from the comparisons for a few of the roadway variables, namely, speed limit, sidewalk presence, and traffic volume. Table 1 shows that these differences are primarily

Table 1. Frequency of speed limit, paved sidewalk, and wide paved shoulder by site type.

Site Type	**Paved Sidewalk**	**Paved Shoulder***	**Speed Limit in km/h (mi/h)**						**Total**
			32 (20)	**40 (25)**	**48 (30)**	**56 (35)**	**72 (45)**	**89 (55)**	
Crash Site	No	No	1	2	0	11	14	8	36
	No	Yes	0	0	0	2	4	1	7
	Yes	No	0	0	0	4	0	0	4
	Yes	Yes	0	0	0	0	0	0	0
Far Comparison	No	No	2	13	0	5	8	1	29
	No	Yes	0	0	0	0	2	1	3
	Yes	No	0	5	1	6	3	0	15
	Yes	Yes	0	0	0	0	0	0	0
Near Comparison	No	No	1	6	0	11	15	3	36
	No	Yes	0	0	0	0	2	1	3
	Yes	No	0	2	0	4	0	0	6
	Yes	Yes	0	0	0	1	1	0	2
Total			4	28	1	44	49	15	141

*Paved shoulder width ≥0.76 m (2.5 ft)

between the crash sites and the more distant comparison sites. The distribution of observed traffic volumes for the three site types is presented in Table 2. Observed pedestrian volumes appeared to differ very little across site types, with at least one pedestrian observed about 50 percent of the time at each of the three site types. The 90th percentiles for observed hourly pedestrian volumes were 10, 8, and 8 for crash, far, and near sites, respectively.

Table 2. Motor vehicle traffic volume distribution by site type (hourly vehicle volume for the outside lanes at the hour the crash took place).

	Site Type		
Percentiles	**Crash Site**	**Far Comparison**	**Near Comparison**
10th	32	13	14
25th	85	22	26
50th	174	66	103
75th	502	241	285
90th	942	625	644

With respect to other characteristics of the data, paved shoulders (of any width) were present at 61.7 percent of the crash sites, 29.8 percent of the far comparison sites, and 57.4 percent of the near comparison sites. There were no sidewalks on either side of the street at 80.9 percent of the sites visited, with no sidewalks at 91.5 percent of the crash sites and 75.5 percent of the non-crash comparison sites. In general, the data indicated that the crash locations tended to be more rural, have higher speed limits and traffic volumes, be more likely to have paved shoulders, and be less likely to have sidewalks when compared to the non-crash comparison sites.

Statistical analyses were carried out by including the variables listed above in a series of conditional logistic models. Conditional logistic analysis is a standard method of analysis for matched case-control studies (12). In this setting, each observation consists of a response variable indicating a case (crash location) or comparison and values of each of the independent variables. The procedure maximizes the likelihood that a case is correctly classified as a function of the independent variables (e.g., roadway variables), given the condition that exactly one of each matched triplet is a case. Table 3 contains results from SAS PROC PHREG obtained by using a best subset selection criterion for selecting best subsets of seven independent variables input to the procedure.

The results in Table 3 show that speed limit is clearly the dominant variable for discriminating between crash and comparison sites. Beyond this, the models are not unique in the sense that different combinations of variables yield similar values of the score statistic, a goodness-of-fit measurement having an approximate P^2 distribution with degrees of freedom equal to the number of included variables. This is not surprising, given the correlated nature of the variables. Table 4 shows the parameter estimates and associated statistics for the best three-variable model, those being speed limit, presence of sidewalk, and traffic volume.

This model shows speed limit to be highly significant, while presence of sidewalks and traffic volume are significant at levels just below and just above the 0.05 level. While speed limits are not perfect measures of roadway speeds, it was believed that this adequately approximates the

Table 3. SAS PROC PHREG procedure: Best subsets selected by score criterion.

No. of Variables	Score Value	Variables Included
1	15.39	Speed limit
1	11.11	Gutter pan width
2	19.18	Speed limit, gutter pan width
2	19.17	Speed limit, paved sidewalk
3	22.25	Speed limit, paved sidewalk, traffic volume
3	21.51	Speed limit, paved sidewalk, gutter pan width
4	23.59	Speed limit, traffic volume, gutter pan width
4	22.61	Speed limit, unpaved walkable space, gutter pan width

Table 4. Results for three variable models.

Variable	Coefficient (Estimate)	Standard Error	P^2	p-Value	Risk Ratio	95% Confidence Intervals
Speed Limit	0.1094	0.0381	8.22	0.0041	1.116	(1.035, 1.202)
Paved Sidewalk	-2.1346	1.077	3.93	0.0474	0.118	(0.014, 0.976)
Traffic Volume	0.0019	0.0010	3.69	0.0549	1.002	(1.000, 1.004)

speeds of vehicles on these roadways for the purpose of this analysis. When more variables are added to the model, significance levels of some variables increase to about 0.10 or higher. Table 4 also contains a column heading “Risk Ratio.”

For the variable “presence of sidewalk,” the Risk Ratio = 0.118. This means that given the data at hand, when speed limit and traffic volume are taken into account, the likelihood of a site with a paved sidewalk being a crash site is 88.2 percent lower than a site without a sidewalk. This should not be interpreted to mean that installing sidewalks would necessarily reduce the likelihood of pedestrian/motor vehicle crashes by 88.2 percent in all situations. However, the presence of a sidewalk clearly has a strong beneficial effect of reducing the risk of a “walking along roadway” pedestrian/motor vehicle crash.

Risk ratios for speed limit and traffic volume are also shown in Table 4. As expected, increases in traffic volume and speed limit are associated with a greater likelihood of a location being a crash site. The results in Table 4 also show that by increasing the traffic volume by 1 unit (e.g., from 300 to 301 vehicles per hour), the risk ratio is 1.002. This means that the probability that the location is a crash site increases by 0.2 percent. For an increase in vehicle volume of 100 (e.g., from 300 to 400), there would be an increase in the probability that the location is a crash site by a factor of $(1.002)^{100} = 1.22$ (a 22 percent increase). The speed limit risk ratio was 1.116. This means that each 1.6-km/h (1.0-mi/h) increase in speed limit increases the likelihood of a location being a crash site by a factor of 1.116. An 8-km/h (5-mi/h) increase in speed limit increases the likelihood by $(1.116)^{5} = 1.73$, while a 16.1-km/h (10-mi/h) increase yields a factor of $(1.116)^{10} = 3.0$.

With regard to other potential roadway variables, data were collected for on-street parking and for street lighting. None of the sites sampled contained bicycle lanes and data were not collected for sidewalk buffer strips. Given the sample size, the diversity of urban and rural sites, and the minimal number of nighttime crashes, on-street parking and street lighting did not prove to be significant in any of the final specifications of these models. This is not to suggest that these variables are not important factors regarding the incidence of “walking along roadway” crashes, but that the sample here was not adequate to effectively analyze these factors.

ANALYSIS OF THE ROADWAY AND DEMOGRAPHIC FACTORS USING THE BINARY LOGISTIC MODEL

Following the collection of roadway attributes, each of these crash sites was manually entered into ArcView for GIS plotting purposes. The sites were then linked with the roadway characteristics mentioned above and then with the information from the 1990 U.S. Census block group within which they were located. As the nearby comparison sites were likely to have the same Census data, and hence no variation in the neighborhood variables, this analysis used only the crash sites and the faraway comparison sites. This data file was then loaded into SPSS and a binary logistic regression was run. An illustration of the location of crash sites, non-crash faraway comparison sites, and the percentage of single-parent households by U.S. Census block group is shown in Figure 1.

The methods used to compare the attributes of the sites include GIS maps, a binary logistic regression model, and a table showing the mean of each variable for the crash sites and the corresponding mean for the comparison sites. The binary logistic model was chosen because, since this analysis only looked at the crash and faraway comparison sites, the binary logistic model accounts for the alternate

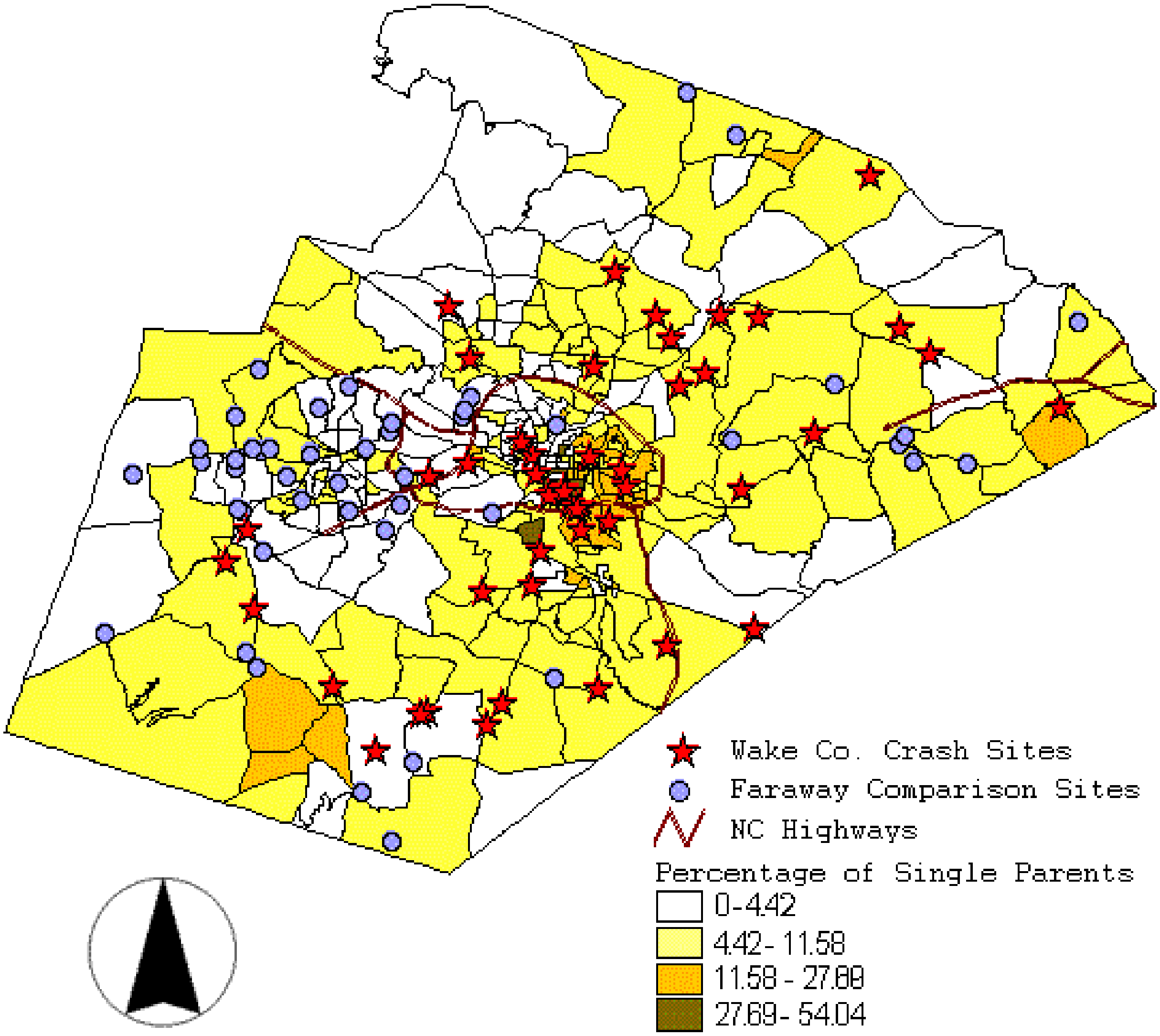

Figure 1. Wake County pedestrian "walking along roadway" crash locations (1993-1996), non-crash faraway comparison sites, and single-parent household percentages.

possibility that a site will be either a crash (1) or a comparison (0) site. This model identifies the statistical significance and degree to which certain attributes distinguish a crash site from a comparison site and gives the marginal effects of each relationship.

The model specification included a variety of geometric factors that were statistically significant in the analysis discussed previously. Added to these factors were a number of variables based on Census data that were believed to potentially correlate with crash sites and also to approximate some ways in which specific neighborhoods may contain greater, or different, risks of "walking along roadway" crashes for pedestrians.

The average median household income in the block groups of crash sites is $31,653, while it is $41,279 at non-crash, faraway comparison sites. Nearly 2.7 percent of the residents around crash sites take the bus to work and 2.7 percent walk. At the non-crash, faraway comparison sites, less than 0.25 percent take the bus and 1.1 percent walk. Minorities comprised 39 percent of the block groups around crash sites, but only 15 percent of non-crash, faraway comparison sites. Just over 63 percent of the homes in crash neighborhoods were owner-occupied, while non-crash, faraway comparison sites were nearly 76 percent owner-occupied.

Through the binary logistic regression (see Table 5), several roadway design factors and neighborhood characteristics were found to be statistically significant. These results were very similar to the results of the conditional logistic modeling above and confirmed that reduced crash risk was associated with lower traffic volumes, lower vehicle speeds, and having a sidewalk present. The binary logistic analysis also showed that wide, unpaved shoulders reduce the risk of "walking along roadway" crashes. However, having controlled for these geometric factors, Census variables that were significantly correlated with crash sites were:

- Percentage of single parents with children.
- Less than 30 percent of housing stock built after 1980.

On the other hand, variables significantly correlated with non-crash, faraway comparison sites were:

- High percentage of families within households.
- Extremely low levels of unemployment (less than 1.75 percent).

When reading through the results of this binary logistic regression, and specifically when looking at the coefficients and marginal effects, it is important to keep in mind the fact that the data set used to produce this model consisted of sites in only one North Carolina county. Therefore, the numeric values associated with each variable should be understood to be relative and indicative of a clear pattern, but not a definitive finding that can necessarily be generalized to all other jurisdictions. A brief discussion of some of the neighborhood factors is given below.

Percentage of Single Parents

As mentioned in Roberts, single parents with children are likely to have less ability, given the other demands on their time, to extensively monitor their children (4-5). Children in neighborhoods characterized by large numbers of this household type may take part in riskier behavior without the supervision of an adult. Thus, it was expected that the percentage of single parents might be positively correlated with the likelihood of a location being a crash site.

The model supports this hypothesis, showing that an increase from 7 to 8 percent in the number of single-parent households results in a 13-percent increase in the likelihood of a location being a crash site. However, complicating this finding is the lack of a clear relationship between the ages of pedestrians struck walking along the roadway and the percentage of single parents in the block group.

Percentage of Housing Stock Built After 1980

In this model, newer housing is believed to be a proxy for a number of possible characteristics of neighborhoods that may influence the likelihood of a "walking along roadway" crash. It is

Table 5. Effects of marginal changes in independent variables in the binary logistic model.

Variable	Mode or Mean	Coefficient (Estimate)	p-Value (Significance)	Probability Site Is a Crash Site at Mean/Mode	Probability Site Is a Crash Site With Marginal Change
Constant		-8.8161	0.0002		
Paved Sidewalk Absent	1	1.9903	0.0572	0.4771	0.1109
Speed Limit (mi/h)* Divided by 5	8	0.8135	0.0572	0.4771	0.6730
Paved Shoulder Greater Than 0.76 m (2.5 ft)	0	31.1738	0.0210	0.4771	1.0000
Paved Shoulder Dummy Variable Interacted With Speed Limits	0	-3.3395	0.0171	1.0000	0.9875
Grassy and Other Unpaved Shoulder Space	1	-2.3327	0.0062	0.4771	0.9039
Percentage of Single Parents With Children	7	0.2646	0.0040	0.4771	0.5431
Less than 30 Percent of Housing Stock Built After 1980	0	2.4171	0.0129	0.4771	0.9110
More Than 85 Percent of Households Composed of Families	0	-2.1301	0.0416	0.4771	0.0978
Unemployment Less Than 1.75 Percent	0	-1.9415	0.0322	0.4771	0.1158
Vehicle Volume	280	0.0025	0.0336	0.4771	0.4833
Pedestrian Volume	3	0.0022	0.9821	0.4771	0.4776

* 1 mi/h = 1.6 km/h

expected that newer neighborhoods are more likely to contain amenities such as better designed roads, large yards, and nearby parks. These factors might influence the driving patterns and use of the roadway by residents. In addition, it is likely that the percentage of newer housing is indicative of higher property values and more recent development, both indicators of the socioeconomic status of a neighborhood. For these reasons, it is expected that areas with a small percentage of houses built after 1980 might be more highly correlated with crash sites.

This model supports the hypothesis that older neighborhoods are more likely to have pedestrian/motor vehicle crashes than newer neighborhoods. The marginal effects indicate that sites in neighborhoods with less than 30 percent of their housing built since 1980 were 90 percent more likely to be crash sites than areas with more than 30 percent new homes.

Percentage of Families

The U.S. Census defines a family as "a group of two or more people, one of whom is the householder, living together, who are related by birth, marriage, or adoption." Families indicate the presence of groups of people who can rely on each other for a variety of different resources. The possibility that another family member will have a vehicle and provide transportation reduces the need for family members to walk as a form of transportation. Families are also likely to participate in activities together and provide supervision of other family members and children. Because of these types of behavior, it is expected that areas with a large proportion of families will be more strongly correlated with the non-crash, faraway comparison sites than with crash sites.

The model supports the hypothesis that having more family households reduces the likelihood of a location being a crash site. The marginal effects showed that areas with more than 85 percent of households being families were 79 percent less likely to be crash sites than areas with less than 85 percent families.

Unemployment

Areas with extremely low levels of unemployment are also areas in which individuals could be assumed to place a high value on their time and personal safety. In addition, employed individuals will probably have less free time to walk in the street and are also financially more able to own a car and thus take a greater percentage of their trips by car. For all of these and other possible reasons, it is expected that areas with very high employment would be less likely to be crash sites than areas with higher levels of unemployment.

The model supports this hypothesis and had a negative coefficient for the dummy variable testing for areas with less than 1.75 percent unemployment. The analysis found these locations to be 75 percent less likely to be crash sites, when compared to neighborhoods with a greater level of unemployment.

Pedestrian and Vehicle Volumes

The socioeconomic variables discussed above measure exposure indirectly, whereas pedestrian and vehicle volumes directly measure exposure. It is expected that greater numbers of either pedestrians or vehicles would increase the likelihood of a location being a crash site, because greater numbers of pedestrians and vehicles are present for possible conflict. However, the non-crash, faraway comparison sites were picked without considering pedestrian or vehicle volumes, so it is expected that the variations in pedestrian and vehicle volumes should not be substantial.

This model found that pedestrian volume, while higher at the crash sites, was not statistically significant in this particular sample of sites. This result does not mean that pedestrian exposure is not important. Instead, it is clearly the result of pedestrian volumes being relatively low (generally less than 5 pedestrians per hour) at most of the sites and fairly similar between crash sites and control sites. Vehicle volume, however, was significant and was positively correlated with crash sites. The marginal effects showed that the increase from 280 vehicles to 290 vehicles per hour, for example, increased the likelihood that a location was a crash site by 1.3 percent.

Grassy and Other Unpaved Shoulder Spaces

It was expected that very wide grassy areas and other unpaved shoulder spaces might be less likely to be crash sites, compared to sites with little or no shoulder. This is because even where sidewalks are absent, a wide unpaved space on the shoulder provides a safe environment for people to walk. Furthermore, it may be less likely for a vehicle to strike a pedestrian on an unpaved shoulder than on a paved shoulder, because the vehicle must run off the road, causing noise and other disturbances that could alert the pedestrian and/or the driver to the problem prior to a crash.

A width of 1.2 m (4 ft) is comparable to a narrow sidewalk and is wide enough that it is expected to provide the average pedestrian with a place to walk off of the pavement. Segments with 1.2 m (4 ft) or more of walkable unpaved space were expected to be less likely to be a crash site than those without such space.

The model found that an unpaved shoulder of 1.2 m (4 ft) or more makes a location 89 percent less likely to be a crash site. This is consistent with the conceptual reasoning on this variable and suggests that such sites have adequate walking space and are less in need of sidewalks than sites with less than 1.2 m (4 ft) of walkable unpaved space.

CONCLUSION

Roadway characteristics such as the absence of sidewalks, higher traffic volumes, higher vehicle speeds, and narrower unpaved shoulders increase the likelihood that a pedestrian/motor vehicle "walking along roadway" crash will occur. By controlling for these factors, this study also found that neighborhood factors influence the likelihood of a location being a crash site. Specifically, neighborhood characteristics that increase the likelihood of a "walking along roadway" crash include:

high percentages of single-parent households, large amounts of older housing (i.e., housing built before 1980), few households composed of families, and high levels of unemployment. It is believed that neighborhood factors capture the extent and type of exposure (i.e., safe or unsafe walking behavior) that takes place in conjunction with these factors.

There are treatments that may decrease the likelihood of a location becoming a crash site. Specifically, sidewalks appear to be the most appropriate treatment on neighborhood streets, while wide unpaved shoulders may be more suitable in more rural areas. Furthermore, neighborhoods with larger numbers of single parents, older housing stock, greater dependency on public transit, fewer families, and higher unemployment might warrant consideration for improvements to pedestrian facilities. By physically separating the individual from the traffic, these improvements would provide a safer place for pedestrians to walk than in the travel lane or on a paved shoulder.

As part of a larger study for the Federal Highway Administration, the results of this study are being used to develop improved national priorities and guidelines for the installation of sidewalks, walkways, and shoulders. Providing such facilities for pedestrians will not only reduce pedestrian/motor vehicle crashes, but also improve pedestrian access. Such facilities also encourage more walking, which improves the health and longevity of those who walk regularly. Design guidelines for sidewalks are given in a 1998 report by the Institute of Transportation Engineers entitled, *Design and Safety of Pedestrian Facilities* (13).

It should also be mentioned that the analyses in this study were limited to all "walking along roadway" crashes in Wake County, North Carolina, in a 4-year period (1992-1996). While such a study could certainly be conducted in other areas of the country, the results here are consistent with the findings of previous research on roadway and neighborhood issues in terms of factors that affect pedestrian/motor vehicle crash experience.

Beyond the variables tested here, it is expected that other variables, such as alcohol and drug usage, crime rate, and other indications of risk-taking, could be successfully incorporated into this type of model to further explain behaviors that increase the risk of exposure to this type of crash. Even more appropriate would be more qualitative research involving the interviewing of neighborhood residents and those familiar with a variety of neighborhoods to determine some of the root causes for the current levels of risk and what they believe to be locally appropriate countermeasures.

REFERENCES

(1) Hunter, W., J. Stutts, W. Pein, and C. Cox. *Pedestrian and Bicycle Crash Types of the Early 1990s.* Publication No. FHWA-RD-95-163. Federal Highway Administration.

(2) Carlin, J.B., P. Taylor, and T. Nolan. "A Case-Control Study of Child Bicycle Injuries: Relationship of Risk to Exposure." *Accident Analysis and Prevention*, Vol. 27, No. 6, 1995, pp. 839-844.

(3) Knoblauch, R.L., B.H. Justin, S.A. Smith, and M.T. Pretrucho. *Investigation of Exposure-Based Pedestrian Accident Areas: Crosswalks, Sidewalks, Local Streets, and Major Arterials*. Publication No. FHWA/RD-87-038. Federal Highway Administration.

(4) Roberts, I. "Adult Accompaniment and the Risk of Pedestrian Injury on the School-Home Journey." *Injury Prevention*, Vol. 1, No. 4, 1995, pp. 242-244.

(5) Roberts, I., R. Norton, and B. Taua. "Child Pedestrian Injury Rates—The Importance of 'Exposure to Risk' Relating to Socioeconomic and Ethnic Differences in Auckland, New Zealand." *Journal of Epidemiology and Community Health*, 1989.

(6) King, D.M., S.D. Lawson, S. Proctor, and K. Johal. "Child Pedestrian Accidents in Inner Areas: Patterns and Treatment." *Traffic Management and Road Safety.* Proceedings of Seminar held at the PTRC Summer Annual Meeting, University of Bath, England, from 7-11 September 1987, Vol. P291, 1987, pp. 159-177.

(7) Epperson, B. "Demographic and Economic Characteristics of Bicyclists Involved in Bicycle-Motor Vehicle Accidents." In *Transportation Research Record 1502.* Transportation Research Board, National Research Council, Washington, D.C., 1995, pp. 58-64.

(8) Christie, N. *The High-Risk Child Pedestrian: Socio-Economic and Environmental Factors in Their Accidents.* TRL Project Report, 1995, (PR 117).

(9) Bagley, C. "The Urban Setting of Juvenile Pedestrian Injuries: A Study of Behavioural Ecology and Social Disadvantage." *Accident Analysis and Prevention*, Vol. 24, No. 6, 1992, pp. 673-678.

(10) Braddock, M., et al. "Using a Geographic Information System to Understand Child Pedestrian Injury." *America Journal of Public Health*, Vol. 84, No. 7, 1994, pp. 1158-1161.

(11) Stokes, M.E., C.S. Davis, and G.G. Koch. *Categorical Data Analysis Using the SAS System*. SAS Institute, Inc., Cary, NC, 1995.

(12) SAS Institute, Inc. *SAS/STAT Software Changes and Enhancements Through Release 6.11*. Cary, NC, 1996.

(13) Institute of Transportation Engineers, Committee TENC-5A-5. *Design and Safety of Pedestrian Facilities*. March 1998.

APPENDIX A. INTERNATIONAL BOULEVARD SIDEWALK IMPACT STUDY: SeaTac, WASHINGTON

Before

After

by

Richard L. Knoblauch

OVERVIEW

This research was conducted by the Center for Applied Research, Inc., as part of a subcontract from The University of North Carolina Highway Safety Research Center. Task Order 11, Evaluation of Pedestrian Facilities, was part of a Federal Highway Administration research project, Pedestrian and Bicyclist Safety—Administrative and Technical Support.

OBJECTIVES

The purpose of this study was to determine the effect of a major sidewalk installation project along a 12-block section of International Boulevard in SeaTac, Washington (State Highway 99 from S. 188th Street to S. 200th Street). This stretch of Highway 99 is the area for Phase II of International Boulevard improvements. The area of observation was defined as the street frontage of International Boulevard from just north of the intersection with S. 188th Street to just south of the intersection with S. 200th Street.

BACKGROUND

This section of roadway has undergone significant enhancement in the past year. The improvements include: new road surface; 2.4-m- (8-ft-)wide sidewalks on either side; street trees; a center median with trees and an earthen berm; and street lighting on high poles for illuminating the roadway, as well as smaller lights on shorter poles for illuminating the sidewalks. In addition, a traffic signal with pedestrian heads and marked crosswalks were installed in the middle of the site at 192nd Street. This intersection was previously stop-sign controlled on the minor leg. SeaTac has recently incorporated as a city (the area was previously unincorporated and was administered by King County) and International Boulevard is the main street through town. Formerly, it was known as State Highway 99, and was the main artery between Seattle and Tacoma until the construction of Interstate 5 in the early 1960s. As such, it was developed with an auto-oriented character, and the businesses that lined the street tended to be motels, gas stations, and fast-food outlets. More recent development and redevelopment have been influenced by SeaTac International Airport, which is about 0.8 km (0.5 mi) north of the study area. Currently, the study area includes several motels, fast-food outlets, gas stations, rental car lots, airport parking lots, office buildings (including the headquarters of Alaska Airlines), small professional offices (doctors, chiropractors, etc.), a self-storage facility, an apartment building, and several convenience stores. There has been no significant redevelopment along the study area in the last year. Figures 1, 2, and 3 show “before” and “after” views of three different locations along International Boulevard.

METHOD

The data collection protocol was developed to determine the effect of sidewalk construction on pedestrian behavior. Because other street improvements (i.e., median, repaving, new crosswalk) were also done at the same time, it was not possible to attribute any of the effects observed solely to the sidewalk improvement.

Observation Zones: For the purpose of data collection in the field, the study area was divided into 11 zones. The length of these zones ranged from 88 to 169 m (288 to 555 ft). The borders of each zone were set to conform as closely as possible to pre-construction transitions from one pedestrian surface to another. The zones included only International Boulevard and the pedestrian areas along the boulevard and did not extend down any of the intersecting streets or their pedestrian areas.

Observation Periods: Each zone was observed for a period of 10 minutes before the observers moved to the next zone. The days of the week and the times of the day for observation were chosen so that the before (1997) and after (1998) periods were comparable. The weather in 1998 was slightly better than the weather in 1997.

Observation Procedures: During each 10-minute observation period, observers were positioned near the middle of a zone. They were positioned so that they could see all pedestrians entering and leaving the zone, as well as those pedestrians moving from point to point within the zone. A data collection form was developed so that the observers could record the following information:

- Vehicle volumes.
- Vehicle speeds.
- Pedestrians walking:
  - Distance walked.
  - Location walked (i.e., shoulder, curb, sidewalk).
- Pedestrians crossing:
  - In crosswalk.
  - Not in crosswalk.
- Pedestrian/vehicle conflicts:
  - Signal timing.

(a) Before.

(b) After.

Figure 1. Zone 5: Looking south.

(a) Before.

(b) After.

Figure 2. Zone 5: Looking north.

(a) Before.

(b) After.

Figure 3. Zone 4: Looking north from 192nd Street.

RESULTS

The results of the data collection effort are summarized in Table 1. Although northbound volumes increased by 9.5 percent, southbound volumes decreased by 10.5 percent. The overall decrease in volume was 2.2 percent. None of these differences were significant. Vehicle speeds were also essentially unchanged from 1997 to 1998.

Pedestrian volumes increased by 15 percent from 1997 to 1998, but the difference was not significant. The length of the average pedestrian trip increased 33 percent. This difference was significant. Apparently, after the improvements, somewhat more pedestrians were walking further. An examination of the age distribution of the pedestrians observed revealed no meaningful differences. There was a slight increase in the number of female pedestrians observed (from 30.0 percent to 38.2 percent). It was also found that pedestrians were more likely (22.7 percent in 1997 vs. 35.2 percent in 1998) to be traveling in groups. It could be hypothesized that the improvements resulted in a more pedestrian-friendly environment that was more likely to be used by women and groups of pedestrians, but there was no way to prove this hypothesis. There was no change in the percentage of pedestrians observed carrying parcels or shopping bags (13.2 percent in 1997 vs. 12.6 percent in 1998).

The changes in pedestrian walking location were more dramatic and very statistically significant. In 1997, almost half (42 percent) of the pedestrians were observed walking on the shoulder and 8 percent were walking along the curb at the shoulder. Installing sidewalks along both sides of International Boulevard resulted in all of the pedestrians in 1998 walking on the sidewalks. Although there was a 38-percent increase in pedestrian crossings (from 6.1 pedestrian crossings per hour in 1997 to 8.1 crossings per hour in 1998), this difference was not statistically significant. There was, however, a statistically significant change in pedestrian crossing location. In 1997, 66 percent of the crossing pedestrians used one of the marked crosswalks and 7 percent crossed at an intersection, but not in a crosswalk. In 1998, 89 percent crossed in a marked crosswalk. It was not known whether this change was attributable to the installation of the signalized intersection at 192nd Street or to the other changes (i.e., sidewalks and/or median) that were made. There was also a marked decrease in percentage of mid-block crossings (27 percent in 1997 and 11 percent in 1998). Although it could have been hypothesized that the reduction in mid-block crossings was due to the addition of continuous sidewalks on both sides of the roadway, there was no way to prove that this was the case.

In addition to recording specific data on pedestrians in the observation zone being studied, the field researchers kept a tally of pedestrians seen "jaywalking" (crossing lanes of traffic) outside of the observation zone. In 1997, there were 6.8 jaywalkers per hour; less than half that number (3.1) of jaywalkers were observed in 1998. Because jaywalking and conflict data were collected as simple tallies, statistical analysis is not possible. However, this change supports the reduction in percentage of crossings that occurred at mid-block locations that was discussed earlier.

For the purpose of this study, "pedestrian/motor vehicle conflicts" were defined as any altered pedestrian *or* driver behavior that was apparently intended to avoid a crash. This would include drivers braking or slowing down or pedestrians slowing or running while crossing in response to an approaching vehicle. There was a marked reduction in pedestrian/motor vehicle conflicts. In 1997, 2.9 conflicts per hour were observed and the number dropped to 0.9 conflicts per hour in 1998. It is not known whether this reduction was due to the overall reduction in mid-block crossings that was observed or to the median, which permitted jaywalkers to divide their crossing into two separate, somewhat safer, crossing events.

DISCUSSION

Overall, the effects of the International Boulevard improvement project appeared to be very positive. More pedestrians were walking further and they were no longer walking along the shoulder. There were also reductions in mid-block crossings, jaywalking, and pedestrian/motor vehicle conflicts. Although it was not possible to determine that the changes were directly attributable to any one of the improvements (e.g., sidewalks, median, or additional signalized intersection), there is little doubt that the entire improvement project resulted in a safer, more pedestrian-friendly environment.

Table 1. Results of the International Boulevard sidewalk improvement project.

Data Element	Before (1997)	After (1998)	Significance Test	Significance Level
Vehicle Volume: Northbound Southbound	 792 veh/h 1,112 veh/h	 867 veh/h 995 veh/h	 t = 7.881 t = 0.799	 0.444 NS* 0.950 NS
Vehicle Speeds	75.0 km/h (46.6 mi/h)	74.4 km/h (46.2 mi/h)	t = 0.087	0.931 NS
Pedestrian Volume	24.0 ped/h	27.7 ped/h	t = 0.726	0.469 NS
Distance Walked, Average Pedestrian Trip Length	63 m (205 ft)	84 m (275 ft)	t = 2.216	0.029
Pedestrians Walking: On Sidewalk Curb, at Shoulder On Shoulder	 42% 8% 50%	 100%	 Pearson Chi Square = 304.312	 0.000
Crossings, per Hour per Zone	6.2	8.1	t = 0.644	0.521 NS
Pedestrian's Crossing Location: In Marked Crosswalk In Unmarked Crosswalk Mid-Block	 66% 7% 27%	 89% 0% 11%	 Pearson Chi Square = 18.328	 0.000
Pedestrians Jaywalking, per Hour	6.8	3.1	N/A**	
Pedestrian/Motor Vehicle Conflicts, per Hour	2.9	0.9	N/A	

*NS- Not significant.
**N/A- Not applicable.

APPENDIX B. RECOMMENDED PRIORITIES AND GUIDELINES FOR SIDEWALKS AND WALKWAYS

by

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INTRODUCTION

According to *A Policy on Geometric Design of Highways and Streets*, (also known as the American Association of State Highway and Transportation Officials' "Green Book"): "Providing safe places for people to walk is an essential responsibility of all government entities involved in constructing or regulating the construction of public rights-of-way."

It is a basic principle that there should be well-designed safe places for people to walk along all public rights-of-way. How this will be accomplished will depend on the type of road, whether it is new construction or a retrofitted area, and available funding.

On February 24, 1999, Federal Highway Administration (FHWA) Administrator Kenneth R. Wykle, in a memorandum to FHWA field offices, stated, "We expect every transportation agency to make accommodations for bicycling and walking a routine part of their planning, design, construction, operations, and maintenance activities." Again, on February 28, 2000, Administrator Wykle sent a memorandum to the field offices in transmitting the new Design Guidance language called for in the Transportation Equity Act for the 21st Century (TEA-21). The guidance, entitled "Accommodating Bicycle and Pedestrian Travel: A Recommended Approach – A U.S. DOT Policy Statement on Integrating Bicycling and Walking Into Transportation Infrastructure," states that bicycling and walking facilities will be incorporated into all transportation projects unless "exceptional circumstances" exist. The exceptional circumstances are spelled out, and he asked the division offices to work with State departments of transportation (DOTs) in the implementation of the guidance.

Government agencies at the State, regional, and local levels are developing regulations for funding, installing, and retrofitting sidewalks. Because there is a great need to improve sidewalk facilities, it is important for these transportation agencies to direct funding to sidewalk improvement and installation projects that will be most beneficial to the safety and mobility of all citizens.

This document is intended to provide agencies at the State, regional, and local levels with tools that they can use to develop guidelines for creating places for people to walk.

This document is limited to creating guidelines for sidewalks that address only one major pedestrian need; other needs that merit further consideration include the ability to cross a street and intersection design.

BASIC PRINCIPLES

Many communities may wish to revisit their roadway planning and rehabilitation criteria. Policies, standard plans, subdivision regulations, and right-of-way requirements should be considered to make sure that sidewalks are included in new construction and rehabilitation projects.

Goals and Objectives

Typically, communities should focus on: (1) improving conditions for people who are currently walking (including improved accessibility to sidewalk facilities for pedestrians with disabilities), (2) increasing levels of walking, and (3) reducing the number of crashes involving pedestrians. Setting targets will help in the development of criteria for installing and retrofitting sidewalks.

Pedestrian Facilities

There are several ways in which pedestrians can be accommodated in the public right-of-way:

Sidewalks: Sidewalks on both sides of a street are generally the preferred pedestrian facility. They provide the greatest degree of comfort for pedestrians and the presence of sidewalks has been associated with increased safety for pedestrians. The Uniform Vehicle Code defines a "sidewalk" as that portion of a street between the curb lines, or the lateral lines of a roadway, and the adjacent property lines intended for use by pedestrians. In most cases, sidewalks are paved, usually with concrete. To comply with Federal Americans With Disabilities Act (ADA) guidelines, newly constructed sidewalks must be accessible to people with disabilities.

Off-Road Paths: An off-road path—paved or unpaved—can be an appropriate facility in rural or low-density suburban areas. A path is generally set back from the road and separated by a green area or trees. Paths can be flexible in that they can deviate from the exact route of a road in order to provide more direct access for key destinations. Paths that generally follow the roadway alignment are sometimes known as "side paths."

Shoulders: Wide shoulders on both sides of a road are the minimum requirement for providing at least a possible place for people to walk. They are not as safe as paths or sidewalks, but they are better than nothing. Shoulders are also beneficial for motorists and cyclists, and future sidewalks or paths should be created in addition to, not in replacement of, the shoulders.

Shared Streets: In very limited unusual circumstances, it may be possible to allow shared use of a street for people walking and driving. These are usually specially designed spaces such as pedestrian streets or "woonerfs." Guidelines for developing these kinds of places can be found elsewhere in the FHWA's *Pedestrian Facilities Users Guide: Providing Safety and Mobility* (see www.walkinginfo.org).

New Construction and Retrofitting

Places for people to walk should be provided in all new construction. Retrofitting will require priorities to be set, and these guidelines are intended to help identify where the need is greatest for adding sidewalks and other facilities.

NEW CONSTRUCTION

New Sidewalk Installation

All new construction must include places for people to walk on both sides of a street or roadway. New construction in urban and suburban areas should provide sidewalks. Recommended guidelines for new sidewalk and walkway installation are given in Table 1.

Phased Development of Sidewalks

In developing and rural areas, it may be acceptable – although less desirable – to start with shoulders and unpaved paths and then phase in sidewalks as development accelerates. Criteria for installing sidewalks along with new development should be implemented with the following in mind:

Space for Future Sidewalks: Space for future sidewalks must always be secured and/or reserved when a new right-of-way is being created or an existing one is being developed. If roadways are to be widened, additional right-of-way must be acquired; existing sidewalks should not be narrowed to accommodate a wider roadway.

"Triggers" for Future Sidewalk: In rural settings, if sidewalks are not installed at the time of development, guidelines are needed to determine when sidewalks will be required and how they will be funded. For example, sidewalks might be required on residential streets once an area has a density of more than four dwelling units per acre and on arterial streets once they are within a school walking zone or have transit service.

Funding for Future Sidewalks: If sidewalks are not installed at the time of development, there needs to be clear regulations as to who (developer, property owner, or governmental agency) will pay for the sidewalks. Whoever is paying for the road must pay for the sidewalk. If there is money for a road, there is money for a sidewalk. Developer contributions to sidewalks must be set aside in an account at the time of development.

Retaining Rural Character

There is a desire in some residential developments to retain a rural atmosphere. Very often this occurs in places that are not truly rural, but rather suburban or exurban (they may have been rural before being developed). Frequently, it is in such places that pedestrian crashes occur that are directly attributable to pedestrians not having places to walk. To address both the goal of having safe places to walk and the desire of the community to retain a certain atmosphere, path systems can be developed that do not look like traditional sidewalks, but do meet walking needs. Even in rural areas, people do want to walk and such facilities should be provided.

Developers in outlying areas may argue that the land use will never fully develop into a pedestrian area. Given that people walk despite not having facilities – for exercise, going to friends' houses, accessing

Table 1. Recommended guidelines for new sidewalk/walkway installation.

Roadway Classification and Land Use	**Sidewalk/Walkway Requirements**	**Future Phasing**
Rural Highways (<400 Average Daily Traffic [ADT])	Shoulders preferred, with a minimum width of 0.9 m (3 ft)	Secure/preserve right-of-way (ROW) for future sidewalks.
Rural Highways (400 to 2000 ADT)	1.5-m (5-ft) shoulders preferred, and minimum of 1.2-m (4-ft) shoulders required.	Secure/preserve (ROW) for future sidewalks.
Rural/Suburban Highway (ADT >2,000 and Less Than 1 Dwelling Unit (d.u.)/.4 hectares (ha) [1 d.u./acre])	Sidewalks or side paths preferred. Minimum of 1.8-m (6-ft) shoulders required.	Secure/preserve (ROW) for future sidewalks.
Suburban Highway (1 to 4 d.u/.4 ha [1 to 4 d.u. /acre])	Sidewalks on both sides required.	
Major Arterial (residential)	Sidewalks on both sides required.	
Urban Collector and Minor Arterial (residential)	Sidewalks on both sides required.	
Urban Local Street (Residential—Less than 1 d.u /.4 ha [1 d.u./acre])	Sidewalks on both sides preferred. Minimum of 1.5-m (5-ft) shoulders required.	Secure/preserve (ROW) for future sidewalks.
Urban Local Street (Residential—1 to 4 d.u./.4 ha [1 to 4 d.u./acre])	Sidewalks on both sides preferred.	Both sides required if density becomes greater than 4 d.u./ .4 ha (4 d.u./acre) or if schools, bus stops, etc. are nearby.
Local Street (Residential—More than 4 d.u./.4 ha [4 d.u./acre])	Sidewalks on both sides required.	
All Commercial Urban Streets (Commercial Areas)	Sidewalks on both sides required.	
All Streets in Industrial Areas	Sidewalks on both sides preferred. Minimum of 1.5-m (5-ft) shoulders required.	

1 acre = 0.4 hectares (ha)

transit, etc. – it is neither rational nor acceptable to build places that do not have places for people to walk. Residential developments that were added in suburban areas, until recently, typically had sidewalks. And they functioned very well.

Sidewalks may not be needed on short residential cul-de-sacs (61 m [200 ft] or less), if there is a system of trails behind the houses and driveway aprons are properly constructed for pedestrians with disabilities. However, it is not a good practice to have an entire neighborhood without sidewalks.

Sidewalk Continuity

Sidewalks should be continuous; interruptions may require pedestrians to cross a busy arterial street mid-block or at an unsignalized location in order to continue walking. Sidewalks should also be fully accessible to side streets and adjacent sidewalks and buildings.

RETROFITTING SIDEWALKS

Many of the streets built in recent decades do not have sidewalks, and these streets need to be retrofitted. In other cases, existing sidewalks need to be replaced. Establishing priorities for installing sidewalks involves three steps: (1) develop a prioritized list of criteria, (2) develop a methodology for using the criteria to evaluate potential sites, and (3) create a prioritized list of sites for sidewalk improvements.

Criteria

The following are suggested criteria for establishing priorities. Select three or more of them when developing your own set of criteria. The key is to select criteria that produce the outcomes desired for your community.

Speed: There is a direct relationship between speed and the number and severity of crashes; high-speed facilities may rank higher if speed is a criterion.

Street Classification: Arterial streets should take precedence, because they generally have higher pedestrian use (due to more commercial uses) and a greater need to separate pedestrians from motor vehicles (due to higher traffic volumes and speeds). Also, arterials are the main links in a community.

Crash Data: Pedestrian crashes seldom occur with high frequency at one location, but there are clearly locations where crashes occur due to a lack of sidewalks. Usually, there is a pattern of pedestrian crashes up and down a corridor, indicating a need to provide sidewalks throughout, not just at crash locations.

School Walking Zones: School walking zones typically extend from residential areas to an elementary school. Children are especially vulnerable, making streets (especially arterials) in these zones prime candidates for sidewalk retrofitting.

Transit Routes: Transit riders need sidewalks to access transit stops. Arterials used by transit are prime candidates for sidewalk retrofitting.

Neighborhoods With Low Vehicle Ownership: Twenty percent of the U.S. population has a disability and 30 percent of the population does not drive. Walking is the primary mode of transportation for many of the people in this country. People with disabilities live throughout the community. If they are not seen in the community, it may be due to the fact that adequate facilities are not provided. In addition, car ownership is lower and crash rates are often higher in low- and moderate-income neighborhoods with lots of children. Therefore, some locations with high pedestrian use (neighborhoods with more children and elderly persons and where vehicle ownership is low) should be given special consideration for sidewalks.

Urban Centers/Neighborhood Commercial Areas: Areas of high commercial activity generate high pedestrian use, even if they are primarily motorists who have parked their cars. Sidewalks are needed to improve safety and enhance the economic viability of these areas.

Other Pedestrian Generators: Hospitals, community centers, libraries, sports arenas, and other public places are natural pedestrian generators where sidewalks should be given priority.

Missing Links: Installing sidewalks to connect pedestrian areas to each other creates continuous walking systems.

Neighborhood Priorities: Local residents may have a sense of where the most desired walking routes exist. Neighborhood groups or homeowners associations can provide a prioritized list of locations where they see a need for sidewalks. Agencies should be cautious about using this criterion, as it is not desirable to let neighborhood pressure override addressing a key safety concern. However, it may be useful to monitor requests from pedestrians with disabilities.

Methodology

The two recommended methodologies for selecting locations for improvement are: (1) the overlapping priorities method, and (2) the points method. Establishing priorities should consume only a small percentage of a program budget—the level of effort put into prioritization should be proportionate to the size of the capital budget.

There is no single right way to select which criteria to use when developing priorities. The criteria and methodology should balance safety measures, such as vehicle speed and pedestrian crash data; pedestrian usage measures, such as proximity to schools or commercial areas; continuity between origin and destination; and accessibility for pedestrians with disabilities.

Overlapping Priorities Method: The easiest and cheapest way to identify overlapping priorities is through graphical representation. The intent is to identify locations that meet multiple criteria. This methodology is especially useful in cases where there is not a lot of staff time and funding for detailed analysis. It can be accomplished using a GIS system or it can be done by hand.

The best way to describe this methodology is by example. Assume that priorities are going to be developed based on transit routes, proximity to schools, people with disabilities, and neighborhood commercial areas. Start with a map of your jurisdiction. Using a colored pen, identify those arterials that have high transit use. Draw a half-mile circle around every elementary school and around locations that attract people with disabilities. Color in the neighborhood commercial areas. This visual approach will make areas of overlapping priorities become immediately clear. The streets without sidewalks within the overlapping areas are the highest priority for retrofitting sidewalks.

Points Method: A weighted points system can be used where staff time and funding are available for more detailed analysis, or if there is a large amount of capital available for side- walk construction. If there are a lot of competing projects, a more sophisticated point system can be used to explain to the public why certain projects were funded and others were not.

A point system can be developed in many ways. The system should be simple and produce desired outcomes. Any and all of the criteria listed above can be assigned a range of numbers and then be used to analyze the need for improvement at given locations. For example, a corridor could be assigned points based on the number of "walking along roadway" crashes over a 5-year period; the number of buses that travel the corridor during peak times; and the proximity to elementary schools. This method is time-consuming because it will be necessary to analyze multiple locations with sidewalk needs to create a list of priority projects.

Prioritized List: Both the overlapping priorities and the points methods will produce an initial list of prioritized projects. The next step is to refine the list so that it works, using common sense. One important consideration is that when roadways are resurfaced, rehabilitated, or replaced, curb ramps must be added if there are pedestrian walkways. In addition, the U.S. Department of Justice considers bus stops to be pedestrian walkways requiring access for people with disabilities, so areas near transit should be given priority accordingly. Improving pedestrian crossings, particularly on arterial streets, may also be an important part of some projects. Other important questions include: Are priority locations ones that might be expected? Are there many surprises? Are priority locations in line with community priorities and expectations? Are some priorities at locations with very low pedestrian use? If the answer to these questions is "yes," then the criteria or the methodology should be evaluated and possibly revised to create outcomes that better reflect expectations and desires. The methodologies should be used to prioritize known needs, not to create a new set of priorities that don't make sense.

The final step is to create packages of fundable projects. The prioritization process should result in reasonable packages that decision-makers can embrace and support. For example, it may be possible to install sidewalks on both sides of every arterial within a half mile of every elementary school for 5 million dollars over a period of 5 years. Or, it may be possible to replace sidewalks in neighborhood commercial areas for 2 million dollars over a period of 3 years. The objective is to take what may appear to be an unsolvable problem (endless need for more funds) and to package it in such a way that it begins to address some of the most critical pedestrian needs in a community.

SIDEWALK DESIGN GUIDELINES

Sidewalk Placement in Large and Small Cities

Continuous sidewalks should be placed along both sides of all fully improved arterial, collector, and local streets in urban and suburban areas. Sidewalks should connect to side streets and adjacent buildings. Accessible crossings should be provided across median islands, frontage road medians, and other raised islands.

Case Study: Seattle

Seattle recently completed an inventory of all sidewalks in the city using a three-step process:

- An intern was hired to review aerial photographs to determine whether a sidewalk existed. This information was then recorded as a new layer on the existing GIS street database.

- The intern field-checked all locations where there was some uncertainty regarding the presence of a sidewalk (about 10 percent of the aerial photographs were not clear).

- Each of 13 neighborhood groups that cover the city were given a draft copy of the inventory and were asked to check it for errors.

The total effort took the equivalent of one full-time person working for 6 months in a city with a population of 530,000, 218 km^2 (84.3 mi^2) of land use, and 2,659 roadway km (1,652 roadway mi) comprised of 1,934 residential street km (1,202 residential street mi) and 724 arterial km (450 arterial mi). Once the inventory was completed, the information was combined on a map with three other types of information:

School Walking Zones: A colored circle identified a half-mile area around each school.

Pedestrian Generators: A second color was used to identify a half-mile area around key pedestrian generators, such as hospitals, libraries, and community centers.

Neighborhood Commercial Areas: A third color was used to identify the dozen neighborhood commercial areas in Seattle (approximately one for each of the major neighborhood areas).

Once the map was printed, it was very easy to see where three colors overlapped, two colors overlapped, etc. The final step was to have the computer calculate the sidewalk deficiencies in the overlapping areas. They found, for example, that there were less than 3.2 km (2 mi) of arterial streets that were within school walking zones, a pedestrian generator area, and a neighborhood commercial area that did not have sidewalks on either side of the street.

There were nearly 4.8 km (3 mi) of arterial streets that were within school walking areas, but were outside of neighborhood commercial areas and pedestrian generators, that did not have sidewalks on either side of the street. There was a citywide deficiency of more than 32 km (20 mi) of arterial streets that lacked sidewalks on both sides of the street.

By developing these and other measurements, the pedestrian program was able to put together packages of information that demonstrated what could be accomplished with additional funding. What everyone thought was an unsolvable multi-million-dollar problem was reduced to a series of smaller, fundable projects that decision-makers could endorse. The result was increased funding and a new optimism that meaningful progress could be made on solving Seattle's sidewalk deficiencies.

Sidewalks, Walkways, and Shoulders in Rural Areas

A safe walking area must be provided outside the motor vehicle roadway. Sidewalks along rural roads should be well separated from the roadway. Isolated residential areas should have a pedestrian connection to the rest of the rural community for school access, shopping, and recreational trips.

An off-road path—also known as a side path—is a type of walkway used in some rural settings. This path, which may be paved or unpaved, is separated from the roadway by a grass or landscaped strip, without curbing. This maintains a rural look, but is safer and more comfortable than a shoulder.

A paved or unpaved shoulder should be provided as a minimum along the road. Paved shoulders are preferred to provide an all-weather walking surface and they also serve bicyclists and improve the overall safety of the road. A 1.5-m- (5-ft-) wide shoulder is acceptable for pedestrians along low-volume rural highways. Greater width, up to 2.4 to 3.0 m (8 to 10 ft), is desirable along high-speed highways, particularly those with a large number of trucks. An edgeline should be marked to separate the shoulder from the roadway.

Sidewalk Width

The width of a sidewalk depends primarily on the number of pedestrians who are expected to use the sidewalk at a given time – high-use sidewalks should be wider than low-use sidewalks. "Street furniture" and sidewalk cafes require extra width, too. A sidewalk width of 1.5 m (5 ft) is needed for two adult pedestrians to comfortably walk side by side, and all sidewalks should be constructed to be at least this width. The minimum sidewalk widths for large or small cities are:

Local or collector streets	1.5 m (5 ft)
Arterial or major streets	1.8 to 2.4 m (6 to 8 ft)
Central business districts	2.4 to 3.7 m (8 to 12 ft)*
Along parks, schools, and other major pedestrian generators	2.4 to 3.0 m (8 to 10 ft)

*A 2.4-m (8-ft) minimum width is recommended in commercial areas with a planter strip, and a 3.7-m (12-ft) minimum width is recommended in commercial areas with no planter strip.

These widths represent a clear or unobstructed width. Point obstructions may be acceptable as long as there is at least 914 mm (36 in) for wheelchair maneuvering (no less than 1,219 mm [48 in] wide as a whole); however, every attempt should be made to locate streetlights, utility poles, signposts, fire hydrants, mailboxes, parking meters, bus benches, and other street furniture off of the sidewalk. When that is not possible, sidewalk furnishings and other obstructions should be located consistently so there is a clear travel zone for pedestrians with vision impairments and a wider sidewalk should be provided to accommodate these obstructions.

Similarly, when sidewalks abut storefronts, the sidewalk should be built 0.6 m (2 ft) wider to accommodate window shoppers, and to avoid conflicts with doors opening and pedestrians entering or leaving the buildings.

Many 1.2-m (4-ft) sidewalks were built in the past. This width does not provide adequate clearance room or mobility for pedestrians passing from the opposite direction. All new and retrofitted sidewalks should be 1.5 m (5 ft) or wider.

Sidewalk Buffer Width

Buffers between pedestrians and motor vehicle traffic are important to provide greater levels of comfort, security, and safety to pedestrians. Landscaped buffers provide space for poles, signs, and other obstructions; they serve as a snow storage area; and they protect pedestrians from splash. The ideal width of a planting strip is 1.8 m (6 ft). Minimum allowable landscape buffer widths are:

Local or collector streets	0.6 to 1.2 m (2 to 4 ft)
Arterial or major streets	1.5 to 1.8 m (5 to 6 ft)

With a landscaped buffer between the sidewalk and the street, care must be taken to ensure that the bus stops are fully accessible to wheelchair users and have connections to the sidewalk. Irrigation may be needed in areas with low precipitation.

Buffers also provide the added space to make curb ramps and landings accessible. When the ramps and landings are designed properly, they are also better utilized by pedestrians pushing strollers or pulling carts and luggage.

If a planting strip is not provided between the sidewalk and the roadway, then the sidewalk width should be a minimum of 1.8 m (6 ft).

Where landscaped sidewalk buffers cannot be provided due to constraints, on-street parking, a shoulder, or a bicycle lane can serve to buffer pedestrians from motor vehicle traffic lanes. The overriding principle is that a narrow sidewalk should never be placed right next to moving traffic.

Sidewalk Surface

Concrete is the preferred sidewalk surface, providing the longest service life and requiring the least amount of maintenance. Asphalt is an acceptable walkway surface in rural areas and in park settings, and crushed granite may also be an acceptable all-weather material in parks or rural areas, but they generally require higher levels of maintenance and are less desirable for wheelchair users.

Sidewalks may be constructed with bricks and pavers if they are constructed to avoid settling; bricks should be easy to reset or replace if they cause a tripping hazard. Also, bricks and/or pavers can cause vibrations that are painful for pedestrians who use mobility aids and, therefore, it may be appropriate to use bricks or pavers only for sidewalk borders in certain situations. There are stamping molds that create the visual appearance of bricks and pavers; these have the advantages of traditional concrete without some of the maintenance issues and roughness associated with bricks and pavers. There are commercially available products that produce a variety of aesthetically pleasing surfaces that are almost impossible to distinguish from real bricks and pavers. However, stamped materials can also have maintenance issues, since, for example, the sidewalk may never look the same again after repairs are made.

It is also possible to enhance sidewalks aesthetically, while still providing a smooth walking surface by combining a concrete main walking area with brick edging where street furniture (lights, trees, poles, etc.) can be placed. For example, in a central business district, a 4.6-m (15-ft) total sidewalk width might include a 2.4-m (8-ft) unobstructed concrete sidewalk with a 2.1-m (7-ft) edge.

Sidewalk Grade and Cross-Slopes

Sidewalks should be built to accommodate all pedestrians and should be as flat as practical. Sidewalks should be held to a running grade of 5 percent or less, if possible. However, for obvious reasons, sidewalks that follow the grade of a street in hilly terrain cannot meet this requirement and may follow the grade of the street. The maximum grade for a curb ramp is 1:12 (8.3 percent).

The maximum sidewalk cross-slope is 1:50 (2.0 percent) to minimize the effort needed for wheelchair users and still provide drainage. At least 0.9 m (3 ft) of flat sidewalk area is required at the top of a sloped driveway to accommodate wheelchair use. In some cases, it may be necessary to bend the sidewalk around the back of the driveway to achieve 0.9 m (3 ft) of level terrain.

Curb Ramps

Curb ramps must be provided at all intersection crossings (marked or unmarked) and mid-block crosswalks for wheelchair access. These ramps also accommodate strollers, carts, the elderly, and pedestrians with mobility limitations. Curb ramps should be as flat as possible and they must have a slope no greater than 1:12 (8.3 percent). Abrupt changes in elevation at the top or bottom should be avoided. The minimum curb ramp width is 914 mm (36 in); however, 1,219 mm (48 in) is the desirable minimum. If a curb ramp is located where pedestrians must walk across the ramp, the ramp must have flared sides of no more than 1:10 (10 percent) slope. These flares are not needed where ramps are placed in a landscaped area. Curb ramps also require a minimum of 914 mm (36 in) of level and clear passage (1,219 mm [48 in] or more is desirable) at the top.

Two separate curb ramps, one for each crosswalk, should be provided at each corner of an intersection. Diagonal curb ramps provide no directional guidance to vision-impaired pedestrians, and force wheelchair users to maneuver in the crosswalk. Raised islands in a crossing must have at least a 1,219-mm (48-in) cut-through that is level with the street; this is generally preferable to curb ramps, which force wheelchair users to go up and down.

Obstacles Along the Sidewalk

The distance to the bottom of signs placed in or next to a sidewalk should be at least 2.1 m (7 ft) above the sidewalk surface to avoid injury to pedestrians. Bushes, trees, and other landscaping should be maintained to prevent encroachment into the sidewalk. Jurisdictions should adopt ordinances requiring local property owners to trim the landscaping they place along their frontage to maintain unobstructed sidewalks. The jurisdictions should provide an inspection procedure or a system of responding to sidewalk encroachment and maintenance complaints.

Guy wires and utility tie-downs should not be located in or across sidewalks at heights below 2.1 m (7 ft). When placed adjacent to sidewalks or pedestrian walkways, the guy wires should be covered with a bright yellow (or other high-visibility) plastic “guard” to make the wire more visible to pedestrians. Guy wires of any color will not be visible to blind pedestrians and must not be located within the pedestrian route. Other obstacles include signal controller boxes, awnings, temporary signage, newspaper racks, fire hydrants, and similar items.

Accessibility

The easiest way to visualize accessibility requirements (grade, cross-slope, and unobstructed width) is with the concept of a "continuous passage." Sidewalks must provide a continuous route at a 2-percent maximum cross-slope at a minimum width of 0.9 m (3 ft). This does not mean that 0.9 m (3 ft) is an acceptable sidewalk width, just that at no point shall the level area be less than 0.9 m (3 ft) wide. This applies mainly at obstructions, driveways, and curb ramps.

Snow

Municipalities that do not remove snow on sidewalks should have an ordinance requiring property owners to clear the snow and keep the sidewalks accessible to pedestrians. When the latter is the case, municipalities should educate property owners as to why this is important and have enforcement efforts in place to ensure compliance.

Bus Stops and Shelters

It is generally preferable to place bus shelters between the sidewalk and the street, or between the sidewalk and adjacent property, so that waiting passengers do not obstruct the flow of pedestrians along the sidewalk. Benches and other street furniture should be placed outside the walking paths to maintain the accessibility of the walkway and to provide good pedestrian service. In addition, curb ramps should be provided at bus stops, because it is not always possible for the bus to pull up close enough to the curb to deploy a lift.

Lighting

Good streetlighting improves the visibility, comfort, and security of pedestrians. It is impractical to provide lighting in most rural areas In urban areas, it is important to light at least the intersections and other pedestrian crossing areas. Lighting is also recommended in areas where there is a high concentration of nighttime pedestrian activity, such as churches, schools, and community centers. Where continuous lighting is provided along wide arterial streets, it is desirable to place the lights along both sides of the street. Continuous streetlights should be spaced to provide a relatively uniform level of light. In shopping districts or in downtown areas with high concentrations of pedestrians, it may be desirable to provide pedestrian-level lighting in addition to the streetlighting in order to improve the comfort and security of pedestrians. The preferred pedestrian-level lights are mercury vapor or incandescent. Low-pressure sodium lights may be more energy-efficient, but are undesirable because they create considerable color distortion. Pedestrian-level lighting may also be installed in selected areas of pedestrian activity to create a sense of intimacy and place.

Other Design Considerations

Sidewalks should be built within the public right-of-way or in a sidewalk easement along the right-of-way. This will provide access to the sidewalk for maintenance activities and will prevent the adjacent property owners from obstructing or removing the sidewalk in the future.

Care must be taken to avoid planting trees or large bushes in the landscape buffer area that will obscure the visibility of a pedestrian attempting to cross or enter a street and an approaching motorist. Trees with large canopies planted between the sidewalk and street should be generally trimmed up to at least 2.4 m (8 ft) high and bushes should be kept to about 762 to 914 mm (30 to 36 in) in height. Trees with large-caliper trunks may not be appropriate near intersections and in other situations where they may block visual sight triangles.

Meandering sidewalks are sometimes used where a wide right-of-way is available and there is a desire to provide a high level of landscaping, such as in a park or along a waterway or other natural feature. It is often believed that meandering sidewalks create a more pleasant walking environment. The reality is that they unnecessarily create a longer walking distance and are inappropriate for sidewalks along a street.

Sidewalks should be built along both sides of bridges. Pedestrian rails or guardrails are required along the outside of the bridge. On bridges with high-speed traffic, concrete barriers between the traveled way and the sidewalk may be considered to shield pedestrians from errant vehicles. However, this adds cost, weight, and width to the bridge, and the transition from barrier to guardrail or curb at each end often creates an awkward transition for pedestrians, who must detour around the barrier to access the bridge sidewalk.

Rollover curbs should not be used next to sidewalks as they encourage motorists to park on planting strips or sidewalks. They may be problematic for some visually-impaired people, since they don't create a definitive edge between the street and adjacent uses.

Sidewalk Depth: Concrete sidewalks should be built to a minimum depth of 101.6 mm (4 in) and to a minimum depth of 152 mm (6 in) at driveways.

SIDEWALK COST CONSIDERATIONS

The actual cost of providing sidewalks will be different for each region of the country and varies with the seasons. Actual bid prices are also influenced by how busy contractors are at the time of construction.

The cost of constructing sidewalks alone is relatively low; typical bids run between \$24 and \$36/m^2 (\$20 and \$30/yd^2), which roughly translates to \$43 to \$64/running m (\$12 to \$20/running ft) for 1.82-m- (6-ft) wide sidewalks. Therefore, sidewalks on both sides of the roadway can run roughly between \$150,000 to \$250,000/mi (Oregon DOT, 1999).

Factors to consider when calculating the cost of sidewalks:

Presence of curb and gutter: The cost of providing curb and gutter, which presumes the need to also provide a street drainage system, runs much higher than the cost of sidewalk. A standard perpendicular curb ramp and top landing need a minimum border width of almost 3.7 m (12 ft) at intersections if there is a 152-mm (6-in) curb. A 152-mm curb reduces the minimum border width to 3.0 (10 ft). Yet, on many urban streets, this work must be performed prior to installing the sidewalks. If this is the case, only the cost of the sidewalks and curb ramps should be attributed to expenditures for pedestrians—catch basins are provided to drain the roadway surface used by motor vehicle traffic.

Number of driveways: To comply with the Americans With Disabilities Act, many existing driveways must be replaced with ones that provide a level passage at least 0.9 m (3 ft) wide. It can also be advantageous to inventory all existing driveways to see if any can be closed, resulting in a cost-savings.

Number of intersections: While intersections represent a reduction in the sidewalk, curb ramps are required where sidewalks cross intersections and the cost of providing additional traffic control at each intersection should be considered.

Obstacles to be removed: The cost of moving or removing obstacles such as power poles, signposts, and fire hydrants vary too much to be itemized here; however, it is required that they be moved if they obstruct access. These costs must be calculated individually for each project.

Structures: While minor sidewalk projects rarely involve new structures such as a bridge, many projects with significant cuts and fills may require retaining walls and or culvert extensions. The cost of retaining walls must be calculated individually for each project.

Right-of-way: While most sidewalk projects can be built within the existing right-of-way, especially infill projects, some may require some right-of-way easements. An alternative to acquiring right-of-way is to narrow the roadway, which should consider the needs of bicyclists (e.g., through bicycle lanes or shoulders, at a minimum width of 1.5 m [5 ft].

Miscellaneous factors: Planters, irrigation, benches, decorative lampposts, and other aesthetic improvements cost money, but they are usually well worth it if the impetus for the project is the creation of a more pleasant and inviting walking environment.

When project costs appear to be escalating due to one or more of the above-listed items, especially retaining walls or acquiring right-of-way, consideration may be given to narrowing the sidewalk in constrained areas as a last resort. The full sidewalk width should be resumed in non-constrained areas. This is preferable to providing a narrow sidewalk throughout, or dropping the project because of one difficult section.

Tips to reduce total cost:

Stand-alone vs. integrated within another project: Sidewalks should always be included in road construction projects. Stand-alone sidewalk projects cost more than the same work performed as part of a larger project. Sidewalks can be "piggybacked" onto projects such as surface preservation, water or sewer lines, or the placement of utilities underground. Besides the monetary savings, the political fallout is reduced, since the public does not perceive an agency as being inefficient (it is very noticeable if an agency works on a road and then comes back to do more work later). The reduced impact on traffic is a bonus.

Combining projects: Cost-savings can be achieved by combining several small sidewalk projects into one big one. This can occur even if the sidewalks are under different jurisdictions, or even in different localities, if they are close to each other. The basic principle is that bid prices drop as quantities increase.

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets*, 1984.

Axelson, P. et. al., *Designing Sidewalks and Trails for Access*, Federal Highway Administration, July 1999.

Institute of Transportation Engineers. *Design and Safety of Pedestrian Facilities: A Recommended Practice of the Institute of Transportation Engineers*, March 1998.