Clear Zone Requirements for Suburban Highways

KING K. MAK, ROGER P. BLIGH, AND HAYES E. ROSS, JR.

The growth of an urban area typically extends outward along arterial highways. The nature of the land use along the highways gradually changes from rural and agricultural use to suburban use with strip commercial developments. The resulting growth in traffic volume and frequent turning movements cause congestion and increased accident experience, which necessitates widening the existing two-lane highways to four or more lanes. Under current design guidelines, urban roadways must have a minimum clear zone width of 0.46 m (18 in.) beyond the face of the curb. On the other hand, high-speed rural arterial highways typically require a clear zone width of 9.1 m (30 ft) or more beyond the edge of the travelway. Some intermediate design requirements of clear zone width are needed for this transitional type of suburban, high-speed, curb-and-gutter roadway. Furthermore, the widening of the highway reduces the available clear zone width unless additional right-of-way is purchased. In other words, after the highway is widened the typical clear zone width of 9.1 m (30 ft) common to rural highways may be needed to provide more travel lanes. This paper presents the results of a study to determine an appropriate and cost beneficial clear zone requirement for such suburban, high-speed, arterial highways in an upgrading or reconstruction situation.

The growth of an urban area typically extends outward along major arterial highways. The nature of the land use along the highways gradually changes from rural and agricultural to suburban with strip commercial developments, such as service stations, fast food restaurants, and shopping centers. The resulting growth in traffic volume and frequent turning movements can cause congestion and increased accident experience, which may necessitate widening the existing two-lane highways to four or more lanes. Also, in anticipation of future growth, these suburban arterial highway sections are designed with curb-and-gutter cross sections and often with two-way left-turn center lanes, typical of urban type roadways. However, these highway sections will remain suburban in nature for a period of time, i.e., with moderate traffic volume and high speed, and speed limits ranging from 80.5 to 88.6 km/hr (50 to 55 mph). The land use and resulting traffic volume will continue to grow until these highway sections become urban roadways with high traffic volume and lower speed limits [i.e., 72.4 km/hr (45 mph) or less].

These suburban arterial highway sections pose some interesting problems because they serve as a transition from rural- to urban-type highways at the fringes of urban areas. Under current design guidelines (*1*), low-speed [i.e., 72.4 km/h (45 mph) or less] urban roadways with curb-and-gutter cross sections and no shoulders must have a minimum clear zone width of 0.46 m (18 in.) beyond the face of the curb. On the other hand, high-speed rural arterial highways with shoulders and parallel drainage ditches are typically required to have a clear zone width of 9.1-m (30-ft) or more beyond the edge of the travelway (i.e., edgeline or edge of pavement).

Widening a two-lane highway within the existing right-of-way (ROW) reduces the available clear zone width. In other words, unless additional ROW is purchased, the typical clear zone width of 9.1 m (30 ft) common to rural arterial highways may be needed to provide more travel lanes. The problem then is to determine what clear zone width is required for such suburban, high-speed, arterial highways and under what conditions the improvements will be cost-effective.

A study was undertaken by the Texas Transportation Institute (TTI) for the Texas Department of Transportation to determine an appropriate and cost-effective clear zone requirement for suburban, high-speed, arterial highways with curb-and-gutter cross sections in an upgrading or reconstruction situation (*2*). This article presents the details of the study, including the research approach, study results, and recommendations.

STUDY APPROACH

A cost-effectiveness procedure based on the encroachment probability model previously developed at TTI was used to assess the incremental benefits and costs associated with various clear zone widths (*3*). The basic concept behind the benefit-cost (BC) analysis is that public funds should be invested only in projects in which the expected benefits are equal to or exceed the expected direct costs of the project. Benefits are measured in reductions in accident or societal costs resulting from decreases in the frequency or severity of accidents. Direct highway agency costs are comprised of initial installation, maintenance, and accident repair costs. An incremental BC ratio of 1.0 was used for the analysis. This indicates that the additional benefits associated with the improvement option over the existing conditions or another improvement option is equal to the increased costs and that the improvement investment is therefore appropriate.

The major activities undertaken in the analysis included:

1. Define typical site conditions for study.
2. Conduct BC analysis on the various clear zone widths for the typical site conditions.
3. Develop clear zone guidelines.

Typical Site Conditions

An effort was made to define the typical site conditions for suburban, high-speed, curb-and-gutter arterial highways from review of field data obtained for a sample of highway sections meeting the study criteria. A total of 16 highway sections were included in the sample, some of the pertinent information obtained for the sampled

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Texas Transportation Institute, Texas A&M University System, College Station, Tex. 77843.

highway sections is summarized in Table 1. Photographs of typical highway sections sampled in the study are shown in Figure 1.

The typical site conditions selected for use with the BC analysis are shown in Table 2. Review of the sampled highway sections showed that the highway types could be categorized into one of the following categories:

1. Four-lane, two-way undivided highways,
2. Four-lane, two-way undivided highway with two-way left-turn center lanes, or
3. Four-lane divided highways.

The more prevalent highway types were four-lane, two-way undivided highways with or without a two-way left-turn center lane, thus, this type was selected for analysis.

Speed limits on these sampled highway sections were between 80.5 to 88.5 km/hr (50 to 55 mph). The highways typically had a 3.7 m (12 ft) lane width with curb-and-gutter cross sections. Most of the sampled highway sections had no shoulders but a few had shoulders 2.4 to 3.05 m (8 to 10 ft) in width. The alignment of the highways was typically straight and level. The traffic volumes on the sampled highway sections varied greatly, ranging from approximately 2,000 to 20,000 average daily traffic (ADT).

For the BC analysis, the speed limit was set at 80.5 to 88.5 km/hr (50 to 55 mph). A lane width of 3.7 m (12 ft) was selected with curb-and-gutter cross sections. The alignment was assumed to be straight and level. To arrive at an incremental BC ratio of 1.0 the traffic volume was varied as needed.

The roadside conditions for these highway sections typically are flat terrain beyond the curb. There was generally a line of utility poles at the ROW line on one side of the highway, with trees, fences, commercial signs, and buildings beyond the ROW line. The density of roadside objects beyond the ROW line varied for each highway section. There were numerous driveways and access points along the highway. The clear zone width typically varied with the ROW width and was clear of obstacles, except for occasional sign supports.

For the BC analysis, the clear zone was assumed to extend to the ROW line and varied in width, starting with a minimum of 3.05 m (10 ft) and increasing in 1.52-m (5-ft) increments. Flat terrain was assumed beyond the curb. A line of utility poles was assumed at the ROW line spaced 76.2 m (250 ft) apart. This spacing is a conservative estimate given that utility pole spacing on rural highways can range from 121.9 to 152.4 m (400 to 500 ft).

As discussed previously, the presence and location of roadside objects beyond the ROW line varied greatly among the sampled highway sections. For the BC analysis, the layout was simplified by using a line of trees as the surrogate for the various roadside objects. Three levels of roadside hazard rating are defined as follows:

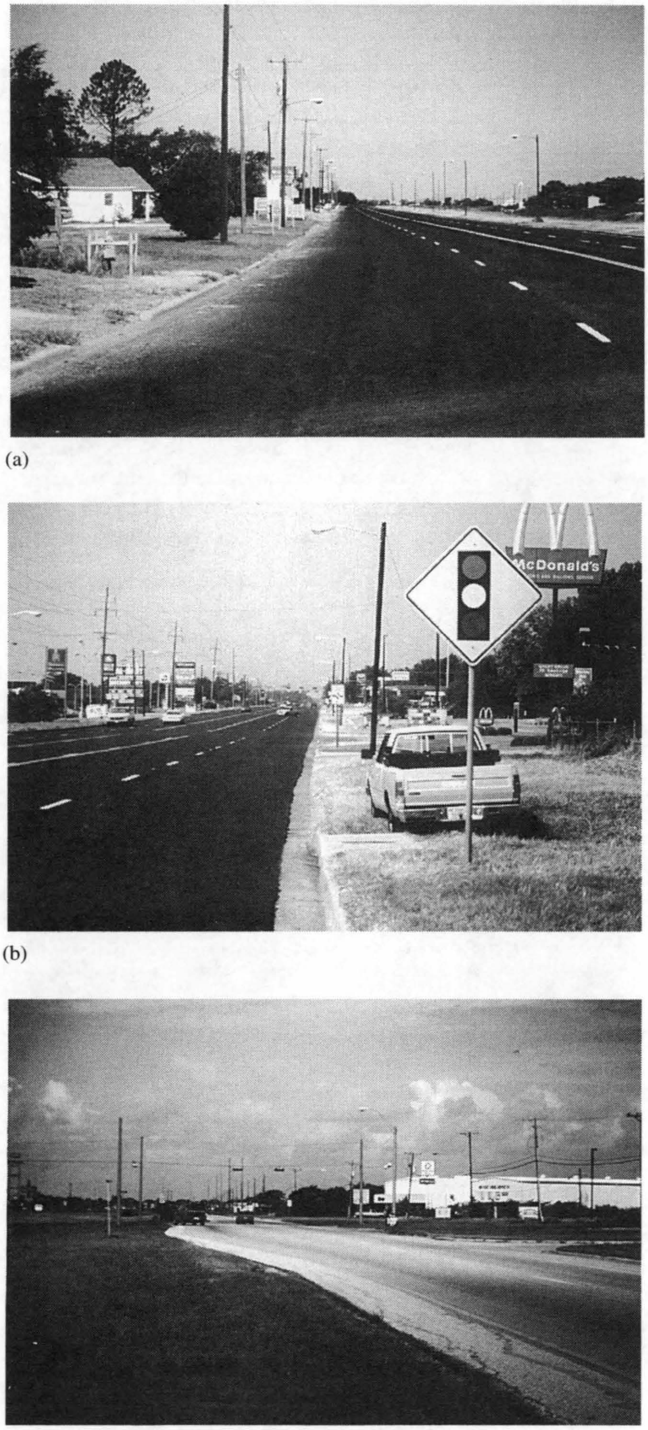
1. Low. A line of utility poles at ROW line with 76.2-m (250-ft) spacing and clear roadside beyond ROW line.
2. Medium. A line of utility poles at ROW line with 76.2-m (250-ft) spacing and a line of trees 1.52 m (5 ft) beyond ROW line spaced 30.5 m (100 ft) apart.
3. High. A line of utility poles at ROW line with 76.2-m (250-ft) spacing and a line of trees 1.52 m (5 ft) beyond ROW line spaced 15.2 m (50 ft) apart.

These three roadside hazard ratings represent varying roadside conditions, from a relatively clear roadside (low rating) to a roadside cluttered with hazards (high rating). The rating that best describes the roadside condition for the specific highway section under study can be selected. For a high hazard rating with trees spaced 15.2 m (50 ft) apart, the probability that an approaching

TABLE 1 Site Conditions for Sampled Highway Sections

Site No.	County	Highway	Section Length km (mi)	Description	AADT	Shoulder Width m (ft)	Clear Zone m (ft)	ROW Cost $\$/\text{m}^2$ ($\$/\text{ft}^2$)
1	Lamb	Loop 430	0.84 (0.52)	4-lane undivided	1,750	2.4 (8)	3.0 (10)	64.58 (6.0)
2	Lamb	US 84	0.31 (0.19)	4-lane TWLTL[a]	4,700	None	6.1 (20)	168.99 (15.7)
3	Tom Green	FM 584	4.98 (3.10)	4-lane TWLTL	5,900	None	≥9.1 (≥30)	N/A[c]
4	Henderson	SH 31	2.19 (1.36)	4-lane TWLTL	13,000	None	N/A	N/A
5	Rusk	US 79	5.03 (3.13)	4-lane TWLTL	5,700	None	7.6 (25)	322.92 (30.0)
6	Smith	SH 64	7.63 (4.74)	4-lane TWLTL	8,900	3.0 (10)	7.6 (25)	122.71 (11.4)
7	Smith	SH 155	7.45 (4.63)	4-lane TWLTL	11,200	None	≥9.1(≥30)	N/A
8	Gregg	Loop 281	4.98 (3.09)	5-lane TWLTL	18,300	None	3.0 (10)	25.83 (2.4)
9	Victoria	SH 185	1.17 (0.73)	4-lane TWLTL	10,200	2.4 (8)	N/A	N/A
10	Calhoun	SH 35	1.62 (1.01)	4-lane divided	12,500	3.0 (10)	N/A	N/A
11	Bastrop	SH 21	1.61 (1.00)	4-lane divided, LT[b] bays	21,000	3.0 (10)	≥9.1 (≥30)	N/A
12	Williamson	US 79	0.99 (0.61)	4-lane undivided	5,500	3.0 (10)	N/A	N/A
13	Comal	SH 46	0.48 (0.30)	4-lane TWLTL	8,200	None	8.2 (27)	69.97 (6.5)
14	Nueces	FM 2444	3.12 (1.94)	4-lane TWLTL	9,200	None	N/A	N/A
15	San Patricio	SH 35	1.88 (1.17)	4-lane divided	10,900	None	N/A	N/A
16	Mills	US 84	0.48 (0.30)	4-lane undivided	3,500	3.0 (10)	5.8 (19)	24.76 (2.3)

Notes,
[a] TWLTL -- Two-Way, Left-Turn Lane
[b] LT -- Left-Turn
[c] N/A -- Not Available



(a)

(b)

(c)

FIGURE 1 Typical sampled highway sections: (*a*) four-lane, two-way undivided, (*b*) four-lane, two-way undivided with two-way left-turn lane, and (*c*) four-lane divided.

vehicle would hit a tree is 0.852. For a medium hazard rating with trees spaced 30.5 m (100 ft) apart, the probability an approaching vehicle would hit a tree is 0.426. Photographs illustrating the three roadside hazard ratings are shown in Figure 2.

The hazards associated with curbs, driveways, and small sign supports within the clear zone were not included in the analysis. The rationale for excluding these hazards in the BC analysis is twofold. First, because the analysis was comparative or incremental in nature, the effects of these hazards would be the same for all clear zone widths, and thus would cancel each other out. Second, the severity associated with these hazards was relatively low and their presence is independent of the clear zone width.

TABLE 2 Typical Site Conditions

- 4-Lane, 2-Way Undivided Highway with or without Center 2-way Left-Turn Lane
- 3.7-m (12-ft) Lane Width, Curb-and-Gutter Section
- No Shoulder/3.05-m (10-ft) Shoulder
- Straight and Level Alignment
- 50-55 mph Speed Limit
- AADT - Varies
- Clear-Zone Width - Varies, Extends to Right-of-Way Line
- Roadside Conditions
  - Flat Terrain beyond Curb
  - Utility Poles
  - Trees
- Roadside Hazard Rating
  - Low - Utility Poles at ROW Line, 76.2-m (250-ft) Spacing
  - Medium - Utility Poles at ROW Line 76.2-m (250-ft) Spacing + Line of Trees 1.5 m (5 ft) beyond ROW Line, Spaced 30.5 m (100 ft) Apart
  - High - Utility Poles at ROW Line 76.2-m (250-ft) Spacing + Line of Trees 1.5 m (5 ft) beyond ROW Line, Spaced 15.2 m (50 ft) Apart
- Estimates of Direct Costs
  - Unit Right-of-Way Acquisition Cost = \$21.53/m^2 to \$64.58/m^2 (\$2/ft^2 to \$6/ft^2)
  - Unit Clearing and Grading Cost = \$0.25/m^2 (\$1,000/acre)
  - Unit Relocation of Utility Pole Cost = \$1,500 per pole
- Traffic Growth Factor = 2.5% Annually
- Percent Trucks = 0% (i.e., All Passenger Car Traffic)
- Life of Project = 10 Years
- Discount Rate = 4%

The severity indexes used in the analysis (Table 3) were obtained from the update to the 1988 AASHTO *Roadside Design Guide* (*4*), now in preparation. As Table 3 shows, the severity associated with an accident increases with impact speed. For the BC analysis, trees were considered rigid point objects and were assigned severity values corresponding to the upper end of the range shown in the table. Although utility poles can also be considered rigid point objects for some impact conditions, accident studies (*5*) and crash tests (*6*) have shown that utility poles will fracture at ground level when the impact energy exceeds a certain level. The impact energy is a function of the mass and speed of the approaching vehicle. Based on a distribution presented by Mak and Mason (*5*) for all vehicle types, 50 percent of utility poles are knocked down when hit at a speed of 64.4 km/hr (40 mph). For this reason, the utility pole hazards were assigned average severity values for the ranges shown in the table.

The accident cost figures in the 1988 AASHTO *Roadside Design Guide* (*4*) were used to convert the accident severity to accident or societal costs, as shown in the following table. Other assumptions were made for the inputs to the BC model, including a traffic growth factor of 2.5 percent annually, 0 percent trucks (i.e., all passenger car traffic), 10 years for the life of the project, and a 4 percent discount rate. The traffic growth factor of 2.5 percent annually represents the upper bound for traffic growth on such highways. The vehicle mix (i.e., percent trucks) is believed to have little or no effect on the clear zone width and to simplify the analysis was thus assumed to be all passenger car traffic. The rationale for selecting a project life of 10 years was that the development and traffic growth on these suburban arterial highways will be such that they will effectively become urban roadways with high traffic volume and lower speed limits in 10 years. Thus, the cost for higher clear zone width requirements would have to be amortized over a period of 10 years, which may or may not be the actual life of the project. The discount rate of 4 percent is a typical value used with BC analyses.

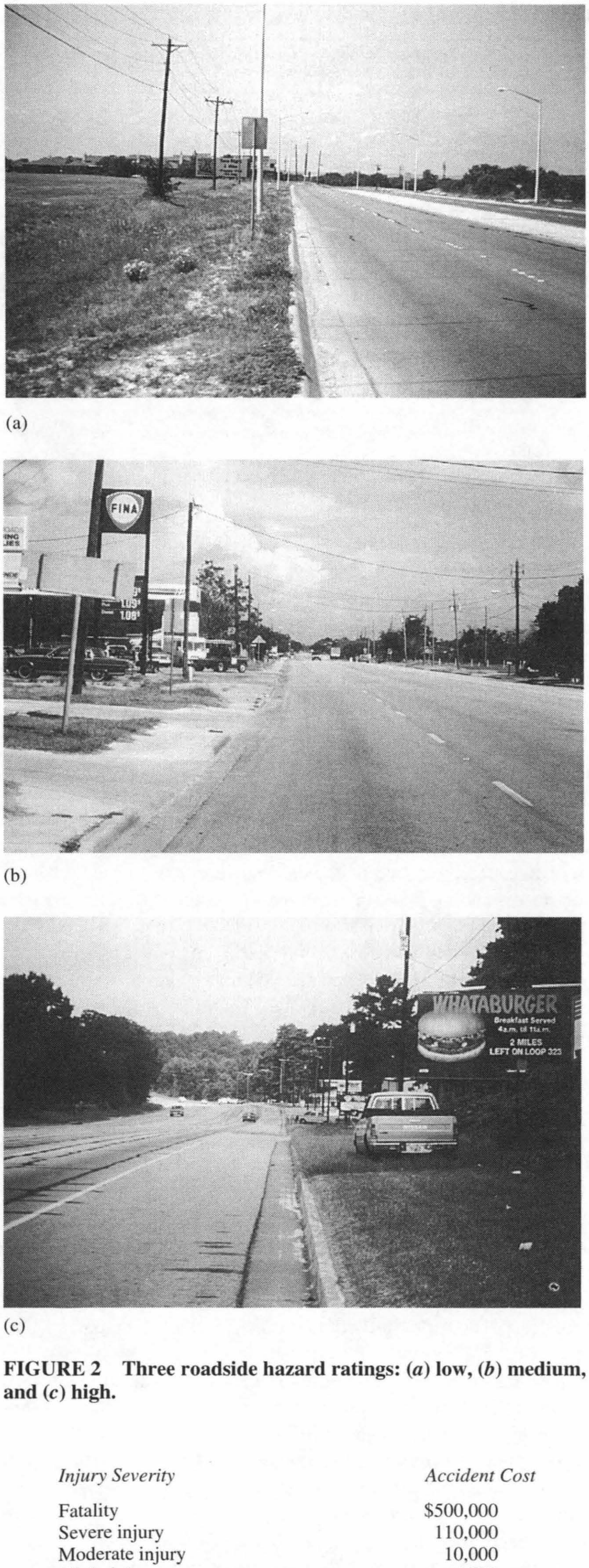


FIGURE 2 Three roadside hazard ratings: (*a*) low, (*b*) medium, and (*c*) high.

Injury Severity	*Accident Cost*
Fatality	$500,000
Severe injury	110,000
Moderate injury	10,000
Slight injury	3,000
Property damage only (Level 2)	2,000
Property damage only (Level 1)	500

TABLE 3 Severity Indexes Used in Analysis

Type of Hazard	Impact Speed							
	64.4 km/h (40 mph)		80.5 km/h (50 mph)		96.5 km/h (60 mph)		112.6 km/h (70 mph)	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Tree, Diameter > 102 mm (4 in.)	2.6-5.0	3.8	3.2-6.0	4.6	3.8-7.2	5.5	4.4-8.6	6.5
Utility Pole	2.6-5.0	3.8	3.2-6.0	4.6	3.8-7.2	5.5	4.4-8.6	6.5

The direct costs associated with increasing the clear zone width include: ROW purchase cost, clearing cost, and the cost to relocate the utility poles. The cost to purchase additional ROW for the sampled highway sections varied from a low of $\$21.53/\text{m}^2$ ($\$2/\text{ft}^2$) to a high of $\$322.92/\text{m}^2$ ($\$30/\text{ft}^2$) with a median of approximately $\$64.58/\text{m}^2$ ($\$6/\text{ft}^2$). The cost to clear and grade the additional clear zone was assumed to be $\$0.25/\text{m}^2$ ($1,000/acre). The cost to relocate the utility poles to the new ROW line was estimated to be $1,500 per pole based on best available estimates.

BC Analysis

The next task was to determine the incremental benefits and costs associated with the various clear zone widths based on the typical site conditions. For this analysis, incremental BC ratios were calculated for various combinations of:

- Clear-zone width,
- Traffic volume (annual ADT),
- Roadside hazard rating, and
- ROW purchase cost.

A baseline clear zone width was assumed for each analysis. The baseline clear zone width was defined as the clear zone width that would be available after a roadway was widened, assuming no additional ROW was acquired. Data from the sampled highway sections indicated that a minimum of at least 3.05 m (10 ft) was typically available for the clear zone width after widening. This should generally be the case given that most two-lane rural highways have at least a 9.1-m (30-ft) clear zone before widening. If the roadway is widened to include four travel lanes and a two-way, left-turn lane, the clear zone would be reduced to a baseline value of approximately 3.7 m (12 ft), assuming 3.7-m (12-ft) lane widths. Thus, the analysis began with a baseline clear zone width of 3.05 m (10 ft).

For this analysis, the alternatives included widening the clear zone width above the baseline value in 1.5-m (5-ft) increments. In other words, if the baseline clear zone width was 3.05 m (10 ft) for Alternative 1, the clear zone width would be 4.6 m (15 ft), 6.1 m (20 ft), 7.6 m (25 ft), and 9.1 (30 ft) for Alternatives 2–5, respectively. The analysis would then be repeated for baseline clear zone widths of 4.6 m (15 ft), 6.1 m (20 ft), and 7.6 m (25 ft).

The objective of the analysis was to determine under what conditions the other alternatives were cost-effective. In other words, when considering a widening or reconstruction project, the analysis is used to determine when it is cost-effective to make capital outlays to provide additional clear zone over the baseline value that would already be available after the roadway is improved.

For each baseline clear zone width, the analysis covered various combinations of roadside hazard rating (i.e., low, medium, and high) and ROW purchase cost. Analysis of these options and determination of appropriate clear zones were based on an incremental BC analysis. For a given roadside hazard rating and ROW purchase cost, the ADT value at which the incremental BC ratio becomes 1.0 was determined for each pair of alternatives under consideration. The appropriate alternative was then determined by first comparing each alternative with the baseline clear zone option and then to each other. The results are summarized in tabular format and discussed in the next section.

STUDY RESULTS

Benefit-Cost Analysis Results

Results of the BC analysis were used to develop tables that identify the most cost-effective clear zone width option for given combinations of baseline clear zone width, roadside hazard rating, and unit ROW acquisition cost. Tables 4–7 show the range of traffic volumes (ADT) for which additional clear zone width is cost-effective for baseline clear zone widths of 3.05 m (10 ft), 4.6 m (15 ft), 6.1 m (20 ft), and 7.6 m (25 ft), respectively. The data in each of these tables are further subdivided according to high, medium, and low roadside hazard ratings, which are denoted as *a*, *b*, and *c*, respectively.

When developing the tables, the unit ROW acquisition cost was varied in increments of \$21.53/m^2 (\$2/ft^2), starting at \$21.53/m^2 (\$2/ft^2), until the ADT at which the baseline clear zone width ceased to be cost-effective exceeded 20,000 vehicles/day. As shown in Table 1, and ADT of 20,000 was the upper limit of the range observed for the sampled sections of highways. For unit ROW acquisition costs above those shown in the tables, it would not be cost-effective to purchase the additional ROW.

Some general observations can be made from the tables. First, as the ROW acquisition cost increases, the ADT required to justify a particular clear zone width also increases. This is expected if one considers that as the direct costs increase, a corresponding increase in benefits is necessary to maintain a BC ratio of 1.0. In the BC analysis, benefits are measured in terms of reductions in accident costs, which are directly related to the traffic volume. In other words, the same safety improvement can result in more benefits (i.e., reduced accident costs) when implemented on a roadway with a higher ADT.

Second, for a given unit ROW acquisition cost, higher ADT values are required to justify the acquisition of additional clear zone width. This observation is similar to the first in that an increase in direct costs must be offset by a corresponding increase in benefits. However, in this case, the increase in direct costs is the result of purchasing additional ROW instead of higher unit acquisition price.

For all the baseline clear zone widths considered, it is not cost-effective to purchase 1.5 m (5 ft) or less of additional ROW. As shown in Tables 4–7, a 1.5-m (5-ft) increase in clear zone width is either not cost-effective or has such a small range of ADT for which it could be considered cost-effective that it would be impractical to implement. This is due to the fact that the incremental benefits achieved over the baseline clear zone width are too small to justify the additional costs. For such small ROW purchases, the direct costs are driven by the utility pole relocation cost, which is a fixed cost based on the number of utility poles. As the clear zone width is further increased, the utility pole relocation cost becomes a smaller percentage of the direct costs, and the incremental benefits become large enough to justify the increased expenditures.

TABLE 4 ADT Range for Which Providing Additional Clear Zone Width is Cost-Effective Based on Baseline Clear Zone Width of 3.0 m (10 ft): (*a*) High, (*b*) Medium, and (*c*) Low Roadside Hazard Rating

(a)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, \$/m^2 (\$/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
3.1 (10)*	<7,200	<16,000	<22,300
4.6 (15)	N/A	16,000-17,400	22,300-25,700
6.1 (20)	7,200-11,400	17,400-24,400	25,700-34,000
7.6 (25)	11,400-17,100	24,400-32,200	34,000-43,700
9.1 (30)	≥17,100	≥32,200	≥43,700

(b)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, \$/m^2 (\$/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
3.1 (10)*	<12,000	<22,000	
4.6 (15)	--	22,000-23,500	
6.1 (20)	12,000-16,700	23,500-31,500	
7.6 (25)	16,700-23,200	31,500-40,800	
9.1 (30)	≥23,200	≥48,800	

(c)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, \$/m^2 (\$/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
3.1 (10)*	<37,800		
4.6 (15)	--		
6.1 (20)	37,800-45,300		
7.6 (25)	45,300-57,000		
9.1 (30)	≥57,000		

* Baseline condition - clear zone width available after widening without any additional right-of-way purchase

For unit ROW acquisition costs of \$64.58/m^2 (\$6/ft^2) or greater, it is not cost-effective to provide additional clear zone width through the purchase of additional ROW. Because \$64.58/m^2 (\$6/ft^2) was found to be the median ROW cost for the sampled highway sections, this would indicate that it is not cost-effective to provide additional clear zone width beyond the existing baseline condition for most roadways.

The use of these tables to select a suitable clear zone width requires only basic information such as ADT, baseline clear zone width, unit ROW acquisition cost, and roadside hazard rating. For example, consider a highway section that has an ADT of 9,000, a baseline clear zone width of 3.05 m (10 ft), a unit ROW acquisition cost of \$43.06/m^2 (\$4/ft^2), and a high roadside hazard rating [these specifications correspond to the conditions in Table 4(*a*)]. The table indicates that a clear zone width of 3.05 m (10 ft) is cost-effective under those conditions. Because this is equivalent to the baseline clear zone width, no additional ROW purchase would be required. If the same highway section had an ADT of 18,000, Table 4(*a*) indicates that a 6.1-m (20-ft) clear zone width would be cost-effective, justifying the purchase of an additional 3.05 m (10 ft) of ROW.

The data presented in Tables 4–7 are further condensed to provide some general clear zone width guidelines for suburban, high-speed arterial highways with curb-and-gutter cross sections. These guidelines are presented in Tables 8–10 for high, medium, and low roadside hazard ratings, respectively. Use of these tables requires the same basic roadway and roadside data but is presented in a dif-

TABLE 5 ADT Range for Which Providing Additional Clear Zone Width is Cost-Effective Based on Baseline Clear Zone Width of 4.6 m (15 ft): (*a*) High, (*b*) Medium, and (*c*) Low Roadside Hazard Rating

(a)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
4.6 (15)*	<12,600	<22,600	
6.1 (20)	--	22,600-24,300	
7.6 (25)	12,600-17,200	24,300-32,300	
9.1 (30)	≥17,200	≥32,300	

(b)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
4.6 (15)*	<18,000	<29,500	
6.1 (20)	--	29,500-31,500	
7.6 (25)	18,000-23,200	31,500-40,700	
9.1 (30)	≥23,200	≥48,700	

(c)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
4.6 (15)*	<47,800		
6.1 (20)	--		
7.6 (25)	47,800-57,000		
9.1 (30)	≥57,000		

* Baseline condition - clear zone width available after widening without any additional right-of-way purchase

TABLE 6 ADT Range for Which Providing Additional Clear Zone Width is Cost-Effective Based on Baseline Clear Zone Width of 6.1 m (20 ft): (*a*) High, (*b*) Medium, and (*c*) Low Roadside Hazard Rating

(a)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
6.1 (20)*	<18,700	<30,500	
7.6 (25)	--	30,500-32,200	
9.1 (30)	≥18,700	≥32,200	

(b)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
6.1 (20)*	<25,000		
7.6 (25)	--		
9.1 (30)	≥25,000		

(c)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
6.1 (20)*	<60,000		
7.6 (25)	--		
9.1 (30)	≥60,000		

* Baseline condition - clear zone width available after widening without any additional right-of-way purchase

TABLE 7 ADT Range for Which Providing Additional Clear Zone Width is Cost-Effective Based on Baseline Clear Zone Width of 7.6 m (25 ft): (*a*) High, (*b*) Medium, and (*c*) Low Roadside Hazard Rating

(a)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
7.6 (25)*	<26,800		
9.1 (30)	≥26,800		

(b)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
7.6 (25)*	<34,500		
9.1 (30)	≥34,500		

(c)

Clear Zone Width, m (ft)	Unit Right-of-Way Acquisition Cost, $/m^2 ($/ft^2)		
	21.53 (2.0)	43.06 (4.0)	64.58 (6.0)
7.6 (25)*	<76,500		
9.1 (30)	≥76,500		

* Baseline condition - clear zone width available after widening without any additional right-of-way purchase

ferent format. For instance, consider a highway section that has an ADT of 14,000, a baseline clear zone width of 4.6 m (15 ft), a unit ROW acquisition cost of $21.53/m^2 ($2/ft^2), and a high roadside hazard rating [these specifications correspond to the conditions in Table 8(*a*)]. The table indicates that a 7.6-m (25-ft) clear zone is cost-effective. With a baseline clear zone width of 4.6 m (15 ft), the purchase of an additional 3.05 m (10 ft) of ROW will be required to attain a clear zone width of 7.6 m (25 ft).

Clear Zone Width Guidelines

Although the data is rather straightforward, it is complicated by the use of different tables depending on specific site conditions. An alternative may be to use a single table as a statewide guideline for establishing clear zone width requirements for suburban, high-speed arterial highways with curb-and-gutter cross sections. Further discussion of Tables 8–10 follows.

For highway sections with a high roadside hazard rating, Table 8 indicates that additional clear zone width is not cost-effective when the unit ROW acquisition cost exceeds $43.06/m^2 ($4/ft^2). For highway sections with a medium hazard rating, Table 9 indicates that it is not cost-effective to provide additional clear zone width when the unit ROW acquisition cost equals or exceeds $43.06/m^2 ($4/ft^2). For highway sections with a low roadside hazard rating, Table 10 indicates that keeping the existing baseline clear zone width is the most cost-effective option for all unit ROW acquisition costs considered in the analysis.

Based on data collected on the sampled highway sections, the typical or average suburban, high-speed arterial highway with curb-and-gutter cross sections would have a medium roadside hazard rating and a median unit ROW acquisition cost of $64.58/m^2 ($6/ft^2), which corresponds to the conditions specified in Table 9(*b*). It is interesting to note that for these average site conditions, the purchase of additional clear zone width is not cost-effective, regardless of the ADT or baseline clear zone width.

TABLE 8 Clear Zone Requirements for High Roadside Hazard Rating: Unit Right-of-Way Acquisition Cost is (*a*) \$21.53/m^2 (\$2.00/ft^2), (*b*) \$43.06/m^2 (\$4.00/ft^2), and (*c*) \$43.06/m^2 (4.00/ft^2)

(a)

Baseline Clear Zone Width m (ft)	AADT			
	<8,000	8,000-12,000	12,000-16,000	>16,000
3.1 (10)		6.1 (20)	7.6 (25)	9.1 (30)
4.6 (15)			7.6 (25)	9.1 (30)
6.1 (20)	Do Nothing			9.1 (30)
7.6 (25)				

(b)

Baseline Clear Zone Width m (ft)	AADT			
	<8,000	8,000-12,000	12,000-16,000	>16,000
3.1 (10)				6.1 (20)
4.6 (15)		Do Nothing		
6.1 (20)				
7.6 (25)				

(c)

Baseline Clear Zone Width m (ft)	AADT			
	<8,000	8,000-12,000	12,000-16,000	>16,000
3.1 (10)				
4.6 (15)		Do Nothing		
6.1 (20)				
7.6 (25)				

TABLE 9 Clear Zone Requirements for Medium Roadside Hazard Rating: Unit Right-of-Way Acquisition Cost is (*a*) \$21.53/m^2 (\$2.00/ft^2) and (*b*) \$43.06/m^2 (\$4.00/ft^2)

(a)

Baseline Clear Zone Width m (ft)	AADT			
	<8,000	8,000-12,000	12,000-16,000	>16,000
3.1 (10)			6.1 (20)	7.6 (25)
4.6 (15)				7.6 (25)
6.1 (20)	Do Nothing			
7.6 (25)				

(b)

Baseline Clear Zone Width m (ft)	AADT			
	<8,000	8,000-12,000	12,000-16,000	>16,000
3.1 (10)				
4.6 (15)		Do Nothing		
6.1 (20)				
7.6 (25)				

The most conservative conditions would be a combination of a high roadside hazard rating and the lowest unit ROW acquisition cost [i.e., \$21.53/m^2 (\$2/ft^2)], which corresponds to the conditions specified in Table 8(*a*). This table indicates that for traffic volumes greater than 16,000 ADT a 9.1-m (30-ft) clear zone width is cost-effective for baseline clear zone widths up to and including 6.1 m (20 ft). For traffic volumes between 12,000 and 16,000 ADT, a 7.6-m (25-ft) clear zone width is cost-effective for baseline clear zone widths of 3.1 m (10 ft) and 4.6 m (15 ft). For traffic volumes between 8,000 and 12,000 ADT, a 6.1-m (20-ft) clear zone width is cost-effective for a baseline clear zone width of 3.1 m (10 ft).

The conditions depicted in Table 8(*b*) [i.e., high roadside hazard rating and unit ROW acquisition cost of \$43.06/m^2 (\$4/ft^2)] are somewhere between the average and the most conservative conditions. The roadside hazard rating is high, although the unit ROW acquisition cost of \$43.06/m^2 (\$4/ft^2) is between the lowest cost of \$21.53/m^2 (\$2/ft^2) and the median cost of \$64.58/m^2 (\$6/ft^2). The only instance in which additional clear zone width is cost-effective is for traffic volumes greater than 16,000 ADT and a baseline clear zone width of 3.1 m (10 ft).

Similarly, the conditions specified in Table 9(*a*) [i.e., medium roadside hazard rating and unit ROW acquisition cost of \$21.53/m^2 (\$2/ft^2)] are between the average and the most conservative conditions. The roadside hazard rating is medium, whereas the unit ROW acquisition cost is the lowest at \$21.53/m^2 (\$2/ft^2). This table indicates that for traffic volumes greater than 16,000 ADT, a 7.6-m (25-ft) clear zone width is cost-effective for baseline clear zone widths of 3.1 m (10 ft) and 4.6 m (15 ft). For traffic volumes between 12,000 and 16,000 ADT, a 6.1-m (20-ft) clear zone width is cost-effective for a baseline clear zone width of 3.1 m (10 ft).

Clear zone guidelines should be conservative so that the site conditions on which the guidelines are based are valid for a majority of the roadways for which they will be applied. However, overly conservative guidelines could lead to too many applications that are not cost-effective. The average conditions depicted in Table 9(*b*) are not conservative enough, whereas the conditions specified in Table 8(*a*) are too conservative. Thus, the choice is between conditions depicted in Table 8(*b*) or Table 9(*a*) which are both conservative but not extremely so.

After careful consideration, the conditions in Table 8(*b*), [i.e., high roadside hazard rating and unit ROW acquisition cost of \$43.06/m^2 (\$4/ft^2)] are considered the more appropriate choice and therefore are recommended. As mentioned previously, the results in this table are still very conservative with the highest roadside hazard rating and a below median ROW acquisition cost of \$43.06/m^2 (\$4/ft^2).

The recommendations contained in Table 8(*b*) are rather straightforward. For a baseline clear zone width of 3.05 m (10 ft) and an ADT greater than 16,000, a 6.1-m (20-ft) clear zone width is recommended. This would require the purchase of 3.05 m (10 ft) additional ROW. For all other baseline clear zone and ADT combinations, the purchase of additional ROW is not cost-effective.

The site conditions on which the recommended table is based are conservative by design. This is necessary due to the wide range of roadway and roadside conditions for which these guidelines will be

TABLE 10 Clear Zone Requirements for Low Roadside Hazard Rating (All Unit Right-of-Way Acquisition Costs)

Baseline Clear Zone Width m (ft)	AADT			
	<8,000	8,000-12,000	12,000-16,000	>16,000
3.1 (10)				
4.6 (15)		Do Nothing		
6.1 (20)				
7.6 (25)				

applied. However, it is obvious that there will be some sites for which these recommendations will be very conservative and for which a reduced clear zone width may be justified. In these situations, it may be desirable to make a more precise determination of an appropriate clear zone width based on the actual characteristics of the roadway under consideration. The data tabulated in Tables 4–7 can be used for this purpose because the roadside hazard rating, ADT, baseline clear zone width, and unit ROW acquisition cost are known.

Consider a roadway that has a baseline clear zone of 3.05 m (10 ft), a low roadside hazard rating, a unit ROW acquisition cost of \$21.53/m^2 (\$2/ft^2), and an ADT of 20,000. The clear zone guidelines shown in Table 8(*b*) would indicate a 6.1-m (20-ft) clear zone. However, a more site-specific evaluation using Table 5(*c*) indicates that the baseline clear zone width of 3.05 m (10 ft) is cost-effective and that no additional ROW purchase is required.

SUMMARY AND RECOMMENDATIONS

This study was undertaken to determine the most appropriate and cost-effective clear zone width requirements for suburban, high-speed arterial highways with curb-and-gutter cross sections. Typical site conditions for this class of roadway were defined based on field data obtained from a selected sample of highway sections. An incremental BC analysis was used to determine incremental BC ratios for various combinations of clear zone width, traffic volume (ADT), roadside hazard rating, and unit ROW acquisition cost. The results of this analysis were tabulated to identify ADT ranges for which different clear zone widths become cost-effective. Based on these results, the following general observations were made.

- It is not cost-effective to purchase 1.5 m (5 ft) or less of additional ROW.
- For unit ROW acquisition costs greater than \$43.06/m^2 (\$4/ft^2), it is not cost-effective to provide additional clear zone width through the purchase of additional ROW.
- For roadways with a low roadside hazard rating, it is not cost-effective to provide additional clear zone width beyond the existing baseline clear zone width.

A general clear zone policy should be established based on the results in Table 8(*b*). For a baseline clear zone of 3.05 m (10 ft) and an ADT greater than 16,000, a 6.1-m (20-ft) clear zone width is recommended. This would require the purchase of 3.05 m (10 ft) additional ROW. For all other baseline clear zone width and ADT combinations, the purchase of additional ROW is not cost-effective and therefore is not recommended.

However, because of the probabilistic nature of the BC analysis and the assumptions inherent therein, a certain degree of judgment should be exercised in applying this data. The typical site conditions (e.g., straight and level alignment, flat terrain beyond curb, 0 percent truck use, etc.) used in the analyses are based on the sampled highway sections included in this study and may not be representative of site conditions throughout the nation. Thus, great care should be taken in applying the study results to other states. A sensitivity analysis to assess the effects of the various parameters included in the typical site conditions would be helpful. Unfortunately, a sensitivity analysis was beyond the scope of this study.

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