CHAPTER 2
BARRIER WARRANTS

2.1 THE WARRANTING PROCESS

Warranting of roadside barriers is difficult to quantify. It is more a process to ensure that all important issues are addressed rather than a "cookbook" approach. This process is summarized in Figure 2.1:

Figure 2.1: Barrier Warranting Process

1. **Determine the needed clear zone.**
2. **Identify potential hazards.**
3. **Analyze strategies.**
4. **Evaluate roadside barriers.**

Each of these steps is addressed in this chapter. This process is designed to identify only the most severe hazards close to the roadway that are appropriate for shielding by barriers. It takes into account both the cost of a barrier and the expected crashes into that barrier. Local conditions, policies and resources are also considered in this process.

2.2 DETERMINE THE NEEDED CLEAR ZONE

2.2.1 The Clear Zone

The area adjacent to the edge of a traveled way available for the safe recovery of an errant vehicle is known as the clear zone. If adequate clear zone distance is available, there is a reasonable expectation that most drivers of vehicles that leave the roadway will have enough room to regain control and return to the pavement without a serious crash occurring. The desirable clear zones used for barrier design and evaluation purposes will not provide sufficient space for all vehicle departures. Some degree of risk is acceptable in the interest of economy. The first step in the warranting process is to determine the required clear zone because it is normally not necessary to shield hazards located outside the clear zone.

2.2.2 Clear Zone Table

Chapter 3 of the AASHTO *Roadside Design Guide* (RDG) contains charts and tables suggesting that the needed clear zone is a function of design speed (see the *Project Development and Design Manual* for a discussion of design speed), side slopes and horizontal curvature: all conditions that may work against the driver's attempts to regain control of the vehicle. Additional modifications are made for low traffic volume as an economic consideration, recognizing that low volumes result in a lower crash probability. The *RDG* clear zone recommendations provide limited information for low speed conditions. Table 2.1 is an extension of the *RDG* table to account for speeds below 60 km/h (40 mph).

Table 2.1 is intended as an aid in determining what potential hazards should be considered for barrier warrants. Although it may be useful as suggested minimum clear zones for geometric design, Table 2.1 is not a design standard. Appropriate references for designing slopes are in Chapter 9 of the *Project Development and Design Manual* and the *RDG*. In general, slopes should be designed to avoid the need for barriers. Although foreslopes as steep as 1V: 3H are traversable, slopes steeper than 1V: 4H are not recoverable and are difficult to maintain. They should be considered marginal from a safety perspective. Ideally, foreslopes should be 1V: 4H or flatter. If that objective cannot be met, a combination (or "barn roof") slope should be provided, with the top slope 1V: 4H or flatter then breaking to a steeper slope.

Table 2.1: Clear Zone Distances from Edge of Through Traveled Way

(Metric Units)

DESIGN SPEED	DESIGN ADT	FORESLOPES			BACKSLOPES		
		1V: 6H or flatter	1V: 5H to 1V: 4H	1V: 3H	1V: 3H	1V: 5H to 1V: 4H	1V: 6H or flatter
30 km/h	Under 750 750 - 1500 1500 - 6000 over 6000	0.5 - 2.0 1.0 - 2.0 1.5 - 2.5 2.0 – 3.0	1.0 - 2.0 1.5 - 2.5 2.0 - 3.0 2.0 - 3.0	**	0.5 - 2.0 0.5 - 2.0 1.0 - 2.0 1.5 - 2.5	0.5 - 2.0 0.5 - 2.0 1.0 - 2.0 1.5 - 2.5	0.5 - 2.0 1.0 - 2.0 1.5 - 2.5 2.0 - 3.0
40 – 50 Km/h	Under 750 750 - 1500 1500 - 6000 over 6000	1.0 - 2.0 1.5 - 2.5 2.0 - 3.0 2.0 - 3.0	1.5 - 2.5 2.0 - 3.0 2.0 - 3.0 3.0 - 3.5	**	0.5 - 2.0 1.0 - 2.0 1.5 - 2.5 2.0 - 3.0	0.5 - 2.0 1.0 - 2.0 1.5 - 2.5 2.0 - 3.0	1.0 - 2.0 1.5 - 2.5 2.0 - 3.0 2.0 - 3.0
55 km/h	Under 750 750 - 1500 1500 - 6000 over 6000	1.5 - 2.5 2.0 - 3.0 3.0 - 3.5 3.4 - 4.5	2.0 - 3.0 2.0 - 3.5 3.5 - 4.5 4.5 - 5.0	**	1.0 - 2.0 1.5 - 2.5 2.0 - 3.0 3.0 - 3.5	1.0 - 2.0 1.5 - 2.5 2.0 - 3.0 3.0 - 3.5	1.5 - 2.5 2.0 - 3.0 3.0 - 3.5 3.5 - 4.5

* See the AASHTO *Roadside Design Guide* for design speeds 60 km/h and higher.

** Foreslopes between 1V: 4H and 1V: 3H are traversable but non-recoverable. Since vehicles will not reduce speed or change direction on these slopes, the needed clear zone is determined by the slopes above and below the non-recoverable slope and extended by the width of the non-recoverable slope. See Chapter 3 of the *RDG* for more information on this procedure. Foreslopes steeper than 1V: 3H are considered hazards.

Table 2.1: Clear Zone Distances from Edge of Through Traveled Way

(Continued) (U.S. Customary Units)

DESIGN SPEED	DESIGN ADT	FORESLOPES			BACKSLOPES		
		1V: 6H or flatter	1V: 5H to 1V: 4H	1V: 3H	1V: 3H	1V: 5H to 1V: 4H	1V: 6H or flatter
20 mph	Under 750	2 - 6	3 – 7	**	2 - 6	2 - 6	3 - 7
	750 - 1500	3 - 7	5 - 8		2 - 6	2 - 6	3 - 7
	1500 - 6000	5 - 8	6 - 10		3 - 7	3 - 7	5 - 8
	over 6000	7 - 10	7 - 10		5 - 8	5 - 8	7 - 10
25 - 30 mph	Under 750	3 - 7	5 – 8	**	2 - 6	2 - 6	3 - 7
	750 - 1500	5 - 8	6 - 10		3 - 7	3 - 7	5 - 8
	1500 - 6000	7 - 10	7 - 10		5 - 8	5 - 8	7 - 10
	over 6000	7 - 10	10 - 12		7 - 10	7 - 10	7 - 10
35 mph	Under 750	5 - 8	6 – 10	**	3 - 7	3 - 7	5 - 8
	750 - 1500	7 - 10	7 - 12		5 - 8	5 - 8	7 - 10
	1500 - 6000	10 - 12	12 - 14		7 - 10	7 - 10	10 - 12
	over 6000	12 - 14	14 - 16		10 - 12	10 - 12	12 - 14

* See the AASHTO *Roadside Design Guide* for design speeds 40 mph and higher.

** Foreslopes between 1V: 4H and 1V: 3H are traversable but non-recoverable. Since vehicles will not reduce speed or change direction on these slopes the needed clear zone is determined by the slopes above and below the non-recoverable slope and extended by the width of the non-recoverable slope. See Chapter 3 of the *RDG* for more information on this procedure. Foreslopes steeper than 1V: 3H are considered hazards.

2.2.3 Horizontal Curve Adjustment

On the outside of horizontal curves errant vehicles are likely to leave the roadway tangent to the curve. Consequently, additional clear zone is needed for recovery. Table 3.2 of the *RDG* suggests multipliers for adjusting clear zones on the outside of horizontal curves. The *RDG* recommends that this adjustment be used where there is reason to expect the curve to be a concern. A crash history, inadequate superelevation and serious hazards within the adjusted clear zone may be reasons to consider using an adjusted clear zone. Since roadside crashes are more likely to occur on the outside of horizontal curves, the use of these adjustments should always be considered. Adjustments on the inside of horizontal curves are not appropriate. Table 2.2 expands the *RDG* table to account for lower speeds.

Table 2.2: Horizontal Curve Adjustments

KCZ (Curve Adjustment Factor) (Metric Units)

RADIUS (m)	DESIGN SPEED (km/h)			
	30	40	50	55
350				1.2
300			1.2	1.2
250		1.2	1.2	1.2
200		1.2	1.2	1.3
150		1.3	1.3	1.4
100		1.4	1.4	1.5

KCZ (Curve Adjustment Factor) (U.S. Customary Units)

RADIUS (ft)	DESIGN SPEED (mph)			
	20	25	30	35
1150				1.2
950			1.2	1.2
820		1.2	1.2	1.2
720		1.2	1.2	1.3
640		1.2	1.3	1.3
570		1.3	1.3	1.4
380		1.4	1.4	1.5

Note: The clear zone correction factor is applied to the outside of curves only. Curves with a radius greater than 350 M (1,150 ft) do not require an adjusted clear zone.

2.2.4 Opposing Traffic Clear Zone

For opposing traffic on a two-lane/two-way road, it is valid to consider the centerline as the edge of the travel way, so the near side lane is part of the opposing traffic clear zone. Therefore, the 1V: 6H or flatter foreslope column should be used in determining opposing traffic clear zones. For most low volume, low speed conditions hazards will be outside the opposing traffic clear zone except, possibly, on the outside of horizontal curves.

2.2.5 Effects of Curbs on the Clear Zone

Curbs offer little or no redirection for vehicles departing the roadway. Although generally a lower speed impact with a curb results in more redirection, crash tests and crash analyses find that curbs are frequently mounted by an impacting vehicle even at very low speeds. It is inappropriate to construct curbs for the purpose of avoiding or minimizing clear zone requirements. The decision to place curbs should be based on other factors including drainage, available right of way and land-use characteristics. The following guidance is for determining clear zone requirements if curbs are already present:

- At speeds of 40 km/h (25 mph) or lower, right-of-way is usually very restricted and roadside safety issues may not be a major design priority. In these cases it may be appropriate to eliminate or minimize the need for a clear zone if a vertical curb with a height of 150 mm (6 in) or higher is present. A minimum horizontal clearance of 0.5 m (1.5 ft) should be provided beyond the back of the curb.

- At speeds of 50 km/h (30 mph) to 70 km/h (45 mph), the presence of curbs may be a consideration for using the minimum clear zones in the ranges shown in Table 2.1 of this guide.

- At speeds of 80 km/h (50 mph) or higher, curbs will vault a vehicle causing it to become airborne. The severity of the vaulting is a function of the height of the curb and the slope of the face. If curbs with a height of 150 mm (6 in) or higher are present, the higher end of the clear zone range should be selected.

2.2.6 Application of the Clear Zone

The following list includes some helpful considerations for the selection of the clear zone:

- The RDG clear zone recommendations are based on limited research, along with engineering judgment and experience. The clear zones as recommended in the RDG and in Table 2.1 of this guide are approximate ranges and are not precise. The designer must also consider site-specific conditions, operating speeds, location and practicality.

- At very low volumes (under 400 ADT), it is common that rights-of-way are restricted, there are an overwhelming number of hazards and very little funds are available for corrective actions. Thus clear zones may appear impractical. Nevertheless, in these cases the clear zone concept can be used to make the roadway as safe as possible. As a minimum, a traversable consistent shoulder should be provided. As much as possible of the recommended clear zone (which is relatively small for low volume conditions) found in Table 2.1 should be provided. Figure 2.2 illustrates a low volume road with minimum clear zones. The use of the warranting process for the conditions discussed in this chapter helps identify the most serious hazards close to the roadway that may justify corrective actions. The barrier warranting procedure takes very low ADT conditions into account.

- The approximate center of the range is suggested for average conditions. The high end of the range is appropriate for sites with higher risk conditions and the low end for less severe conditions.

- Vehicles can and will encroach beyond the recommended clear zones. If severe hazards exist beyond these clear zones, they should be considered for protection.

- Design speed should be used to determine the clear zone. When the design speed is unknown, it may be appropriate to use the posted speed. If the operating speed is greater than the design and posted speeds, it may be more appropriate to use the operating speed.

- If the roadway slopes vary, the slope conditions on the approach to the hazard are used rather than those at a cross section at the hazard to determine clear zone. The approach can be determined by using a 10-degree angle of departure from the edge of pavement.

- See Section 3.3.4 and example problems F and G in the RDG for information on the calculation of clear zones for combination slopes.

Figure 2.2: Roadway with 2M (6 ft) to 2.4 M (8ft) Clear Zone

2.3 IDENTIFY POTENTIAL HAZARDS

2.3.1 Potential Hazards

Once the desired clear zone is determined, fixed objects and roadside features that may be hazards within the clear zone can be identified. There are many conditions that present some degree of risk if struck but are not serious enough to consider shielding with a roadside barrier. Tables 2.3 through 2.6 list hazards and their potential severity. Severity increases from 1 to 3, with Group 3 being the more severe.

Table 2.3: Fixed Objects

Potential Hazard	Group 1 (Low Severity)	Group 2 (Moderate Severity)	Group 3 (High Severity)
Bridge piers, abutments and railing ends			X
Boulders, less than 0.3 m (1 ft) in diameter		X	
Boulders, 0.3 m (1 ft) in diameter or larger			X
Non-breakaway sign and luminaire supports		X	
Individual trees, greater than 100 mm (4 in) and less than 200 mm (8 in) diameter	X		
Individual trees, greater than 200 mm (8 in) diameter		X	
Groups of trees, individually greater than 100 mm (4 in) diameter*			X
Utility poles		X	

* Because of driver expectancy, a group of trees at a consistent offset for lengthy distances may experience lower encroachment rates, even though the offset may be within the clear zone. In such instances, it may be appropriate to consider the trees a Group 2 hazard.

Figure 2.3: Unshielded Bridge Rail End

Table 2.4: Drainage Features

Potential Hazard	**Group 1** (Low Severity)	**Group 2** (Moderate Severity)	**Group 3** (High Severity)
Cross Drain Culvert Ends:			
Exposed culvert ends with no headwalls, 1 m (36 in) in diameter or less		X	
Exposed culvert ends with no headwalls, greater than 1 m (36 in) in diameter			X
Sloped culvert ends, less than 1.2 m (4 ft) in diameter	X		
Sloped culvert ends, greater than 1.2 m (4 ft) and less than 2.4 m (8 ft) in diameter		X	
Sloped culvert ends, 2.4 m (8 ft) or greater in diameter			X
Vertical headwalls, less than 1.0 m (3 ft) in height		X	
Vertical headwalls, 1 m (3 ft) or higher			X
Headwalls with parallel sloped wingwalls, 0.6 m (2 ft) or less height		X	
Headwalls with parallel sloped wingwalls, greater than 0.6 m (2 ft) height			X
Headwalls with flared and sloped wing walls, 1.0 m (3 ft) or less height		X	
Headwalls with flared and sloped wing walls, greater than 1.0 m (3 ft) height			X
Culvert end sections with crashworthy grates	X		
Parallel Drain Culvert Ends:			
Exposed culvert ends with no headwalls, less than 0.6 m (2 ft) in diameter	X		
Exposed culvert ends with no headwalls, 0.6 m (2 ft) and less than 1.2 m (4 ft) in diameter		X	
Exposed culvert ends, 1.2 m (4 ft) or greater in diameter			X
Mitered culvert ends, less than 1 m (3 ft) in diameter	X		
Mitered culvert ends, 1 m (3 ft) or greater in diameter		X	
Vertical headwalls, less than 1 m (3 ft) above ditch section		X	
Vertical headwalls, 1 m (3 ft) or higher above ditch section			X

Table 2.5: Grading Features

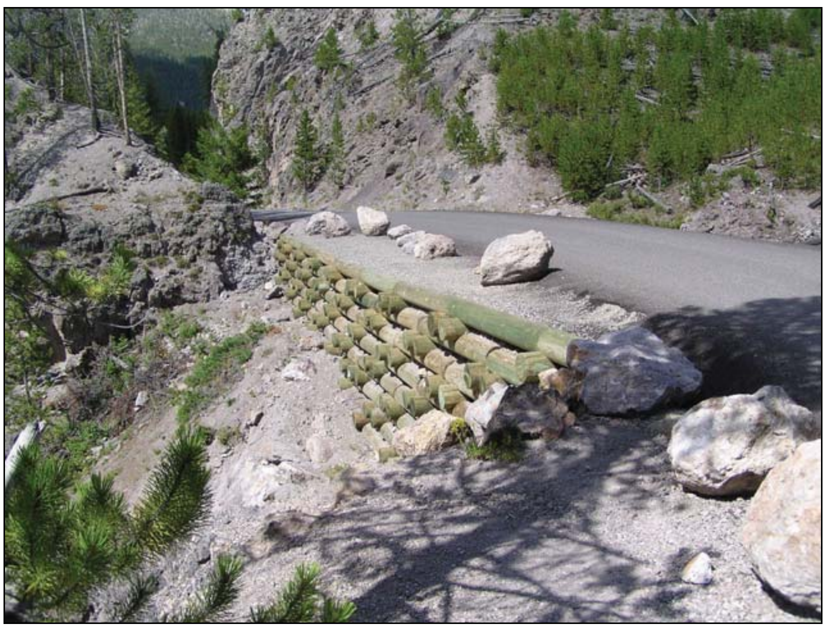
Potential Hazard	Group 1 (Low Severity)	Group 2 (Moderate Severity)	Group 3 (High Severity)
Parallel Ditches:			
Ditches outside the preferred cross section on Figures 3.6 and 3.7 of the *RDG* and with foreslope flatter than 1V: 3H	X		
Ditches with foreslopes 1V: 3H or steeper (Deep ditches should also meet the foreslope criteria below)		X	
Slopes			
1V: 3H foreslope less than 2 m (7 ft) high*	X		
1V: 3H foreslope 2 m (7 ft) and higher*		X	
1V: 2H to 1V: 1.5H foreslope less than 4 m (13 ft) high*		X	
1V: 2H to 1V: 1.5H foreslope 4 m (13 ft) high and higher			X
Vertical foreslope or fill wall less than 2 m (7 ft) high		X	
Vertical foreslope or fill wall 2 m (7 ft) and higher			X
Backslopes that are uneven, or with deep erosion ruts, large rocks, and trees		X	
Vertical backslope with horizontal projections of 200 mm (4 in) or smaller	X		
Vertical backslope with horizontal projections larger than 200 mm (4 in)		X	
Downward intersecting slope (transverse to travel way, such as a river bank) 1V: 4H or steeper, between than 0.5 (2 ft) high to 2 m (6 ft) high		X	
Downward intersecting slope (transverse to travel way, such as a river bank) 1V: 4H or steeper, 2 m (6 ft) or higher			X
Upward intersecting slope (transverse to travel way, such as an overpass fill) 1V: 4H to flatter than 1V: 1.5H, greater than 0.3 m (1 ft) high		X	
Upward intersecting slope (transverse to travel way, such as an overpass fill) 1V: 1.5 H or steeper, greater than 0.3 m (1 ft) high			X

* Slopes are assumed to be relatively smooth and free of obstacles. If slopes are uneven, have deep erosion ruts, large rocks and trees or other vegetation that may cause a vehicle to be unstable, then the classification should be increased one category. Conditions at the bottom of these slopes must also be evaluated.

Table 2.6: Other Features

Potential Hazard	**Group 1** (Low Severity)	**Group 2** (Moderate Severity)	**Group 3** (High Severity)
Parallel smooth retaining wall or cut slope	X		
Retaining wall parallel or flared away from approaching traffic at flatter than 1:8	X		
Retaining wall flared away from approaching traffic at 1:8 or steeper		X	
Water at a depth of 0.3 m (1 ft) to 1 m (3 ft)		X	
Water at a depth of 1 m (3 ft) or deeper			X

Figure 2.4: Vertical Drop and Boulders



2.3.2 Crash History

Crash history, if available, can also be of assistance in identifying and evaluating hazards. In order to identify significant patterns, a history of several years is needed. Three to five years is usually sufficient, but even longer periods are useful for low volume roads. There is a certain amount of randomness with roadside crashes. Therefore, a crash analysis should look for patterns of crashes at several sites that share common characteristics, such as roadway features and hazard types. Care must be taken to avoid overreacting to one severe crash at a specific site when there is no established pattern. Otherwise, an expensive corrective action may be constructed to correct a problem that may never recur.

2.3.3 Innocent Bystander Warrant

A final consideration is what is known as the innocent bystander warrant. In this case the issue is not protecting the occupants of an errant vehicle, but protecting non-motorists or sensitive roadside conditions. Examples are a school playground that is within the needed clear zone, pedestrian facilities within the clear zone that will be used frequently by many pedestrians who may be inattentive to traffic or homes within the clear zone. Application of this warrant is difficult to quantify but it should follow the same general process discussed in this chapter, evaluating both risks and costs of placing or not placing barriers.

2.4 ANALYZE STRATEGIES

2.4.1 Probability and Severity

The concepts of probability and severity must be understood to effectively evaluate roadside safety alternatives. The probability (or likely frequency) of a vehicle striking any roadside object or condition (including barriers) is determined by a complex set of variables, including:

- Traffic volume
- Speed
- Roadway characteristics (number and width of lanes, shoulders, divided or not, etc)
- Horizontal curvature
- Grade
- Size and offset of the hazard or barrier
- Rate of encroachment (affected by familiarity of drivers, driver distractions, driver expectancy and design consistency of the roadway)

Severity is a measure of the consequences of crashes once a hazard or condition is struck, regardless of probability. Severity is a function of speed and the relative seriousness of crashes. Severity is measured by the mix of likely crash types: fatal, injury and property-damage-only. Severity can be measured by a severity index using a 0 to 10 scale. Appendix A of the *RDG* defines this scale using proportions of crash types. For example, of all the crashes that might occur with a roadside feature evaluated as a Severity Index of 5.0, 15 percent will be property-damage-only, 77 percent will be injury crashes and 8 percent will be fatal crashes.

2.4.2 Strategies for Corrective Action

Possible strategies are summarized in Table 2.7.

Table 2.7: Strategies for Corrective Actions

Strategy	Possible Corrective Actions
Reduce the probability of vehicles leaving the roadway	• Flatten horizontal curves • Provide adequate superelevation • Provide standard lane widths • Pave with a skid-resistant surface • Widen shoulders • Pave shoulders • Mark centerline and edge lines • Delineate sharp curves • Provide shoulder rumble strips
Eliminate the hazard	• Remove the hazard • Relocate the hazard to outside the clear zone
Reduce the severity of the hazard	• Make the hazard crashworthy or breakaway • Shield with a barrier
Accept the risk and leave the hazard unprotected	• Delineate the edge of traveled way • Install object markers on the hazard, if appropriate

Figure 2.5: Delineation on a Horizontal Curve

2.4.3 Strategies for Specific Hazards

Of the severity groups discussed in Section 2.3.1, Group 1 hazards are estimated to have a severity index of below 3.0 (fatalities are unlikely), Group 2 hazards have a severity index of 3.0 to 4.9 (some possibility of serious injury and fatality, but probably less severe than barriers) and Group 3 hazards have a severity index of 5.0 and higher (may be more severe than a crash into a barrier). Currently acceptable roadside barriers are estimated to have a severity index of 4.9. All these severity indices are estimated at 100 km/h (62mph), but generally will have the same relative meaning at lower speeds.

Group 2 hazards should be considered for the same corrective actions as Group 3 hazards if they have crash histories or are located so that a vehicle could strike more than one hazard in the same run-off-the-road event.

The following strategies are generally appropriate for the severity groups identified in Section 2.3:

Severity Group	Possible Corrective Actions
Group 1	Accepting the risk and leaving the hazard is usually appropriate. Avoid placing these conditions in the clear zone or take simple, low-cost corrective actions if possible. Group 1 hazards commonly do not justify expenditure of substantial funds to correct.
Group 2	Consider cost-effective strategies to reduce probability, eliminate the hazard or reduce the severity of the hazard. Because these hazards generally do no warrant shielding with a roadside barrier, the cost of a corrective action should be less than the expected cost of a barrier. If a new road, avoid placing Group 2 hazards in the clear zone.
Group 3	Evaluate for possible use of roadside barriers if it is too expensive or impractical to eliminate either the hazard or make it crashworthy. If a barrier is found not to be warranted or if an alternate treatment is less expensive than a barrier, treat as a Group 2 hazard.

Solutions can include combinations of strategies. For instance, if a large cross drain culvert headwall is within the clear zone, a combination of effective corrective actions might be to improve the shoulders, add edge lines, extend the headwall to outside the clear zone, and remodel the headwall to make it more crashworthy.

2.5 ANALYZE THE NEED FOR ROADSIDE BARRIERS

2.5.1 Barrier Considerations

Barriers are not an ideal treatment for roadside hazards on low volume, low speed roads for a number of reasons, including the costs of installation, maintenance and repair as well as possible environmental and aesthetic impacts. The frequency of crashes into barriers will be larger than crashes into the hazard (simply because barriers are closer to the travel way and longer than the condition being shielded). Crashes into barriers can be serious events. For all these reasons, the alternate strategies and corrective actions discussed in Section 2.4 should be carefully evaluated before deciding on a barrier. Barriers should be considered only when other strategies are too costly or impractical and there is a reasonable expectation that the barrier will be a better choice than leaving the hazard unprotected.

The benefits, costs, impacts and risks of barriers should be considered, including:

- Cost of construction, maintenance, and repair when struck. These costs can be estimated with a fair degree of certainty.

- Probability and severity of striking the barrier compared to striking the hazard. This is more difficult to estimate because predicting potential outcomes is a very complicated evaluation considering many variables. Analytical tools that can quantify potential impacts on both the hazard and the corrective action are available to assist in this analysis. Otherwise, judgment based on experience and training must be applied.

- Aesthetic impacts of the barrier. In parks and similar settings the aesthetics of some roadside barriers may be a valid concern. One concern may be the barrier itself and another may be view obstruction. Chapter 3 discusses both rustic-appearing barriers that have been developed specifically to mitigate aesthetic concerns and barriers that minimize view obstruction.

- Environmental impacts of the barrier. There are two types of environmental impacts commonly associated with the installation of roadside barriers. Widening of a relatively flat area beyond the shoulder is frequently necessary to accommodate the width of a barrier. That widening could create environmental concerns. Also concrete and masonry barrier systems that are solid walls may restrict the movement of small animals. Environmental impacts that might be associated with barriers are usually quite small. Neither aesthetic nor environmental impacts can be quantified for direct comparison with other factors, but they should be considered when appropriate.

2.5.2 Analytical Procedures

Economic analysis is useful in evaluating the need for barriers. The computerized Roadside Safety Analysis Program (RSAP) quantifies all the concerns discussed except aesthetics and environmental. RSAP evaluates the probabilities and severities of roadside hazards and barriers, along with construction, maintenance and repair costs to determine the benefit/cost ratio of a corrective action such as a roadside barrier.

Although RSAP can provide a very site-specific analysis, there are problems with the system, particularity as applied to low volume roads. An alternative warranting process based on RSAP analysis is presented in Appendix A. The application of this process ensures consistent assumptions and does not require any knowledge of the RSAP system. It is designed to eliminate some of the concerns with RSAP.

2.5.3 Subjective Procedure

If either RSAP or the procedure discussed in Appendix A is not used, a subjective evaluation can be made by following these steps:

1. Determine the needed clear zone.

2. From Tables 2.3 through 2.6, identify hazards within the clear zone that may warrant barriers. Hazards that may warrant barriers include those in Group 2 if there is a clear crash history or multiple hazards serve to increase the severity. All hazards in Group 3 may warrant barriers.

3. Evaluate the use of barriers using the considerations listed in Table 2.8. Although this is a subjective analysis, it can lead to a reasonable decision concerning the use of roadside barriers.

Table 2.8: Barrier Warrant Considerations

Consideration	Barrier is more warranted if:	Barrier is less warranted if:
Speed	70 km/h (45 mph) or higher	40 km/h (25 mph) or lower
Hazard on outside of horizontal curve	350 m (1,150 ft) or smaller radius	Radius larger than 400 m (1,430 ft)
Hazard does not fit the descriptions in Tables 2.3 through 2.6	Hazard is more severe	Hazard is less severe
Size of hazard	Very large	Very small
Traffic volume	Above 1,000 vpd	Below 400 vpd
Hazard on inside of horizontal curve	350 m (1,150 ft) or smaller radius	Radius larger than 400 m (1,430 ft)
Hazard on a downgrade	5 percent or greater	Less than 3 percent
Crash history	Clear crash pattern	No crash pattern
Anticipated cost of barriers	Expected costs are low	Expected costs are high
Roadway cross section	Severe section elements	Good section elements
Multiple hazards exist at the site	Many additional hazards	
Aesthetic impacts		Serious concerns
Environmental impacts		Serious concerns

Table 2.8 is intended as a guideline for barrier considerations. It is likely that specific sites will have some considerations identified in both columns and some in neither column. The considerations are not necessarily equal in importance.

Appendix A contains a more quantifiable procedure that is based on economic analysis.

2.5.4 Bridge Rail Ends

Bridge rail ends on the right side of approaching traffic (near side) are rigid objects, frequently very near the traveled way. Because of their severity, they should never be considered “not warranted.” Even though the warranting tables in Appendix A might indicate a bridge rail is not warranted, it should be considered “possibly warranted” and at least considered for shielding. The far side bridge rail will usually be outside the clear zone of opposing traffic for most low volume and low speed conditions. When the far side is outside the clear zone it still should be considered for shielding if any of the following conditions exist:

- The travel lanes are 3 m (10 ft) or less.
- Passing is allowed and expected.
- There is a crash pattern.

2.6 EXAMPLE PROBLEMS

The following are example applications of the warranting process described in this chapter. Appendix A includes the same example problems using the warranting procedures described in the appendix.

Problem 1

Roadway data:	A two-lane road, with 3.6 m (12 ft) lanes and 1.2 m (4 ft) paved shoulders. There is a tangent section and a 46 m (150 ft)-long horizontal curve on a 240 m (800 ft) radius. The whole section is on a 3 percent downward grade.
Traffic data:	400 present ADT with a 3 percent annual growth factor. Design speed is 50 km/h (30 mph). On the tangent section actual speeds may exceed the design speed.
Hazard data:	The hazard is a 1V: 2H foreslope 18 m (60 ft) high, offset 1.8 m (6 ft) from the edge of travel way on the outside of the horizontal curve. The slope is 150 m (500 ft) parallel to the road, including both the horizontal curve and the tangent section. There are some scattered trees and small boulders on the slope.
Other issues:	Because of the remote location, barrier construction is expected to be costly. There are no crash data available. There are no aesthetic or environmental issues.

Solution:

1. The hazard is at an offset of 1.2 m (6 ft). From Table 2.1, the clear zone range is 1.0 - 2.0 m (3 - 7 ft). From Table 2.2, the horizontal curve adjustment factor is 1.2. The higher end of the range is selected as the desired clear zone because of the seriousness of the hazard. Therefore, the slope is within the clear zone in both the tangent and curved sections. The slope is outside the clear zone for opposing traffic.

2. From Table 2.5, the slope is a Category 3 hazard so a barrier should be considered.

3. From Table 2.8, the following considerations apply to the possible use of barriers:

   Reasons to Use Barriers

   a. The hazard is on the outside of a horizontal curve (for some of the section)
   b. The hazard is more severe that the description in Table 2.4
   c. The hazard is large
   d. There are multiple hazards at the site

   Reasons Not to Use Barriers

a. The hazard is on a tangent (on some of the section)
b. The traffic volume is low
c. The downgrade is not very steep
d. Costs of a barrier are expected to be high
e. Roadway section elements are good

Because of the hazardousness of the site, it appears that a barrier is warranted at least on the horizontal curve section of this road. Barriers may be appropriate on the tangent, but the warrant is less clear.

Problem 2

Roadway data: A two-lane road, with 3.6 m (11 ft) lanes and 0.6 m (2 ft) paved shoulders. This is a flat and tangent section. The roadway approaches a bridge across a river. On the approach the road leaves a cut section with a 1V; 6H foreslope to a ditch, and then approaches the bridge on a fill with 1V: 3H side slopes. The slope break for the fill is 0.6 m (2 ft) from the edge of the shoulder. The fill is approximately 2.4 m (8 ft) high. On the far side a similar fill extends 60 m (200 ft) where the fill flattens to 1V: 4H. There are no pavement markings on the road or the bridge.

Traffic data: 1,100 present ADT with a 1 percent annual growth factor. Design speed is 70 km/h (45 mph).

Hazard data: An 8.5 m (28 ft) wide bridge crosses a river with water depths of approximately 1.5 m (5 ft). The bridge rail is a vertical concrete wall.

Other issues: This roadway is in a park with serious aesthetic concerns.

Solution:

1. Table 2.1 shows the clear zone range is 4.5 - 5.0 m (14 - 16 ft). Assuming 3.3 M (11 ft) lanes on the bridge, the bridge rail is located 1.0 m (3 ft) from the traveled way and is in the clear zone. The bridge rail on the opposing traffic side is outside the clear zone. The 1V: 3H slope is traversable but not recoverable, so the approach clear zone is (using the mid-point of the range):

CZ = 4.7 + (3 * 2.4) = 11.9 m

Or, CZ = 15 + (3 * 8) = 39 ft

The river is also in the clear zone.

2. Tables 2.3 and 2.6 indicate that both the bridge rail and the river are Category 3 hazards so a barrier should be considered.

3. From Table 2.8, the following considerations apply to the possible use of barriers:

Reasons to Use Barriers

a. Speed is high
b. The hazards are more severe that the description in Table 2.4
c. Traffic volume is high
d. There are multiple hazards at the site

Reasons Not to Use Barriers

a. The hazard is on a tangent
b. There is no downgrade
c. There are aesthetic concerns

Barriers are recommended for both approach sides to the bridge. Barriers are not needed on the far sides because the bridge rails are outside the opposing traffic clear zones.