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Case for Removing Bridge or Culvert Rails on Low-Volume Rural Roads

BOB L. SMITH

Concrete or masonry bridge rails, parapets, or hubguards (if more than 4 in higher than the roadway surface) on narrow bridges and culverts on low-volume (ADT < 400) rural (LVR) roads are dangerous roadside obstacles. Based on the current state of knowledge it is suggested that, in many instances, striking the end of a rigid bridge-culvert rail is more hazardous to the motorist than traversing the adjacent stream bed or drainage area when rails have been removed. The case for rail removal is supported by the effective widening of the roadway due to rail removal, convenience to farmers in moving wide, low farm equipment, and benefit/cost ratios. The benefits are estimated reductions in annual accident costs and were calculated by using current published data on estimated collision frequencies, accident severity indices, and accident costs. The costs are the estimated costs of rail removal. There is a need for roadside hazard research aimed specifically at the problem of quantifying the hazard of vehicles that strike bridge-culvert rails versus the hazard of vehicles running off the road after rail removal.

The concrete or masonry bridge rails, parapets, or hubguards (if more than 4 in higher than the roadway surface) on narrow bridges and culverts are dangerous roadside obstacles or hazards.

A bridge rail is a longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure (1). It is apparent, in driving on low-volume (ADT < 400) rural (LVR) roads, that in many instances it would be far better for the vehicle to go over the side of the structure than to strike the bridge rail, especially the end of the rail.

Informal discussions with roadside hazard research engineers at Texas Transportation Institute and Southwest Research Institute of "When is it better, on LVR roads, to strike the rail rather than traverse the ditch next to the culvert or bridge?" resulted in the following consensus: It is almost always better to take to the ditch than hit the bridge rail--unless the ditch is very deep, steep, or the culvert or bridge has a large drop off to its bottom. In other words, the best safety strategy is to remove the bridge rails on narrow LVR structures.

The validity of this consensus is supported by the widely accepted priority of actions or strategies with regard to existing roadside obstacles (hazards) (2; 3, p. 340; 4):

1. Remove the obstacle,
2. Relocate the obstacle to a point where it is less likely to be struck,
3. Use breakaway devices to reduce the severity,
4. Use impact attenuation devices to reduce severity, or
5. Protect the driver through redirection of the errant vehicle (use of guardrails or roadside barriers).

A roadside barrier is a longitudinal barrier used to shield hazards located within an established minimum width clear zone (1).

Strategy 1, removal of bridge rails, is supported by the American Association of State Highway and Transportation Officials (AASHTO) (1, pp. 111, 3, 5, 15).

> ...Current criteria suggest that bridge rails should be installed on all bridge structures; however, the view is now held by some highway engineers that these criteria are too restrictive and in some cases have resulted in the unnecessary use of bridge rails. A possible example of this would be their use on a short structure that spans a shallow stream or drainage area on a low-volume rural roadway. Many such structures do not have an approach roadside barrier to shield the bridge rail end. It is likely that the exposed end of the rigid bridge rail is more hazardous to the motorist than would be the stream or drainage area. Judgment must therefore be used to determine if the overall hazard of the bridge rail and the approach roadside barrier necessary to shield the bridge rail end is less hazardous than the roadside condition being shielded. Warrants for barriers to shield culverts can be established from the criteria in Section III-A....
>
> ...It has been said that a traffic barrier is like life insurance--it is good to have as long as it is not needed. Although this is an over-

statement, it cannot be overemphasized that a traffic barrier is itself a hazard. Every effort should be made in the design stage to eliminate the need for traffic barriers. Existing highways should be upgraded when feasible to eliminate hazardous conditions that require barrier protection. A traffic barrier should be installed discriminately and only when it is unfeasible to remove the hazardous condition...

...Typically the cost-effective procedure can be used to evaluate three options: (1) remove or reduce the hazard so that it no longer needs to be shielded, (2) install a barrier, or (3) leave the hazard unshielded. The third option would normally be cost-effective only on low volume and/or low speed facilities, when the probability of accidents is low.

...A clear, unobstructed flat roadside is highly desirable. When these conditions cannot be met, criteria to establish barrier need for shielding roadside objects are necessary. Roadside obstacles are classified as nontraversible hazards and fixed objects. These highway hazards account for over 30 percent of all highway fatalities each year and their removal should be the first alternative considered. If it is not feasible to remove or relocate a hazard, then a barrier may be necessary. However, a barrier should be installed only if it is clear that the barrier offers the least hazard potential....

In the AASHTO report (1) there are also several footnotes, tables, and special comments in recommended procedures that indicate that the fixed object should be removed or relocated, if practical, so that a barrier is unnecessary.

Strategy 2, relocate the obstacle, is usually not cost effective because of limited right-of-way, relatively high costs, and limited effectiveness on LVR roads (4). Strategies 3 and 4 are not applicable. Strategy 5, installation of guardrails, is not generally cost effective for any ranges of LVR volumes (4).

Thus, it appears there are two reasonable strategies to use on existing rails on narrow bridges or culverts on LVR roads:

1. Remove them.
2. Leave them as they now exist.

It would, of course, be very helpful if warrants were available for bridge rail removal. In the absence of such warrants the following is offered as guidelines for considering removal of rails.

GUIDELINES FOR REMOVAL OF BRIDGE RAILS

One of the primary practical reasons for removing the rails is for convenience to farmers in moving wide farm equipment (combines and discs, in particular) from one location to another. Most combines can be readily raised vertically 24 in above the roadway. Equipment, more than 24 ft wide, should be expected to be transported on trucks whose widths will generally be considerably less than 24 ft; thus, the clearance heights will be no problem. It follows, then, that bridges narrower than 24 ft that have rails over 24 in high on roads used for movement of wide farm equipment are likely candidates for rail removal. For safety, if the rails are removed they should be removed, preferably, to the height of the roadway surface or should extend no higher than 4 in above the surface.

Roadside Safety Considerations

Bridge and culvert rails are dangerous roadside obstacles (hazards). Where feasible, such roadside hazards should be removed since it is likely that the end of the rigid bridge rail is more hazardous to the motorist than the stream bed or drainage area. Judgment must be used in determining if the hazard of the bridge rail end is less than the hazard of the stream bed or drainage area. It appears likely that, for bridges or culverts 6 ft or less in depth, (i.e., the height of roadway surface above the stream bed), the bridge rail end is probably the greater hazard, and for depths greater than 9 ft the bridge rail end may be the lesser hazard.

For many narrow bridges and culverts it is obvious that the ditch at the culvert or bridge is no more hazardous than the mile after mile of unprotected roadside ditch. In these cases, the best strategy, from a safety standpoint, is to remove the bridge rail.

If the rail is removed, the roadway, in effect, is widened at that location. Figure 1 shows a minimum distance of about 0.5 ft from the centerline of outside wheel to inside of the rail for the safe traversing of a structure.

Figure 2 shows that, after rail removal, in an emergency the centerline of outside wheel could travel down the outside edge of the cut-off rail.

The effective widening, on one side of the roadway, is approximately w+0.5, where w is the width of rail in feet. For a 6-in rail width the widening of the roadway is 1 ft and for a rail width of 12 in the roadway widening is 1.5 ft. Where both rails are removed, the total roadway will be widened 2-3 ft.

In the case of a 16-ft-wide bridge-culvert, this provides an 18- to 19-ft clear roadway after rail removal, an increase in roadway width of 13-19 percent. This additional roadway width must certainly contribute to increased safety at the bridge site. A Minnesota study (6) reports on numerous studies that have documented that lane widths of 11 or 12 ft are significantly safer than 9- or 10-ft lanes. The same study shows a decrease in the accident rate of about 15 percent when pavement widths for rural highways are increased from 18 to 20 ft. Surely, then, there must be a significant increase in safety at a site where narrow bridge widths, from 16 to 22 ft, are increased by 2 or 3 ft. This should be especially significant when the width of an existing bridge is narrower than the approaching roadway.

Figures 3 and 4 show that the width in which a vehicle can impact the end of the bridge rail is about twice the width of the vehicle. The AASHTO report (1) uses an effective width of the vehicle of 92 in to represent an automobile in a partial skid. This shows that there is a 12-15 ft width in which a vehicle can impact the end of the rail. Any impact with the bridge rail end will probably result in a severe accident with a high probability of a fatality or injury accident occurring (1). The severity index (2) is estimated at 9 and estimated cost per accident is $160 000.

Assume now that the rail has been removed. If a vehicle encroaches as shown in Figures 3 or 4, it appears likely that:

1. The vehicle's outside wheel may stay on the top of the cutoff rail (Figure 3), in which case the vehicle will incur little or no damage and the probability of an injury or fatality occurring is very low.

2. The outside wheel may drop over the cutoff edge, which will probably cause vehicle damage and perhaps injuries to occupants. From a Texas Transportation Institute (TTI) report (5, p. 25), this might be compared with striking a culvert headwall

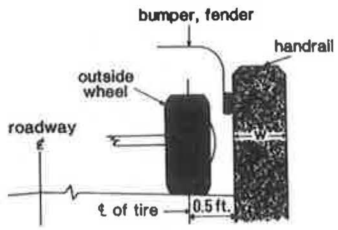


Figure 1. Effective roadway width before rail removal.

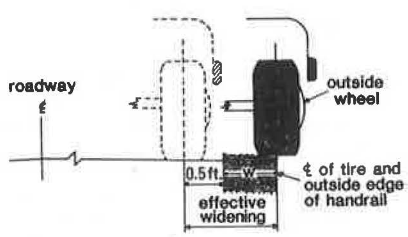


Figure 2. Effective widening of roadway on one side after rail removal.

Figure 3. Impact on outside edge of vehicle.

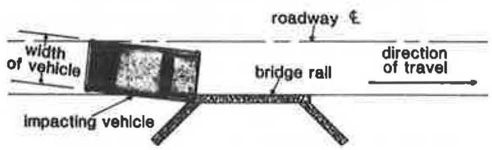
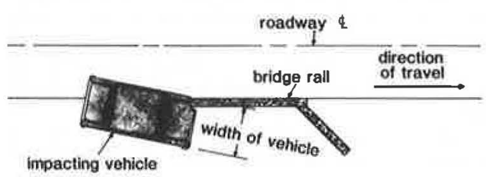


Figure 4. Impact on inside edge of vehicle



with a severity index of 7.9 with an estimated cost per accident of $120 000.

3. The vehicle may vault over the edge and land in the drainage ditch. If the ditch is low and relatively smooth, the severity index is estimated to lie between 3 and 5 and costs per accident between $6000 and $17 000, respectively (5, p. 25).

By using material in the TTI report (5, p. 25), the estimated annual accident costs for the above examples are given in Table 1 for average daily traffic (ADT) of 50, 100, and 200 vehicles.

For narrow bridges one would also expect some additional accident costs based on the probability of striking the bridge rail on the left. This additional cost is not included in Table 1. Note that the annual accident costs in Table 1 are for one side of a structure. The annual costs for rails on both sides of the road would be expected to be about twice the costs in Table 1.

The accident costs in Table 1 suggest that the removal of a rail on one side of a bridge will result in the reductions in annual accident costs as shown in the table below.

	Accident Cost Reduction ($/year)	
ADT	Range	Average
50	0-88	44∿50
100	0-192	96∿100
200	0-400	200∿200

Table 1. Annual accident costs for various severity indexes and ADTs.

		Annual Accident Costs[a] ($)		
Severity Index	Cost per Accident ($)	ADT = 50 cf[b] = 0.000 55	ADT = 100 cf[b] = 0.0012	ADT = 200 cf[b] = 0.0025
3	6 000	3	7	15
5	17 000	9	20	43
7.9	120 000	66	144	300
9	160 000	88	192	400

Notes: Assumption is that bridge rail is 10 ft long x 1 ft wide, located at roadway edge.
cf = collision frequency (accidents per year).
[a]Annual accident costs = cost per accident x cf (accidents/year).
[b]From TTI report (2, Figure 5.1.17).

Table 2. Present worth of future accident cost reductions.

		Present Worth of Future Accident Cost Reductions for n years ($)			
ADT	Approximate Avg Annual Cost Reduction ($)	n = 1 Year	n = 2 Years	n = 5 Years	n = 10 Years
50	50	45	87	190	305
100	100	90	174	380	610
200	200	180	348	760	1220

Note: Present worth = average annual accident cost reduction x $^{i}_{n}$PWF where PWF = present worth factor at interest rate i and n = number of years' accident reductions; i = 10 percent; n = 1, 2, 5, 10 years; and $^{10}_{1}$PWF = 0.9, $^{10}_{2}$PWF = 1.74, $^{10}_{5}$PWF = 3.8, $^{10}_{10}$PWF = 6.1.

Table 3. Benefit/cost ratios.

		B/C Ratios			
ADT	Cost of 1 Rail Removal ($)	n = 1 Year	n = 2 Years	n = 5 Years	n = 10 Years
50	50	0.90	1.74	3.80	6.10
	100	0.45	0.87	1.90	3.05
	500	0.09	0.17	0.38	0.61
100	50	1.80	3.48	7.6	12.2
	100	0.90	1.74	3.8	6.1
	500	0.18	0.35	0.76	1.22
200	50	3.60	6.96	15.20	24.40
	100	1.80	3.48	7.60	12.20
	500	0.36	0.70	1.52	2.44

Table 2 gives the present worth of various future accident cost reductions for ADTs from 50, 100, and 200 vehicles.

The benefit/cost (B/C) ratios for various ADTs, cost per rail removal, and number of years of accident reductions are given in Table 3.

Benefits are assumed to be the present worth of future accident cost reductions for a selected ADT and number of years of accident reductions (n).

Costs are the cost of removing one rail.

For example, the B/C ratio for ADT = 100, cost of one rail removal = $50, and n = 2 years is

B/C = $174 (from Table 3)/$50 (cost to remove one rail) = $3.48

B/C ratios greater than 1.0 show that the benefits received are greater than the costs incurred.

It is apparent from Table 3 that significant economic benefits are gained from rail removal, especially when the costs per rail removal are in the $50-$100 range.

The benefits may be even greater if the outside rails are removed from the bridges or culverts on horizontal curves. Glennon (4), the Minnesota study (6), AASHTO (1), and TTI (5, p. 25) clearly show the need for additional roadway widths on the outside of horizontal curves.

One of the vexing problems with the removal of rails from existing narrow bridges or culverts is that of liability of the local government unit. Since most of the structures in question were built many years ago under then-prevailing width and roadside barrier standards, it appears that leaving the structures as they exist will not result in liability for the governmental unit.

On the other hand, their removal may increase safety. It seems likely that if rails are removed and an accident occurs there may be some lawsuits in which it is claimed that striking the old rail was safer than the new design (i.e., rail removed). Claims that the old rail was safer and proof of this are probably more difficult to deal with than proof that rail removal is safer.

RESEARCH NEEDED

There is a need for some roadside hazard research aimed specifically at this problem. County or local road engineers need warrants for bridge and culvert rail removal or a set of guidelines for quantifying the hazard of vehicles striking various bridge and culvert rails versus the hazard of vehicles running off the road into the adjacent ditch, stream bed, or drainage area.

It would be most helpful if a set of, say, severity indexes were developed for specific roadside hazards on LVR roads considering typical speeds, roadway cross-sections, alignment, and roadside hazards.

ACKNOWLEDGMENT

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Cost Responsibility for Low-Volume Roads in Virginia

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Cost responsibility is a research tool for determining the amount highway user groups should contribute to the financing of highways. Several cost-responsibility studies have been conducted at the national and state levels; however, most have omitted from analysis the cost responsibility for low-volume roads. This study presents the method and calculations of cost responsibility for Virginia's 43 000 miles of low-volume roads. Costs were divided for allocation purposes into three categories—occasioned, demand-driven, and common costs. Costs in the categories are divided among four vehicle classes by various methods. Data and methods for three major cost areas are described in detail: site preparation and geometry, pavement construction, and pavement repair and resurfacing. The results of the study show that 75 percent of the costs on low-volume roads is the responsibility of cars and light trucks. The remaining 25 percent is the responsibility of heavy trucks. The study also shows that on low-volume roads the per mile cost responsibility for each vehicle class is more than twice that of high-volume roads.

Cost responsibility has emerged as a central issue in nearly every recent discussion of highway financing. The term cost responsibility has come to mean an analysis of the extent to which highway user groups contribute an equitable share of the costs of financing highways. At the federal level, Congress mandated the completion of a four-year cost-responsibility study by 1982; in the states, at least 20 cost-responsibility studies have been undertaken in the past few years.

Interest in cost responsibility has been spurred by the impact of several recent phenomena on the highway financing system. Highways in the United States are unique among publicly financed facilities in that they have been financed largely by those who use the roads. At the national level, about 70 percent of highway funding has come from user payments (1). The dedication or earmarking of user payments for highway financing has been held to be a major factor in the comparatively high level of development of the highway system (2). In recent years, however, funds from user payments have not met expectations for the continuing development of the system. The Arab oil embargo, mandated increases in fleet fuel efficiency, restrictions on the supply of motor fuel, and general economic malaise have contributed to the revenue shortfall.

The failure of established user tax sources to produce the expected amount of revenues gives impetus for a change in the level or structure of highway taxes. From a political perspective, it is easier to pass tax increases if the burden is distributed fairly. In a social sense, the charges for highway use can suboptimize the resource allocation and consumption patterns for highways. This can be accomplished by establishing an equitable and effi-