Pennsylvania's Guide Rail Standards: A Cost-Effective Change

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Over the past seven years, we have seen a revitalization of Pennsylvania's highway system. Under the leadership of Dr. Thomas D. Larson we have seen over 25,000 miles of highway rehabilitated or reconstructed. We have seen almost 500 bridges rehabilitated or reconstructed. We have enacted not one, but two Billion Dollar Bridge Bills. We have transferred ownership of over 2,000 miles of basically local use highways to municipal governments. And we have seen the revenue initiatives necessary to provide the funding for a highly energized staff to meet the challenges associated with these accomplishments. In short, we have made a difference.

One of the priorities of the Larson Administration at PennDOT has been maintenance first. By this, we mean that the rehabilitation and restoration of our existing roads and bridges takes priority over all other functions in the Department. Pennsylvania currently has over 42,000 miles of highway which are owned and maintained by PennDOT. This total exceeds the entire state-owned milage of all the New England states plus New York state. Nevertheless, we have developed a cycle which enables us to restore over 6,000 miles of highway each year. These restoration projects do not merely involve roadway improvements; they are all-inclusive. The roadway surface is improved, shoulders are upgraded, and the appropriate drainage and guide rail improvements are made.

Like all public institutions, PennDOT does not have an endless supply of funds, even though some lawyers might argue that we have deep pockets. To better manage our highway restoration programs, in 1983 we sequestered a task force of some of the Commonwealth's top managers, and charged them with development of a system to manage our paving programs. The result was STAMPP, the Systematic Technique to Analyze and Manage Pennsylvania Pavements. This methodology provided excellent information on the pavement surface, but was still lacking in information on other components of the roadway environment, specifically the drainage and highway safety hardware. A second task force, composed of another group of Department engineers, was charged with developing a methodology to inventory the type, location, and condition of drainage and guide rail along our state highways. Without boring you with a great many details, suffice it to say that this task force was successful in developing and implementing a methodology to survey the amount and condition of all guide rail and drainage facilities. Both surveys were initiated in 1985, the guide rail being update annually, and the drainage being collected over a four-year period and updated periodically based on the type and condition of the particular drainage appurtenance.

One of the major findings of that task force was the fact that we had a significant amount of guide rail along our highways which, in our opinion, was of questionable value. Admittedly we did find a number of guide rail installations which we did not question either the need for, or the adequacy of. However, we did find a lot of substandard guard fence badly in need of replacement. We also found some old and dilapidated guard fence, which in our opinion, was not needed. We found short, non-functional sections which were more of a hazard than the hazard they were trying to protect us from. We found substandard end treatments, which may pose more of a safety hazard than if the slope behind were left unprotected. We found non-functional bridge end treatments. And we found guide rail that met all acceptable standards, but was really not needed. In one case, it could be argued that the guide rail would prevent errant vehicles from entering the school yard, an argument that none of us would question. We also encountered guide rail protecting errant vehicles from brand new vehicles. While I am sure that the Chevrolet dealer appreciates this guide rail, I don't think it is PennDOT's responsibility to protect his new vehicles, given the roadway and geometric conditions prevalent at this site.

Clearly, there was a need to take a hard look at the standards which led to installations such as those which I have just presented. Secretary Larson agreed with this assessment. Enter task force number three. We assembled a multi-talented group of individuals representing highway safety, design, maintenance, research, and program development. We included representatives from all three levels of PennDOT: Central Office, District Offices, and County Maintenance Offices. And, to keep us all honest we included a representative of the Federal Highway Administration's Pennsylvania Division Office. A meeting with top officials in PennDOT, including Secretary Larson and a number of his Deputies, made it very clear that they felt the time was ripe for a change in our thinking regarding guide rail standards and warrants. The task force was charged with a four-point program:

1. Evaluate and reestablish guide rail warrants using a cost-effectiveness analysis.
2. Identify areas where existing guide rail can be removed.
3. Review design standards and recommend areas of cost reduction.
4. Recommend an implementation program.

Our first step was to conduct an exhaustive literature search. Promising articles were distributed among the task force members for review, to sort out the useful and useless. In the end, we resolved that the way to go, at least for Pennsylvania's purposes, was included in AASHTO's Guide for Selecting, Locating and Designing Traffic Barriers. Most specifically, Chapter VII, which presents a cost-effectiveness methodology. This methodology addresses guide rail use based on encroachment frequencies, severity of impacting a warranting feature, embankment slopes and heights, and available clear zone. The analysis considers three options for each situation:

1. Remove or reduce the hazard so that shielding is not necessary, such as flattening slopes;
2. Install a barrier; and
3. Do nothing; leave the hazard unshielded.

Put another way, we all know the purpose of a barrier system:

1. Protect vehicles from embankment slopes,
2. Protection from fixed objects, and
3. Protection from non-traversable roadside hazards.

The trade off, if you will, which we face is at what point is it more cost-effective to leave a slope unprotected and therefore allow vehicles to attempt to negotiate the unprotected slope, rather than installing a barrier which will surely be impacted.

The formula used in the AASHTO Barrier guide is really quite straight-forward: it compares the total annual cost associated with the obstacle to that associated with a barrier. In the case of a slope, the slope, the slope itself is considered the obstacle. The formula takes into account the initial cost, average damage cost per accident, average maintenance cost, average occupant injury and vehicle damage cost per accident, estimated salvage value, and, most importantly, collision frequency.

The collision frequency is characterized by this formula:

$$C_f = E_f / 10{,}560\ [(L+62.9)P1 + 5.14\ P2]$$

The Formula includes factors for encroachment frequency, Ef, horizontal length of the obstacle, L, probabilities (P1 and P2) of an encroachment equaling or exceeding a given lateral displacement, A. We looked at ADT values of 20,000, 5,000, 2,000, 750, and 400 vehicles per day, which correspond with ADT breaks in PennDOT's design standards. The following chart shows the values used in our analysis.

ADT	A (rail) (feet)	A (slope) (feet)	E_f	P1 (%)	P2 (%)
20,000	10	12	7.5	93	90
5,000	8	10	2.0	95	93
2,000	6	8	3.4	97	95
750	4	6	1.4	98	97
400	2	4	0.8	99	98

For example, given an ADT of 20,000, guide rail was assumed to be placed 10 feet from the edge of the roadway, the slope was assumed to begin 12 feet from the edge of pavement, the encroachment frequency was 7.5 (taken directly from AASHTO's table 5.1.16), and the two probabilities were found to be 93 and 90 percent, again based on AASHTO formulas.

Standard AASHTO-recommended values were modified to incorporate Pennsylvania-specific conditions. A fatal accident was valued at $299,100, an injury accident at $13,080, and PDO accident at $1,680. These are the very same values used in our Highway Safety Improvement Program in Pennsylvania. These figures were combined with Pennsylvania accident history data to develop severity indices using Glennon's formula:

$$SI = 24F + 6I + P/N$$

Guide Rail installation costs were likewise based on actual Pennsylvania experience: $10.00 per linear foot for weak post guide rail, and $16.50 per foot for strong post guide rail. An average damage cost of $400 per incident was determined from previous damage experience. An average maintenance cost of $1.50 per foot, and salvage value of $3.00 per foot were both based on data extracted from Pennsylvania's Highway Maintenance Management System.

Guide rail lengths of 150, 300, 500, 750, and 1,000 feet were then analyzed to determine the total annual cost associated with each guide rail installation. The total

annual cost for a slope of the same length was then equated to these figures to, in essence, work backward to determine the maximum height of slope which would be acceptable, from a cost-effectiveness standpoint. With all other factors known, we then solved for the average accident cost associated with the slope. This dollar value was equated to a severity index based on the aforementioned Pennsylvania-specific figures, and the height of the slope Pennsylvania-specific figures, and the height of the slope was calculated from the formula shown below.

$$\log SI = 0.556 + 0.160 \log h + 0.324 \log s$$

A microcomputer program made the job fairly easy. The result was the set of embankment warranting criteria for ADT shown here.

Slope	More than 5,000	751- 5000	400- 750	Less than 400
1 ½ :1	4[a]	6	9	17
2:1	8	10	16	31
2 ½ :1	12	16	25	49

[a] In feet

You will note that the 2,000 ADT figure is not included. This particular ADT yielded values very similar to those found at the 5,000 figure, so the two were combined into a single listing. Three observations immediately come to mind as you review our findings:

1. As ADT decreases, reduced accident frequency permits greater slope height.
2. As the rate of slope decreases, the reduced severity associated with it permits greater slope height.
3. The greater the length of slope, the greater the slope height.

Further work by the task force resulted in a number of significant recommendations.

1. The height of weak post guide rail should be reduced to 30 inches for all new construction.
2. The height of strongpost guide rail should be reduced to 27 inches, and rub rail should be eliminated, for all new construction.
3. The standard bridge protection should be reduced to a minimum length of 50 feet. This previously had been 125 feet.
4. The minimum length of guide rail in advance of an obstruction should be reduce to 50 feet.
5. Each District Engineer retains the option of providing guide rail treatment at locations with a previous accident history of the potential for accidents, at locations where personal safety would be compromised, and in socially sensitive areas.
6. Undoubtedly, the most significant finding of the task force, is that the chart be adopted as Pennsylvania's guide rail warranting criteria for slopes.

Based on these recommendations, we conservatively estimate that the Pennsylvania Department of Transportation can save over $5 million per year in guide rail installation and maintenance costs. We estimate the annual cost to remove unwarranted guide rail at $1.8 million over each of the next four years, leaving a net savings of $3.4 million per year.

It was our further recommendation that these monies be plowed back into the guide rail improvement program, to enable the Department to upgrade substandard guide rail which will still be required under the new criteria. An annual program to systematically upgrade substandard guide rail in accordance with these criteria can produce savings in terms of improved highway safety, reduced tort liability, and decreased maintenance needs. As a first step, each District has been asked to include projects to upgrade guide rail protection of bridge parapets as part of their annual highway safety efforts.

These recommendations were presented to top management, which enthusiastically endorsed them and forwarded them to the Federal Highway Administration for their approval. After a period of approximately 3 months, we received word from FHWA that they likewise concurred with the concept and approved the warranting criteria as presented.

We have printed and distributed these revisions, and our District designers have incorporated the revised criteria into projects to be constructed in 1986. We think these criteria present a logical, cost-effective means of dealing with the problems associated with too much outdated guide rail and guard fence, while at the same time recognizing our responsibility to provide for safe highway environment for our motoring public. The effects of limited highway budgets, make this cost-effectiveness approach the only sensible means of dealing with this challenge. In Pennsylvania, we like to think it will keep us out of some very big holes.