VDOT Virginia Department of Transportation

VTRC Virginia Transportation Research Council

A Benefit-Cost Analysis Tool for Assessing Guardrail Needs for Two-Lane Rural Roads in Virginia

Perspective In Virginia, run-off-the-road crashes represent 64 percent of all roadway crashes. Guardrail can shield vehicles from roadside hazards such as trees, culverts and embankment slopes. The Virginia Department of Transportation (VDOT) *Road Design Manual* provides guidance to help VDOT determine where to install guardrail.

Guardrail shields an embankment slope on a low-volume Virginia rural road. (VDOT i-vision image)

These guidelines sometimes can warrant putting in guardrail at a location on a two-lane low-volume road where installation may not be practical. Moreover, the guidance in the *Road Design Manual* does not specifically consider guardrail benefits and costs or the crash history of rural low-volume roads.

The Virginia Transportation Research Council (VTRC), VDOT's research division, developed and tested a simple spreadsheet tool to provide benefit-to-cost comparisons for guardrail installations on two-lane, low-volume roads. The tool takes into account the expected frequency and severity of crashes both into the existing roadside hazard and into the proposed guardrail. Called the "Low-Volume Road Guardrail Benefit-Cost Analysis Tool," it can quickly approximate benefit-to-cost analyses of guardrail for these rural two-lane roads.

The tool mimics the "input-output" relationship of a sophisticated computer modeling program — the Roadside Safety Analysis Program, version 3 (RSAPv3) — which the Transportation Research Board issued in 2012. If the same information related to guardrail installation is entered into the spreadsheet tool as would

be set up in a run of the RSAPv3 model, the tool will, with good accuracy, calculate the RSAPv3 output — a benefit-to-cost ratio. The VTRC's spreadsheet tool takes much less time and effort to produce that output than it would take to set up, check and run the RSAPv3 model.

VDOT area traffic engineers can use the ratio output to compare guardrail benefits — i.e., the expected reduction in the societal costs of crashes before and after guardrail installation — on low-volume, two-lane roads to the direct costs of guardrail — including construction, maintenance and repair.

The study recommends that VDOT's Traffic Engineering Division encourage the use of the new spreadsheet tool when considering the need for guardrail at locations on low-volume two-lane roads. Incorporating the benefits and costs of guardrail use into the decision-making process likely will lead to more efficient allocation of VDOT resources.

VDOT's Traffic Engineering Division will encourage users of the tool — VDOT area traffic engineers — to provide the VTRC researchers with results and feedback for two years on how the tool performs. VTRC will use the feedback to help refine the tool.

$r^2 = 0.943$
Slope = 0.980
RMSE = 2.32
Bias = -0.07
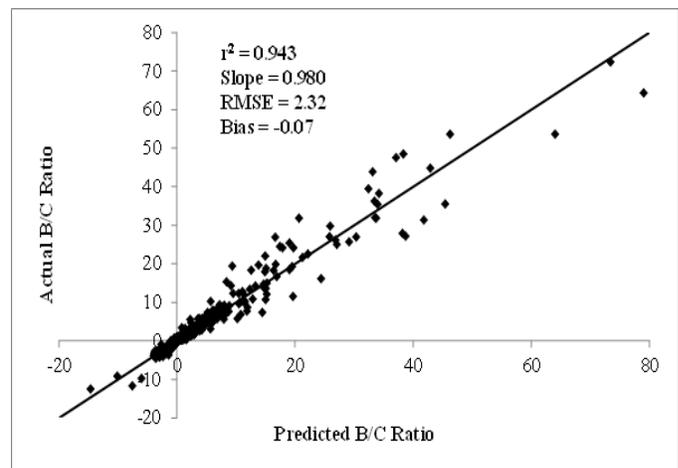
Plot of actual vs. predicted RSAPv3 output benefit-to-cost ratio

For the full report, search 16-R5 📄 at vtrc.virginiadot.org. For more information about the study, contact Justice Appiah, VTRC research scientist, Justice.Appiah@vdot.virginia.gov.

Background VDOT's Area Traffic Engineers Committee requested the VTRC study that resulted in the development of the Low-Volume Road Guardrail Benefit-Cost Analysis Tool. Area traffic engineers wanted to make informed, defensible investment decisions about installing guardrail on low-volume roads across the state.

To do that, they needed additional guidance beyond that provided by the warranting method set forth in VDOT's *Roadside Design Manual*. The committee suggested that VTRC use the Roadside Safety Analysis Program (RSAP) software to develop a tool that gives the same benefit-to-cost ratio results as RSAP but that is easier to use.

RSAP simulates the complex interactions among road, roadside and traffic characteristics to predict the likelihood and severity of crashes into roadside hazards and the associated costs. The difference in crash costs reported by RSAP for two scenarios — one with and the other without a guardrail — constitutes the expected "benefit" of installing the guardrail. This benefit is compared to the direct costs associated with the guardrail to derive a benefit-to-cost ratio estimate.

In 2012, a National Cooperative Highway Research Program study updated RSAP to incorporate new research findings developed in the 10 years since the software's initial release. The updated version, RSAPv3, was used for this study. It is the most comprehensive tool available for evaluating the cost-effectiveness of roadside safety treatments.

Research and Recommendations RSAPv3 has numerous factors that affect the output benefit-to-cost ratio. The researchers, informed by a review of the literature and discussions with VDOT staff, considered a subset of nine factors most relevant for this study. The factors used were average daily traffic; vertical grade; lane width; hazard size; hazard offset; guardrail length; guardrail construction cost; cost of a fatal crash; and a metric to quantify hazard severity.

The VTRC research team generated 120 test cases consisting of plausible combinations of the nine selected factor values. The researchers then ran those cases in RSAPv3 to obtain the benefit-to-cost ratio output. The team used the data from the RSAPv3 runs to develop a predictive model using a statistics software package. The model they developed operates in such a manner that the

benefit-to-cost ratio it predicts for each of the 120 test cases is an exact match of the actual RSAPv3 output.

The researchers used standard statistical procedures to check the validity of the model they developed. Results indicated good agreement between the actual RSAPv3 benefit-to-cost ratio output and the model-predicted benefit-to-cost ratios. Thus the predictive model is a good approximation of the true input-output relationship in RSAPv3 and may serve as a surrogate to RSAPv3 for Virginia two-lane road guardrail benefit-to-cost analyses.

The research team embedded the predictive model in a simple spreadsheet tool for easy, practical application. Once set up, the tool calculates benefit-to-cost ratios almost instantaneously. The study provides example problems to demonstrate how the tool can be used to distinguish cases for which the application of guardrail is potentially cost-beneficial from those that are not.

ADT:
Speed Limit (mph):
Grade (%):
Lane Width (ft.):
Hazard Type:
Hazard Severity (EFCCR):
Hazard Size (ft.):
Hazard Offset (ft.):
Guardrail Length (ft):
Construction Cost ($):
Fatal Crash Cost ($):

Benefit-Cost Ratio   ---

Comments:

USER GUIDE   SEVERITY CALCULATOR   **BENEFIT-COST RATIO CALCULATOR**

Screenshot of the analysis tool showing the benefit-to-cost ratio calculator

This research contributes to VDOT's goal of using data-driven models to prioritize and determine how VDOT allocates transportation funding. The potential is high for widespread use of the Low-Volume Road Guardrail Benefit Cost Analysis Tool by VDOT area traffic engineers; they reviewed and provided feedback on the tool as VTRC developed it.