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Summary:

Cost-benefit analysis of new standards for guard rails in Norway

This report contains a cost-benefit analysis of new standards for guard rails on public roads in Norway. A preliminary edition of the new standards was issued by the Public Roads Administration in November 2000.

Standards for guard rails

The standards for guard rails are part of the design standards for roads in Norway. The standards contain warrants for the use of guard rails, guidelines for the choice of type of guard rail, and technical specifications for installing guard rails. The warrants for the use of guard rails specify, in fairly great detail, the types of hazards from which road users are to be protected by means of guard rails. Such hazards include steep side slopes, rocks near the roads, lakes near the road, and a number of fixed objects, like bridges.

The previous standards for guard rails was issued in 1993. In the new standards, the warrants for using guard rails have been tightened. This means that there will now be more locations that satisfy these warrants, and where guard rails are to be installed. The current design of guard rail ends, which is to turn the guard rails down and anchor them in the ground, is no longer permitted. Using guard rails to separate oncoming traffic on wide roads that no not have a median is now permitted.

Measures included in the cost-benefit analysis

According to the guard rail standards, alternatives to using guard rails should always be considered. In addition to guard rails, alternative measures were therefore included in the cost-benefit analysis. More specifically, the following measures were included:

- Guard rails along the roadside, to protect from steep embankments or other hazards
- Median guard rails on divided highways
- Median guard rails on wide, but undivided highways
- New design of guard rail terminals
- Prolonging guard rails to eliminate terminals

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- Removal of fixed objects near the road, as an alternative to guard rails
- Flattening of side slopes near the road, as an alternative to guard rails.

The analysis included national roads in Norway only. These roads were classified into 16 groups according to type of road, speed limit, and traffic volume. Around 1,300 police reported injury accidents are recorded annually on these roads. Accidents in which a guard rails was struck are not included.

The effects of guard rails

Guard rails are mainly intended to reduce accident or injury severity. Installing guard rails may., however, affect the number of accidents as well, not just their severity. The effects of guard rails along the roadside and median guard rails have been extensively evaluated. The results of these evaluation studies were summarised by means of meta-analysis. Results were stated in as great detail as possible. The effects of median guard rails on undivided roads and of the new design of guard rail terminals are not very well known.

Assumptions made in cost-benefit analysis

It was assumed that guard rails, and the alternative measures to guard rails, affect the number and severity of accidents only. In other words, these measures do not have any effect on mobility or the environment. Road accident costs stated in 1999-prices were used. These costs are (1 NOK = 0.11 USD):

One fatality	20.84 mill NOK
One very seriously injured person	14.27 mill NOK
One seriously injured person	4.70 mill NOK
One slightly injured person	0.63 mill NOK

Property-damage-only accidents were not included. A discount rate of 5% per year was used. Annual traffic growth was assumed to be 1.4%. The time horizon of the analysis was 30 years. The social opportunity cost of tax-funded public expenditures was assumed to be 1.2 times the outlays on public budgets. It was assumed that the length of need for guard rails is 1.5 times road length, meaning that there has to be a guard rail on both sides of the road in 50% of the cases.

Results of cost-benefit analysis

A total of 246 combinations of road classes and measures were analysed. 176 of these refer to guard rails along the roadside (including terminals), 6 refer to median guard rails, and 64 refer to alternative measures.

Benefits were greater than costs in 127 of the analyses, which equals 52%. In general, benefits exceed costs for most measures on roads that have a traffic volume of more than 10,000 vehicles per day. On roads that have an AADT below 1,500, benefits were in no cases greater than costs.

Guard rails along the roadside are most cost-effective to protect from rock sides, trees and bridges. Guard rails are cost-effective on steep and high embankments. The new standards warrant the use of guard rails on embankments that are less steep and lower than the older standards. These changes are in most cases not cost-effective, i. e. costs are greater than benefits.

Median guard rails on divided highways – in Norway motorways – is cost-effective, provided steel guard rails are used. Guard rails to separate oncoming traffic on undivided highways is cost-effective if traffic volume is more than 5,000 vehicles per day, otherwise not.

The new design of guard rail end terminals is not cost-effective. The reason for this, is that there are rather few accidents involving vehicles that strike guard rail ends. It is more cost-effective to prolong guard rails, thereby reducing the number of terminals.

Removing fixed objects close to the road is very cost-effective, provided it can be done at a cost of no more than 50,000-100,000 NOK per kilometre of road. It was assumed that this measure mainly consists of cutting down trees near the road, in terrain where guard rails are not warranted.

Flattening side slopes is, in general, less cost-effective than installing guard rails.

Can the results be trusted?

The results of any cost-benefit analysis are obviously uncertain. As part of the analysis, a sensitivity analysis was made with respect to three parameters:

- The effects of guard rails on the number and severity of accidents
- The length of need for guard rails
- The discount rate

As far as the effects of guard rails and alternative measures are concerned, a worst case and a best case were defined. These cases corresponded to the 95% confidence limits for the effects of the measures. For guard rail length of need, 1.2 times road length, and 1.8 times road length were used as alternatives to 1.5 times road length, which was the best estimate. For the discount rate, 8% per year was used as an alternative to 5% per year.

It was found that the results of the cost-benefit analysis were quite sensitive to the assumptions made regarding the effects of the measures in road safety. In the basic analysis, costs exceeded benefits in 52% of the cases (246 in total). In the worst case analysis, this share dropped to 22%. In the base case analysis, it jumped to 70%.

Results were more robust with respect to the other two factors for which a sensitivity analysis was made. The share of analysis in which benefits exceeded costs ranged from 46% to 59%, depending on the assumptions made about the length of need for guard rails. Using a 8% discount rate, reduced the share of cost-effective measures from 52% to 41%.

Can the use of guard rails be based strictly on cost-benefit analysis?

The analyses that have been made indicate, even if one relies on the most optimistic version, that guard rails are almost never cost-effective on roads with an AADT below 1,500. If taken literally, the analyses imply that guard rails should not be installed on any of these roads.

This is obviously a troublesome conclusion, especially in Norway, where many low volume roads pass along fjords or in steep mountains. Running off the road in these remote and wild areas is definitely very hazardous. If highway agencies have an objective of protecting road users from a hazardous environment, then traffic volume is simply not relevant. The hazard posed by a deep lake or a steep hill do not depend on traffic volume.

It would therefore seem that, in practice, the priorities set for the use of guard rails in Norway cannot rely on cost-benefit analysis exclusively.