Institute of Transport Economics
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ENGLISH **Summary**

Disutility stemming from avalanche, landslide and rockslide risk

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During 2024–2025, there has been a clear need for a better understanding of the benefit component "disutility stemming from avalanche, landslide and rockslide risk" in cost-benefit analysis. This refers to willingness to pay (WTP) to reduce the frequency and width of avalanches, controlled for the risk of death, severe injuries and road closures. The study finds that WTP is stable across regions and recommends using a common valuation factor nationally but distinguishes between rail and road. The discomfort can be caused by factors such as minor injuries, material damage and subjective insecurity. Double counting is considered limited. The values are considered reasonable given the correct use of data and the recommendation for linear valuation. Non-linear features are considered, but complicated to implement. The study recommends sensitivity analyses and the use of adjusted avalanche data to ensure realistic results and emphasizes that the inclusion of these disutility estimates provides more complete analyses of avalanche protection measures.

Background and purpose

During 2024-2025, it has become clear that cost-benefit analyses that include the willingness to pay to reduce avalanche, landslide and rockslide risk (avalanche frequency and width) can have significant benefits. The background for the assignment is that the transport agencies needed better explain this benefit and ensure that the underlying data and methods are well founded, even in the case of remarkably large benefits. This is broken down into four central themes. The transport agencies therefore needed a good and easy-to-understand description of this willingness to pay, where the following factors are addressed:

1) A specific description of what has been captured, in a way that can be communicated to outsiders.
2) Double counting: The extent to which the effect may entail double counting of other factors that have already been captured elsewhere in the cost-benefit analysis.
3) Specificity: The extent to which the value is specific to the projects where the survey was carried out and thus should not be applied on a general basis.
4) Reasonableness assessment: An assessment of the magnitude of the beneficial effect of these values on projects where they have been tested.

Finally, we make a clear recommendation regarding the extent to which the values can be used as they are, or whether adjustments are needed for it to be applied.

What is captured by the disutility stemming from avalanche, landslide and rockslide risk

Since Navrud et al. (2020), we have had estimates of the traveller's willingness to pay for reducing the avalanche risk (avalanche frequency and width), when the risk of death, serious injuries, road closures and travel time have been controlled. In short form, we refer to this as **disutility stemming from avalanche risk**.

We normally do not know anything about the motives behind valuation. In stated preference studies (SP studies), we can ask about this, but do not necessarily get the full range of motives. Based on the literature and our own assessments, we have listed consequences that were not specified in the most recent valuation study of avalanche risk (Navrud et al., 2020) and thus are probably not controlled for. There are many consequences of avalanches, beyond safety and accessibility aspects for one's own travel, that can motivate willingness to pay for avalanche protection measures (see Chapter 2). However, we will emphasize the following consequences, which were not controlled in the SP study, as plausible drivers of disutility stemming from avalanche risk.

- Risk of minor injury
- Risk of material damage (e.g., vehicle)
- Accessibility aspects that are not captured by the “days of closure” attribute (e.g. the burden of road closure uncertainty, *regardless* of whether or not you plan to travel on the route)
- Subjective/perceived insecurity beyond objective serious accident risk

We do not have data to establish their relative importance in the motives behind the disutility associated with avalanche risk. There may also be other motives. However, we believe that these points are so extensive that the magnitude of the valuations of changed avalanche frequency and width (controlled for deaths, severe injuries, road closures and travel time) can be perceived as reasonable.

Possible double-counting

Under the accounting category “Society at large” in cost-benefit analyses (CBAs), there are a few points that we cannot rule out will be double-counted with estimated disutility stemming from avalanche risk.

The proportion of estimated accident costs associated with avalanches in a CBA that deals with minor damage and material damage can be double-counted with the disutility stemming from avalanche risk. This amounts to 6%-12% of the average estimated accident costs as a result of avalanches.

It may be the case that some assessment of the non-priced effects (NPEs) “Visual Landscape Impacts” and “Biodiversity impacts” of an avalanche measure emphasizes the effect of reduced frequency and size of avalanches as a result of the measures. In such a case (especially if it is visible from the road), we cannot rule out that some effects are double-counted.

Beyond this, we consider the risk of double counting of components in conventional cost-benefit analyses to be very low.

How representative are the parameters

Completed tests show no significant difference in the valuation of avalanche frequency and width between the investigated routes in Nordland, Hordaland and a generic avalanche-prone stretch of road or rail in Norway. There is also very little difference in the valuation of disutility from avalanche risk, regardless of whether their reference trip was in an avalanche-prone area. Based on this, and the fact that the range of variation for avalanche frequency and width in the survey covers the spectrum for avalanche-prone stretches in Norway, we consider the valuation of disutility from avalanche risk to be non-specific to the studied stretches of road or rail. We therefore recommend that the valuation factors be used in general.

However, we find a significant difference between valuation among train passengers and travelers on the road (bus and car). This difference may be due to the fact that, as shown in Chapter 5.4, the respondents have a higher valuation per avalanche at low frequencies than at high frequencies, and that the sample for train passengers was presented with choices that on average entailed lower avalanche frequencies. Concluding whether train passengers have a different valuation than travelers on the road, or whether the difference is due to the fact that they were presented with different levels of avalanche frequency, requires further work. Our assessment is that until this has been investigated further, it is reasonable to maintain the recommendation given in Magnussen et al. (2022). Here, one set of linear valuation factors for rail and road traffic was recommended.

Reasonableness assessment

It is important to note that the main reason why discomfort from avalanche risk is normally calculated as greater than all other benefits related to avalanches combined, is that *all* road users are exposed when they pass an avalanche point, regardless of whether avalanches occur. Since avalanches occur rarely, even on avalanche-prone stretches, few travelers are exposed by the direct effects (detouring, personal injuries and repair costs). **The fact that effects that are small per road user, but affect a large number of road users, are greater than effects that are large per road user who is affected, but affect few road users, should not be surprising**. To take a similar example, the road user benefit of saving a few minutes of travel time due to a road project will normally be significantly greater than a sharp reduction in serious accidents.

The question of whether the effect is of reasonable magnitude should be assessed on the basis of whether the individual components of the calculation are reasonable, rather than the final size of the effect. The following three questions can be asked

1) Is the valuation per traveler and per avalanche frequency and width reasonable?
2) Is the number of affected travelers reasonable?
3) Is the data on avalanche frequency and width used as input in the analysis reasonable?

Our assessment regarding point 1: Our overall assessment is that the valuation per traveler is reasonable, given realistic input data on avalanche frequencies and widths. The fact that avoiding the risk of avalanches on one of Norway's most landslide-prone stretches of national road is valued at the equivalent of saving about 15 minutes is not unreasonable. For combinations of avalanche frequencies and widths of a more normal nature (less than one avalanche per year, narrower than 10 meters wide), the valuation will correspond to the value of one minute or thereabout in saved travel time.

Our tests show that the respondents have monotonously increasing, but diminishing valuation with greater frequencies and widths of avalanches, landslides and rockslides. However, more work is required to determine whether and, if so, what form of function a non-linear valuation should follow. Furthermore, our assessment is that using a non-linear function for valuation of avalanche frequency will be very data-intensive and will probably require integration of (correct and adjusted) landslide point data in the Regional Transport Models (RTM) and integration of the valuation in RTM. If a linear valuation is used, and landslide points are used as a unit of analysis, analyses can be carried out relatively easily today. If avalanche risk per avalanche point, rather than per journey, is used in the valuation, part of the need for a non-linear valuation will in practice also be removed. Our assessment is therefore that it would be a safe, reasonable and appropriate approach to use linear valuation of avalanche frequency where the valuation is made per avalanche point. When it comes to exploring the use of non-linear valuation of avalanche width, we consider it more fruitful, as this will in all cases be combined with the use of avalanche points as a unit of analysis.

Our assessment regarding point 2: Since the valuation of avalanche frequency and width is very stable across groups, our assessment is that it is reasonable to assume that all road users who pass by avalanche points to be covered by the impact. However, when it comes to snow and ice avalanche risk, we find it unreasonable that road users should have any disutility associated with such avalanches outside the winter season, **when** it is not physically possible that such avalanches **can** occur. We therefore recommend that disutility from avalanche risk is only calculated for travelers during the winter season for snow and ice avalanches. For other types of avalanches and rockslides, travelers should be used as a basis for the whole year.

Our assessment regarding point 3: The use of unadjusted data on avalanche frequency and width from the Norwegian Road Data Bank's (NVDB) road object type 824 "avalanche point" will normally give greatly overestimated estimates of monetized disutility from avalanche risk. The adjustments recommended in Aalen et al. (2025) must be implemented to ensure reasonable results. However, the fact that correct data must be used in the calculations does not give grounds for questioning the reasonableness of points 1 and 2 above.

Our assessment of analyses carried out where errors in input data have not been prominent: We find the overall order of magnitude of the estimates of the disutility from avalanche risk to be reasonable. The estimated estimates have weaknesses, but with the methodology proposed in this report, these weaknesses can be minimized. At the same time, the results show that if errors in data on avalanche risk are cleaned from the analyses, results of a reasonable magnitude will be achieved. If the methodology and recommendations proposed in this report are used, our assessment is that reasonable estimates will be achieved.

Can we continue to use the parameters in the willingness to pay function as they are?

If the alternative is not to include "disutility stemming from avalanche risk" as a component of a CBA that includes avalanche measures, then we consider it far better to include the willingness to pay parameters as they are. Using the parameters as they are, it may be appropriate to carry out sensitivity analyses to test how robust the results in the CBA are to the parameter values. Using the parameters as they are, we propose the following:

- Sensitivity analysis of +/- 25% on calculated discomfort at avalanche risk. This represents a 95% confidence interval for the estimates
- In the case of analyses where the expected avalanche frequency is over 10 per year, and/or the expected avalanche width is higher than 120 meters, a sensitivity analysis can also be made with a 50% lower valuation of discomfort in the event of an avalanche risk. This will both help to highlight aspects of a declining willingness to pay function and help to mitigate the effects of the fact that this represents rarely avalanche-prone points and may be based on exaggerated assessments in NVDB's road object type 824 "avalanche points".

However, we see that it is possible to use a more precise willingness to pay function. Simple tests of non-linearity indicate that willingness to pay for both reduced avalanche frequency and width is monotonously positive but decreasing. This is thoroughly documented in Appendix B, where you can also find example calculations.

Implementing a positive, but decreasing, willingness to pay function for avalanche frequency is possible, but it increases complexity considerably. The willingness to pay to avoid disutility from avalanche risk is estimated at the travel level, not at the point level. If there is more than one avalanche point included in a CBA, one would prefer to know where the travelers drive from and to, which entails calculations from RTM, which is far too laborious in the short term.

We still believe that it is most appropriate for CBAs to use avalanche points as the unit of analysis to make it practically feasible. Since a trip can easily contain several avalanche points, often with frequencies of less than 10 per year (i.e. frequencies in the area where linear valuation underestimates travelers' valuation), there is a risk of overestimating if non-linear valuation per journey is used using landslide points as a unit of analysis.

It is less complicated to implement positive, but decreasing, willingness to pay functions for avalanche width, but it involves certain trade-offs. An important strength of the decreasing function is that expected avalanche widths of the order of 100 meters or more are not exaggerated. However, such avalanche widths are relatively rare, with approximately 80% of registered avalanches being smaller (Wangsness et al., 2024). Since the SP data cover almost the entire range of avalanche widths, it gives somewhat weak resolution within the interval of “normal” avalanche widths. It will also provide a significantly higher valuation than the previously recommended linear willingness-to-pay function at “normal” avalanche widths. In addition, the KlimaVei project points out that NVDB's road object type 824 “avalanche point” tends to exaggerate avalanche widths (typically with a minimum width of 20 meters, although this is significantly larger than what has been registered historically). We therefore consider it more appropriate to continue the linear willingness to pay function for reduced avalanche width but carry out sensitivity analysis with 50% lower valuation if the expected avalanche width in an avalanche point is 120 meters or greater. Analyses that include avalanche points with such avalanche widths should also require extra review of the input data, so that one has a good basis for assuming that the avalanche points in question actually have such "abnormally" large avalanches as an expected value.

Finally, we would like to point out the importance of using expectational data on avalanche frequency and width in analyses. Use of unadjusted data on avalanche frequency and width from NVDB's road object type 824 “avalanche point” will normally give greatly overestimated estimates of monetized disutility of avalanche risk. The adjustments recommended in Aalen et al. (2025) should be implemented to ensure reasonable results.

Correcting for possible double counting

As pointed out, we cannot rule out that there may be some double counting when a CBA of avalanche protection measures calculates both changes in accident costs and disutility from avalanche risk. In the worst case, this double count is limited to minor injuries and material damage. A conservative approach for the analyst would then be to subtract an amount from the calculated disutility of avalanche risk, which corresponds to a predefined proportion of the estimated accident costs associated with avalanches. In order not to make the burden on the analyst unnecessarily large, we consider it appropriate to deduct 9% of the estimated accident costs[2] from the estimated willingness to pay for reduced avalanche frequency and width. Such an item could be called, for example, "Deductions to prevent double counting of accident costs for minor injuries and material damage".

Furthermore, we consider it appropriate that the assessment of the NPEs "Visual Impacts on Landscape" and "Impacts on biodiversity" does not take into account the effect of reduced avalanche frequency and width on these NPEs, as a result of avalanche measures. It is appropriate to "tone down" exactly those aspects in the assessments of these NPEs so that they are not double counted. However, we believe that this will very rarely be decisive for the overall assessment of NPEs.

[2] Wangsness et al. (2024) find that minor personal injuries and material damage account for 6%-12% of the average estimated accident costs per case of avalanches that hit vehicles