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Ability to forecast avalanches

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Introduction

In January 1994 the SNV organised a conference on the subject of "Avalanches and juridical implications". On that occasion Dr. H.-K. Stiffler, a specialist on the subject of law on snow, held a report on the juridical fundamentals in general, in which he asserted that, from the legal point of view, avalanches (and the related accidents) could be forecast. At that time not all the persons present agreed with this statement[1]. On the pages that follow we shall analyse, from the scientific point of view, the ability to forecast the hazard of avalanches (namely of avalanches in general) and of a single avalanche, for the purpose of verifying the previous assertion in the light of today's knowledge.

Fresh snow, an important factor for the formation of avalanches

The major part of avalanches occurs during or just after a period of strong precipitations. The more the fresh snow is plentiful, major is the avalanche risk (fig. 1). On its own, however, the quantity of fresh snow is not sufficient for forecasting such a hazard. The formation of an avalanche is the result of interaction among more than one factor, among which precipitations, wind, temperature/solar radiation and the snow layer. Even if in the span of three days as much as 100 cm of fresh snow is accumulated,

[1] Cf. Ammann (1996, page 52). In the course of the discussion held during the conference, agreement was reached on the expression "fully able of being forecast". This formula was assimilated also in the 3rd edition of the Swiss Law on the subject of Sport on Snow (Schweizerisches Schneesportrecht, Stiffler, 2002).

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the avalanche hazard is not always “strong” or “very strong” (cf. fig. 1). Since the characteristics of the snow level may vary depending on the weather belt (more or less snowy), the quantity of fresh snow considered critical for the spontaneous formation of major avalanches varies depending on the weather belt. In areas particularly snowy, for example, such avalanches will tend to be present with greater probability starting from an 80 cm. thickness of fresh snow, while in an area with little snow the critical threshold will be equal, for example, at only 50 cm. The recurrence with which such critical values are recorded may be similar in both areas, for example about every 5-10 years.

In cross-country, for the purpose of evaluating whether the “marked” degree of hazard has been reached, reference is made to Werner Munter and to his concept of critical threshold of fresh snow. From some time now there exists a reference table (table 1) for major spontaneous avalanches which studies the relation between quantity of fresh snow and avalanche activity. The centimetres of fresh snow indicated on the table are values purely indicative, since the local conditions may determine parameters decidedly different – for example even only by effect of the geographical position within a determined weather belt.

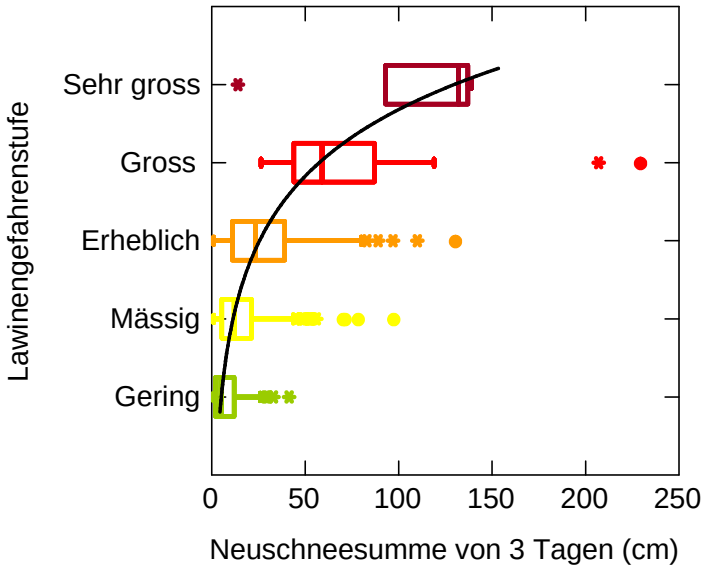

Figure 1: relation between the quantities of fresh snow fallen in three days and the degree of avalanche hazard (ascertained). Data based on: 10 years (from 1985/1986 to 1994/1995), test field: Weissfluhjoch, 2,540 metres above sea level.

Table 1: evaluation table relative to major spontaneous avalanches (damaging)[2]

Quantity of fresh snow	Consequences for buildings, communication roads and villages
Up to 30 cm	Hazard almost non-existent.
30 – 50 cm	Some buildings and communication roads at risk in unfavourable circumstances.
50 – 80 cm	Possibility of sporadic avalanches up to the bottom of the valley, single buildings and communication roads at risk.
80 – 120 cm	Are forecast more avalanches of major entity up to the bottom of the valley, isolated buildings, communication roads and certain parts of exposed villages are at risk.
More than 120 cm	Catastrophic situation, possibility of avalanches of major entities, even rare or up to then not observed; maximum hazard for villages and communication roads.

[2] The above mentioned table serves for evaluating the hazard of major spontaneous avalanches (damaging) (dry snow) to which are exposed buildings, communication roads and villages during or just after a period of plentiful snowing. The given centimetres of fresh snow indicate the increase of the fresh snow layer in the period of 1-3 consecutive days of snowing and which refer to the average accumulation of snow in representative test fields. It is generally assumed a favourable structure of the snow layer. The depth of detachment of avalanches, therefore, coincides approximately with the depth of the fresh snow layer. An unfavourable snow layer structure, instead, increases risks, since it can determine also the detachment of fragments of snow no longer fresh causing generally more consistent avalanches. The indicated values in the table are valid in case of relatively low temperatures, since the avalanche hazard decreases at about 0°C. Interruptions of snowing between a snowfall and the next, exercise a stabilising action, especially in case of higher air temperatures. Lowering of temperatures during the snowy period, or even changing from

Hazard of avalanches - avalanche

The degree of hazard forecast is always referred to a determined region. In case of a "very strong" hazard, according to the European hazard of avalanches scale, "several avalanches of major entities" are forecast. However, in one region there may be tens of avalanche prone sites. How is it then possible to evaluate the probability that an avalanche may start rolling in a determined area? Should an avalanche be forecast for each avalanche prone site?

From a statistics carried out, for example, for the Urseren Valley (region of San Goddard) it resulted that, during the unhappy winter of 1951, the fall of avalanches was observed in about one third of the areas of potential detachments.

In particularly serious circumstances, sometimes it is possible that, in the regions where the forecast avalanche hazard is "very strong", an avalanche is formed only in 10% of the avalanche prone sites. Does this mean that the avalanche barriers or the ordered evacuations were wrong? If the number of avalanche barriers is compared with the number of avalanches actually occurred during their happening, an average proportion of 5-10 is obtained: this means, for example, that an avalanche of considerable proportions occurs only every seven avalanche barriers. This number of consistent false alarms is due to the uncertainty of the forecast or, in other words, at the impossibility of forecasting the actual detachment of an avalanche within a determined avalanche prone site.

Generally, the probability that an avalanche occurs in a determined avalanche prone site is about equal, even in the case of "very strong" hazard, to less than 10%, for which the fall of an avalanche cannot be forecast accurately. In certain sites, however, the probability may be even greater. In this case – when infrastructures and especially roads are at risk – appropriate permanent measures of structural protections must be arranged, since, in their absence, the risk (deaths/year) could be equal to about 10^{-2}.

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rain to snow at the beginning of such a period, has a positive effect, contrary to a rise of temperatures after a cold start.

Ability to forecast a single avalanche

Even if the formation of a single avalanche depends on the complex interaction among multiple meteorological parameters and the snow layer, there is a constant to be considered: the ground. Avalanches occur always on the same places, notwithstanding the continuous change of the conditions. The construction of snow sheds is useful and possible just thanks to this. It follows, therefore, that above all the avalanches of major entities are widely possible to be forecast in terms of place, since it is practicably impossible that a mass of such proportions detaches outside from a well known avalanche prone site at an inappropriate moment. However, surprises do happen. Instead, as previously mentioned, it is not possible to forecast neither the exact moment of the disaster nor the precise dimensions of an avalanche near the area of the deposited snow.

In cases of avalanches caused by skiers, the situation is slightly more complex, since skiers run very different grounds. It follows that also the place of the detachment is determined mainly by fortuitous reasons that cannot be singled out beforehand. Even for this typology of avalanche, it is generally possible to forecast the ground on which an avalanche prone activity may occur. Even the periods of greater avalanche risk may be forecast in a reliable manner, although, even in case of probability and therefore greater located hazard, the possibility that an avalanche may occur on a determined versant is generally rather low. Concerning the avalanches caused by skiers, it is not possible – also due to the variability of the snow layer – to forecast the location and the exact moment of their detachment. On the other hand, in case of a “noteworthy avalanche hazard” there is a strong probability that at least one avalanche prone event may occur in a determined area: from the juridical point of view, therefore, the fall of an avalanche in the presence of a “noteworthy” hazard (as long as the hazard should be recognisable) is to be considered as being able to be forecast; in other words, there exists an evident possibility of avalanches or, as can be read on the interpretative support of the avalanche bulletin, a "possible detachment", for which skiers must consider the possibility of causing an avalanche. The probability for the single skier remains in any case very low, for which the non occurrence of the event may be cause of predestined errors of evaluation.

Conclusions

Regarding the major spontaneous avalanches, it may be stated that *the* avalanches (plural!), namely the hazard of spontaneous avalanches in general, can widely be forecast, while *the* avalanche (singular!), namely the single event, cannot be forecast

with precision in terms of a place (including dimensions) and time. Obviously, however, even for a single avalanche it is possible to forecast a greater probability of detachment, for which generally it is clear when and where it is necessary to adopt provisional measures of protection. The fact that the moment and the dimensions are not possible to be forecast exactly, in fact, does not mean that it is not necessary to intervene; on the contrary, the uncertainty of the forecast may involve a reduced level of activation, for which in certain cases maximum care must be taken.

In the juridical sphere, the ability to forecast is defined differently. In case of an accident caused by an avalanche, it must firstly be established if there exists a negligent behaviour[3]. In other words, it must be made clear whether the presence of a greater risk, namely a risk that a reasonable person would not take, could or could have not been forecast. Under such a point of view, therefore, it does not concern to establish whether the detachment of the avalanche could or could have not been forecast, but rather only whether it was possible to recognise a greater risk, a hazard for which there existed the obvious possibility of an avalanche.

Going back to the initial statement, from the juridical point of view it is shown that, in fact, the major spontaneous avalanches can be widely forecast. It is possible, however, that in a determined case temporary protection measures were adopted, but that the avalanche was of extraordinary proportions, something that – from a technical point of view – it could not have been forecast by the person in charge of safety. There is a similar situation when an avalanche occurs just before arranging an avalanche barrage or just after its elimination. As a rule, in these cases a negligent behaviour should not subsist.

In the case of avalanches caused by skiers, from the technical and juridical point of view, it cannot be stated that the detachment of an avalanche can be forecast – for example when it should occur particularly on a well-used versant in case of a "moderate" hazard.

In cases of accidents that occurred in the course of an avalanche and probably due to a wrong behaviour, generally an expert’s investigation is necessary for ascertaining whether the degree of hazard was recognisable in order to discover a possible violation of the duty of diligence; the avalanche itself should not be necessarily possible to be forecast. In such a situation, the probability – generally low – that the single event may occur (a

[3] Generally there subsists an adequate causal relationship.

very low percentage) is not considerable. In certain cases, however, it must be established whether the said event was or was not extraordinary (for example of unexpectedly major proportions).

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