A PROCESS-BASED DEFINITION OF SITE-SPECIFIC AVALANCHE WARNING

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ABSTRACT: The definition of site-specific avalanche warning is based on the process of assessing the probability of an avalanche to release in one or several specific avalanche paths and whether its runout might endanger people or infrastructure. This process includes an assessment of the release probability in a predefined avalanche path and assessment of the probability that the avalanche run out length reaches a certain object in the path, given the actual topographical and snow properties in the path. The resulting impact probability is valid for a defined time period and serves as the input to active risk management systems where this avalanche impact probability can be combined with the anticipated consequences of an avalanche. This process clearly differs from regional avalanche warning where the entire avalanche terrain in a region, including all aspects, elevations and weather variations has to be considered to conclude in one avalanche danger rating for the entire region. The new definition is valid for single path operations as well as for warning services that cover a large number of predefined avalanches paths and objects and is therefore independent of the size of the warning area. The international EAWS (European Avalanche Forecasting Services) working group on site specific avalanche warning has elaborated a list of definitions and clarifications of site-specific avalanche warning versus regional avalanche warning. For example, avalanche problems might be used at both scales, while the European avalanche danger scale is strictly limited to the regional services. The information pyramid should be used at all scales, while the target group differs from defined users such as road authorities for site-specific services to the broad public for regional warnings. Recommendations on best practice for site-specific avalanche services are given for the avalanche technical, administrative, and operational aspects of such services. The definition and best practice were adopted as EAWS recommendations at the 2022 general assembly of the European Avalanche Services.

KEYWORDS: Avalanche warning, site-specific, regional, local, European Avalanche Warning Services

1. INTRODUCTION

Human activities in avalanche terrain require an active risk management strategy that addresses the avalanche problem at hand and offers mitigation strategies that allow the activities to take place. In many situations, avalanche warning is the most cost-effective mitigation measure to allow human activities in avalanche terrain (Lachapelle, 1980). The method can address many different scales, purposes and target groups. Regional warnings are mostly issued by public services and cover large areas with a general description of the avalanche situation commonly within a predefined region. The information given in regional warnings is usually too general for applications in risk management of roads, railroads, settlements and other infrastructure. Several terms have been suggested for such detailed avalanche warnings, such as "local" (Föhn, 1998), "applied" (McClung and Schaerer, 2022) or "operational" (Brun et al., 1989) warning. While the term "forecasting" is preferred in North-America, in Europe usually "warning" is used to describe the process of assessing the avalanche danger from day to day. All of these terms lack a clear definition and delimitation from the commonly known regional avalanche warning. In areas where both such services operate, this often leads to confusion. The lack of a clear definition, guidelines and standards implies also a wide range of different solutions in assessment of the hazard, communication to users and application of the warnings in risk management at the site (Jaedicke et al., 2018). The approach of Statham et al. (2017), gives a general method for assessment of

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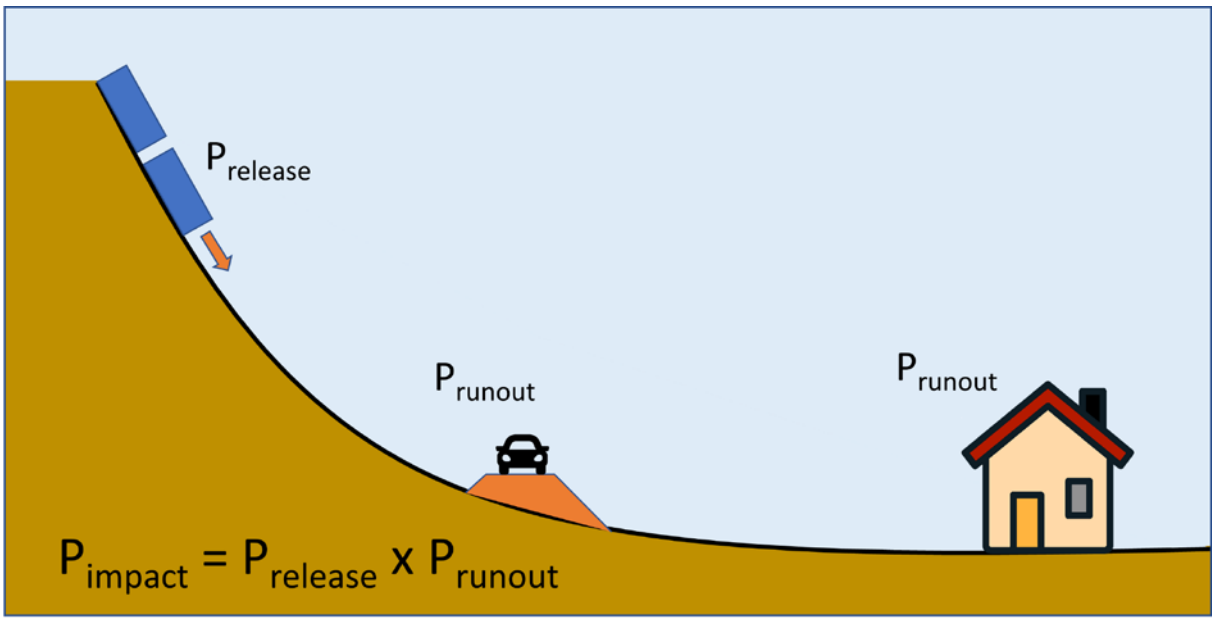

Figure 1: Illustration of impact probability as a product of avalanche release probability and avalanche runout probability. The impact probability depends on the location of the object in the avalanche path and can be different for two objects while the release probability is the same.

avalanche hazard at all scales and for all kinds of application from regional warning, to personal assessment for ski trips. This paper continues the discussion and aims to present a process-based definition of the type of avalanche warning that is needed for avalanche risk management at exposed locations.

2. BACKGROUND

Regional and more detailed avalanche warning services coexist at many places in Europe and are partly even driven by the same services (e.g. LWD in Tyrol). The former delineation between "regional" and "local" avalanche warning was based on the simple rule of area. Regional avalanche warnings need to cover areas larger than 100 km2. Given the fact, that some regions, especially in the Alps, are smaller (e.g. in Switzerland or Italy) and a new definition of the European danger levels which does not include a size limitation of the region is given by the EAWS, The European Avalanche Warning Services (2022a), also a better definition of the more detailed avalanche warning is required. An international working group was established to gather information on the existing warning services in Europe, to develop a new and generally valid definition of regional and site-specific avalanche warning and give best practice guidelines on how such a service should be operated.

3. SURVEY

A survey was conducted to get an overview over the present state of site-specific avalanche services in Europe (Jaedicke et al., 2018). The survey was answered by 208 services from 9 countries. The results showed a general adoption of the EAWS standards for use of avalanche problems, avalanche size and information pyramid (EAWS, The European Avalanche Warning Services, 2022b). Many of the services also use the European Avalanche Danger Scale to communicate the results of their assessments. The methods and routines of the services showed a large variability from well established services with a team of several experts and advanced technical tools to one-man businesses with a notebook. The overall impression after the survey was that clear definitions and guidelines are needed both for the development of the services as well as an orientation for the clients who are in need of an appropriate warning service.

4. THE PROCESS BASED DEFINITION

Detailed avalanche warning originates from the need of risk management at given sites such as settlements, roads, construction sites and touristic operations. The main input to that risk management is the probability of an avalanche to reach the object at hand within a given period of time. A prerequisite is the proper assessment of the avalanche terrain and functionality of eventual physical mitigation measures in the area to identify the relevant avalanche paths and their exposure to critical weather situations. The identified paths,

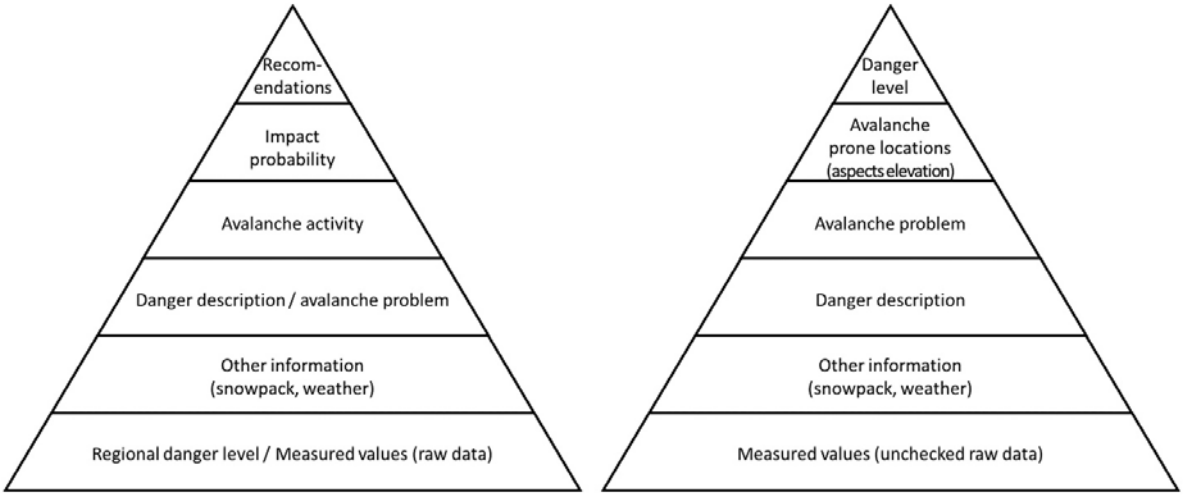

Figure 2: The EAWS information pyramid for the presentation of avalanche warning to user. Left the adjusted version for site-specific avalanche warning. Right the original version for regional services.

the location of the exposed object, the position of the release area in relation to critical weather are site-specific. They can vary significantly from one side of a valley to the other. Hence the term "site-specific" avalanche warning. Avalanche risk management requires assessment of the avalanche probability to reach a given object, road stretch or building in a defined avalanche path. Therefore, we define site-specific avalanche warning as the assessment of the probability of an avalanche to release in one or several specific avalanche paths and whether its runout might endanger people or infrastructure (modified after Stoffel and Schweizer, 2008). Estimates of the release probability and avalanche runout probability for an individual path generally have a high uncertainty. This uncertainty needs to be considered when decisions on temporary measures are taken. The term "site-specific" originates from the desire to find a generally applicable term that is precise and linguistically sound in all languages that are in use in the European Avalanche Warning Services. The former term "local" is unprecise, leads to different interpretations and associations in different languages and is therefore dismissed.

5. RELATION TO REGIONAL AVALANCHE WARNING

The definition of site-specific avalanche warning alone is not enough to clearly delineate it from regional avalanche warning. Therefore, properties and terms such as spatial and temporal extend are defined both for site-specific and regional avalanche warning. Examples are typical user groups (e.g. specific users of site-specific warnings versus the general public for regional warnings) or the use of available data (aggregation of data for specific assessment of a path versus generalization of data for regional warning), etc. The European Avalanche Danger Scale (EAWS, The European Avalanche Warning Services, 2022a) is clearly restricted to the use in regional avalanche warning. The danger levels should never be used to describe the avalanche situations in single paths or mountain sides (as final result of the assessment), since the danger levels always represent a "function of snowpack stability, the frequency distribution of snowpack stability, and avalanche size for a given unit (area and time)". This implies that a range of slopes, aspects and elevation bands need to be covered to be able to obtain that spatial frequency. In site-specific avalanche warning, the main product is the impact probability (EAWS, The European Avalanche Warning Services, 2022c), defined as " is a function of the (in)stability of the snow cover in a given avalanche path (not an area) and the probability of an avalanche to reach a certain object or point in the given path (impact probability)" as illustrated in Figure 1.

Other EAWS standards such as the avalanche problems and avalanche size can be used equally in both site-specific and regional avalanche warning. The information pyramid (Figure 2) has been adjusted, adhering to the principle of the most important information to be presented first. In the new version for site-specific avalanche warning the top of the pyramid presents the impact probability and mitigation recommendations, which normally are predefined actions that are triggered by the impact probability issued that day.

The definitions point out that the "site-specific avalanche hazard assessments are a very valuable source of information for regional danger analysis, assessment and verification. Therefore, the assessment of the site-specific danger arises as a unit within the regional danger but may differ substantially if the site-specific situation deviates

significantly from the regional situation." On the other hand "regional avalanche danger assessments are useful information at the site-specific level to frame the operational context but are not sufficient to adequately characterize the danger situation of the individual avalanche path", (EAWS, The European Avalanche Warning Services, 2022c)

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6. RECOMMENDATIONS FOR SITE-SPECIFIC AVALANCHE WARNING SERVICES

The survey on site-specific avalanche warning services showed the need to provide some recommendations and guidelines on how to set up such a service. The recommendations aim to include the basic requirements that need to be met for a site-specific warning service to ensure the quality and persistence that the clients can expect from a professional service. They aim to be general enough to cover most of the existing services and should be possible to be met even by small services. The four sections of the recommendations cover 1) the administrative part, 2) the avalanche technical part, 3) operation of the service and 4) the product of the service. The administrative part includes requirement for documentation, responsibilities, workflow and education of the involved experts. Special emphasis is given to quality control and location of responsibilities.

Quality control systems are highly recommended, preferably with an internal review routine before the warning is issued. The clarification of responsibilities between the risk owner (the client) and the avalanche warning service is essential to avoid misunderstandings and confusion in critical situations. The recommendations (Figure 3) clearly divide the roles of the risk owner and the warning service. The warning service is responsible to provide the impact probability and the risk owner is responsible to enforce the risk mitigation measures predefined in an action plan. This division of responsibilities and the preparation of action plans prior to the winter season is essential to avoid ad hoc solutions in critical situations.

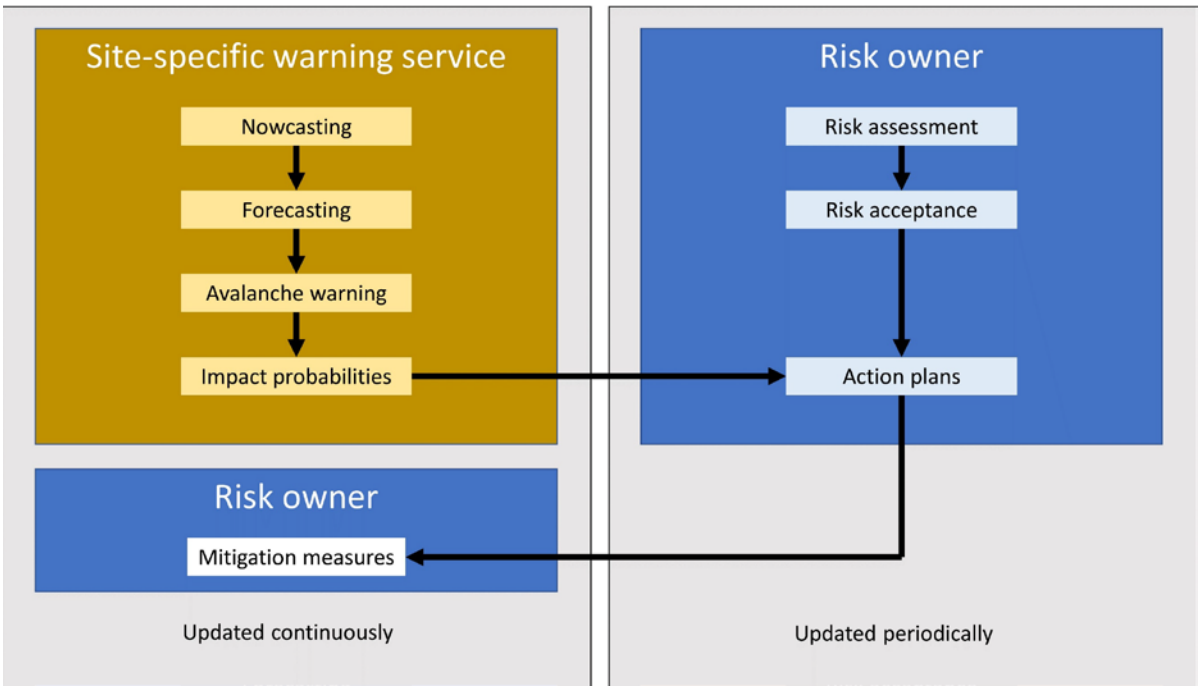

Figure 3: Workflow and responsibilities as recommended by the working group. The deployment of mitigation measures might be organized differently in some member countries where the warning service is a part of the risk owner. Here, the risk owner is the administrative entity that manages the risk in a given situation by enforcing actions to reduce the risk for persons and /or infrastructure.

The avalanche technical part describes the required data, technical documentation of the warning area such as avalanche history and hazard maps, the endangered objects and an overview over the available mitigation strategies.

For the operation of the service, it is recommended to provide a documentation of the weather, snow and avalanche observations that are used and which weather forecast services that are considered. It is also highly recommended to maintain a logging system for all input data and the resulting assessments such as impact probability, avalanche problems and description of the avalanche situation.

The central product of the service should be the impact probability for the monitored objects based on the meteorological and nivological conditions at the location of the object and a development of the situation based on the available weather forecast for the area. This product should adhere to the EAWS standards for the modified information pyramid, the avalanche problems and avalanche size.

7. DISCUSSION

In contrast to Statham et al (Statham et al., 2017), our definition focuses on the impact probability as a product of release and run out probability. In the conceptual model, the run out probability is covered by the avalanche size. But avalanche size in itself does not give sufficient information on the probability that the object at hand will be impacted. Roads high up in a mountain site can be hit by frequent small avalanches leading to high impact probability each time they can be released. On the other hand, large wet snow avalanches can have short run outs while small highly fluidized dry snow avalanches can reach extremely far and thereby endanger the exposed object. There are also several examples where the runout probability is equal to one, regardless of the size of the avalanche for example at roads along the steep coastal roads in Northwest Island (Wastl et al., 2011).

8. CONCLUSION

Regional avalanche warning in Europe has been working on standards and guidelines for many years and the European services are working actively on a harmonization of their work and their products. Contrary, services that offer avalanche warning at a more detailed level lack even a common term for their work. We present the definition of "site-specific" avalanche warning as a multilingual and commonly acceptable term based on the process of site-specific assessment of impact probabilities for exposed objects followed by a set of recommendations for site-specific warning services. The presented definition and guidelines were approved by the general assembly of the European avalanche services in Davos in 2022 for the future use in Europe (https://www.avalanches.org/site-specific-avalanche-warning-in-europe/). The coming years will show their applicability in practice of the European site-specific services.

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