LOCAL MANAGEMENT OF AVALANCHE HAZARD ON THE AOSTA VALLEY'S ROADS AND IDENTIFICATION OF EVENT SCENARIOS

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ABSTRACT: The Region of the Aosta Valley, situated in the far north-western part of Italy, borders to the north and west with Switzerland and France. 60% of its territory is at altitudes above 2000 m a.s.l.. In the regional cadaster 1926 avalanche sites were recorded from 1970 to 2011, affecting a total area covering slightly over 15% of the region. Over the years, the construction of several avalanche shelters have greatly reduced the hazard of avalanche events on roads and on vulnerable assets, however, they are not sufficient to totally control the danger avalanches pose to these infrastructures. To improve avalanche hazard management, the Region of the Aosta Valley, with the regional law n. 29/2010, approved the constitution of the Local Avalanche Committees (CLV).
Starting from the regional avalanche bulletin, the CLV ensure the local management of this hazard, as is well demonstrated in the 2011-2012 winter season. Nevertheless, to help the CLV during the decision process new and more advanced tools are necessary. Ideal tools would allow them to associate a specific scenario of distribution and snowpack stability to a corresponding avalanche event scenario.
In this work, we illustrate the essential features of the law, the practical application of the work of a CLV, and the actions in the 'Italy-Switzerland 2007-2013 - Project "STRADA" who try to provide concrete tools for the evaluation of event scenarios at slope scale for frequent avalanche events.

KEYWORDS: roads, avalanche hazard management, event scenarios

1 INTRODUCTION

The Autonomous Region of the Aosta Valley is situated in the far north-western part of Italy, and borders to the north and west with Switzerland and France. It is a completely mountainous region ranging from a lowest altitude of 345m to the highest of 4,810m. 60% of its territory is at altitudes above 2000 m a.s.l.. The region covers 3,263 sq km and is framed by a perimeter of mountains which includes all the peaks higher than 4,000m in the Western Italian Alps: the Monte Rosa and Cervino ranges to the north - east, the Gran Paradiso range to the south and the Grand Combin (in Switzerland) to the north.

At the average level of 2000 m, from the analysis of manual stations, the snow cover reaches 150-170 days/year from the middle of November to late May, the average height of snowpack (Hs) is between 65 and 125 cm, with the average quantities of snow (Hn) of 380-430 cm from early December to late April (Segor V. et al., 2011).
The Regional Avalanche Cadaster records 1926 avalanche sites, affecting a total area *covering* slightly over 15% of the region. Among all these sites, 922 phenomena can reach the roads (Table 1) and 432 can cause damage to buildings, ranging from primary residences to rural huts.

Road typology	N°of events	Affected length (km)	%
National roads 192,60 km	74	16,27	8,45%
Regional roads 496,40 km	195	44,14	8,89%
Municipal roads 1620,93 km	653	91,34	5,63%
TOTAL 2309,93 km	**922**	**151,75**	**6,57%**

Table 1: Roads affected by avalanches in the Autonomous Region of the Aosta Valley.

Over the years, the construction of several avalanche shelters has greatly reduced the hazard of avalanche events on roads and on vulnerable assets, however, they are not sufficient to totally control the danger that avalanches pose to these infrastructures. In the last 35-40 years snow

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Figure 1: Cogne – Licony - snow umbrellas.

bridges and snow nets have been built in 172 sites (Fig. 1) together with numerous passive structures, such as deflecting or restraining dams, and 36 tunnels were built to prevent closure caused by avalanches on the national and regional roads (Fig. 2).


Figure 2: example of deposition area that blocks the tunnel entrance and obstructs the road for about 20 m.

As clearly shown by the data above (Table 1), we are far from the total “structural” protection, which moreover would be unachievable for technical and economic reasons, but “non structural” measures can be put into field.
Road closures, evacuations, artificial triggering of avalanches, snow modeling of the deposition area (Segor et al., 2010), and “remote-event” controlled traffic lights are some examples but these are very difficult to manage on a large scale by the central Avalanche warning service. The need is to move to local management to increase the effectiveness of the measures.

2 LOCAL MANAGEMENT OF AVALANCHE HAZARD ON THE AOSTA VALLEY’S ROADS

Intense snowfalls generate avalanche events that can interact with the roads and infrastructures, sometimes threatening the population. Prevention is necessary to try to mitigate the potential risks, and a good evaluation of the snowpack local condition is fundamental to handle the closure of roads, and above all their reopening.
Several villages located in remote valleys are only accessible through a single access road and in the past it was quite usual for them to remain isolated for several days because of intense snowfalls and avalanche danger. Now most of these villages receive a lot of tourists and the residents need to be able to leave the valley every day. Modern society does not accept conditions of isolation and this determines the need to manage readily and rapidly the emergency caused by an avalanche.
The last large scale critical situation was during the 2008-2009 winter season, when from the 14th to the 17th of December almost 200 mainly medium and large size spontaneous avalanches were registered and these reached the valley floor, affecting the roads and some infrastructures, disrupting power lines and communications and isolating entire villages. To manage this critical situation, the Regional Council of Aosta Valley on August 4th 2010 passed the regional law n. 29, the "Regulations on Local Avalanches Committees" with which the Local Avalanches Committees (CLV) were set up and which governed their powers and functions. On 15th October 2010, the Regional Council further defined the CLV’s method of operating. It defined the methods of supporting the Regional Avalanche warning service, the municipalities and operators of the ski resorts. It regulated how to forecast, to evaluate weather conditions and to state of stability of the snowpack. Furthermore, it regulated how to manage surveillance, early warning and eventual intervention in situations of risk and emergency, to ensure local control of dangerous situations over the territory of competence, based on uniform criteria and methodologies (subsection no. 3 of art. 2, resolution no. 2774).

2.1 The regional law

As part of the municipalities with a high avalanche risk, 17 CLVs have been set up. Each CLV is composed of: one to three mountain-guides, the operational managers of the ski resorts within the area of relevance and the Commander of the forest rangers unit having jurisdiction, all of them trained by the regional Avalanche warning service following the AINEVA – National Association of Snow and Avalanche Warning Services – professional education guidelines.

The CLVs are advisory bodies which support the Region, the municipalities and the operators of the ski resorts. The CLVs aim to ensure the local control of dangerous situations on the territory of competence.

Activities established by the law, to be carried out by the CLVs:

- preparing the avalanche management plan of activities (PAV), which identifies the measures for evaluating the danger of avalanche risk in the area of competence;
- obtaining data and information related to the avalanche danger on the territory of competence and its likely development;
- expressing, on request, technical advice about the avalanche danger on the territory of competence and its likely development;
- supporting the activities of the Mayor for the adoption of any measures of competence and initiatives to be taken in relation to the critical state in place;
- transmitting to the regional structures the data collected and the opinions expressed;
- cooperating in emergency management with the Municipal Operations Center and Joint Center and the coordination of relief efforts.

The total cost resulting from the application of Articles 1 and 6 of Law n. 29/2010 is set at € 300,000 for the year 2010 and € 200,000 per annum with effect from 2011 for the 17 CLVs.

2.2 CLV activities - winter 2011-2012

From the first snowfall the CLVs monitor, on their territory of competence by filling in a daily register of activities, the evolution of the local snow meteorological conditions (data of automatic stations, observation of avalanches,...) and compare them with the regional data of the snow and avalanche bulletins.

The winter of 2011-2012 was the first where the CLVs worked following such a method.

To better explain how their work is conducted it is useful to illustrate with an example. Between the afternoon of the 13th and the early morning of the 16th of December 2011 heavy snowfalls affected the region, bringing up to 150 cm of fresh snow at 2500 m with moderate to strong westerly winds accompanying the snowfall, all resulting in many avalanches of considerable size.

11 CLVs were active and worked autonomously keeping in touch and comparing data outsourced by the regional avalanche warning service and evaluating locally the critical situations.

The local evaluations of the various CLVs determined in single cases the maintenance of road opening or the choice of preventive closure of road sections.

In particular, one CLV was severely tested in the course of these days: on their area of competence they had to handle an avalanche which fell seven times dangerously reaching and blocking the roadway, destroying an old wooden bridge and endangering two buildings (Fig. 3).

Among the decisions taken by this CLV there was also the choice of spending the night inside the school for a group of children and then providing instructions for their evacuation.

During those days the CLV met 16 times evaluating and acting according to the evolution of the snow conditions, verbalizing each activity.

The same situation was repeated on January 5th, as the same avalanche, associated with a new heavy snowfall and the action of strong winds from the North West, hit again. In this case an hour before the fall of the avalanche on the road, the CLV had previously closed the road section, with criticism for their choices because the Mayor and his councillors did not consider the situation critical.

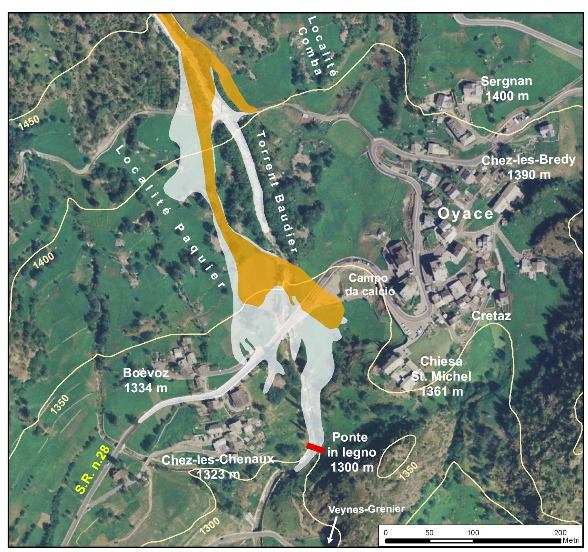

Figure 3: extract mapping of the avalanche, the event of the 16th of December 2011 in white, the event of the 5th of January 2012, in orange.

How much of this decision is attributable to luck or experience? And how much to prudence and responsibility? How hard is it to manage communications and understand the critical issues?
These are some of the questions that still have no answers.

2.3 Future developments

The constitution of the CLVs shows, after the experience of the 2011-2012 winter season, that they are a good solution for local avalanche danger management, being a tool that integrates well the initial phase of prevention, consisting in the Snow and Avalanche Bulletin conducted on a regional scale.
To improve the management of the local avalanche risk a meticulous study of the event scenarios is necessary as well as careful analysis of the feasibility of artificial triggering to mitigate the risk of avalanches. One of the pillars of analysis is the study of avalanche basins to identify what are the potential sites in the region in which to intervene with artificial detachment in order to clear the slopes or channels that generate events on roads. The responsibility, the effectiveness and the rapidity of the response are three fundamental issues on which work is needed to define if, where and how, to carry out any artificial detachment.

3 PROJECT "STRADA" – "ITALY-SWITZERLAND 2007-2013"

3.1 Description of the project

Founded in early 2010, the project "STRADA" – "Strategies for adaptation to climate change for the management of natural hazards in the border region - Operational Programme under the European Territorial Cooperation border, Italy / Switzerland 2007/2013", is a project called "strategic" that was strongly desired by all the administrations of the border region, Italian and Swiss. In general, the project deals with the impact of climate change on natural hazards so composite and articulated, taking into account various elements of planning and management decisions.
In particular, under activity 4, the project provides, among other things, based on a thorough analysis of the climatic context, the development of methodologies for the study of avalanche phenomena, to be used in strategies about mitigation risk in specific application areas such as management, security, roads and ski areas.
Avalanche safety personnel often face the problem of whether to close a road, train or a ski slope. Those decisions are often very difficult to make, as they demand forecasting of meteorological conditions and corresponding snow cover characteristics as well as their influence on avalanche dynamics and prospective run-out distances.
Present avalanche mitigation methods do not directly associate snow cover properties with avalanche dynamics and, as a result, there are also no specific dedicated decisional tools.
One aim of the project STRADA is to develop a procedure to automatically detect potential release zones and to estimate run-out distances of frequent snow avalanches by taking into account the effect of snow cover both in the release and flowing zones.

3.2 Assessing the effect of snow cover parameters on location and extension of release zone and runout distance

Existing mathematical algorithms for automatic definition of avalanche release zones mainly focus on terrain parameters such as slope and curvature (Maggioni and Gruber, 2003). While these algorithms may work correctly for the definition of extreme avalanches release zones, they work poorly on a smaller scale where snow distribution and the influence of the wind on the snow deposition play a major role in the definition of the release area extension.
In one task of the project STRADA, in order to improve the efficiency of these algorithms and thus, to link the release areas of frequent avalanches to both terrain and snow cover distribution, how snow cover changes topography is investigated, and in particular terrain roughness (Sappington et al., 2007). To this aim, snow-cover distribution is first characterized at different test sites by performing terrestrial and airborne laser scanning at regular time intervals during the winter seasons. In a second phase, smoothing functions to apply to the real topography to mimic the smoothing effect of snow on terrain are developed. Finally, algorithms to detect areas characterized by homogeneous roughness are formulated to identify potential release areas.
A second task of the project STRADA deals with the understanding on how snow cover affects

avalanche mobility and thus the run-out distance. As avalanches move downward they sweep along part or all of the underlying snow cover (Sovilla et al., 2006). Depending on the erosion depth, layers with various characteristics are dragged. Average temperature of the entrained snow, its density and its water content can play a major role in the avalanche mobility by giving origin to highly fluidized layers as in the case of cold and light snow or dense granular layers as in the case of warmer and more cohesive snow.
To assess the influence of different snow typologies on avalanche dynamics, avalanches measured at the Vallée de la Sionne test site (Sovilla et al., 2008; Sovilla et al., 2010) are combined with corresponding snow cover scenario reconstructed by using the snow cover models ALPINE 3D and SNOWPACK (Lehning and Fierz, 2008).
By using a new generation of numerical avalanche dynamic models which can take into account both entrainment of snow and influence of snow temperature on avalanche dynamics (Bartelt et al., 2006; Bartelt and Buser, 2009; Buser and Bartelt, 2009), well documented avalanches are back calculated to estimate avalanche mobility as a function of snow characteristics.
Simulations are performed using RAMMS (Rapid Mass Movements). RAMMS is a two-dimensional dense snow avalanche dynamic model with multi-layered entrainment, based on the 2-D shallow water equations, which is routinely used in Switzerland to calculate snow avalanche run-out and flow velocities. A detailed presentation of the model and case studies are given in Christen et al. (2010a,b). To describe the frictional deceleration forces for the frequent avalanches considered in the project STRADA a RKA extension of the traditional the Voellmy-Salm model, which also include an energy equation tacking into account variation of temperature of the flow, is used. For details on this approach see Bartelt et al., (2006), Bartelt and Buser, (2009) and Buser and Bartelt, (2009).
By combining the new algorithms for automatic definition of avalanche release zones with this new modelling approach, it will finally be possible to calculate avalanche scenarios which link average snow cover conditions to expected avalanche location and mobility.
This pioneering approach opens new possibilities in the field of management of communications roads and ski resorts, but also for numerous other applications where a more realistic knowledge of real time causes and effects is needed.

4 CONCLUSIONS

The 2011-2012 winter season confirms the following benefits that were the basis of the necessity for having a law on local avalanche management:

- concomitantly multi-action in several areas of the region;
- prompt action before and after the events;
- care awareness of the task accomplished.

On the other side some difficulties arose:

- need of standardization, for all the CLVs, of training and method of conducting the activities;
- awareness of the necessity of recording in writing the activities perfomed and decisions taken .

The tools which will be provided by the project STRADA, aim to help the work of the CLVs by tracing several event scenarios. Another future necessity, on which we are working, is the creation of a common platform for the management of the work the CLVs conduct, in order to facilitate the delicate task they are asked to perform. The platform will automatically survey the actions taken by the CLV leaving more time for the analysis of critical situations.

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