AN AUTOMATIC AVALANCHE RISK MANAGEMENT SYSTEM (AVALARMS)

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ABSTRACT: Endesa, a gas and electricity company belonging to the Enel group, has dozens of roads leading to its hydropower assets, scattered in a wide area in the Catalan Pyrenees. Some of them are used during winter and are threatened by snow avalanches. For the avalanche risk to be weighed when using these roads, an automatic system has been put in operation to assess the risk level on each of them (AVALARMS) using the public regional avalanche forecasting. For such purpose in all the avalanche paths that threaten these roads avalanche events have been analyzed and modelled to determine when they can be released, and from which size they can reach the road. This solution is GIS-based and the whole process has been automated so that road users receive daily emails or Telegram messages indicating which restrictions apply on the roads in their area.

KEYWORDS: Automatic Avalanche Risk Management, Road Safety.

1. INTRODUCTION

Safety is a top priority for Endesa, both for its own staff and its contractors, inside and outside its facilities. In this regard, avalanches that threaten roads are of concern to the company, specifically those 200 paved and non-paved roads accessing the hydropower assets in the Pyrenees (over 350 km).

All these infrastructures are located in the Western Catalan Pyrenees (Figure 1), in an area of around 1.700 km^2. This territory has elevations slightly exceeding 3.000 m, and occupies a transition zone between a humid oceanic climate in the north, and a climate with continental characteristics in the south.

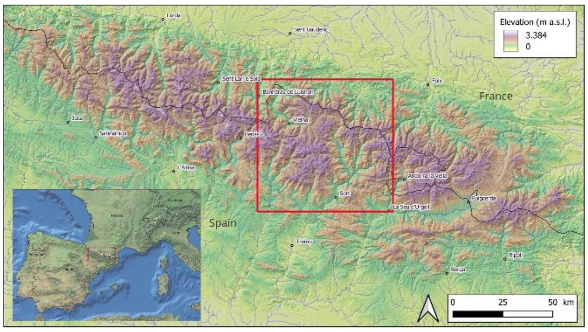

Figure 1: Location of the study area.

Among these roads, there are several dirt roads that cannot be used during winter due to the presence of snow on them, being the helicopter the only transportation alternative. Nevertheless, there are some roads that are used almost daily.

The scope of the project AVALARMS is the daily assessment of the avalanche hazard in each of these roads in order to estimate the avalanche risk and therefore manage their safety.

2. BACKGROUND

Since the construction of the power plants in the Catalan Pyrenees, starting early in the first half of the 20th century, the avalanche hazard has been an issue of concern, and some accidents and even a casualty have been reported (e.g. Copisa 1979).

At the beginning of the operation of the plants, there was no proper avalanche risk management. When the first regional avalanche reports appeared (in the early 1990's, ICGC 2020), the people in charge of the plants started using them to decide whether to use the roads or not, based on the avalanche hazard level exclusively, and typically restricting traffic only when it was 4 or 5 out of 5 in the European Avalanche Danger Scale.

The systematisation of the avalanche bulletins available in the area at the beginning of the 21st century (Martí et al., 2009), with detailed information about the distribution of the hazard, its origin and the size of the expected avalanches, made it possible to determine the hazard level on each road in a much more systematical way, based on all the parameters described in the avalanche report.

3. AVALARMS TOOL

AVALARMS is a tool that uses the avalanche cartographic information (spatial information) of the avalanche paths that reach the road accesses to Endesa hydropower assets, and the public regional avalanche forecasting (temporary information) to assess the avalanche risk in these infrastructures. The system is GIS-based and the

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whole process is automatic, providing a daily risk communicate for each one of these roads.

3.1 Spatial information

A survey was conducted in the different areas involved to determine on which roads the avalanche hazard was to be monitored.

Within the selected roads, there are a few that are used quite often during winter (namely accesses to powerplants and main dams), while the rest are occasionally used. The two that are more frequently used (almost daily) are the accesses to Montamara and Sallente powerplants (5 and 6 km respectively).

The network of the selected roads was overlapped with the information available in the avalanche database of Catalonia (BDAC, Oller et al., 2005), of the ICGC (update 2023) to check all the avalanche paths crossing them. These crossing points were referred to as critical points.

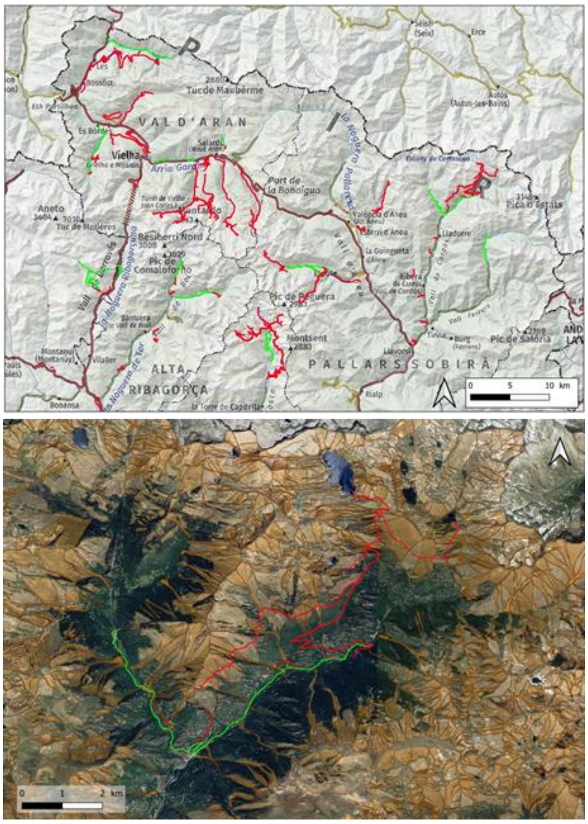

Figure 2. Up: Accesses within the study area. In green: Accesses belonging to the scope of the project; in red: Those accesses that fall out of it. Down: Some of the accesses (Montamara and Montalto) overlapped with the avalanche cartography. In orange: Avalanche paths (BDAC-ICGC, 2023).

Taking advantage of the fact that public avalanche bulletins report elevation, aspect and size of the expected avalanches for each of the avalanche paths involved, all the release areas in the avalanche cartography were analysed to determine heights and aspects. Equally, all the avalanches that could reach the critical points along the roads were modelled to determine their minimum size to hit the road. The software RAMMS::AVALANCHE (Christen et al., 2008) was used to attain this goal.

Since the avalanche bulletins use the EAWS Avalanche Size Scale to describe avalanche sizes for each avalanche path (151 in all) the maximum release area was determined, and the potential avalanche sizes were modelled from size 2 to size 4.

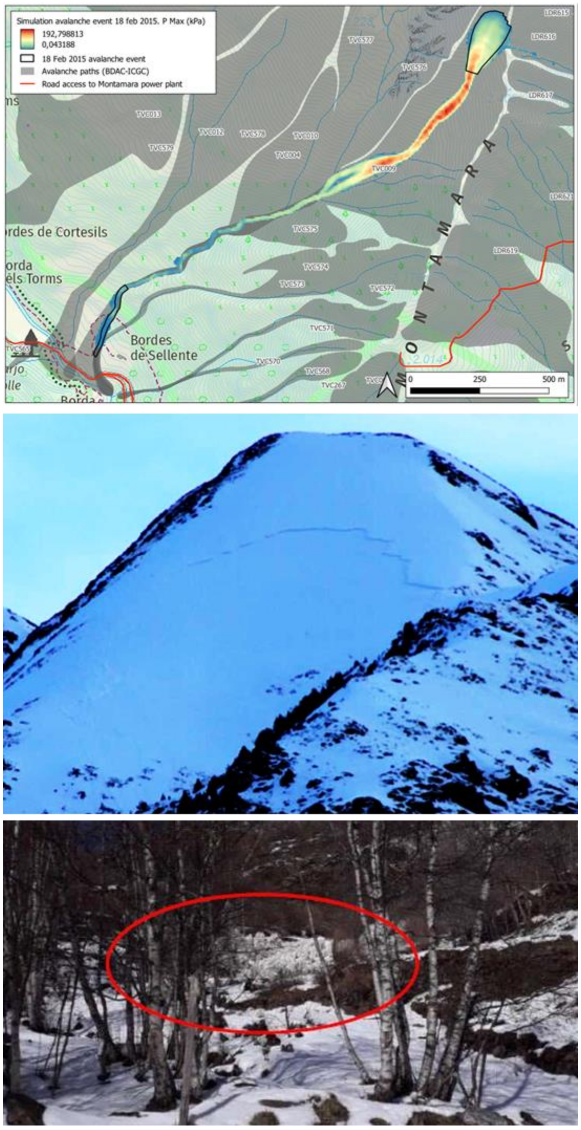

Figure 4: Up: Back analysis of the event occurred on 18th February 2015 in TVC009 avalanche path. Centre: Crown of the released slab. Down: Deposit of the avalanche seen from the road.

For each size, the typical snow volume according to EAWS size scale was assigned to the release area (1.000 m^3 for size 2, 10.000 m^3 for size 3 and 100.000 m^3 for size 4). Using snow depths related to return periods, the extent of the release areas was estimated based on both of the above indicated parameters.

The location of the avalanche release areas for each avalanche size was defined based on the avalanche inventory and terrain characteristics.

Avalanches were simulated in order to know from which size they could reach the road starting from size 2 (distinguishing between wet and dry conditions for each size). When a specific avalanche size was proven enough to hit the road, no further simulations were done in that specific avalanche path.

In order to assess the modelling results in an avalanche path with well-known avalanche events, a back analysis was performed (Figure 4). Furthermore, during the modelling process, results were compared with avalanche observations in other avalanche paths when available.

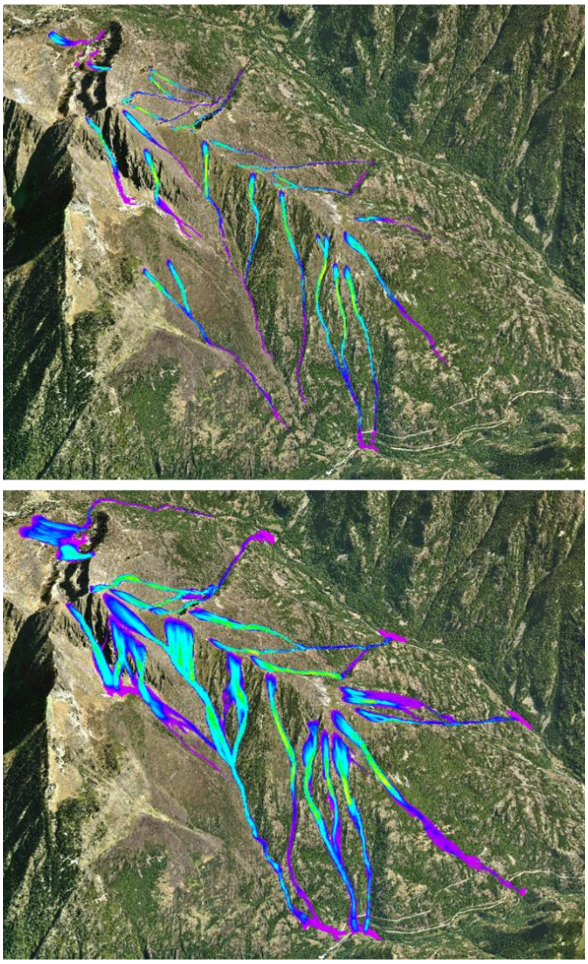

Figure 5: Size 2 (up) and size 3 (down) simulations for Montamara and Montalto accesses. With size 2, two avalanches can reach Montamara road, with size 3, several avalanches can reach both roads.

Moreover, for the two most important accesses (Montamara and Sallente powerplants), all the avalanche paths were inspected in the field to identify evidence of avalanche activity on the vegetation to characterize their extent and frequency in more detail.

The goal of this work was to build up a database of the avalanche variables reported in the public avalanche bulletins (avalanche size, aspect and elevation of the starting zone) for each avalanche path, and the results of their combination in terms of whether or not the avalanches reach the road.

3.2 <u>Temporary information</u>

The temporary information used by the system was the daily public regional avalanche forecasting.

The roads within the scope of the project belong to three snow-climate regions (García et al., 2007, Figure 6) differentiated in the avalanche bulletins:

- Aran / Pallaresa Northern strip
- Pallaresa
- Ribagorçana

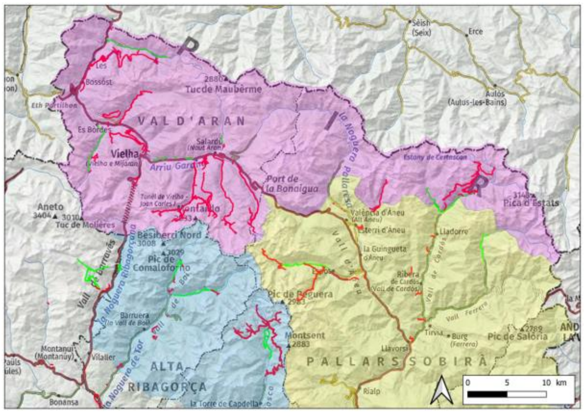

Figure 6: Road network and the three snow-climate regions: Aran / Pallaresa Northern strip (purple), Pallaresa (yellow) and Ribagorçana (blue).

The ICGC (Institut Cartogràfic i Geològic de Catalunya) issues a daily regional avalanche forecast covering the three snow-climate regions. This information is used by the system to predict the avalanche danger in Pallaresa Northern strip, Pallaresa and Ribagorçana.

The ICGC bulletin also covers the Aran region. In spite of this, as the Aran valley government (Conselh Generau d'Aran, CGA) releases a highly detailed public avalanche report every day, which is based on a higher density of field data, this report prevails in this region for AVALARMS.

A Python script was created to automatically extract the relevant information published in the APIs (Application Programming Interface) of both avalanche centers. The extracted information includes the hazard level, which can vary with elevation, and the following variables, per avalanche type:

- Spatial distribution (aspects / elevations)
- Size
- Origin (accidental / natural)

All this data was stored in a Postgres + Postgis database table.

3.3 Determination of risk levels

With the daily information regarding the hazard distribution, the Postgres + Postgis database checks which avalanche areas match the aspects and elevations and are thus likely to produce an avalanche. Then, the database determines, according to the expected avalanche size, in which avalanche path an avalanche can reach the road, according to the results of the modelling explained above.

For each road, the number of avalanches that could potentially hit it is worked out to assess the exposure to the hazard in case there was traffic on it. This value, along with the hazard level, the size of the avalanche and its origin (naturally or accidentally triggered) are used to determine the risk level on each road, using the formula shown in figure 7.

Risk = Probability · Exposition · Consequences

PROBABILITY	Hazard level				
Triggering	1	2	3	4	5
Natural	1	2	3	5	5
Accidental (within release areas)	1	2	3	5	5
Accidental (outside release areas)	1	1	2	4	5

EXPOSITION	Access exposition		
Activity	Low	Medium	High
Road maintenance	4	5	5
Snow removal	3	4	5
Traffic with snow	2	3	4
Traffic with clean road	1	2	3

CONSEQUENCES	Avalanche size				
	1	2	3	4	5
Consequences	1	2	4	5	5

Figure 7: Risk equation and weights assigned to the risk variables.

Accordingly, a protocol is applied, ranging from total closure to unrestricted use. In the middle – range values, restrictions apply to reduce exposure, limiting the use of the roads to urgent needs or forbidding snow removal, if necessary, since this activity dramatically increases the time spent within the critical points.

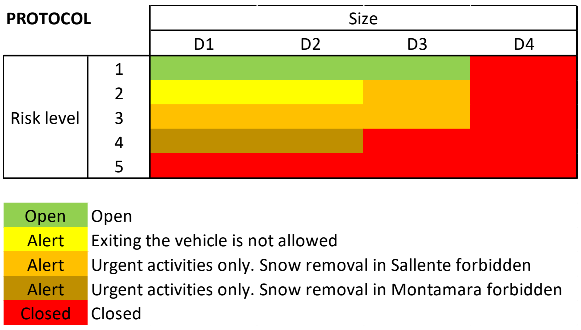

Figure 8: Access protocol.

3.4 Information flow

Every time a new avalanche bulletin is issued, the database automatically receives all the information and works out the level of risk on each road, assuming it is used.

These results can be checked with a GIS software connected to the spatial database, as shown in figure 9.

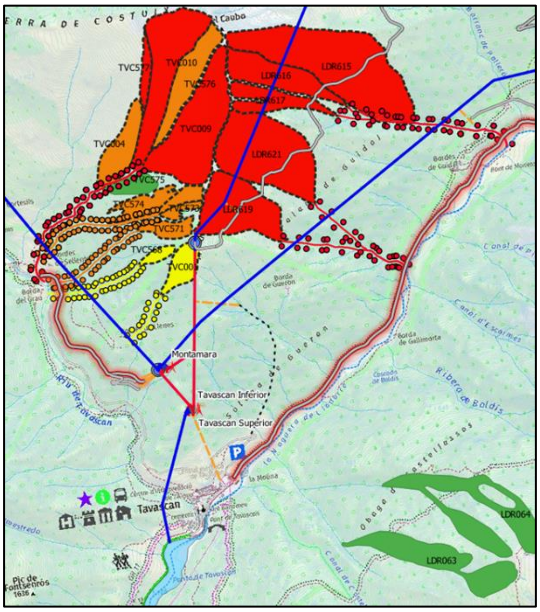

Figure 9: A view of Montamara and Montalto accesses in traffic-light colours according to the protocol applied to each of them.

Nevertheless, the users of the roads within Endesa's staff get an email informing about the protocol to be applied on each road whenever an avalanche report is issued.

For third-party users, this information is also available by means of an open multilingual Telegram bot (AVALARMS), which is updated with the same frequency.

For the staff in the mountainous areas to fully understand the AVALARMS messages, they were informed about the critical points along the roads in their region and trained in rescuing avalanche victims using the avalanche rescue equipment (beacons, proves and shovels) in an ad-hoc course. This equipment is available on each of the areas for the staff to use whenever the protocol requires so.

4. RESULTS AN FURTHER DEVELOPMENTS

The AVALARMS system uses the regional public avalanche forecasting to assess the probability of avalanche occurrence on the one hand, and on the other, the avalanche dynamic modelling to assess whether the expected avalanches can reach the accesses to Endesa's facilities or not. In this manner, AVALARMS takes advantage of a more general forecasting information at the regional scale to predict avalanche activity at the local scale. However this transformation is limited by the change of scale, being relatively imprecise, and this is solved through a result on the preventive side, which is just appropriate for those accesses seldom used.

Nonetheless, the output for roads that access powerplants or big dams will be reviewed to strike a good, tailored balance between safety and operation on each of them. In this regard, the hazard level determination in a particular release area could be improved considering not just the simple match between elevations and aspects, but also to what extent this match is achieved. When matches are partial, the hazard level could be revised in some way. The actual avalanche frequency could also be taken into account in a future version of the system.

The installation of an automatic snow-weather station to assist the decision-making process for one of the most critical of these roads, the road leading to Montamara powerplant, is also foreseen. This road is located close to the border between two snow-climate regions (Pallaresa and Pallaresa Northern strip), to both of which the database assigns the worst conditions. The weather-station data would contribute to discriminate which of the two datasets is more appropriate at every single moment. It could also help checking some of the values contained in the avalanche report.

The fact of using AVALARMS and the analysis of its output during winter seasons will allow the process of striking a good balance between safety and operation to begin.

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REFERENCES

Christen, M., Bartelt, P., Kowalski, J., Stoffel, L., 2008: Calculation of dense snow avalanches in three-dimensional terrain with the numerical simulation programm RAMMS. In: International Snow Science Workshop 2008, Proceedings. September 21-27, 2008. Whistler, BC, CAN. 709-716.

Conselh Generau d'Aran. Avalanche bulletin: https://lauegi.report/bulletin/latest, last access: May 2024.

COPISA (1979). Informe sobre la nieve caída en la obra Estangento-Sallente a partir de la segunda quincena de diciembre de 1978.

EAWS. Standards. Avalanche size: https://www.avalanches.org/standards/avalanche-size/, last access: July 2024.

García, C.; Martí, G.; García, A.; Muntán, E.; Oller, P.; Esteban, P. (2007): Weather and snowpack conditions of major avalanches in the Catalan Pyrenees. Proceedings of the Alpine Snow Workshop. Forschungsbericht 53. P. 49-56.

ICGC. Avalanche bulletin: https://bpa.icgc.cat/, last access: May 2024.

ICGC. Avalanche cartography WMS service: https://geoserveis.icgc.cat/geoserver/nivoallaus/wms?, last access: January 2023.

ICGC (2020). El servei de prevenció d'allaus a Catalunya: coneixement i prevenció. 9 – Monografies Tècniques.

Martí, G.; Pujol, J.; Fleta, J.; García, C.; Oller, P.; Costa, O.; Martínez, P. (2009). A new iconographic avalanche bulletin for the Catalan Pyrenees: a beginning for a future avalanche forecasting database. Proceedings of the International Snow Science Workshop. 27 September to 2 October 2009. Davos, Switzerland. P. 361-365.

Oller, P.; Marturià, J.; González, J.C.; Escriu, J.; Martínez, P (2005): El servidor de datos de aludes de Cataluña, una herramienta de ayuda a la planificación territorial. In proceedings of: VI Simposio Nacional sobre Taludes y Laderas Inestables. Valencia, 21-24 de Junio de 2005. E. P. 905-916. Alonso, J. Corominas, L. Jordà, M. Romana, J.B. Serón (Eds.).