SENSITIVE AVALANCHE PATHS: USING A NEW METHOD FOR INVENTORY AND CLASSIFICATION OF RISK

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ABSTRACT

The dangerousness of all avalanche paths which threat winter living buildings is upon inventory and classification in France. It seeks to reveal the avalanche sites which deserve particular precautions and a deepened avalanche study. Under the order of the French Department of Environment, the Cemagref Institute established methods and tools in 2003 and 2004, and the National Forest Service filled the data.

The method is simple and original. Its main characteristics are to be as objectives as possible, and short to fill (around one hour for a well known site). The different main criteria are vulnerability (major one), morphology, history and snow-climatology. The dangerousness of a site is classified in 3 groups: strong sensitivity, with around 10% of the number, doubtful, with around 20%, and low.

The inventory has been realised by the National Forest Service in 2003: 1276 avalanche paths with buildings were detected all over France, and 1915 with roads only. The classification is filled for 227 avalanche paths in March 2005 and for around 390 new in May 2006. It represents ~41% of the total. The paper shows the results for these sites. The classification for another group of 286 avalanche sites (~23%) is in course in 2006.

Local public authorities are informed of the results of this program, and a web site, www.avalanches.fr, provides data of all sites. Avalanche hazard maps and avalanche permanent survey will be committed for the strong sensitive sites which don't have them yet.

KEYWORDS: Avalanche risk, inventory, classification, data base.

1 THE CONTEXT

On February 9, 1999, an avalanche killed 12 people and destroyed 14 country cottages of the hamlet of Montroc in the Chamonix-Mont-Blanc city, situated in the French Alps. The administrative report (1) put forth 19 recommendations: the first is about the identification of the "sensitive paths", i.e. sites with stakes (in particular habitat) whose operation cannot be apprehended in a simple way. Since 2001, the French ministry of ecology and durable development, started a program: to establish a tool, a method, allowing to identify the corridors and to treat on a hierarchical basis according to the risk they generate, in order to later on distribute the efforts of prevention as well as possible. In this objective the Cemagref institute joined with several external experts coming from companies called ASI, Météorisk and Toraval. This elaboration required several months of work.

As we know, there is no such avalanche method, even for other natural hazard, in France or in another country.

The tool to be developed aimed particularly at achieving the following goals:

- ➔ to privilege the protection of the lives rather than that of the goods,
- ➔ to study the structural, chronic human vulnerability: dwelling place or road, other than the ski fields,
- ➔ to distinguish the "sensitive" corridors clearly, like the one of Montroc, which is a priori around 10% of the sites,
- ➔ to obtain a relative simplicity of implementation, 1 to 3 hour maximum of analysis by avalanche path,
- ➔ to allow at quantified comparisons between sites, with a national level, by a classification according to three levels of dangerousness /sensitivity:
  - low sensitivity: a priori the site does not deserve detailed attention; required

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selectivity: ~70 % of the sites;
- doubtful sensitivity: the site can deserve a study specifying the avalanche risk; required selectivity: ~20 % of the sites;
- strong sensitivity: the site requires a thorough study of the avalanche risk; required selectivity: ~10 % of the sites.

The word "dwelling" had to be specified: it is a construction able to be occupied several hours per day in the winter, and not strictly only a housing where one sleeps: for example a restaurant of altitude, a refuge, a store must also be taken into account. But the isolated ski lifts, the ski slopes, the zones of sporting frequentation towards mountain, in spite of the lives which can be there, are not integrated because their safety with respect to the avalanche risk is not related to the zoning of prevention.

Conversely, to go towards exhaustiveness, as soon as a doubt exists concerning the threat on a dwelling, or a road, the tool should be used in order to check. At least it then brings a convenient classification. It can especially reveal a strong sensitivity, ignored until there through lack of having reflected thoroughly: it is its initial goal!

With this method, we hope to well detect the hundred corridors of which it would really be necessary to be worried in priority.

2 THE DESCRIPTION OF THE METHOD

2.1 *Principles*

First we describe the final state of the method and hope to clarify its use, without evoking the preliminary multiple and collective analyses. The avalanche sensitivity of various paths is evaluated starting from the same criteria, balanced the ones compared to the others. A simple system of office plurality of these weightings provides an estimate that allows a classification.

Four independent groups of criteria emerge:
- ➔ the vulnerability concerned (qualification of the dwellings and the transportation routes), see the table in Appendix 7.1;
- ➔ the morphology of the site (surfaces, slope angles, difference in altitude, increasing potentialities), see the table in Appendix 7.2;
- ➔ the known avalanche history (frequency, going beyond, irregularity, uncertainty), see the table in Appendix 7.3;
- ➔ the snow-climatology of the massif (snowing up, influence of the wind), see the table in Appendix 7.4;.

Their relative importance has then been structured in a voluntarily very uneven way: that is to say a respective percentage close to 50, 25, 15 and 10; the vulnerability "weighs" half of the whole and five times more than snow-climatology! Then the criteria of quantification of the sensitivity have been identified and treated on a hierarchical basis in order to tend towards the previous objective.

The user must have a rather beforehand good knowledge both of phenomenon avalanche and of each studied site: that exempts him at going on each site. However it will be necessary for him when the precise determination of the vulnerability appears delicate, because its influence is capital. A certain ease of use was required: only the information rather easily available was integrated. Moreover, the comparison inter-sites is possible only if these criteria are common, or very well shared, between the whole of the avalanche paths of France.

Thus for each criterion selected (example in morphology: worsening potentiality), at least one relevant element is identified (ex: possible starting zone above) and a class of values is defined (ex: surface from 2 to 5 ha). Lastly, a "weight", a specific weighting, is allotted, in close connection with the internal distribution in each group. Of course, the development of this sort key required several tests!

These elementary weights are added for each criteria group. To reinforce the distinction, the assessment is then carried out according to a double combination of the same criteria:
- ➔ either the general addition of the total weight of each 4 groups,
- ➔ or the multiplication of the sub-total of the vulnerability group with the total of the addition of the weights of each 3 others groups, that is the hazard, corresponding more to the risk.

In the current state of the method, according to groups' of criteria, weightings are distributed overall as follows:

Table 1: Distribution of the extreme level-headedness

Level-headedness	Vulnerability	Morphology	History	Snow-climatology	Addition	Multiplication
Minimal	0	0	1	4	5	0
Maximal	180 or 237	77	47	16	320 or 377	25 200 or 33 180

2.2 *Preliminary test*

In the development phase, two preliminary tests were undertaken on 2 different samples:

- ➔ one carried out by only one "user" on several tens of diversified corridors of the same commune, to qualify the sought distinction,
- ➔ the other carried out by each member of the group, on 8 "particularly sensitive" corridors, to appreciate the "stability" of the method according to the user.

The test of qualification: the commune chosen for the test comprises 140 paths on the map of probable localization of the avalanches, including 21 with a non null vulnerability (within the meaning of the method). Among the 119 corridors without vulnerability, 19 were retained to lead to a sample of forty. This test allows proposing two initial sensitivity scales.

With use, the scales could be adjusted, in particular the limits between doubtful and low. These two practical, Addition and Multiplication, inevitably do not give the same classification for the same path. That partly shows uncertainty on the result, which also closely depends on the terminals of classification. The user will have to slice. But the sites without vulnerability are always in the category of low sensitivity.

On the 8 sites with doubtful or high sensitivity of the test (located at the top of the complementary orange horizontal line), the distribution of the sum of the weightings obtained for each 4 groups approaches close enough to the one desired. Morphology still remains relatively important as regards to the vulnerability. However more one goes towards the strong sensitivity plus the tendency good is.

The method allows a good distinction between the various corridors. In the particular case of this test, two corridors are thus distinguished clearly.

The test of stability: Seven users practised the method on eight (or almost!) identical avalanche paths. When there is no result, it is that the user did not test the path concerned.

The particular site of Montroc with information available before 1999 was tested:

- ➔ five users affected it of a high sensitivity,
- ➔ one found it with a doubtful sensitivity (by addition) and low by multiplication,
- ➔ another classified it with a low sensitivity according to 2 calculations.

In these the last 2 cases, without any doubt, because of a strong reduced evaluation of the vulnerability!

Several abacuses of assistance have been worked out for morphology. For the "History", a minimum statistical treatment can remain delicate. An Excel spreadsheet placed at the disposal finally allows a certain automation of the tiresome operations. This tool can also be relatively easily integrated into the expert system called "Nivolog" used in many stations (Swiss and French).

4 THE PRESENT USE

In 2003, the French specialized service already indexed approximately 3200 paths threatening the dwellings or the roads in France. Nearly 1300 of them threaten the dwellings. Thus the real test has started at the end of the year 2004.

At that time we have build a new data base with MSAccess. It helps very much the local user (easy and quick to manage) and the data user. We write also a complete handbook (22 pages, with schemes, maps and the necessary technical elements). Each year we also prepare a special short training course to learn the method. We have précised the avalanche limit which must be taking into account. This last point is very important to get a good comparison between different local users.

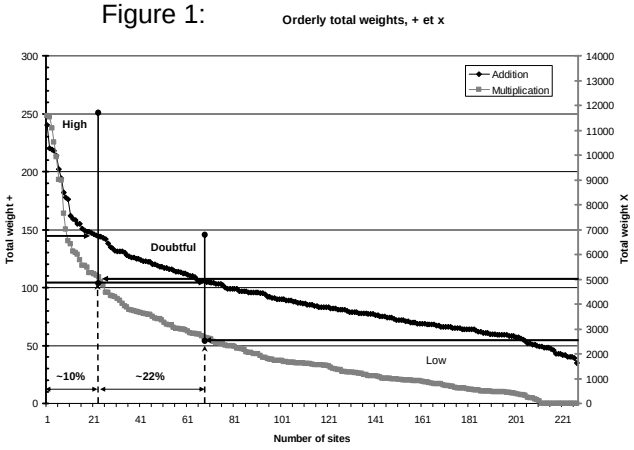
The first real test classifies 227 sites. With this result, to obtain around 10% in the high class and around 22% in the doubtful class we change a little bit the Addition scale, but not the Multiplication. And we have:

Table 2 : Sensitivity scales

Sensitivity	Addition	Multiplication
Low:	=< 105	=< 2500
Doubtful:	105 < x =< 145	2500 < x =< 3000
High:	>145	>3000

We have obtained the orderly total weights as follow:

Figure 1:



The hazard is not correlated with the vulnerability. But the Addition weight is very well correlated with the Multiplication one (see figure 2).

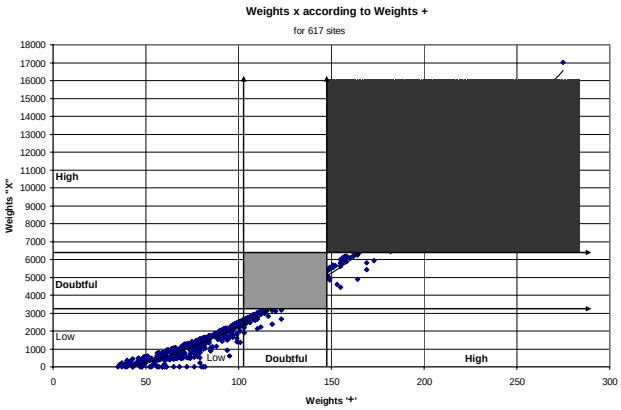


Figure 2: Distribution of the weights X according to the weights + for the 617 sites

With another group of 390 sites we increased hardly the number in the high class, because the main part of these sites is located in the north of the Alps, around Mont-Blanc massif, which is occupied with many houses. The 2 top sensitive sites are now coming from Chamonix.

With the 248 sites which are classified in High and doubtful sensibility, the repartition between the 4 different groups looks not so bad: just a little bit too much for the vulnerability (56% against 50% in the initial view).

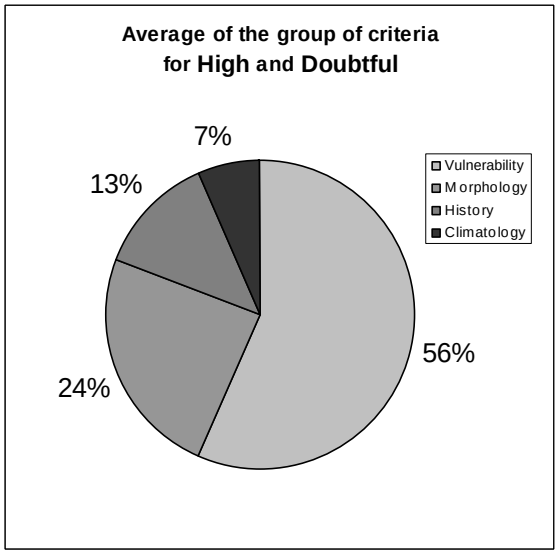


Figure 3: Distribution of the average level-headedness according to the 4 criteria groups, for the 258 sites with doubtful or high sensitivity

5 CONCLUSION

This new tool is definitely a decision-making aid for the identification and the classification of the avalanche sites, according to the extent of the generated risk. It functions well in the large majority of the cases. But it can underestimate some paths with very original working. In fact, in the current state of snow knowledge, the exhaustiveness of the risk identification and the relevance of the segregation of the sites can only be completely apprehended with one in-depth expertise. Only this one can finely integrate the whole data, those evoked in this tool but also all the other quantitative or qualitative information, possibly available (ex: type of avalanche, particular historical event, specific calculations, snow and meteorological data, geographical characteristics, effectiveness of protection works, etc.) which are not taken into account.

Thus the use of this tool can prove to be reducing great natural diversity of the situations: all the local variations, the specific potentialities cannot be explicitly recognized there. It will always be necessary to hold account of it in the appreciation of the results. The final "weight" obtained indicates more one tendency than a precise value.

Nevertheless the proposed tool constitutes:

- ➔ Firstly in its implementation, a fast support of reasoning intended for the engineers and technicians specialized in natural mountain risks,
- ➔ Then in its results, by the comparison which it generates, an invaluable help towards the decision for the authorities concerned. Thus it contributes to the opinions of the experts and to the actions of the decision makers.

The result obtained by the suggested method does not impose the renewal of an in-depth avalanche risk study which would be already made. On the other hand it will generate some where these studies miss. According to conclusions' of these later specific studies, existing prevention and risk management measurements (zoning, protection, alert, help) should be examined and supplemented as a need.

6 BIBLIOGRAPHIE

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7 Appendix

7.1 *Vulnerability table*

1 Vulnerability criterion	**Element**, in comparison with the **avalanche past limit**		**Class**	**"Weight"** possible
1.1 **Occupants** : **Number of winter lives** (or number of winter occupied accommodations x 4)	**1.1.1** **inside** the limit		> 20	36
			from 5 to 20	24
			1 to 4	12
	in the axe, towards the total length of the avalanche, to a **distance** included (in horizontal projection) between :	**1.1.2** 0 and 5%	> 20	24
			from 5 to 20	16
			1 to 4	8
		1.1.3 5 and 10%	>20	16
			from 5 to 20	8
			1 to 4	4
		1.1.4 10 and 20%	>20	10
			from 5 to 20	5
			1 to 4	3
1.2 **Living places** / Facilities showing an **unusual sensitivity**	**1.2.1** **inside** the limit		Aid	16
			Community	12
			Industrial	8
	in the axe, towards the total length of the avalanche, to a **distance** included (in horizontal projection) between :	**1.2.2** 0 and 5%	Aid	10
			Community	8
			Industrial	5
		1.2.3 5 and 10%	Aid	6
			Community	4
			Industrial	3
		1.2.4 10 and 20%	Aid	4
			Community	3
			Industrial	2
1.3 Roads : threaten **length**	**1.3.1** **inside** the limit		>= 100 m	10
			< 100 m	5
	in the axe, towards the **total** avalanche **length**, (added to previous) between :	**1.3.2** 0 and 5%	>= 100 m	7
			< 100 m	4
		1.3.3 5 and 20%	>= 100 m	3
			< 100 m	1
1.4 Roads : **Unusual sensitivity**	**Maximum number**, in usual winter traffic, of **vehicles** (1 bus = 5 cars) which can be together engaged in the threaten area :		> 20	8
			5 to 20	4
			1 to 4	2
			Total **Vulnerability** weight **=**	

7.2 *Morphology table*

2 Morphology criterion	**Element**		**Class**	**"Weight"** possible
2.1 Past limit: **Surfaces** (in projection, by ha)	**2.1.1 Starting zone** (known) (slope angle >53%=28° and <120%=50°)		>= 10	10
			5 =< < 10	6
			2 =< < 5	2
	2.1.2 Ratio Known starting zone / Runout zone (slope angle<27%=~15°)		>= 3	7
			1,5 =< < 3	4
2.2 Past limit: **Slope angles** (by° and %)	**2.2.1 Along 100 to 200 m above the first stake** (dwelling place, road), or from the known end of the deposit		>=27% =~15°	8
			18%=10° =< <27%	5
			9%=~5° =< < 18%	2
	2.2.2 average		>= 58% =~30°	5
			47%=~25° =< <58%	3
			36%=~20° =< <47%	1
	2.2.3 in the starting zone (along ~100 m)		=< 62% =32°	4
			62%< =<75%=~37°	2
2.3 Past limit: **Difference in altitude** (by m)	**maximum**		>= 800	5
			300 =< < 800	3
2.4 Increasing potentialities for a possible starting zone (slope angle >28°=53% and <50°=120%)	**Been situated above** the past one :	**2.4.1** Surface (by ha)	>= 5	8
			2 =< < 5	5
			< 2	2
		2.4.2 Difference of altitude (by m)	>= 400	5
			150 =< < 400	3
	Been situated on the side to the past one, and **connectable** above of the stake or of the known runout zone :	**2.4.3** Surface (by ha)	>= 5	6
			2 =< < 5	4
			< 2	2
		2.4.4 Difference of altitude (by m)	>= 400	4
			150 =< < 400	2
	2.4.5 Presence of **seracs**		yes	5
2.5 Increasing potentialities for the possible flowing and runout zone (slope angle <28°=53%)	**2.5.1 Possible change in trajectory:** on the side (deviation, confining) or in the lengthways (rise, etc.)		yes	8
			no	0
	2.5.2 Presence of **forest** around the flowing zone		yes :	2
			no	0
			Total **Morphology** weight **=**	

7.3 *Historical table*

3 **History** criterion	**Element**	**Class**	**"Weight"** possible
3.1 **Number of events divided by the number of observed years**	**3.1.1** avalanches which has reached at least one winter stake (dwelling place, road, ...)	>= 0,1 (10 years)	15
		0,03 (30 years) =< < 0,1	10
		0,01 (100 years) =< < 0,03	6
	3.1.1 avalanches stopped without impact, to a distance less than 100 m from a winter stake	>= 0,2 (5 years)	10
		0,1 =< < 0,2	7
		0,03 =< < 0,1	4
3.2 **Overtaking of border** on the avalanche map	**3.2.1** Map from the years 70	yes / doesn't exist	4
		no	1
	3.2.2 Map from the years 90	yes / doesn't exist	3
		no	0
3.3 **Working irregularities** of the path	Ratio between : - maximum number of years between 2 successive starts, whatever the runout altitude may be - minimum number of years ...	>= 10 or unknown	4
		10 > >= 4	2
3.4 **Quality and uncertainty upon the historical data** (in the duration, in consistency with the geographical data, with the natural variability of the data)	**3.4.1** Duration of the series	short =< 20 years	4
	3.4.2 Existing thorough historical study (not only the avalanche map)	**3.4.2.1** Yes	-4
		3.4.2.2 Imprecise path limit	5
		3.4.2.3 Existing data clearly absurd	2
		3.4.2.4 Imprecise path limit and existing data clearly absurd	7
		Total **Historical weight** =	

7.4 *Snow-climatology table*

4 Snow-climatology criterion	**Element**	**Class**	**"Weight"** possible
4.1 **Snowing up** according to the mountains	**4.1.1** **Variability** between the years	Strong	7
		Average	4
		Low	2
	4.1.2 **Quantity**	Strong	4
		Average	2
		Low	1
4.2 **Wind influence** for to add snow **into** the **starting zone**		Strong	5
		Average	3
		Low	1
		Total Snow-climatology weight =	