A MULTI-LEVEL AVALANCHE RISK ASSESSMENT METHODOLOGY: A CASE STUDY FROM NORTHWESTERN ITALY (AOSTA VALLEY)

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ABSTRACT: The increasing frequency and magnitude of natural extreme events endangering the built environment highlight the need for effective policy-oriented tools to assess, manage, and mitigate the associated risk. This work presents a simple multi-level methodology recently adopted in Italy for the risk assessment of buildings and infrastructures exposed to avalanche hazards, with a focus on supporting risk-informed decision-making. For each exposed element, the procedure provides risk matrices in which five risk classes (low, medium-low, medium, medium-high, high) are defined based on the evaluation of hazard, vulnerability, and exposure. These factors are assessed through simplified and standardized criteria, relying on existing hazard mapping and key characteristics of the exposed assets, including individual buildings and linear infrastructures (network systems). The methodology is designed to be integrated into policy frameworks, providing a basis to support the prioritization of interventions and the optimal allocation of public financial resources. The application of the proposed methodology is shown with respect to a municipality in the Valle d'Aosta region (north-west Italy), considering multiple avalanche basins. The results provide a hierarchical classification of risk, supporting both at the scale of individual buildings within each basin and across different basins within the investigated territory. The strengths and limitation of the proposed framework are discussed, highlighting its potential to bridge the gap between technical risk assessment and operational risk governance in avalanche-prone areas.

KEYWORDS: risk management; built environment; vulnerability; exposure; resource allocation

1. INTRODUCTION

The assessment of avalanche risk represents a fundamental component of spatial planning and civil protection in alpine environments, where buildings and transportation infrastructure are frequently located in proximity to active avalanche paths. Consequently, the availability of rapid, reproducible, and scalable assessment procedures is essential to support local authorities in resource allocation and the prioritization of mitigation measures, particularly where comprehensive quantitative and probabilistic risk analyses cannot be systematically undertaken because of time and cost constraints.

Several countries have developed specific guidelines and methodologies for avalanche hazard zoning and risk mitigation (Canadian Avalanche Association, 2002; Eidgenössisches Institut für Schnee- und Lawinenforschung SLF, 2007; Ministère de l'Écologie, du Développement durable et de l'Énergie, 2015; Issler et al., 2023). In Italy, a multi-level methodology for the assessment and mitigation of snow avalanche risk to buildings and infrastructures has recently been introduced within the *Linee guida per la valutazione e la mitigazione del rischio valanghe di neve sulle infrastrutture e costruzioni* (Chiaia & Frigo, 2024). The methodology is structured into four progressively detailed levels of analysis, ranging from the inventory of exposed assets to risk management and mitigation, and adopts a semi-quantitative, class-based approach integrating the three classical components of risk: hazard, vulnerability, and exposure.

This paper presents the results of a joint research activity between *Fondazione Montagna Sicura – Montagne Sûre* and *Politecnico di Torino*. The study aims to apply the italian methodology at the municipal scale, using Rhêmes-Notre-Dame (Aosta Valley, Italy) as a case study, to provide a comparative assessment of avalanche risk conditions and support the identification of priority areas and exposed elements for mitigation and civil protection actions. The assessment encompassed the built environment exposed to avalanche hazard within four settlements of the municipality: Artalle, Chanavey, Rhêmes-Notre-Dame (Bruil), and Pont-Chaudanne-Pellaud, for a total of 81 buildings distributed across ten avalanche basins. The analysis also included the SR24 Regional Road as an example of linear

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transportation infrastructure, together with two strategic facilities for emergency management: the Municipal Operations Centre (COC) and the emergency helicopter landing site.

Section 2 describes the study area and the characteristics of the investigated hamlets. In Section 3, the main principles of the methodology are presented. Section 4 discusses the application of the methodology for a representative study area, while the results for the remaining hamlets are briefly summarized. Section 5 discusses the main results, considering both the individual study areas and the overall municipal context. Finally, Section 6 summarizes the main conclusions and outlines possible directions for future research.

2. STUDY AREA

The municipality of Rhêmes-Notre-Dame is located in the upper Rhêmes Valley (Aosta Valley, northwestern Italy) and is characterized by a typical alpine geomorphological setting, where numerous avalanche basins directly interfere with the built environment, including the main and only-road running the valley. For the purposes of this study, four areas within the municipal territory were considered: Artalle; Chanavey; Rhêmes-Notre-Dame (Bruil, the municipal centre); and Pont-Chaudanne-Pellaud, considered jointly.

Each area is affected by one or more officially mapped avalanche basins, which can be identified through the Avalanche Cadastre of the Autonomous Region of Aosta Valley (Debernardi and Segor, 2013), the official cartographic database of avalanche-prone areas established pursuant to Article 37 of Regional Law No. 11 of 6 April 1998 (*Legge Regionale 6 aprile 1998, n. 11*; Autonomous Region of Aosta Valley, 1998). The actual interaction between the mapped avalanche hazard zones and the built environment was also verified through GIS overlay analysis with the Regional Technical Map. In total, ten avalanche basins were identified as directly interacting with the built environment (Fig. 1).

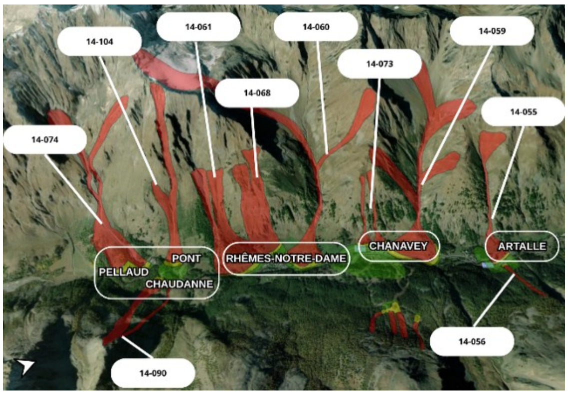

Figure 1: Avalanche basins identified and grouped by hamlet. *(Source: https://mappe.partout.it/)*.

Table 1 summarizes the distribution of the exposed buildings for each study area, and lists the corresponding avalanche basins, together with their official identification code.

Table 1: Surveyed hamlets, number of assessed buildings, and interfering avalanche basins.

Hamlet	***N° of exposed elements***	***Avalanche basins***
Artalle	13	14-055, 14-056
Chanavey	26	14-059, 14-073
Rhêmes-Notre-Dame (Bruil)	25	14-060,14-061, 14-068
Pont-Chaudanne-Pellaud	17	14-090, 14-104, 14-074

In addition to the individual buildings, the assessment included a section of the SR24 Regional Road, the main road serving the valley's settlements. Among the avalanche basins affecting the road, four were selected to represent different combinations of mapped hazard conditions, road-network vulnerability, related to the presence of avalanche protection galleries and alternative routes, and exposure, expressed in terms of the population potentially isolated in the event of road interruption. The selected basins were 14-052 (Money), 14-054 (Artalle), 14-068 (La Grand Platta), and 14-104 (Torrent Ergioi).

Two strategic facilities were also considered in the assessment because their continued functionality is particularly important for emergency management and response: the Municipal Operations Centre (COC), located in Bruil, and an emergency helicopter landing site situated at the football field in the hamlet of Chanavey.

3. METHODOLOGY

In this section, the main features of the adopted methodology are presented, which is documented both in the Italian National Guidelines (Chiaia & Frigo, 2024) and in the corresponding scientific paper (Rubino et al., 2026). The general structure of the adopted methodology is schematically shown in Figure 2, where the four levels of analysis are represented through a flowchart.

The first two levels of the assessment focus on the identification and characterization of the exposed assets: (i) Level 0 consists of a preliminary documentary analysis aimed at identifying the assets potentially affected by avalanches within the defined territorial domain; (ii) Level 1 involves field inspections and on-site surveys to verify, integrate, and validate the information collected at the previous stage. Level 2 represents the core of the procedure and assigns each exposed element a Risk Class (RC) according to a five-level scale (Low, Medium-Low, Medium, Medium-High, and High). Finally, Level 3 addresses risk management and mitigation activities under the responsibility of local authorities, whose outcomes may lead to an update of the assigned RC.

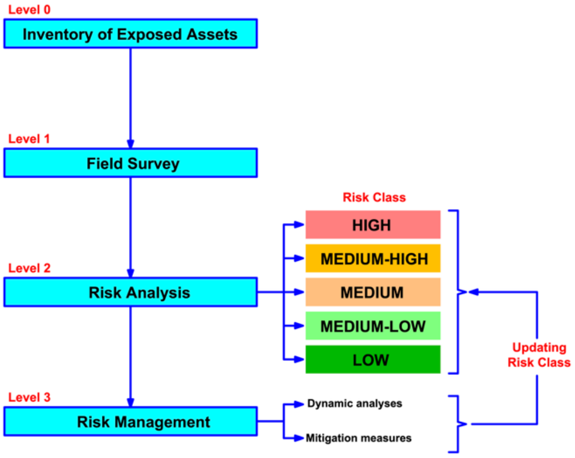

Figure 2: Flowchart of the proposed multi-level approach (Rubino et al., 2026).

Level 2 estimates risk through a semi-quantitative class-based approach (IUGS, 1997), in which the three classical components of risk – hazard (H), vulnerability (V), and exposure (E) – are evaluated on an ordinal scale ranging from 1 (Low) to 5 (High). The assessment of each factor is based on primary parameters, representing the dominant variables for classification purposes, and secondary parameters, which introduce adjustments according to the specific characteristics of the exposed element and the surrounding territorial context.

For hazard, the primary parameter is represented by the official hazard zoning of areas exposed to snow avalanches and avalanching phenomena. In Aosta Valley, avalanche mapping is provided consistently with the Regional Law No. 11/1998, which distinguishes three mapping classes: V1 high hazard (red zone); V2 medium hazard (yellow zone); and V3 low hazard (green zone). This classification is translated within the proposed framework as follows:

- High hazard class: V1 (red zone);
- Medium hazard class: V2 (yellow zone);
- Low hazard class: V3 (green zone).

This primary classification is adjusted through a secondary parameter related to the presence and effectiveness of protective measures, e.g., snow supporting structures, check dams, and deflection structures (Margreth, 2007). The mapped hazard class is reduced by one level when effective active or passive protection measures are present, remains unchanged when only monitoring systems are available (as these do not modify the physical interaction with the phenomenon), and is increased by one level in the absence of any protection measures, thereby extending the original three-class cartographic scale to the five-class scale adopted by the methodology.

For vulnerability, the structural typology of the building is used as primary parameter to classify the vulnerability into five increasing levels:

- High vulnerability class: special structures such as towers and bridges;
- Medium-high vulnerability class: masonry buildings, timber frames;
- Medium vulnerability class: RC frames;
- Medium-low vulnerability class: RC walls;
- Low vulnerability class: structures with specific protective measures against avalanche loads.

This primary classification is adjusted through two secondary parameters: the geometric interaction between the element and the area affected by avalanche (total or partial, the latter applying, also, to underground structures or buildings affected by individual protective measures such as deflection wedges or earth embankments), and, for linear infrastructures, the redundancy of the transportation network (Dalmasso et al., 2025). Each secondary parameter may increase the vulnerability class by one level.

For exposure, the primary parameter is the functional use of the structure, divided into five classes, ranging from abandoned uninhabited buildings (low class) to residential settlements and accommodation facilities (high class), including storage buildings/warehouses, local roads, public infrastructures, and cultural heritage assets:

- High exposure class: residential settlements and accommodation facilities;
- Medium-high exposure class: infrastructures and cultural heritage assets;
- Medium exposure class: local roads;
- Medium-low exposure class: storage buildings;
- Low exposure class: uninhabited buildings.

The exposure class may be increased by one level in the case of strategic facilities relevant for emergency management.

The three ordinal scores, each one ranging from 1 to 5, are combined into a risk index (R) according to the Equation (1):

$$R = p_H \cdot \mathrm{H} + p_V \cdot \mathrm{V} + p_E \cdot \mathrm{E} \qquad (1)$$

where the weights are non-negative and sum to unity. In accordance with the previous works

(Chiaia & Frigo 2024; Rubino et al., 2026), the following values $p_H = 0.40$, $p_V = 0.20$, and $p_E = 0.40$ are adopted. These weights assign greater relative importance to hazard and exposure compared with vulnerability. The resulting index ranges continuously between 1 and 5 and is subsequently discretized into five Risk Classes: High ($4.5 \leq R \leq 5$), Medium-High ($3.5 \leq R < 4.5$), Medium ($2.5 \leq R < 3.5$), Medium-Low ($1.5 \leq R < 2.5$), and Low ($1 \leq R < 1.5$). Final results can be collected in risk matrices (Fig. 3), in which the risk class can be determined as a function of the hazard, vulnerability, and exposure factors.

<table>
<tr><th colspan="2">Hazard Class
HIGH</th><th colspan="5">Exposure Class</th></tr>
<tr><th colspan="2"></th><th>HIGH</th><th>MEDIUM-HIGH</th><th>MEDIUM</th><th>MEDIUM-LOW</th><th>LOW</th></tr>
<tr><th rowspan="5">Vulnerability Class</th><th>HIGH</th><td colspan="2">HIGH</td><td colspan="2">MEDIUM-HIGH</td><td>MEDIUM</td></tr>
<tr><th>MEDIUM-HIGH</th><td>HIGH</td><td colspan="3">MEDIUM-HIGH</td><td>MEDIUM</td></tr>
<tr><th>MEDIUM</th><td>HIGH</td><td colspan="2">MEDIUM-HIGH</td><td colspan="2">MEDIUM</td></tr>
<tr><th>MEDIUM-LOW</th><td colspan="3">MEDIUM-HIGH</td><td colspan="2">MEDIUM</td></tr>
<tr><th>LOW</th><td colspan="2">MEDIUM-HIGH</td><td colspan="3">MEDIUM</td></tr>
</table>

Figure 3: Example of risk matrix (Rubino et al, 2026).

4. RESULTS

4.1 Chanavey case study

The area of Chanavey, selected as the representative case study in Rhêmes-Notre-Dame for the methodological assessment, includes 26 buildings (codes C.1–C.26 in Fig. 4) distributed across two adjacent avalanche basins, i.e., 14-059 (Cussunaz-Quesseunaz) and 14-073 (Roccioni di Chanavey). The latter are characterized by substantially different risk mitigation conditions: in basin 14-059 no protective measures are present, whereas basin 14-073 is protected by snow avalanche supporting structures (*avalanche sheds/supporting structures*).

Within basin 14-059, most exposed buildings are located in the medium-hazard area, with only two falling within high-hazard area (Fig. 4). Because of the absence of any protection measures at the basin scale, the methodology applies a one-level increase of the mapped hazard level, leading to a predominant Medium-high hazard class for the exposed elements. The latter mainly consist of masonry buildings and timber-frame structures. Considering also the complete geometric overlapping between the buildings and the avalanche area, the vulnerability is mainly classified as Medium-high or High. Buildings C.2 and C.23 represent specific cases where individual protective measures – a deflection wedge and an earth embankment, respectively – allowed the interference condition to be classified as partial. Exposure is predominantly classified as High, due to the prevalence of residential buildings occupied also during the winter season. Conversely, building C.2, which is used exclusively during the summer period, is assigned a Medium-Low exposure class, and the ski facility, whose access is already subject to dedicated risk management procedures, is intended as a storage/warehouse-type asset.

In basin 14-073, the presence of avalanche supporting structures implies that the hazard class remains unchanged with respect to the original official hazard mapping. As a result, the hazard class associated to the exposed buildings remains predominantly Low. On the other hand, vulnerability and exposure factors remain substantially comparable to those of buildings located in the adjacent basin.

The resulting Risk Classes (RC) assigned to the exposed elements in the Chanavey hamlet are reported in Figure 4, where each building is represented through a colour code, in accordance with the figure caption. Overall, the comparison between the two basins indicates that, under comparable vulnerability and exposure conditions, the hazard factor is the main variable affecting the resulting risk classes of the exposed elements. Buildings located within basin 14-073 are generally assigned lower Risk Classes, mainly ranging from Medium-Low to Medium, whereas higher classes prevail in basin 14-059. Within the adopted methodology, this difference is primarily attributable to the lower hazard levels associated with the presence of snow-supporting structures.

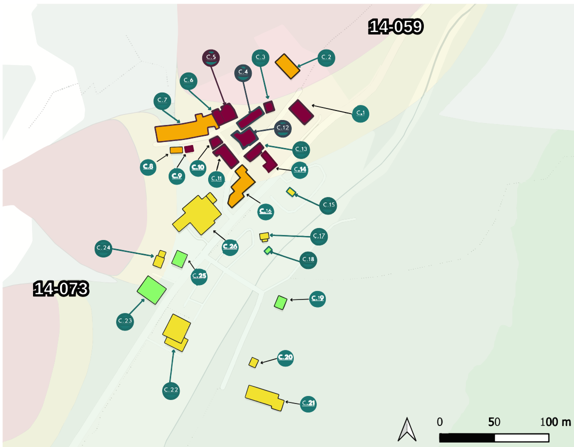

Figure 4. Risk Class (RC) for the exposed elements in the Chanavey hamlet. The colour scale represents the five risk levels: red (High), orange (Medium-high), yellow (Medium), light green (Medium-low), and green (Low).

4.2 Territorial prioritization

The same assessment of the risk class was carried out for the remaining hamlets of the municipality: Artalle, Rhêmes-Notre-Dame (Bruil), and Pont-Chaudanne-Pellaud. Within these areas, the methodology assigns each exposed building to the corresponding risk class, thus allowing a hierarchical assessment, both at the basin and hamlet scales.

To identify priority areas for subsequent avalanche risk mitigation and civil protection actions, five territorial prioritization criteria were applied at the scale of individual hamlets. The selected criteria were: (i) maximum risk class, which assigns to each hamlet the highest Risk Class (RC) among all surveyed buildings; (ii) total RC sum, obtained by summing the risk class values of all buildings within the hamlet; (iii) percentage of buildings above the critical threshold, defined as the proportion of buildings with RC ≥ 4, corresponding to the Medium-High and High risk classes; (iv) average risk class, calculated as the arithmetic mean of the RC values assigned to the buildings; and (v) weighted combined index, calculated according to the same principle as the average risk, but by first squaring each RC value before summation and normalization. This latter criterion therefore assigns a greater relative weight to buildings characterized by higher risk classes while reducing the influence of the total number of buildings.

Results are collected in Table 2, where the comparison highlights how the different prioritization criteria are differently affected by the number of exposed elements within each hamlet. In particular, the total RC sum gives greater relevance to large settlements. Accordingly, this criterion ranks Rhêmes-Notre-Dame (Bruil) as the second most critical hamlet in absolute terms (score equal to 70), mainly because of the high number of surveyed buildings (25), despite its relatively low average risk level and the absence of buildings exceeding the critical threshold (0%). Conversely, normalized criteria, namely the average risk and the weighted combined index, are not influenced by the settlement size, but they focus on the risk distribution among the exposed elements. These criteria identify Chanavey as the highest-priority hamlet, followed by Pont-Chaudanne-Pellaud, Artalle, and finally Rhêmes-Notre-Dame (Bruil).

Table 2: Comparison of the five territorial prioritization criteria applied at the hamlet scale.

Hamlet	***Max RC***	***Total RC sum***	***% buildings ≥ critical threshold***	***Average RC***	***Weighted combined index***
Chanavey	5	100	57.7% (15/26)	3.85	16.08
Pont-Chaudanne-Pellaud	5	61	52.9% (9/17)	3.59	13.47
Artalle	4	44	46.2% (6/13)	3.38	11.85
Rhêmes-Notre-Dame	3	70	0.0% (0/25)	2.80	8.00

4.3 Road infrastructure and strategic constructions

The application of the methodology to the SR24 Regional Road, considered as a linear infrastructure, required an adaptation of the assessment criteria. The primary vulnerability class is assumed as medium for the entire road section, and it is adjusted according to the extension of avalanche interference, the presence of protective structures, and the availability of alternative routes (network resilience). Exposure was instead defined according to the population potentially isolated upstream of each potential disruption point, divided into five classes of homogeneous population ranges in accordance with the data provided by the Municipal Civil Protection Plan.

Four representative avalanche basins interfering with the road section were chosen for the application of the methodology, i.e., 14-052 (Money), 14-054 (Artalle), 14-068 (La Grand Platta), 14-104 (Torrent Ergioi), as shown in Fig. 5.

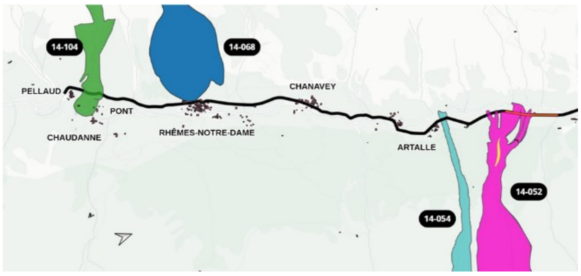

Figure 5. Avalanche basins interfering with the SR24 Regional Road.

The road is affected by the high-hazard area of Basin 14-054, which is further characterized by the absence of mitigation measures, finally leading to High hazard class. Considering also the total overlapping with the basin area and the absence of alternative routes (High vulnerability class) to manage the almost totality of the exposed population (High exposure class), the methodology predicts the highest Risk Class (High) for this basin.

Similarly, to the previous case, basin 14-052 is characterized by high exposure, as a road interruption would isolate the entire potentially present population located in the upper part of the municipality. However, the presence of defence systems, both at the basin scale (deflection structure) and for the specific infrastructure (avalanche protection gallery), affects the hazard and vulnerability factors, thus reducing the overall risk classification to Medium-High.

Basins 14-068 and 14-104 show lower risk conditions. The former benefits from active protection measures (two *O'BellX*^{TM} structures), whereas the latter, despite the absence of direct mitigation measures, is characterized by the availability of alternative routes. In both cases, even though because of different reasons, a Medium RC is assigned by the methodology.

The overall results are summarized in Table 3, which reports, for each basin under consideration, the main information related to the presence of protective measures and the number of people potentially isolated, together with the predicted risk class.

Table 3: Risk Class of avalanche basins interfering with the SR24 Regional Road.

Basin	***Protective measures***	***Potentially isolated population***	***Risk Class (RC)***
14-052	Deflection structure + avalanche protection gallery	2910	Medium-High
14-054	-	2890	High
14-068	Two Obelix	1910	Medium
14-104	-	445	Medium

Regarding the two strategic facilities identified within the municipality, the Municipal Operations Centre (COC) was assigned a Medium RC. In fact, the structure exhibits total geometric overlap with avalanche basin 14-073, which is nevertheless equipped with defence structures. Vulnerability was classified as medium due to its reinforced concrete construction combined with complete spatial exposure, whereas exposure was considered high given the regular and continuous presence of people within the building.

The emergency helicopter-landing site, located at the football field in the Chanavey hamlet and fully falling within avalanche basin 14-073, obtained a Medium-Low RC. Despite the total geometric interference with the basin, the effective hazard level is mitigated by the presence of avalanche supporting structures in the release zone. Regarding the facility-specific risk components, vulnerability was estimated as medium-low, consistent with the nature of the infrastructure (an open-air sports field lacking complex elevated structural elements) notwithstanding the total spatial interference. Finally, exposure was classified as medium-low rather than low; this higher class was specifically assigned in light of the facility's highly strategic role and essential function in emergency management.

5. DISCUSSION

The results obtained for the entire municipal territory show a substantial consistency among the different exposed elements, e.g., individual buildings, road infrastructure, and strategic facilities, in identifying the areas characterized by the highest criticalities. In particular, the convergence between normalized prioritization criteria (average risk and weighted combined index) and the criterion based on the percentage of buildings exceeding the critical threshold provides a cross-validation of the resulting priority ranking. The analysis highlights the relevance of the Chanavey area within civil protection planning, along with basin 14-059 as a potential site of interest for the planning of mitigation measures. These findings provide an informative contribution to support local decision-makers in guiding future sustainability analyses for intervention strategies, encompassing both structural and non-structural management measures.

The comparison between the two avalanche basins affecting Chanavey represents a significant example of the capability of the methodology to differentiate heterogeneous risk conditions within the same settlement area. Despite comparable building characteristics and land-use categories, the presence of active protection measures (avalanche supporting structures) in basin 14-073 results in a significant reduction of the Risk Class (RC) compared with the adjacent basin 14-059, where no protective measures are present. A similar result can be observed at the scale of Rhêmes-Notre-Dame (Bruil), where the widespread presence of mitigation measures, such as supporting terraces and *Obelix* structures, allows risk levels to remain limited despite the highest number of exposed buildings within the municipality. This finding highlights the importance of adopting normalized indicators with respect to sample size, avoiding risk classification systems based solely on the number of exposed elements.

The application of the methodology to the SR24 Regional Road further confirms the crucial role of effective defence systems at the basin scale. The basin without mitigation measures (14-054) represents the most relevant area among those interfering with the road infrastructure, consistently with the high criticality identified for the nearby buildings of Artalle. Conversely, basins characterized by active protection measures or alternative routes are associated with lower Risk Classes. The assessment of strategic facilities also highlighted the relevance of the exposure component related to the strategic function of the asset, independently of the actual settlement load. In particular, the Chanavey emergency helicopter-landing site, although located within an avalanche-prone area, benefits from the same active protection measures implemented in basin 14-073, which contribute to reducing the associated risk level.

The discretization of the risk index allows the continuous model output to be converted into a rapid classification framework, enabling direct comparison both among different territorial units, in support of civil protection planning and management activities, and among individual avalanche basins. This approach is consistent with the planning-oriented purpose underlying the National Guidelines.

Some intrinsic limitations of the methodology should nevertheless be acknowledged, being mainly related to the typological criteria adopted to classify the hazard, vulnerability, and exposure factors. While such typological approaches permit a rapid risk assessment, which is particularly useful for planning-oriented applications, they involve some degree of simplification. Regarding hazard assessment, the presence of protective measures is introduced only as a secondary parameter, without explicitly accounting for the specific function of the different types of defence systems or for their actual state of conservation and efficiency. Analogously, the vulnerability class does not consider aspects such as maintenance conditions, building age, or structural deterioration, which may significantly affect the actual damage susceptibility of individual assets. For linear infrastructures, the assumption of network redundancy as a secondary parameter may lead to significant oversimplifications when dealing with complex systems interconnected within the investigated territory. Finally, the exposure classification based solely on land use does not allow differences in actual occupancy levels to be distinguished within the same functional category, particularly for structures that differ in size and occupancy capacity.

6. CONCLUSIONS

This study applies a methodology recently adopted in Italy for the assessment and mitigation of snow avalanche risk at the scale of the entire municipal territory of Rhêmes-Notre-Dame (Aosta Valley, Italy). The analysis involved: (i) 81 buildings distributed across four hamlets; (ii) a section of the regional road network; (iii) two strategic facilities for emergency management. The procedure, based on a weighted combination of hazard, vulnerability, and exposure components, provided a consistent risk classification both at the hamlet scale and at the individual avalanche basin scale, effectively distinguishing similar settlement contexts characterized by different levels of structural protection and mitigation.

The detailed analysis of the Chanavey case study showed the ability of the methodology to discriminate risk conditions within the same settlement area, with particular reference to the role of protective measures. The application of the procedure to the remaining hamlets, the road network, and the strategic facilities, permitted to identify Chanavey and basin 14-059 as priority areas for further assessment in terms of civil protection planning and the evaluation of potential structural and management mitigation measures, according to the adopted prioritization criteria.

Beyond the specific case study, which represents a first application of the Italian National Guidelines to a real alpine context, the obtained results show the potential of the proposed approach as a rapid and structured screening tool for territorial-scale avalanche risk assessment (Ortner et al., 2023). Its main value lies in supporting the identification of priority areas where more detailed investigations, mitigation measures, or civil protection actions may be required. In this sense, this study can be viewed as the first step in establishing a methodological framework for future applications to other mountain territories, with the final aim of supporting planning and risk management activities by policymakers operating in mountain regions.

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