Analytical approach to natural-anthropogenic geomorphological hazards in relation with winter tourist activity in the mountainous environment: Poiana Braşov ski area case study

Cosmin PLOPEANU^a, Andreea ANDRA-TOPÂRCEANU^{a1}

^aUniversity of Bucharest, Faculty of Geography, Av. N. Bălcescu, 1, Bucharest, Romania

Abstract: The natural and anthropogenic-generated geomorphological hazards in the mountainous area have immediate consequences, with different degrees of danger on the tourist phenomenon, considering that modern tourist improvements boost the flows of tourists to the areas with high tourist attractiveness. At the level of the tourist's individual relation to the geomorphological hazards, an increase of the damage is noticed, in the context of relative mountain education and experience. Our paper analyses the triple relationship existing between the natural-anthropogenic geomorphological hazards, the tourists, respectively the tourist infrastructure, and the legislative regulations in the field of winter tourist activities, applied to the Poiana Braşov ski area. The main objectives were to identify and analyse the land instability factors and the geomorphological hazards, to determine the risk exposure of tourists and the ski area, as well as to identify managerial solutions for the existing risks in the upper part of Mount Postăvaru. The mountainous characteristics of this mountain area are given by the relatively low altitudes, steeply slopes, high isolation degree in relation to the surrounding geographic regions, which represent, on its Northern highest part the morphologic support for ski slopes with different difficulty degrees. The interaction between the anthropic and the natural factors induces instability of the slope surfaces; therefore, the resort is subjected to several types of geomorphological processes with variable intensities. The natural-anthropogenic geomorphological hazards may damage the ski area, the tourist activities and the tourists, generating accidents among them, on the grounds of the tendency of increasing tourist flows.

Key words: *geomorphological hazards, Poiana-Brasov ski area, tourist activity, injured tourists*

1. Introduction

Nowadays, the study of the natural hazards and risks, especially the geomorphological ones, represents a necessary stage in the territorial planning of

¹Corresponding author: Andreea ANDRA-TOPÂRCEANU, E-mail: andreea.andra@geo.unibuc.ro, Received: September 2019, Revised: September 2019, Published: October 2019.

human activities, as a consequence of the negative impact they have on society. In the last decades, the increasing frequency of natural hazards and of the corresponding material and human losses brought about wide and interdisciplinary approaches at the level of the European Commission ([Barredo, 2007](#)).

The scientific studies performed in Romania, on the distribution, causality and frequency of geomorphological hazards generating damage to the anthropic improvements and to persons had the fundamental purpose of reducing and efficiently preventing their consequences, at present, having in place legislation presenting the main stages of drafting risk maps and measures for reducing disasters.

One of the shared functionalities of the natural and anthropic environments is the tourist one, being determined by the attractiveness of the natural and anthropic resources, thus implying both investments for the tourist improvements and tourist flows. The tourist attractiveness (natural and anthropic resources, tourist objectives, and tourist infrastructures) is constituted in the form of the engine of tourists' motivation in initiating and performing tourist activities. Therefore, the tourists travel to the areas where the diversity, the values of uniqueness, esthetics and notoriety offered by the environment or the tourist infrastructure is attractive ([Mazorana, 2010](#)). The environment characterized by such tourist attributes manifests through the high energy of its natural and anthropic factors, becoming an active environment ([Panizza, 1996](#)); the magnitude of the dynamics of the tourist areas may sometimes exceed the limits of their resource qualities, transforming into dangers for tourists and tourist infrastructure. The tourists have intrinsic motivations above the possible hazards they may be exposing to, but, according to the legislation, they are warned against the risks they could be exposed to. On the territory of Romania, as a result of its landscape configuration, there are lots of geographic areas with amazing tourist resources and, at the same time, with high vulnerability, where the tourists perform activities with different degrees of danger.

In our study, we analyze the relation between the natural-anthropic geomorphological hazards and the tourist activity in the largest ski area in the Romanian Carpathians, Poiana-Braşov resort, by emphasizing the main factors causing tourist risks while performing winter tourist activities. The main objectives of the study are to identify the natural and anthropic geomorphological hazards and their impact on the tourist activity in Poiana-Braşov resort, to analyze the instability factors of the slope areas, especially of the ski area, to map the areas where the tourists or the infrastructure become risk elements, for the purpose of identifying efficiency measures, according to the resort management established through the legislation in effect.

2. Theoretical background

We can speak of the term risk only where people and their goods are present, respectively, in our case, the tourists, in the context of the manifesting of natural or anthropic-induced events with negative effects above their expectations (White, 1974, Armas, 2007, Danci, 2012, Andra-Topârceanu, 2018). The natural risks represent the possibility of occurrence of damages following a dangerous event in a space with vulnerability to that event. Risk also includes the concept of risk elements, such as people, buildings, infrastructure or services (Armaş, 2006). Risk is quantified by the possibility of occurrence of the damages caused and that always implied the notion of probability of occurrence (Sorocovschi, 2003). In risk research, risk is defined as a functional relationship between the probability of hazard occurrence and the evaluation of the impact degree (Mazzorana, 2010) of the risk elements. Eitzinger and Weidemann, (2009) claimed, based on statistics, that, during trips, people expose themselves to different degrees of risk, and the selection of a destination is not done only based on price and image of the respective destination, but also based on personal safety, perceived in relation to the respective destination. Even though the tourists are directly, exposed to certain risks, either consciously or unconsciously, the main motivation in choosing a tourist destination is their security and safety during the holiday (Eitzinger, Weidemann, 2009). Any tension within the system may affect the tourist activity and may create discomfort for the tourists. Events of the natural hazard type, increasingly frequent in the recent years, determined the introduction of the concept of risk in tourism management, because the values of risk in the spatial planning of a resort must be considered when correctly managing the natural dangers (Mazorana & Fuchs, 2010).

Natural hazards manifest on the tourism phenomenon in the conditions when the vulnerability of the territory is not null, and the possible damages may vary from the loss of human lives to the damaging of goods, infrastructure and tourist activity. Vulnerability encompasses all geomorphological processes, respectively mass movements which may include snow, rock debris, soil, vegetation and water, which may generate damages to the anthropic element placed in their direction of movement (Kienholz, 1978). Such geomorphological processes with different degrees of danger we can also find in our study area, such as: snow avalanches, rills, gullies, torrential processes, landslides rock falls on the surface, individual rock falls and sheet erosion on the surface. Hazard is defined as being “that process which can determine the unbalancing of the natural systems” (Socorovschi, 2005). Geomorphic hazards are any threats or a succession of threats to the human communities, result

from the land instability issues, resulted from the instability traits of the morphological surfaces, capable of creating damages to the physician and social space where they occur, not only in the short-lasting moment, but also long-term, due to their associated consequences (Alcantara, 2002).

These are phenomena, processes or activities with damaging potential, which may cause the loss of human life, may generate damages to property, damages to the environment and economic damages (Kron, 1994). Armas, (2007) claimed that vulnerability may constitute the key to reduce risk and to diminish possible damages, but also the extent to which a system exposed to a hazard can be affected. The manner in which vulnerability is approached within the decision-making policies and practices is influenced by the approach to hazard (Masson, 2015). The assessment of vulnerability requires the ability to identify and understand the susceptibility of the risk elements. (Birkmann-2006) In a wider sense, “vulnerability is a characteristic of human, social behavior and of the physical environments describing the degree of susceptibility (resistance) to the impact of natural dangers. (Glade, 2010) The term vulnerability “describes the conditions of a society or of an element in danger and, also, the determination of the potential impact of the hazard identified, in terms of possible losses of interruptions of the system” (Birkmann, 2007). In order to achieve a high level of protection against the effects of geomorphological hazards, the planning process must observe rules which allow an efficient management of the hazard consequences. Thus, in order to efficiently mitigate the risk, one must consider also other concepts, such as ecologic sustainability, technical viability, concept feasibility, as well as a maintenance strategy. It is important to understand the vulnerability as a feature of a community or environment of interest, in order to avoid the serious impacts of hazards on human life and infrastructure; the assessing risk areas and losses in the past and the current ones provide important data about possible losses in the future, as well as stated Birkmann (2007). The data-related with vulnerability can be used both at a local and at global level.

Natural risk management is defined in the specialty literature as being “the entirety of policies, administrative decisions and operational activity, which are connected to different stages of risk” (Bădila, 2007, Danci, 2012) and it also includes the type of random events such as accidents, which disrupt the normal flow of tourist activities (DEX). In short, risk management consists in a series of intervention strategies, aimed at diminishing or eliminating the possible damages caused by natural hazards, materialized in analysis processes and prevention actions, intervention during accidents, disasters and in the post-impact stage (Sorocovschi, 2008).

3. Methodology

In order to reach the main objective, cartographic, topographic 1:25.000, geographic and geological 1:50.000 material was analyzed, as well as information on the improvement of the resort and ski area within PUG (T.N. General Urban Plan) and PUD (T.N. Detailed Urban Plan) Brasov. The calculation of the indexes related to the pressure and impact of the tourist activities served to identify the dynamic of the tourist phenomenon before and after the development and expansion stage of the ski area.

The study uses two indexes:

a) Tourism density index based (TD) on the formula: $TD = \frac{NT}{NR}$;

b) Tourists pressure (TP), applying $TP = \frac{NT}{TA}$.

Where, DT: tourism density index; NT: number of tourists; NR: number of residents; TP: tourists pressure or tourists impact; TA: tourist area;

The geomorphic mapping on geomorphological hazards and interest areas were performed in the period June 2018 – May 2019, being analyzed and synthesized by employing QGIS 2.18.18 and ArcGIS 10.3.1. The field investigation methods used in identifying the characteristics of the risk elements were of socio-tourist nature: the questionnaire method in order to test the perception of the tourists and the interview method applied in case of the authorities in Poiana-Braşov resort, applied in the interval 2018 - 2019.

4. Geographical settings of case study

The first mentioning of the mountainous area pre-existent to the mountain resort which will become the most famous and modern in the Romanian Carpathians, Poiana-Braşov in the Mount Postăvaru, is found in a plan drafted by engineer Maetz Karoly, on the subalpine grass lands and the grazing activities (Manta, 1989). However, the practice of winter sports started in the 19th century, after two pupils within Honterus school in Braşov, as a consequence of a local tradition, 200 years old, of hiking in the mountains in the summer, climbed Postăvaru Mountain for the first time during winter (1857), deed considered remarkable and dangerous for those times. Afterwards, after erecting the first cabin, Postăvaru, in 1883, the mountainous area has increasing their tourist importance and was arranged for the tourists, in time, in 1906 thus becoming the mountain resort had hosting the longer ski slope in the Romanian Carpathians for long time, Drumul Roşu. The Poiana Brasov resort was the host of the first national and international winter sports competitions for youth,

in 1909. The tourist activity in the resort is currently operating throughout the year, registering annually an average of the number of tourists in excess of 150 000, but the activity is more intense in the summer and winter seasons. Because it is a mountain resort for practicing winter sports and the tourist flow is recorded in January and February, in our study, we will approach the relationship between the winter tourist activities and the geomorphological hazards in the cold season.

Poiana Brasov resort (4.74 km², 950 m altitude) has a ski area modernized in 2009 – 2011, composed of 7 slopes and 21 variants or ski routes, extended to 24 km length, with a total surface of the slopes of 0.85 km² and of the ski area of 2.028 km² (PUG, 2010), 10 installations of special transport on cable, artificial snow installations and night lighting, to which off-tracks are added (Table 1).

Altitudinal, the ski area unravels between 1000 m and 1800 m, on sedimentary deposits of the Mesozoic limestone and conglomerates and, to a smaller extent, of sandstones, sands and gravels (Figure 1 a). The present geomorphic processes acting on the landscape in Poiana-Braşov resort are: sheet erosion, rills, gully processes, torrentially, snow avalanches and rock falls as well as the anthropic-induced processes.

Table 1 Ski piste technical parameters from Poiana Braşov ski resort.

Ski trail	Lupului	Subtel eferic	Kanzel	Sulinar	Drumul Roşu	Bradul	Stadion
Rating of difficulty	Difficult	Difficult	Difficult	Interme diate	Easy - interme diate	Easy	Easy
Summit elevation (m)	1,703	1,700	1,760	1,705	17,665	1,106	1,040
Base elevation (m)	975	1,050	1,651	1,070	1050	1,035	1,010
Length (m)	2,605	2,200	297	2,820	4752	430	612
Vertical drop (m)	728	650	109	635	715	71	30
Area (ha)	17	2	4	9	7	3	1
Average width (m)	28	35	50	35	22	70	50
Nocturne equipment	x	x	x	x	x	yes	x
Snow making gun	yes	yes	yes	yes	yes	yes	yes

Source: after Ana Teleferic data

Tabel 2. Ski lifts equipment in Poiana Braşov ski resort

Names	Length (m)	Elevation difference (m)	Upper station elevation (m)	Opening hours
Capra Neagră cable car	2,809	797	1,775	9.00-16.00
Kanzel cable car	2,449	693	1,727	9.00-16.00
Postăvaru Express	2,140	693	1,727	9.00-16.00
gondola car	314	128	1,783	X
Kanzel ski lift	502	197	1,704	X
Ruia ski lift	492	169	1,326	X
Subteleferic ski lift	301	32	1,039	9.00-16.00
Stadion ski lift	455	77	1,114	9.00-16.00
Bradul ski lift	800	209	1,150	9.00-16.00
Lupului chairlift	1,150	375	1,710	9.00-16.00

Source: after Ana Teleferic data

The analysis of the study area indicated an increase of the instability of the slope surfaces, through the increase of frequency of geomorphological hazards, generated by the association of the natural and the anthropic control factors ([Mihai, 2005](#)), especially during the extension and development of the ski area. The geomorphological hazards in relation to the economic-social development and the extension of tourist improvements may generate the increase of environmental degradation, thus rising the vulnerability degree ([Socorovschi, 2005](#)). The factors causing slope instability within Poiana Braşov resort are: geological, geomorphological, bioclimatic and anthropic.

The tectonic, structural and lithological conditions within the resort area boundary induce the triggering of geomorphological processes by means of different resistance and behavior variable with the action of external agents. The geomorphological processes with higher risk potential in the resort area manifest on the limestone and the tectonized conglomerates extending in the ski area ([Petrescu, 1972](#)) (Figure 1, a). The limestone and conglomerates, though rough rocks, are subjected to the action of the external agents through processes of weathering, like frost wedging and chemical alteration, thus modifying the versant stability. The categories of rocks located at the base of Poiana Braşov ski area are gravels and sands which make up part of the foundation grounds for the reception tourist infrastructure, being less exposed to the action of the natural external agents. There is a favorable connection between the ski area infrastructure and the categories of

rocks, the infrastructure of special tourist transport being arranged on the most solid categories of rocks, the lime stones conglomerates. Where the buildings required a solid geological foundation, the authorities observed this need, a good example being the cable car poles, the cabins in the upper part of the mountain, as well as the Postăvaru Cabin.

Another factor contributing to the resort land instability is the geomorphological factor. The geomorphological parameters (hypsometry, slope gradient, aspect) and the morpho-graphic elements determine the current shape of the geomorphological surfaces and the dynamics of their modelling. Slope gradient is a geomorphological parameter which varies in close connection to lithological diversity, playing an important role in defining the type and intensity of the geomorphological hazards. The analysis of the spatial distribution of the slopes emphasizes the fact that the morphological surfaces 25°-38° range have the largest expansion in the ski area space (40 %) and alternate with other land surfaces from 20°-25°, 16°-20° and 10°-16° ranges (Figure 1, c). The land surfaces with lower slope degrees (7°-10° and 0°-7°) are the support to the accommodation, public food, road transport and cable transport infrastructure. At the same time, among them unravel the low difficulty slopes Stadion and Bradul and the track dedicated to the tubing activity. The morphological surfaces comprised between 38° and 65° occupy approximately 11%, are found outside the ski area and anthropic-induced landscape within the resort area and are characteristic for the steep slopes with a high dynamic of gravitational processes. The aspect is a parameter indicating the different ground thermal regime of the versant surfaces, derived from the variation in the distribution of the solar radiation on different topographic surfaces, also depending on the use of the land, being important in determining the intensity of the geomorphological hazards. Within Poiana-Braşov resort, the largest part is given by the semi-shaded versants, 38%, and the sunless versants, with a share of 24% of the area surface, amounting to 62% of the total surface of the resort area, from the altitude of 1010 m until 1770 m, offering the morphological support of the ski area.

The geomorphological processes which have impact into the landscape of Poiana-Braşov resort ski area are: surface washing, gullies and rill processes torrentiality, snow avalanches, sliding, rock falls and the anthropic processes (fig.1, c.). The variation of the slope values calls for a variety of geomorphological processes, and the tourist activity and the human presence in the area, both during winter and during the summer season, is a factor of their increased intensity.

Figure 1. a) Geology of Poiana Brasov ski area (left), redrawn after Geological map 1:50.000 scale; b) Spatial distribution of geomorphological processes (right); c) slope degree spatial distribution (upper right)

The most obvious processes within the area are ravine, rills and torrentiality, 4.1 % in the ski area, both on the ski slopes and outside them. Rills are highly influenced both by the flow of water on the slopes and by the anthropic activity (bicycle wheels, car tires, snow-mobile platforms, skis where the layer of snow is thin). In the mountain areas, man is subjected to a range of natural phenomena, which must be included as an integral part of the territory, in any local improvement plan (Kienholz, 1978). The avalanches are processes identified outside the anthropic area, in a proportion of 2.5 %. They created avalanche tracks, with dimensions ranging between 700 and 740 de meters. Within the off-piste area, small avalanches and small individual rock falls occur at the edge of the ski slopes, where there are high differences of slope degrees. By means of the resort modernization process, the percentage of the ski slopes increased to 6.7 % (resulted from measurements using

satellite images) and a large part of the forest vegetation in the ski area was cleared. The clearing needed for the expansion of the ski area has a serious immediate consequence, namely the emergence of new gullies and torrentially organisms, the intensification of the surface washing processes and the emergence of individual rolling on the new versants created along the slopes. Man is a geomorphic agent, because he can initiate, accelerate, reduce or terminate the geomorphological processes in a mountain area (Kienholz, 1978). In order to identify the impact that geomorphological hazards have on the tourist activities and the possible damage, it is necessary to identify the risk elements. Damages may occur on the risk elements, such as humans, buildings, infrastructure or services (Armaş, 2007). Within Poiana-Braşov resort, damages were identified on the following types of risk elements: of human nature, infrastructure and environment.

Risk in the resort is generated by the damage occurred, but this always implies the concept of occurrence probability (Sorocovschi, 2003). One of the elements most exposed to risk is represented by the tourists.

Figure 2. a) The dynamics of tourists in Poiana -Braşov resort during the 2008 – 2016 periods (INSS Poiana-Braşov).

Figure 2 b) Evolution of number of skiers on Poiana-Braşov ski area (after AnaTeleferic data).

The human risk element is composed of the potential tourists arriving to the resort, the staff employed within the reception structures and the local authorities. According to INSS Braşov, the number of tourist arrivals in the accommodation units in year 2016, in the period January-August, was 172,357 tourists, out of which 31604 were foreign tourists. From the point of view of the evolution of the number of tourist arrivals in the resort, starting with the year 2009, the fluctuation tendency is ascending, starting from a number of 103,603 tourists in year 2009 and reaching 217,999 thousand in the year 2015. In 2016, the number of tourists reached from

January to September to 172,357 thousand (Figure 2, a). We are certain that if we were to add the tourists during the season of winter sports, the graph would have an ascending tendency (Figure 2, b), fact which brought about in year 2018 a high tourist density, of 622.9 tourists /residents, increasing every year, and a touristic intensity of 256,471 tourists/km² on the ski area, related to 9083 tourists/km in the same year.

According to Ana Teleferic, in the winter of 2014-2015, more than 1.3 million of uses of ski lifts by skiers were recorded, double from the previous season. Thus, in the winter season 2013-2014, there was a number of 650 thousand tourists who had skied on the ski area in the resort. In the following years, the number of winter sports practitioners increased, such as in 2015-2016 they increase their number with approximately 400 thousand and with other 439 thousand tourists in the next winter season, 2016-2017. Calculating the tourism density index and tourists pressure it can be emphasized that the higher tourists flow was record in 2015 (Table 3).

Table 3. Tourist parameters time-variation regarding the tourist flow (2009-2016).

Parameters	2009	2011	2012	2013	2014	2015	2016
Tourism density index	296	398	443	490	521	622	492
Tourist pressure	207,200	164,081	182,414	201,814	214,828	256,471	205,186

Regarding the rescue services, during year 2018-2019, the highest number of calls to the Braşov mountain rescue service was recorded in January, reaching 225 calls, followed by February, with 201 calls. The lowest number is recorded in November, with just 1 call, followed by December, with 40 calls, and March, with 59 calls (Figure 3). A preliminary conclusion indicates that the months during which the most mountain rescue requests occur are January and February, one cause being the continuity of the winter tourist activities, natural consequence of the preservation of the winter layer and of the free days during the winter holidays, respectively the prolonged vacations some tourists enjoy. Also, the variation of the number of emergency calls to the mountain rescue has a higher frequency at an interval of approximately 5 days, the increase in the number of calls being simultaneous with the increase in the number of tourists, as a result of the influence of weekend on the tourist flow. The intervention points of the Mountain rescue Service are located at the base and in the upper area of the ski area, which allows rapid intervention. At the same time, the low altitudes, the isolated position of the mountain, as well as the short distance between the resort and the town of Brasov favor rapid interventions of

the helicopter in emergency situations. Still, in the period 2017-2018, there were approximately 635 cases of bodily injury, psychological damages due to panic, when the tourists requested the mountain rescue intervention, without recording deaths, the quality of the vacation being, implicitly, affected. The rapid intervention of the mountain rescue from both extremities of the ski area, the relatively low altitudes of Postavaru Mountain, the configuration and degree of modernization of the ski area, allow such a situation of tourist safety

Figure 3. The characteristics of thee emergency callings to Rescue Mountain team (SALVAMONT) in Poiana Brasov in 2018-2019 winter; (Data Source: *SALVAMONT Braşov*).

The authorities claim that, annually, the number of accidents is increasing, most victims being registered during the winter season. In January 2019, the number of injured persons was with 100 higher than in the previous season, 2017-2018, despite the fact that the season was only in the half of its running. From this information, we deduce that the number of injured persons increases annually. Since 2013, the number of winter sports practitioners in the resort has increased considerably, being now three times higher, thus generating much more accidents, compared to the previous years.

The tourist infrastructure constitutes a risk element comprising the entirety of the tourist structures in the resort, the cable means of transport and the tracks within the ski area, necessary for the performing of the tourist phenomenon. The reception structures with functions of accommodation and public food are built in a proportion

of 99 % at the base of the ski area, where the hazards processes are not so evident, except for Postăvaru Cabin and Dudes Pub, which are located in the upper side of the ski area. The ski lifts have starting points both, in the base area of the ski area and at different altitudes, and thus, the arrival cabins located in the upper part are most exposed to natural hazards.

The ski slopes are vulnerable to degradation caused rather by the tourist pressure, but also by the natural factors. Compared to the two elements mentioned before, as a result of the anthropic pressure and of the natural factors, along the slopes deteriorations caused by surface washing, ravine and gullies processes and individual rock falls which rolling on the ski slope may occur, originating on the neighboring versants. The ski area is the component most affected among all elements of the tourist infrastructure.

Geomorphological hazards of the type of sheet erosion are more frequent along the slopes and the ski routes (variants) with low and intermediary difficulty, the relatively low values of the slopes being a favoring factor; the convex-built transversal profile of the slopes and the lay-out of the drains along the slopes prove the existence of these processes, but also their maintenance. Processes of the rills, ravine, gullies type are specific to sectors with slopes of more than 15° of the medium and difficult ski slopes, and the rain water surface runs off to collector drains, for rapid elimination of water from the slope and their overgrowing with grass, was the measure applied in order to remove these hydrodynamic geomorphological hazards (Figure 4). As a consequence of the improvement works (cutting, levelling, widening) on the ski slopes, regardless of their difficulty degree, they are affected by small and individual rock falls which rolling from the above versants and pausing on the surface of the ski tracks, which may generate accidents (Table 4). The sectors with a higher density of these processes are those engraved on conglomerates, to the detriment of those developed on limestones. During the end of winter season months, depending on the facing of the slope surfaces, ice is formed along ski slopes, affecting the tourists' skiing activity, phenomenon which may generate accidents and human injuries.

Drumul Roșu ski slope is intensively used track, both during winter, to skiing and in summer to hiking and down hills. In its upper part has sectors affected by the sheet erosion.

Figure 4. Longitudinal cross sections on following ski trails: a) Kanzel; b) Subteleferic; c) Lupului; d) Sulinar; e) Bradul; f) Stadion; g) Drumul Roșu.

From the base to the cabin, rills and ravine processes occurs, created by the action of motor vehicles climbing to Postăvaru Cabin. Also, in certain narrow sectors of the track rocks roll on the track; this can generate accidents among the tourists. The Stadion and Bradul ski slopes have no processes which may generate material damages to the ski area.

These two low difficulty piste trails operate without interruption, even in unfavorable weather conditions, due to the favorable position at the base of the ski area. Often, the tourist activity is temporarily stopped on the ski area, except for these

ski tracks, which are accessible at all times, both to adults and to children, due to their low difficulty.

Table 4. Distribution of geomorphic hazards related to ski slopes from Poiana Brasov ski area

ski trails	sheet erosion	rills, ravine and gullies erosion	debris free falls	ice layer	anthropic geomorphic processes	avalanches	injuries/damages
Kanzel	x	x	-	-	-	x	x
Subteleferic	x	x	x	x	x	-	x
Lupului	x	x	x	x	x	x	x
Sulinar	x	x	x	x	x	x	x
Drumul Rosu	x	x	x	x	x	-	x
Stadion	x	-	-	-	x	-	-
Bradul	x	-	-	-	x	-	-
Off-piste	x	x	x	x	-	x	x

The dominant geomorphic hazards along the off-piste trails are torrentiality and small-size avalanches, usually pulver-type.

Poiana-Braşov ski area is composed of the main ski tracks, ski lifts and a series of variants connecting these ski slopes. The width of the intersection between two ski slopes is, according to certain safety and quality standards, sufficiently wide to ensure the safe movement of skiers on both tracks. Within the tracks in Poiana Braşov, where some tracks are in junction, the width of the intersection area is reduced, as in the case of the second intersection between the Subteleferic and Drumul Roşu slopes. The areas afferent to the different junctions between the slopes are charted and analyzed in the map of the density of ski slopes and the data has been corroborated with the frequency and space distribution of tourists losing balance, falling or being hurt, in an attempt to avoid one another. The reasons why the ski slopes represent a danger for the tourist in Poiana Brasov resort are determined by the under-dimensioning of the width of the ski slopes in intersections and curves. According to Poiana-Braşov Mountain rescue, in year 2017-2018 there were 635 accidents resulting in minor and major damages. In the map (Figure 5), indicates the main places where skier tourists crash, fall and injure themselves. These are individual injuries and have not been directly caused mainly by any of the natural geomorphological hazards. We notice also, there are some dangerous sectors of ski slopes affected by individuals rock falls being difficult for skiers to avoid these and bypass each other.

Figure 5 a) Density of ski sfrom Poiana Brașov resort; b) Distribution of the frequency of skiers which suffered crashes, falls and injuries along ski slopes in 2017-2018 winter (after mountain rescue service Salvamont Poiana-Brașov data).

The preliminary analysis results showed that the tilt break along the ski slopes determine an increase in the number of injuries, thus illustrating an inadequacy between the experience of the skiing tourists and the difficulty degree of the slope they selected, even more so in the conditions of narrow slopes. Thus, in the winter season 2017-2018, more than 55 tourists fell at the base of Kanzel slope, on Lupului slope, at the intersection with the 3A variant, at the last slope break at the base of the track, at the first and second intersection between Drumul Roșu and Subteleferic track (55 skiers), at the base of Subteleferic track, at the curve to the West of Drumul Roșu slope, downwards from Lacului Poiana-Ruia, but also at its base, between 35 and 55 skiers (Figures 6,7). The following areas, with a lower number of accidents and fallen tourists, between 25 and 35, are the sectors with a very steep slope, such as the base of Kanzel, Sulinar track in its upper part, the vicinity of the first intersection between Drumul Roșu and Subteleferic and the windings on Drumul Roșu track, where there are also slope degree differences.

Figure 6. Distribution of skiers injuries by types of tourists and type of injuries.

Figure 7. Skiers crashing a), non-observant tourists b) and small fragments of rocks' fall on ski trails c). Photos : Cosmin Plopeanu, a) and Andreea Andra-Topârceanu, b) and c).

As mentioned before, Drumul Roșu track, according to the legislation, should have a width of 30 meters, but it currently has only 22 lateral meters, which makes difficult the passing of the tight curves, especially those located downwards of the slope level, the causes being the narrowing of the track, the high speed, but also the meeting of other tourists, many tourists getting injured in these areas. The lowest numbers are under 20 tourists and can be seen at the base of all tracks and in the vicinity of the areas with the highest number of fallen tourists. The main causes why tourists get injured practicing winter sports are the non-observance by the authorities of the track dimensions at their intersection, the non-observance of the dimensions of the average difficulty track Drumul Roșu, according to *"Regulations on the homologation, improvement, maintenance and exploitation of the ski slopes and routes for recreation in year 2001"*, but also the passing from one slope difference to another. The human risk element is not directly affected by the geomorphological hazards analysed above, the accidents being caused due to completely different causes. We conclude that the

intersection of slopes and the narrow space afferent to certain junctions determine the loss of balance and the occurrence of slight accidents among the tourists.

A part of the tourists crashing and falling on the ski slopes within the Poiana-Braşov ski area injure themselves, according to the Mountain rescue data. Apart from these above-mentioned causes, mountain rescue adds the fact that the tourists do not observe the meaning of the signs, do not listen to the warning of the mountain rescue or take advantage of the fact that they have accumulated experience in practicing winter sports and, thus, attempt high difficulty slopes or certain stunts, and this is how accident occur. From the tourists' point of view, the most dangerous tracks are Lupului track and Subteleferic track, and the most dangerous parts are the areas with steep slope, the curves, the areas with lack of visibility, the parts with lack of snow, but also parts of the track where obstacles are present. (Table 6).

Table 6. Factors-induce human risk elements and distribution of injuries and accidents interpretation within Poiana Brasov ski area, winter season 2017-2018 (after mountains rescue service Salvamont Poiana-Braşov data)

Factors-induce human risk elements		Human injuries	
Summer	Winter	slightly injuries	seriously injuries
Lack of proper equipment for hiking	lack of proper equipment for winter sports	hits, crashes, contusions, ligament stretching, muscle soreness, sprains	fractures, concussions
Non-observance of the meaning of the signs	non-observance of the meaning of the signs		
lack or low levels of skiing experience	lack or low levels of skiing experience		
Non-observance meteorological warnings	non-observance of forewarnings of mountain rescue service		
Ground roughness	Negligence		
	poor visibility due skiing		
	dangerous standing on the ski slope		
	icy patches on the ski slope		
	thin snow layer		
Total number of accidents in winter season 2017-2018 = 635 cases			
364 men		271 women	
524 Romanian tourists		111 foreign tourists	
282 sprains		117 fractures	

The causes why they consider that practicing winter sports may generate accidents on the ski area within Poiana-Braşov are not observing the signs, low visibility, very steep slopes, very high speed, unbalancing, tourists skiing chaotically or stopping on the ski tracks, the tourists taking photographs in the middle of the tracks or filing the descent, loss of control, as well as lack of experience.

4. Conclusions

The geomorphological analysis indicated that the geomorphological hazards, of the type of individual rock falls, snow avalanches, rills, ravine and gullies processes, torrentiality and sheet erosion cause no considerable losses in Poiana-Braşov resort. However, some areas of Poiana Braşov ski resort are affected by geomorphological hazards, natural and anthropic-triggered having effects on the safety of tourists. In order to mitigate the negative effects and the damage among skiing tourists in Poiana-Brasov resort, the following measures are necessary:

1. the re-dimensioning of the width throughout the entire Drumul Roşu slope, of the intersections, track curves and “of the areas of falling, sufficiently dimensioned, free of any obstacle”, according to the Romanian and European legislation, as intersections of Drumul Roşu slope with variants 1A, 1DA and 3A;
2. the installing of nets or other technical solutions to protect against individual rolling (of rock fragments) from the level of the cut versants of the slopes, which become natural obstacles;
3. the provision of artificial snow for the track sectors where the layer of snow is now maintained in the intervals with positive temperatures or where it is insufficient;
4. the multiplying of warning panels for all dangers on the ski slopes, as well as the observance, according to the legislation in force, of the civil violation measures for the tourists with inadequate behavior while performing tourist activities.

The tourist reception infrastructure of the resort lacks obvious issues, except certain sectors of some small ski slopes in the ski area. At present, in order to diminish the damage caused to the ski area and to the tourists, the observance of the environmental regulations is needed, respectively the establishment of collection ditches for the waters coming from the melting snow and rain, to apply tough legislative measures regarding deforestation in the resort perimeter, action which intensifies or triggers the geomorphological processes. At the same time, where the width of the difficult slopes allows it, measures can be taken to thicken the forest, in order to stop the existing processes and their action. It is also necessary to observe

the legislative regulations on the protection of the soil and vegetal carpet which is year by year more deteriorated due to the tourist pressure.

The Mountain rescue team in Poiana Braşov mentions the fact that, often, the tourists do not observe the weather warnings or their warnings and venture out, exposing themselves to risks. The rocks and steep slopes may create adherence issues and the tourists may injure themselves even with proper equipment (e.g. the whitish limestone in the vicinity of Postăvaru peak). During the winter season, there are some additional factors generating serious accidents, such as the lack of visibility due to the occurrence of fog or steep slopes, the tourists' lack of attention, the stopping of tourists in the middle of the slopes, and the presence of rock fragments which remains on the ski slopes. The snow layer may be insufficient or melt in some points, forcing tourists to suddenly avoid these places and, most of the time, they fall and hurt themselves. The same situation is seen on tracks, where the slope sector is much accentuated, thus allowing the formation of ice, a phenomenon which frequently generates injuries.

Another very important factor is the non-observance of the meaning of the signs generates much more serious accidents then in the summer season. The lack of experience of tourists or unadaptation to the difficulty degree of the slopes increases the incidence of accidents. Other factor of generating accidents is the absence of adequate equipment for hiking and for practicing winter sports. Sources of increased exposure to residual risks of tourists remain: experience and attention, low education for mountain environment and the attitude towards the possible threats. The distribution on genders and origin of the bodily injuries indicate a slight difference between the injured women and men to the detriment of the latter and an obvious difference between the Romanian and foreign injured tourists.

The research of the geomorphological hazards acting at local level on the tourist infrastructure and especially on the tourists implies the evaluation of the degree of vulnerability of the ski area in the resort and the identification of the possible risks.

Together with hazards, vulnerability also depends on the number of risk elements subjected to the possible dangers, and in Poiana Braşov ski area the number of risk elements is high. In order to eliminate or mitigate all these issues, it is necessary to strict observe the legislation in effect. The elimination of the stress caused by crowdedness or unfavorable weather conditions, which prevent the use of the cable transport means may be removed by the use of ski lifts, which can operate also in conditions of strong wind, but also by means of using a better technique for the live sending of the operating condition of the cable means of transport. Vulnerability may be decreased through the implementation of the signalized system required by the

European legislation, raising the awareness of the tourists, related to their experience and type of tracks, or by observing the track intersection routes. Knowing the spatial variation of the vulnerability degree induced by the manifestation of the natural geomorphic hazards and of those derived from the tourist pressure and the pressure specific to the arranging and maintenance of the ski area, hence of the tourist impact on the environment, is an important element in the management of Poiana-Braşov resort.

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