

An action plan to reduce the effects of noise and air pollution in mountain resorts served by roads. Case study: Parang Resort

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Abstract. Road traffic represents a source of pollution of environmental components, having a significant negative impact on human health. The most obvious forms of environmental degradation associated with road traffic are noise and air pollution. In the case of Parâng Resort, a mountain area in Hunedoara County, Romania, road traffic is increasing as a result of the modernization of the DJ 709 F access road. This intensification of traffic generates additional pressures on the environment and affects the development of tourist activities, as well as the health and comfort of tourists and local communities. This paper is a continuation of a previous research, which aimed at monitoring road traffic and ambient noise levels in Parâng Resort. The main purpose of the current study is to develop an action plan aimed at reducing the impact of noise and air pollution in mountain tourist areas crossed by roads, the case study being carried out for the same objective: Parâng Resort. The monitoring results revealed significant levels of noise and air pollution, underlining the need to implement mitigation measures. Based on these findings, a detailed action plan is proposed, which includes concrete solutions and interventions aimed at reducing the negative effects of pollution. The identified solutions are realistic, technically and financially feasible, and have been designed to integrate into the natural and architectural landscape of the resort. Through this integrated approach, the paper contributes to the substantiation of sustainable practices for managing and reducing the impact of road traffic in mountain tourist areas.

1 Introduction – generalities and legal regulations regarding noise and air pollution

1.1. Noise pollution

The sound is the result of the vibration of particles in a medium that can be perceived auditory.

Noise can be defined as any sound considered unwanted or disturbing, which can interfere with the ability to speak or listen. It can be loud enough to be disturbing or it can

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be simply annoying. The human limit of tolerance of noise is generally considered to be around 65 decibels (dB). The relationships between noise and other components of the environment are determined by the impact that noise exerts on them, with particular emphasis on ecosystems, fauna and the human environment (sanitary and territorial systems) [1].

Law no. 121/2019 and Directive no. 2002/49/EC of the European Parliament on the assessment and management of environmental noise establish a general framework for the development of measures to avoid, prevent, and reduce noise generated by main sources such as motor vehicles, trains, aircraft, industrial equipment, etc. It also regulates the negative effects on the environment and humans with a special focus on:

- built-up areas;
- parks, public gardens, or other quiet areas in an urban agglomeration;
- quiet areas in open spaces;
- proximity to educational institutions, hospitals, and other buildings and areas sensitive to noise.

Order of the Minister of Health no. 119/2014, published in the Official Gazette of Romania, Part I, no. 127 of February 21, 2014, for the approval of the Norms of Hygiene and Public Health regarding the living environment of the population, establishes the noise limits (continuous, equivalent, A-weighted sound pressure level) for the time interval 06:00 – 22:00 at the value of 50 dB(A), and for the time interval 22:00 - 06:00 at the value of 40 dB(A) [2].

According to the Standard SR 10009:2017 [3] which establishes the admissible limits of the noise level in the ambient environment, which are differentiated according to the functional areas and spaces, a noise limit of 45 dB is imposed in recreation areas.

There are several factors that influence the level of noise in the case of road traffic such as: power and mass; tire performance; driving style; street sounds; road slope; vibrations; friction of mechanisms; circulation of flows (heat, air); etc. The noise emission of 4x4 and goods transport vehicles is generally higher than that of 4x2 and small vehicles. Also, the noise emission is higher on steep road than on regular roads [4].

The noise limit level produced by the engines of new vehicles must not exceed the limits established according to the type of vehicle, its mass and engine power. In the last decades of the 20th century, the noise generated by the engines of new vehicles was significantly reduced. However, in the same period, the power and weight of the engines on average increased.

1.2. Air pollution

Substances present in the atmosphere that alter its normal composition and have harmful effects on the living environment on Earth are considered pollutants. The level of pollution varies depending on the concentration of the pollutants and the time of action. Pollutants affect aquatic and terrestrial ecosystems when the pollutants dissolve in water or precipitate in the form of acid rain [5].

The largest share of gases that pollute the air comes from motor vehicles, as a result of their very large number.

At national level, law no. 104/2011 provides for measures to define and establish objectives for ambient air quality. The aim is to reduce, avoid, and prevent the occurrence of harmful events and their negative effects on human health and the environment, to monitor and to obtain information on air quality.

The National System for Integrated Assessment and Management of Air Quality (SNEGICA) implements the ambient air quality law.

At European level, reducing pollution, monitoring and assessment of air quality and public awareness are important objectives. The level of pollution has to be minimized to reduce the negative effects on human health and ecosystems, especially on the sensitive populations/ecosystems [6].

2 Materials and methods

2.1 Short description of Parâng mountain resort and of DJ709F access road

The Parâng mountain resort (figure 1.a.) is located in the massif of the same name, part of the Southern Carpathians. The massif is famous for its numerous natural attractions such as peaks over 2000 m and glacial lakes, and for the mountain trails that start from the resort (figures 1.b. – 1.d.).

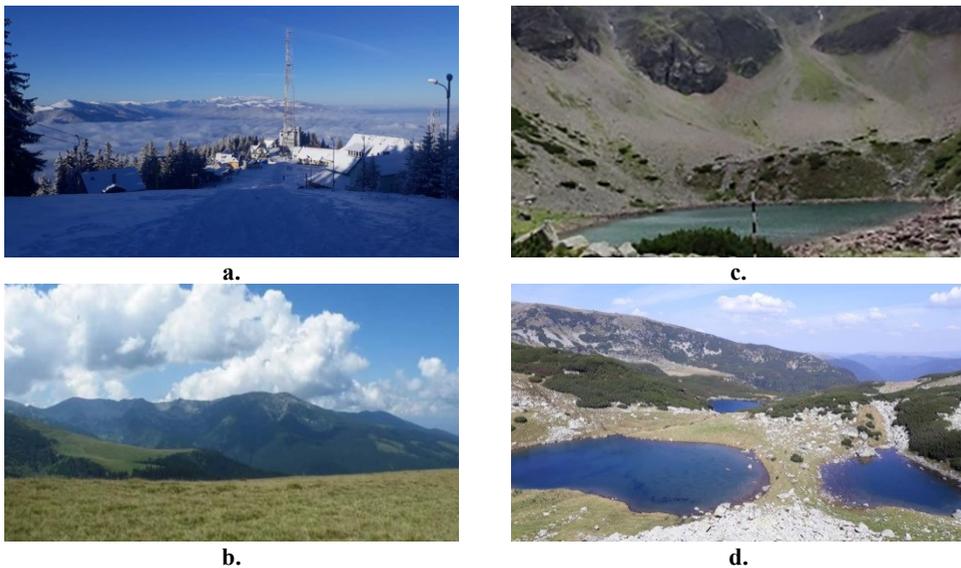


Fig. 1.a. Parâng Resort in winter; **b.** The ridge of the Parâng Massif seen from the Huluзу Saddle; **c.** Mija Lake; **d.** Gâlcescu, Pencu and Vidal Lakes.

The climate, natural features, and specific elements make the Parâng Massif an important tourist spot that can be visited in any season, so many tourist cabins have been built in the resort and down, in the Rusu – Petroşani area [4].

The Parâng Resort is located approximately 10 km from the city of Petroşani, and the connection between them is made by the national road DN7A and county road DJ709F, the latter having a total length of 12.6 km. Originally a dirt road, difficult to access, DJ709F has entered a modernization process, with the works being completed in 2023 (except for the section KM 11+425 to KM 12+600 which remains closed to public traffic) [4].

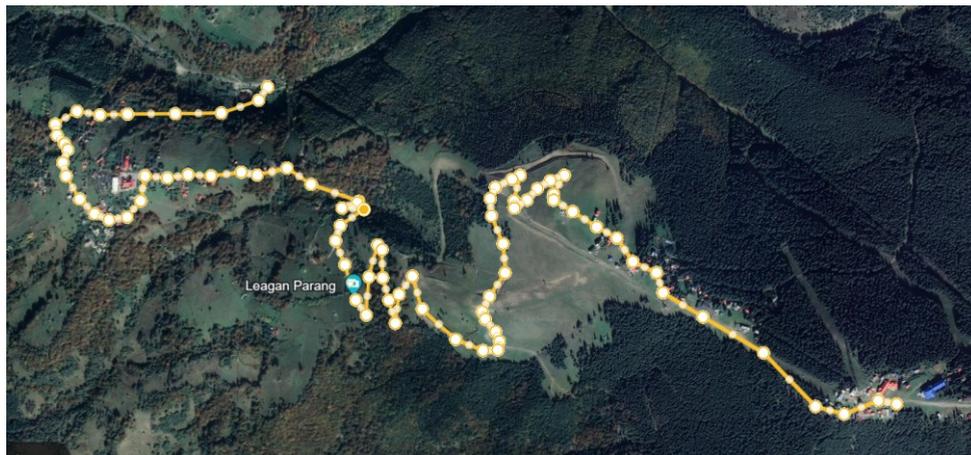


Fig. 2. The modernized road sector serving Parâng Resort (*Processed by the authors based on satellite images extracted from Google Maps*).

The modernization of the county road DJ 709F was of major utility for attracting tourists and for the development of the resort. But, as expected, these opportunities come with a number of disadvantages like intensification of traffic and increased noise and atmospheric emissions.

2.2 Considerations regarding the level of pollution and its effects on the environment, tourism and tourists

The opening of public traffic on the section km 6 + 600 - km 11 + 425, determined the increase in noise and gas emissions resulting from the circulation of private vehicles, and the road conditions (mountainous area, with serpentine and steep slopes) enhanced their level.

The following aspects were established for the assessment of the noise level [4]:

- 4 monitoring points were established (A, B, C and D);
- Monitoring program: Saturdays and Sundays, May – June, periods of interest for the study (table 1):

Table 1. Monitoring program.

Monitoring point	In the morning	In the evening
A	07:00 – 08:00	17:00 – 17:30
B	08:00 – 09:00	17:30 – 18:00
C	09:00 – 10:00	18:00 – 18:30
D	10:00 – 11:00	18:30 – 19:00

- The height of the measurement point: 150 cm above ground level;
- The average distance between the noise source to the cabins: 4-5 m;
- Incident sound was taken into account and interferences were avoided (sounds reflected from the cabin facades).

Observations:

- More than half of the properties are built in the area of points C and D.
- The noise is mainly caused by excessive acceleration of vehicle engines on the steep road. The noise produced during the mornings and evenings is disturbing for locals, for tourists who came to relax in the silence of nature, but also for wild animals.

- The monitoring was made from May to June, in weekends, when the resort is crowded. The most intense period is in the summer season (from May to September). In the summer, the number of tourists and vehicles are significantly increased compared to other periods (in weekends there are more tourists than in the rest of the week).

- Traffic monitoring indicated a total number of 585 vehicles in circulation (ascent/descent)/10 days of observations.

The CEM DT-815 digital sound level meter (figure 3, left) is an easy-to-use, high-performance, and reliable sound level meter specially designed for quick and convenient noise measurements. It is equipped with a memory that can store up to 50 records.

Features:

- measurement range: 30–130 dB at frequencies between 31.5 Hz and 8 kHz;
- accuracy ± 1.4 dB;
- noise measurement ranges: low 30–80 dB, medium 50–100 dB, high 80–130 dB, Auto 30–130 dB;
- $\frac{1}{2}$ inch electret condenser microphone;
- switchable A/C type frequency weighting;
- FAST (125 ms)/SLOW (1s) type frequency weighting;
- four-digit display, 0.1 dB resolution;
- display rate 0.5 s;
- date/time memory;
- OVER alarm function at >130 dB and UNDER at <30 dB;
- max/min/hold function;
- battery autonomy (9V) 30 hours (low battery indicator);
- automatic shutdown;
- dimensions 210x55x32 mm;
- operating temperature 0–40 °C, storage -10–60 °C;
- operating humidity 10–90 % (RH), storage 10–75 % (RH);
- CE certification – IEC61672-1 Class 2 [7].

The calibration of the sonometer was performed with 0554-0452 Calibrator (figure 3, right). Can be used for $\frac{1}{2}$ and 1 inch sound level meters. Switchable sound pressure level 94 dB (A) and 104 dB (A), 1000 Hz, distortion factor <3 %, accuracy ± 0.5 dB according to IEC 60942 accuracy Class 2, 9 V battery [8].

Both the sound level meter and the calibrator are in the possession of the University of Petroșani.



Fig. 3. CEM-DT 815 sound level meter (left); 0554-0452 Calibrator (right).

Figure 4 graphically represents the limits of values determined according to the types of vehicles encountered on the route.

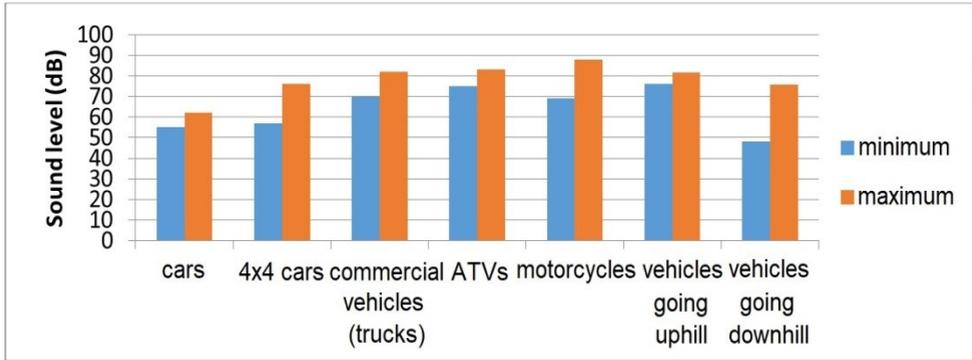


Fig. 4. Limite de valori privind nivelul de zgomot în Stațiunea Parâng (Processed by the authors based on satellite images extracted from [9]).

Equivalent noise level was determined for the two moments of the day [9]:

- mornings: 69.854 dB;

- evenings: 70.25 dB.

Making a comparison with the noise limit for recreational areas, set at 45 dB [10-13], a significant excess of up to 55% is found.

The noise produced by road traffic in Parâng Resort is disturbing, affecting the well-being, relaxation, and peace of people. The noise also affects wildlife having psychological effect, such as behavioral changes.

Regarding air pollution, this was evaluated according to the CO₂ emissions that result in large quantities and contribute to the increase in the greenhouse effect and climate change [4,14].

According to [14], the amount of CO₂ emissions varies depending on the type of vehicle (approx. 2240 g CO₂/l or 120 g CO₂/km - in the case of diesel engines and approx. 1955 g CO₂/l or 225 g CO₂/km - in the case of petrol engines).

According to [4], the vehicles running the mountain road during the monitoring period (of which 0,5% electric, 72,65% diesel, and 26,85% petrol engines) emitted over **86 kg CO₂/km and over 400 kg CO₂/section km 6 + 600 - km 11 + 425 (4,825 km)**.

The calculations were made considering a normal road, but it is important to take into consideration the road conditions such as the level difference, the serpentine and high inclination of the road, the increased fuel consumption which can considerably increase the noise and the gas emissions.

Switching to electric or hybrid cars, rationalizing vehicles, changing fuel, using public transportation, cycling, or walking can reduce emissions.

3 The action plan

Access as close as possible to the objectives, as is the case with tourist resorts, represents a comfort, but it comes not only with advantages but also with numerous disadvantages (figure 5).

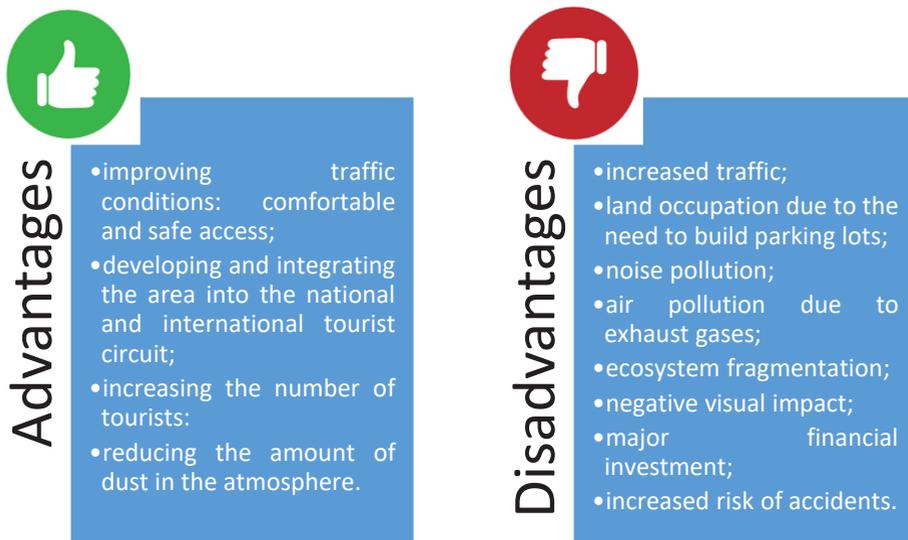


Fig. 5. Advantages and disadvantages of rehabilitating the road to Parâng Resort.

Knowing the advantages and disadvantages (also supported by the results of a SWOT analysis conducted by the authors [4]), is necessary to understand the importance of developing access routes to mountain tourist areas, respectively limiting them.

Among the solutions to minimize noise and air pollution generated by road transport on the environment, at the Parâng Resort, as a result of the opening of public traffic on the county road DJ709 F Rusu area – Parâng Massif, it is recommended to implement specific measures, such as:

- restricting traffic on the road sector between KM 6+600 - KM 11+425 (access allowed only to cabin owners);
- imposing speed limits;
- sanctioning non-compliance with the imposed rules;
- introducing public transport;
- establishing a public transport program;
- purchasing electric vehicles;
- using cable transport;
- extending the operating programs of cable transport facilities;
- creating vegetation curtains.

The method of implementing these measures is detailed below.

3.1 Restricting traffic on the analyzed road sector

Restricting traffic on the road sector between KM 6+600 - KM 11+425 involves prohibiting public traffic from the intersection with the Rusu area to the Parâng Resort and installing a card-based barrier to allow access for cabin owners (figure 6) and for public transport.



Fig. 6. Proposed area for the location of the barrier (*Processed by the authors based on satellite images extracted from Google Maps*).

The introduction of this measure would minimize road traffic in the resort and implicitly the level of noise and air pollution. In addition, it represents the best option considering the fact that there are not enough parking spaces in the resort. In the resort, there are approximately 20 parking spaces that serve tourists staying at the Parâng Villa and Kristian Guesthouse cabins plus 10 spaces at the landscape observation point. All of these, however, are insufficient and do not meet the demands.

Limiting the traffic speed leads to a reduction in the noise level produced by 4-5 dB [1]. Although the road conditions do not support high-speed traffic to and in the Parâng Resort, during the monitoring period it was observed that depending on the type and power of the engines, higher speeds than those recommended were recorded. Limiting the speed to max. 50 km/h and even installing speed monitoring cameras on the analyzed section are indicated. The application of cumulative sanctions for speeding, exceeding noise limits, and producing higher emissions as a result of non-compliance with the rules should be considered.

3.2 Introducing public transport and establishing a program

It is recommended to introduce public transport (minibus, bus) that operates according to a well-established schedule.

Considering the schedule of the 2 cable car facilities (new chairlift from 10:00 to 16:00 and old chairlift from 09:00 to 17:00), their maintenance days (new chairlift on Tuesdays and old chairlift on Thursdays; on maintenance days the functional chairlift takes over the total volume of tourists), the operating periods (new chairlift – generally from Friday to Saturday and every day during holidays or on request and old chairlift – every day, except for maintenance days), the following schedule is proposed for public transport:

- in summer, each 30 minutes in the following time intervals:
 - 7:00 – 10:00;
 - 17:00 – 22:00.
- in spring and autumn, hourly in the intervals:

- 7:00 – 11:00;
- 16:00 – 20:00.

➤ in winter – road closed.

In summer, spring, and autumn, tens and hundreds of tourists (the largest volume of tourists being recorded in summer) set off on the mountain trails, and the starting and stopping times of the chairlifts are not suitable, tourists being forced to leave late on the trail and rush to reach the chairlift for the descent. This limits the time interval available for hiking. Therefore, the recommendation is that in summer, when there are most tourists, public transport should be introduced at 30 minute intervals, and in spring and autumn at one hour intervals, before and after the chairlift operating schedule.

During the summer period, 2 minibuses of 20-40 seats would be needed (one on the ascent, one on the descent), the route being covered in a maximum of 30 minutes (approximately 150-300 tourists will thus arrive in the resort). In spring and autumn, a single minibus, depending on the flow of tourists, could be sufficient (the round trip being a maximum of 1 hour).

In order to properly implement public transport, it is necessary to build bus stops. The following locations are proposed for bus stops (figure 7):

- starting stations: old chairlift area (1), new chairlift area (2). These areas are served by parking lots totaling several hundred paid and free parking spaces and there are additional spaces for the construction of new parking lots;
- intermediate and final stations (at points of interest in the resort): Poienița area (3), Pilon 17 area (4), Mountain Rescue base area (5; end of the paved road).



Fig. 7. Proposed locations for bus stops (Processed by the authors based on satellite images extracted from Google Maps).

To harmonize with nature, it is proposed to build green stations, as simple as possible, from natural materials (figure 8).

The construction of new parking spaces at the base of the resort could offer tourists a convenient and safe option to park their vehicles during their stay in the area.

While in the Rusu area, the number of parking spaces is satisfactory, in the area of the old chairlift it is necessary to create new multi-storey parking spaces and two areas of land available for this purpose have been identified (figure 9.a).

Estimated number of parking spaces that could be created:

- parking A = 800 m² (figure 9.b.; considering the standard dimensions of parking spaces: parking angle in relation to the road 90°, space width 2.30 m, space length 5.50 m, parking space area 12.65 m², this results in 63 parking spaces per floor or approx. 200 spaces/3 levels, including spaces that can be built on the land in front of the building);

- parking B = 300 m² (figure 9.c.; considering the standard dimensions of the parking spaces: parking angle in relation to the road 90°, space width 2.30 m, space length 5.50 m, parking space area 12.65 m², this results in 23 parking spaces per floor or approx. 100 spaces/4 levels, including spaces that can be built on the land adjacent to the building).



Fig. 8. Bus stop (Processed by the authors based on image extracted from Alamy stock image platform)

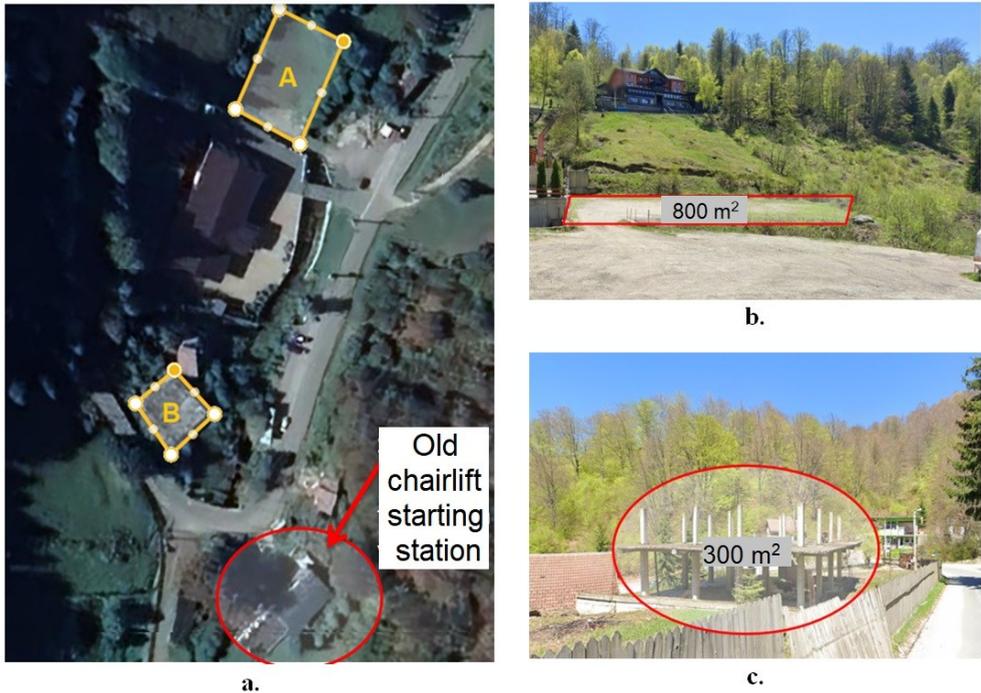


Fig. 9.a. Proposal for the location of multi-storey car parks A and B; **b.** Proposal for the construction of parking lot A (approx. 200 spaces/3 levels); **c.** Proposal for the construction of parking lot B (approx. 100 spaces/4 levels) (Processed by the authors based on satellite images extracted from Google Maps).

According to the current situation, in the area of the old chairlift there are approximately 50 arranged parking spaces, most of which are paid parking spaces. The construction of 2 multi-storey car parks would ensure at least 300 new parking spaces.

3.3 Purchasing electric vehicles

The purchase of electric public transport vehicles would bring significant benefits, as they are not only silent, but also contribute positively to air quality through the lack of emissions on site. Considering that 2 minibuses would be sufficient, the investment would not be a major one and impossible to achieve.

For cabin owners who own and drive electric vehicles in the resort, tax reductions or other types of benefits can be proposed.

3.4 Using cable transport

Promoting the use of cable transport (existing chairlifts, figures 10 and 11) for tourists could be an effective solution for reducing road traffic and environmental impact.



Fig. 10. Old chairlift.



Fig. 11. New chairlift.

Perhaps the main advantages of this type of transportation (apart from those pursued in this paper) are the beautiful experience and the stunning landscapes that can be admired from the seat.

3.5 Extending the operating programs of cable transport facilities

Extending the operating hours of the two chairlifts would provide tourists with more time to benefit from the transport facilities and fully enjoy the attractions in the area.

Extending the operating hours of the two chairlifts can be proposed instead of implementing the public transport solution, but this solution involves new employment (which would be a benefit for locals) and working in shifts. However, it must be taken into account that the weather in the mountains is changeable, some tourists come with children of different ages, with bulky luggage, others have altitude sickness, for these cases car transport is an advantage.

The operating hours of the chairlifts, depending on the season and the time it gets dark, are proposed to be: 7:00 – 17:00/22:00.

3.6 Creating vegetation curtains

The development of vegetation curtains in accessible areas could bring multiple benefits, including improved air quality and noise reduction.

Vegetation curtains are a good sound insulator and are often used along roads near residential areas. Similarly, vegetation curtains can be created in the Parâng Resort along the DJ 709F road, near the tourist cabins to reduce the noise level resulting from traffic in the area.

Vegetation reduces noise pollution through a phenomenon called sound attenuation, which is the reduction of sound intensity. Normal sound attenuation occurs as sound energy dissipates over long distances until there is not enough energy left to cause air molecules to vibrate. Vegetation speeds up the normal attenuation mechanisms of absorption, deflection, refraction, and masking. The leaves, twigs, and branches of trees, shrubs and even herbaceous plants absorb and deflect sound energy. Refraction of sound waves occurs when sound passes through plant structures. Vegetation generates masking sounds, represented by the rustling of leaves, the swaying of branches, and the creaking of stems. Also, the sounds of wildlife attracted to urban vegetation, such as birds and insects, mask noise pollution [15].

To be effective noise barriers, these trees must have foliage that reaches the ground. To reduce noise throughout the year, it is recommended to plant a mixture of green species, such as spruce, pine, and others. Deciduous trees, for example, are not effective during periods when they lack foliage.

In the Parâng Resort, vegetation curtains can only be created in the Poieniță area (figure 12) since downstream there are no more objectives to protect, and upstream a portion of the road crosses a forest, while the other portion intersects with cable transport lines under which there cannot be trees or buildings.



Fig. 12. Proposal for the creation of roadside vegetation for protection against noise pollution (Processed by the authors based on satellite images extracted from Google Maps).

The vegetation curtains will consist of species appropriate to the altitude, namely conifers: fir, spruce, and pine. The seedlings will be transplanted from the forests in the area. The species can be combined to form mixtures of species, and depending on the type of the immediately neighboring forests, different mixture formulas can be formed.

In the northern part (according to figure 11), even afforestation works can be carried out, the land having no form of use in recent decades (it is currently a low-value pasture).

In addition to protecting nearby cabins from vehicle noise and contributing to improving air quality, these vegetation curtains will also have other positive effects (especially through their role as a wind barrier) such as:

- protecting the cabins against slushy snow that can reach several meters thick around them;

- uneven snow deposits in the Poienița area – due to the wind, in some places the snow is deposited/accumulated in layers of several meters thick, while in others the land remains completely clear of snow. Therefore, vegetation has the advantage of preventing the formation of strong wind gusts in these areas and reducing or eliminating this effect.
- safe operation of cable transport facilities – in the mentioned area and, in general, in the mountain area, wind gusts are very strong, and for the safety of tourists (and the facilities themselves), the chairlifts are stopped. The vegetation curtains created in the area could eliminate problems regarding the operation of the chairlifts during strong winds.
- tourist comfort – winds reduce the felt temperature, so vegetation will minimize these effects, which are not pleasant when you are in the chairlift, especially in winter, for 10-25 minutes.

Conclusions

Access to the Parâng mountain resort, which has become a major tourist attraction, is a subject of great controversy. On the one hand, tourists want peace and relaxation, and on the other hand, they are looking for comfortable and safe travel solutions, preferring to get as close as possible to the tourist attractions with their personal vehicles, instead of using other means of transport.

The research carried out shows that the vehicles registered during the monitoring period would have emitted almost half a ton of CO₂ into the atmosphere if they had traveled the entire section analyzed. The road conditions, with a difference in level of over 500 m, the steep slope, and the serpentines, can considerably increase fuel consumption and, implicitly, emissions. In order to reduce these emissions, measures can be taken such as switching to electric or hybrid cars, rationalizing vehicles, changing fuel, using public transport, cable cars, bicycles or walking.

As a conclusion of the study, the noise generated by road traffic in the Parâng resort can have negative effects on the environment, people, and tourist activities. There is a decrease in the number of wild animals in frequently visited areas and a decrease in the benefits of spending time outdoors, such as relaxation, good mood, and tranquility, due to the creation of high discomfort conditions.

For the development of the Parâng Resort and attraction of tourists, the modernization of the county road has proven to be a beneficial decision. However, noise and air pollution represent a major disadvantage.

To improve the situation, measures could be implemented that allow access only to cabin owners, public transport, and emergency vehicles.

Also, establishing and implementing a traffic schedule could contribute to improving the quality of life.

Extending the operating hours of the chairlift and encouraging its use by tourists could reduce dependence on personal vehicles, thus reducing noise and air pollution.

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