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Assessment of land suitability for high-speed road infrastructure development: case study of the Brașov – Covasna sector

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Assessment of land suitability for high-speed road infrastructure development: case study of the Brașov – Covasna sector

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Evaluarea pretabilității terenurilor pentru dezvoltarea infrastructurii rutiere de mare viteză. Studiu de caz: sectorul Brașov – Covasna. Drumul propus în sectorul cuprins între orașele Brașov și Covasna este fundamentat pe o analiză multicriterială de favorabilitate, care integrează factori naturali și antropici esențiali pentru proiectarea și dezvoltarea infrastructurii rutiere de mare viteză. Printre aceștia se numără pantele, litologia, stagnogleizarea solurilor, precum și utilizarea terenurilor. Analiza de referință evidențiază existența unor restrictivități în zonele montane, unde potențialul morfodinamic accentuat favorizează producerea unor procese geomorfologice active, în timp ce zonele depresionare, cu relief neted, oferă condiții favorabile, dar pot fi limitate de densitatea mai mare a așezărilor umane. Harta finală de favorabilitate a rezultat din agregarea celor patru factori de studiu menționați. Totodată, în proiectarea celor două alternative de drum de mare viteză s-a ținut cont și de infrastructura rutieră existentă. Pe baza acestei hărți de favorabilitate au fost identificate două variante de traseu, dintre care prima s-a dovedit optimă, traversând mai multe areale favorabile într-un procent de 52,34%. Implementarea acestui sector de drum de mare viteză ar contribui la descongestionarea traficului, îmbunătățirea conectivității și stimularea dezvoltării economice regionale.

Cuvinte cheie: infrastructură de transport, geomorfologie environmentală, analiză multicriterială, factori naturali și antropici, pretabilitate.

Assessment of land suitability for high-speed road infrastructure development: case study of the Brașov – Covasna sector. The proposed road sector between the cities of Brașov and Covasna is based on a multicriteria suitability analysis that integrates essential natural and anthropogenic factors relevant to the design and development of high-speed road infrastructure. These include slopes, lithology, soil stagnogleization, and land use. The reference analysis highlights the presence of constraints in mountainous areas, where increased morphodynamic potential favors the occurrence of active geomorphological processes, while depression areas characterized by smoother relief provide more favorable conditions, although they may be limited by the higher density of human settlements. The final suitability map was obtained through the aggregation of the four aforementioned study factors. At the same time, the design of the two high-speed road alternatives also considered the existing road infrastructure. Based on this suitability map, two route alternatives were identified, of which the first proved to be optimal, crossing favorable areas in a proportion of 52.34%. The implementation of this high - speed road would contribute to traffic decongestion, improved connectivity and the stimulation of local and regional economic development.

Keywords: transport infrastructure, environmental geomorphology, multicriteria analysis, natural and anthropogenic factors, land suitability assessment.

1. INTRODUCTION

High-speed transport infrastructure represents one of the fundamental factors shaping the development dynamics of any geographical region (Păunescu et al., 2021). In the current global economic context, regional competitiveness can be supported through direct investment in this sector, highlighting the importance of a geographical approach within the analytical process (Dobre, 2016).

A development model requires an environmental geomorphology study, as it has the capacity to identify solutions aimed at maintaining a balance between the natural and anthropogenic environments (Panizza, 2011).

The assessment of environmental components represents the basis of such analyses, aiming to prevent potential issues that may arise during the design of road infrastructure (Păunescu et al., 2019).

Multicriteria suitability analysis uses up-to-date GIS methods and techniques. From this perspective, the planning of transport infrastructure involves the identification of natural and anthropogenic factors that control territorial functionality (Negulescu, 2024). Therefore, digital modeling and the evaluation of terrain characteristics were applied in accordance with the factors that define suitability for the development of the road network.

In this context, the present study is based on a multicriteria suitability analysis of the sector between the cities of Brașov and Covasna, considering the main factors influencing the development of road infrastructure (Purcăreață et al., 2015). The aim of this type of analysis is to identify favorable areas for the design of an optimal transport corridor, namely a road connection between the cities of Brașov and Covasna, intended both to increase transport flow capacity and to improve the connectivity of settlements to the TEN-T road transport network in Romania.

The study is based on several specific objectives. The first objective consists of delineating the study area between the cities of Brașov and Covasna. Another objective involves the preparation and processing of the database (vector and raster data) for each of the four analysis factors. The third objective is the development of the suitability map for road infrastructure planning, representing the final product of the multicriteria analysis. The final objective consists of identifying two alternative road alignments, taking into account the spatial distribution of favorable areas.

A road sector within the Brașov–Covasna area may be of interest both to local residents and to public authorities due to its potential to stimulate socio-economic development at both the local and regional levels. At the same time, such an analysis provides a systematic and well-founded approach that may support local and regional authorities in making informed and justified decisions regarding the development and construction of high-speed road infrastructure.

The present study is both timely and relevant, and its selection reflects the interest in improving infrastructure development and quality of life in the area, as well as the capacity to apply scientific methods and techniques to support the sustainable and efficient development of high-speed road infrastructure. Moreover, the choice of the case study is motivated by multiple strategic, social, economic, and technical considerations.

2. METHODOLOGY

2.1. Study area

The study area selected for the design and construction of road infrastructure is located in the central-eastern part of Romania and covers between the cities of Brașov and Covasna (Figure 1). This strategic location provides good accessibility as well as geographical relevance, representing a zone of interaction between different physical-geographical, cultural, social, and economic regions. Moreover, the study area is part of the Central Development Region and Macroregion 1. The administrative-territorial units (ATUs) intersected by the study area total 30 units. From a demographic perspective, the study area includes several populated settlements with a total population of 505,064 inhabitants. The most populated settlement within the study area is the Municipality of Brașov, with 291,195 inhabitants in 2025 (National Institute of Statistics, 2025).

From a physical-geographical perspective, the study area overlaps the Brașov Depression (with its subdivisions: the Bârsa Depression, the Prejmer Depression, and the Râul Negru Depression), the Moldavian – Transylvanian Carpathians (with its subdivision the Baraolt Mountains), and the Curvature Carpathians (with its subdivisions: the Piatra Mare Massif, the Postăvaru Massif, and the Întorsura Buzăului Mountains; Ielenicz, 2007; Posea, 2005).

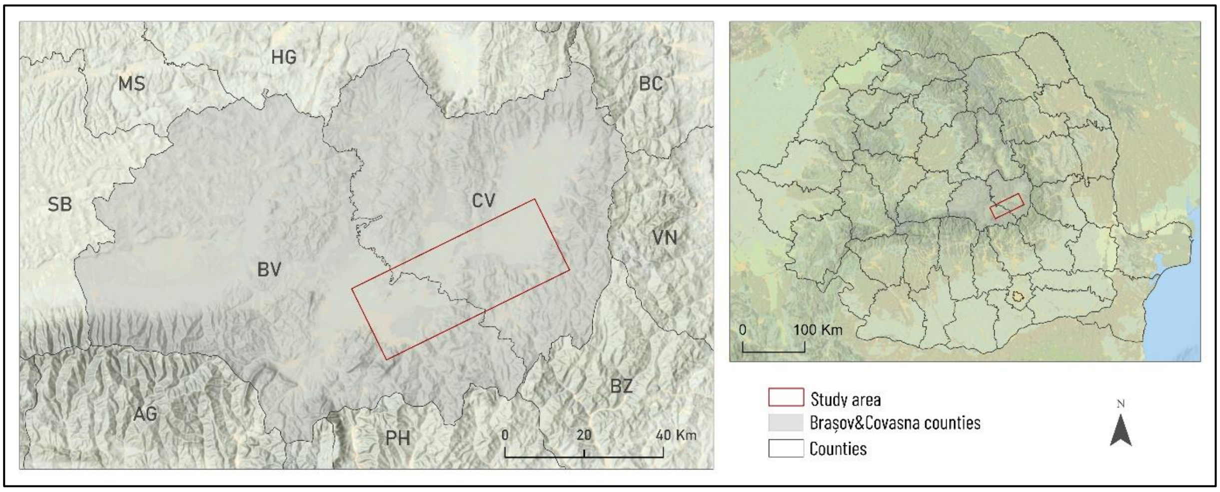

Figure 1. Study area

2.2. Data analysis

For the implementation of the multicriteria suitability analysis, GIS methods and techniques were used. For the preparation of the cartographic materials, a series of vector and raster datasets were employed for each analyzed factor (Table 1).

Table 1. Spatial datasets used in the analysis

Data name	Data type	Source	Use
curbe_25_est	vector, line	Military Topographic Map of Romania, scale 1:25,000, Military Topographic Directorate	for slope gradient analysis
geo200_6_03	vector, polygon	Geological Map of Romania, scale 1:500,000, Geological Institute of Romania	for lithological analysis
clc_18_s70	vector, polygon	European Environment Agency, CORINE Land Cover, 2018	for land use analysis
romania_sol	vector, polygon	Soil Map of Romania, scale 1:200,000, National Research and Development Institute for Soil Science, Agrochemistry and Environmental Protection	for soil stagnogleyization analysis

Data processing was carried out in several stages using ArcGIS Pro software. Various cartographic materials were produced based on the previously mentioned datasets, using the Stereo 70 projection and the Dealul Piscului 1970 datum (Mihai et al., 2008). In the first stage, cartographic representations were generated for each analyzed factor using vector data. Subsequently, the vector data were converted into raster format. The resulting raster datasets were reclassified with values ranging from 0 to 10 (very low suitability to very high suitability) to ensure the homogeneity of the database.

To generate the slope map (Spatial Analyst Tools, Surface) was applied. The resulting raster data were then classified into five slope classes: below 5°, 5.1–10°, 10.1–15°, 15.1–25°, and above 25.1°. The raster information was subsequently reclassified with values ranging from 1 to 10 (from very low suitability to very high suitability) using the Reclassify function (Table 2).

For the preparation of the soil stagnogleization intensity map, polygon-type data were used. The vector data were clipped to the study area using the Clip function and classified into four classes: high, moderate, low and none.

Subsequently, values ranging from 3 to 10 (from very low suitability to very high suitability) were assigned to each category of soil stagnogleization intensity (Table 3). A new field containing the previously established values was added to the attribute table, after which the Feature to Raster function (Conversion Tools, To Raster) was used to generate the reclassified soil stagnogleization intensity map.

Table 2. Values used for slope gradient reclassification

Initial value	Reclassification value	Favorability classes
Below 5^0	10	Very high
5.1 - 10^0	7	High
10.1 - 15^0	5	Moderate
15.1 - 25^0	3	Low
Above 25.1^0	1	Very low

Table 3. Values used in soil stagnogleyization reclassification

Initial value	Reclassification value	Favorability classes
None	10	Very high
Low	7	High
Moderate	5	Moderate
High	3	Low

For the preparation of the geological map, polygon-type vector data were used. These datasets were clipped to the boundaries of the study area using the Clip function (Analysis Tools, Extract), after which the rock types were identified based on their codes from the attribute table (corresponding to the geological ages of rocks in Romania).

Each rock category was assigned a value ranging from 1 to 10 (from very low suitability to very high suitability) (Table 4). A new field containing the assigned values was then added to the attribute table. Subsequently, the Feature to Raster function (Conversion Tools, To Raster) was applied to convert the vector data into raster format.

Table 4. Values used for lithological reclassification

Initial value	Reclassification value	Favorability classes
Sands, gravels, boulders, loess, andesites, schists	10	Very high
Limestones, conglomerates, flysch, volcano-sedimentary formations	7	High
Sandstones, flysch	5	Moderate
Clays and marls alternating with other rocks, loessoid deposits	3	Low
Marls, clays, unconsolidated formations with marly-clayey intercalations	1	Very low

For the preparation of the land use map, polygon-type vector data from the Corine Land Cover dataset (2018) were used. Using the Clip function (Analysis Tools, Extract), the data were clipped to the boundaries of the study area.

Subsequently, the data were classified and symbolized according to land use categories (LABEL3_RO). A new field was added to the attribute table, in which each land use category was assigned a value ranging from 0 to 10 (from very low suitability to very high suitability) (Table 5). In addition, the Feature to Raster function (Conversion Tools, To Raster) was used to convert the vector data into raster format.

Table 5. Values used in land use class reclassification

Initial value	Reclassification value	Favorability classes
Arable land, agricultural land, crops, sparsely vegetated areas, shrub transition areas, secondary grasslands	10	Very high
Forests, subalpine vegetation, marshes	5	Moderate
Natural grasslands, vineyards, orchards, mining extraction areas, rocky areas, water bodies	3	Low
Continuous/discontinuous urban fabric and rural space, industrial/commercial units, recreational areas, communication networks and associated land, urban green areas, airports, landfills, construction sites	0	Very low

The main output of the multicriteria analysis performed in ArcGIS Pro software is the suitability map, which represents a useful tool for identifying favorable and restrictive areas for the design of the proposed express road in the Brașov–Covasna sector (Zăhărăchescu, 2024). The suitability map (SM) for the construction of the proposed road was generated by multiplying the raster datasets obtained for each analyzed factor, using the calculation formula:

SM = Power (S × G × LU × Ss, 0.25), where: S = slope, G = geology, LU = land use, and Ss = soil stagnogleization intensity.

The formula was applied using the Raster Calculator function (Map Algebra). After applying the formula, the map was reclassified into five suitability categories (Negulescu, 2025). Subsequently, based on the suitability map, two alternative road alignments were digitized within the sector delimited between the cities of Brașov and Covasna (Triantaphyllou, Sanchez, 1997). Subsequently, the lengths and their corresponding shares for each suitability class were determined.

3. RESULTS

According to the applied methodology, all analyzed information related to slope, soil stagnogleization intensity, the lithological factor represented by rock types, and land cover were integrated within the suitability map for road infrastructure planning in the Brașov – Covasna sector.

At the same time, the suitability map highlights the most appropriate areas for the development of human activities, particularly for the development of high-speed road infrastructure, based on a complex multicriteria spatial analysis (Dobre et al., 2011).

The use of multicriteria analysis for major road transport projects represents a useful tool for the preparation of road infrastructure development projects (Dobre, 2009). Moreover, this type of map can provide valuable information for subsequent stages of the project, particularly when planning the geometric structures of a road alignment (tunnels, bridges, and cuttings; Păunescu et al., 2019).

The resulting suitability map (Figure 2) indicates that approximately 50% of the reference area is characterized by very high suitability, while 21% of the area presents high suitability. Together, these categories account for 61% of the total study area considered for road infrastructure planning and construction. This percentage corresponds mainly to secondary grasslands, quasi-horizontal surfaces (with slope values below 5°), the absence of highly porous rocks (such as marls and clays), and areas with low or absent soil stagnogleization intensity.

In contrast, areas with low suitability represent 9% of the total surface, while those with very low suitability account for 7%, together totaling 16% of the reference area. These values are mainly determined by the increased morphodynamic potential (associated with the presence of clays and marls and steep slopes), as well as by built-up areas (transport infrastructure networks and their associated land, continuous urban fabric, discontinuous urban fabric, rural settlements, and industrial units).

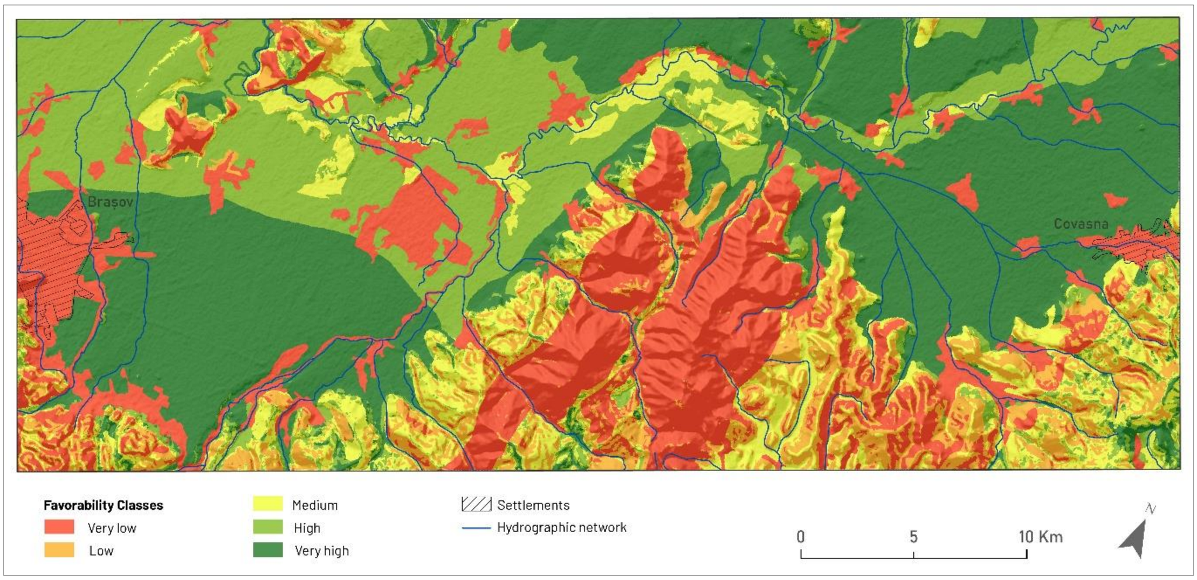

Figure 2. Suitability map

Based on the suitability map, two high-speed road alternatives were designed by making use of the most suitable areas. The first proposed road alternative for the connection between Brașov and Covasna (Figure 3) has a length of 45.1 km and overlaps predominantly with areas of very high suitability (52.34%) and high suitability (41.81%), together accounting for 94.15% of the total route length. In addition, the first route alternative crosses areas with medium suitability in a proportion of 5.85%.

The second road alternative (Figure 4) has a length of 49.2 km and crosses areas with very high suitability (47.31%) and high suitability (51.44%), totaling 98.75% of the route length. Furthermore, the road segment overlaps areas with medium suitability in a proportion of 1.25% (Table 6).

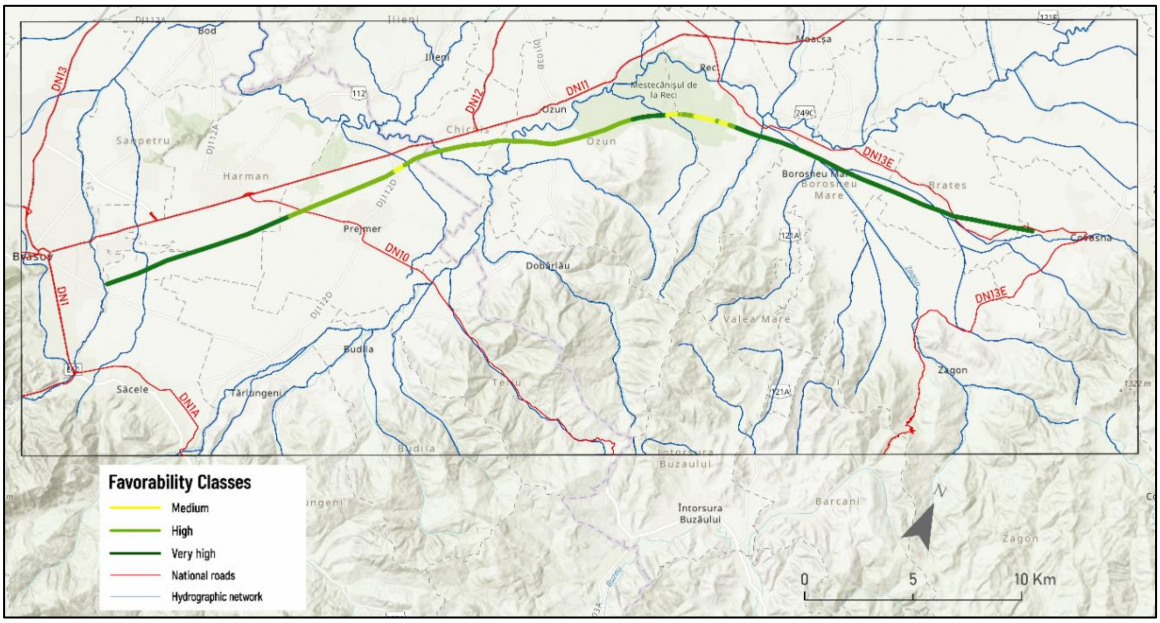

Figure 3. Correlation of the first proposed road alternative with the favorability classes

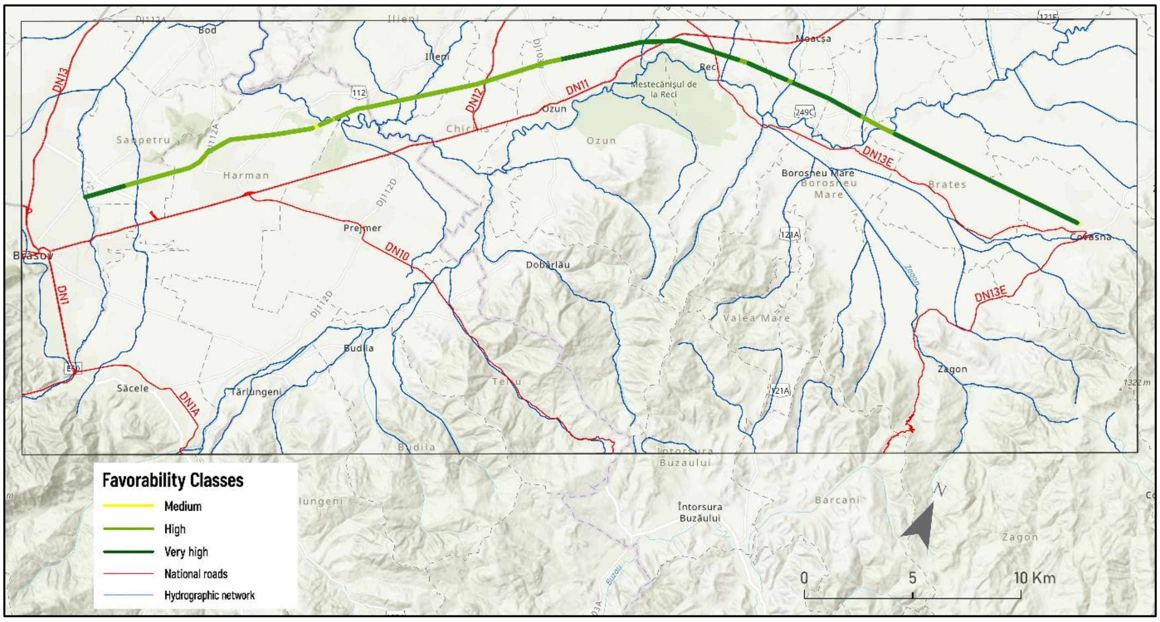

Figure 4. Correlation of the second proposed road alternative with the favorability classes

Table 6. Lengths and corresponding weights for each favorability class

	Alternative 1		Alternative 2	
Favorability classes	**Weight (%)**	**Length (m)**	**Weight (%)**	**Length (m)**
Moderate	5.85	2637.4	1.25	615
High	41.81	18858	51.44	25 308.4
Very high	52.34	23504	47.31	23 276.5
Total	100	45100	100	49200

4. DISCUSSION

Alignment 1 crosses a larger proportion of areas with very high suitability (52.34%) compared to the second alignment. In addition, the total length of Alignment 1 is shorter (45,100 m compared to 49,200 m), which implies a reduced construction time, lower long-term maintenance costs, and a lower impact on the traversed territory. A shorter infrastructure corridor is generally more efficient from both an economic and a functional perspective.

The first proposed road alignment intersects 11 administrative - territorial units: Brașov, Săcele, Hărman, Prejmer, Chichiș, Ozun, Reci, Boroșneu Mare, Brateș, and Covasna (National Agency For Cadastre And Land Registration, 2015). The proposed high-speed road alignment could attract significant economic investments and a larger number of residents to the administrative-territorial units intersected by the route. Thus, it may stimulate local and regional economic development by improving access to markets, while the faster connection between the two urban centers could encourage industrial and commercial development along the corridor.

In this context, the proposed project could lead both to the creation of new jobs to support the labor force and to the stimulation of economic competitiveness for business environment development. The first proposed road alignment creates road connections with the following national roads: DN10 and DN13E. The establishment of these road connections may also contribute to reducing travel times and transport costs, thereby increasing the efficiency of passenger and freight mobility in the area.

The development of a high-speed road between Brașov and Covasna would also contribute to improving regional connectivity and territorial cohesion, facilitating integration with major national and European transport corridors, including the TEN-T network. In addition, given the strategic role of Brașov as an important regional growth pole, improving its connectivity with surrounding areas such as Covasna County may strengthen its function as a transport and economic hub in central Romania.

The development of high-speed road infrastructure may have a significant impact on the environment, influencing various aspects of ecosystems. The construction of a high-speed road would lead to significant deforestation and changes in land use patterns. These actions may result in habitat fragmentation for animal species, creating both physical and behavioral barrier effects.

Consequently, road infrastructure can affect animal communities by restricting their mobility and limiting access to essential resources. In this context, one possible solution to mitigate the negative effects of habitat fragmentation is the construction of ecological corridors (ecoducts, wildlife crossings, tunnels, etc.). An ecological corridor is defined as a natural or designed area that ensures the conditions necessary for movement, reproduction, and refuge for wildlife species. In order for these structures to function effectively as animal crossings, several essential conditions must be ensured. On the one hand, the crossing area should remain in a state as natural as possible, closely resembling local habitats, and on the other hand, the obstruction of animal passages by fences, stored construction materials, or other anthropogenic elements should be avoided (Lazăr et al., 2020).

5. CONCLUSIONS

The proposed road alignment in the Brașov – Covasna sector represents a solution based on multicriteria suitability analysis. In other words, multicriteria suitability analysis can represent an important source of information.

Thus, it relies on established scientific, objective, and independent foundations and aims to evaluate all relevant natural and anthropogenic components (slopes, soil stagnogleization intensity, lithology and land use) that play an important role in the design, construction, and operation of high-speed road infrastructure.

At the macro-scale, the study area presents several constraints in mountainous regions, where morphodynamic potential is particularly high due to the occurrence of numerous exogenous geomorphological processes. In contrast, in depression areas characterized by smoother relief, several favorable zones for road infrastructure development were identified, where special engineering works are less costly. However, the higher density of rural and urban settlements in lowland areas may impose certain limitations on the planning of the express road between Brașov and Covasna.

As a result of the multicriteria analysis, a suitability map was generated, based on which two alternative road alignments were proposed. Subsequently, the first alternative proved to be optimal, as it crosses areas with higher suitability values. Furthermore, such a transport corridor would contribute to reducing traffic congestion on national roads within the analyzed sector, improving connectivity between the intersected settlements, and attracting new economic investments.

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