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MULTI-SCALAR SPATIAL INEQUALITIES IN SKI TOURISM INFRASTRUCTURE: A MAUP-INFORMED EXAMINATION OF ROMANIAN SKI AREAS

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Abstract: The study aims to quantify the differences in key ski infrastructure attributes at four territorial levels (development regions, districts, localities, and individual slopes) and assess the impact of scale on changes in these differences (the Modifiable Areal Unit Problem [MAUP]) and its subsequent implications for planning practice. The dataset refers to 2024 and comprises six infrastructural indicators collected for 229 slopes in 72 localities across 20 districts and six development regions. The study employs a multi-level quantitative framework based on the aggregation of spatial data across four hierarchical territorial levels and the construction of standardized composite indices for ski slope infrastructure (ISP), ski lift transport infrastructure (ISI), and their disparity, using min–max normalization within the interval [0,1]. Spatial inequalities and their scale-dependent variability are subsequently evaluated through descriptive spatial statistical analysis and GIS-based multi-scalar comparison (ArcGIS Pro), enabling the empirical assessment of MAUP-related scale effects in Romanian ski tourism infrastructure. The findings demonstrate a clear increase in disparities at lower spatial levels, confirming a pronounced scale effect linked to MAUP. At the regional level, such micro-scale inequalities become largely concealed, generating an impression of spatial homogeneity that is not evident at lower spatial scales. The results highlight the importance of spatial scale in evaluating infrastructural development disparities and provide a planning-relevant framework for mountain tourism destinations, supporting more effective investment targeting, the prevention of resource misallocation, and the mitigation of spatial inequalities affecting destination performance, accessibility, and environmental sustainability.

Keywords: Modifiable Areal Unit Problem; spatial disparities; ski tourism; Romania

1. Introduction

The Modifiable Areal Unit Problem (MAUP) constitutes one of the key methodological challenges in quantitative research on spatial phenomena and remains frequently overlooked

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in the interpretation of geographical data (Buzzelli, 2020; Chen et al., 2022; Deng et al., 2024). In the context of spatial and territorial management, the choice of spatial scale and the procedures of spatial aggregation can significantly shape analytical outcomes and, consequently, influence managerial interpretations that ultimately inform decision-making processes. Within destination management, these scale-dependent effects may fundamentally condition the assessment of visitor numbers, the identification of spatial patterns, and the formulation of strategic decisions.

MAUP demonstrates that the results of spatial data analysis are substantially conditioned by the way spatial units are defined, whether in terms of their size, shape, or aggregation procedures. When the boundaries, scale, or hierarchical configuration of administrative or otherwise delineated territorial units change, the statistical characteristics of the variables under examination also tend to change, which may lead to different—and often contradictory—conclusions (Deng et al., 2024; Openshaw, 1984). This issue is not merely a technical or cartographic concern, but affects the very foundations of geographical research, as it challenges the assumption that spatial patterns exist independently of the methods used to measure them.

In the context of contemporary research, in which the availability of geolocated data and advanced spatial modeling is steadily increasing, the importance of MAUP is rising not only in terms of analytical precision but also in relation to the epistemological reflection of claims made about spatial phenomena (Matlovič & Matlovičová, 2025; Matlovičová, 2015, 2024). The essence of MAUP lies in the fact that the outcomes of spatial data analysis are conditioned by the territorial level at which the data are aggregated. Different spatial units (e.g. points, localities, districts, regions) can produce divergent values even when the underlying phenomenon remains identical. This is an inherent property of spatial data, whereby differences and disparities tend to increase or decline depending on the size and hierarchical position of the selected spatial unit. A significant manifestation of MAUP is the so-called scale effect, which refers to changes in statistical results as a function of geospatial scale. As the scale decreases (i.e. when examining smaller territorial units), identified inequalities and variability typically increase, whereas aggregation at higher levels causes disparities to dissipate into averaged values (Chen et al., 2022; Dark & Bram, 2007). Consequently, analyses undertaken at the lowest hierarchical level (in this case, individual ski slopes) reveal considerable differences, which diminish or even disappear entirely when aggregated at district or regional levels.

In the context of analyzing ski infrastructure, MAUP is particularly relevant, since tourism infrastructure is spatially heterogeneous and conditioned by numerous local factors (including relief, altitude, accessibility, and climatic conditions). Consequently, indicators such as the number, length, or capacity of aerial lift systems display different values depending on whether they are measured at the level of a single slope, a locality, or a broader region. What may appear as pronounced disparity at the micro-level can thus seem relatively homogeneous when observed at the regional scale. MAUP is therefore not merely a random statistical artefact, but a methodological characteristic of spatial data that fundamentally shapes the interpretation of analytical results (Buzzelli, 2020; Chen et al., 2022; Deng et al., 2024; Openshaw & Taylor, 1979). Ignoring this issue may lead to misleading conclusions in spatial planning, investment decision-making, or the assessment of regional disparities in tourism infrastructure development.

2. Scale dependence as a factor in planning the development of ski infrastructure

The concept of MAUP was introduced by Openshaw (1984), who showed that statistical results derived from spatial data are highly sensitive to the choice of areal units, which are arbitrary and modifiable. The partitioning of geographical space influences statistical outcomes, and apparent spatial irregularities often result from the scale and configuration of territorial divisions rather than from the underlying phenomena themselves (Openshaw & Taylor, 1979). MAUP comprises two interrelated dimensions: the scale effect and the zoning effect (Openshaw, 1984; Wong, 2004).

The scale effect refers to changes in statistical indicators resulting from variations in the size or hierarchical level of spatial units. When moving from fine-scale units (e.g. individual ski slopes) to larger aggregated units (localities, districts, regions), variability decreases, extremes are smoothed, and correlations between variables often increase (Deng et al., 2024; Graham & Healey, 1999; Holt et al., 1996; Prouse et al., 2014). As a result, fine-scale analyses reveal greater unevenness in infrastructure distribution, whereas aggregated analyses tend to obscure local disparities aggregate (Buzzelli, 2020; Chen et al., 2022; Dark & Bram, 2007). For example, a micro-region may show significant imbalances in ski lift provision, while at regional scale the situation appears more balanced.

The zoning effect refers to changes in analytical results when spatial boundaries are configured differently while the scale remains constant. Different ways of grouping the same spatial units may produce different statistical values, even though the underlying phenomenon remains unchanged (Chen et al., 2022; Cressie, 1996; Fotheringham & Wong, 1991). In ski infrastructure analysis, assigning slopes to administrative units, tourist regions, or functional mountain areas may lead to different interpretations of spatial inequality. Thus, MAUP affects both cartographic representation and the interpretation of territorial disparities (Buzzelli, 2020).

From a methodological perspective, scale and zoning effects represent systemic sources of spatial aggregation bias and must be explicitly considered when interpreting disparities in ski infrastructure (Chen et al., 2022; Duque et al., 2018; Gehlke & Biehl, 2012). MAUP is particularly relevant in mountain environments, where infrastructure distribution depends on terrain, snow conditions, and accessibility (Hudson, 2003). Disparities in indicators such as slope length, lift number, and transport capacity tend to increase at micro-scale but diminish at regional scale, where inequalities are absorbed into averages.

MAUP also has important implications for regional planning and decision-making (Allmendinger & Haughton, 2009; Bornhorst et al., 2010; Rodríguez-Pose & Fratesi, 2004). Public investment allocation, transport planning, and spatial regulation are typically conducted at higher administrative levels, where disparities appear less pronounced than at the micro-scale (Hall, 2008; Rodríguez-Pose, 2013). This aggregation may create a misleading impression of spatial balance, causing planners to overlook problem areas and micro-regional inequalities. In ski tourism, resorts with inadequate lift infrastructure may be interpreted as part of a balanced region, reducing the likelihood of targeted policy intervention. Aggregated data may therefore hinder the identification of spatial clusters of imbalances and affect infrastructure planning and environmental management (Buzzelli, 2020; Faludi, 2013; Fyall et al., 2012; Healey, 2007).

Within destination management theory, MAUP affects the assessment of accessibility, competitiveness, and attractiveness. Destinations are inherently scale-dependent and may be defined at various spatial levels, from individual resorts to entire regions (Framke, 2002;

Pike & Page, 2014). When analysis focuses on higher spatial scales, micro-regional disparities may remain hidden within aggregated indicators. A region may appear competitive overall, while infrastructural attractiveness is concentrated in a few dominant locations, leaving other areas underserved (Brouder, 2020; Prideaux, 2000; Scott et al., 2008). This may unintentionally reinforce inequalities, as investment is often directed toward already developed areas.

Since MAUP is a systemic property of spatial aggregation, its effects must be examined across multiple territorial levels. Contemporary tourism geography increasingly adopts multi-scale approaches, treating hierarchical levels (slope, locality, micro-destination, region) as complementary explanatory layers capturing different spatial processes (Hall & Page, 2014; Saarinen et al., 2017). The concept of multi-scalar governance reflects the need to coordinate planning and investment across multiple administrative levels (Bramwell & Lane, 2011; Dredge & Jenkins, 2006). In mountain tourism, micro-scale analysis is essential for identifying inequalities, while regional scale is critical for policy implementation and investment decisions (Baggio, 2014; Coles et al., 2006; Haugland et al., 2011). Multi-scale analysis therefore provides a framework for mitigating MAUP distortions by interpreting spatial processes simultaneously across multiple levels.

3. Objectives and research design

Following on from the theoretical frameworks described above, the research aims (I) to quantify inequalities in the indices for ski slope infrastructure (ISP) and ski lift transport infrastructure (ISI) using standardized multi-criteria indicators, (II) to measure the magnitude and direction of disparities between these two infrastructural subsystems, and (III) to assess how the observed disparities change across four hierarchical territorial levels (ski slopes, localities, districts, and development regions), thereby providing an empirical evaluation of the scale effect associated with the MAUP.

This study will examine the MAUP in a model area of Romania, whose winter sports infrastructure is primarily concentrated in the Carpathian mountain system and which provides a relevant empirical setting for analyzing how differences between ISP and ISI vary across hierarchical territorial levels, ranging from individual slopes to development regions. In this context, the study does not aim to evaluate the overall performance of the national winter tourism sector, but rather to use the Romanian case as an empirical framework for assessing the scale-dependent representation of infrastructural disparities and their sensitivity to spatial aggregation procedures. Romania as a dynamically developing winter sports destination, shaped by the physiography of the Carpathians and by seasonal climatic conditions, provides a suitable context for observing how disparities between ski slopes and ISI become manifest across different hierarchical levels of territorial delineation – from individual slopes to development regions. At the same time, it represents an environment in which tourism development, destination management, and spatial planning face persistent tensions between the imperatives of economic development in mountain areas and their underlying environmental and social vulnerability (Richmond et al., 2026). According to National Institute of Statistics (NIS, 2025), Romania's population was 21,778,957, of whom 55.6% lived in urban areas. The urban system, comprising 319 towns and municipalities (with a combined population of 12,112,813), is relatively evenly distributed, with more pronounced concentrations in lowland and upland areas (NIS, 2025). These 319 urban centers largely constitute the principal domestic demand areas for winter sports tourism (NIS, 2025).

The presence of infrastructural differences indicates imbalances affecting the scope of tourism service provision, the opportunities for tourist activities, and ultimately tourist satisfaction in mountain ski areas (Boros & Korcsmáros, 2024; Herman, Gal et al., 2025; Szilágyi et al., 2025). To operationalize the analytical objectives outlined above and to guide the empirical investigation, the study is structured around the following research questions (RQs):

RQ_1: How does the intensity and variability of spatial inequalities between ISP and ISI change across hierarchical levels of spatial aggregation (slope – locality – district – region)?

RQ_2: What is the spatial relationship between the level of development of ISP and ISI in Romanian ski resorts, and where are the most pronounced positive and negative infrastructural disparities identified?

RQ_3: To what extent does the aggregation of data at higher spatial levels contribute to the masking of micro-scale infrastructural inequalities in the context of the MAUP?

These RQs provide the conceptual and analytical framework for examining scale-dependent spatial disparities and for interpreting the empirical results obtained through the multi-scalar comparative methodology applied in this study.

Accordingly, the research evaluates the extent to which the utilization of ski resorts is optimal from the perspective of sustainable development and tests the research hypothesis: *H_1* – There are no differences between ski slopes and ISI.

Methodologically, the study adopts a quantitative multi-level analytical framework combining spatial data aggregation, indicator normalization, and synthetic index construction. The analysis is based on a comprehensive dataset for 2024 documenting the number, length, and capacity of ski slopes and ISI in Romania (I-Tour, n.d.; National Authority for Tourism, 2025; NIS, 2025; Ski in Romania, n.d.). The data were aggregated across four hierarchical territorial levels – six development regions, 20 districts, 72 localities, and 229 ski slopes equipped with six ski lifts, 11 gondolas, 39 chair lifts, 124 ski lifts, and 28 children's ski lifts (NIS, 2025).

All infrastructural variables were subjected to min–max normalization to the interval [0,1], ensuring cross-scale comparability and eliminating dimensional inconsistencies between indicators. On this basis, a variable matrix was constructed enabling the calculation of composite synthetic indices for ISP and ISI using multi-criteria aggregation procedures. Subsequently, a disparity index (DI), defined as the arithmetic difference between the two standardized indices, was calculated to quantify the degree of imbalance between the examined infrastructure components. All component indicators (number, length, and capacity) were assigned equal weights in the construction of the synthetic indices in order to avoid introducing subjective assumptions regarding the relative importance of individual infrastructure attributes and to maintain cross-scale comparability of the composite measures. Given the absence of a theoretically or empirically established basis for differential weighting in the context of ski infrastructure assessment, equal weighting represents a neutral and commonly applied approach in composite indicator construction. The DI was formulated as a difference-based measure (ISP − ISI) rather than a ratio indicator because the difference formulation enables a symmetric representation of both positive and negative infrastructural imbalances and avoids the instability that ratio-based measures may exhibit in cases of very low denominator values.

Identifying differences between ski slopes and ISI in Romania required applying six criteria: three related to ski slopes (number, length, and capacity) and three concerning ISI (number, length, and capacity; Avdić & Avdić, 2023; Boc et al., 2022; Deac et al., 2023; Herman et al., 2024; Herman, Bucur et al., 2025):

$$Z=[z_{ab}]=\begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \ldots & z_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ z_{r1} & z_{r2} & \cdots & z_{rn} \end{bmatrix} \tag{1}$$

where each element Z_{ab} denotes the value of a specific variable (such as number, length, and capacity) for a given reference unit (development regions, districts, localities, and ski slopes). The r rows represent the reference units (six development regions, 20 districts, 72 localities, and 229 ski slopes), while the *n* columns represent the different types of variables collected for each reference unit.

Normalization (Min–Max) of the [0,1] values of the variables ski slopes and ISI was employed to improve comparability and facilitate multicriteria analysis (Avdić & Avdić, 2023; Boc et al., 2022; Deac et al., 2023; Herman et al., 2024; Herman, Bucur et al., 2025):

$$Cab = (zab - min zab)/(max zab - min zab) zb \in S, cab = [0, \ldots, 1] \tag{2}$$

The partial aggregate values of the capacity indicators for the synthetic index of ski slopes (ISP) and for the synthetic index of ski lift transport (ISI) were derived in accordance with the methodological approach proposed by Avdić and Avdić (2023), Boc et al. (2022), Deac et al. (2023), Herman et al. (2024), and Herman, Bucur et al. (2025) as follows:

$$x_b=\sum_{b=1}^{n} c_{ab} \qquad (a=1,\ldots r) \tag{3}$$

Individual values for each category were derived from the synthetic indicator X_a (Avdić & Avdić, 2023; Boc et al., 2022; Deac et al., 2023; Herman et al., 2024; Herman, Bucur et al., 2025):

$$X_a = \frac{1}{n}\sum_{b=1}^{n} x_a \text{ (a=1,...r)}, Xi=Xa \in [0,\ldots,1] \tag{4}$$

where a takes values in the interval [1, r], and *n* denotes the total number of variables included within each category.

Ranking of the reference units (development regions, districts, localities, and individual ski slopes) was conducted using the Symbology tool (Unique Values option) in ArcGIS Pro, based on the synthetic values of the indices related to ski slopes and ISI. The reference units were subsequently classified into four categories using the Symbology tool (Graduated Colors option) and the Manual Interval method in ArcGIS Pro. The classification thresholds were derived using the equal-interval procedure based on the value range calculated according to Equation (5).

$$X(Rpb) = maxRpb – minRpb, t = \frac{M(Rpb)}{4} \tag{5}$$

Group 1: *Xa* ϵ [0, 0.25] = a very low level; Group 2: *Xa* ϵ [0.26, 0.50] = a low level; Group 3: *Xa* ϵ [0.51, 0.75] = a high level; Group 4: *Xa* ϵ [0.76, 1] = the highest level; and where X(Rpb) represents the range Rpb values, max(Rpb) is the maximum value within the Rpb data set, and min(Rpb) is the minimum value within the Rpb data set.

The index of disparity between ski slopes and ISI was subsequently calculated as the difference between the partial synthetic indices:

$$DI = (ISP\text{-}ISI) \tag{6}$$

where DI is index of disparity between ski slopes and ISI; ISP is coefficient assigned to ski slope; ISI is coefficient assigned to ISI.

The resulting differences may assume values between −1 and 1. The greater the absolute value of the DI (i.e. the greater its distance from zero), the more pronounced the imbalance. A value of zero is considered to represent a state of perfect equilibrium between ski slopes and ISI. The individual reference units were classified and subsequently visualized using the "Symbology" tool and the "Unique Values" option in ArcGIS Pro, according to the synthetic values of the DI (Avdić & Avdić, 2023; Boc et al., 2022; Deac et al., 2023; Herman et al., 2024; Herman, Bucur et al., 2025). Specifically, formula (7) was used to determine the classification values.

$$M(Xa) = maxXa - minXa,\ t = \frac{M(Xa)}{4} \tag{7}$$

Where *M(Xa)* is the range of the quantity *Xa*; *max(Xa)* is the maximum value in the set of *Xa*; *min(Xa)* represents the minimum value in the set of *Xa*; and Group 1: *Xa* ϵ [0, 0.25]= a very low level; Group 2: *Xa* ϵ [0.26, 0.50] = a low level; Group 3: *Xa* ϵ [0.51, 0.75] = a high level; Group 4: *Xa* ϵ [0.76, 1] = the highest level; When *Xa* = 0 = perfect balance; Group 1: *Xa* ϵ [0, −0.25] = a very low level; Group 2: *Xa* ϵ [0.26, −0.50] = a low level; Group 3: *Xa* ϵ [−0.51, −0.75] = a high level; Group 4: *Xa* ϵ [−0.76, −1] = the highest level.

The classification thresholds were determined using an equal-interval (manual interval) approach applied to the standardized DI. Since the index values were normalized within the interval [−1, 1], the total numerical range of the index spans 2 units. This range was divided into four equal classes on each side of zero, resulting in interval widths of 0.25. Consequently, the threshold values (0.25, 0.50, 0.75, and 1.00, and their negative counterparts) are not derived from empirical clustering or statistical optimization but represent a typological segmentation of the normalized index designed to ensure comparability of disparity levels across all hierarchical spatial scales analyzed in the study.

For cartographic visualization across multiple spatial scales, vector map data provided by the National Agency for Cadastre and Real Estate Advertising (NAfCRO) were employed (NAfCRO, 2025). The geographical coordinates of the ski slopes and localities were obtained from Google Maps between 10 and 20 January 2025 (NAfCRO, 2025). Spatial data processing and analysis were carried out using Excel (Microsoft 365) and ArcGIS Pro.

4. Results and discussion

The identification and examination of disparities between ski slopes and ISI at the level of development regions, districts, localities, and individual slopes involved the use of three defining indicators, namely number, length, and capacity. The number of ski slopes and ski lift transport facilities constitutes a quantitative measure that provides basic information on the scale and degree of fragmentation of winter sports tourism. In 2024, a total of 229 ski slopes (sl) and 208 ski lift transport installations were identified in Romania (Herman, Gal et al., 2025). The length of ski slopes and ISI likewise represents an indicator of capacity, with implications for the volume of tourism activities in mountain areas and, implicitly, for the classification of winter sports resorts. In 2024, Romania possessed 262,086.34 m of ski slopes and 172,630.89 m of ISI (Herman, Gal et al., 2025). Capacity denotes the optimal daily number of skiers that can be accommodated on slopes and within ski lift transport systems. It depends on a range of factors, including average hourly performance as a function of skier speed and minimum safety distance, slope width, vertical drop, gradient, surface area, hourly capacity of the ski lift transport installations, load factors, and operating times (Ciangă & Deszi 2007; Herman et al., 2021). In 2024, the optimal daily capacity of the 229 ski slopes in Romania was estimated at 188,983 skiers and 137,490 ski lift transport places (Herman, Gal et al., 2025).

4.1. Multi-scalar evaluation of development regions using the ISP indicators of ski slope number, length and capacity

The evaluation of ski tourism potential based on the ISP reveals pronounced territorial differentiation across Romania at multiple spatial levels (Figure 1). At the regional scale, the Centre region clearly dominates, followed by the western and north-western regions, while the lowest values are observed in the south-western part of the country. A similar spatial hierarchy is evident at the district level, where Brașov and Prahova represent the leading areas, whereas districts Bacău and Satu Mare occupy the lowest positions. At the individual level, the highest ISP values are concentrated in well-established mountain resorts, including Sinaia, Straja, Poiana Brașov, and Predeal, while several smaller localities register minimal values. Finally, the analysis of individual ski slopes indicates substantial variability, with a limited number of slopes achieving the highest synthetic index scores, contrasted by beginner slopes that exhibit the lowest values. Detailed numerical values for all territorial levels are presented in Figure 1.

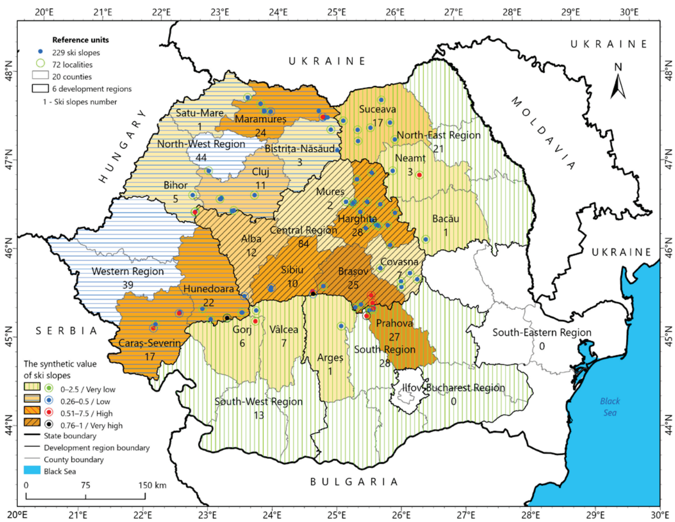

Figure 1. Classification of Romanian regions according to the ISP value of ski slopes.
Note. Prepared by utilizing the data based on: *List of Approved Ski Slopes* by National Authority for Tourism, 2025. (https://se.situr.gov.ro/OpenData/OpenDataList?type=listaPartii). In the public domain; *Ski in Romania* by Ski in Romania, n.d. (http://www.ski-in-romania.com/). In the public domain; *Tour– National Project of Tourist Information and Promotion* by I-Tour, n.d. (https://www.i-tour.ro/). In the public domain; *Administrative Boundaries* by NAfCRO, 2025. (https://geoportal.ancpi.ro/portal/apps/webappviewer/index.html?id=faeba2d173374445b1f13512bd477bb2). In the public domain.

The classification of Romania's development regions according to the ISP values of SL was based on an equal-interval classification of the normalized synthetic index values [0–1], in which the total range of the index was divided into four equal classes (0.25 intervals) to ensure comparability across all hierarchical spatial levels. The classification revealed three typological categories: regions with very high values [1, 0.75] – 16.7%; regions with low values [0.50, 0.25] – 33.3%; and regions with very low values [0.25, 0] – 50%.

At the district level, districts with very high values (10%), districts with high values (25%), districts with low values (15%) and districts with very low values (50%) were identified. At the locality level, localities with very high values (Sinaia and Straja, 2.8%), localities with high values (2.8%), localities with low values (11.1%) and localities with very low values (83.3%) were identified. At the slope level, ski slopes with very high values (0.9%), ski slopes with high values (30 slopes, 13.1%) and ski slopes with low values (86.0%) were identified (Figure 1).

4.2. Spatial inequalities in ISI

As in the case of the synthetic index of ski slopes, the analysis of the synthetic index of ISI entailed the hierarchical classification of development regions, districts, localities, and individual ski slopes. At the regional level, the highest ISI values were recorded in the Centre region, followed by the western and north-western regions, whereas the lowest values were observed in the southern and south-western parts of the country. A similar differentiation is evident at the district level, where Hunedoara, Brașov, Harghita, and Maramureș occupy the leading positions, while Argeș, Bacău, and Mureș rank among the lowest. At the level of individual destinations, the highest values were identified in established mountain resorts such as Straja, Poiana Brașov, Sinaia, and Muntele Mic, whereas several smaller localities exhibit minimal index values. The analysis of individual ski slopes further confirms substantial variability, with a limited number of slopes achieving the highest ISI values and a large group recording very low scores. Detailed numerical values for all territorial levels and the distribution of index values across individual ski slopes are illustrated in Figure 2.

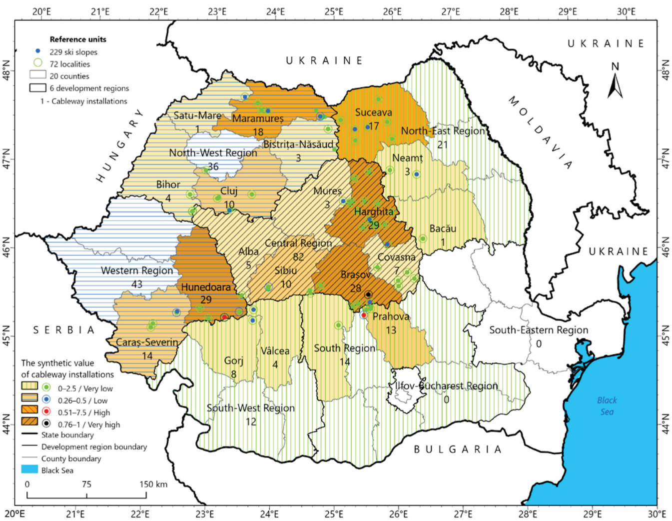

Figure 2. Classification of Romanian regions according to the ISI value of aerial lift (ski lift) infrastructure. *Note*. Prepared by utilizing the data based on: *List of Approved Ski Slopes by* National Authority for Tourism, 2025. (https://se.situr.gov.ro/OpenData/OpenDataList?type=listaPartii). In the public domain; *Ski in Romania* by Ski in Romania, n.d. (http://www.ski-in-romania.com/). In the public domain*; Tour– National Project of Tourist Information and Promotion* by I-Tour, n.d. (https://www.i-tour.ro/). In the public domain; *Administrative Boundaries* by NAfCRO, 2025. (https://geoportal.ancpi.ro/portal/apps/webappviewer/index.html?id=faeba2d173374445b1f13512bd477bb2). In the public domain.

4.3. Synthetic index of spatial disparities in ski lift infrastructure localization (DI)

Based on an examination of component differences between ISP and ISI (a total of six criteria assessed), an DI between the territorial units under study was constructed, ranging from the lowest hierarchical level (individual ski slopes), through localities and districts, to development regions. The results indicate the existence of an inverse proportionality between the DI values and the hierarchical level of the assessed territorial units. In other words, the lower the level of the reference unit (and the smaller its spatial extent), the greater the observed inequalities; conversely, the higher the hierarchical level and the larger the territorial extent, the smaller inequalities were identified. This inverse proportionality between the value of the synthetic indicator of differences and the hierarchical level of territorial division can be interpreted as a significant manifestation of the MAUP, specifically its scale effect.

An assessment of inequalities across the spatial reference categories revealed that the greatest disparities were recorded in the South development region (0.169), Prahova district (0.368), the locality of Sinaia (0.472) and on the ski slope Platoul Soarelui (0.676). In contrast, the lowest values of the difference index were observed in the North-East development region (−0.029), in Vâlcea district (0.001), in the localities of Gura Humorului, M-ții Retezat and Voineasa (0.001), Izvoru Mureșului (−0.001), and on the ski slope Luna Șes (0.011). A perfect balance, with a value of 0 (indicating an identical value of ISI and ISP), was identified at the level of two development regions, namely Centre and South-West (Figure 3).

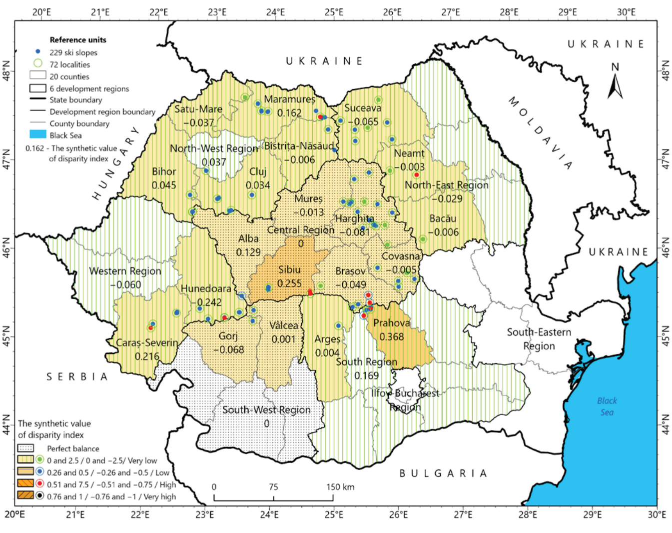

Figure 3. Classification of the examined territorial units (2024) according to the localization DI of ski lift transport.

Note. Prepared by utilizing the data based on: *List of Approved Ski Slopes by* National Authority for Tourism, 2025. (https://se.situr.gov.ro/OpenData/OpenDataList?type=listaPartii). In the public domain; *Ski in Romania* by Ski in Romania, n.d. (http://www.ski-in-romania.com/). In the public domain*; Tour– National Project of Tourist Information and Promotion* by I-Tour, n.d. (https://www.i-tour.ro/). In the public domain; *Administrative Boundaries* by NAfCRO, 2025. (https://geoportal.ancpi.ro/portal/apps/webappviewer/index.html?id=faeba2d173374445b1f13512bd477bb2). In the public domain.

From a typological perspective, the disparities identified were grouped into two broad categories, namely positive disparities and negative disparities.

- Negative disparities, in which the ISI is oversized in relation to the ski slopes and characterized by DI values between −1 and 0, were observed in two development regions (33.3%), 11 districts (55%), 45 localities (62.5%), and six ski slopes (2.6%) (Figure 3). These cases are characterized by ski slope values that are lower than the corresponding values for ISI. For example, in the North-East and West development regions, the respective values for ski slopes were 0.113 and 0.428, while those for the ISI were 0.142 and 0.488. At the district level, Hunedoara and Harghita were distinguished by DI values of −0.242 and −0.081, resulting from the difference between the ski slope indices (0.743 and 0.687) and the ISI indices (0.985 and 0.768). At the locality level, Poiana Brașov, Straja Resort, and Luna Șes recorded ski slope index values (0.641, 0.800, and 0.036) that were lower than those for ISI (0.928, 0.973, and 0.104).

The highest negative DI values were recorded in the West development region (−0.060), Hunedoara district (−0.242), Poiana Brașov (−0.287), and the Drumul Roșu ski slope (−0.256), whereas the lowest values were found in the North-East development region (−0.029), Neamț district (0.003), Izvoru Mureșului (−0.001), and the Pasul Vulcan I ski slope (−0.014).

In accordance with the study's research methodology, negative disparities were further divided into two subtypes: small and very small. Small negative disparities were observed in Poiana Brașov (−0.287) and on the Drumul Roșu ski slope (−0.256), while very small negative disparities were identified in two development regions (33.3%), 11 districts (55.0%), 44 localities (61.1%), and five ski slopes (2.2%).

- Positive disparities, in which the value of ski slopes exceeds that of ISI and where the DI ranges between 0 and 1, were identified in the North-West development region (16.7%), nine districts (45.0%), 27 localities (37.5%), and 223 ski slopes (97.4%) (Figure 3). These disparities indicate that the values of ski slopes are higher than those of the corresponding ISI. For instance, in the South and North-West development regions, the values of the ski slope indices were 0.220 and 0.420, while those of the ISI were 0.050 and 0.383, respectively. A similar situation was observed in Prahova and Sibiu districts, where the ISP values were 0.840 and 0.535, compared to ISI values of 0.473 and 0.280. Among the localities characterised by this type of disparity, notable examples include Predeal (0.339), Sinaia (0.472) and Șureanu (0.340). In terms of ski slopes, Sulinar (0.636) and Platoul Soarelui (0.676) recorded the highest values.

The highest values of the positive DI were observed in the South development region (0.169), Prahova district (0.368), the locality of Sinaia (0.472), and the Platoul Soarelui ski slope (0.676), whereas the lowest values were registered in the North-West development region (0.037), Vâlcea district (0.001), the localities of Gura Humorului, M-ții Retezat and Voineasa (0.001), and the Luna Șes ski slope (0.011).

According to the classification applied in this study, three subtypes of positive disparities were identified: large (18 ski slopes), small (two districts, three localities, and 146 ski slopes), and very small (two development regions, seven districts, 24 localities, and 59 ski slopes).

The identified disparities are not merely descriptive statistical differences but represent structurally differentiated development trajectories of Romanian mountain destinations. Areas characterized by persistent positive disparity values indicate infrastructural systems in which slope expansion has outpaced transport capacity, potentially constraining visitor throughput and reducing destination competitiveness. Conversely, territories displaying negative disparity values reveal potential overinvestment in lift systems relative to slope capacity, suggesting inefficiencies in capital allocation. From a planning perspective, these findings highlight the necessity of multi-scalar infrastructural assessment prior to investment decision-making, as reliance on aggregated regional indicators may obscure localized infrastructural mismatches and lead to suboptimal development strategies.

To verify H_1, which assumes that no differences exist between ISP and ISI, the values of the DI, calculated as the difference between the two synthetic indices (DI = ISP − ISI), were examined across all analyzed spatial units and hierarchical levels. The computed DI values demonstrate that, in the vast majority of territorial units, the index deviates from zero, indicating the presence of measurable differences between the two infrastructure components. Significant positive as well as negative DI values were identified at the levels of regions, districts, localities, and individual ski slopes, with only a limited number of cases exhibiting values equal to zero (perfect balance). These results, derived directly from the calculated synthetic indices and the DI values presented in Figures 1–3, provide empirical evidence that differences between ISP and ISI are systematically present. Therefore, the H_1, stating that no differences exist between ski slopes and ISI, is rejected.

5. Conclusion

As our research has shown, the line between the benefits and risks associated with the use of mountain areas through tourism development is particularly narrow and sometimes difficult to discern (Boros & Korcsmáros, 2024; Richmond et al., 2026; Szilágyi et al., 2025). In this context, identifying and examining differences using the example of ski transport infrastructure in Romania provides a valuable source of empirical information that can be used for effective and sustainable tourism development planning in mountain areas. The study confirmed the basic assumption regarding the relevance of a multi-level analytical perspective, which allows for the detection of hidden inequalities in the structure and intensity of tourism infrastructure at different territorial levels. In relation to RQ_1, the analysis demonstrated that the intensity and variability of spatial inequalities between ISP and ISI increase systematically as the spatial scale becomes more detailed, with the highest variability recorded at the slope and locality levels and the lowest variability at the regional level.

In Romanian mountain areas, the form and extent of identified inequalities in the location of ski infrastructure are influenced by scale effects associated with the MAUP, with the most significant effects occurring at the micro level.

Addressing RQ_2, the results revealed a structurally uneven spatial relationship between the development of ski slopes and ski lift transport systems, characterized by the coexistence of areas with oversized lift capacity relative to slope potential and areas where ski lift provision remains insufficient, with the most pronounced positive and negative disparities concentrated in specific districts, localities, and individual slopes.

The results of the study confirmed that the intensity and nature of inequality are conditioned by the chosen spatial scale (MAUP) and by the method of spatial data aggregation. The empirical analysis confirmed the rejection of H_1, demonstrating the existence of systematic differences between ISP and ISI across the analyzed spatial scales. The differences tend to increase with the increasing granularity of the analysis. The DI, derived from a comparison of the synthetic indicators ISP and ISI, is meaningful only when examined across hierarchically different spatial levels, as each level captures distinct contextual mechanisms of imbalance. At the micro level (slope or locality), inequality may be significantly higher due to specific environmental, orographic, or investment conditions, while at the district or regional level such differences are often masked within aggregated indicators. In response to RQ_3, the findings confirm that aggregation at higher territorial levels substantially masks micro-scale infrastructural inequalities, generating an apparent spatial balance that does not reflect the actual distribution of infrastructural capacities observed at lower analytical scales.

Beyond confirming the presence of the MAUP scale effect, the study extends the classical MAUP analytical framework originally formulated by Openshaw (1984) and further developed in subsequent methodological discussions (Buzzelli, 2020; Chen et al., 2022; Deng et al., 2024; Openshaw & Taylor, 1979) by applying it to infrastructure-based tourism systems rather than to conventional socio-economic or census-based datasets. The study applies a multi-level evaluation of paired infrastructure components (ISP and ISI) across four hierarchical spatial scales in order to identify scale-dependent infrastructural mismatches that may remain analytically concealed in single-scale assessments. In this respect, the contribution of the study lies primarily in the empirical operationalization of infrastructure disparity within destination development analysis, demonstrating how scale-dependent aggregation processes directly influence the planning interpretation of tourism infrastructure imbalances.

In this context, multi-level analysis is not merely a theoretical recommendation but a methodological necessity for identifying and interpreting spatial inequalities in infrastructure. The DI made it possible to identify areas with an excessive density of ski lifts relative to the potential of existing ski slopes and, conversely, areas where ski lift provision is markedly undersized. Multi-level analysis and the DI therefore constitute not only quantitative measures but also tools for the critical interpretation of spatial data in destination planning. For regional and local planning, as well as for destination management, such a perspective is crucial for determining investment priorities, regulating development, or redefining the functional orientation of individual centers. From the standpoint of destination planning and management theory, it is important that this approach does not rely solely on a simple inventory of infrastructure but instead conceptualizes it as a spatially structured system in which the supply of ski slopes and the supporting ski lift infrastructure may develop asymmetrically.

Despite the robustness of the multi-scalar analytical framework, several limitations should be acknowledged. First, the analysis is based on cross-sectional data for a single reference year (2024), which prevents the assessment of temporal dynamics in infrastructural development and the evolution of spatial disparities over time. Second, the study relies primarily on descriptive spatial statistical procedures and composite indicators rather than inferential statistical modeling, which limits the possibility of testing causal relationships between infrastructural development and underlying socio-economic or environmental drivers. Third, the construction of synthetic indices involves normalization and aggregation procedures that may introduce a degree of methodological subjectivity, particularly with regard to classification thresholds and aggregation procedures. Finally, the analysis focuses mainly on physical infrastructure characteristics and does not incorporate demand-side indicators, accessibility measures, or environmental carrying-capacity variables, which may also influence the functional performance of ski tourism destinations. Future research could address these limitations by employing longitudinal datasets, inferential modeling approaches, and broader multidimensional indicator systems capturing both supply- and demand-side determinants of mountain tourism development.

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