Identification of socioeconomically peripheral municipalities in Slovakia through formal regional taxonomy

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Abstract: *Research on spatial polarisation helps to understand the organisation of highly differentiated space. Previous studies have already addressed this topic, and this paper aims to contribute additional insights and findings. This study uses statistical and analytical methods with up to 16 socio-economic indicators derived from the 2021 Census of Population, Houses and Dwellings, and other socio-economic indicators in a given year, or over the 2011-2020 intercensal period. These methods help identify peripheral municipalities in Slovakia and to point out the causes of this phenomenon. Using methods of formal regional taxonomy, four key factors are introduced that significantly improve identification and specification of socio-economic peripheries. These factors form the foundation for a new typology of Slovak municipalities based on peripherality. This typology provides a detailed view of individual factors and points out the accumulation of negative values of the factors. These findings are presented within the basic spatial units of Slovakia as municipalities with cumulated or partially cumulated peripherality.*

Keywords: *spatial polarisation, peripheries, formal regional taxonomy, factor analysis*

Introduction

The existence of people in space leads to the emergence of certain interactions that can be, to some extent, identified. Space can then be differentiated into individual parts, which are delineated by their own relative internal homogeneity and external heterogeneity. The temporal variability of socioeconomic indicators clarifies the variability of human interactions, which depend, among other things, on their spatial possibilities. The intensity with which individual activities are carried out is regularly recorded through repeated collection of statistical data. Their quality interpretation assesses the past, and current, and partially can also predict the future development of the studied area. The optimization and streamlining of human activities are closely related to their often dominant position in the landscape. The combination of natural and socio-economic factors, which can to some extent be adapted, can lead to significant differences in the character of the studied area. The existence of mechanisms influencing the reduction of differentiations at various hierarchical levels is an integral part of advanced regional policy. The localization of areas with intensive spatial human interactions is thus dependent on the economic advantage of the location. It may therefore be assumed the existence of two levels, where uneven development leads to social and economic decline of the area on one hand and unprecedented development on the other. The aforementioned level becomes one of the reasons for migration of certain age groups of the population to economically more developed areas. This issue was further addressed by Novotný and Pregi (2016), discussing selective migration.

The study focuses on the issue of the peripherality of individual regions of Slovakia and the identification of specific key factors of peripherality. The primary goal is to identify socioeconomic differences in Slovakia at the level of municipalities based on selected indicators.

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Identification is carried out through factor analysis. Partial results then enter into further phases of research related to the spatial distribution of socioeconomically less developed municipalities. The outcome is a specific typology of socioeconomically less developed municipalities through identified factors. These factors can be assessed in a broader or narrower sense as factors influencing the emergence of socioeconomically peripheral areas of Slovakia.

Theoretical background

The subjective concept of space and at the same time the issue of its polarisation are currently discussed topics. The geographic space, as a non-homogeneous subject of interest along with its content, changes over time in different parts. Halás (2014) in this context states that in most cases there is a natural tendency to equalise differences between heterogeneous parts of space, but it can never bring complete homogeneity. It is precisely the existence of socio-economic differences between regions that selected theories of regional development discuss and they are one of the reasons for the existence of regional policy (Blažek and Uhlíř 2021).

Heterogeneous areas have thus become cooperative in creating the geographic organisation of space. Human beings, as part of it and the fundamental element in its formation, distinguish several areas and hierarchical levels. The study of geographic space using quantitative approaches consists of various mathematical, numerical, and analytical methods focused on evaluating the essence, structure, and other individual parts serving to define and identify regions. Collectively, this area of geography, with interdisciplinary implications, is called regional taxonomy. Contemporary geographical community utilizes regional taxonomy for analysing and visualising space in terms of quantitative geography. A comprehensive overview of regional taxonomy can be found in the extensive monograph by Klapka (2019).

Spatial polarisation is a natural part of the territory that has emerged from the synthesis of various fragments of geographic space characteristics. This assertion is based on different natural, social, and economic conditions that are represented differently in the territory. The relative external heterogeneity of a functional region and at the same time its internal homogeneity are elemental assumptions for the emergence of a dichotomous space that can be differentiated into centre and periphery. According to Halás (2014), this division will always exist, even in cases where states implement strong equalization policies. However, it is important to note that the concept of spatial dichotomization should not be perceived as a sharp distinction between central and peripheral (marginal) regions. The reason for this is the continuous nature of geographic space, usually represented by a continuous distribution of geographic information (Novák 1989, Feng 2009, Watts 2009, Halás and Klapka 2020).

Contributions from representatives of the so-called new economic geography, Fujita and Thisse (2002), focus on the spatial distribution of economic activities, assuming spatial heterogeneity with the existence of externalities in production. Baldwin et al. (2003), also emphasize that the geographic concentration of a certain workforce contributing to innovations is a source of long-term dynamics and economic growth in a region. This creates a certain concept that Swyngedouw (1997) specifies in the form of interdependencies in polymorphic geographic areas of uneven development. In such cases, these interactions can act through relations between the global, national, regional, and local levels. One issue is the creation of uneven redistributive mechanisms in the labour market and terms of human welfare. Storper (2010) describes this and notes that uneven spatial distribution of development could correspond to greater equality in social income distribution and resources. In this context, it is bold to claim that in the asymmetric socio-economic development of regions, one might expect similar equality in household incomes or welfare distribution without specifying the scale, as pointed out by Schmidt (1998). Decreasing the scale of observation may blur the complex internal heterogeneity of regions but improves orientation in the complex reality.

Regions that are consistently financially undervalued across different levels of government may exhibit greater equality in welfare distribution, especially at the local level. For higher levels, one can discuss a more complex issue where theoretical methodological individualism is potentially problematic. Storper (2010) admits that spatial economics faces a more challenging task in constructing a suitable social welfare function compared to general economics. Wacquant (2009) presents an argument highlighting the inability or unwillingness of ruling classes in wealthy countries to halt the growth of inequalities between regions. Bernt and Colini (2013) explain this phenomenon as a shirking of responsibility for caring for the state's inhabitants by public institutions in favour of promoting mechanisms that create inequalities and shortages. This assertion thus provides space for political expressions that are more sensitive on one hand to the capabilities of citizens and on the other hand allow for the fulfillment of citizens' life plans, who should have equal opportunities according to Dworkin (2000).

The perception of the concepts of periphery and marginality varies significantly across the scientific community. Anglo-Saxon literature tends to differentiate between the two concepts more frequently. Bernt and Colini (2013) argue that the term marginality began to be used in the context of urban problems, while peripherality can be understood as an attempt to progress in understanding intra-regional differences. However, they state that marginalization and periphery are not mutually exclusive at the theoretical macro level. Andreoli (1994) also explains that within a narrower understanding of marginality and peripherality, they can be seen as concepts with different meanings, but in a broader sense, these terms can be considered synonymous. It is not a rule that a peripheral region must show signs of marginality, and at the same time, a marginal region is located at the edge of the area under study. Schmidt (1998) discusses the question of the existence of a centre in the periphery and a periphery in the centre. A marginal area may have an advantageous position in the centre or maybe its direct part. Metaphorically, this situation is likened by Halás (2014) to the Chinese philosophical concept of yin and yang. Seidl and Chromý (2010), Máliková and Spišiak (2013) point out that the perception of these terms in Czech and Slovak geography is more synonymous.

McDonagh (2002) calls for attention to the numerous social dimensions in the same geographic space and an awareness of the existence of various types of spatial peripheries. From Leimgruber's (1994) partial approaches to marginality, Schmidt (1998) selects the perceptual approach, which he considers to be an individual subjective perception of objective reality. Pugh and Dubois (2021) describe the problem of the absence of a definition and consistent language to resolve the confusion in understanding the expression "being peripheral" in different spatial scales. McDonagh (2002) interestingly adds that in reality, every person knows what peripherality is unless asked to define this concept themselves.

Kühn (2015) explains that the term periphery can be understood as a geographic concept of distance from the core. In contrast to the concept of periphery, he describes the existence of peripherization as the production of peripheries by social relationships and their spatial consequences. Pugh and Dubois (2021) perceive the creation of the core-periphery paradigm as a contrast in terms of developmental potential between cities and diverse groups of sparsely populated areas. These areas are diverse in their physical or socio-economic characteristics. Therefore, it may seem that from this perspective, supporting cities is the clearest choice from poverty to prosperity (Glaeser 2011). This is confirmed by the concentration of economic activity in major cities, accumulating economic and political power.

In this context, Rodríguez-Pose (2018) raises the question of whether peripheries, post-industrial, and underdeveloped areas are becoming "places that do not matter." To reflect on the complexity of the whole issue, Lang et al. (2015) present the concepts of polarisation and peripherality in an extensive theoretical discussion. Within this paper, both terms are perceived at the local level as words with similar but not identical meanings. Simply put, marginality refers to the inadequate or low socio-economic integration of an area within the system. Periphery encompasses a wider range of socio-economic and spatial characteristics.

It is important to emphasize that the examination of the more detailed spatial aspect (in terms of distance or accessibility) was not the primary focus of this contribution. Therefore, it is further understood as one of the aspects of the emergence of peripheral areas. Džupinová et al. (2008) delve into the issue of the correlation between spatial and socio-economic peripheries. The authors further detail the theoretical and methodological aspects of research in peripheral areas and also address their specific application in practice down to the micro-regional level. Other works addressing the issue of socio-economically weaker areas and possible causes of peripheries can be found in the studies of Korec and Polonyová (2011), Michálek (2018), and Székely and Novotný (2022).

Due to the existence of regional centres, it can be assumed that differences are being blurred by higher levels of amenities or more positive socio-economic indicators. Therefore, with increasing hierarchical levels, there is a certain elimination of differences between the concepts in question. The geographic concept of peripherality and marginality has a long-term and ongoing development. Scientists still have not found a suitable definition that fully covers this phenomenon in all its complexity at various social and spatial levels.

The formation of spatial interactions is influenced by barriers, which can usually be distinguished as natural and socio-economic. Lukniš (1985) already presents the existence of communication barriers, where the fragmented relief of central Slovakia as a significant natural factor increases the probability of the occurrence of peripheral areas.

One of the factors in the socio-economic shaping of regions is the spatial distribution of the population and the existence of opportunities for potential interaction between settlements. Hurbánek (2005) states that, among other things, the fragmentation of the settlement structure leads to the emergence of marginal regions. Given the availability of a large amount of data, collaboration across a wide spectrum of institutions is important in the context of analyses and approaches to reducing socio-economic regional disparities. The regional and settlement structure of Slovakia is significantly influenced by a multitude of factors that can be included in sophisticated research methods. Halás (2008) identified peripheral areas in Slovakia based on deteriorated indicators in the following groups: human resources, personal amenities, accessibility to centres, and economic amenities. A special group was cumulative peripherality, which indicated deteriorated indicators in three or more groups. From the available results, it is evident that the territory of Slovakia is polarized in a northwest-southeast direction. This confirms previously proclaimed results of research, especially the work of Korec (2005). Looking at the regional scale, some areas have consistently shown significantly undervalued values of indicators entering into various analyses and research.

Even though spatial peripherality is not primarily considered in this paper, it is worth mentioning that territorial-administrative division can be one of the factors in the emergence of peripheral areas. Halás and Hurbánek (2008) identified peripheries in border regions on the borders with Ukraine and Poland. According to their work, the southern part of eastern Slovakia and the border with Hungary show lower levels of peripherality, especially for orographic reasons. The development of settlements and regions in this part of Slovakia smoothly continues the settlement structure of Hungary, so it is necessary to assess it in broader spatial contexts, according to Halás (2014).

Data and Methods

Examination of the territory of Slovakia from socio-economic or spatial perspectives not only highlights the issue of administrative division but also points to the long-standing unresolved problems of social marginality and exclusion. The interaction of factors conditioned by geographic space indicates the existence of peripheral and marginal areas. In this context, it can be considered whether the emergence of socio-economic peripheries is the result of long-term neglect of individual components of the social environment not only by the state. Political

inaction, low economic power, and insufficient connectivity with the centre of the region are considered by Popescu et al. (2021) as a selection of aspects of peripheries formation.

Due to the existence of approximate functional regions (AFRs) proposed by Halás and Klapka (2020) based on daily population flows to work in 2011, and the officially unconfirmed gerrymandering for the creation of the administrative subdivision of Slovakia, these units have been used as a suitable alternative to the current administrative subdivision that reflects the reality of commuting. It is necessary to note that AFRs are composed of districts and do not respect the current administrative boundaries of self-governing regions. The authors point out that any variant of AFR that respects the boundaries of self-governing regions can be considered highly inappropriate.

Peripheral areas of space are a complex issue that requires a specific rigorous approach, with the foundation being the adherence to a correct definition. At a generalized view of peripheral areas, they can be evaluated in terms of the dichotomy of prosperity-regression. However, this assessment cannot be universally applied because experimenting with alternative evaluations requires a more precise analysis that reflects complex social interactions and local spatial distributions. Therefore, peripheral areas cannot be considered just as a group of regions characterized by the regression of selected indicators, as some more straightforward research studies suggest. Leimgruber (1994) presents four basic types of peripherality: geometric, social, economic, and ecological. The diversity of these types also implies different compositions of indicators that identify these regions.

A relatively simple method is comparison, which compares static or dynamic indicators in a region. The availability and quality of regional characteristics are considered by Michálek (2014) as very significant for the objectivity of the entire research. In combination with statistically more sophisticated methods (Gini coefficient, Lorenz curve, Theil and Hoover indexes and their modifications, or other statistical-descriptive methods), a comprehensive analysis of regional disparities represents the most suitable spectrum of evaluations, the objectivity of which is based on quantitative procedures. However, data collection through qualitative and perceptual research can also be an indispensable part of identifying local spatial disparities.

Erlebach et al. (2019) point to ways of identifying peripheries using methods of formal or functional regional taxonomy. In the case of formal regions, it involves the use of methods whose procedures are based on multidimensional analysis with an emphasis on internal homogeneity and external heterogeneity. The beginnings of the identification of formal regions can be traced back to the 1960s (Berry 1961), based on which one can now talk about the "traditional approach". It has been used by e.g. Lattin et al. (2003) or Everitt et al. (2011) and consists of two basic steps. This approach consists of two basic steps:

- mathematical orthogonalisation of the original variables and selection of explanatory factors (PCA, CA),
- reduction of attribute matrix rows or spatial units into typological formal regions (FA).

The identification of socio-economic peripheries in Slovakia is based on the analysis of a multidimensional taxonomic space formed by 16 indexes calculated from data from the 2021 Census of Population, Houses and Dwellings and other socio-economic indicators in a given year, or over the 2011-2020 intercensal period (SO SR 2024, COLSF SR 2024). The choice of indexes partially drew from previous works by Slovak and Czech authors (Matyáš et al. 2007, Džupinová et al. 2008, Halás 2008, Erlebach et al. 2019). As mentioned earlier, the goal of the study is to identify socio-economic differences at the level of municipalities. Therefore, the selected indexes represent basic indicators of the social and economic status of the population, which are collected in the Census of Population, Houses, and Dwellings and are comparable in the long term. The chosen indexes rigorously do not build on previous authors but are a blend and an alternative approach to the study of socio-economic disparities. It can be argued that the choice of indexes has a key impact on the results of the analyses. Therefore,

a choice of indexes in individual analyses and subsequent attempts at interpretative synthesis can provide valuable results in identifying areas of social and economic decline. Across the mentioned works, several used indexes can be divided into the following groups:

- indices of natural population change (1-3),
- age structure indices (4-6),
- index of the educational structure of the population (7),
- indexes of spatial interaction and migration (8-10),
- economic indexes (11-13),
- indexes of housing and household amenities (14-16).

Within this post, 16 indexes were used, which can be divided into the above-mentioned groups based on their focus. The following indexes were selected for each basic spatial unit:

1. Number of births per 1000 inhabitants of middle status over the intercensal period (crude birth rate).
2. Natural population increase per 1000 inhabitants of middle status over the intercensal period (crude natural increase rate).
3. Total increase per 1000 inhabitants of middle status over the intercensal period (crude total increase rate).
4. Aging index (Sauvy's index), which expresses the number of people in post-reproductive age (65+ years) per 100 people in pre-reproductive age (0-14 years).
5. Dependency ratio I, which expresses the dependence of the population in pre-reproductive age on the population in the working age group (15-64 years).
6. Dependency ratio II, which expresses the dependence of the population in post-reproductive age on the population in the working age group.
7. Synthetic indicator of education (SIE) (Toušek et al. 2009) is a recommended indicator within the Database of Strategies: Portal of Strategic Documents of the Czech Republic, and it deals with social capital in municipalities, where higher education increases chances of employment and reflects the potential of human resources in the area. Therefore, higher levels of education are assigned higher weight,

$$S_i = \frac{\left[\left(\frac{u_1}{u}\right)_i + 2\left(\frac{u_2}{u}\right)_i + 3\left(\frac{u_3}{u}\right)_i + 4\left(\frac{u_4}{u}\right)_i\right]}{100}$$

   where u_1 is the number of inhabitants over 15 years old with primary education, u_2 is the number of inhabitants over 15 years old with secondary education without a high school diploma, u_3 is the number of inhabitants over 15 years old with complete secondary education, u_4 is the number of inhabitants over 15 years old with higher education, and u is the total number of inhabitants over 15 years old.
8. Migration balance per 1000 inhabitants of population median in the over the intercensal period (gross migration balance rate).
9. The proportion of departures from the economically active population in the given area (departing index).
10. The proportion of the total number of arrivals to the number of occupied jobs in the given municipality (arriving index),

$$D_i = \left[\frac{[(\sum_j t_{ji}) - t_{ii}]}{[(\sum_j t_{ji}) - (\sum_j t_{ij}) + t_{ii}]}\right] \cdot 100$$

   where t_{ij} is the number of economically active individuals residing in town i and working in town j, t_{ji} is the number of economically active individuals residing in town j and working in town i, and t_{ii} is the number of economically active individuals residing and working in town i.

11. Ratio of the number of unemployed individuals from the economically active population (unemployment rate).
12. Percentage share of the economically active population from the population aged over 15 years old (economic activity rate).
13. Percentage share of individuals in the post-productive age group from the economically active population permanently residing in the given area (share of working retirees).
14. Percentage share of households with access to running water from permanently inhabited dwellings.
15. Percentage share of households with flush toilets from permanently inhabited dwellings.
16. Percentage of dwellings connected to the public sewerage network out of permanently occupied dwellings.

During the following analysis, the standard sequence was maintained: principal component analysis, factor analysis, and subsequently cluster analysis. The combination of these procedures is referred to as factor-cluster segmentation by Dolnicar and Grün (2009), who also explain the critical perspective of some authors on reducing the number of variables. However, this concept was already introduced by Smith (1989) in the classification of market segmentation in tourism. Erlebach et al. (2019) present two advantages offered by this approach. The first is the reduction in the number of variables entering further operations and analyses. The second, more significant advantage is the elimination of redundant correlated variables. The overall combination of multiple methods allows for obtaining broader insights for more precise identification and interpretation of regional differences.

A standardized matrix consisting of 16 indexes and 2924 municipalities in Slovakia was subjected to database suitability testing using SPSS software. The KMO index value (Kaiser 1974) was 0.744, which is considered by the evaluation criteria as a medium level of suitability. Subsequently, a principal component analysis (PCA) was performed. It is important to note that all analytical processes were conducted without explicitly incorporating a spatial aspect into the database. Military districts Záhorie, Lešť, and Valaškovce were excluded from the analysis. Four main components were extracted according to the criterion presented by Kaiser (1960). The result of the analysis is the eigenvalues plot of the correlation matrix (fig. 1), where the values of individual components exceed 1 and their cumulative proportion of variance reaches 68.13%, which can be considered a sufficient explanation of the variability of the original indexes.

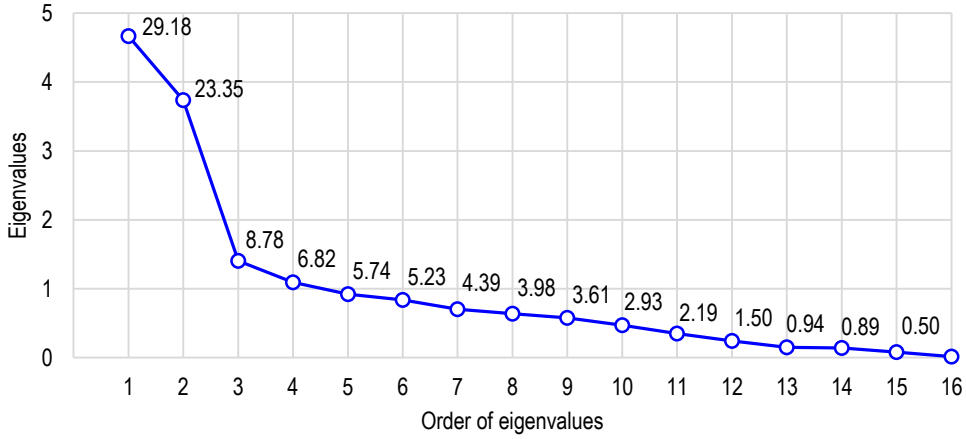

Fig. 1. *Eigenvalues of the correlation matrix with the proportion of variance of each components (%)*

Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration

Subsequently, a transformation, i.e., Varimax rotation, was performed on the components (factors), which is an orthogonal rotation method that ensures appropriate interpretation of the results. The resulting four factors can be characterized using factor loading analysis of individual variables, whose absolute value is greater than 0.60. It is noted that the higher the factor loading value for a particular factor on a given variable, the greater the influence of that factor on the variable. The identification of different types of correlations is possible based on positive and negative factor loading values (tab. 1). In the case of a negative number, represents a negative correlation between variables.

Tab. 1. *Rotated matrix of factor loadings of individual variables*

Variable	Factor 1	Factor 2	Factor 3	Factor 4
V1	-0,453	**0,753**	0,238	0,113
V2	-0,127	**0,877**	0,185	0,197
V3	0,136	0,481	**0,842**	0,108
V4	-0,243	**-0,612**	0,177	0,064
V5	-0,470	**0,721**	0,294	0,126
V6	-0,045	**-0,833**	-0,076	0,064
V7	**0,834**	-0,180	0,109	0,230
V8	0,253	0,015	**0,919**	0,004
V9	**0,752**	-0,148	0,261	0,142
V10	-0,022	-0,171	0,163	0,535
V11	**-0,808**	0,338	-0,052	-0,144
V12	**0,775**	0,195	0,100	0,096
V13	0,254	-0,418	-0,077	0,345
V14	0,297	0,095	-0,072	**0,627**
V15	**0,616**	0,136	-0,015	0,474
V16	0,185	0,179	0,018	**0,703**

Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration

In the case of Factor 1, there is a correlation with five variables, in four cases in a positive sense and in one case in a negative sense. In this context, it can be assumed that an increased value of the synthetic indicator of educational attainment (SIE) causes a higher level of economic activity and thus lower unemployment. Thus, a higher economic activity rate is also directly related to daily commuting. At the same time, it can be assumed that the SIE and the low unemployment rate in a municipality may be related to higher housing amenities, as indicated by the correlation with variable V15. Considering the above characteristic, we can talk about the residential developedness factor (RED).

Factor 2 is also correlated with five variables. In three cases, the correlation is positive. The variables that are related to the increase in the pre-productive component of the population are the ones that stand out. It can be assumed that its increase will subsequently affect the gradual decline in the values of indicators such as the old-age index and the dependency index 2. Factor 2 can therefore be interpreted as a factor of population stability (PPS).

Factor 3 positively correlates with the gross migration balance rate and the gross total increase rate. A closer look at the demographic development issue of the population of Slovakia suggests that the share of migration balance in the total increase/decrease of the population of municipalities has been showing an increasing trend since the change in political regime in 1989. A higher proportion of migration in the total increase may be due to the free migration of individuals for expanded educational opportunities and stable employment. Based on these facts, Factor 3 can be considered as the factor of migration motivation (MIM).

Factor 4 is positively correlated with two variables related to the amenities of permanently occupied dwellings. The unavailability of a public water and sewerage network can

be a significant limiting factor for potential development in both the social and economic spheres. Factor 4 can be referred to as the local amenity factor (LAM).

Factor analysis refers to the reduction of the number of variables studied to identify the relationships between variables. One possibility of factor analysis is the calculation of factor scores for all municipalities. According to Erlebach et al. (2019), there are several ways to calculate factor scores. For this paper, STATISTICA software was chosen, whose algorithms for calculating factor scores utilize refined regression analysis.

Cluster Analysis

Among the clustering methods based on the variability of regional classes is Ward's method (Ward 1963), which, among others (Klapka 2019), is based on the principle of minimizing internal variability within a given class. The merging of interim regional classes into a new cluster depends on the smallest increase in intra-class variability. Due to the uniqueness of the basic territorial units, it can be argued that each unit is an independent interim regional class. In this context, Holčík and Komenda (2015) point out that Ward's method tends to eliminate small clusters and create new clusters of approximately the same size.

To cluster spatial units into regional classes, it is necessary to calculate the minimum distance between all pairs in the matrix. This step needs to be applied when using all agglomerative hierarchical methods. The distance or similarity between two objects is evaluated in each stage of the algorithm. Holčík and Komenda (2015) mention that two objects, an object and a cluster, and two clusters can be compared to each other. Different methods of calculation define the taxonomic distance in various ways. In the presented paper, the so-called Minkowski metric was used with a general expression:

$$d_{ij} = \left(\sum_{m=1}^{p} \left| x_{im} - x_{jm} \right|^{b} \right)^{\frac{1}{b}}$$

where x_{im} represents the value of the m-th regionalization criterion in the i-th basic spatial unit where b takes the value 1 in the denominator of the exponent.

The output of agglomerative hierarchical clustering is a mathematical representation that groups individual interim regional classes or basic spatial units into clusters. However, a more visually and interpretatively informative output of clustering is a dendrogram. In the case of Slovak municipalities, a dendrogram was generated, consisting of 2924 municipalities that were categorized into clusters using Ward's method. Interpreting a dendrogram for many municipalities can be challenging, so the optimal number of clusters was determined using multiple methods. These methods were based on the silhouette measure (Rousseeuw 1987), the CCC method (Sarle 1983) and the Pseudo F method (Milligan and Cooper 1985).

For example, Pászto et al. (2019) chose the silhouette method when analysing the continuity of socioeconomic indicators in the Czech-Polish border region. According to Klapka (2019), the silhouette method has the advantage of being universally applicable to hierarchical and non-hierarchical approaches to creating formal regional classes. Thus, if the silhouette values range from ⟨-1;1⟩ and an average value can be calculated for each regional class in the system, then the higher the silhouette values, the more valid the regional system. The distribution and interpretation of values are proposed in the work of Kaufman and Rousseeuw (1990). For this study, the silhouette method was primarily used to determine the optimal number of formal regional classes. The curve progression (fig. 2) shows a gradual decrease in the silhouette index with an increasing number of clusters. However, for a number of five clusters, an increase in the index value can be observed, making this number identifiable as acceptable for further analysis. Although the potential regional system structure shows the greatest silhouette in two clusters, this option is not suitable for this study. In this regard, Pászto et al.

(2019) state that both a small and a large number of clusters can degrade the planned cartographic output and lead to a less quality interpretation. For this reason, a maximum of 15 clusters was set for analysis. Fig. 3 presents another method for determining the number of clusters, the cubic clustering criterion (CCC) proposed by Sarle (1983). It can be observed that the first part of the curve has a similar character to the silhouette method curve. Subsequently, there is an increase in values, with a higher number of clusters showing higher validity.

Five clusters were also identified using the Pseudo F method (Milligan and Cooper 1985), which captures the tightness of clusters (fig. 4). It is a ratio of the mean sum of squares between groups to the mean sum of squares within group. If the Pseudo F value reaches a local maximum, it can be considered to identify the optimal number of clusters.

When attempting to synthesize the results of different methods, it can be argued that despite their relative heterogeneity, certain consistent outcomes can be found. All methods demonstrate that the highest degree of validity in regional classes is shown by the smallest number of clusters, at the level of two clusters. The similar argument can be made for three and four clusters. However, even though these cluster numbers exhibit the highest level of validity in the regional system, it is likely that their cartographic visualization would not have adequate informative value and might not be sufficiently interpretable. By excluding the first four options from the 15 presented, and then excluding a higher number of clusters on the basis of their low validity (with the exception of the CCC method), the results of the individual methods confirm the proposed cut in the dendrogram (fig. 5) and the creation of five regional classes.

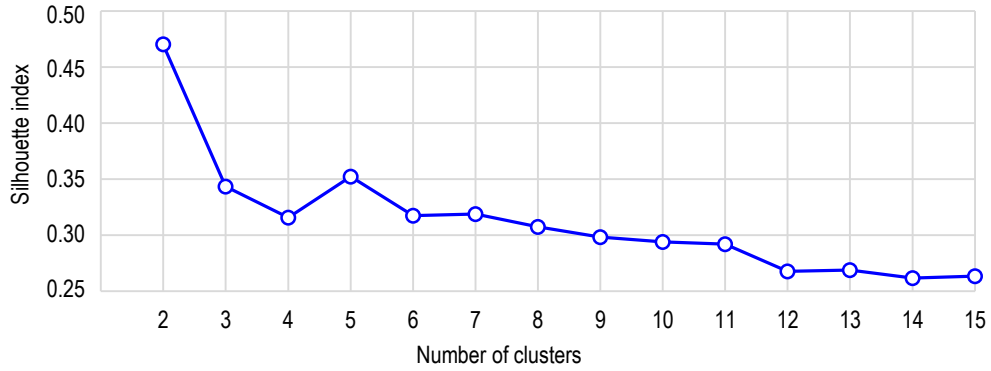

Fig. 2. *Value of silhouette index*

Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration

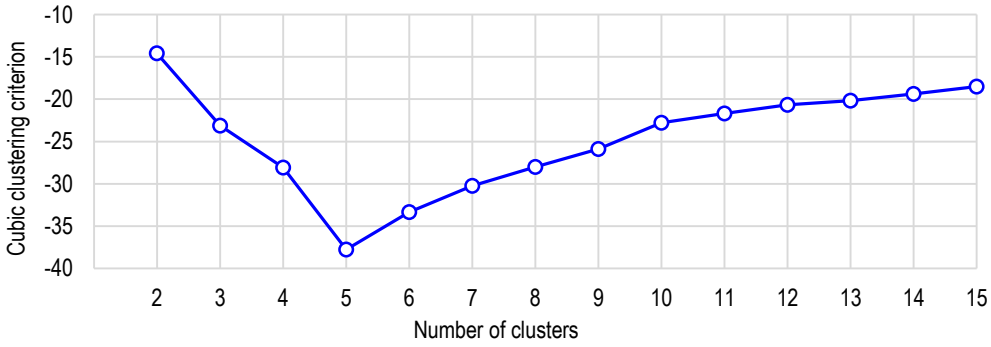

Fig. 3. *CCC method values*

Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration

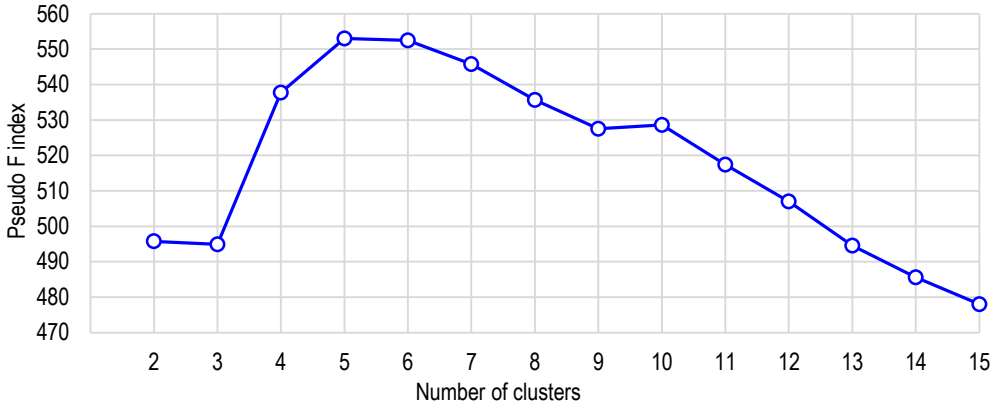

Fig. 4. *Values of Pseudo F index*
Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration

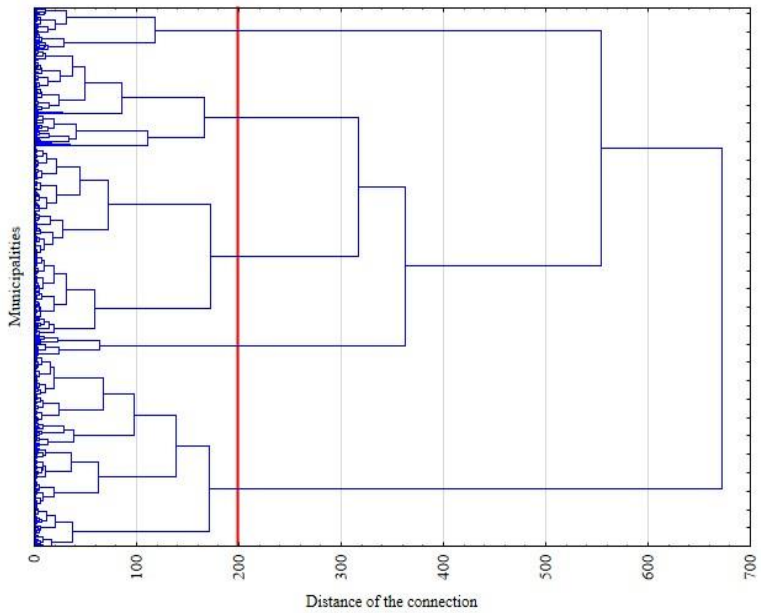

Fig. 5. *Results of cluster analysis using Ward's method and Euclidean distances*
Source: CPHD (2021), SO SR, (2024), COLSF SR (2024), own elaboration

The interim regional classes were categorized into typological formal regions labelled A to E. The first two clusters (A, B) show the best values of the original variables used in the analysis (high values of a synthetic education indicator, low unemployment rate, high housing amenities, etc.). The next cluster (C) represent municipalities whose values deviate minimally positively or negatively from the average values of indicators for the entire area. The last two clusters (D, E) show the least favourable values. Based on the evaluation of factor 1, which covers the largest share of original variables and is considered the most significant, the values of the synthetic education indicator, housing amenities, and employment rate are low. Therefore, clusters E and F can be considered as identifying social and economic peripheries.

Resulting typology of municipalities and discussion of the results of the analyses

The use of the presented methods allowed for tracking peripherality as a significant socioeconomic indicator on multiple hierarchical levels. From a macroregional perspective, the main common characteristic of the results of this study, as well as previous works, is the evident existence of a boundary separating the socioeconomically "rich northwest" from the "poor southeast" (Halás 2014).

Based on a comprehensive assessment of regional ratios on the eastern side of the mentioned boundary, the issue of socioeconomic peripherality of municipalities in selected AFRs (tab. 2) can be highlighted more closely. These are clusters of municipalities classified in categories D and E. The largest share of socioeconomically peripheral municipalities is observed in AFR Rimavská Sobota, Snina and Revúca. In all cases, this represents more than half of the municipalities. The selection of regions indicates that almost half of municipalities in this part of Slovakia show signs of socioeconomic peripherality. Halás and Hurbánek (2008) state that, for example, the Gemer region is a paradoxical example of one of the most precious natural areas in Slovakia, which is also an area with accumulating negative socioeconomic factors.

The typology of municipalities using Ward's method and Euclidean distances (fig. 6) shows that municipalities mainly reflect the regional level of peripherality, or selected factors are reduced or eliminated by the presence of regional centres. In the case of eliminating peripherality, this does not happen in the entire region. Usually, there is a reduction in the values of factors determining peripherality directly in the centre and suburban areas.

For each category of clusters from Ward's method, an interval corresponding to their clustering was calculated based on their factor score values. After calculating the intervals, it was found that the results of the cluster analysis provide a specific localization of peripheral areas in Slovakia. The two groups with the interval-wise lowest factor scores $\langle -\infty; -2{,}0\rangle$ a $\langle -1{,}9; -1{,}0\rangle$ were subjected to a four-factor analysis, which in turn determines the type of socioeconomic peripherality. This analysis is presented in detail in fig. 7.

Tab. 2. *Share of socio-economically peripheral municipalities in selected AFR*

AFR	Number of municipalities (D, E)	Percentage (%)	Total number of municipalities
Bardejov	36	42.9	84
Humenné	44	51.8	85
Lučenec	50	63.3	79
Michalovce	38	30.4	125
Revúca	29	69.0	42
Rimavská Sobota	80	74.8	107
Rožňava	29	46.8	62
Snina	25	73.5	34
Spišská Nová Ves	27	30.3	89
Svidník-Stropkov	45	44.6	101
Veľký Krtíš	38	55.9	68
Vranov nad Topľou	25	36.8	68
Total	**466**	**49.4**	**944**

Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration

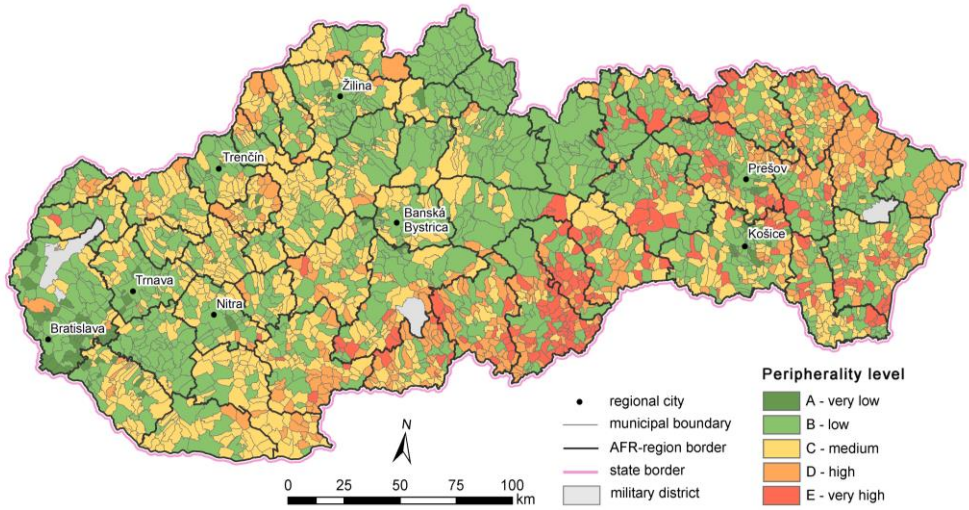

Fig. 6. *Typology of Slovak municipalities based on Ward's method and Euclidean distances from census 2021 data*
Source: CPHD (2021), SO SR (2024), COLSF SR (2024), ZBGIS®, Office of Geodesy, Cartography and Cadastre SR (2024), own elaboration

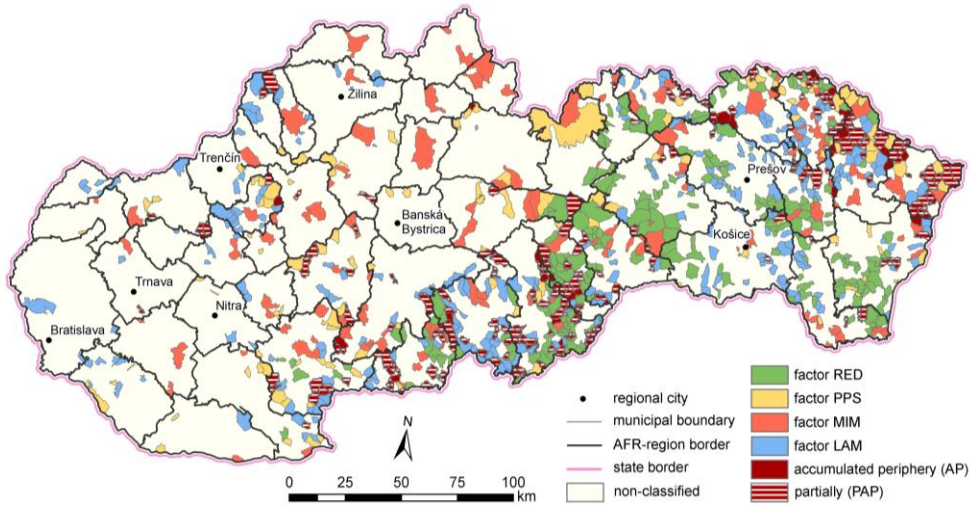

Fig. 7: *Typology of Slovak municipalities based on peripherality according to individual factors from census 2021 data*
Source: CPHD (2021), SO SR (2024), COLSF SR (2024), ZBGIS®, Office of Geodesy, Cartography and Cadastre SR (2024), own elaboration

In fig. 7 it can be observed that the location of the municipalities identified by the RED factor has a certain clustered character, especially in the south of central Slovakia, and further in its central eastern and south-eastern part. Their occurrence in isolated form is very rare. The largest concentrations of municipalities identified by the RED factor are found in AFR Rimavská Sobota, Revúca, Rožňava, Spišská Nová Ves, and near the border of AFR Prešov, Košice, and Vranov nad Topľou, and further in AFR Michalovce. It is important to note that in most cases, these are areas with long-standing unresolved social and economic issues.

A significant part of the local population identifies themselves as belonging to the Roma ethnicity. In this context, Korec et al. (2022) examine the distribution of Roma people and their relationship to selected social phenomena in Slovakia. They point out that in twelve districts, where the highest number of municipalities identified by the RED factor is also located, 50% of all residents of Roma ethnicity live, while they represent only 15% of the total population of Slovakia.

The mentioned inequality of opportunities, social exclusion of selected population groups, lack of adequate job opportunities reflecting the population structure have led to a decline in the already below-average fertility and natural increase rates in the studied regions. In this context, the PPS factor can be highlighted, whose low values represent the low natural increase, coupled with high values of the old-age index and dependency index II. It can be noted that if the natural population growth values in a municipality are low or if there is an overall population decline, there is a possibility that the dependency index II may increase. In such cases, it can be discussed as a municipality with an ageing population that is not attractive to younger generations.

The MIM factor involves migration outflow of population from municipalities based on certain motivations, which can include job opportunities, education, or other personal reasons. The change in the political regime in 1989 also brought about a change in the migration behaviour of the population, fuelled by new types of motivations. A similar situation occurred after Slovakia acceded to the European Union in 2004 and the Schengen area in 2007. The freedom of movement across EU member states' borders and visa-free travel to other countries further expanded the spectrum of motivations for migration, which may be related to the subsequent later entry of young people into adulthood (Džambazovič 2018), possibly leading to the migration of the population to a more socially and economically favourable environment. Looking at Halás' (2008) division of Slovakia, mentioned above, it can be observed that in its western part, the MIM factor is identified mainly by the AFR centres. These are characterised by negative values of the migration balance and positive values of the natural increase, while overall population decline continues to occur. Thus, the low representation of the factor-identified municipalities in the AFRs in question points to a continuing trend of suburbanisation and an increasing proportion of school and land-based commuters. This trend is also indicated by the increase in the number of registered passenger cars in 2021, which increased by 42.5 p.p. compared to 2011 (SO SR 2024). These facts confirm the complexity of identifying social and economic causes of the emergence of peripheral areas.

The previous hypothesis about the impact of the unavailability of the public water supply and sewerage network on the development of the territory is practically observable in the case of the LAM factor, especially in population-smaller municipalities. They are mainly located in the southern part of central and north-eastern part of eastern Slovakia. While in the case of eastern Slovakia it is rather a random distribution, in the case of its western part the municipalities identified by this factor are located mainly in the AFR Bánovce nad Bebravou and at the borders of the certain AFRs, like Púchov or Skalica. The development of local infrastructure in the municipalities is directly dependent on their budget, which can be a significant constraint with a low or decreasing population.

In the case where municipalities showed low values of factor scores in two factors, it was considered partially accumulated periphery (PAP). If this situation occurred in three or four cases, it could be referred to as accumulated periphery (AP). The categorization of municipalities that can be identified as socio-economic peripheries, according to the factors or their two intervals with the lowest FS values, and their combinations with each other, is shown in fig. 8. It is necessary to mention that the number of municipalities identified by at least one factor was 965, representing 33% of the total number of municipalities in Slovakia. Up to 23.40% of municipalities identified by at least one factor consists of municipalities with either partially accu-

mulated or accumulated peripherality. Just 20.31% of municipalities have characteristics of partially accumulated peripherality, with the most numerous being municipalities with a combination of RED and LAM factors. Conversely, the combination of RED and MIM factors represented the smallest share. Looking at tab. 3, it can be noted that 20.65% of Slovakia's population lives in municipalities identified by just one factor with the lowest factor score values. Together with municipalities categorized as partially accumulated periphery and accumulated periphery, less than 22% of Slovakia's population lives in socioeconomically peripheral municipalities. Population-wise, the most significantly represented category of municipalities are those identified by the Migration Motivation Factor (MIM). This is because a significant proportion of them are AFR centres, which are experiencing a decline in population through migration to their suburbs or to more socio-economically favourable environments. As many as 39% of the AFR centres identified by the MIM factor thus represent 7.74% of the population of Slovakia.

A specific case is the accumulated peripherality, represented by 0.08% of municipalities. When looking at the map distribution of these locations, it is evident that they are most prominently represented in the northeast of Slovakia. To a lesser but still significant extent, they are also present in the southern part of central Slovakia. Together with municipalities in the category of partially accumulated peripherality, they form locations that can be called the peripheries of Slovakia with elements of socioeconomic marginality of the population. From a macro-regional perspective, similarities can be found in the localization of peripheral areas with the work of Halás (2008). Typical areas demonstrating identical results are municipalities in AFR Snina, Humenné, Svidník-Stropkov, Rimavská Sobota and Revúca.

Tab. 3. *Share of residents in communities identified by just one factor with the lowest factor scores*

	Number of municipalities	Population	Percentage of residents [%]
RED	216	246 128	4.52
PPS	117	90 917	1.67
MIM	134	659 839	12.11
LAM	272	128 269	2.59
PAP	196	54 770	1.01
AP	30	4 129	0.08
TOTAL	**965**	**1 184 052**	**21.73**
SR	2 924*	5 449 227*	–

Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration
*Note: *The military districts of Záhorie, Lešt' and Valaškovce were omitted from the analyses.*

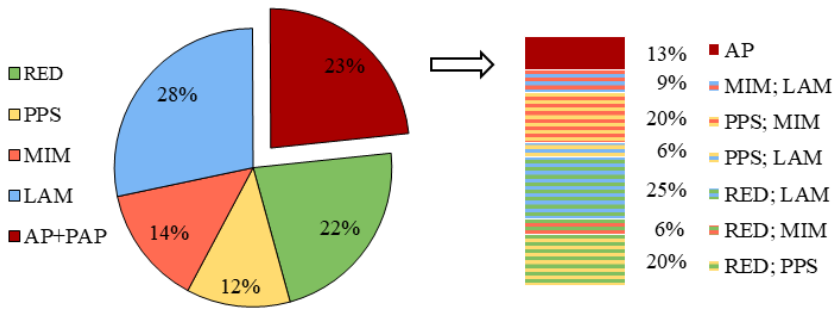

Fig. 8. *Structure of municipalities identified by each factor and their combinations*
Source: CPHD (2021), SO SR (2024), COLSF SR (2024), own elaboration

Conclusions

This study aimed to socioeconomically identify peripheral municipalities in Slovakia and to synthesize the indicators used by methods that are repeatable in the long term, allowing for temporal comparison. Based on the previous works of the cited authors, it may be stated that the results confirm the macro-regional and regional distribution of peripheries. By using factor analysis, a specific typology of municipalities in Slovakia according to their type of peripherality was created, with a unique combination of indicators and resulting factors that have not been used or identified before. Specifically, the results present map outputs of Ward's method and Euclidean distances and also the structure of municipalities based on low values of factor scores of individual factors, including the displayed accumulated peripherality. This provided valuable results confirming the long-term socioeconomic stagnation of the regions, reflected in higher values of negative characteristics. From the macro-regional point of view, the method localized the peripheral areas in the northeastern and southern parts of Slovakia, i.e. in similar territories as in the papers of Gajdoš (2005), Halás (2008), Poláčková (2010), Michálek (2015). The results once again confirm the existence of so-called communication barriers, which will be a recurring result in almost all analyses of Slovakia's peripheries. The area of historical-political development of individual regions and their socioeconomic indicators is particularly interesting, as they influence the attractiveness of the region not only for investment purposes but also for future generations. The level of economic activity and dependence on commuting for employment, schools, or services largely depend on them. The past period of Slovakia's transformation, described by Gurňák et al. (2019), is currently still intensively underway. This is evidenced, for example, by the deterioration of indicators in the Upper Nitra region, which is currently undergoing a socio-economic transformation following the decline of coal mining. Further it is the strong influence of regional cities on the western side of the imaginary Halás (2008) border, the evident effect of suburbanisation on the population in the centres of the AFR, or the persistent lack of access to public water or sewage networks, which affects about one tenth of the municipalities. Therefore, let the presented results be a further confirmation of the socio-economic stagnation or recession of parts of Slovakia with more than one million inhabitants, not excluding the AFR centres, where the migration outflow may mean a low level of motivation of the population to stay there. The persistence of significant regional disparities, which formally did not exist before 1989, is thus one of the country's main problems that should be given increased social and, in particular, political attention. Further detailed investigation of the impact of spatial peripherality on socio-economic peripherality, or the possibility of comparing the presented results with older data observing the evolution of the territory using the same input variables, may be a challenge and an impulse for further research of this issue.

The presented results provide another contribution to the issue of the distribution of peripheral areas at the local level. It shows the distribution of peripheral municipalities in Slovakia using new factors based on data comprehensively capturing the social and economic conditions of the country's population. At the same time, the paper confirms that the issue of spatial disparities is still theoretically, conceptually, and methodologically incomplete in its complexity. The combination of multiple quantitative and qualitative methods allows for obtaining specific results, the quality interpretation of which requires an utmost objective approach. The existence of an ambiguous terminological understanding of periphery and marginality points to possible diversification of interpretation, which may influence the resulting classification. Therefore, it requires a deeper theoretical understanding beyond the scope of this contribution. However, it urges for interdisciplinary exploration across a wide spectrum of relevant scientific disciplines.

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