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Regional Differentiation and Prognosis of Population Ageing in Nuts 3 Regions of V4 Countries by Using Cluster Analysis

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A b s t r a c t

Population ageing in the European area represents one of the most significant processes of the 21st century. In the paper, we have focused on the assessment of ageing through multivariate statistical methods, the method of cluster analysis namely. We evaluated the NUTS 3 regions of the V4 countries that in geographical works have not been explored from this point of view, while focusing on the 2017 – 2021 period and comparing it also with the year 2050. The paper is aimed in pointing out the population ageing in the NUTS 3 regions of Visegrad Group (V4) countries, its impact on the demographic situation in these countries, but also in outlining the trends and prognoses of further development. After the clusters had been created, it was possible to point out the regions with unfavourable demographic development manifesting signs of population ageing and those with favourable demographic development with signs of population rejuvenation. While population ageing will be more intense in Poland and Slovakia, the process will slightly slow down in the Czech Republic and Hungary. New knowledge was obtained using the methods of analysis, synthesis, statistical, graphic and cartographic tools.

Key words:
Ageing Indicators, Ageing Typology, Cluster Analysis, NUTS 3, Population Ageing, Visegrad Group

1 INTRODUCTION

Population ageing process is one of key population processes influencing the development in European countries with impacts on overall progression of their society. The latest report of the World population prospects (2022) concerning the ageing of the world's population clearly points out to the dynamism of this phenomenon in the 21st century, while an increase in the number and share of senior citizens can be identified in almost all countries of the world. Currently, people aged 65 and above represent almost a quarter of the entire European population, with an expected increase of almost 35% by 2050. Thus, population ageing in the European area represents one of the most significant processes of the 21st century. According to Káčerová and Mládek (2012), increasing ratio of elderly people in the population and increasing median age of the population are partly due to the low birth rate. Changes in the age structure as an indicator of dynamic increase in the number and share of seniors and the associated current and expected dependency on the productive sector, health care, social and pension scheme can fundamentally affect every developed society in the world. Moreover, it turns out that this process is gaining momentum and one can hardly expect its reversal in forthcoming decades. Therefore, we agree with several authors (Myck et al., 2021; Széman, 2016) that population ageing represents one of the basic social and political challenges in the 21st century.

The article focuses on the issue of population ageing in the NUTS 3 regions of Visegrad Group countries, its impact on the demographic situation in these countries, but also in outlining the trends and prognoses of further development by using appropriate theoretical and methodological approaches. Considering selected conventional indicators of population ageing, we compare the population ageing changes within the period of 2017 – 2021, as well as future development trends (the year 2050). To fulfil the goal, identification of the factors causing the population changes in terms of their age structure and identification of the population ageing ratio in the V4 regions is necessary. The population ageing will be identified to the NUTS 3 level. In the paper, we have focused on the assessment of ageing through multivariate statistical methods, the method of cluster analysis namely.

Given the existing research conducted on the European countries and the V4 countries (NUTS 2 level), this paper brings added value by addressing the current and dynamic issue of population ageing at the NUTS 3 regional level. This approach provides a more detailed analysis, covering 115 NUTS 3 regions and thoroughly examining 9 ageing indicators for the period 2017 – 2021, along with a forecast for 2050.

To fulfil the objective, hypotheses have been established, which were be evaluated and verified in the paper:

We assume that the selected ageing indicators exhibit statistical interdependence and are therefore suitable for assessing the issue of population ageing during the period 2017 – 2021, as well as for 2050.

We assume that a comparison of the examined years will reveal changes in the age structure of the population in V4 countries by 2050.

We assume that significant changes in the process of population ageing will occur by 2050, not only at the regional level (NUTS 3 regions), but also at the national level across the four evaluated countries.

We evaluated the NUTS 3 regions of V4 countries, which have not been studied in geographic works in this respect, as the vast majority of geographic works examine demographic indicators up to the level of NUTS 2 regions. Based on the above mentioned indicators, it was possible to point out the regions with unfavourable demographic development manifesting signs of population ageing and those with favourable demographic development with signs of population rejuvenation.

Even though the process of population ageing has been going on for a long time in the V4 countries, especially as a consequence of its present-day dynamics, the population ageing and its social impacts are becoming one of the central topics both in the demographic and sociological research and in the increasing number of analyzes concerning geography, economics, healthcare, law and other more or less related scientific disciplines. In addition to the scientific community, relatively wide attention to this topic has recently been paid by politicians, mass media, and the lay public. In general, mainly negative aspects are presented, expressing concerns about the future rapid society ageing and the associated sustainability of social, pension and health care systems in the context of a deepening decline in the workforce (Keenan et al., 2016).

2 THEORETICAL FRAMEWORK

The process of population ageing has become the issue in the centre of attention in European countries. However, it is not only a demographic issue, but regarding the increasing ageing trends, other dimensions of this process are also coming to the fore. Therefore, as stated by Lutz et al. (2008), the population ageing becomes not only an important demographic, but also a social, economic, health, or even cultural topic due to its scope and impacts.

Several authors (Fors et al., 2021; Jaba et al., 2014; Tavares, 2022), point out the fact that the combination of continuous extension of life along with decreasing fertility and its stabilization at a low level have led and is still leading to a significant acceleration of the population ageing. In general, living standards have risen while fertility has fallen, resulting in increasing ratio of elderly people in the society.

There are many various issues related to the ageing process that are currently being addressed. The authors examine the process from different perspectives. The most often, authors compare ageing in different countries, using many different methods to measure it. Some authors are interested in the population ageing dynamics; Manton et al. (1991) compares America and Western European countries, assessing the quantitative dimension of the population ageing in relation to population health. In the paper on the ageing dynamics, Philipov et al. (2014) assess how human capital affects the ageing consequences. According to Cuaresma et al. (2016), Striessnig and Lutz (2014) from a demographic point of view, the increase in human capital will offset the shrinking working-age population, as those most educated tend to work longer and retire at later ages. Šprocha et al. (2018) presented a new concept of observing the age and population ageing through perspective age. They also clarified its methodological background and identified alternative tools derived from it and enabling the assessment of a new dimension of the population ageing process. The population ageing causes intensive changes in demographic behaviour that have appeared in Europe in the end of the 20th and beginning of the 21st century, calling these changes revolutionary. Population development in the countries of V4 group was influenced by common history of the Eastern Socialist Bloc. Isolation from the countries of Western and Northern Europe caused differences in demographic behaviour (Kocourková, 1998). The main reason for the difference was the onset of the second demographic transition, which manifested itself in changes in reproductive and family behaviour in the countries of Western and Northern Europe in the 1960s already (Krejčí et al., 2011; Sobotka, 2008). After loosening the political situation at the beginning of the 1990s, the incipient second demographic transition can be observed in the countries of Central Europe and thus in the V4 countries as well. This radical change in demographic behaviour was characterised by a decrease in the fertility level, increase in the median age of women at childbirth, increase in the median age at birth, and many other factors that resulted in intensification of the population ageing process (Sobotka, 2008). In post-communist countries, including the V4 countries, the decrease in fertility was also a result of rapidly developing urbanization. After the fall of communism, the birth rate has declined due to the delayed founding of families, which was related to a higher median age at marriage and thus also to a higher age of women at childbirth. In the 1990s, a transformation took place in these countries that created a market economy and a multi-party political system (Sobotka, 2011). Some observers speak of a demographic crisis, as some countries have experienced the effects of declining birth rates and large-scale emigration. According to Goldstein et al. (2009) and Sobotka (2011), the birth rate increased only after 2000, even though there was a growing share of women with one child. One-child families have become most common in the V4 countries, Eastern Europe and the Baltic states.

Several population forecasts constructed by experts in the given issue (e.g. Bleha et al., 2018; Šídlo et al., 2020), or institutions (e.g. Czech Statistical Office, 2022; Eurostat, 2020; Hungarian Central Statistical Office, 2022; Statistical Office of the Slovak Republic, 2022; Statistics Poland, 2022) expect a relatively significant acceleration of population ageing, as a result of which the V4 countries should gradually be included in the "above-average old" populations on both the European and also the global scale.

3 MATERIAL AND METHODS

In this paper, the issue of population ageing was explored using multivariate statistical methods of cluster analysis. The objective of cluster analysis is to find similar groups of subjects, where "similarity" between each pair of subjects means some global measure over the whole set of characteristics (Kaščáková et al., 2010). The task of this mathematical-statistical method was to merge the units of the set into groups (clusters) according to the monitored indicators with their internal homogeneity and the differences between the clusters being simultaneously as large as possible. The number of clusters at the beginning of the clustering algorithm is equal to the number of NUTS 3 and at the end all NUTS 3 regions form one cluster. At the same time, each cluster at a lower level is part of a cluster at a higher level.

The output of the cluster analysis is a dendrogram, which needs to convert individual ageing indicators to a common point scale in order to compare the data. To study the similarity of objects, measures of similarity/dissimilarity (distance) are used. In our paper, the object similarity is expressed through the correlation measure. The basic correlation measure used in the cluster analysis is the Pearson correlation coefficient.

The research was carried out for the period of 2017 – 2021. We worked with the average value of each indicator that we obtained by means of a chronological average. Then we converted the various scales to the same point scale through the standard deviation. In addition to this period, we have also prepared a prognosis for 2050. Initially, we worked with nine indicators of ageing. To find out the dependency among them, the Pearson coefficient was used. Cluster analysis, however, requires uncorrelated indicators as inputs. To satisfy this requirement, factor analysis was applied (Mládek et al., 2018)

To assess the suitability of input indicators for factor analysis, the KMO measure (Kaiser-Meyer-Olkin measure = Kaiser's Measure of Sampling Adequacy) is used. It is an index that compares the size of correlation coefficients to the size of partial correlation coefficients. Recommended values of the KMO measure are above 0.5 (Kaiser, 1974), while a higher value indicates more appropriate use of the relevant indicator (the maximum value is 1).

The research included following indicators:

1. ≤14 population ratio – number of inhabitants aged 14 and under to the total number of inhabitants multiplied by 100.
2. 65 and above population ratio – number of inhabitants aged 65 and over to the total number of inhabitants multiplied by 100.
3. Ageing index – number of inhabitants aged 65 and over per 100 inhabitants aged ≤14 years. The higher the ageing index (> 100), the older the population.
4. Median age – weighted arithmetic average of the number of years that members of a given population have lived up to a given moment.
5. Old-age dependency ratio – expresses the burden on the productive part of the population aged 15 – 64 by seniors aged 65 and above. The higher the old-age dependency ratio, the higher the number of residents aged 65 and above per one „provider“ aged 15 – 64.
6. Young-age dependency ratio – expresses the burden of the productive part of the population aged 15 – 64 years by the population aged ≤14 years. The higher the young-age dependency ratio, the higher the number of inhabitants aged ≤14 years per one „provider" aged 15 – 64 years.
7. Billeter's index – ratio of the difference between the population aged ≤14 years and 65 and above and the population in the productive age 15 – 64 years. If the Billeter's index reaches negative values, the population aged 65 and above is higher, thus indicating a higher level of ageing.
8. Economic dependency ratio – ratio of the sum of population aged ≤14 years and 65 and above to the population of productive age 15 – 64 years.
9. 85 and above population ratio – number of inhabitants aged 85 and over to the total number of inhabitants multiplied by 100.

The source of statistical databases for the evaluated indicators during the period 2017 – 2021 and in the year 2050 was EUROSTAT, which coordinates statistical activities at the European Union level.

The data used in the research were interpreted by IBM SPSS Statistics, STATISTICA CZ and ArcMap 10.2.2 programs.

Studied area

The Visegrad Group or the Visegrad Four is an alliance of four Central European states established in 1993: Czech Republic, Hungary, Poland and Slovakia. The European Union has created a common nomenclature of territorial units for statistical purposes known as NUTS, which enables the collection, compilation and dissemination of harmonized regional statistics in the EU. The NUTS nomenclature is hierarchical in that it divides individual member states into three levels: NUTS 1, NUTS 2 and NUTS 3. The NUTS 3 regions of the V4 countries consist of 115 regions – 73 regions in Poland, 14 regions in the Czech Republic, 20 regions in Hungary and 8 regions in Slovakia (Fig. 1).

For the purposes of statistical observations, regions in the EU are often defined inappropriately, such as when urban regions consisting of a city and its surrounding areas are divided. The capital city is often the largest concentration of capital, hosting companies that operate nationwide, yet their economic results are statistically reported centrally in the capital. Clearly, the most favorable position within post-communist countries is held by the capitals of the former Czechoslovakia – Prague and Bratislava. However, the difference is that NUTS 3 Hlavní město Praha is considered a unit by itself (the city alone), while the Bratislava region includes both the city and its surrounding area (NUTS 3 Bratislavský kraj). A similar situation exists in the case of NUTS 3 Budapest and NUTS 3 Miasto Warszawa. If the urban center is separated from its hinterland, the rule of internal cohesion and interregional disparities is not respected (Mejstřík, 2010). This impacts various demographic processes, as well as population ageing. At the level of those NUTS 3 regions where cities are part of a broader region, these effects are not identifiable. In contrast, in those NUTS 3 regions where a NUTS 3 unit consists of a single city, these effects can be statistically demonstrated more clearly.

4 RESULTS

Population ageing and its dynamics

Comparison of the time period 2017 – 2021 and the prognosis for 2050 has revealed significant changes in the age structure of the population. Remarkable shift of the population age to higher age categories and subsequently some decrease in the child-age population ratio can be observed there. In these period 2017 – 2021, the age pyramid of the V4 population represented a regressive age structure determined by constantly decreasing number of the children born. This situation will not change even by 2050; the age pyramid of this type, i.e. the gradual narrowing of its base and the birth of fewer and fewer children, will continue to prevail. According to the prognosis, the growth of the population aged 85 and above is expected (Fig. 2). In 2050, the group of inhabitants over 85 will be the fastest growing senior group; its size will be 2.6 times larger when compared to the current numbers. This population ageing results in increasing average life expectancy as well.

Intensity of the ageing process is comprehensively documented by increase of the median age, which is evident common feature of all the countries under research. Regarding the population median age, the

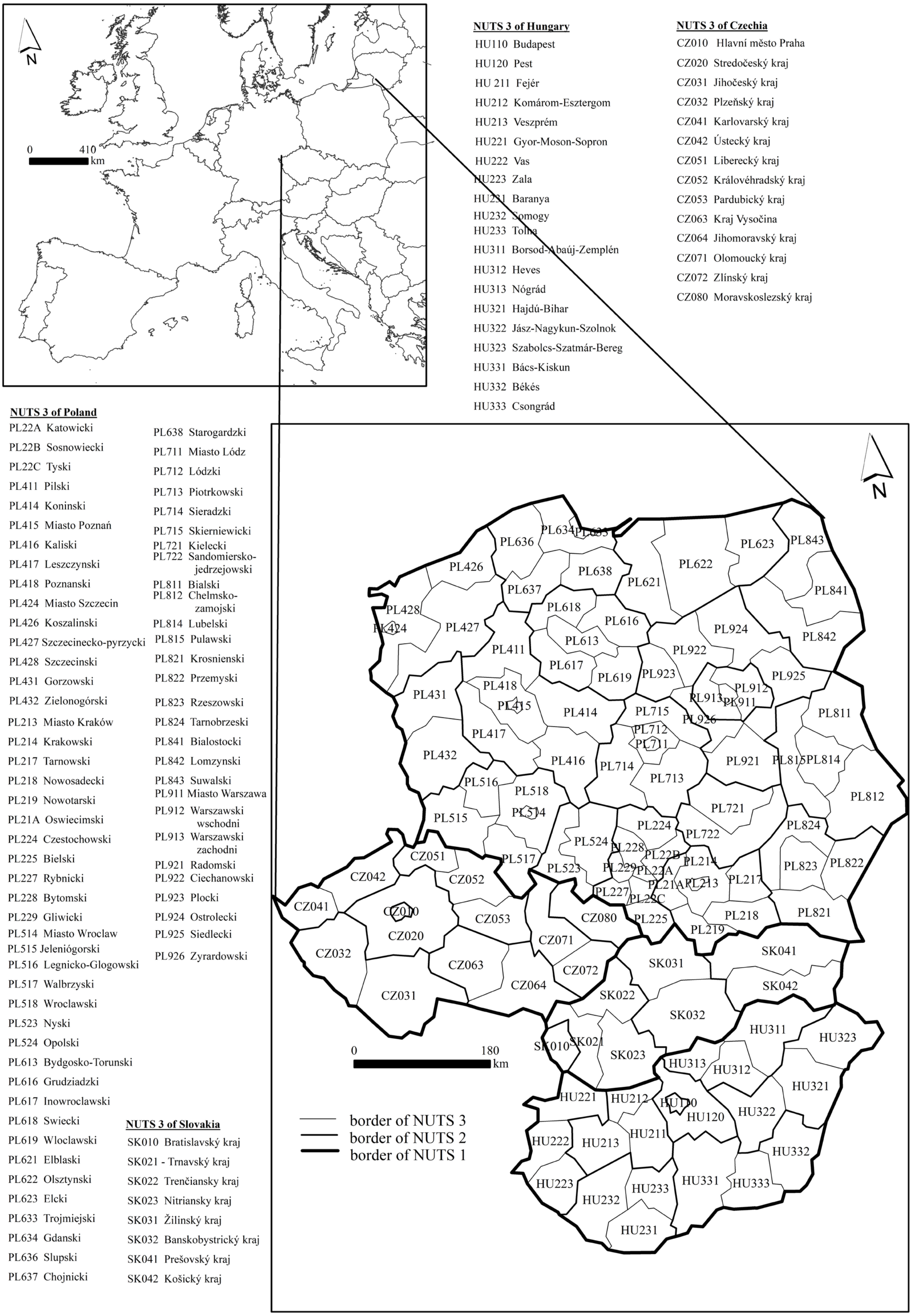


Fig. 1. NUTS 3 regions of V4 countries

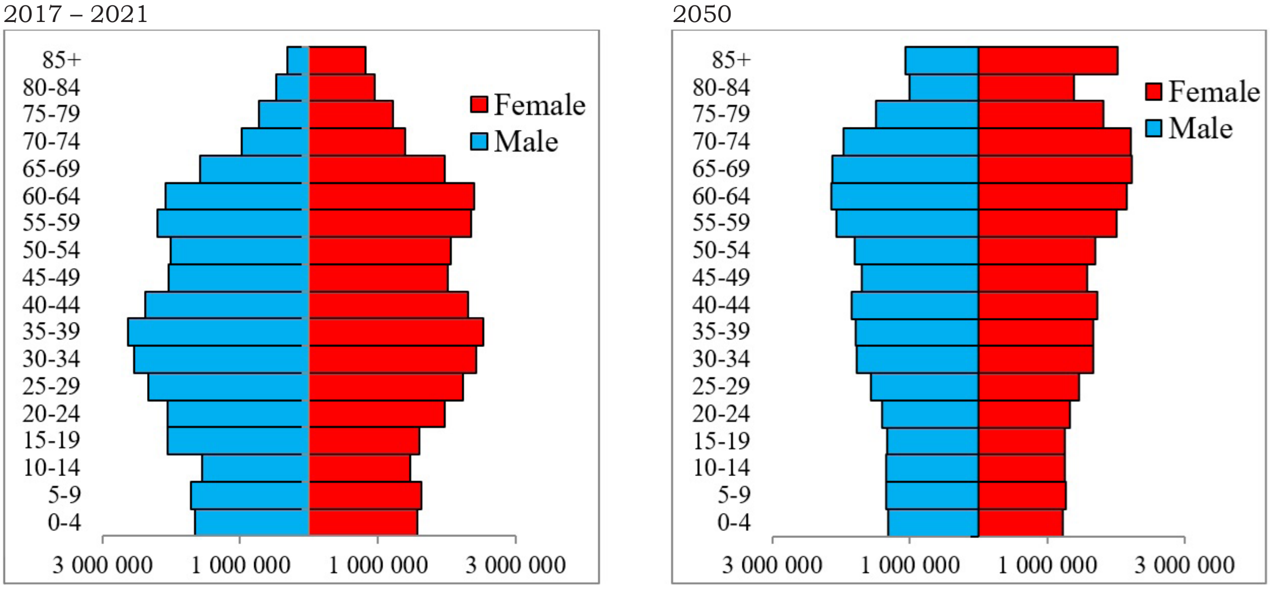


Fig. 2. Age Pyramid of V4 Countries (2017 – 2021 and 2050)
Source: Data of Eurostat, compiled by author

Tab. 1. Assessed population ageing indicators in the period 2017 – 2021

V4 countries	**≤14 (%)**	**65 and above (%)**	**median age (year)**	**Ageing index (%)**	**Billeter´s index (%)**	**old-age dependency ratio (%)**	**young-age dependency ratio (%)**	**age dependency ratio (%)**	**life expentancy (year)**	**85 and above (%)**
Czechia	15.2	18.2	41.6	119.7	-4.4	27.3	22.9	50.2	78.6	1.9
Hungary	14.7	18.3	42.1	125.3	-5.3	27.2	21.9	49.1	75.7	2.0
Poland	15.2	15.5	39.7	103.6	-0.4	22.3	21.9	44.2	77.1	2.0
Slovakia	15.2	14.4	39.3	96.2	1.2	20.4	21.6	42.0	76.8	1.5
V4	15.1	16.2	40.4	109.6	-1.8	23.6	21.8	45.5	77.1	1.9

Source: Data of Eurostat, compiled by the author

Tab. 2. Assessed population ageing indicators in 2050

V4 countris	**≤14 (%)**	**65 and above (%)**	**median age (year)**	**Ageing index (%)**	**Billeter´s index (%)**	**old-age dependency ratio (%)**	**young-age dependency ratio (%)**	**age dependency ratio (%)**	**life expentancy (year)**	**85 and above (%)**
Czechia	14.9	29.0	47.3	169.8	-25.3	51.9	26.6	78.5	84.0	2.2
Hungary	13.8	28.7	48.5	169.7	-26.0	50.0	24.0	74.0	83.1	3.2
Poland	11.9	30.4	51.1	217.5	-31.9	52.8	20.9	73.8	82.0	3.8
Slovakia	13.8	29.9	49.9	186.1	-29.4	52.7	23.4	76.0	84.5	3.2
V4	13.6	29.5	49.2	185.8	-28.1	51.9	23.7	75.6	83.4	3.1

Source: Data of Eurostat, compiled by the author

lowest was in the Slovak Republic and the highest in Hungary (Tab. 1) According to the prognosis, the median age is forecasted to increase by an average of 6 – 10 years by 2050. The growth will be highest in Slovakia and Poland. By 2050, it will grow to 49.4 years, which will also be the highest median age of all the V4 countries (Tab. 2). This is related to the assumed decline in the population by 2050, continual postponement of fertility timing due to higher marital age, which is 32 years at present. According to EUROSTAT's prognosis (2020), the population ageing in Slovakia will be the most intense of all EU countries.

Similarly, as the median age and the population aged 65 and above increases, so does the ageing index. The situation of the population ageing will continue to worsen and even intensify until 2050 (Tab. 1, 2). The increase will be evident in every country, most intensively in the territory of Slovakia (increase by 93 %) and Poland (increase by 110%). This prognosis confirms the assessment from previous analyzes that Slovakia will be one of the oldest V4 countries, as well as of the whole Europe. According to the Statistics Poland (2022), the high population ageing ratio is also evident in Poland; the country is expected to experience a population decline by 6 million inhabitants by 2050. Another reason is the low birth rate, as there are 1.32 children per woman, which is significantly below the population replacement level with two children per woman. In the V4 countries, this situation of constant increase in elderly populations and declining birth rates, that causes a big pressure on health care and pension systems, has prompted a nationwide effort to focus on these issues (Frątczak, 2016; Leszko et al., 2015). Currently in the period of 2017 – 2021, the old-age dependency ratio of persons aged 65 and above to the working population of productive age of 15 – 64 is 23.6 persons per 100 working people, but the ratio assumed by 2050 is over 51.9 persons per 100 working people (Tab. 1, 2). The higher the economic dependency ratio, the more economically dependent the population is. High unemployment creates economic dependents even among the people of productive age. The strong population years from the communist era will gradually move to the pensioners and will be replaced by the weak post-revolutionary generations.

Based on Tabs. 1 and 2 and the presented analysis, the hypothesis can be confirmed that in the studied periods, there will be a change in the age structure of the population in the individual V4 countries. However, the most significant changes will be observed mainly in Slovakia and Poland, where there will be a significant increase in all ageing indicators, and in comparison with the other V4 countries, there will also be the most notable decrease in the number of children under 14 years old (in the case of Poland by 3.3% and Slovakia by 1.4%).

Regional Differentation of Population Ageing in NUTS 3 Regions of V4 Countries

As we stated in the methodology above, similarity of objects can be expressed by the correlation measure. Values of the Pearson correlation coefficient of individual NUTS 3 regions are presented in the correlation matrix (Tab. 3).

In the period of 2017 – 2021, a very high direct dependency (r = 0.994), which approaches the number 1, is manifested between the population age group 65 and above and the old-age dependency ratio, and a very high indirect dependency (r = –0.993) is manifested between the ageing index and the Billeter's index. On the contrary, the individual indicators show a very weak correlation with the 85+ age group, which in this case appears to be statistically insignificant for determining the rate of ageing in combination with the other indicators (Tab. 3).

The established hypothesis that selected ageing indicators exhibit statistical dependence and are therefore suitable for assessing the issue of population ageing was not confirmed in the case of indicator the 85 and above during the period from 2017 to 2021.

Similarly, we monitored the impact of indicators on the population ageing in 2050 (Tab. 4).

In 2050, a very high direct dependency (r = 0.983), approaching the number 1, occurs between the ageing index and the median age and very high indirect dependency (r = –0.974) occurs between the Median age and the Billeter's index. Other dependencies can be derived from Tab. 4. The lowest dependency is shown by indicators with the economic dependency ratio (median age, ageing index, Billeter's index, old-age dependency ratio, young-age dependency ratio), but in the case of indicators ≤14, 65 and above, 85 and above, it can be defined as a moderate positive dependency according to the correlation table.

The established hypothesis that selected ageing indicators exhibit statistical dependence and are therefore suitable for assessing the issue of ageing was confirmed in 2050. As a result, all indicators were incorporated into the ageing research for that year.

In order to fulfil the cluster analysis requirement, that the variables should be uncorrelated, we used the factor analysis. To assess the suitability of its input indicators, we used the KMO measure. Resulting values for our variables are presented in Tab. 5.

The overall KMO ratio is higher than 0.5 (Kaiser, 1974); it is 0.797 for 2017 – 2021 and 0.687 in 2050. Therefore, these input data can be considered suitable for the factor analysis use. Tab. 6 shows the communality values for each input variable. For the 2017 – 2021 period, the 85 and above indicator has a very low communality value. Since the hypothesis that selected ageing indicators exhibit statistical dependence and are therefore suitable for assessing the issue of population ageing was not confirmed for this indicator during the period from 2017 to 2021, and since this indicator also had a low communality value, it was excluded from the ageing research.

To determine the number of hidden variables (factors) from the original indicators, eigenvalues from the covariance or correlation matrix were used. Since the input indicators were diverse, we used a correlation matrix.

For the period 2017–2021, we repeated the factor analysis omitting the indicator with the lowest communality, i.e. that of 85 and above. The KMO value increased from 0.797 to 0.829. As it is clear from the results concerning this period (Tab. 7, 8), the first two factors explain up to 98.587% of the total data variability and therefore they will be used in the cluster analysis as input uncorrelated variables.In the dendrogram, each NUTS 3 region is classified into a specific type based on the similarity of the monitored indicator values. These values were compared with the average values of V4. Those indicators that were positively compared to the V4 average are considered indicators positively affecting the population and influencing its rejuvenation. This group includes: high ratio of the population aged ≤ 14, low median age, low ratio of 65 and above population, low ratio of 85 and above (in the case of 2050), low ageing index, low economic dependency ratio, low old-age dependency ratio and low young-

Tab. 3. Pearson correlation coefficient of NUTS 3 regions of V4 countries in the 2017 – 2021 period (correlation matrix)

Indicator	≤14	65 and above	85 and above	median age	Ageing index	Billeter´s index	old-age dependency ratio	economic dependency ratio	young-age dependency ratio
≤14	1	-.761*	-046	-.804*	-.909*	.901*	-.685*	-.151	.973*
65 and above	-.761*	1	.271*	.926*	.951*	-.967*	.994*	.756*	-.590*
85 and above	-.046	.271*	1	.074	.179	-.197*	.295*	.368*	.043
median age	-.804*	.926*	.074	1	.929*	-.934*	.904*	.600*	-.670*
Ageing index	-.909*	.951*	.179	.929*	1	-.993*	.914*	.531*	-.794*
Billeter´s index	.901*	-.967*	-.197*	-.934*	-.993*	1	-.933*	-.565*	.776*
old-age dependency ratio	-.685*	.994*	.295*	.904*	.914*	-.933*	1	.823*	-.498*
economic dependency ratio	-.151	.756*	.368*	.600*	.531*	-.565*	.823*	1	.082
young-age dependency ratio	.973*	-.590*	.043	-.670*	-.794*	.776*	-.498*	.082	1

* Correlation is significant at the 0.05 level
Source: Compiled by the author in IBM SPSS Statistics

Tab. 4. Pearson correlation coefficient of NUTS 3 regions of V4 countries in 2050 (correlation matrix)

Indicator	≤14	65 and above	85 and above	median age	Ageing index	Billeter´s index	old-age dependency ratio	economic dependency ratio	young-age dependency ratio
≤14	1	.949*	.841*	-.603*	-.533*	.567*	-.514*	.417*	.486*
65 and above	.949*	1	.961*	-.358*	-.285*	.319*	-.297*	.473*	.262*
85 and above	.841*	.961*	1	-.166	-0,097	.135	-.043	.470*	.079
median age	-.603*	-.358*	-.166	1	.983*	-.974*	.848*	-.089	-.893*
Ageing index	-.533*	-.285*	-.097	.983*	1	-.972*	.844*	-.036	-.895*
Billeter´s index	-.567*	.319*	.135	-.974*	-.972*	1	-.939*	-.054	.794*
old-age dependency ratio	-.514*	-.297*	-.143	.848*	.844*	-.939*	1	.213*	-.538*v
economic dependency ratio	.417*	.473*	.470*	-.089	-.036	-.054	.213*	1	.245*
young-age dependency ratio	.487*	.262*	.079	-.893*	-.895*	.794*	-.538*	.245*	1

* Correlation is significant at the 0.05 level
Source: Compiled by the author in IBM SPSS Statistics

Tab. 5. Results of KMO ratio and Bartlett´s test of sphéricity in the 2017 – 2021 period and in 2050

KMO and Bartlett´s Test		2017 – 2021	2050
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.797	0.687
Bartlett‘s Test of Sphericity	Approx. Chi-Square	4828.028	3122.909
	df	36	36
	Sig.	0.000	0.000

Source: Compiled by the author in IBM SPSS Statistics

Tab. 6. Communalities of input variables

Indicators	2017 – 2021		2050	
	Initial	Extraction	Initial	Extraction
≤14	1.000	0.973	1.000	0.956
65 and above	1.000	0.992	1.000	0.956
85 and above	1.000	0.403	1.000	0.919
median age	1.000	0.903	1.000	0.983
Ageing index	1.000	0.989	1.000	0.978
Billeter´s index	1.000	0.997	1.000	0.987
old-age dependency ratio	1.000	0.985	1.000	0.805
economic dependency ratio	1.000	0.925	1.000	0.501
young-age dependency ratio	1.000	0.950	1.000	0.734

Source: Compiled by the author in IBM SPSS Statistics

age dependency ratio and low Billeter´s index. Those indicators that developed negatively compared to the V4 average are considered indicators adversely affecting the population and its ageing. This group includes: low ratio ≤14 years old, high median age, high ratio of 65 and above, high ratio of 85 and above (in the case of 2050), high ageing index, high economic dependency ratio, high old-age dependency ratio, high young-age dependency ratio and high Billeter´s index.

Based on Tab. 9, it can be stated that clusters 2, 3 and 5 in the period of 2017 – 2021 included regions that, with the exception of one or two indicators, were favourably affected by the ageing indicators, as they were positive compared to the V4 average. These clusters included regions with a lower share of the population aged 65 and above, lower median age, lower ageing index and Billeter´s index and with low old-age dependency ratio; regions in the cluster 2 have also population aged ≤14 above-average; regions in the cluster 3 have also favourable economic dependency ratio; and regions in the cluster 5 have also favourable young-age dependency ratio. The clusters 1, 4 and 6 included regions with unfavourable situation, as negative values of individual ageing indicators prevailed over positive ones.

Based on Tab. 9 and Fig. 5, six clusters were separated for the period 2017–2021 on the basis of the dendrogram. Of all the NUTS 3 regions under research, cluster 1 included 23 regions from the Czech Republic; three regions belonged to Hungary and three regions to Poland. Individual indicators showed unfavourable values. The exception was the age group under 14, which was slightly above average (by 0.2%) compared to V4 countries. Cluster 2 included nine regions with favourable values and, compared to V4, they were those of younger population. These regions were predominantly parts of Poland (5), Hungary and the Czech Republic. In this cluster, only the economic dependency ratio (by 0.1%) and the young-age dependency ratio showed a negative effect. Cluster 3 with 25 regions and cluster 4 with 26 regions represent a large number of NUTS 3 regions. However, while cluster 3 reflected younger population with positive values of demographic indicators (6 indicators out of 7

Tab. 7. Eigenvalues and the explained variance ratio with omitted variable in the 2017 – 2021 period

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.427	80.337	80.337	6.427	80.337	80.337
2	1.460	18.250	98.587	1.460	18.250	98.587
3	0.102	0.270	99.858			
4	0.011	0.138	99.995			
5	0.000	0.003	99.998			
6	9.569E-05	0.001	99.999			
7	3.958E-05	0.000	100.000			
8	1.805E-05	0.000	100.000			

Extraction Method: Principal Component Analysis
Source: Compiled by the author in IBM SPSS Statistics

Tab. 8. Eigenvalues and the explained variance ratio with omitted variable in 2050

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.268	58.537	58.537	5.268	58.537	58.537
2	2.512	27.909	86.446	2.512	27.909	86.446
3	0.914	10.155	96.601			
4	0.238	2.639	99.240			
5	0.048	0.531	99.771			
6	0.013	0.146	99.917			
7	0.005	0.056	99.973			
8	0.002	0.026	100.000			
9	2.250E-05	0.000	100.000			

Source: Compiled by the author in IBM SPSS Statistics

showed a positive effect), cluster 4 showed the opposite because of prevailing unfavourable values of individual indicators, thus expressing an ageing population. In both clusters, the population was mainly from Poland, cluster 3 with younger population living mainly in the north, west and extreme south-east of the country near the border with Slovakia. Regions in cluster 4 with an ageing population are those in the central and eastern part of this country. Within Slovakia, 20% of the population belongs to cluster 3; within Hungary, cluster 4 with an ageing population is represented in the northern and eastern parts of the country. Cluster 5 included 18 regions with a young population and, compared to V4, with favourable values of individual indicators. In this cluster, 50% of the regions of Slovakia, 1 region of Hungary and 13 regions of Poland are represented. Cluster 6 includes 14 regions, most of which are located in the southern part of Hungary. These are regions with an unfavourable situation and an ageing population.

Similarly, based on the dendrogram, NUTS 3 regions of V4 countries in 2050 were grouped into several clusters according to similar individual indicators. However, there were significant changes in the average values compared to the period 2017 – 2021: ratio of the population under 14 will decrease (by 2.5%), ratio of the population 65 and above will increase (by 10.6%), the average age will increase (by 8.3 years), the Billeter's index and ratio of economic indicators of ageing will increase (economic dependency ratio by 25.6%, old-age dependency ratio by 24.6%). Young population economic dependency ratio will decrease slightly. In clusters 1 – 4, compared to the V4 average, most indicators will manifest themselves positively and will have a favourable effect on the population in the countries in 2050. In clusters 5 – 7, compared to the V4 average, the values of demographic indicators of ageing will develop negatively, having an adverse effect and influencing the population ageing negatively (Tab. 10).

Based on Tab. 10 and Fig. 6, seven clusters were separated for 2050 on the basis of the dendrogram. Cluster 1 includes seven NUTS 3 regions from the Czech Republic, Hungary and Poland. Of nine monitored indicators, seven show favourable values thus pointing out that, compared to the V4 average, the population in these regions is younger. The situation is similar in cluster 2 with the values closest to the V4 average. It points out to the young popvulation living in these regions, mainly the parts of the Czech Republic and Poland. In this cluster, we evaluated the economic indicators of ageing (economic dependency ratio, old-age/young-age population economic dependency ratio) as negative, but compared to the V4 average, their values are only slightly above the average. In total, 16 NUTS 3 regions belong here. The favourable values of demographic indicators compared to the V4 average are also in the regions included in cluster 3 (15 regions) and in cluster 4 (26 regions). They are region with young population; as many as 8 out of 9 indicators are of positive values. The regions in cluster 3 are situated in the east of Slovakia and Hungary, scattered also in Poland and the Czech Republic. The regions in cluster 4 are located in Hungary and the northern part of Poland. Clusters 5, 6 and 7 show unfavourable values of individual indicators compared to the already deteriorated V4 average. The worst situation is in cluster 6, in which none of the demographic indicators showed a positive effect. This includes 18 regions situated in Poland and Slovakia. The unfavourable situation regarding population ageing is also in cluster 5 (22 NUTS 3 regions) and 7 (11 NUTS 3 regions). These regions mainly cover the territory of Poland; the regions in cluster 5 are also located in the south of Hungary; and the regions in cluster 7, with the exception of Poland, are located in the central part of Slovakia.

The cluster analysis that compares different periods under research and is based on individual demographic indicators shows regional differences in NUTS 3 regions

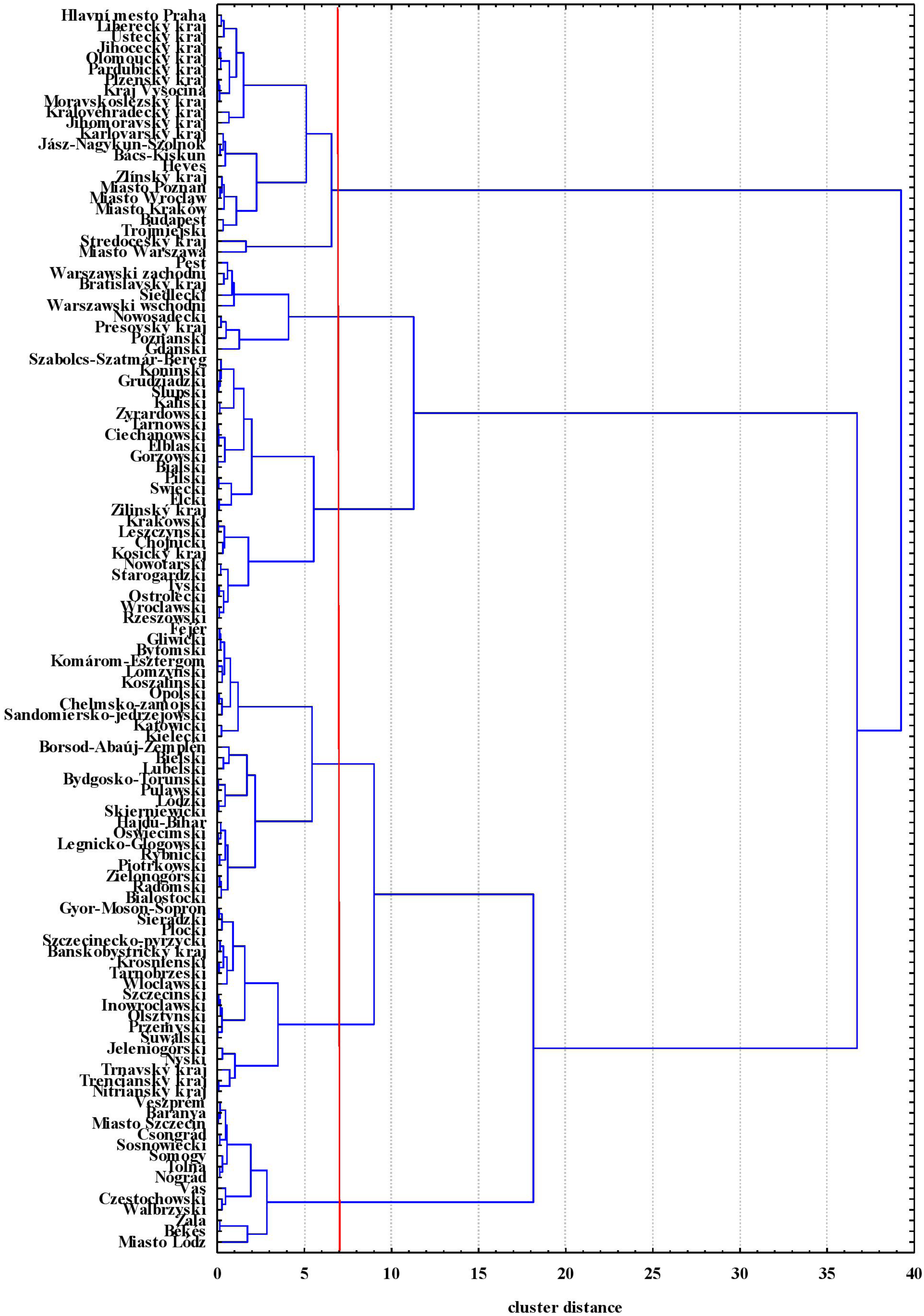


Fig. 3. Dendrogram of population ageing in NUTS 3 regions of V4 countries (2017 – 2021)

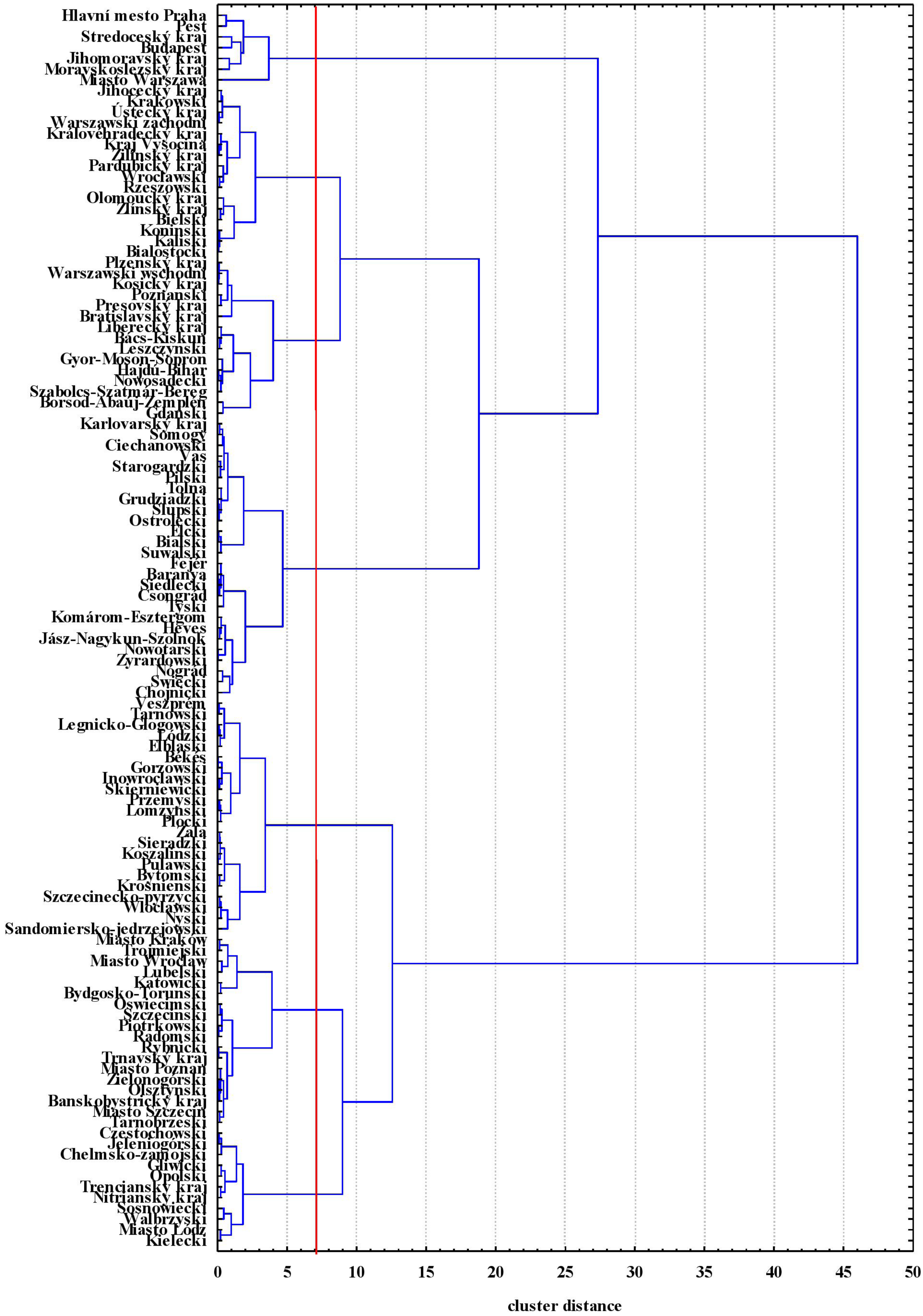


Fig. 4. Dendrogram of population ageing in NUTS 3 regions of V4 countries (2050)

of the V4 countries. While population ageing will worsen in Poland and Slovakia, the ageing process will improve moderately in the Czech Republic and Hungary, which is also documented by Fig. 7 and 8.

Based on the typology, it is possible to confirm the hypothesis that by 2050, significant changes in population ageing will occur not only at the regional level (NUTS 3) but also at the national level in the four evaluated countries. By 2050, even a reversal in population ageing is expected, as in the V4 countries, where the situation regarding population ageing was still favorable during the period from 2017 to 2021 (Slovakia, Poland), it will worsen this process.

Even before 1980, population ageing in the Czech Republic and Hungary was already approaching that of Western European countries. The Czech Republic and Hungary have achieved a positive impact of migration on population rejuvenation due to migration dynamics. In the period 2017 – 2021 NUTS 3 Hlavní město Praha and the NUTS 3 Středočeský kraj were categorized as low ageing populations. In terms of median age, these regions belong to the youngest NUTS 3 regions in the Czech Republic with high foreign migration from both Eastern and Western European countries. By 2050, the situation is expected to improve in the other surrounding NUTS 3 regions, but in two NUTS 3 regions mentioned above a slight situation deterioration is expected. Population ageing in Hungary is similar to that in the Czech Republic. According to Divinský (2001), both the capitals, Prague and Budapest, that affect the population of the NUTS 3 regions Hlavní město Praha and NUTS 3 Budapest, have shown stagnation (Prague) to depopulation (Budapest) tendencies in the last decades. By the period 2017 – 2021 there was a gradual population ageing which was observed mainly in the NUTS 3 Nitriansky kraj and Trnavský kraj (Slovakia). By 2050, population ageing will have intensified further, except in the NUTS 3 Bratislava region, where the Slovak capital is located. It is currently the only NUTS 3 region in Slovakia with the most progressive age population composition, where the child component under 14 dominates over the 65 and above population. It is just the capital city that is the destination of foreign migrants, at the same time, the Bratislava region is an area of intensive suburbanisation, which is increasing the number of inhabitants outside the central city in the peripheral parts (Hardi, 2012).

More significant changes have also occurred in Poland. By 2017 – 2021, the North, North-West and West retained their position of a younger population, but the central and eastern parts of the territory started to age. By 2050, only 40% of NUTS 3 regions will retain a young population. The capital Warsaw and the NUTS 3 Warszawski Wschodni and NUTS 3 Warszawski Zachodni regions maintain their positive position with young population influencing the favourable demographic situation. These regions have the most

Tab. 9. Values of input demographic ageing indicators of NUTS 3 regions of V4 countries in clusters in 2017 – 2021

Variable	**Ø V4**	**Mean (2017 - 2021)**					
		Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**
≤14	15.3	15.5	18	16.3	14.8	14.6	13.4
65 and above	18.3	20.2	15.4	16.2	18.6	17.5	21.2
median age	41.8	42.8	39.2	39.9	42	41.6	44.6
Ageing index	121.6	132.5	86.1	99.8	126.4	120.3	158.3
Billeter´s index	-4.6	-7.6	3.9	0.1	-5.8	-4.3	-11.9
old-age dependency ratio	27.6	31.3	23.1	24	27.9	25.9	32.3
economic dependency ratio	50.6	55.1	50.7	48.1	50.1	47.5	52.8
young-age dependency ratio	23.6	23.8	26.9	24.1	22.1	21.6	20.4

Favourable values of demographic indicators compared to the average value of V4

Unfavourable values of demographic indicators compared to the average value of V4

Source: Compiled by the author

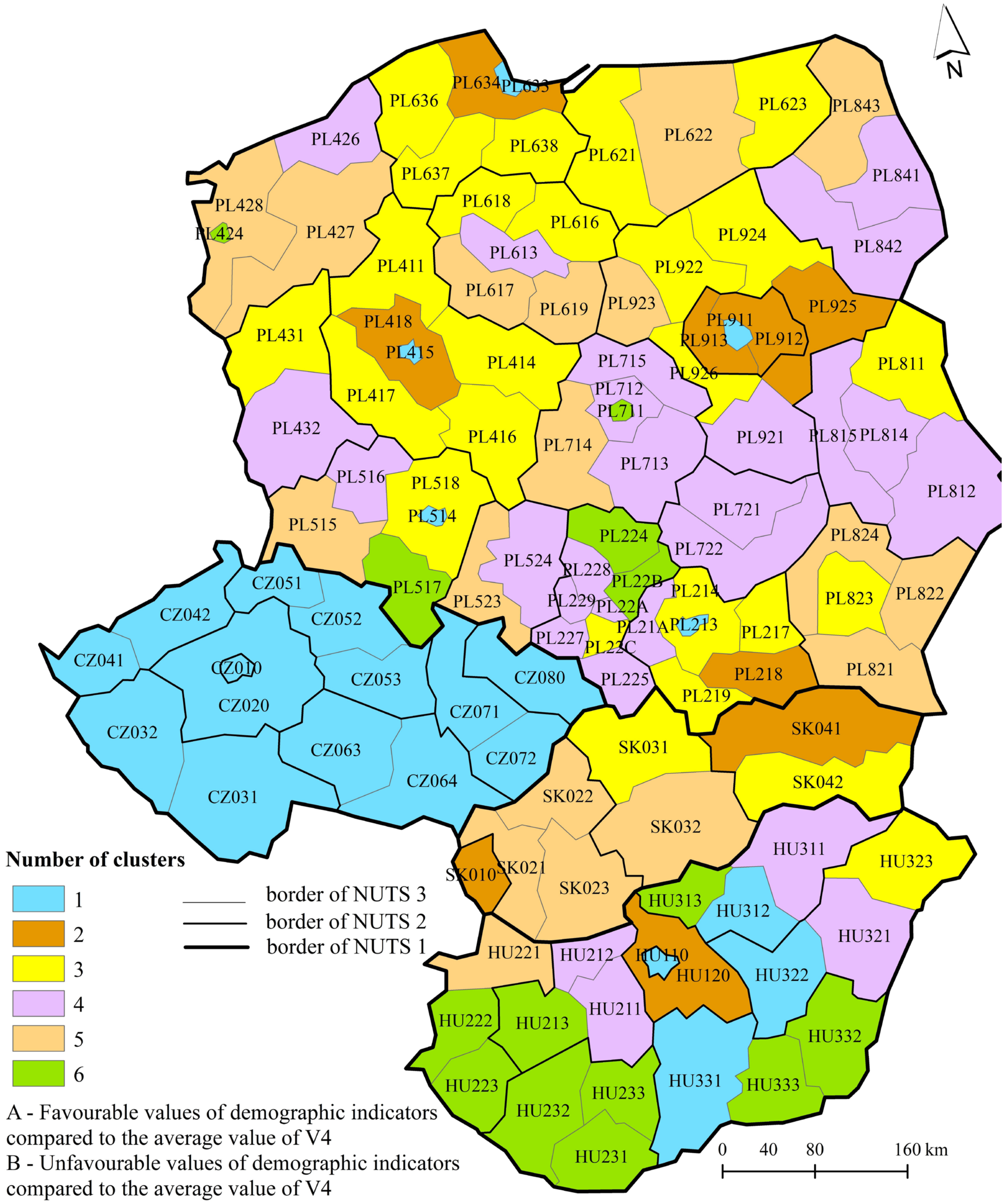
Tab. 10. Values of input demographic ageing indicators of NUTS 3 regions of V4 countries in clusters in 2050

Variable	**Ø V4**	**Mean (2017 - 2021)**						
		Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**	**Cluster 7**
≤14	12.8	14.6	13.6	14.8	13	11.5	11.9	10.8
65 and above	29.9	27	29.6	26.9	29.2	31.6	30.8	33.4
85 and above	3.6	2.7	3.3	2.9	3.5	4	3.9	4.4
median age	50.1	46.5	49	46.6	50.2	52.3	51.6	53.6
Ageing index	238.7	186.3	219.2	181.7	225	276	259.4	310.5
Billeter´s index	-29.9	-21.3	-28.1	-20.7	-28	-35.2	-33.1	-40.5
old-age dependency ratio	52.2	46.4	52.2	46.2	50.6	55.4	53.9	59.8
economic dependency ratio	76.2	83	77.8	74.3	72.5	74.6	78.4	80
young-age dependency ratio	22.3	25.1	24.1	25.5	22.6	20.2	22.3	19.3

Favourable values of demographic indicators compared to the average value of V4

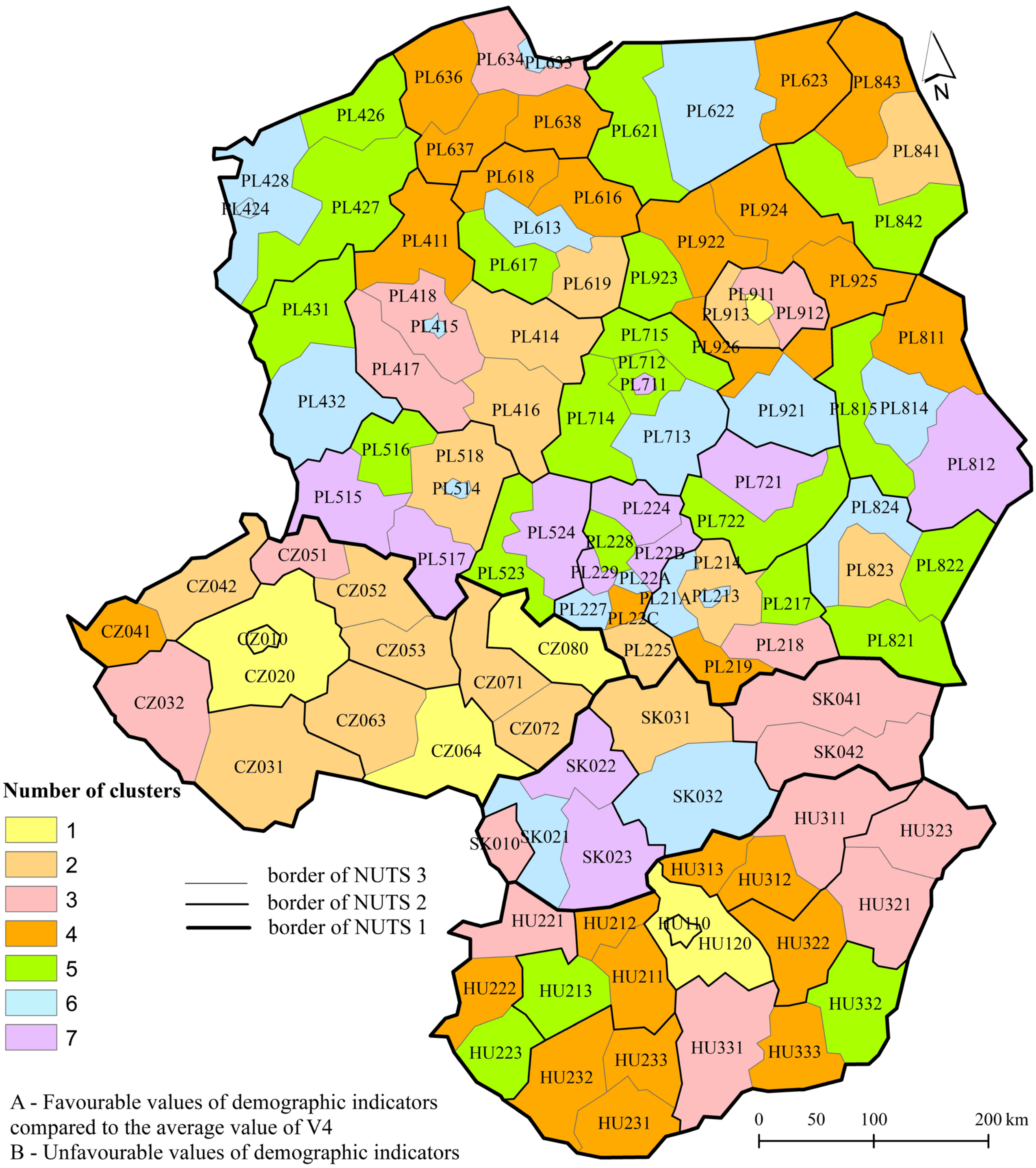
Unfavourable values of demographic indicators compared to the average value of V4

Source: Compiled by the author



Indicator	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
≤14	A	A	A	B	B	B
65 and above	B	A	A	B	A	B
median age	B	A	A	B	A	B
Ageing index	B	A	A	B	A	B
Billeter ´s index	B	A	A	B	A	B
Old-age dependency ratio	B	A	A	B	A	B
Economic dependency ratio	B	B	A	A	A	B
Young-age dependency ratio	B	B	B	A	A	A

Fig. 5. Regional differentiation of NUTS 3 regions of V4 countries according to cluster analysis in 2017 – 2021



A - Favourable values of demographic indicators compared to the average value of V4
B - Unfavourable values of demographic indicators compared to the average value of V4

Indicator	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
≤14	A	A	A	A	B	B	B
65 and above	A	A	A	A	B	B	B
85 and above	A	A	A	A	B	B	B
median age	A	A	A	B	B	B	B
Ageing index	A	A	A	A	B	B	B
Billeter ´s index	A	A	A	A	B	B	B
Old-age dependency ratio	A	B	A	A	B	B	B
Economic dependency ratio	B	B	A	A	A	B	B
Young-age dependency ratio	B	B	B	B	A	B	A

Fig. 6. Regional differentiation of NUTS 3 regions of V4 countries according to cluster analysis in 2050

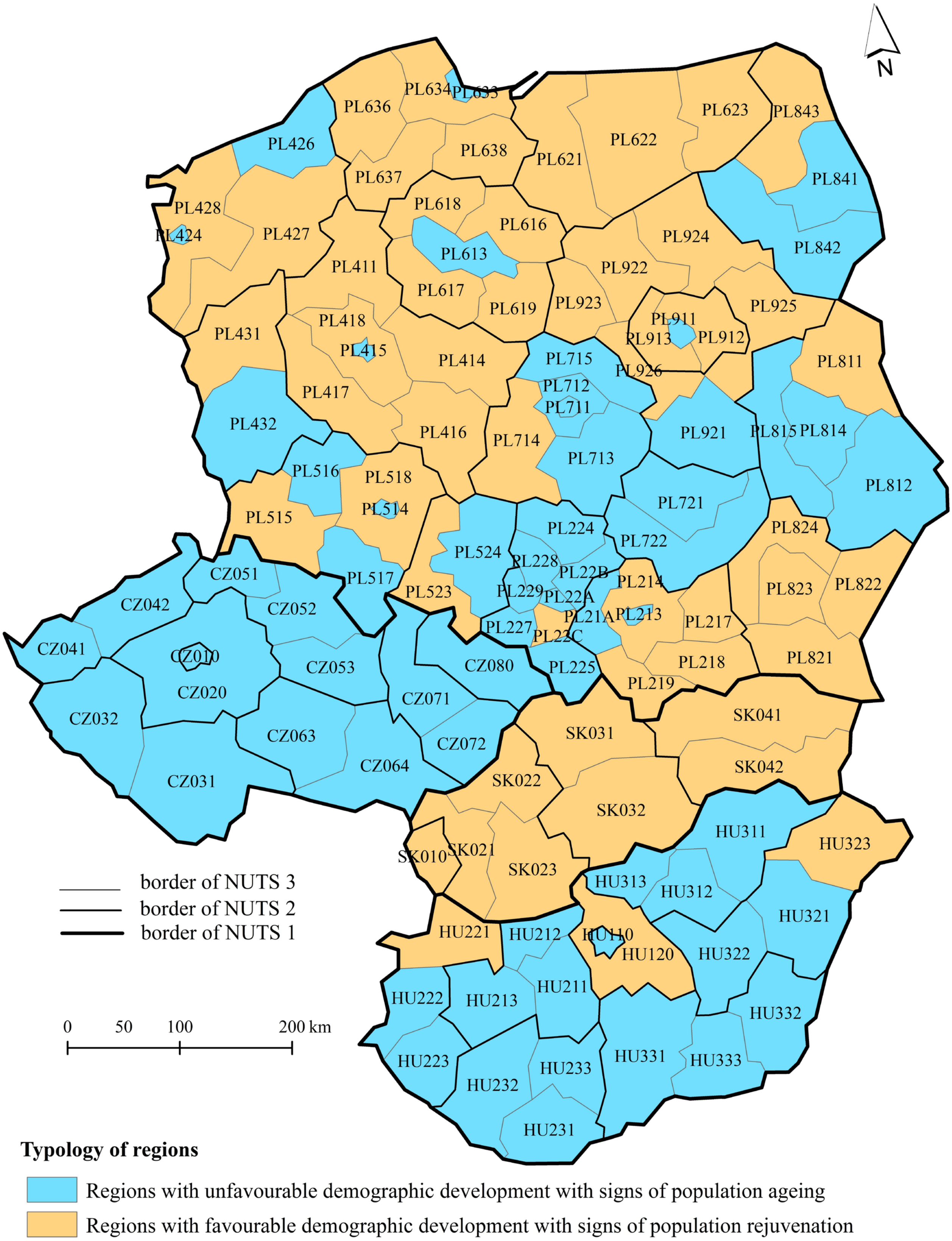


Fig. 7. Typology of ageing in NUTS 3 regions of the V4 countries according to cluster analysis in 2017 – 2021

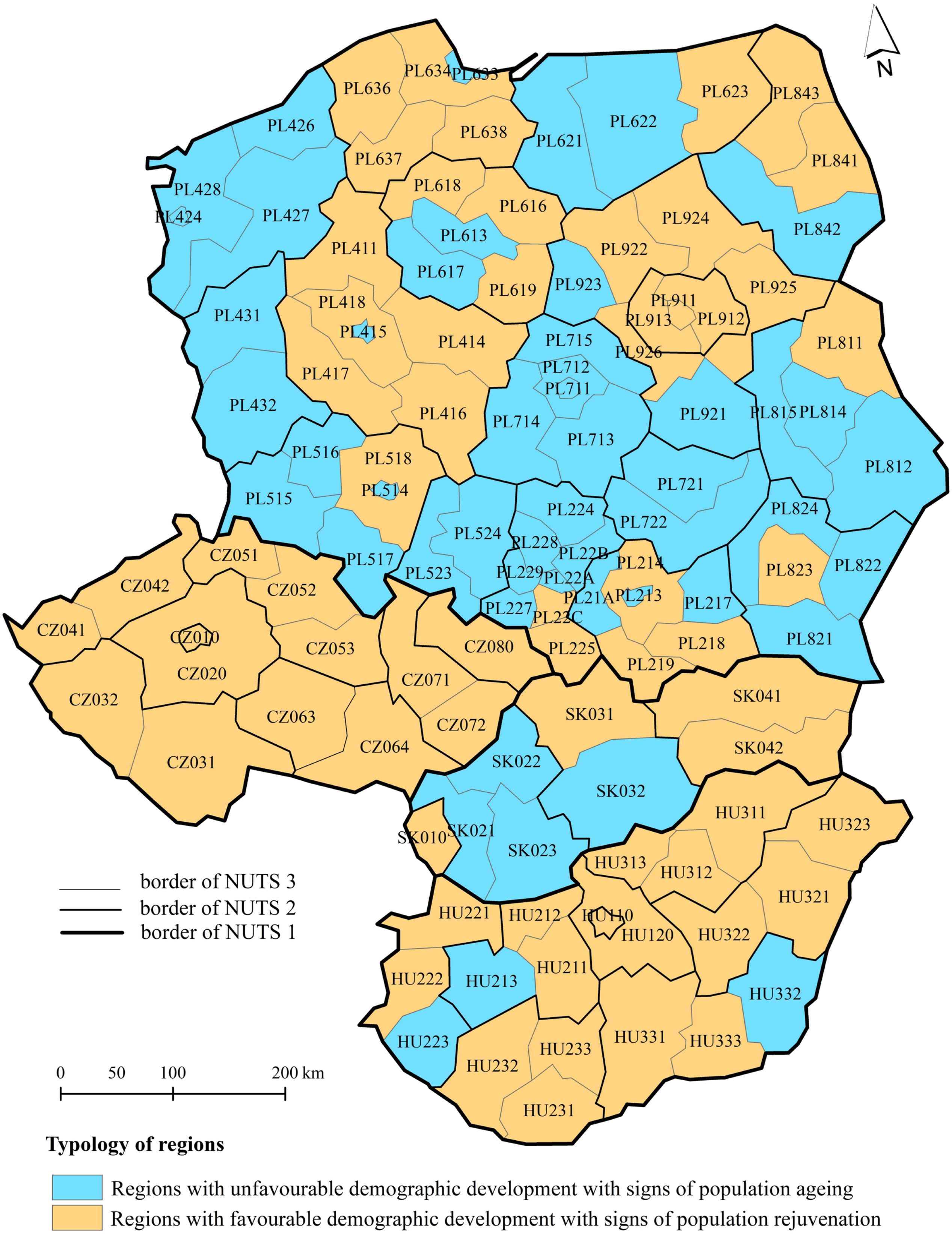


Fig. 8. Typology of ageing in NUTS 3 regions of the V4 countries according to cluster analysis in 2050

progressive age population structure (especially the highest share of children). According to Grzegorz and Szymańczak (2012), these are the regions with a strong labour market and scientific, research and academic facilities, which strengthen the regions' position in the European context.

5 DISCUSSION

Ageing is an irreversible process that has been increasing dynamically in the V4 countries and throughout Europe in recent years. The demographic, economic and social ageing consequences became one of the most frequent research topics across the scientific society.

In the paper, we have considered ageing indicators to determine the rate of population ageing in the NUTS 3 regions of the V4 countries over the period 2017 – 2021, as well as future trends (2050). By means of verifying the established hypotheses, we identified NUTS 3 regions in which the situation in terms of population ageing is favourable and, conversely, NUTS 3 regions that are less favourable in terms of ageing.

In determining the statistical dependence of individual indicators of ageing, we relied on standard indicators of ageing, which have also been used in their papers on the example of different regions, e.g. by Mládek et al. (2018), Długosz (2007) and others. However, in geographical papers on population ageing, statistical dependence between individual indicators has not been found, but it has been assumed that they influence each other. In our paper, this statistical dependence was studied, but it was not confirmed for the indicator 85+ in 2050. Both single-component indicators (≤ 14, 65 and above, 85 and above) and complex ageing indicators (ageing index, Billeter's index, old-age dependency ratio, economic dependency ratio, young-age dependency ratio) were studied.

Through economic indicators, the paper found that the increasing number of seniors is gradually burdening the economic population component which has an impact on the economic growth of each V4 country. In this paper, we have confirmed that the working-age population in the V4 countries is indeed economically burdened via the economic dependency ratio, the old-age dependency ratio and the young-age dependency ratio.

As life expectancy increases and the population reaches higher age, there is an increase of the population over 65, and at the same time, as the fertility rate decreases, the number of people under 14 is decreasing. Also authors Ediev et al. (2019), Abeysinghe (2019), have confirmed that the population transitioning to post-working age will be larger than the younger age groups that are expected to replace it, which will not only put an economic burden on individual countries, but will also put a significant strain on the social and health care systems. On the positive side, life expectancy in individual countries is increasing; in the paper we pointed out that while life expectancy in the V4 countries was 77.1 years between 2017 and 2021, it is expected to rise to 83.4 years by 2050.

The increase in population ageing has also been confirmed by the age pyramids, that clearly show an increase in the 65 and above population and more significant increase in the 85 and above population. We have pointed out that by 2050, the 85 and above age group will be the fastest-growing senior group, its size will be 2.6 multiple of its current size. Therefore, we agree with Requena et al. (2010) that increasing average life expectancy is a positive process, but it is also necessary to improve seniors' quality of life and to introduce policies that would also raise the fertility rate of the population and thus elevate the share of child component of the population.

When verifying further hypotheses that in the years under study there will be changes in the age structure of the population in the V4 countries, and this change will be evident not only at the regional level (NUTS 3 regions), but also at the national level, we confirmed the above hypotheses. In particular, the most significant changes will occur in Slovakia and Poland, where all ageing indicators will increase significantly by 2050 and the number of children under 14 will decrease the most (by 3.3% and 1.4% for Poland and Slovakia respectively) compared to other V4 countries. It has been confirmed that the population is not ageing homogeneously in all NUTS 3 regions. While in most NUTS 3 regions in Slovakia and Poland the situation will worsen and the ageing process will intensify by 2050, in the NUTS 3 regions of the Czech Republic and Hungary the situation will improve. The fact that in the Czech Republic and Hungary there will be a positive manifestation of population ageing in 2050 and in Slovakia and Poland there will be an unfavourable increase in ageing has been confirmed by other authors, although their methodology for assessing the ageing process was different (Repaská, 2022; Káčerová et al., 2012; Káčerová & Ondačková, 2015; Sobotka, 2011; Sanderson & Scherbov, 2020). In addition to the authors mentioned above, regional ageing in Europe has also been addressed by Rees et al. (2012), who analysed the decline in the labour force due to ageing. According to the authors, between 55% and 70% of European regions are expected to experience a decline in the workforce of 10% or more. In most regions of Eastern Europe, the labour force may decline by more than 30%. The authors' assertion was confirmed in our research, which found that the old-age dependency ratio will increase by 28.3% by 2050.

Considering the results of the study, some limitations of the explained approach should be pointed out. The first limitation is that our analysis includes the treatment of selected ageing indicators that were currently available up to NUTS 3 level. We processed all available databases and established their suitability through the detection of statistical dependence. Although the approaches followed were conventional and we only processed the retrospective side of the ageing process, which also limits our research, we were nevertheless able to distinguish within countries regions with favourable and less favourable ageing of the population.

The second limitation of the research was the presence of so-called urban NUTS 3, which are exclusively limited to the capital city. For the purposes of statistical observations, regions in the EU are often defined inappropriately, for example, when urban regions consisting of a city and its surroundings are divided. This division reinforces the 'capital city effect' in tracking regional differences within countries. This fact is also confirmed in our paper. In the V4 countries, the so-called NUTS 3 city regions that are also capital cities (Hlavní město Praha, Miasto Warszawa, Budapest) experience a less pronounced ageing of the population compared to the surrounding regions. These NUTS 3 urban regions serve as the main destination points for foreign migrants and are a rapidly transforming territory that is strengthening its domestic and foreign position. In the case of the NUTS 3 Bratislava Region, where the capital city is part of the region, the favourable position is influenced by suburbanisation. This process deepens the ageing of the population in the centre of Bratislava, where there is an outflow of population, and at the same time rejuvenates the population in the suburban areas where it is moving to. To deal with similar issues, it would be useful to consider merging urban NUTS 3 with the surrounding region to make the regions more comparable. However, a limiting factor is both merging and averaging the data, which reduces its credibility, accuracy and objectivity.

6 CONCLUSIONS

The ageing of the population is a significant characteristic of the 21st century, which is irreversible, very dynamic and impacting the whole society in the forthcoming years. This process will deepen even more by 2050. Numerously stronger age-groups born in the 1970s and 1980s will begin to retire, and due to persistently low fertility, there will be no adequate replacement for them on the labour market. In the V4 countries, an increase in the population aged 65 and above is evident, along with a decline in the productive-age population and in the population under the age of 14, and growth of the 85 and above population ratio and old-age dependency ratio.

Comparison of the time period 2017 – 2021 and the prognosis for 2050 has revealed significant changes in the age structure of the population. Remarkable shift of the population age to higher age categories and subsequently some decrease in the child-age population ratio can be observed there. In these period, the age pyramid of the V4 population represented a regressive age structure determined by constantly decreasing number of the children born. This situation will not change even by 2050. Intensity of the ageing process is comprehensively documented by increase of the median age, which is evident common feature of all the countries under research. Regarding the population median age, the lowest was in the Slovak Republic and the highest in Hungary. According to the prognosis, the median age is forecasted to increase by an average of 6 – 10 years by 2050. The growth will be highest in Slovakia and Poland. By 2050, it will grow to 49.4 years, which will also be the highest median age of all the V4 countries. Similarly, as the median age and the population aged 65 and above increases, so does the ageing index. The situation of the population ageing will continue to worsen and even intensify until 2050. The increase will be evident in every country, most intensively in the territory of Slovakia (increase by 93%) and Poland (increase by 110%). Currently, the old-age dependency ratio of persons aged 65 and above to the working population of productive age of 15 – 64 is 23.6 persons per 100 working people, but the ratio assumed by 2050 is over 51.9 persons per 100 working people.

In this paper, the issue of population ageing was explored using multivariate statistical methods of cluster analysis. Similarity of objects can be expressed by the correlation measure. In the dendrogram, each NUTS 3 region is classified into a specific type based on the similarity of the monitored indicator values. The cluster analysis that compares different periods under research and is based on individual demographic indicators shows regional differences in NUTS 3 regions of the V4 countries. While population ageing will worsen in Poland and Slovakia, the ageing process will improve moderately in the Czech Republic and Hungary. By the period 2017 – 2021 there was a gradual population ageing which was observed mainly in the NUTS 3 Nitriansky kraj and Trnavský kraj (Slovakia). By the year 2050, population ageing will have intensified and increased even further, the favourable situation will only be in the region NUTS 3 Bratislavský kraj, in which the Slovak capital is located. It is currently the only NUTS 3 region in Slovakia with the most progressive age population composition. More significant changes have also occurred in Poland. By 2017 – 2021, the North, North-West and West retained their position of a younger population, but the central and eastern parts of the territory started to age. By 2050, only 40% of NUTS 3 regions will retain a young population. The capital Warsaw and the NUTS 3 Warszawski Wschodni and NUTS 3 Warszawski Zachodni regions maintain their positive position with young population influencing the favourable demographic situation. These regions have the most progressive age population structure (especially the highest share of children).

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