SPATIAL AND ASPATIAL MEASURES OF SEGREGATION IN THE CASE OF OSTRAVA CITY

Igor IVAN[1], Jiří HORÁK[2]

[1]Institute of Geoinformatics, Faculty of Mining and Geology, VSB-Technical University of Ostrava, 17.listopadu 15/2172, Ostrava-Poruba, 70833
igor.ivan@vsb.cz

[2] Institute of Geoinformatics, Faculty of Mining and Geology, VSB-Technical University of Ostrava, 17.listopadu 15/2172, Ostrava-Poruba, 70833
jiri.horak@vsb.cz

Abstract

Ostrava is driven by a deindustrialization process similar to other European industrial cities. Nevertheless, they are different in the stage of this process. Ostrava in this respect is unique because the process of deindustrialization started also in parallel with the end of socialism. The city partly passed a transformation which is proved in this article using selected spatial metrics on the level of basic settlement units in Ostrava city. The most common aspatial measure of segregation is index of dissimilarity. In order to incorporate the space dimension into calculations, the spatial alternatives of this index were developed and implemented in GIS SW because of its computational complexity. In addition to the application of this index of dissimilarity, spatial alternatives of this index are also introduced in this article. It does not work only within a single territorial unit, but it also considers the possibility of contact across the border into neighbouring units (based on their shared boundary, as well as its length or geometric shape of area) and multi-group measure of segregation which can accommodate more than two groups of population. These methods are applied to employment structure of the population (employment in service and industry sector, employed people over 64 years) at the basic settlement units level in the Ostrava city, derived from censuses of 1980 and 2001. Results of aspatial and spatial indices; their complementarity and appropriateness for a more comprehensive description of segregation are compared and discussed. Such type of studies has its significance especially for decision sphere and it can prepare more focused precautions to solve local problems, to provide more focused work of field workers, to provide some special help programs, to build effective community centres or even to solve problems connected to housing strategy (targeted construction of high level and social level housing in the same area).

Keywords: spatial measures, segregation, deindustrialization, GIS, Ostrava

INTRODUCTION

Ostrava represents a member of these cities where heavy industry, the engine of industrial economic growth, began to decline as in others economies of cities in developed countries in the final third of the twentieth century. As the result of closure, mechanization, suburbanization of industry and through the global shift of industrial employment from the core to semi-peripheral and peripheral countries of the world economy, these world cities have lost lot of their manufacturing employment since the mid-1960s (more in Fyfe, Kenny 2005). Ostrava became an important industrial centre of former Austria-Hungary and this fact brought a long-term influx of new population and spatial development of the city. The population of Ostrava rose continuously throughout almost all modern censuses (since 1869). The biggest waves of immigration came during the 1950s and the population of Ostrava increased about 18% (38,000 inhabitants) for 10 years. This trend continued also during the 1960s, when the positive natural change and migration gains increased the population about another 43,000 inhabitants (17%). More about industrial and modern history of Ostrava can be found in Hruška-Tvrdý et al. (2010). The changes of population within cities caused by deindustrialization can change the social status of people (in both ways) and can increase the speed and size of residential segregation. Residential segregation is defined by Massey, Denton (1988) as “the degree to which two or more groups live separately from one another, in different parts of the urban environment”. The development of demography and the rapid rate of changes in urban areas created needs for specialised measures to describe not only the level of segregation. Some of these have been adopted and accepted immediately while others continue to remain the subject of discussions (McKibben, Faust, 2004). From the spatial aspect these measures can be divided in measures which calculate with space and its specifics and those which are completely aspatial. The percentage distribution belongs to these aspatial measures as probably the simplest measure used to describe the population distribution. Other possible measures are the Gini concentration ratio and the Lorentz curve are devices for representing the inequality of two distributions (Plane, Rogerson, 1994) and these are other representatives of aspatial measures. Researchers began to develop more and more complex indices of segregation with rising availability of data and computer processing. A turning point was the research of Massey, Denton (1988) who conducted a cluster analysis of 20 indices of segregation and they grouped them into five categories of evenness, exposure, concentration, centralization and clustering with recommendation of a single best index for each group. Although some of these indices are commonly used to describe spatial segregation, they suffer from their aspatiality. This paper describe the use of selected members of these indices of residential segregation (classic index of dissimilarity and index of segregation) and developed spatial measures to describe some changes in urban environment of Ostrava caused by deindustrialization.

QUANTIFICATION OF SEGREGATION

Aspatial measures

This chapter describes selected segregation measures which do not work with space and they are not effective to differentiate different spatial distribution patterns among population groups. *Index of dissimilarity* has been found as the most useful index for the evenness dimension of segregation (Massey, Denton, 1988) and it is described by Duncan and Duncan (1955). It measures the dissimilarity of two groups in the area or the percentage of one group that would have to change residence to produce an even distribution of the two groups among areas. The index ranges from 0, indicating no residential segregation, to 1, indicating complete residential segregation.

$$D = \frac{1}{2}\sum_{i=1}^{k}\left|\frac{x_i}{X} - \frac{y_i}{Y}\right|, \qquad (1)$$

where $x_i$and y_i represent the members of the studying groups X and Y in unit i, X and Y the entire population of the group X and Y in the territory (city) and k represents the number of subunits in the territory.

This measure has been one of the most popular measures of residential segregation but in recent years, it has come under criticism that it can measure only two groups at one time. So the residential segregation of university educated people can be compared to people with basic education, but university educated people cannot be compared to people with basic education and with high school education simultaneously. Nevertheless, a series of studied has revealed the inadequacies of this index from the spatial perspective and a set of spatial segregation indices has been proposed during past decades (Wong, 2003). Two key criticisms are called as the ‘checkerboard’ problem and the modifiable areal unit problem (MAUP) (Reardon, O’Sullivan, 2004; Wong, 2004).

Spatial measures

Spatial measures have been introduces but not been adopted widely because they are difficult to compute even within Geographic Information Systems (GIS) due to a low instant support of such operations. That is why spreadsheets or database tools are more often employed for calculations. The history of spatial dimension in segregation measuring has been started by Jakubs (1981) who incorporated distance measures to capture the proximity among population groups. The recent approach of capturing spatial dimension is to incorporate potentially relevant spatial aspects into calculations – neighbourhood relationship and the geometric characteristics of units. To make these spatial metrics more popular, some of these measures were implemented as the set of tools in GIS environment (ArcView GIS) by David W.S. Wong (Wong, Chong, 1998; Wong, 2000, 2003, 2004). These measures can handle the traditional two-group settings or the multi-group settings.

The first spatial measure was introduced by Morill (1991) who modified the dissimilarity index with a term to compare different population in neighbouring units. This new *neighbour-adjusted* $D(adj)$ *index* solves the problem that different population groups locating next to each other should have a relatively low level of segregation.

$$D(adj) = D - \frac{\sum_i \sum_j \left| c_{ij} \times (z_i - z_j) \right|}{\sum_i \sum_j c_{ij}}, \tag{2}$$

where D is index of dissimilarity, z_i and z_j are the proportions of minority (or majority) between areal units i and j, while c_{ij} will be zero if i and j are not neighbours, and one if they are (Wong, 2003).
This index was further improved by the premise that the intensity across mutual boundary is not simple function of adjacency, but it is more dependent on the length of mutual boundary. This new *boundary-adjusted* $D(w)$ *index* was developed and defined as

$$D(w) = D - \frac{1}{2} \sum_i \sum_j w_{ij} \left| z_i - z_j \right|, \tag{3}$$

where all terms are defined as before, and

$$w_{ij} = \frac{d_{ij}}{\sum_j d_{ij}}, \tag{4}$$

where d_{ij} is the length of mutual boundary between units i and j and the denominator is basically the total length of the boundary of the unit i (Wong, 2003). Calculations of w_{ij} may be even more common and may cover different aspects of spatial adjacency including topological or distance measures (Horák, 2006).

The last improvement is based on the premise that the level of interactions is also a function of the size and shape, or the compactness of the two adjacent units. The new *index* $D(s)$ *with compactness measures* was derived and defined as

$$D(s) = D - \frac{1}{2} \sum_i \sum_j w_{ij} \left| z_i - z_j \right| \times \frac{\frac{1}{2}\left[\left(\frac{P_i}{A_i} \right) \left(\frac{P_j}{A_j} \right) \right]}{\max\left(\frac{P}{A} \right)}, \tag{5}$$

where the $\frac{P_i}{A_i}$ is the perimeter-area ration for the unit i and $\max\left(\frac{P}{A}\right)$ is the maximal perimeter-area ratio among all units in the region (Wong, 2003).

All these spatial versions has the same limitation as the classical dissimilarity index, it compares only two population groups. For multi-group comparisons, the multi-group version of dissimilarity index was introduced – *Multi-group D(m) index* and the *spatial version of multi-group index SD(m)*. More about these multi-group indices can be found in Wong (2003).

The last spatial segregation measure defined by Wong (2003) is based upon explicit spatial dissimilarity, or the concept of spatial congruence. It is based on premise that different groups do not have similar distribution patterns. To capture overall spatial distribution of each population group, a standard deviational ellipse (Lee, Wong, 2001) can be used. After construction of multiple ellipses for each population group, they are compared and combined to derive an index of segregation based upon the ratio of the intersection and union of all ellipses. This *ellipse-based measure S* is defined as

$$S = 1 - \frac{E_1 \cap E_2 \cap E_3 \cap \ldots E_n}{E_1 \cup E_2 \cup E_3 \cup \ldots E_n}, \tag{6}$$

where E_i is the deviational ellipse describing the distribution of population group i (Wong, 2003). A more clustered distribution will generate a smaller ellipse and more dispersed distribution will generate larger ellipse with the rotation corresponding to the orientation of the distribution.

The ellipse-based measure can be written also as *S=1-CAC*, where *CAC* is the coefficient of Areal Correspondence (Horák, 2009). It would be possible to apply also a resemblance matrix or other measures of a spatial overlay.

DATA FOR SEGREGATION AND DEINDUSTRALIZATION EVALUATION

Changes of population structure and its distribution within the city can be described and documented by above described spatial segregation measures. Data required in the segregation analysis usually specifies personal features like nationality, race, education, income or economical status (McKibben, Faust, 2004). Such complex demographical and economical data is provided by census.

Deindustrialization can be evaluated by different indirect indicators. Changes in sectoral employments are considered to be on the most important. The basic hypothesis assume the deindustrialization influence the spatial distribution of employed population in selected sectors or economical branches and this movement will be recognised by relevant changes of segregation indices.

Main aspects of deindustrialization are described by (using census data from several last periods):

- lower employment in industry (defined as the number of employees in industry),
- higher employment in service sector (defined as the number of employees in service sector[1]),
- higher employment of people older than 64 years (defined as the number of employees older than 64 years),
- employed as workers (1980) (defined as the number of workers) and employment in insurance and financial sector (2001) (defined as the number of employees in the sector).

The last aspect cannot be mutually compared but generally, while workers represent the industrial aspect of the employment situation in the city, people employed in insurance and financial sector could represent the post-industrial era of the city. The anticipated results are decreasing of spatial segregation of employment sectors due to a higher mixture of new employment possibilities. The increasing social differentiation and segregation stands against this development. This is caused by increasing level of unemployment rate (compared to 1980), more differentiated range of wages etc. and can lead even to creation of socially excluded localities (more in Horák et al., 2010).

CASE STUDY OF OSTRAVA

The case study is focused on utilization of classical index of dissimilarity and its spatial version to describe the impact of deindustrialization process on employment structure in Ostrava as it was explained in the previous chapter.

Above mentioned data from census 1980, 1991 and 2001 at the basic settlement units are applied to investigate selected aspects of deindustrialization:

The table 1 describes the main changes in population and employment situation in Ostrava for 20 years. This time series covers the most important aspects of deindustrialization in employment sectors, but in case of possible extension on results from scheduled census in 2011, the changes would be bigger and more exact and the population could be potentially more segregated. This idea of current development supports the real change of population in Ostrava. The decrease during 20 years was only 1.7%, but the decrease since 2001 to 2010 (1. 1.) is bigger than 3%. Similar situation should be in case of the change of economically active people where the decrease is slightly bigger than in case of population. So, the level of decrease in Ostrava is bigger for economically active people and the drop in the last decade should be again even bigger than the development in analyzed 20 years. While the population decrease has its peak after 2001, the change of employment structure took place during the 1990s (this is evident in Table 1). The stated aspects of deindustrialization are supported by results in table 1 – massive reduction of people employed in industry (less about almost a half) and on the other hand high increase of people employed in service sector (more than 60%) as well as the employment of people older than 64 years (more than 50%). This higher employment of older people may be caused by two factors: they are employed usually in less physically demanding positions and they simply must work to maintain their standard of living.

Table 1. Changes in population and employment in Ostrava between 1980 and 2001.

	1980	2001	change	
population	322 073	316 744	-5 329	-1.7%
economically active	164 378	160 210	-4 168	-2.5%
employed in industry sector	81 702	42 944	-38 758	-47.4%
employed in service sector	64 083	102 991	38 908	60.7%
employed and older than 64 years	3 009	4 511	1 502	49.9%

Spatial distribution of people employed in industry sector has been changed quite significantly (Fig. 1). Averagely, reduction is evident in all units of the city. While the share of economically active in industry from economically active was around 50% in 1980 with high level units placed near a geographical centre of the city, in 2001 the ratio is averagely about 20% with quite heterogeneous distribution.

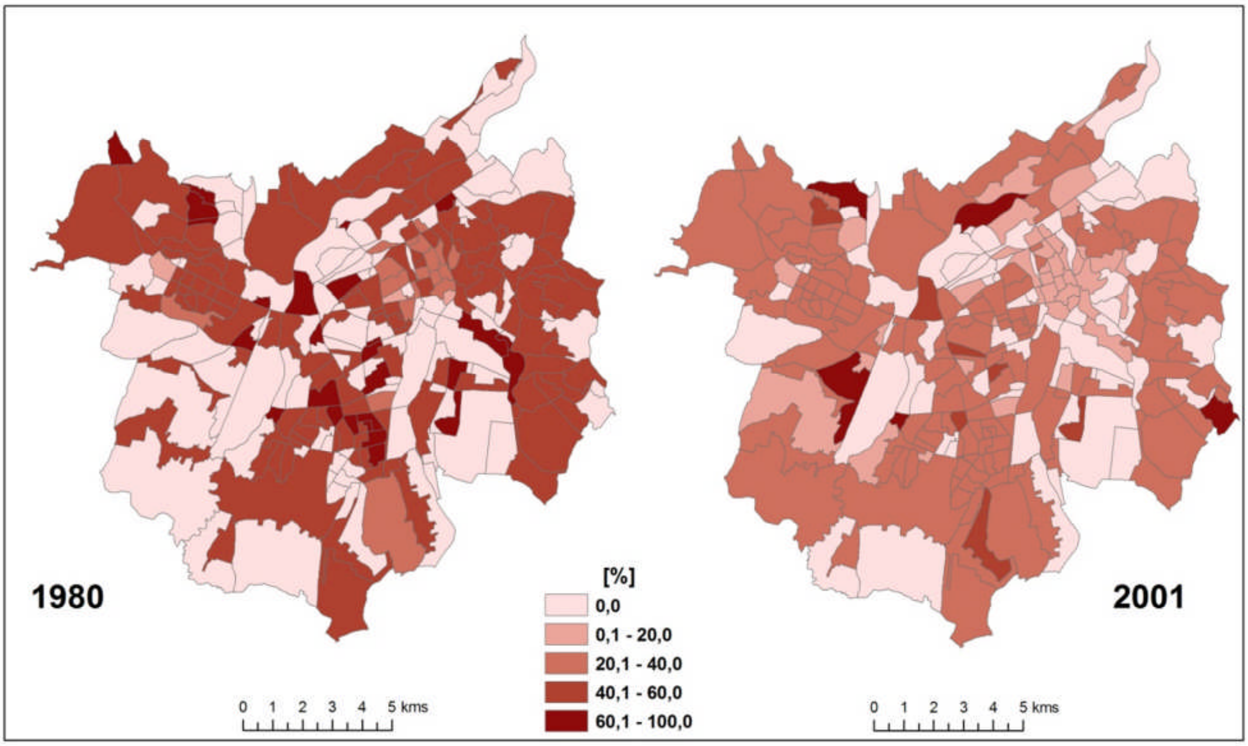

Fig. 1. Change of employment in industry (ratio of economically active in industry per 100 economically active)

Completely different development is in case of employment in service sector (Fig. 2). In 1980, a few important service areas are located around the city centre and in Poruba district (due to the presence of the

[1] service sector is defined as the total number of employees except employees in agriculture, industry and construction

Technical University of Ostrava) but others areas denote a low level of service sector. The map depicting situation in 2001 indicates much bigger ratio of economically active in services per 100 economically active and in almost all basic settlement units in Ostrava, there is more than 60% of economically active people employed in service sector.

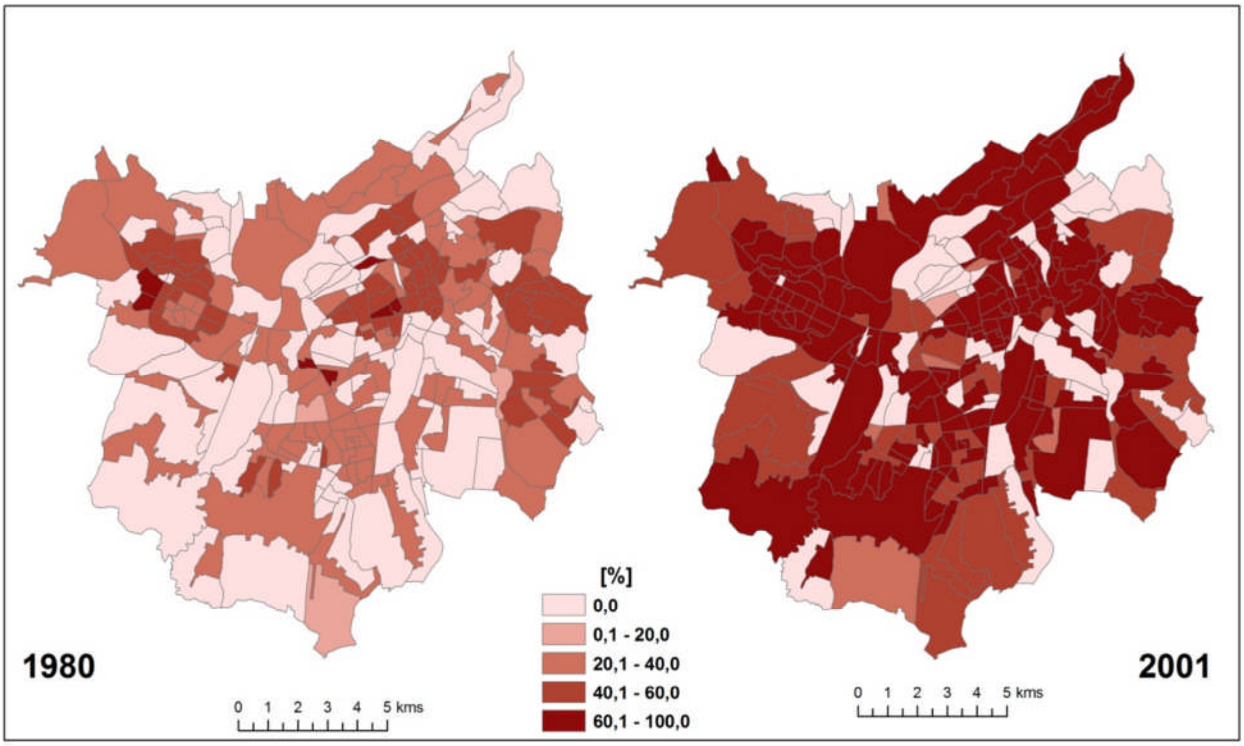

Fig. 2. Change of employment in services (ratio of economically active in services per 100 economically active)

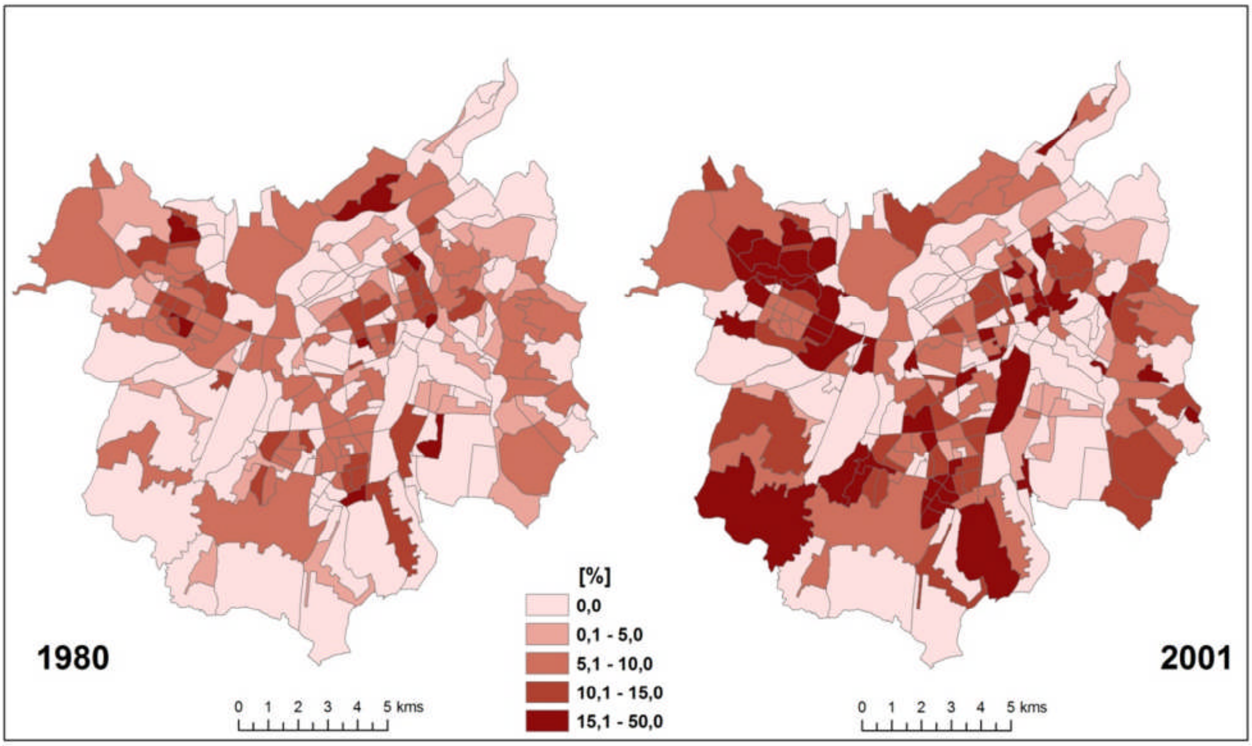

Fig. 3. Change of employed 65+ (ratio of employed 65+ per 100 people 65+)

The significant increase is evident in case of change in employment people over 64 years too (Fig. 3). Most of units have the ratio of employed 65+ per 100 people 65+ up to 10% in 1980 but in 2001 significant number of units has the ratio higher than 15%. These units are situated mainly in the west part of the city (Poruba, Pustkovec) and in the southern parts (Hrabuvka, Zabreh, Dubina, Hrabova or Polanka nad Odrou).

The changes in the share of main economical sectors are clearly depicted as well as the movement in the distribution of high and low level units. The main research question is if these significant changes are also articulated in changes of spatial segregation (uneven spatial distribution in broader sense of understanding).

Classical index of dissimilarity

The classical index of dissimilarity was used to analyze the mutual segregation of people employed in service sector, industry sector, workers and employed people older than 64 years (hereafter as employed 65+). The results from 1980 (Table 2) indicate higher segregation of employed 65+ in comparison to all other groups, the level of segregation is similar. Slightly higher segregation is between the service sector and industry sector and between workers and service sector.

Table 2. Index of dissimilarity – census 1980.

1980	industry sector	service sector	workers	employed 65+
industry sector	x	0.144	0.042	0.271
service sector	x	x	0.169	0.265
workers	x	x	x	0.274

The results of dissimilarity index based on results from 2001 indicate slight decreasing level of segregation in case of the same groups as in 1980 but the differences are quite small. The biggest decrease of segregation is between employed 65+ and service sector. The least segregation is between industry and service sector and this signifies the evenness in the geographical distribution of these groups. This approach is not quite free of the MAUP but this spatial level provides good conditions to avoid MAUP maximally. The only way to be free of the MAUP would be by the use of individual-level data what faces many problems.

Table 3. Index of dissimilarity – census 2001.

2001	industry sector	service sector	insurance and financial sector	employed 65+
industry sector	x	0.097	0.154	0.235
service sector	x	x	0.104	0.194
insurance and financial sector	x	x	x	0.262

Neighbour-adjusted D(adj) index

This first member of segregation measures yields significant decreasing level of segregation in case of all analyzed groups, thus the neighbouring effect influence positively results. This fact indicates the existence of a positive spatial association among neighbouring units but the level of this spatial association is very variable. In Ostrava, there is averagely almost 6 neighbouring units (maximum is 21 (!) units and minimum is only 2 units). The biggest smoothing effect of neighbouring units is in case of segregation between industry and service sector and workers and service sector. Here, this index does not indicate almost any segregation. Results of index between employed 65+ and others groups are in different order, compared to index of dissimilarity but still almost similar.

Table 4. Neighbour-adjusted D(adj) index – census 1980.

1980	industry sector	service sector	workers	employed 65+
industry sector	x	0.032	0.016	0.228
service sector	x	x	0.040	0.209
workers	x	x	x	0.204

In results from 2001, the influence of neighbouring units on the decrease of segregation reaches similar level as in case of the situation in 1980. This measure indicates almost no segregation between industry and service sector which is slightly lower than 20 years ago, what is anticipated development. The level of segregation has been decreased in all comparable populations between two censuses.

Table 5. Neighbour-adjusted D(adj) index – census 2001.

2001	industry sector	service sector	insurance and financial sector	employed 65+
industry sector	x	0.023	0.108	0.154
service sector	x	x	0.079	0.161
insurance and financial sector	x	x	x	0.190

Boundary-adjusted D(w) index

Theoretically this index should provide more accurate results than *D(adj)* because the impact of adjacency should be adjusted by the length of the shared boundary. The average length of shared boundary between two units is 727 metres, but the variability is quite significant (minimum is 0.6 metres and maximum over 10 kilometres). Results of this index (Table 6) yield slightly smaller values than in Table 4 with one exception. This caused the fact that longer mutual boundaries are between more homogeneity neighbouring units.

Table 6. Boundary-adjusted D(w) index – census 1980.

1980	industry sector	service sector	workers	employed 65+
industry sector	x	0.031	0.013	0.227
service sector	x	x	0.044	0.205
workers	x	x	x	0.201

This index would yield higher level of segregation than *D(adj)* if the length of shared boundaries would be longer with units with different employment structure. It is the case of segregation between industry and service where the *D(w)* indicates slightly higher level of segregation. However, the index signifies minimal level of segregation, even small increase of segregation is evident compared to 1980. The biggest impact of the length of shared boundary is in case of segregation between industry sector and employed 65+.

Table 7. Boundary-adjusted D(w) index – census 2001.

2001	industry sector	service sector	insurance and financial sector	employed 65+
industry sector	x	0.033	0.102	0.150
service sector	x	x	0.083	0.159
insurance and financial sector	x	x	x	0.192

Index D(s) with compactness measures

This index extends boundary-adjusted *D(w)* index by edge density or perimeter/area ratio of particular units. Compared to results in table 6, the level of segregation is more significant between all groups but still smaller than by using classical index of dissimilarity. The biggest influence of edge density and the biggest increase is again in case of segregation between industry and service sector. This increases are probably influenced by lower spatial compactness of particular units (boundaries follow the rivers, irregular built-up area in periphery).

Table 8. Index D(s) with compactness measures – census 1980.

1980	industry sector	industry sector	industry sector	industry sector
industry sector	x	0.105	0.023	0.256
service sector	x	x	0.126	0.244
workers	x	x	x	0.249

Similar increasing level of segregation is in 2001. The explanation is similar as previously. Compared to results in table 8, the situation of comparable groups is better what corresponds to the general development.

Table 9. Index D(s) with compactness measures – census 2001.

2001	industry sector	service sector	insurance and financial sector	employed 65+
industry sector	x	0.057	0.137	0.206
service sector	x	x	0.098	0.182
insurance and financial sector	x	x	x	0.241

CONCLUSIONS

This paper provides the description of aspatial and mainly spatial measures of segregation. These three introduced spatial indices have been already implemented into GIS environment and used to describe the change of employment structure in Ostrava between 1980 and 2001. Generally, the level of segregation decreased between 1980 and 2001 between all analyzed groups what corresponds to assumed development. Employed people over 64 years are the most segregated group; the level of segregation was the biggest between this and all other analyzed groups. Incorporation of influence of shared boundary between units or even its length caused in case of Ostrava another decrease of segregation. A practical use of the last introduced index D(s) with compactness measures is arguable because segregated localities can be separated by rectangular barriers (trunk roads, railways) as well as by curved barriers (rivers, forests) and this index favors the curved barriers. The MAUP has not been studied yet, but Wong (2004) claims, based on previous studies, that aspatial measures yield higher levels of segregation when data gathered for smaller areal units are used. This can be the next direction of this research to study the internal heterogeneity of particular municipal districts in Ostrava as well as incorporation of another attributes as describing factors of deindustrialization processes.

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