MISCELLANEA GEOGRAPHICA – REGIONAL STUDIES ON DEVELOPMENT
Vol. 19 • No. 3 • 2015 • pp. 22-35 • ISSN: 2084-6118 • DOI: 10.1515/mgrsd-2015-0012

Measures of social segregation in the context of Warsaw, Berlin and Paris metropolitan areas

Abstract
Social segregation is a subject common in contemporary studies of metropolitan areas. Until recently, studies of segregation focused on the distribution of ethnic groups, immigrants, and the poor. Today, they also cover additional indicators such as demographic properties, education, and affiliation with social and professional categories, which can also serve to determine the causes of the segregation (including the self-segregation of the rich). This article aims to point out the measures of segregation that present the segregation levels in the most complete manner, along with their application in the context of three European metropolitan areas: Warsaw, Berlin, and Paris. The first part of the article is a review of the existing approaches to segregation measures, followed by the selection of research method, presentation of the analysis' results, and evaluation of the applied methods; presenting the opportunities and limitations in research of the social segregation phenomenon.

Keywords
Segregation measures • social segregation • Warsaw • Berlin • Paris

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Received: 16 December 2014
Accepted: 26 June 2015

Introduction

Social segregation is a broad concept that refers to the separate inhabitation of various population groups within different parts of a city[1]. Determining the segregation level entails various methodical problems. The selected progress mode affects both the results that have been obtained and their credibility. The first issue is in the selection of the social categories covered by the analysis. Literature concerning segregation usually includes essays concerning the distribution of racial groups in the United States including Feinstein (2011) and Kaufman (2011); or groups of the poor/excluded or immigrants in Europe (including White 2011, Musterd & van Gent 2012). The "image" presented is incomplete. Data that is less common in literature includes demographic properties, household structures, education, income level, and affiliation with social and professional categories. The second problem associated with establishing the segregation level is the selection of the geographic space covered by the research. The most commonly covered areas are either cities or entire metropolitan areas, whereas the metropolitan area as a functional whole seems more appropriate. Another issue concerns the areal units composing the research area, which are usually communes and districts, as these areas usually have available statistical data; although smaller entities would provide more specific analyses. The third methodical problem, seemingly the most difficult one, concerns the selection of the segregation measures from those suggested in the literature. This article aims to point out the measures of segregation that present the segregation level in the most complete manner based on current knowledge, and its application in the context of three European metropolitan areas: Paris, Warsaw, and Berlin. The first part of the article is a review of the existing approaches to segregation measures, followed by research method selection, presentation of the analysis' results, and evaluation of the applied methods.

[1] A list of scientific approaches to this phenomenon is provided by Maloutas (2012), who presents the contextual diversity of the segregation process; and by Musterd and Ostendorf (2011), who focus their contemplation on the relationships of polarisation, exclusion, and segregation growth, as well as the transformations occurring in states with social care.

Existing segregation measures – literature review

The literature includes numerous studies that refer to the measures of segregation and attempt to arrange the existing state of the information. The most important articles include those by Reardon and O'Sullivan (2004), Feitosa et al. (2007), Reardon and Firebaugh (2002a), Grannis (2002) and Reardon and Firebaugh (2002b). The available sources arrive at the conclusion that the most complete way of arranging segregation measures is through the application of three criteria. The first is chronological criteria (i.e. three generations of indices), which allows expression of the measurement evaluation. The second is the segregation dimensions, which presents the ambiguity of segregation. The third utility criteria is index classification, which differs between the focus on one, two or multiple group analyses.

First, Second and Third Generation of Indices

The first generation measure usually include the dissimilarity index *D* popularised by Duncan & Duncan (1955) (the most common) and the interaction index *P* (Bell 1954 as cited in Massey & Denton 1988). Other indices worth mentioning include the Gini index

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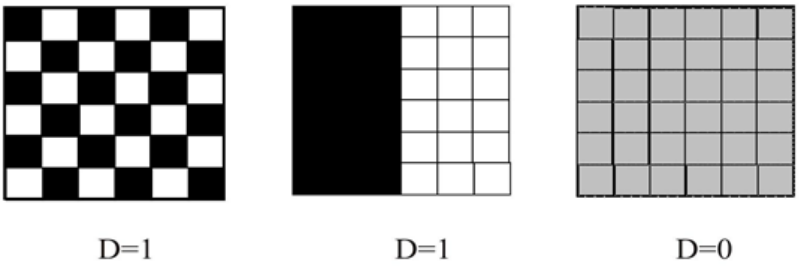

Figure 1. The checkerboard problem
Source: Reardon & O'Sullivan 2004, Measures of Spatial Segregation, Pennsylvania State University

(Cowell 1977 as cited in Massey & Denton 1988), the information theory index (Bell 1954 as cited in Massey & Denton 1988)) and the Atkinson index (Atkinson 1970 as cited in Massey & Denton 1988)).

The limitations of such measures most common in the literature include the following: (1) aspatial nature – the spatial distribution of various population groups, i.e. the fundamental property of segregation remains unmeasured; (2) global nature – segregation defined for an entire city, although it is divided into individual areal units, which differ among one another; (3) two-group nature – the first generation studies focused on the distribution of the minority group within the majority group, which was associated with the presence of one significant minority group in this period in the United States.

The latter limitations were met by the second-generation measures, which were developed in the 1970s when the multiple group analyses or analyses conducted for social classes (Feitosa et al., 2004) gained more significance. These measures mostly constituted generalised versions of prior indices, while some of them were absolute measures referring to minority and majority groups among districts (e.g. dissimilarity index *D*, interaction index *P*), and some were examples of relative measures, that is the level of minority and majority group segregation compared to each other (e.g. relative concentration index *RCO*). All were criticised for failing to meet the spatial criterion and global nature of the segregation measures.

The 1980s saw the beginning of the use of spatial measures (third generation measures) aimed at meeting the checkerboard problem identified by White (1983) (Fig. 1). White (1983) noticed that the existing first and second generation measures ignored the spatial proximity (neighbourhood) of areal units and only focused on the racial population structure[2].

The second spatial limitation is the so-called modifiable areal unit problem (MAUP), which results from the method of gathering statistical data; that is, their aggregated nature[3]. Both of the aforementioned limitations would be eliminated completely if there was information on precise population distribution (Reardon & O'Sullivan 2004; Sadahiro & Hong 2013, Reardon & Firebaugh 2002a; Cohn & Jackman 2011). The special indices most commonly quoted in the literature have been gathered together by Reardon, O'Sullivan (2004).

[2] To visualise the problem, imagine a checkerboard, each square of which represents an exclusively black or white district (Fig. 1). If all black squares are moved to one side and all white ones to the other, we should expect more segregation, because not only are all districts racially uniform, but most of them will also be surrounded with similarly homogeneous areas. Despite the fact that the neighbourhood of units with the same demographic structure suggests greater segregation, the index *D* does not change. The checkerboard problem is frequently discussed in contemporary literature, including the work done by Dawkins (2004, 2006), Reardon and O'Sullivan (2004), Feitosa et al. (2004, 2007), and Sadahiro and Hong (2013).

[3] Areal units such as districts or census regions do not correspond to the social and spatial city structure. Consequentially, the people living in nearby streets but in different areal units are more distant than the people living farther apart, but within the same areal unit.

Measures of Segregation Dimensions

Social segregation is not an explicit concept because the population inhabiting a given area may be "segregated" in various ways. In response to this, Massey and Denton (1988) introduced the five segregation dimensions: (1) unevenness refers to the diverse population distribution in relation to areal units; (2) exposition is the likelihood of contact with the representatives of other groups (interaction index) or own group (isolation index). The former dimension may be abstract, but the latter refers to actual segregation, the experience of the urban population; (3) concentration refers to the relative, physical space inhabited by a group of people; (4) centralisation is a specific variation of concentration, i.e. it defines the level of inhabitation near the city centre; and (5) clustering refers to the proximity of areal units inhabited by a given population group. The final dimension is the only one that solves the checkerboard problem. Massey and Denton (1988) also suggested multidimensional analyses of this phenomenon (Table 1).

Based on the above divisions, and placing more focus on the spatial understanding of segregation, Reardon and O'Sullivan (2004) introduced a division into two segregation dimensions (Fig. 2). The first, evenness/clustering, refers to the balance in population group allocation; while the second, isolation/exposure, refers to the potential of living near the representatives of own/other population groups. Centralisation and concentration may be perceived as specific subcategories of spatial unevenness.

One, two and multiple group measures

The third suggested division of the existing segregation measures can be based on the number of groups covered by the study. One-group measures express the distribution of one group in relation to all; two-group measures compare the distribution of two population groups compared to each other; multiple group measures describe the distribution of several groups simultaneously. The segregation measures divided into the number of groups compared and the five aforementioned segregation dimensions are available at the Geo-Segregation Analyzer website (2014).

The modified location quotient LQ_p is a measure that is frequently applied, but that does not fit under any of the suggested divisions (Węcławowicz 1992). This is a typically geographical factor, which provides the foundation for cartograms. It expresses the identification of areal units with population overrepresentation (LQ_p >1) and underrepresentation (LQ_p<1). Segregation is also expressed on maps with the entropy (diversity) index *H* of percentage shares (Geo-Segregation Analyzer 2014).

In conclusion, it should be noted that there are numerous other indices undergoing analyses, some of which are currently only at the stage of mathematical testing and have not, as yet, been applied empirically. Mathematical testing is based on tests

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Table 1. Segregation dimensions and measures

The Dimensions of Residential Segregation	
Unevenness	
D	Index of Dissimilarity
G	Gini Index
H	Entropy Index Or Information Index
A1	Atkinson Index with b=.10
A5	Atkinson Index with b=.50
A9	Atkinson Index with b=.90
Exposure	
xPy	Interaction Index
xPx	Isolation Index
V	Correlation Ratio Or Eta Squared
Concentration	
DEL	Duncan's Delta Index
ACO	Absolute Concentration Index
RCE	Relative Concentration Index
Centralization	
PCC	Proportion In Central City
ACE	Absolute Centralization Index
RCE	Relative Centralization Index
Clustering	
ACL	Absolute Clustering Index
SP	Spatial Proximity Index
RCL	Relative Clustering Index
DPxy	Distance Decay Interaction Index
DPxx	Distance Decay Isolation Index

Source: Massey, Denton, 1988, The Dimensions of Residential Segregation, Social Forces, Vol. 67, No. 2

for fulfilling the segregation indices' evaluation criteria[4] (Reardon & O'Sullivan 2004; Reardon & Firebaugh 2002a; Karpiński & Wysieńska 2012).

Application of Existing Measures

The indices for the analysis were chosen after Massey and Denton[5] (1988), who selected the following indices for multidimensional analyses based on mathematical and empirical tests: dissimilarity index *D* (unevenness), isolation index ${}_xP_x$ (exposure), relative concentration index *RCO* (concentration), absolute centralisation index *ACE* (centralisation), and spatial proximity index *SP* (clustering). Each of the first three dimensions received a one and two group analysis. This saw the introduction of two additional calculations: the interaction index ${}_xP_y$ for exposure, and the delta index *DEL* for concentration. The cartograms were based on the calculated modified location index LQ_p. (Annex 1)

The Warsaw, Berlin and Paris Context

The studies cover three selected European metropolitan areas: Warsaw (hereinafter WMA), Berlin (BMA), and Paris (PMA). The examples therefore cover Central Europe, Western Europe, and the boundary between these two regions (the former East and West Berlin). The studies were conducted with full awareness of their mutual distinctiveness and of the great diversity across these regions. The results were not extrapolated to cover the other cities in the region, nor were the cities compared to each other. According to the transformation paradigm[6], successive stages of urban development (from Central European city to Western European city) are not subject to the analysis, since they developed under different contexts.

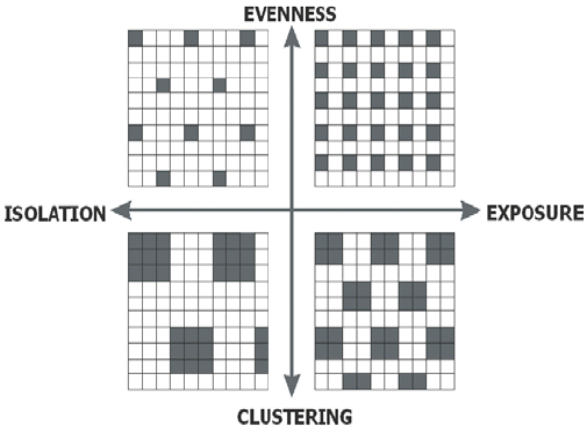

Figure 2. Spatial segregation dimensions
Source: Reardon & O'Sullivan 2004, Measures of Spatial Segregation, Pennsylvania State University

Analyses of multiple metropolitan areas produce many problems. One of these is the incomparability of administrative unit sizes (Table 2). The areas analysed in the PMA see the greatest number of units, and these are also the smallest ones; while the BMA has the lowest number of units while being the biggest in area. Only the cities of Paris and Warsaw have comparable sized areas and administrative divisions.

The next barrier concerns access to statistical data for both the years and the scope. France and Germany hold relatively recent data for both lower-level administrative units and census regions. The most recent census that gathered credible and detailed data for Polish cities was conducted in 2002, before Poland's entry into the European Union. In contrast to the French and German data, access to the statistical data for Polish census regions is limited and very expensive. Furthermore, every country focuses on gathering different data, which is conditioned by state policy. For example in Germany, the data concerning immigrants is very detailed (the integration policy), while the same data is very general in France and Poland (due to, respectively: assimilation policy and the small number of immigrants in society).

This article analyses the most recent data at the level of communes and districts for education, which is a satisfactory measure in determining population status and is relatively easy to access for all of the studied areas.

1-group analysis

In the WMA, in most dimensions, people with higher education have the greatest level of segregation. They are followed by people without diplomas, whereas the city of Warsaw itself, is more homogenous than the entire metropolitan area (Table 3). This results from the city's past socialistic profile; that is, the promotion of an egalitarian city through a residential policy and is not that different from all other socialist bloc countries (Kovacs 2013; Polanska 2011; Sýkora

[4] Criteria for segregation indices evaluation: (1) scale interpretability or size invariance, (2) arbitrary boundary independence or organizational equivalence, (3) location equivalence, (4) population density invariance, (5) composition invariance, also population composition problem, (6) principle of transfers and exchange, (7) additive spatial decomposability, and (8) additive grouping decomposability.

[5] The suggested analysis seems correct for the first stage of metropolitan segregation research. Specific analyses constitute the next research stage.

[6] Transformation – social changes following the collapse of the communist system, where the transformation process takes a completely different trajectory from that in the West. The transformations are unique to a region or country. This term is the opposite of the "transitional period", i.e. the process of "making up for historical deficiencies" and "catching up to the West". (Zarycki 2000)

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Table 2. List of administration units of the metropolitan areas of Warsaw, Berlin and Paris

		Warsaw (2002)		Berlin (2006, 2012)		Paris (1999, 2009, 2011)	
		communes of metropolitan area	city districts	communes of metropolitan area (Land Brandenburg*)	city districts (Bezirke)	communes of metropolitan area (Île-de-France)	city districts (arrondissement)
units number		**72**	**18**	**418**	**12**	**1280**	**20**
surface (km^2)	minimum	6	9	3	20	0.1	1
	maximum	166	80	417	168	172	16
	average	75	29	70	74	9	5
population	minimum	5654	13 731	380	218 935	28	17 614
	maximum	54 505	235 381	153 347	364 794	113 085	236 491
	average	16 569	93 844	6 004	281 269	8473	111 705

Source: Institut National de la Statistique et des Etudes Economiques, Statistisches Bundesamt, Statistical Office in Warsaw, July 2014

Table 3. Measures of segregation for the metropolitan area and city of Warsaw for 2002

	Warsaw Metropolitan Area				Warsaw			
indicators	**unevenness - D**	**exposure - $_aP_a$**	**concentration - DEL**	**centralization - ACE**	**unevenness - D**	**exposure - $_aP_a$**	**concentration - DEL**	**centralization - ACE**
higher education	0.186	0.776	0.754	0.821	0.086	0.735	0.388	0.440
post-secondary school	0.092	0.949	0.702	0.624	0.019	0.945	0.391	0.440
upper secondary school	0.066	0.622	0.684	0.728	0.016	0.593	0.400	0.456
basic vocational school	0.178	0.821	0.493	0.468	0.110	0.887	0.406	0.439
primary school	0.138	0.756	0.513	0.536	0.066	0.829	0.391	0.440
primary school unfinished or no education	0.248	0.958	0.400	0.378	0.077	0.986	0.353	0.402

Source: own calculations based on the data of the Statistical Office in Warsaw, July 2014

1999). The difference between the cities of Western Europe and Poland has been shrinking since the 1980s (Polanska 2011). This shrinking difference was the effect of housing deficiencies and the construction system, which introduced various living conditions in individual cities, regions, and districts, and thus the urban space became more elite from the 1970s onwards (Węcławowicz 1992, 2007). During the transformations following 1989, the privatisation of the housing sector and withdrawal of the public sector promoted social and spatial polarisation (Warzywoda-Kruszyńska 2011; Gądecki 2009). In Warsaw, people with a higher education are not the most separated group, because many of them still live in "mixed" housing districts, just as during socialism, which is evidence of the social and spatial inertia of Warsaw (see Smętkowski 2009).

In the BMA, the results show that there is little difference between the individual groups (Table 4). The highest segregation level concerns people with higher education. There are slight differences between people with secondary education and people with primary education. Much like the results in Poland, the metropolitan area shows greater segregation differences than the city of Berlin itself. The category of people who graduated in the German Democratic Republic (GDR) is

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Table 4. Measures of segregation for the metropolitan area and city of Berlin for 2012

	Berlin Metropolitan Area				Berlin			
indicators	**unevenness - D**	**exposure - $_aP_a$**	**concentration - DEL**	**centralization - ACE**	**unevenness - D**	**exposure - $_aP_a$**	**concentration - DEL**	**centralization - ACE**
polytechnic / university	0.122	0.313	0.715	0.732	0.118	0.372	0.286	0.259
secondary school (high school) or equivalent degree	0.083	0.161	0.657	0.693	0.127	0.190	0.201	0.193
completion of the GDR education polytechnic school	0.305	0.275	0.331	0.306	0.518	0.214	0.433	0.020
main (elementary) school graduation	0.056	0.181	0.614	0.610	0.106	0.201	0.225	0.215
without school diploma	0.050	0.184	0.635	0.665	0.092	0.207	0.266	0.299

Source: own calculations based on the data of the Statistisches Bundesamt, July 2014

noteworthy. In this group, the segregation trends dominate both the BMA and the city itself. For nearly 40 years, since the end of the Second World War until the 1990s, the State of Brandenburg belonged to the GDR, and Berlin was divided into east and west. East Berlin, which contained within its borders the historical part of the city, was the capital of the German Democratic Republic, hence administrative functions, economic and cultural activities were concentrated in this part of town. West Berlin, in fact, lost its position and survived only thanks to funding submitted by the government of the Federal Republic of Germany (FGR). During the division of the city into two parts, housing policy was conducted in different ways, which contributed to the diversity of the spatial distribution of social groups. Researchers into segregation in Germany point out the considerable differences in the spatial behaviour between the former inhabitants of the GDR and FRG[7] (they include Tomann 1996; Clapham 1995; Kemper 1998). The people who graduated in the GDR are still living in the districts built during the socialist era.

In the PMA, the spatial and structural aspects of the arrangement of the obtained results are similar to that of Warsaw, but the values are slightly higher (Table 5). The obtained results are characteristic of Paris society, where the people with the highest status strive to live in rich enclaves, and the residents have a similar way of life: from school, through college, to professional careers (Grzegorczyk 2013; Préteceille 2006; Maurin 2004). The high degree of the homogeneousness of Paris results from the revitalisation programmes conducted in the 1960s and, on a smaller scale, the 19th-century revitalisation conducted by Haussmann[8].

[7] Tomann (1996) points out that the FRG is dominated by households that take advantage of the well-kept urban tissue, and where the differences in social status are low. This space does not present visibly poor areas or abandoned buildings. Most of the older buildings in the city centres have been reconstructed or revitalised. The lower standard homes are occupied mainly by immigrants. There is also a high demand for lower standard and rental homes, the causes of which include the effective regulation of housing policy and the continuous inflow of new residents. The GDR continues to present signs of the "former" socialist policy. Numerous multi-storey buildings are in ruin and require extensive reconstruction or demolition. There are also partially abandoned areas. Despite the numerous positive changes observed in these areas, they continue to be less popular among the locals.

[8] In those days, the industrial functions were moved, along with the living quarters for the poor, beyond the northern city limits. In the 19th century, the facades of the buildings along the streets were renovated, but the courtyards were left untouched.

2-group Analysis

In the WMA, people with a short period of primary education or no education have the greatest separation (Table 6), and it is at the highest when compared to individuals with higher education. The Warsaw community is clearly divided into two groups: people with no education, primary education, and vocational education, who live in similar urban areas; and people with higher education, post-secondary education, and secondary education, who live in different districts and communes. The fact that people with higher and secondary education were inhabiting similar areas was pointed out by Węcławowicz (1992) in the analyses of the 1970s and 1980s.

In the BMA, only people from the GDR are separated from other groups, especially from those with a higher education (Table 7). The values obtained are the highest among the metropolitan areas that were studied. The analysis of the results in Germany shows that there is no great spatial diversity associated with education. The correlation of the indices and other properties, such as age, income, or ethnic origin, would allow for the establishment of greater differences (as pointed out by Kemper 1996; Friedrichs 2011).

In the PMA, the comparison of two population groups distinguishes the people with higher education, who are separated from all other population groups, especially from the people with no education and vocational education (CAP and BEP); over 40% of the population would have to change their place of residence for the populations of these groups to be evenly dispersed (Table 8). The lowest dissimilarity indices for people with higher education appear for people with a short period of higher education and secondary education, but they are still high; approximately 25% of the population would have to change their place of residence to achieve social mixture. The other population groups hold higher dissimilarity indices with the group of people with no education, although they are considerably lower than those quoted previously. Therefore, the thesis of Maurin (2004) concerning the social separation of every social group in France is partially confirmed, which includes the unique separation of the most educated group, i.e. the high elitism of the Paris community. The commune and district separation trends among the remaining population groups are much weaker.

Analysis with the interaction index has two serious limitations. First of all, it should be interpreted as the probability of contact among people of various population groups (e.g. with different

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Table 5. Measures of segregation for the metropolitan area and city of Paris for 2009

	Île-de-France			Paris			
indicators	**unevenness - *D***	**exposure - $_aP_a$**	**concen-tration - *DEL***	**unevenness - *D***	**exposure - $_aP_a$**	**concen-tration - *DEL***	**centrali-zation - *ACE***
long period of higher education	0.262	0.493	0.758	0.087	0.805	0.196	0.147
short period of higher education	0.075	0.156	0.682	0.022	0.141	0.222	0.077
upper secondary school (baccalaureat, BP - Brevet Professionnelle)	0.045	0.201	0.685	0.023	0.175	0.213	0.077
basic vocational school (CAP-Certificat d'aptitude professionnelle, BEP - Brevet d'Etudes Professionnelles)	0.157	0.246	0.644	0.116	0.099	0.284	0.026
lower secondary school (BEPC - Diplôme national du brevet)	0.071	0.066	0.686	0.067	0.053	0.243	0.046
Certificate of Primary Education (CEP - Certificat d'études primaires)	0.127	0.083	0.661	0.097	0.052	0.265	0.038
without any diploma	0.178	0.288	0.723	0.134	0.172	0.295	0.061

Source: own calculations based on the data of the Institut National de la Statistique et des Etudes Economiques, July 2014

Table 6. Dissimilarity index D for the metropolitan area of Warsaw for 2002

	higher education	**post-secondary school**	**upper secondary school**	**basic vocational school**	**primary school**	**primary school not completed or no education**
higher education		0.107	0.125	0.362	0.321	0.420
post-secondary school	0.107		0.033	0.261	0.223	0.335
upper secondary school	0.125	0.033		0.239	0.201	0.311
basic vocational school	0.362	0.261	0.239		0.050	0.108
primary school	0.321	0.223	0.201	0.050		0.127
primary school not completed or no education	0.420	0.335	0.311	0.108	0.127	

Source: own calculations based on the data of the Statistical Office in Warsaw, July 2014

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Table 7. Dissimilarity index D for the metropolitan area of Berlin for 2012

	polytechnic / university	secondary school (high school) or equivalent degree	completion of the GDR education polytechnical school	main (elementary) school graduation	without school diploma
polytechnic / university		0.063	0.424	0.113	0.081
secondary school (high school) or equivalent degree	0.063		0.3825	0.073	0.0508
completion of the GDR education polytechnic school	0.424	0.382		0.340	0.354
main (elementary) school graduation	0.113	0.073	0.340		0.051
without school diploma	0.081	0.051	0.354	0.051	

Source: own calculations based on the data of the Statistisches Bundesamt, July 2014

Table 8. Dissimilarity index D for the metropolitan area of Paris (Île-de-France) for 2009

	without any diploma	primary school	lower secondary school	basic vocational school	upper secondary school	short period of higher education	long period of higher education
without any diploma		0.165	0.159	0.182	0.182	0.239	0.406
primary school	0.165		0.090	0.092	0.120	0.168	0.371
lower secondary school	0.159	0.090		0.117	0.057	0.109	0.319
basic vocational school	0.182	0.092	0.117		0.139	0.187	0.416
upper secondary school	0.182	0.120	0.057	0.139		0.072	0.287
short period of higher education	0.239	0.168	0.109	0.187	0.072		0.246
long period of higher education	0.406	0.371	0.319	0.416	0.287	0.246	

Source: own calculations based on the data of the Institut National de la Statistique et des Etudes Economiques, July 2014

education) in their place of residence, whereas most contact occurs outside of the place of residence[9]. The other limitation is the dependence of the interaction index on the demographic structure of the society. This has significant theoretical substantiation, because a greater share of the given group increases the probability of interaction with its representatives. However, at the interpretative stage, the results for this index often differ from those for other segregation indices and may lead to misleading conclusions. The interaction index in table 9 shows the highest relative segregation of people with higher education, but the results are very low. There was no attempt to present the remaining calculations relating to the limitations of this index.

Similarly, the relative concentration index *RCO* is limited, as it cannot be established for groups with a very small population or when one areal unit is much bigger than the others, e.g. Warsaw in the WMA. Such analyses are incomplete and fail to show the proper relative concentration, therefore, their results are not presented in this article.

[9] This limitation seems less important in the case of such big units as districts or communes.

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Table 9. Interaction index ${}_xP_y$ for the metropolitan area of Paris (Île-de-France) for 2009

	without any diploma	primary school	lower secondary school	basic vocational school	upper secondary school	short period of higher education	long period of higher education
without any diploma		0.002	0.002	0.003	0.005	0.004	0.013
primary school	0.004		0.001	0.003	0.004	0.004	0.011
lower secondary school	0.005	0.002		0.003	0.005	0.004	0.014
basic vocational school	0.003	0.001	0.001		0.003	0.003	0.008
upper secondary school	0.005	0.002	0.002	0.003		0.005	0.015
short period of higher education	0.005	0.002	0.002	0.003	0.006		0.016
long period of higher education	0.010	0.003	0.004	0.006	0.011	0.009	

Source: own calculations based on the data of the Institut National de la Statistique et des Etudes Economiques, July 2014

Table 10. Spatial proximity index SP for $f(d_{ij})=\exp(-d_{ij})$ for Warsaw (2002), Berlin (2010), and Paris (2009)

Level of education	Warsaw	Level of education	Berlin	Level of education	Paris
higher education	0.998	polytechnic / university	1.017	long period of higher education	1.014
post-secondary school	1.000	secondary school or equivalent degree	1.209	short period of higher education	1.000
upper secondary school	0.995	the GDR education polytechnic school	1.775	upper secondary school	1.000
basic vocational school	0.995	main (elementary) school graduation	1.165	basic vocational school	1.003
primary school	0.994	without school diploma	1.095	lower secondary school	1.001
primary school not completed or no education	0.993			primary school	1.001
				without any diploma	1.007

Source: own calculations based on the data of the Statistical Office in Warsaw, Statistisches Bundesamt, Institut National de la Statistique et des Etudes Economiques, July 2014

Spatial Analysis

The spatial proximity (*SP*) index shows the level of clustering of minority groups.[10] The results obtained for Warsaw show that there are no clusters of people from specific groups, and the people with various education levels inhabiting specific districts are evenly spread in the urban space (value close to 1.00) (Table 10). In Berlin, the obtained results indicate the greatest clustering tendency among the groups covered by the study. In all cases the *SP* was over 1.00, and in the case of people who graduated in the GDR it was 1.77. The interpretation of the results shows that this group has the greatest clustering tendency. In Paris, the results depart slightly from the value of 1.00, which indicates an even spread of the individual population groups. People with the highest (in the beautiful western districts) and lowest (northeastern part of the city) education present a small clustering tendency. The low values may result from the homogeneous and simultaneously elite profile of the city. In all of the studied areas, greater values of the *SP* index can be expected for the entire metropolitan areas, which would correspond to the analysis conducted in this article.

The last index to be analysed was the modified location index LQ_p. The WMA shows a characteristic loss of its intensity with reduced distance (distance-decay pattern), with islands of stronger concentration for people with higher education in Warsaw (Ursynów (1.58), Żoliborz, Wilanów, and Śródmieście) and its neighbouring communes (Podkowa Leśna (2.12)). This also applies to the westernmost and easternmost areas of the metropolitan area with a high concentration (LQ_p reaching the value of 5) of people with no education or a short period of primary education (Fig. 3, 4).

[10] The previously discussed indices focused on the allocation of specific groups in the general population (*ID*, ${}_sP_s$, *DEL*) or the distance from the given central point (*ACE*). *SP* concerns the allocation of the minority groups in relation to each other in specific spatial units (communes, districts). High *SP* indicates the presence of concentration areas of the given groups in the neighbouring units, which is evidence of e.g. ethnic enclaves. The low grouping level means that there are no such clusters in the space and that the representatives of the individual groups are spread evenly. This indicator was developed to distinguish cities with numerous minority clusters from those with a single enclave, which often occupies a considerable area. The main problems in *SP* calculation include the establishment of the average distance between the specific analysed units (communes, districts). This study presents the procedure recommended by White (1983), where the index is calculated with the negative function of the exponent distance between units *i* and *j*: $f(d_{ij}) = \exp(-d_{ij})$, thanks to which the influence of the neighbourhood drops suddenly with the distance from the target unit.

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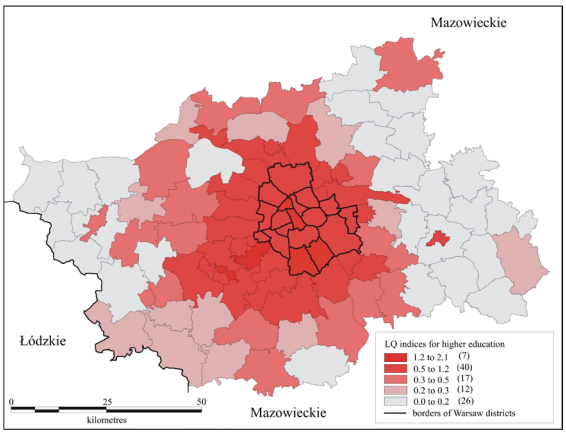

Figure 3. Distribution of people with higher education in the WMA in 2002 expressed with the location index LQ_p
Source: own calculations based on data of the Statistical Office in Warsaw, July 2014

In the BMA, the LQ_p results obtained are clearly higher than those of the WMA. People with higher education tend to concentrate mainly in the western and south-western parts of the Brandenburg Land. The highest LQ_p value was obtained in Berlin and other cities of the Land, such as Potsdam, Cottbus, Brandenburg, and Frankfurt (Oder). The phenomenon gets less intense as the distance from Berlin grows. The concentration of people with no education is present mainly in the western part of Berlin, where the percentage of immigrants is highest. In the BMA, the highest values were achieved in the communes of Oder-Spree and Potsdam-Mittelmark. (Fig. 5, 6).

For the PMA, the analysis of the cartogram (Fig. 7) indicates a strong self-segregation of people with higher education. that is, a high indicator value and proximity of areal units. This group is focused in the western part of the city and the neighbouring western communes of the internal agglomeration, or areas currently inhabited by the grand French bourgeoisie and aristocracy. These are the traditional so-called "beautiful districts" of Paris (*les beaux quartiers*), the most expensive and prestigious area in the city. The greatest LQ_p indices are present in districts V, VI, and VII (over 1.7). People with no education are concentrated mainly in the north-eastern communes of the internal agglomeration (Fig. 8). The industrial and transport profile of this area dates back to the 19th century. The highest LQ_p values for people with no education are in the communes of Hautefeuille (4.75), Clichy-sous-Bois (4.2), and district XIX (1.7), for people with primary education (CEP) in Gravon (5), and for people with vocational education (CAP BEP) in Montenils (6). These areas host a considerable share of social housing (Grzegorczyk 2013; Grzegorczyk 2014). Such fragmentation of the PMA remains an important problem for its development. French urban policy is focused on this issue; however, its effectiveness is limited. One cause, *inter alia,* of this ineffectiveness is associated with governance difficulties in the PMA, which are a result of an unsuitable territorial division: too small a city in too vast a region (Burgel 2008).

Conclusions – What Provides Opportunities and What Causes Problems?

This article has aimed to point out the measures of segregation that present the segregation level in the most complete manner, and their application in the context of three European metropolitan areas: Paris, Warsaw, and Berlin. The multidimensional analysis presented in the article provides a broader view of segregation, but it should be noted that more detailed studies providing for more complex conclusions could be provided by analyses on a more detailed scale.

The argument in this article presented the following social segregation properties:

- the existing differences in the level and nature of the phenomenon between the countries of Western and Central Europe;
- the highest segregation in groups of extreme social status (particularly in people with high education);
- the highest segregation in relation to entire metropolitan areas and the relative homogeneity of capital cities;
- visible spatial inertia in all of the analysed metropolitan areas;
- capital city space becoming more elite, where:
  - Paris presents the highest segregation of the top social status groups, who inhabit the rich western enclaves, the so-called "beautiful districts",
  - Warsaw presents a concentration of the top social status groups mainly in the city, and simultaneously the highest segregation level in groups with the lowest status,
  - Berlin presents a concentration of the top social status groups and considerable differences in the segregation level of the western and eastern parts. West Berlin presents a concentration of people with lower education.

The significance of the social and spatial processes seem to be an important determinant of the level and nature of segregation in the metropolitan areas analysed. With its contextual segregation development or the path-dependent process, the Maloutas thesis (2012) seems to be correct in light of the conducted analysis for the three selected metropolitan areas. The historical differences in the economic and political systems of the three areas studied; the different courses of state transformation and intervention, specifically concerning housing policy, and the inherited urban structures divided, and continue to divide, the variations of social segregation. The importance of the spatial context, enforcement of the mutual network, condition of households, individual choices, and the neighbourhood effect, all specified by Maloutas (2012) in the typology of segregation contexts may be observed only after more detailed analyses concerning smaller areal units. The summary of the methods of segregation studies provides the following conclusions:

- As a measure of social status, the level of education is useful due to its broad availability, although the differences in the specification of successive education levels between the countries are noticeable.
- A more direct measure of social status is the social and professional population structure (see Préteceille 2006, Grzegorczyk 2013), but Polish statistical data only provides this for the city of Warsaw.

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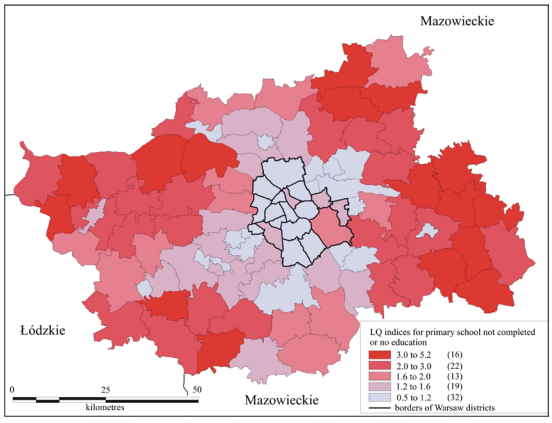

Figure 4. Distribution of people with no diploma in the WMA in 2002 expressed with the location index LQ_p
Source: own calculations based on data of the Statistical Office in Warsaw, July 2014

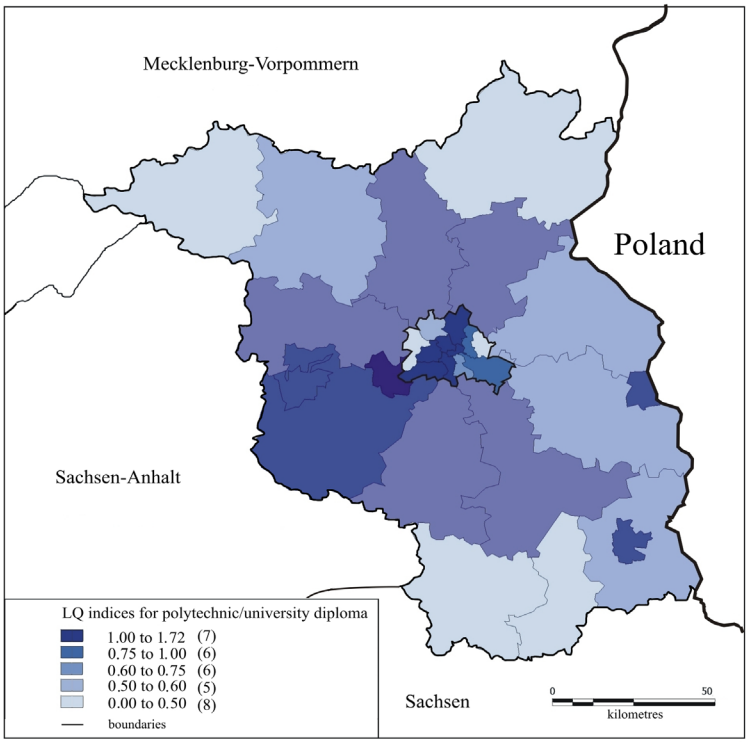

Figure 5. Distribution of people with higher education in the BMA in 2012 expressed with the location index LQ_p
Source: own calculations based on data of the Statistisches Bundesamt, July 2014

- The study operationalisation for metropolitan areas remains difficult due to the availability of GIS data and statistical data, particularly in the research of Polish cities.
- As previously discussed, studies for units smaller than communes and districts are recommended, although there is a clear limitation produced by the availability of statistical data.
- The existing segregation measures allow for the study of social segregation (professional literature using segregation measures are dominated by studies of ethnic and racial segregation) and establishment of social and economic enclaves; therefore, these studies are the answer to the challenges of the age of globalisation.
- Segregation measures are suitable for domestic comparative studies, whereas comparisons of international cities are less recommended due to the contextual nature of the phenomenon.
- The highest usability is presented by the following indices: dissimilarity *ID*, delta *DEL*, spatial proximity *SP*, and location LQ_p, while the indices of isolation ${}_aP_a$, interaction ${}_aP_b$, and relative concentration *RCO* are considerably limited.

The aforementioned studies partially solve the problem of the spatial analysis of segregation. Therefore, in the context of the development of GIS and new segregation measures, it would be wise to apply other measures in dynamic studies covering

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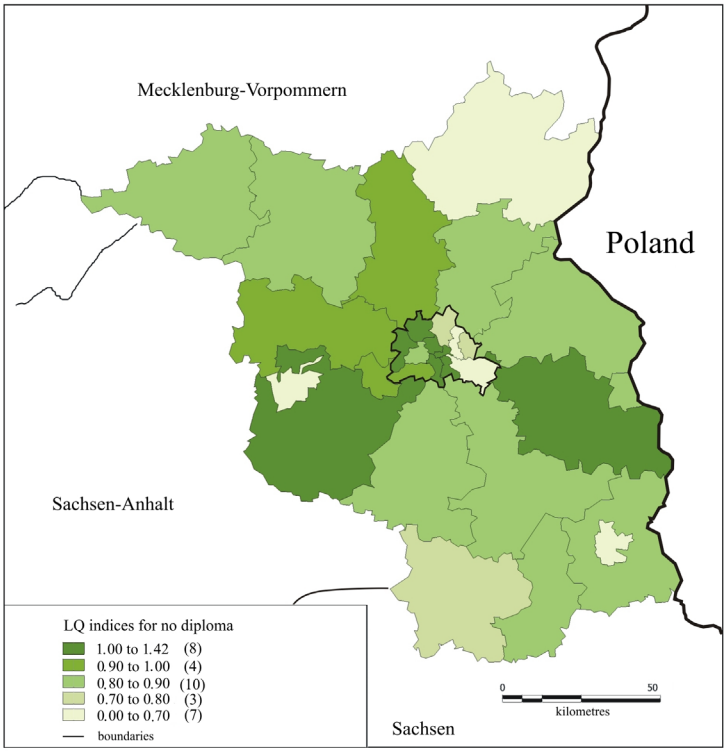

Figure 6. Distribution of people with no diploma in the BMA in 2010 expressed with the location index LQ_p
Source: own calculations based on data of the Statistisches Bundesamt, July 2014

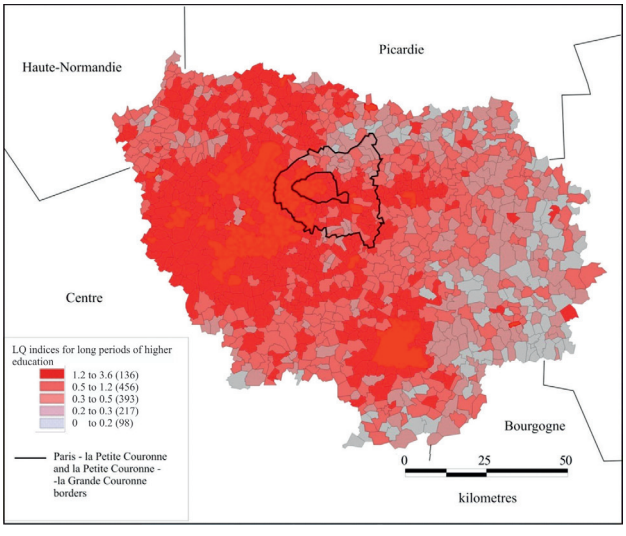

Figure 7. Distribution of people with a long period of higher education in Île-de-France in 2009 expressed with the location index LQ_p
Source: own calculations based on data of the Institut National de la Statistique et des Etudes Economiques, July 2014

a greater statistical data group (e.g. age, household structure, social and professional categories, unemployment level, immigrants, and foreigners). In light of the review of the literature, the promising measures include the Gini index (Massey& Denton 1988 as cited in Gini 1912), spatial modification of the Gini index (Dawkins 2004), and the global and local spatial segregation indices presented in the work of Feitosa et al. (2007).

Acknowledgements

This project is financed by the National Science Centre in Poland (funds granted based on the decision number DEC-2013/09/B/HS4/01492)

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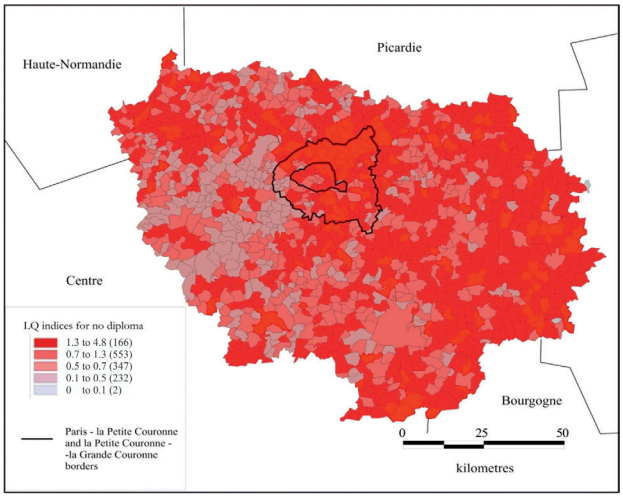

Figure 8. Distribution of people with no diploma in Île-de-France in 2009 expressed with the location index LQ_p
Source: own calculations based on data of the Institut National de la Statistique et des Etudes Economiques, July 2014

Annex 1

Formulas used in this article.

1. Dissimilarity index (*D*)

$$D = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{y_i}{Y}\right|$$

D ϵ ⟨0 ,1⟩

where x_i and y_i is the number of members in the analysed groups in *i* area unit, *X* and *Y* – the groups' population number in the whole city subdivided into *n* area units.

2. Isolation index ($_xP_x$) and interaction index ($_xP_y$)

$$_xP_y = \sum_{i=1}^{n}\left(\frac{x_i}{X}\times\frac{y_i}{t_i}\right) \quad _xP_x = \sum_{i=1}^{n}\left(\frac{x_i}{X}\times\frac{x_i}{t_i}\right)$$

$$P \in <0,1>$$

where t_i is the total population number in *i* area unit.

3. Delta index (*DEL*)

$$DEL = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{a_i}{A}\right|$$

DEL ϵ <0,1>

where a_i is the land area of *i* area unit, *A* – the total land area in the city.

4. Absolute centralisation index (*ACE*)

$$ACE = [\sum_{i=1}^{n}(X_{i-1}\times A_i)] - [\sum_{i=1}^{n}(X_i \times A_{i-1})]$$

ACE ϵ <-1,1>

where X_i and Yi is the respective cumulative proportions of *X*'s and *Y*'s population in tract.

5. Relative concentration index (RCO)

$$RCO = [\frac{\sum_{i=1}^{n}(\frac{x_i a_i}{X})}{\sum_{i=1}^{n}\frac{y_i a_i}{Y}} - 1] / [\frac{\sum_{i=1}^{n_1} t_i \frac{a_i}{T_1}}{\sum_{i=n_2}^{n} t_i \frac{a_i}{T_2}} - 1]$$

RCO ϵ <-1,1>

where a_i is the land area of *i* area unit, *A* – the total land area in the city, n_1 – the rank of the tract where the cumulative total population of areal units equals the total minority population of the city, summing from the smallest unit up, n_2 – the rank of the tract where the cumulative total population of units equals the minority population totalling from the largest unit down, T_1 – the total population of tracts from 1 to n_1, and T_2 – the total population of tracts from n_2 to n.

6. Spatial proximity index (*SP*)

$$P_{xx} = \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{x_i x_j c_{ij}}{X^2} \quad P_{xy} = \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{x_i y_j c_{ij}}{XY} \quad SP = \frac{XP_{xx} + YP_{yy}}{TP_{tt}}$$

SP>0

where x_i is population number in *i* area unit, x_j- population number in *j* area unit, c_{ij} – distance function between areas, P_{xx} – average proximity between group X members, P_{xy} average proximity between members of X and Y, P_{yy} - average proximity between group Y members , P_{tt} - average proximity among all members of the population.

7. Modified location index LQ_p

$$LQ_p = \frac{_k x_i / y_i'}{_kX / Y'}$$

$LQ_p \geq 0$

where $_kx_i$ – population number in *k* group and in *i* area unit, y_i' – population number in *i* area unit decreased by *k* group population, $_kX$ – population number in *k* group in the whole city, *Y'* – city population number decreased by *k* group population in the city.

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