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Estimating the actual population in suburban areas. The case of Czernica municipality (Wrocław suburban zone)

Abstract: Residential suburbanization is one of the processes, which takes place on a large scale in the vicinity of large cities. The suburban areas of Wrocław are no exception, witnessing a dynamic influx of people and increased construction activity. This article strives to identify the scale of residential suburbanization based on the case study of Czernica municipality, which is part of the suburban area of Wrocław. The discussion of the problem of population underestimation is attributed to the failure to comply with obligations of compulsory registration at the place of residence. It led to disparities between the actual local population size and the official statistical records. This analysis seeks to determine how many people actually reside in the Czernica municipality using a proprietary method of estimating the actual number of residents based on pooled statistical data on registered residence originating from the General Electronic Civil Registration System (the PESEL register) from 2012 and spatial data from the Topographic Database (BDOT) of 2013. The article presents the scale of population underestimation in the Czernica municipality in years 2012–2013 and possibilities and limitations in application of the method constructed by authors in other suburban areas.

Key words: residential suburbanization, population statistics, population estimation, suburban areas, Wrocław

Introduction

Declining reliability of population statistics is one of the biggest challenges in demographic analyzes (Keilman, Kučera 1991, Sakson 2002, Gołata 2005, Sleszyński 2005, 2011, 2016, Jończy 2010). The difficulties with validating the actual number of residents can be attributed to mass migrations that have coincided with the socio-economic developments and the technological advancements in the transport sector (Jończy 2010, Szymańska, Biegańska 2011a, Matusik et al. 2012, Pytel 2012, Kubeš 2013, Gałka 2018, Šašek et al. 2019, Dolińska et al. 2020, Il-

nicki, Szczyrba 2021). Since the statutory obligation to register the place of residence ceased to be enforced in Poland and the migratory flows could no longer be effectively monitored, disparities between the data recorded in public statistics and the actual number of residents in some localities have emerged. The greatest differences are found in suburban settings that have attracted people who leave cities for more spacious and peaceful environs (Śleszyński 2011, 2016).

A similar situation is evident in the suburban area of Wrocław, which is one of the most dynamically developing areas in Poland due to the influx of new residents and intensive construction activity (Namyślak, Sikorski 2010, Ciok, Leśniak 2015, Heffner 2016, Biegańska 2019, Szmytkie 2019). This area is often considered to be a model example of residential suburbanization in the vicinity of a large city. It is an effect of very dynamics and duration of the processes, which have taking place in this area since the second half of the 19th century. However, the processes of suburbanization taking place at the turn of the 20th and 21st centuries had the most significant impact on the transformation of the contemporary settlement network surrounding Wrocław (Szmytkie 2020). Residential suburbanization in the vicinity of Wrocław has been discussed many times before in the literature (Zathey 2002, Gonda-Soroczyńska 2009, Namyślak, Sikorski 2010, Szewrański et al. 2013, Ciok, Leśniak 2015, Ciok 2017, Szmytkie 2019). The available body of evidence also includes cross-sectional studies discussing to the entire Dolnośląskie Voivodeship or its selected areas (Zipser 2006, Kajdanek 2012, Maciejuk 2012, Mayer, Szmytkie 2014, Szmytkie 2019). Unfortunately, the majority of studies on residential suburbanization explore the scale of this phenomenon as determined on the basis of existing statistical data referring to the size and intensity of construction activity in suburban areas, as well as official population data, which may not accurately reflect the actual size of migratory flows. Moreover, a significant share of publications on construction activity relates to single-family housing, leaving aside the aspects of demographic and spatial changes generated by the emerging multi-family housing, however important for the suburban areas.

This article presents a method of estimating the actual number of people residing in smaller statistical units (municipalities or statistical localities) situated in a suburban area, where intensive processes of residential suburbanization take place. It is also intended to discuss the disparities between the actual number of residents and the population data included in official statistics. To achieve the research purpose of this study, the authors constructed a new research method, based on the comparison of statistical data on residential registrations (PESEL register) from the 2012 and the spatial data from the Topographic Database (BDOT) of 2013. The results of the study are illustrated by the case of Czernica municipality, which is characterized by intense construction activity attributed to the influx of people from the nearby city of Wrocław. The following research hypothesis was tested in this study: "The actual number of residents in the Czernica municipality is higher than reported in official statistics. The highest levels of population underestimation are typical for areas with more dynamic construction

activity, which is an example of suburban areas of Wrocław”. This hypothesis was tested in conjunction with the following auxiliary research questions:

1. What is the actual number of residents of the Czernica municipality, and what is the level of underestimation of residential suburbanization in this area?
2. Which localities of the Czernica municipality are characterized by the greatest disparities between the actual population and the population data reported in the official statistics?
3. Is there any correlation between construction activity and population movements affect on the level of underestimation of the population size in the Czernica municipality?

Residential suburbanization in suburban zones

The growing interest in the development of suburban zones in post-socialist countries can be attributed to the scale and dynamics of suburbanization processes taking place in these countries (Brezdeń, Szmytkie 2019). Many different definitions of this complex and multidimensional phenomenon have been proposed in the literature (Wójcik 2012, Zborowski, Raźniak 2013). Suburbanization is mostly defined as a series of urbanization changes in rural areas resulting from the expansion of cities, i.e. rural areas are progressively incorporated into the administrative boundaries of a city (Brueckner 2000, Champion 2001, Szymańska, Matczak 2002, Schneider-Sliwa 2006, Hirt, Stanilov 2007, Paccione 2009, Szymańska, Biegańska 2011b). This approach draws on a model of urban development in which suburbanization is identified as the second stage of city development in a theory of a city life cycle (Klaassen, Paelinck 1979, van den Berg et al. 1982). It is characterized by an intense population growth and housing development, in particular single-family housing (residential suburbanization), in suburban zones. With the dynamic expansion of the suburban areas, transition zone between the urban and rural landscape becomes increasingly blurry, and the dichotomy between these two types of settlements adopted so far in the literature has been replaced by the term urban-rural continuum (Whitehand 1967, 1988, Caves 2005, Knox, Mc Carthy 2005, Nuissl, Rink 2005, Bański 2006, Sýkora, Ouředníček 2007, Bański 2012, Szmytkie 2020). Sometimes a distinction is made based on interactions between urban, peri-urban and rural zones (Korcelli et al. 2012). The differences between the suburbanization model in Poland and the Western European model of suburbanization result from the dynamic changes in population and spatial arrangement with which the asymmetries and imbalances caused by the post-war policy are neutralized. The fast, chaotic and spontaneous process of suburbanization in Poland is often determined by the fact that several stages of the development cycle of the city take place simultaneously (Stanilov 2012).

Residential suburbanization is one of the ways in which suburban zones can develop, and is most often defined as the outflow of people from the city center to the newly emerging housing developments in a suburban zone. The dynamic

growth of single-family housing in the vicinity of large cities contributes to the depopulation of central districts of the city (Zborowski 2002, Sýkora, Ouředníček 2007). Also, this process has an impact on the formation of new settlement structures in rural areas around cities, followed by the expansion of built-up and urbanized areas and their increasing share in the overall structure of land use, at the expense of arable land and undeveloped areas (Matlovič, Sedláková 2007, Sýkora 2007, Kubeš 2015). Lower prices of land in the suburban areas, the development of the individual transport, growing wealth of the society, favorable housing policy pursued by suburban municipalities, the desire to improve the existing housing conditions, and the pressure of developers are the main factors that drive the process of residential suburbanization (Zborowski 2002, Matlovič, Sedláková 2007, Sýkora, Ouředníček 2007, Zborowski, Raźniak 2013, Kubeš 2015). The expansion of suburban areas around the largest cities often means that increasingly more undeveloped areas are gobbled up in a dynamic and disorganized manner, and their functions become changed. It may also involve degradation of the landscape. An uncontrolled urban development is referred to as urban (or suburban) sprawl (Brueckner 2000, Ewing 2008, Mantey, Sudra 2016, Sudra 2019).

However, it is necessary to specify that changes in migratory trends taking place in the suburban area are spatially diversified and correlated with the dynamics of the construction activity, which is currently one of the distinguishing features of rural areas located around large cities (Zathey 2002, Bański 2008, Ciok, Leśniak 2015, Ciok 2017, Mantey, Sudra 2019). Single-family housing in the suburban area tends to concentrate along the main communication routes, with areas of disorganized, fragmented and scattered development in the areas situated in-between those routes (Wójcik 2006, Biegańska 2019, Mantey, Sudra 2019). The intensifying urbanization pressure in the suburban area contributes to the loss of the primary function of villages, degradation of traditional rural landscape, and changes in the morphology and physiognomy of rural settlements (Miszewska 1985, Lisowski, Grochowski 2009, Bański 2012, Staszewska 2012). The progress of suburbanization processes taking place in the vicinity of Wrocław is no different from the specific patterns of suburbanization in other countries of Central and Eastern Europe (compare with Sýkora 1999, Hirt, Stanilov 2007, Sýkora, Ouředníček 2007, Kubeš 2013).

The transformations taking place in the suburban areas are most evident in the spatial development of rural areas, i.e. growing housing densities, coexistence of urban and rural settlement forms, non-agricultural land use, and the expansion of infrastructure facilities (Brueckner 2000, Soós, Ignits 2003, Matlovič, Sedláková 2007, Ewing 2008, Lisowski, Grochowski 2009, Kajdanek 2011, Zborowski, Raźniak 2013, Kubeš 2015, Mantey, Sudra 2019, Szmytkie 2021). The ongoing process of depopulation of city centers causes a decrease in tax revenues of urban municipalities, which is accompanied by increasingly intense road traffic, the growing costs of expansion of technical infrastructure, as well as the growing costs and time of commuting to work for people who moved to rural areas (Brzeziński 2011). Moreover, the process of suburbanization contributes to

the overcoming of disadvantages in the socio-economic structure of the population of suburban zones, originally inhabited by less educated people with lower incomes. Currently, these disproportions have narrowed, and owning a house on the outskirts of the city is often considered a sign of a high social status (Sýkora, Ouředníček 2007).

The problem of population underestimates in suburban areas

Reliable information about the number of people living in a given area is one of the cornerstones of evidence-based social, economic, and spatial policy. Official population statistics in Poland are limited to the register of residents based on permanent or temporary residence registrations, and leave out people who are not registered at their actual place of residence (Śleszyński 2016). The problem of underestimation in population size estimates concerns areas characterized by a positive net migration, particularly large urban agglomerations and the surrounding areas that expand as a result of suburbanization. Similar disparities are also characteristic of some peripheral municipalities whose population is overestimated (Śleszyński 2014, Latocha et al. 2018). If we compare the current population records of 2001 and the data collected during the national census of 2002, the disparity between the registered population and the actual number of residents of these areas is estimated at up to 20% (Śleszyński 2005).

In Poland, a population and housing census is conducted according to the Act on population records and identity cards of April 10, 1974, as amended (Journal of Laws 2006). According to this act of law, every person having a Polish citizenship or residing in the territory of Poland has the duty to register their residence, and when changing the place of residence – to deregister the former place of permanent or temporary residence. Permanent residence is defined as the intention to permanently reside in a given place, at the address indicated. Temporary residence is defined as temporary residing away from the place of permanent residence for no more than two consecutive months. Once this period elapses, an individual should register for a permanent residence. This can be the case when, for example, an individual takes up employment, starts education or treatment, holidays, residence on grounds of family situation or active military service, or is put into a prison, reformatory or care institution outside the place of permanent residence. Pursuant to the Act, an individual can have only one permanent residence and one temporary residence. Sanctions for failure to comply with the registration obligation are described in detail in the Code of Petty Offenses (Journal of Laws 1971). Failure to register the residence was categorized as an offense until January 1, 2013, when the sanctions were officially lifted. From then on, despite the formal obligation to register the place of residence, there is no penalty for failure to comply, which means that the obligation to register residence is merely pursued for record keeping.

There are many reasons why people in Poland fail to register their residence. Many people question whether the state authority diligently enforces the legal provisions as penalties for failure to comply with the registration obligations are imposed only occasionally. Another notable reason is the inconvenience associated with the issue of new documents or introducing changes to existing documents (e.g. banking records, mobile telephony subscriptions). Instead, a mailing address can be provided to be used in the administrative procedures, which is very convenient. A new place of residence can be provided as a mailing address, which means that there is no need to notify the municipal office of any changes of the place of residence. Some people fail to report a changed place of residence to be able to take advantage of some economic benefits offered to the residents of a particular municipality, such as lower fees and rates of public services at a former place of registration as compared to the actual place of residence (e.g. the amount of fees for municipal waste collection, vehicle registration). Some foreigners attempt to avoid having a registered place of residence in Poland to avoid double taxation. Students are another population group that is difficult to track down in the official population statistics as only a small fraction of students registers their temporary residence when they move for education. Starting a family and having children are one of the most common reasons why people register a new place of residence. This is driven by the more frequent use of various types of health care services or educational and childcare institutions, which means people need to settle their administrative matters in order to be able to take advantage of the benefits available to residents of a given locality (Bijak et al. 2007, Śleszyński 2011, 2016).

Following the relaxation of residential registration regulations and the ensuing deterioration in the quality of statistical data concerning the population size, it becomes problematic to pinpoint the exact number of residents, especially at the lowest-tier statistical units. The majority of attempts to estimate the actual population of a given area concerned the Mazowieckie Voivodeship or the capital city of Warsaw. Śleszyński (2011) attempted to estimate the number of people in the municipalities of the Mazowieckie Voivodeship based on data concerning the inconsistencies in the address data of individuals insured at the Social Insurance Institution (ZUS). Bijak et al. (2007) also attempted to reliably estimate the actual number of residents of Warsaw. In their methodological study, they comprehensively discussed the feasibility of non-standard statistical information (data from the tax registers of the Ministry of Finance, insurance registers of the National Health Fund, registers of the National Electoral Commission (PKW), corrections based on the estimates of the Administration and Civic Affairs Office, or church statistics). They also presented calculations based on data on the municipal services in the city, including data on the level of water consumption and sewage production collected from the Municipal Water and Sewage Company, waste management (data from the City Clearing Board), and information obtained from satellite and aerial photos. Based on information about daily commuting to Warsaw and the number of passengers using means of public transport or road traffic analyses, they estimated what they referred to as 'daily population',

i.e. people spending the day in a given area and returning to their place of residence to spend the night there.

These researchers estimated that the actual number of residents of Warsaw is underestimated by approx. 60 thousand people, as evidenced in the core variant of calculations (Bijak et al. 2007). According to the analyzes that accounted for the total population of the Mazowieckie Voivodeship, it can be concluded that the actual number of residents is underestimated by at least 112 thousand people compared to data in the public registers. According to an analysis of spatial distribution of this phenomenon, the greatest disparities are expected to occur in the regional capitals (61%) and in the municipalities belonging to their suburban areas, where the level of underestimation is about 19%. Other dynamically developing urban centers follow suit. Based on analyses of the scale and intensity of construction activity in Wrocław, the population of the city could have increased by approx. 160–200 thousand people from the beginning of the 21st century. However, according to public statistics, in the same period the population of Wrocław has been steadily declining by approx. 2.9 thousand people (Szymtkie 2021).

Study Area

More and more often, people living in cities decide to move to other places in search of a cleaner and more attractive natural environment, more rest and recreation options, or well developed communication and social infrastructure. They increasingly choose to settle in areas close to large urban agglomerations, and the distance from the administrative borders of the city is no longer the main criterion as transportation options are becoming more and more convenient. The rural municipality of Czernica located in the eastern part of the Dolnośląskie Voivodeship is a good example to illustrate this trend. Czernica is located in the first ring of municipalities surrounding Wrocław (Fig. 1). It consists of 13 villages and 2 hamlets, inhabited by a total of 11,468 people according to 2012 data. By 2019, the population of the Czernica municipality increased to 16,619 people. The settlement network (Fig. 2) runs along two main communication routes from Wrocław to the village of Chrzastawa Wielka (crossing the villages of Dobrzykowice, Nadolice Małe, Nadolice Wielkie and Chrzastawa Mała) and from Wrocław to Jelcz-Laskowice and Oława (crossing the villages of Kamieniec Wrocławski, Gajków, Jeszkowice, Czernica and Ratowice).

The post-war period in Poland and other post-socialist countries in the Central and Eastern Europe was marked by fast and centrally planned industrialization and urbanization, which contributed to a systematic population influx to large cities. The population of Wrocław continued to grow until 1991, when it reached its peak size of over 643.6 thousand residents (Bagińska, Szymtkie 2005). At the turn of the 20th and 21st centuries, however, there was a fundamental change in population trends as a result of migration flows from urban to rural areas, including those in the immediate vicinity of Wrocław (Bagiński 2000, Ilnicki 2002, Zathey 2002, 2003, Gonda-Soroczyńska 2009, Maleszka, Szymtkie 2009,



Fig. 1. Municipalities forming the first ring of the Wrocław suburban zone
Source: own study.

Kajdanek 2011, Szmytkie 2020) and other large cities. Between 1988 and 2019, the number of people living in the first ring of municipalities around Wrocław increased from 104.1 thousand up to 179.4 thousand, i.e. by 72.4%, and the highest population growth recorded in the municipalities of Czernica (+140.0%) and Długołęka (+108.8%) (Fig. 3). This dynamic population growth was accompanied by the concentration of construction activity in these areas. The intensity of the residential suburbanization contributes to the highly advanced transformations taking place in the villages belonging to the Czernica municipality, in which

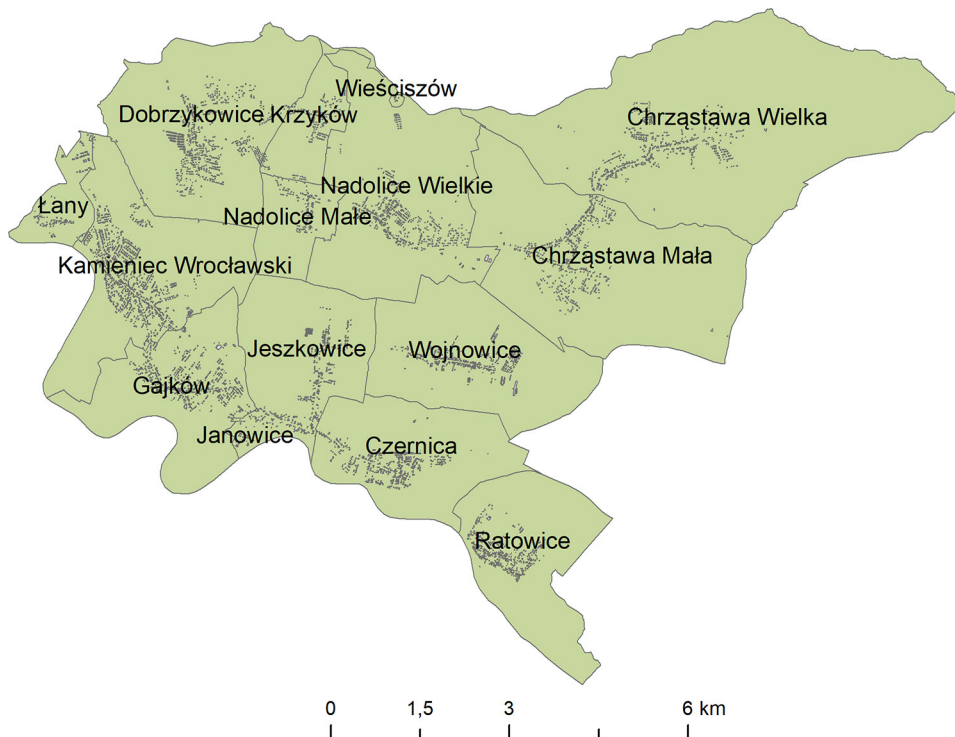


Fig. 2. Statistical localities in the Czernica municipality
Source: own study.

the effects of urban sprawl are evident. The emerging settlements of single-family housing and the growing number of multi-family buildings profoundly change the morphology and physiognomy of villages and may disrupt the spatial order.

Data and Methods

The actual number of residents of the Czernica municipality was estimated at the level of statistical localities. The estimation method was based on a correlation of spatial data concerning the number of residential buildings obtained from the Topographic Database (BDOT) of 2013 and the data provided by the Ministry of Digitization in the General Electronic Civil Registration System (the PESEL register), specifying the number of people with registered residence in each municipality in 2012 r. The choice of the years and statistical and spatial data considered in the analysis was depended on our availability of correlation of them. Furthermore, this research is a presentation of new method, which can allows to determine the scale of population underestimation.

The multistage estimation procedure began with the processing of statistical data from the PESEL register (2012):

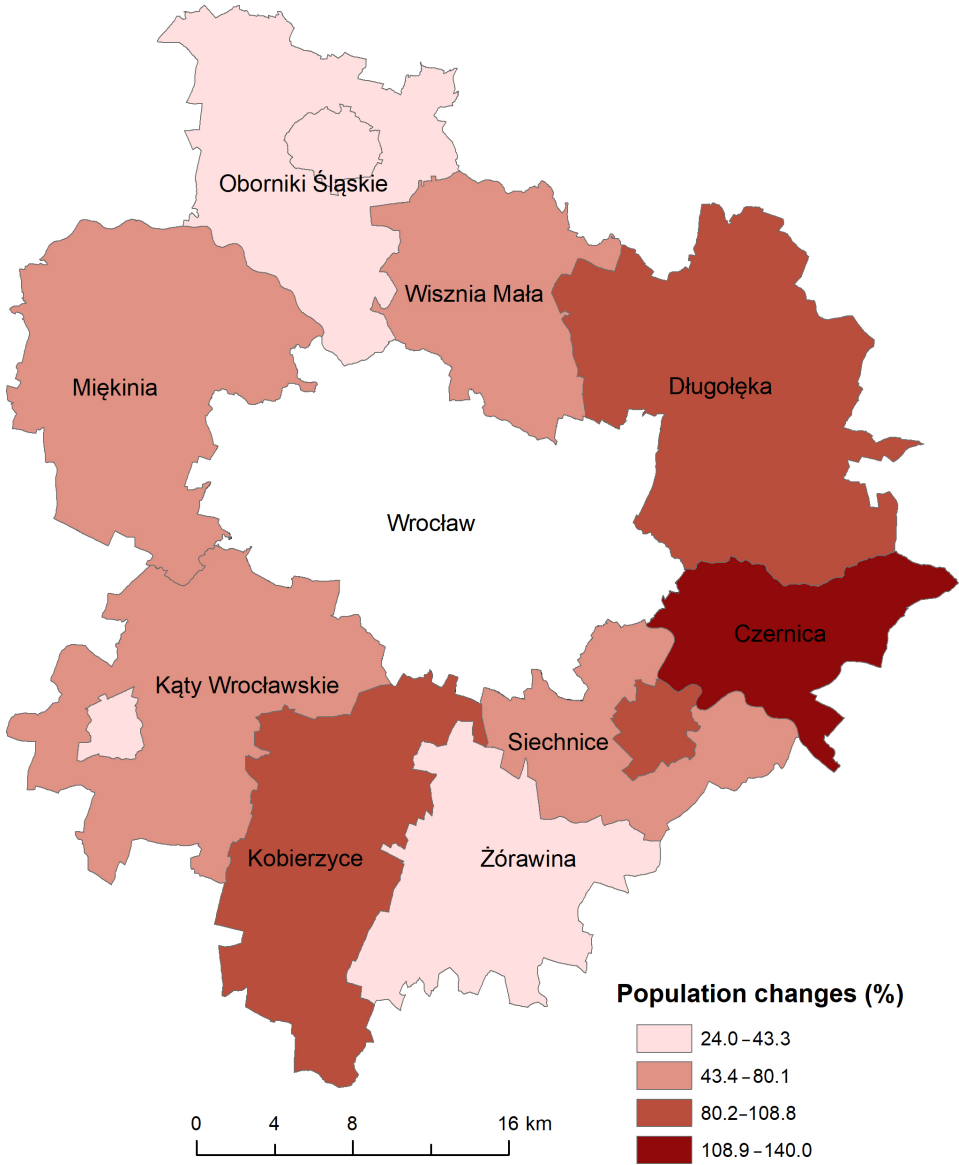


Fig. 3. Population changes in the municipalities of the Wrocław suburban zone, 1988–2019
Source: own study based on data from 1988 National Census and GUS 2020.

- 1) the number of single-family buildings (B_p),
- 2) the number of residents of single-family buildings (P_{SF}),
- 3) the number of residents of multi-family buildings (P_{MF}).

It is worth to point out that multi-family buildings were defined as buildings consisting of at least two apartments. Then the average number of people per one

single-family building was calculated according to the collected statistical data from PESEL register. It can be presented in following way:

$$AP = \frac{P_{SF}}{B_p}$$

The next step was to obtain spatial data from the BDOT database specifying the number of single-family buildings (B_B). The data of the number single-family buildings from the PESEL register (B_p) and BDOT database (B_B) were compared, which was an important element of the analysis. After verifying the data from both databases, a disparity was found in the number of buildings, what presents one of the examples – Krzyków locality (Fig. 4). The lower numbers of single-family buildings in the PESEL register (B_p) than in BDOT database (B_B) can be explained by the fact that the number of buildings was estimated on the basis on the address data of people registered as residents of these buildings. More number of single-family buildings in BDOT database (B_B) proves that in the research area is more residents than evidenced in the official statistics, because they failure to comply with obligations of compulsory registration at the place of residence. At this stage of comparing the databases, there were inaccuracies related to the lack of some buildings in the BDOT database, despite the fact that they appear were in the PESEL register. If any buildings are missing in the spatial information captured in BDOT database, this means that the objects failed to be vectorized and the existing database has not been updated. In order to reliably analyze the current stock of residential buildings in the Czernica municipality, the number of single-family houses listed and missing in the BDOT (B_M) was collated. Then multiplied the average number of people per one single-family buildings from PESEL register and the number of single-family buildings from BDOT database (expressed with the sum of number listed and non-vectorized single-family buildings):

$$AP = \frac{P_{SF}}{B_p} \times (B_B + B_M)$$

Afterwards added up the calculated value and the number of registered residents of multi-family buildings from PESEL register (P_{MF}). This whole procedure can be described using the following formula:

$$AP = \frac{P_{SF}}{B_p} \times (B_B + B_M) + P_{MF}$$

where:

AP – actual population size,

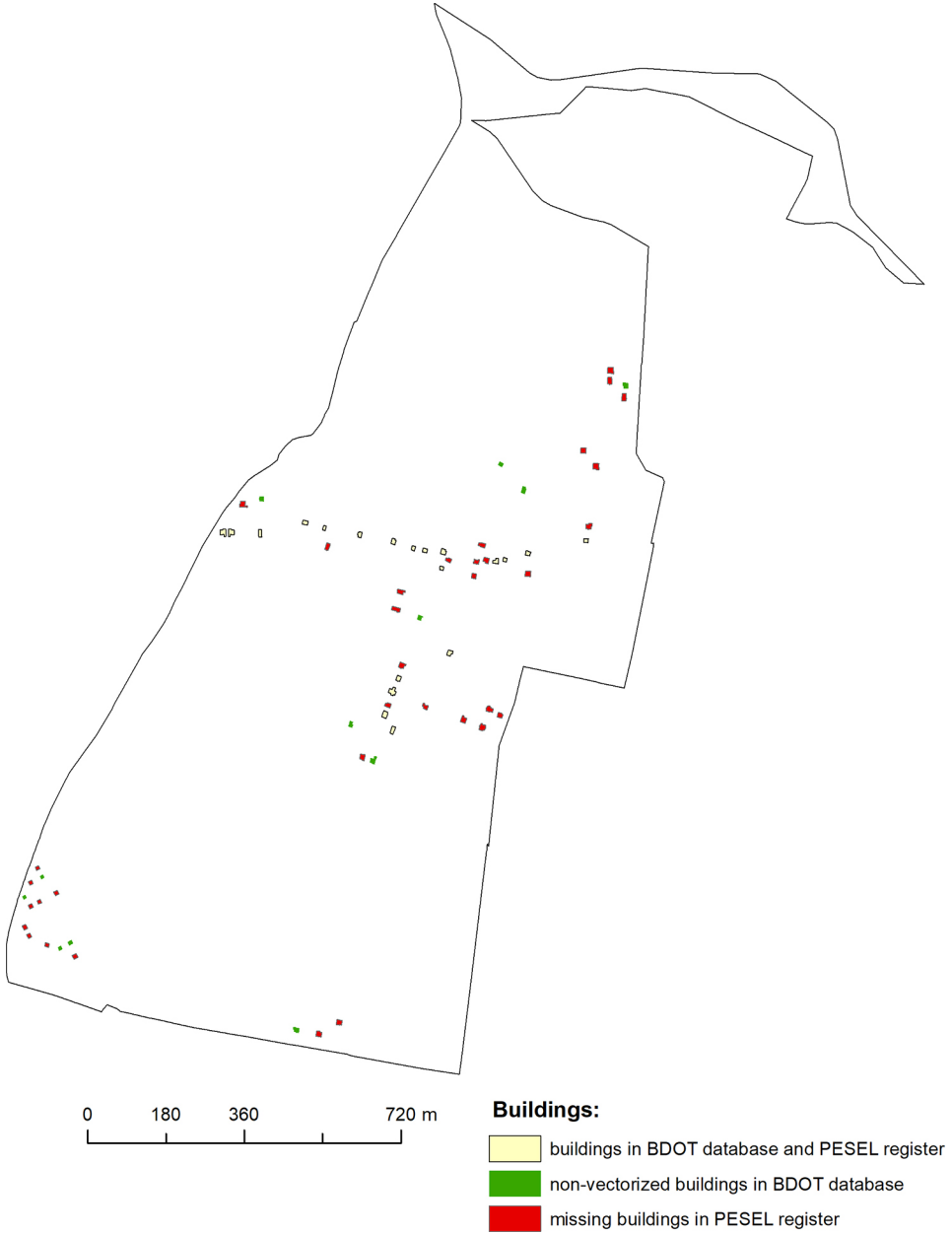


Fig. 4. Comparison of the number of single-family buildings between the PESEL register and BDOT database in the Krzyków locality
Source: own study based on statistical data from the Topographic Database (BDOT) of 2013 and the General Electronic Civil Registration System (PESEL) of 2012.

- P_{SF} – number of residents of single-family buildings (the PESEL register),
- B_P – number of single-family buildings (the PESEL register),
- B_B – number of single-family buildings (the BDOT database),
- B_M – number of single-family buildings not captured in BDOT (PESEL vs. BDOT),
- P_{MF} – number of people living in multi-family buildings (the PESEL register).

The last stage was to compare the statistical data contained in the PESEL register concerning the number of registered residents and the calculated value of the estimated actual population in individual localities. The obtained difference indicates the degree (percentage) of underestimation of the actual population residing in a given area.

When using this estimation methodology to determine the actual population size, it is important to be aware that the calculations are always affected by measurement errors and estimation errors inherent to the calculation method itself. The most common measurement error stems from incomplete statistical data, which is the key problem addressed in this study. This error concerns the number of people registered in the PESEL register and can be traced to the non-enforcement of the legal obligation to register one’s place of residence in Poland. There are also gaps in the spatial information about some buildings in the BDOT database as they have not been vectorized, which is also the case in the Czernica municipality. The database on spatial objects fails to be regularly updated with new buildings erected in rural localities (Table 1). The incompleteness of the BDOT database was revealed when the data contained there was compared to the number of buildings and addresses assigned to them in the PESEL register. The

Table 1. Disparities in the number of single-family buildings between PESEL register and BDOT database for Czernica municipality in the years 2012–2013

Statistical localities	Number of buildings not recorded in the PESEL register	Number of buildings not recorded in the BDOT database	Number of buildings recorded in BDOT database and PESEL register
Chrzóstawa Mała	96	93	149
Chrzóstawa Wielka	140	165	132
Czernica	45	65	123
Dobrzykowice	263	116	226
Gajków	113	95	193
Jeszkowice	49	84	114
Kamieniec Wrocławski	169	133	445
Krzyków	34	33	62
Łany	15	8	30
Nadolice Małe	23	40	44
Nadolice Wielkie	110	104	155
Ratowice	64	137	76
Wojnowice	57	95	81
Total	1,178	1,168	1,830

Source: own study based on the PESEL register (2012) and BDOT database (2013).

largest disparities in this respect were found in the village of Chrzęstawa Wielka, which is also one of the localities which is believed to be characterized by the highest population underestimation. As a matter of fact, the disparities occur in each locality and are determined by their size and the scale of residential suburbanization. In the course of the analysis, it was decided to take account of these disparities in the population size estimation procedure. For this purpose, the buildings missing from the BDOT database were identified using the addresses assigned to them in the PESEL register. The buildings were then vectorized and added to the BDOT database, and the number of single-family residential buildings included in the spatial database was aggregated.

Results

As mentioned before, the highest disparities between the actual population size and the statistical data contained in the official registers in the suburban area were revealed in localities characterized by dynamic suburbanization. In 2013, the number of residential buildings in the Czernica municipality was more than 3.5 times higher than in 1988 (Table 2). Likewise, the total population of the municipality in official statistics increased by approx. 90% during the analyzed quarter century. Construction activity in suburban areas is most often generated by population influx from cities. Therefore, using the linear Pearson correlation

Table 2. Changes in the number of residential buildings and the number of residents in the Czernica municipality between 1988 and 2012–2013

Statistical localities	Number of buildings			Population		
	1988	2013	Change [%]	1988	2012	Change [%]
Chrzęstawa Mała	115	338	193.9	622	937	50.6
Chrzęstawa Wielka	103	437	324.3	582	894	53.6
Czernica	125	233	86.4	994	1,230	23.7
Dobrzykowice	37	605	1,535.1	400	1,140	185.0
Gajków	114	401	251.8	538	1,014	88.5
Jeszkowice	106	247	133.0	593	817	37.8
Kamieniec Wrocławski	225	747	232.0	1,110	2,161	94.7
Krzyków	27	129	377.8	117	314	168.4
Łany	28	53	89.3	130	166	27.7
Nadolice Małe	30	107	256.7	126	227	80.2
Nadolice Wielkie	64	369	476.6	452	988	118.6
Ratowice	169	277	63.9	902	940	4.2
Wojnowice	48	263	447.9	358	640	78.8
Total	1,191	4,206	253.1	6,924	11,468	65,6

Source: own study based on National Census (1988), the PESEL register (2012) and BDOT database (2013).

coefficient, there is a strong positive correlation (0.776) between a change in the number of residential buildings between 1988 and 2013 [%], and a change in population size [%] in individual rural localities belonging to the Czernica municipality. The disparities in population data were also confirmed by a moderate positive correlation (0.549) between the dynamics of changes in construction activity [%] and the degree of underestimation of the actual number of residents of the village [%] as calculated on the basis of the developed methodology (Fig. 5).

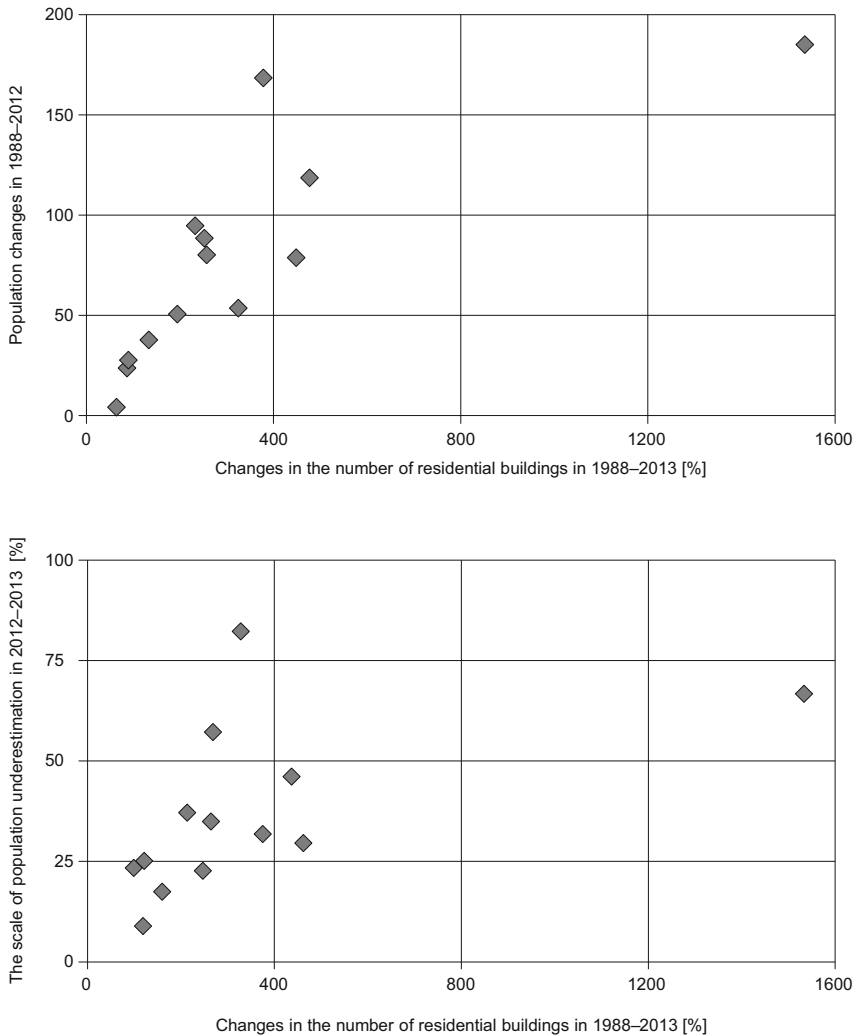


Fig. 5. The correlations between the dynamics of construction activity, population changes, and the scale of population underestimation in the Czernica municipality
 Source: own study based on the 1988 National Census, PESEL register (2012) and BDOT database (2013).

As revealed in an analysis of the results of population estimation, the underestimation of population size in the Czernica municipality is spatially diversified. The mean level of population underestimation is on average approx. 41%, and accordingly, the area is estimated to be inhabited by approx. 4,454 individuals, who are not registered as residents of this municipality (Table 3). The largest differences between the actual number of residents and those included in official statistics were found for localities adjacent to the Wrocław municipality (such as Chrzastawa Wielka – 83.3%). The similar situation is in case of the Dobrzykowice locality (68.7%) and the Nadolice Małe locality (59.7%). The last two localities border on territory of Wrocław, thus a short travel time to the city and they are characterized by the dynamic construction activity and high population changes in the period of 1988–2012 and 1988–2013. The Chrzastawa Wielka locality is further than two mentioned villages, but it borders on the Długoleka municipality, which is one of the municipality with rapid growth of residential suburbanization. Moreover, in these localities, multi-family housing is developing on a larger scale than in the rest parts of the Czernica municipality. The situation is an effect of location of the village in an area of great landscape value, surrounded by forests, where a significant proportion of the area consists of farmland on low quality soils. These lands are now willingly converted into housing. The scale of the analyzed problem decreases with the increasing distance from Wrocław. The voivodeship road No. 455 running through the area of Gajków and Kamieniec Wrocławski as well as municipal roads providing better access to Wrocław for the residents of Czernica are also important determinants of increased construc-

Table 3. The scale of population underestimation in the Czernica municipality

Statistical localities	Population according to the data of the Municipal Office	Population according to the PESEL register	Actual population in 2012–2013	Population underestimation [%]
Chrzastawa Mała	908	937	1,319	40.8
Chrzastawa Wielka	838	894	1,639	83.3
Czernica	1,231	1,230	1,405	14.2
Dobrzykowice	1,139	1,140	1,923	68.7
Gajków	1,012	1,014	1,407	38.7
Jeszkowice	814	817	999	22.3
Kamieniec Wrocławski	2,158	2,161	2,748	27.2
Krzyków	314	314	426	35.8
Łany	166	166	215	29.5
Nadolice Małe	226	227	363	59.7
Nadolice Wielkie	987	988	1,321	33.7
Ratowice	941	940	1,202	27.8
Wojnowice	637	640	955	49.3
Total	11,371	11,468	15,922	38.8
Average	874.69	882.15	1,224.77	38.8

Source: own study based on the PESEL register (2012) and BDOT database (2013).

tion activity in this area. The exception in the scale of population underestimation is small locality – the Łany villages, which borders on territory of Wrocław and where the analyzed phenomenon is on one of the lowest level. It is a result of specified location of village, whose development is limited by some spatially barriers. In the north and northwest of village is area of Strachociński forest, in the west and southwest is Odra river and floodplain (protected under the Natura 2000 programme) and in the earth is voivodeship road No. 455 and No, 372. Therefore, there are built only a few single-family houses and the same causing lower level of population underestimation in this locality (Fig. 6).

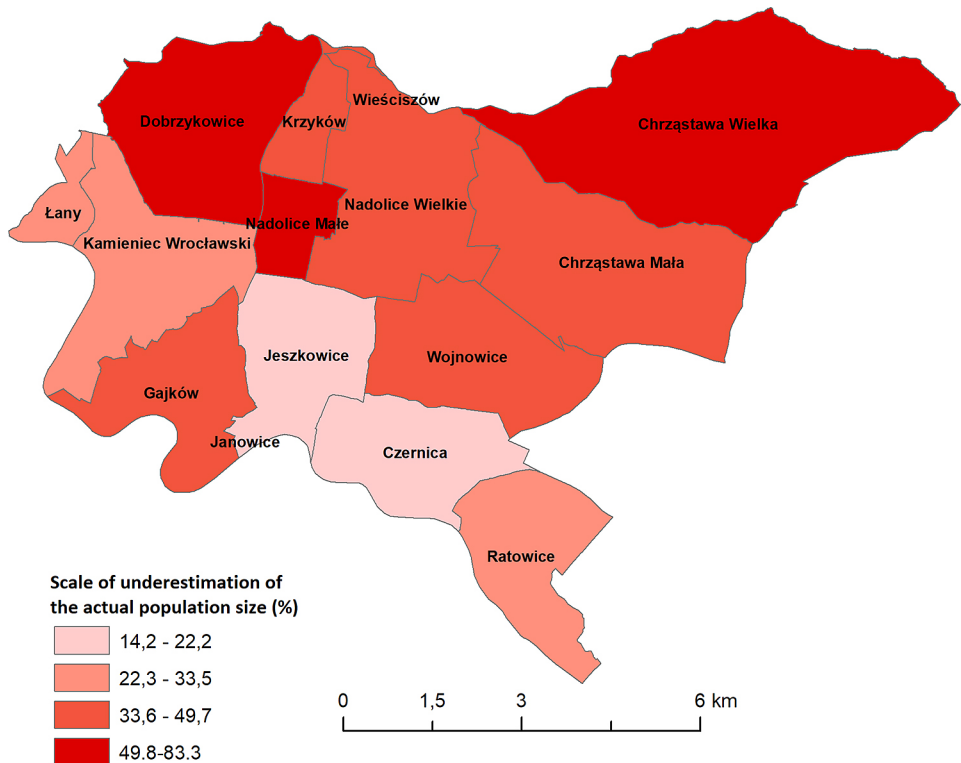


Fig. 6. Scale of underestimation of the actual population size (%) in the Czernica municipality in 2012–2013

Source: own study based on statistical data from the Topographic Database (BDOT) of 2013 and the General Electronic Civil Registration System (PESEL) of 2012.

Discussion

Discrepancies in the number of people registered as residents in the official state registers as based on the notified registrations and de-registrations of residence have been revealed in an analysis of the available statistical data and spatial in-

formation. The differences between the population size recorded in the official statistics and the actual population status is particularly evident in suburban zones, where dynamic changes related to an uncontrolled influx of residents and the ongoing residential suburbanization processes are observed. Suburban zones are areas where these processes are particularly intense, which contributes to the fact that the number of residents and the resulting scale of residential suburbanization can be significantly underestimated, as discussed by Śleszyński (2005, 2011). Unfortunately, this phenomenon becomes more and more prominent each year as the state authorities are rather lenient when it comes to enforcing and penalizing non-compliance with the obligation to register residence.

The method used in this study demonstrated that the population of the Czernica municipality is higher by at least 4,454 people than evidenced in the official statistics; in other words, it is underestimated by around 41%. This is just an approximate number of residents of the analyzed municipality, based on the correlation of statistical information from the General Electronic Civil Registration System (PESEL) that provides data on the number of people registered in a given locality, and the spatial information on the number of buildings from the Topographic Database (BDOT). Undoubtedly, this is one of the advantages of the method used here as the statistical and spatial data are universally accessible and can be freely used by local government authorities and the cooperating public institutions. Other methods used so far to estimate population size are often based on data that are more difficult to access or do not reflect the overall population structure in a given region, such as social insurance data from the Social Insurance Institution, without taking account of individuals insured with the Agricultural Social Insurance Funds operating as a separate social insurance institution (Śleszyński 2011). Other methods of estimating the population size are based on data of natural persons submitting the annual tax return to the Tax Office, or registers of the National Electoral Commission, which includes data on the number of people with active voting rights (Bijak et al. 2007). These methods do not capture the group of people in pre-working age, people submitting annual tax returns outside the municipal unit they are registered with, people declaring their willingness to vote in another constituency, or those who have lost their voting rights. Therefore, in order to generate more reliable and complete data on local residents at all age groups, it would perhaps be more reasonable to use data on persons insured in the National Health Fund, on the basis of declarations submitted by patients concerning their choice of a primary care physician. However, in order to obtain this piece of information, a special request needs to be submitted to the IT service provider responsible for the collection and processing of patients' personal data (Bijak et al. 2007). Moreover, the choice of a primary care physician and the place of residence of patients may not overlap. In rural localities, some residents prefer to register for medical care in a nearby town, therefore some people may choose to use healthcare services in neighboring municipalities. The residents of the Czernica municipality can travel to healthcare centers in Wrocław, Siechnice, or Jelcz-Laskowice.

The method used in this study does not fully eliminate the problem of completeness of the input data. It was particularly evident in the case of the Topographic Database, which did not contain data on some of the existing buildings included in the PESEL register. In order to explore the disparities between the information collected in both databases, the number of non-vectorized buildings in BDOT database had to be adjusted. Moreover, the method used in this study helps identify suburban localities where the scale of residential suburbanization is underestimated, but does not account for information about the social characteristics of the population and does not capture exact demographic events. More detailed information about the specificity of the population is provided by the method developed by Śleszyński (2011), which is based on the correspondence addresses of persons insured at the Social Insurance Institution. With this method, its author was able to identify most underestimated age groups in the official statistical data.

The advantage of the method used in this study is that information on the actual population size can be obtained at the level of statistical localities, which provides a more detailed estimation of the population size compared to other methods. The obtained results can be considered more reliable as they combine statistical and spatial data concerning the analyzed localities. There is a multitude of studies on residential suburbanization analyzed as evidenced in the scale and intensity of the construction activity, but without providing information on the migration flows from the cities to the suburban areas (Śleszyński 2011, 2016, Szmytkie 2019, Długosz, Szmytkie 2021). The method used here solves this problem as it includes both aspects of this phenomenon. In addition, it takes account of the need to interpret satellite and aerial images in order to analyze spatial information about the housing development. In this case, spatial data are collected from the BDOT database.

The procedure of estimating the actual number of residents presented in this study may be used as a supplement or a means to verify the reliability of other population estimation methods and may become a source of data necessary to correct the number of residents of a municipality or statistical localities belonging to this municipality. Incomplete information on the population size may be financially disadvantageous for a municipality in terms of tax revenues as local residents may often settle accounts with a tax office other than that assigned to their official place of residence. Local tax revenues which crucially depend on the number of local residents often reduce the amount of subsidies received by municipalities from the state budget. It is therefore important to validate the number of residents in order to be able to correctly implement social policies and investment planning pursued by the local governments, as well as to set the directions of local economic development. This method may contribute to improving the reliability of population statistics in the rapidly growing suburban areas.

Conclusions

Suburban zones are evolving as a result of suburbanization processes, what is the effect of migration and dynamic developing construction activity. In the Czernica municipality, which belongs to the suburban area of Wrocław city, significant disparities have been identified between the number of registered residents included in the official statistics, and the number of people actually living in this area. The result of the research confirms the hypothesis and indicates that more people live in the Czernica municipality than it is reported in the official statistics. The actual population as compared to population data (PESEL register) of 2012 was found to be underestimated by on average approx. 41%. In other words, there live at least 4,454 people more than was evidenced in PESEL register. There is also correlation between construction activity and population movements, what affects on the level of underestimation of the population size in the Czernica municipality. The highest scale of underestimation characterizes three localities: the Chrzastawa Wielka (83.3%), the Dobrzykowice (68.7%) and the Nadolice Małe (59,7%), in which also recorded dynamic construction activity and population changes in the years 1988–2012 and 1988–2013. This area of increased construction activity and migration flows depends on the communication routes leading to and from the city. In the case of Czernica municipality, the greatest role in the development of residential suburbanization is played by voivodeship road No. 455 connecting Oława with Wrocław. Moreover, the dynamics of residential suburbanization is spatially diversified. The more distant from the city center, the less attractive locality becomes as a possible place of residence. For this reason, Jeszkowice, Janowice, Czernica and Ratowice were characterized by a lower level of underestimation of the population size in relation to other statistical localities located in the Czernica municipality. In parts of the suburban areas located further from the city, the process of residential suburbanization is characterized by a lower intensity of changes in population and is also correlated with the intensity of construction activity in a given area.

The reason why population is underestimated in the suburban area of Wrocław is that people generally no longer report a change of residence (or a new address of residence) to state institutions as they move from city centers to suburban areas. This problem also applies to other regions of Poland. The research method used in this study reflects the disproportions between the number of residents officially registered in the Czernica municipality and the number of people actually residing in this area. This methodology is far from perfect as the directions of migration flows are captured in the suburban area of Wrocław without identifying the specific demographic characteristics of the population (e.g. age and sex of migrants). On the positive side, the method has a simple structure and provides results at the highest possible level of detail, namely statistical localities. The actual population of the Czernica municipality illustrates the scale of underestimation of migration phenomena in the suburban area of Wrocław, as represented by official statistics. Therefore, it seems necessary to introduce modifications to the procedure used to register demographic data related to population mobility in

order to minimize the spatial costs incurred by the areas subjected to residential suburbanization, as well as to improve the reliability of demographic statistics. The method used here may constitute an implication of research for other areas in which suburbanization takes place, struggling with the problem of underestimated population size, and a source of information on the actual number of residents of a given area for municipal authorities. It should be noted, however, that this research procedure generates only approximate orders of magnitude of the number of people residing in the analyzed area.

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Metoda szacowania rzeczywistej liczby ludności w strefie podmiejskiej. Przykład gminy Czernica (powiat wrocławski)

Zarys treści: Jednym z procesów zachodzących intensywnie w otoczeniu dużych miast jest suburbanizacja rezydencjonalna. Nie inaczej jest w przypadku obszarów podmiejskich Wrocławia, gdzie obserwowany jest dynamiczny napływ ludności i wzmożony ruch budowlany. Celem artykułu była identyfikacja skali procesów suburbanizacji rezydencjonalnej na przykładzie gminy Czernica, stanowiącej część strefy podmiejskiej Wrocławia. Publikacja porusza problematykę niedoszacowania wielkości ruchu migracyjnego w otoczeniu dużych miast, wynikającą z niezgodności ewidencji ludności w odniesieniu do faktycznego miejsca zamieszkania. Wynika to z braku obowiązku meldunkowego przez co faktyczna liczba ludności różni się od tej wykazywanej w statystykach publicznych. Niniejszą analizę, ukazującą faktyczną liczbę mieszkańców gminy Czernica, przeprowadzono z zastosowaniem autorskiej metody szacowania rzeczywistej liczby ludności, wykorzystując zagregowane dane statystyczne o zameldowaniach z bazy Powszechnego Elektronicznego Systemu Ewidencji Ludności (rejestr PESEL) oraz dane przestrzenne z Bazy Danych Obiektów Topograficznych (BDOT).

Słowa kluczowe: suburbanizacja rezydencjonalna, statystyka ludnościowa, szacowanie populacji, strefa podmiejska, Wrocław