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MULTIPLE-DIMENSIONAL ANALYSIS AND EVALUATION OF INFRASTRUCTURE BOARDS IN THE POLISH ARMED FORCES

ABSTRACT

Background: In this article the authors raise the issue related to the multiple-dimensional analysis and evaluation of infrastructure boards in the Polish Armed Forces. The use of Chernoff 's face for six explanatory variables enabled the observation of similarities and discrepancies of infrastructure boards undetectable with the analysis and evaluation of the raw data themselves.

Methods: The following research methods were applied: literature analysis of the issues related to the infrastructure boards and multiple-dimensional analysis, analysis of source documents and comparisons. For research purposes, the explanatory variables were gradually analyzed and evaluated (the number of complexes, the area of complexes in hectares, the usable floor area in square meters, the area of forests in hectares, the capacity of buildings in cubic meters), as well as the dependent variables (infrastructure boards) with the application of research tools, such as bar charts and descriptive statistics. Then, the multiple-dimensional analysis and its evaluation were applied for two groups of three explanatory variables using the research tool of Chernoff's face. The last phase of the research was the application of multinational analysis for all explanatory variables of dependent variables investigated in the article. In addition, Statistica computer programme was used, as a research technique and the following research tools were applied: bar charts and Chernoff's face charts.

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Results: The application of multiple-dimensional analysis enabled the observation of relationships and discrepancies between infrastructure boards. The most similar boards entities to each other are located in: Olsztyn, Wrocław, Gdynia, Lublin, Zielona Góra, Poznań and Kraków. In the group remaining three ones have much bigger size of the faces. These three entities which are different from those seven analyzed ones above are: Warszawa, Szczecin and Bydgoszcz.

Conclusions: The results obtained from the multiple-dimensional analysis enables the appropriate planning procedure with the application of infrastructure boards in the context of the accommodation of subunits and other significant aspects which arise from the explanatory variables of dependent variables presented in the article.

Keywords: infrastructure boards, multiple-dimensional analysis, evaluation, planning.

INTRODUCTION

A critical analysis of the literature makes it possible to state that the military infrastructure is all permanently attached to the ground, fixed installations, manufactured goods or devices to support and supervise military operations. [DD 4.23.3 - Organization of construction and technical maintenance of field infrastructure, DGRSZ, Warsaw 2018, pp. 2-1]. On the other hand, military infrastructure in the D-4 B logistics doctrine is defined as an element of the state's defense infrastructure, which consists of objects, stationary and mobile devices, as well as organs intended for their maintenance and operation [Logistic doctrine of the Armed Forces of the Republic of Poland D-4 B, Polish Armed Forces Support Inspectorate, Bydgoszcz 2014, p. 133].

The research problem of the work focuses on the multidimensional analysis and assessment of Infrastructure Boards in the Polish Armed Forces. The main goal of the study is to use a multidimensional data analysis of variables explaining dependent variables to detect the similarities and differences of ten infrastructure managements.

The article uses two multidimensional methods in the form of: grouping and linear ordering. The application of the grouping method allowed to isolate the group to which a different number of explanatory variables were assigned. Thanks to this, it was possible to observe which elements of the objects are similar in terms of adopted criteria [K. Nermend, 2017, Methods of multi-criteria and multi-dimensional analysis in decision support, p. 151]. Linear ordering methods have allowed the classification of individual group elements. The use

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of multidimensional methods was intended to indicate, highlight relationships, invisible tendencies from the point of view of raw data recorded in raw form.

The subject of the study is the Infrastructure Boards (ZI) in the Polish Armed Forces, while the subject of the study is six variables explaining the infrastructure management in the form of: the number of complexes, the area of complexes in hectares, the usable area of buildings in m^2, the number of buildings, the area of forests in hectares, and the volume of buildings in m^3. The article uses research methods, which include: literature analysis, which concerned issues related to infrastructure management and multidimensional analysis, analysis of source documents, and comparison. In addition, a research technique was used in the form of the Statistica computer program. Moreover, the following research tools were used: bar charts and Chernoff face charts. The article consists of the introduction, two substantive points, summary and conclusions.

INFRASTRUCTURE MANAGEMENTS AND MULTIDIMENSIONAL ANALYSIS

When analyzing Infrastructure Boards in the Polish Armed Forces, at the beginning of this substantive point the institutions responsible for the functioning of the infrastructure subsystem were explained and presented. An important unit in the area of infrastructure subsystem is the Department of Infrastructure of the Ministry of National Defense, which performs legislative and normative functions in the field of infrastructure, including a special infrastructure office. The organizer of the Functional System for the infrastructure subsystem in the Polish Armed Forces is the Logistics Management Board - P4 of the General Staff of the Polish Army. The function of Gestor and the Central Logistics Authority in the field of infrastructure is performed by the internal unit of the Infrastructure of the SZ Support Inspectorate.

Infrastructure managers and investors are ten Infrastructure Boards (ITs). Eight of them are: District Infrastructure Boards (RZI) with headquarters in Szczecin, Olsztyn, Wrocław, Gdynia, Lublin, Zielona Góra, Kraków and Bydgoszcz. There is also the Military Infrastructure Board (WZI) in Poznań, and the Capital Infrastructure Board (WZI) in Warsaw. Management boards differ from each other in location and other features which are generally described in the article as explanatory variables (six were adopted: number of complexes, area of complexes in hectares, usable area of buildings in m^2, number of buildings, forest area in hectares, and volume of buildings in m^3) dependent variables - ten Infrastructure Boards (ZI).

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A large number of methods are visible in the literature as part of multidimensional comparative analyzes. They are used to search for relationships invisible from the perspective of raw data, often presented only in the form of tables. Multidimensional analyzes are considered to be a group of statistical methods by which at least two variables describing a dependent variable are analyzed [Łuniewska M., 2006, Methods of multivariate comparative analysis on the capital market, p. 9]. A research tool in the form of a Chernoff face was used in the article for multivariate analysis and evaluation of ten Infrastructure Boards.

Chernoff's faces are a kind of picture chart that creates a self-contained category. Cases are visualized here by faces in such a way that the relative values of the variables are represented by the size or position of the various elements of the human face. Due to its unique properties, this technique is considered by some researchers to be the most advanced multidimensional exploratory technique that reveals hidden systems of interrelationships between variables, impossible to detect in any other way.

MULTIDIMENSIONAL ANALYSIS AND ITS ASSESSMENT

The first stage of the study was to analyze and evaluate dependent variables which were Infrastructure Boards with explanatory variables listed in Figures 1 to 3 and in Table 1 regarding: list of complexes in numbers managed by ZI, area of complexes managed by ZI in ha, and forest area in the complexes managed by ZI in ha. The explanatory variables are listed from largest to smallest

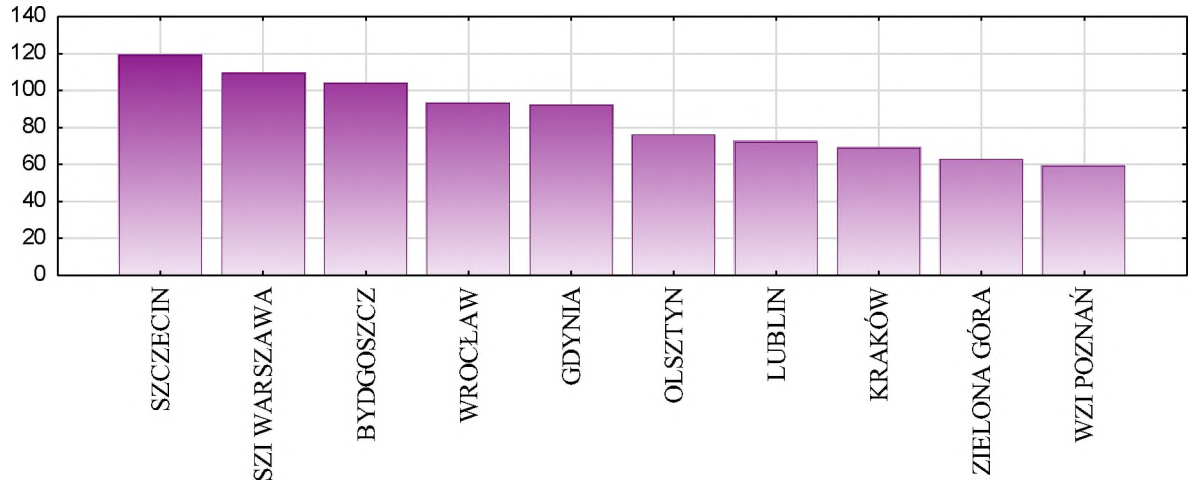

Fig. 1. List of complexes in numbers managed by ZI.
Source: [Own work based on data obtained from Jałowiec 2019].

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Figure 1 shows that the largest number of complexes managed by Infrastructure Boards is visible in Szczecin, and then in order from largest to smallest in: Warsaw, Bydgoszcz, Wrocław, Gdynia, Olsztyn, Lublin, Kraków, Zielona Góra and the smallest in Poznań.

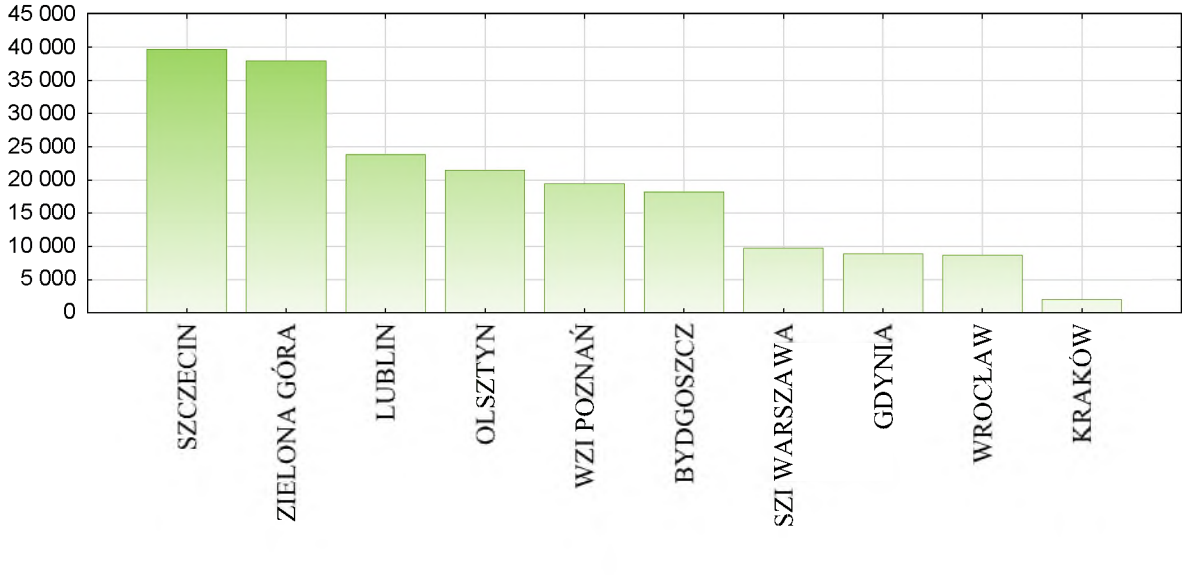

Fig.2. Area of complexes managed by IT in hectares.
Source: [Own work based on data obtained from Jałowiec 2019].

Analyzing and assessing the area of complexes managed by Infrastructure Boards in hectares (Figure 2), the occurrence of groups of dependent variables of similar level was observed. The highest group were infrastructure managements in Szczecin and Zielona Góra. The group closest to the arithmetic average includes four boards, which include: Lublin, Olsztyn, Poznań and Bydgoszcz. The Infrastracture Board in Kraków is definitely the lowest in the ranking, followed by Wrocław, Gdynia and Warsaw.

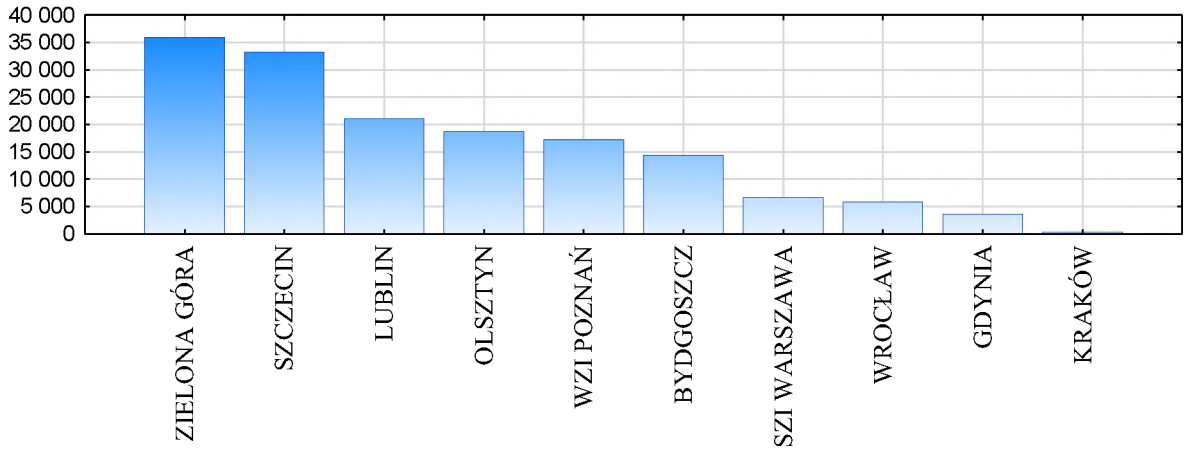

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Fig 3. Forest area within the complexes managed by ZI hectares.
Source: [Own work based on data obtained from Jałowiec 2019]

The assessment of Figure 3 is the detection of groups of dependent variables of similar level. The highest group is: Zielona Góra and Szczecin. The closest to the arithmetic average is a group such as the explanatory variable for the area of complexes managed by IT in hectares - Figure 2. The lowest level is visible in Krakow, followed by Gdynia, Wrocław and Warsaw.

Then, descriptive statistics were analyzed (Table 1) of three groups of explanatory variables (summarized in Figures 1 to 3) dependent variables (ten Infrastructure Boardes).

Table 1. Descriptive statistics of data on: number, area of complexes including forest area in areas managed by ZI

	N	Arithmetic mean	Median	Total	Deviation Standard	Skewness	Kurtosis
Number of complexes	**10**	85,60	84,00	856	20,73	0,29	-1,33
Area of complexes [ha]	**10**	18 993,71	18 810,38	189 937,15	12 441,27	0,57	-0,51
Including forest area [ha]	**10**	15 700,99	15 793,05	157 009,94	12 122,20	0,53	-0,72

Source: [Own work based on data obtained from Jałowiec 2019].

The assessment of the performed descriptive statistics analysis is the observation that the arithmetic average of the primary data considered is greater than the median for: number of complexes and area of complexes in hectares. The reverse situation is visible for the explanatory variable named forest area in hectares. The largest standard deviation from the arithmetic mean is for the explanatory variable: the area of complexes in hectares and amounts to 12,441.27, as well as the largest sum of dependent variables regarding the primary data considered - 189 937.15. The distribution of three explanatory variables is asymmetrical on the right, more flattened than normal.

The next step was to perform multidimensional analysis using the Chernoff face research tool, where the dependent variables were ten infrastructure managements, and the variables explaining them were the three variables presented in Figures 1 to 3, which were: lists of complexes in numbers managed by ZI, the area of complexes managed by ZI in ha, and forest area within the complexes managed by ZI in ha. The explanatory variables (Figure 4) are given facial features:

- Face / width - the area of the complexes in hectares;
- Ears / level - forest area in hectares;

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- Nose / length - number of complexes.

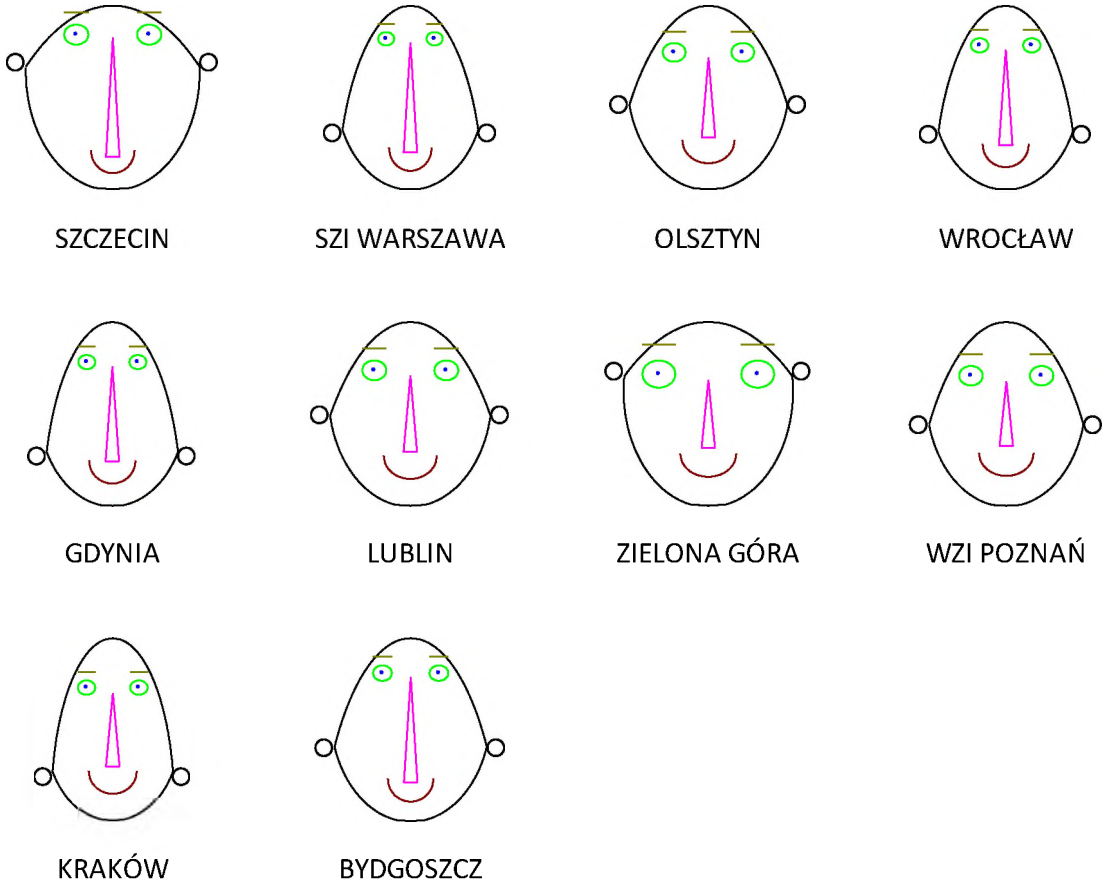

Fig.4. Multidimensional analysis of data on: the area of complexes, including forest area and the number of complexes in ZI regions.
Source: [Own work based on data obtained from Jałowiec 2019].

The assessment of Figure 4 is the observation that the longest noses are visible in: Szczecin, Warsaw and Bydgoszcz. This means that there are the largest number of complexes on these boards. The smallest (shortest nose) is in Poznań, Zielona Góra and Krakow. Assessing the forest area (ears level) the highest is visible in: Zielona Góra and Szczecin, and the lowest definitely in Kraków. The highest surface area of the complexes in hectares (face / width) is visible in Szczecin and Zielona Góra, and the lowest in Kraków.

The next stage of research is the analysis and evaluation of the next three explanatory variables (Figures 5-7) dependent variables which are ten Infrastructure Boards.

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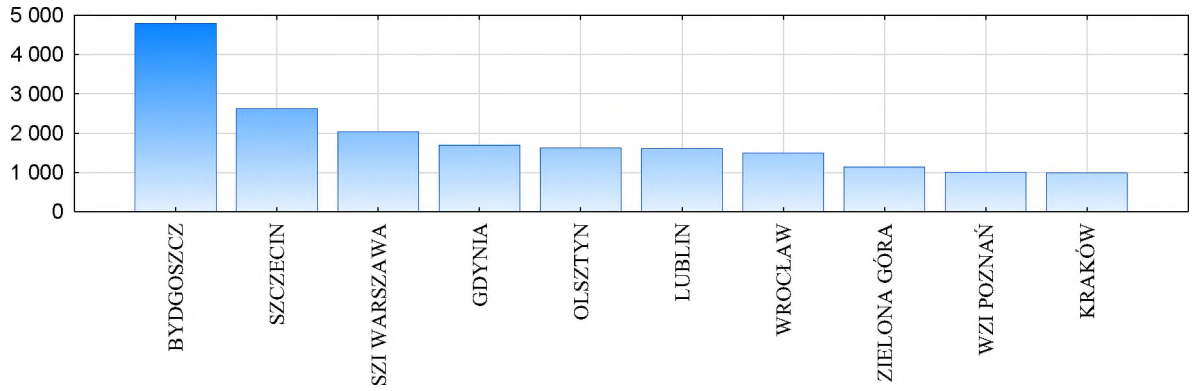

Fig. 5. Number of buildings in the complexes managed by ZI.
Source: [Own work based on data obtained from Jałowiec 2019].

The assessment of Figure 5 is that the definitely highest level of buildings is managed by Infrastructure Board in Bydgoszcz. It can be assumed that, on average, it is twice the level of the arithmetic mean of the other considered dependent variables for the examined explanatory variable. Whereas the other managements, when considering the number of buildings, oscillate around the arithmetic average.

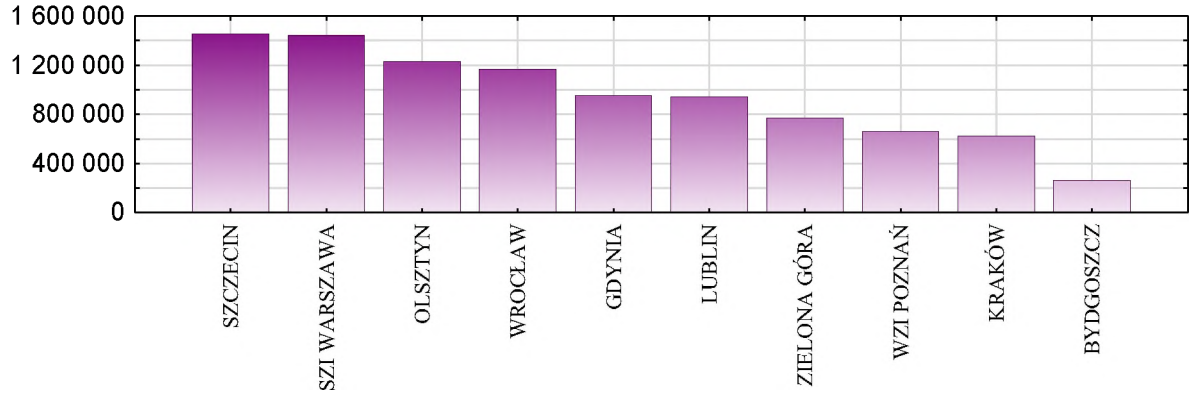

Fig. 6. Usable floor area of buildings in complexes managed by IT in m2.
Source: [Own work based on data obtained from Jałowiec 2019].

The assessment of Figure 6 is the observation of dependent variable groups with a similar value of the explanatory variable considered. The highest group consists of two boards: Szczecin and Warsaw. Then in order from largest to smallest are: Olsztyn and Wrocław. The third group is: Gdynia and Lublin. Fourth: Zielona Góra, Poznań and Kraków. The lowest level is visible in Bydgoszcz.

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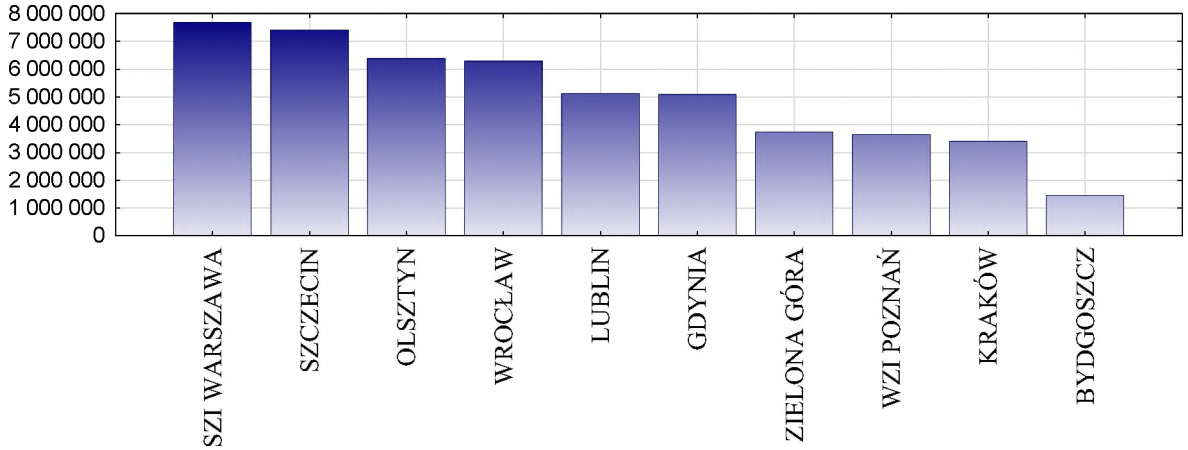

Fig. 7. Cubature of buildings in the complexes managed by ZI in m3.
Source: [Own work based on data obtained from Jałowiec 2019].

The explanatory variables regarding the volume of buildings in the complexes managed by the Infrastructure Boards are similar to the usable area. The top group consists of two boards: Warsaw and Szczecin. Then in order from largest to smallest are: Olsztyn and Wrocław. The third group is: Lublin and Gdynia. Fourth: Zielona Góra, Poznań and Kraków. The lowest level is visible in Bydgoszcz.

Then, descriptive statistics were analyzed (Table 2) of three groups of explanatory variables (listed in Figures 5 to 7) dependent variables (ten Infrastructure Boards).

Table 2. Descriptive statistics of data on: the number, usable area and volume of buildings in areas managed by ZI.

	N	Arithmetic mea	Median	Total	Deviation Standard	Skewnes	Kurtosi
Number of buildings	10	1 898,80	1 615,50	18 988	1 128,39	2,17	5,31
Buildings volume [m3]	10	5 017 494,20	5 101 824,50	50 174 942	1 974 023,58	-0,32	-0,55
Usable floor area of build [m2]	10	949 430,70	948 012,50	9 494 307	382 037,31	-0,28	-0,53

Source: [Own work based on data obtained from Jałowiec 2019].

The assessment of the performed descriptive statistics analysis is the observation that the arithmetic average of the primary data considered is greater than the median for: the number of buildings and the usable area. The reverse situation is visible for the explanatory variable called building volume. The largest standard deviation from the arithmetic mean is for the explanatory variable: the volume of buildings and amounts to 1 974 023.58, as well as the largest sum of dependent variables regarding the primary data considered - 5 101 824.50. The distribution of

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the analyzed data for the variable dependent number of buildings is right-handed asymmetrical and slender than normal. On the other hand, left-hand asymmetry is visible in the other explanatory variables, and the distribution is more flattened than normal.

Then, a multidimensional analysis was performed using the Chernoff face research tool, where ten dependent management boards were the dependent variables, and the explanatory variables were the three variables presented in Figures 5 to 7, which were: usable area of buildings in m^2, volume of buildings in m^3, and the number of buildings . The explanatory variables (Figure 8) are given facial features:

- Face / width - usable area of buildings in m^2;
- Ears / level - volume of buildings in m^3;
- Nose / length - number of buildings.

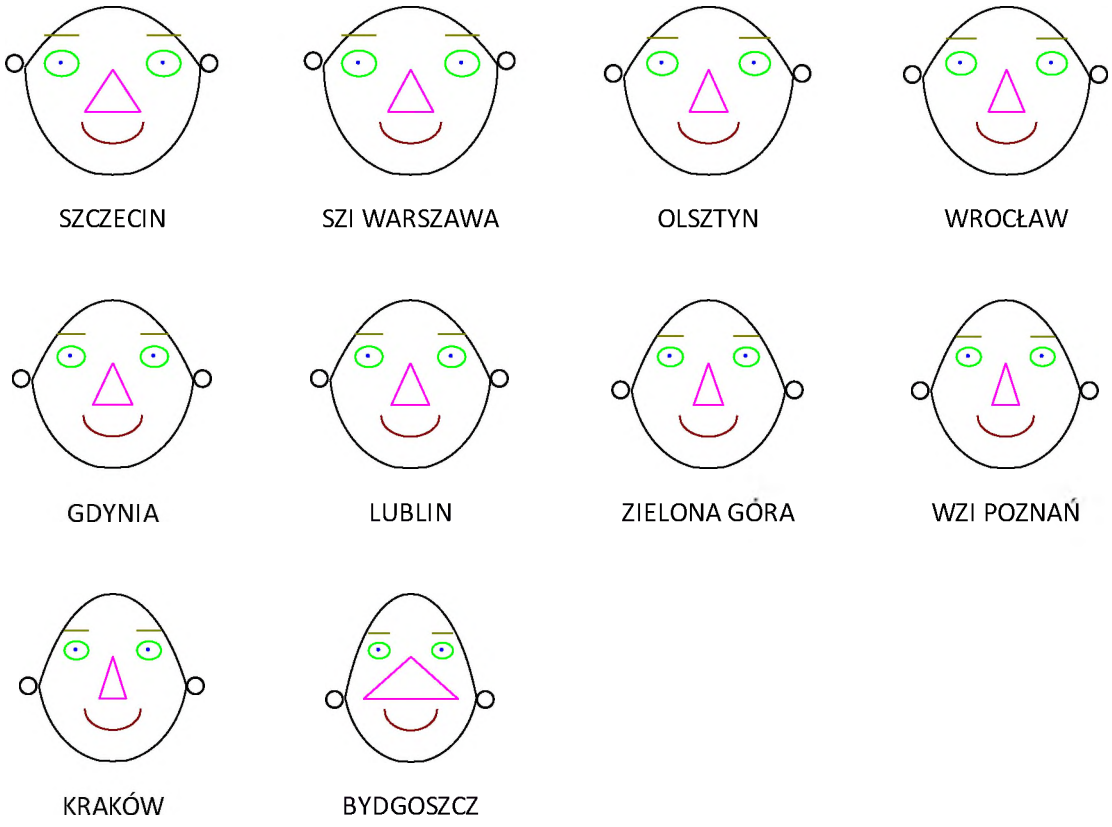

Fig. 8. Multidimensional analysis of data on: usable area, volume and number of buildings in ZI regions.
Source: [Own work based on data obtained from Jałowiec 2019].

The assessment of Figure 8 is the observation that the largest usable area of buildings (face / width) is visible in: Szczecin, Warsaw, Olsztyn and Wrocław. The lowest level was recorded

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in: Bydgoszcz, Kraków and Poznań. The level of ears looked similar - the volume of buildings. When assessing the number of buildings (nose / width), it should be stated that the highest level is definitely in Bydgoszcz, and in other managements it oscillates around the arithmetic average. Moreover, it can be observed that in Szczecin and Warsaw the number of buildings slightly differs from the arithmetic average of the boards concerned.

Then, for research purposes, in order to detect similarities and differences in the considered Infrastructure Boards, the research tool in the form of Chernoff face was used once again (Figure 9), where the explanatory variables were six variables in the form: number of complexes, area of complexes in hectares, usable area of buildings in m^2 , number of buildings, forest area in hectares, and building volume in m^3.

The explanatory variables have been given the following facial features:

- Face / width - number of complexes;
- Ears / level - Area of complexes in hectares;
- Nose / length - Usable floor area of buildings in m^2;
- Mouth / length - Number of buildings;
- Eyes / distance - forest area in hectares;
- Nose / width - building volume in m^3.

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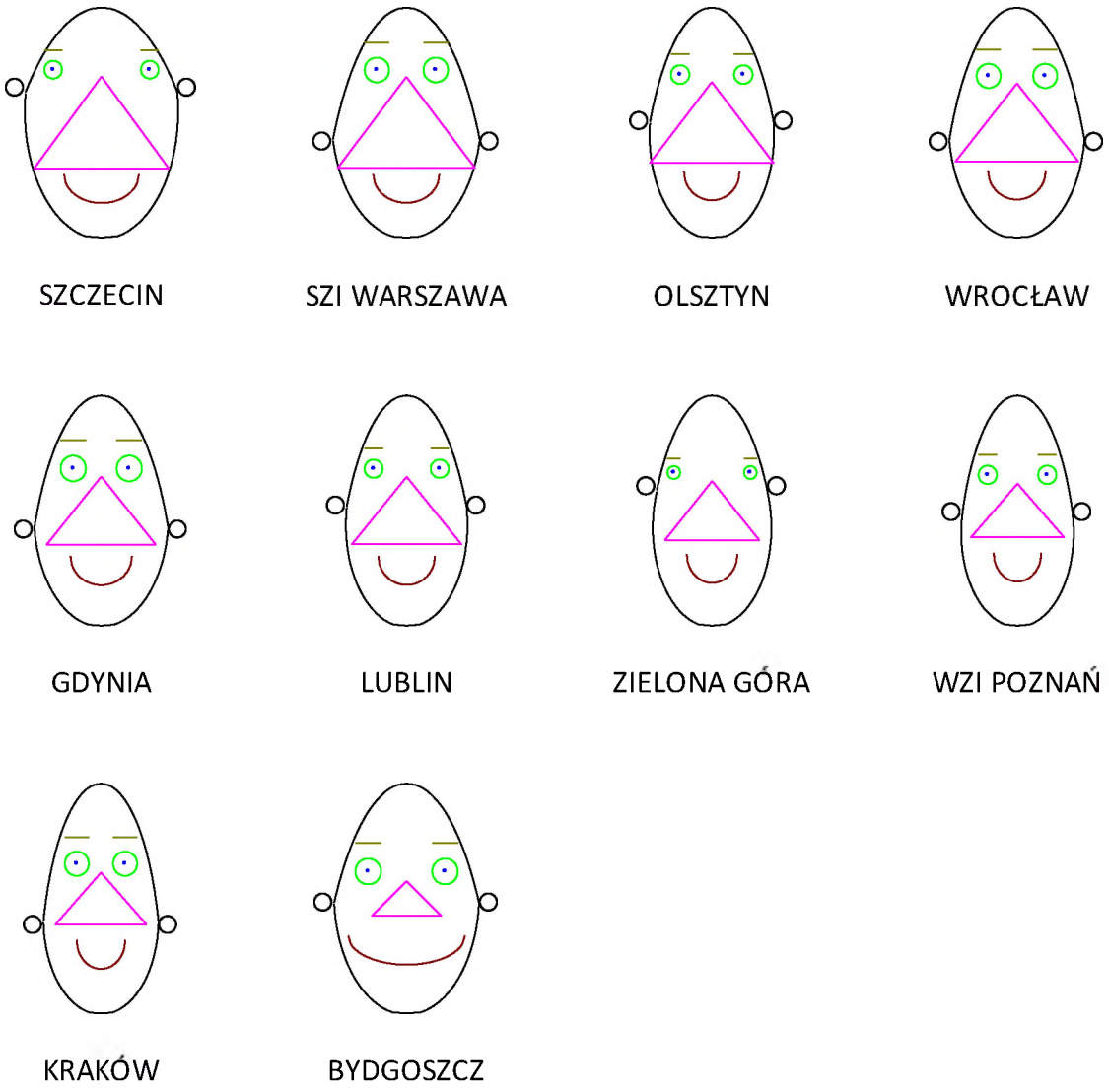

Fig.9. Multidimensional analysis of data regarding: number of complexes, area of complexes, usable area of buildings in [m^2], number of buildings, including forest area and building volume [m^3] in ZI regions.
Source: [Own work based on data obtained from Jałowiec 2019].

The evaluation of the multidimensional analysis applied in the form of Chernoff's Face (Figure 9) is that seven out of ten infrastructure boards are very similar to each other (similar head shape - Figure 9). These include the following boards: Olsztyn, Wrocław, Gdynia, Lublin, Zielona Góra, Poznań and Kraków. The three Infrastructure Boards differ from the others. They are: Szczecin, Warsaw and Bydgoszcz. It should also be added that Warsaw and Szczecin are very similar. They differ in the level of ears (the surface of the complexes) and the distance

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between the eyes (forest area). The area of the complexes in hectares is definitely larger in Szczecin than in Warsaw, similarly to the area of forests.

The Infrastructure Board in Bydgoszcz differs from all others by the length of the mouth - the number of buildings and the nose - the length and width. A small nose in Bydgoszcz means that there is the smallest area and volume of buildings from all other boards under consideration.

CONCLUSIVE REMARKS

The main goal of the article has been achieved. A multidimensional analysis of primary data was carried out using the Chernoff Face charts, which allowed to observe the relationships and differences between Infrastructure Boards. Infrastrucure boards based in Olsztyn, Wrocław, Gdynia, Lublin, Zielona Góra, Poznań and Kraków are the most similar. The other three have a much larger face size. The group of three Infrastructure Boards differing from the other seven analyzed included the following: Warsaw, Szczecin and Bydgoszcz. Moreover, the management boards in Warsaw and Szczecin are very similar. They differ (Figure 9) in the level of ears (the surface of the complexes) and the distance between the eyes (forest area). The area of the complexes in hectares is definitely larger in Szczecin than in Warsaw, similarly to the area of forests.

The next stage of research should be the use of further research tools, such as icicle charts related to grouping of variables, and testing the distance from individually obtained groups.

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