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THE APPLICATION OF CZEKANOWKI'S DIAGRAM IN A PROCESS OF GROPUING OF PUBLIC UNIVERSITIES DUE TO THE LEVEL AND STRUCTURE OF COSTS

Abstract

In this article a usage of Czekanowski's diagram is presented as a tool used in a comparative analysis of polish public universities. The study was conducted in a spatial frame during two academic years and concerned 57 public universities of academic character. The application of Czekanowski's diagram in an initial analysis of a level and structure of costs of public universities is a tool which can be used by internal and external decision-makers in a process of creating a strategy of a creative usage of public resources and ranking lists. The results should constitute a basis for further and at the same time more detailed cause and effect analysis.

Key words:

Taxonomic methods, public universities, an analysis of costs level.

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1. Introduction

Managing public universities depends to a great degree on effective management of economic information. Its presentation is particularly vital and it should be clear and open. These requirements are especially important in comparative analysis which allows creating rankings. The rankings allow undertaking certain actions in the area of evaluating situation of a unit with reference to other similar institutions, eg. those that are in a given group. Spatial analysis of costs can be used by internal and external decision-makers in a process of creating a new strategy of an effective usage of public sources. Obtained results should constitute a basis for further more detailed cause and effect analysis.

The aim of this work is to present possibilities of methods by which we can group budget units due to the level and structure of generated costs in order to rationalize politics of financing universities. This article is a continuation of conducted researches in the area.

2. Theoretical basis of the method

A classification of public universities due to the level and structure of costs in a spatial frame was conducted with the usage of Czekanowski's diagram. This method is the oldest taxonomic method which was first published in 1909 by a well known anthropologist Jan Czekanowski. At present it is also used in other fields of science as a universal method of statistical classification. The essence of the diagram is the fact that it shows the most important relations and similarities of researched objects and at the same time shows detailed connections between the units. (Czekanowski, 1913).

To draw a Czekanowski's diagram you should follow the procedure (Nowak, 1900, p. 64–65); (Panek, Zwierzchowski, 2013, p. 58–59):

1. Define matrix between objects $\boldsymbol{D}[d_{ii'}]$ with the usage of any certificate

2. Distance measurements in matrix *D* are divided into classes that constitute ranges of objects similarities. Correct setting of similarities scale has a decisive influence on final results of set division of researched objects

3. Each class of object similarities is given a particular graphic symbol which gives us Czekanowski's diagram that is not in order and this allows for eye evaluation of object ordering

4. Objects ordering are done by arranging the diagram which means that the lines and corresponding columns are ordered so that the graphic symbols representing possible distances concentrate along main diagonal. When they carry away from main diagonal graphic symbols equivalent of longer distances has appeared

5. A sequence of objects ordering is specified by a sequence of equivalent lines (columns). Czekanowski's diagram arranges researched objects in a linear way.

One of an advantage of Czekanowski's taxonomic method is that while classifying the whole distance matrix is considered. Very often objects are classified in typological group only when there are similarities of the highest degree between them all or between most of them.

To optimize ordering maximization of function criterion was used (Panek and Zwierzchowski, 2013):

$$F = \sum_{i=1}^{n} \sum_{i'>1}^{n} d_{ii'} w_{ii}, \tag{1}$$

$w_{ii'}$ is the weight of elements of distance matrices, defined on the basis of one of the following formula:

$$w_{ii'} = \frac{|i - i'|}{n-1}, \tag{2}$$

$$w_{ii'} = \frac{1}{n(n-1)} \left(2n|i - i' - 1| + i + i' - (i - i')^2\right), \tag{3}$$

$$w_{ii'} = \frac{1}{n(n-1)} \left(2n|i - i'| + 2 - i - i' - (i - i')^2\right). \tag{4}$$

Objects grouping ordered by the usage of Czekanowski's method was done with the usage of so called measuring instrument of grouping correctness (Podolec and Zając, 1978). The basis for constructing this measuring instrument is the assumption that in an optimal grouping particular groups should be composed of objects between which there is so called close connection and between

groups so called distant connection. A measuring instrument of grouping correctness is defined as:

$$Q = \frac{n^{pb}}{n^{w}} \cdot \frac{n^{pd}}{n^{z}}, \tag{5}$$

where n^{w}, n^{z} is a number of connections respectively inside and outside of isolated groups,

n^{pb}, n^{nd} is a number of connections respectively close inside groups and distant outside of isolated groups.

The choice of representatives was done by the usage of the centre of gravity method (Pluta, 1976). In this method the units of one element groups are treated as representatives of classified set. In the case of a group with more than two elements, for each object there is an average distance estimated from other units from this group. A representative becomes an object which has the smallest average distance because it is the most similar to other units from the group. For two element group an average distance is estimated for each unit from every previously indicated representative from other groups. A representative becomes an object for which an average distance estimated is the biggest because it will be the least similar to the remaining representatives.

Additionally, in this paper another criterion of public universities division was used as to compare if the obtained classification is a natural division of universities and follows from its internal structure. To evaluate a level of similarity of results from two different classifications of the same group of economic objects we use indices of grouping results conformity.

Assuming, that due to one division of group of objects $O_1, O_2, \ldots, O_N$ we obtain P typological groups $A_1, A_2, \ldots, A_P$ with number $N_1, N_2, \ldots, NP$ and due to another division we obtain Q typological groups $B_1, B_2, \ldots, B_Q$ with number equal to $B_1, B_2, \ldots, B_Q$, we receive an index of conformity on the basis of cross tabulation. In this tabulation N_{pq} determines the number of objects which at the same time belongs to a group A_p i B_q.

The index of conformity of results from two classifications is created according to a formula (Czerwińska and Gemborzewski, 1975):

$$w = \frac{1}{P+Q} \cdot \left(\sum_{p=1}^{P} z_{p0} + \sum_{q=1}^{Q} z_{0q} \right), \tag{6}$$

where

$$z_{p0} = \max_{q} \{ z_{pq} \} \quad (p = 1,2,\ldots P), \tag{7}$$

$$z_{0q} = \max_{p}\{z_{pq}\} \quad (q = 1,2,...Q) \tag{8}$$

and

$$z_{pq} = \frac{N_{pq}}{\max\{N_{p\bullet}, N_{\bullet q}\}}. \tag{9}$$

This index is normalized and its value says about the level of results similarities of the classification. The bigger the value it is more probable that the obtained classifications will overlap. Index *w* equals one only when comparable divisions give identical results.

3. Empirical material and the results of the researches

The objects of the research were public universities. The researched universities were initially divided into six groups according to the following scheme: general universities (U), universities of technology (T), universities of economics (E), universities of life sciences (R), universities of physical education (S) and pedagogical universities (P). Full names of all regions in Poland were included in Table 9 (Appendix). The research was conducted in 2004 and 2006. The data concerning structure of costs in particular years were standardised. A starting point for the research was a matrix of distance, defined as a certificated «town»[1]. Distance measuring instruments of this matrix were divided into five classes of similarities. Each similarity class were given graphic symbols which create so called chaotic Czekanowski's diagram. In this paper a close connection can be understood as a connection between objects to which a graphic symbol of the lowest class is assigned. The remaining connections between groups are treated as distant connections.

3.1. Grouping of universities in 2004

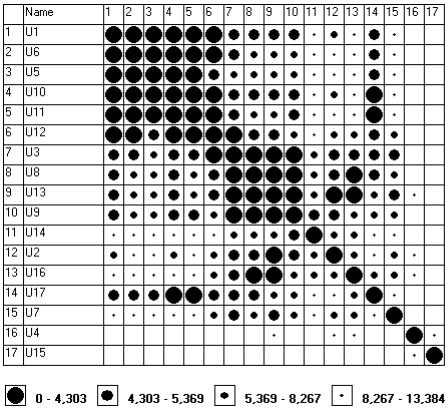
The results of grouping of public universities is shown on the basis of Czekanowski's diagram in Figure 1.

Due to the fact that the number of universities in particular categories did not exceed 18, it was decided that it will consider 10 groups of universities maximum. What follows, the optimal division of universities according to a measuring instrument of correctness was conducted with this assumption.

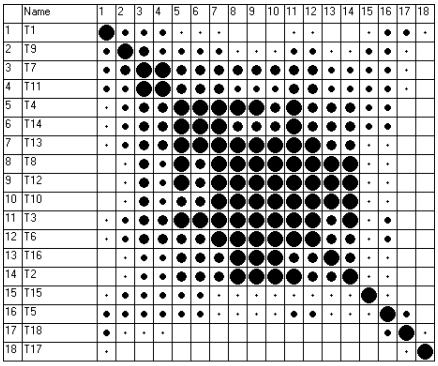
[1]Due to limitation of the paper, distance matrices were not included.

Figure 1

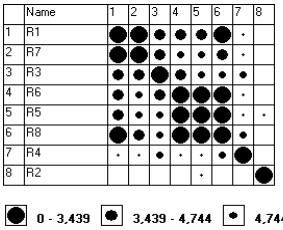
Orderly Czekanowski's diagram considering criterion of costs structure in 2004



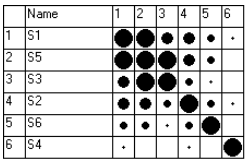
General universities

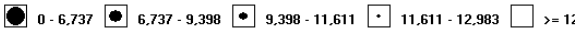


Universities of Technology

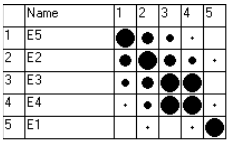


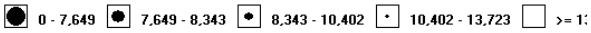
Universities of Life Sciences



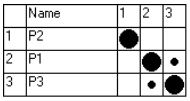


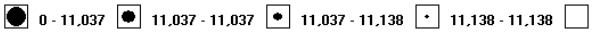
Universities of Physical Education





Universities of Economics





Pedagogical universities

Source: Self-study with the usage of MaCzek programme authorised by A. Sołtysiak, P.Jaskulski.

Another step of this research was the choice of representatives in typological groups on grounds of the classification results. In this situation one object is chosen from each group. This choice should be made so that the representatives are the most similar to the remaining elements of the group that they are from and least similar to each other.

Each division of each university category was given a value of measuring instrument of correct grouping, a representative and average value of variables that were used in grouping. The results are in Table 1 and 2.

Table 1

The value of a measuring instrument of grouping correctness and representatives of group in a universities division with the usage of Czekanowski's method on the basis of costs structure (2004)

Group	University	Representative
General Universities, Q=0,9229		
Group 1	U1,U5,U6,U10,U11,U12	Uniwersytet Opolski
Group 2	U3,U8,U9,U13	Uniwersytet Marii Cure Skłodowskiej w Lublinie
Group 3	U14	Uniwersytet Warmińsko-Mazurski w Olsztynie
Group 4	U2	Uniwersytet im. Adama Mickiewicza w Poznaniu
Group 5	U16	Uniwersytet Wrocławski
Group 6	U17	Uniwersytet Zielonogórski
Group 7	U7	Uniwersytet Łódzki
Group 8	U4	Uniwersytet Jagielloński w Krakowie
Group 9	U15	Uniwersytet Warszawski
Universities of Technology, Q=0,8323		
Group 1	T1	Akadamia Górniczo-Hutnicza im.Stanisława Staszica w Krakowie
Group 2	T9	Politechnika Łódzka
Group 3	T7,T11	Politechnika Krakowska im. Tadeusza Kościuszki
Group 4	T4,T14	Politechnika Częstochowska
Group 5	T2,T3,T6,T8,T10,T12,T13,T16	Politechnika Białostocka
Group 6	T15	Politechnika Śląska w Gliwicach
Group 7	T5	Politechnika Gdańska
Group 8	T18	Politechnika Wrocławska
Group 9	T17	Politechnika Warszawska
Universities of Life Sciences, Q=0,9583		
Group 1	R1,R7	Uniwersytet Technologiczno-Przyrodniczy im. J.J.Śniadeckich w Bydgoszczy
Group 2	R3	Uniwersytet Przyrodniczy w Lublinie
Group 3	R5,R6,R8	Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie
Group 4	R4	Uniwersytet Przyrodniczy im. Augusta Cieszkowskiego w Poznaniu
Group5	R2	Szkoła Główna Gospodarstwa Wiejskiego w Warszawie

Group	University	Representative
Universities of Economics, Q=1,000		
Group 1	E5	Uniwersytet Ekonomiczny we Wrocławiu
Group 2	E2	Akademia Ekonomiczna w Poznaniu
Group 3	E3,E4	Uniwersytet Ekonomiczny w Krakowie
Group 4	E1	Akademia Ekonomiczna im. Karola Adamieckiego w Katowicach
Universities of Physical Education, Q=0,8889		
Group 1	S1,S3,S5	Akademia Wychowania Fizycznego i Sportu im. Jędrzeja Śniadeckiego w Gdańsku
Group 2	S2	Akademia Wychowania Fizycznego im. Eugeniusza Piaseckiego w Poznaniu
Group3	S6	Akademia Wychowania Fizycznego we Wrocławiu
Group 4	S4	Akademia Wychowania Fizycznego Józefa Piłsudskiego w Warszawie
Pedagogical Universities, Q=1,000		
Group 1	P1	Wyższa Szkoła Pedagogiczna w Częstochowie
Group 2	P2	Akademia Pedagogiczna im. Komisji Edukacji Narodowej w Krakowie
Group3	P3	Akademia Pedagogiki Specjalnej im. Marii Grzegorzewskiej w Warszawie

Source: Self-study.

Table 2

Average values of characteristics in particular groups of public universities in 2004 in universities division ordered with the usage of Czekanowski's method on the basis of costs structure (cost in thousand PLN)

Group	Amortisation	Materials and energy	Services	Taxes and fees	Remuneration with overheads	Remaining costs	The value of sold goods and materials	Remaining operating costs	Financial costs	Average costs	Average number of students
General Universities											
1	4341,2	4968,7	5188,8	451,0	74984,3	4850,2	81,1	319,7	149,2	95334,0	19637,0
2	9769,5	17904,7	15806,5	245,9	165683,9	11020,5	205,6	1013,7	713,3	222363,5	34977,8

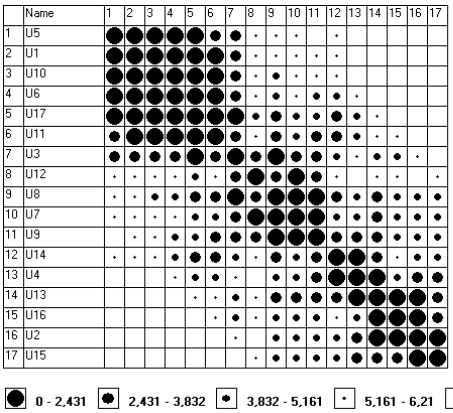
Group	Amortisation	Materials and energy	Services	Taxes and fees	Remuneration with overheads	Remaining costs	The value of sold goods and materials	Remaining operating costs	Financial costs	Average costs	Average number of students
3	11745,4	24293,8	23050,4	507,5	167270,0	10450,7	2915,4	1246,4	811,4	242291,0	35886,0
4	23035,3	22854,8	21279,3	268,2	244098,0	23951,6	11,6	367,0	393,0	336258,8	48728,0
5	14019,2	16521,9	29505,7	271,8	195924,8	15293,9	0,0	1877,5	2593,3	276008,1	39887,0
6	3926,8	9300,5	5712,4	264,4	92388,3	3699,5	0,0	377,0	2844,8	118513,7	22659,0
7	6663,9	17586,3	24378,5	6641,3	199591,3	14268,0	2,7	302,8	591,5	270026,3	38609,0
8	21983,7	42689,5	38612,4	148,9	320323,3	46507,0	62,2	16786,4	575,2	487688,6	39547,0
9	46586,4	32592,0	47904,9	6133,6	361267,0	74001,8	0,0	7773,1	2835,4	579094,2	50652,0
Universities of Technology											
1	18371,7	14040,9	17324,1	298,3	236804,0	26375,3	6,0	2384,0	1117,9	316722,2	28528,0
2	16051,4	14913,8	23944,2	100,4	154295,1	20141,6	26,0	503,6	558,1	230534,2	20299,0
3	9308,1	9975,1	14378,2	516,5	126732,6	5748,4	0,2	748,5	377,9	167785,3	17736,5
4	5818,3	7080,9	8504,5	122,3	81185,0	9444,0	26,1	411,4	203,3	112795,6	15637,0
5	3014,6	4317,9	3852,8	152,2	51466,3	2873,4	33,1	669,1	103,0	66482,2	11935,6
6	11067,3	11857,4	12165,8	3850,3	211228,8	15536,9	20,5	881,8	53,2	266662,0	31435,0
7	14219,9	21184,1	16224,9	180,2	139837,7	9133,5	149,5	2310,7	827,2	204067,7	16033,0
8	25382,1	19680,5	35490,7	1051,4	243341,7	9988,1	24,9	4173,8	922,7	340055,9	31964,0
9	20450,9	35795,7	36283,7	525,5	322368,4	36788,2	790,5	4234,7	1052,2	458289,8	29223,0
Universities of Life Sciences											
1	2680,2	6600,8	5316,7	142,2	54530,6	4020,1	323,1	149,5	70,8	73833,7	10399,5
2	3151,1	7292,5	6639,5	1897,8	73891,1	5984,3	303,7	349,1	201,6	99710,7	11554,0
3	3461,6	8531,2	8683,9	87,5	81071,5	5057,2	9,6	414,1	105,4	107422,0	17284,0
4	8366,7	21006,9	6859,2	3408,1	93910,9	13239,6	135,5	6887,2	481,7	154295,8	12766,0
5	50833,9	42506,5	19422,7	542,5	145642,0	79903,0	35,9	2721,5	917,3	342525,3	21167,0
Universites of Economics											
1	2933,6	6915,4	4873,1	387,4	84378,5	6550,3	1069,7	1359,8	168,4	108636,2	17270,0
2	2480,5	6161,6	4804,9	72,5	76150,9	7216,4	0,0	522,4	90,9	97500,1	13191,0
3	3592,3	6244,8	10575,4	124,3	99553,9	5223,5	0,0	194,3	137,6	125646,0	16007,0
4	2284,3	3603,3	5762,5	1882,1	53438,8	3662,7	0,0	28,1	18,9	70680,7	12637,0
Universities of Physiacal Education											
1	1062,6	2339,5	2227,1	72,1	24334,4	789,0	0,1	288,7	27,9	31141,3	3961,7
2	2000,2	4355,6	2218,8	49,4	33749,4	4620,5	0,0	75,1	38,6	47107,6	4388,0
3	1817,4	2985,0	3512,5	610,0	32284,3	2105,8	10,4	139,3	71,8	43536,5	4054,0
4	1165,3	6722,7	6736,5	122,6	42639,7	1586,3	0,0	7687,7	97,9	66758,7	6050,0
Pedagogical Universities											
1	810,9	2913,4	2362,9	588,6	47518,6	964,8	169,7	952,3	89,7	56370,9	10894,0
2	2381,6	3905,4	5374,3	191,8	73694,1	2429,3	0,1	770,1	15,3	88762,0	16223,0
3	435,3	1042,3	1555,4	8,9	20939,6	423,9	0,0	107,9	0,3	24513,6	6356,0

Source: Self-study.

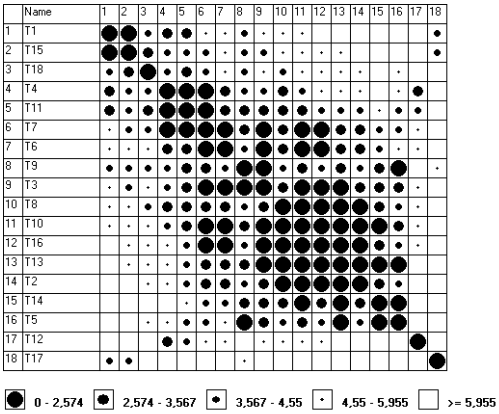
Additionally, as to estimate the conformity of classification results there was another division of public universities used according to a criterion of a number of students with the usage of cross tabulation and the index of division conformity. Characteristics regarding the number of students included students of intramural studies and extramural (including evening) undergraduate and master's students and the number of intramural and extramural post graduate students. The results of public universities grouping according to additional criterion presented on the basis of Czekanowski's diagram are shown in Figure 2.

Figure 2

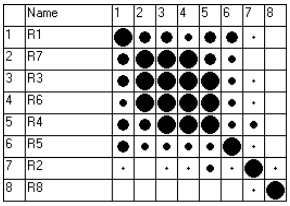
Orderly Czekanowski's diagram on the basis of criterion of students number (2004)



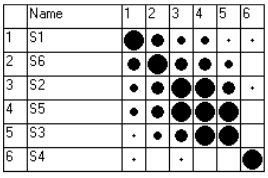
General Universities



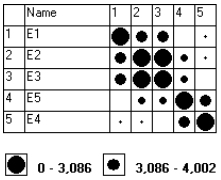
Universities of Technology



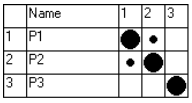
Universities of Life Sciences



Universities of Physical Education



Universities of Economics



Pedagogical Universities

Source: Self-study with the usage of MaCzek programme authorised by A. Sołtysiak, P. Jaskulski.

Because of grouping, after optimization of correctness measuring instrument for general universities we have received 7 groups of objects, for universities of technology 9 groups, for universities of economics and for universities of physical education 4 groups, 5 groups in case of universities of life sciences and

3 groups for pedagogical universities. A division of public universities in the mentioned categories and with a measuring instrument of grouping correctness were written down in Table 3.

Conformity of divisions was indicated on the basis of cross tabulation (Table 4).

Table 3

Universities division with the usage of Czekanowski's method regarding the number of students and the value of measuring instrument of grouping correctness

Group	Universities
General Universities, Q = 0,9325	
Group 1	U1,U5,U6,U10,U11,U17
Group 2	U3
Group 3	U12
Group 4	U7,U8,U9
Group 5	U4,U14
Group6	U2,U13,U16
Group 7	U15
Universities of Technology, Q = 0,8978	
Group 1	T1,T15
Group 2	T18
Group 3	T4,T7,T11,
Group 4	T6
Group 5	T9,T3
Group 6	T2,T8,T10,T13,T16
Group 7	T5,T14
Group 8	T12
Group 9	T17
Universities of Life Sciences, Q = 0,9286	
Group1	R1
Group 2	R3,R4,R6,R7
Group 3	R5
Group 4	R2
Group 5	R8
Universities of Economics, Q = 1,000	
Group 1	E1
Group2	E2,E3
Group 3	E5
Group 4	E4

Group	Universities
Universities of Physical Education, Q = 0,8889	
Group 1	S1
Group 2	S6
Group3	S2,S3,S5
Group 4	S4
Pedagogical Universities, Q=1,000	
Group 1	P1
Group 2	P2
Group 3	P3

Source: Self-study.

Table 4

Cross tabulation and value of conformity of grouping index for public universities in 2004

		costs									
		1	2	3	4	5	6	7	8	9	sum
students	1	5	0	0	0	0	1	0	0	0	6
	2	0	1	0	0	0	0	0	0	0	1
	3	1	0	0	0	0	0	0	0	0	1
	4	0	2	0	0	0	0	1	0	0	3
	5	0	0	1	0	0	0	0	1	0	2
	6	0	1	0	1	1	0	0	0	0	3
	7	0	0	0	0	0	0	0	0	1	1
	sum	6	4	1	1	1	1	1	1	1	17

General Universities, *w = 0,5052*

		costs									
		1	2	3	4	5	6	7	8	9	sum
students	1	1	0	0	0	0	1	0	0	0	2
	2	0	0	0	0	0	0	0	1	0	1
	3	0	0	2	1	0	0	0	0	0	3
	4	0	0	0	0	1	0	0	0	0	1
	5	0	1	0	0	1	0	0	0	0	2
	6	0	0	0	0	5	0	0	0	0	5
	7	0	0	0	1	0	0	1	0	0	2
	8	0	0	0	0	1	0	0	0	0	1
	9	0	0	0	0	0	0	0	0	1	1
	sum	1	1	2	2	8	1	1	1	1	18

Universities of Technology, *w = 0,6019*

		costs					
		1	2	3	4	5	sum
students	1	1	0	0	0	0	1
	2	1	1	1	1	0	4
	3	0	0	1	0	0	1
	4	0	0	0	0	1	1
	5	0	0	1	0	0	1
	sum	2	1	3	1	1	8

Universities of Life Sciences, *w = 0,6917*

		costs				
		1	2	3	4	sum
students	1	0	0	0	1	1
	2	0	1	1	0	2
	3	1	0	0	0	1
	4	0	0	1	0	1
	sum	1	1	2	1	5

Universities of Economics, *w = 0,7500*

		costs				
		1	2	3	4	sum
students	1	1	0	0	0	1
	2	0	0	1	0	1
	3	2	1	0	0	3
	4	0	0	0	1	1
	sum	3	1	1	1	6

Universities of Economics, *w = 0,7500*

Source: Self-study.

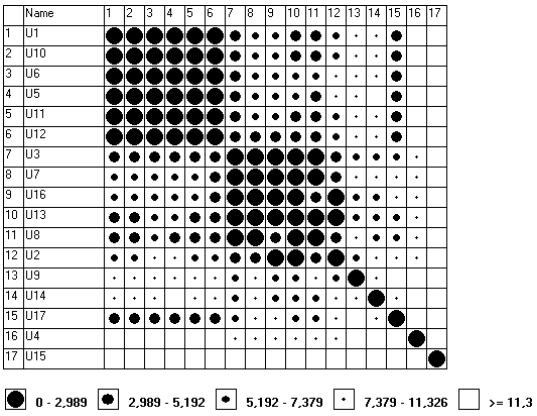
The highest level of conformity of grouping was in case of pedagogical universities but this is an effect of small number of universities taken into consideration. This is the most probable reason for such results in classification. Universities of physical education and universities of economics were characterized by high level of grouping conformityregarding two different characteristics. The lowest value of conformity index in 2004 obtained general universities for which conformity of students' number and generated costs in the groups were on the level of 50%.

3.2. Grouping of universities in 2006

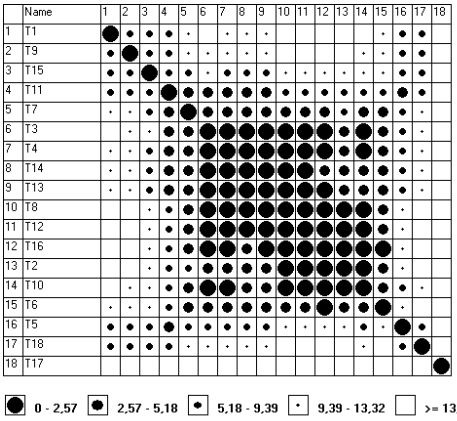
Results of public universities grouping presented on the basis of orderly Czekanowski's diagram in 2006 are shown in Figure 3.

Figure 3

Orderly Czekanowski's diagram on the basis of costs structure criterion in 2006



General universities



Universities of Technology

	Name	1	2	3	4	5	6	7	8
1	R1	●	●	●	•	●	●	·	
2	R3	●	●	●	•	●	●	•	
3	R6	●	●	●	●	●	•	•	
4	R5	•	•	●	●	●	•	·	·
5	R8	●	●	●	●	●	●	·	
6	R7	●	●	•	•	●	●	·	
7	R4	·	•	•	·	·	·	●	
8	R2				·				●

● 0 - 4,92 ● 4,92 - 6,31 • 6,31 - 9,37 · 9,37 - 15,03 □ >= 15,03

Universities of Life Sciences

	Name	1	2	3	4	5	6
1	S1	●	●	●	•		•
2	S3	●	●	●	•		•
3	S5	•	•	●	●	·	•
4	S2	•	•	●	●	·	·
5	S4			·	·	●	
6	S6	•	•	•	·		●

● 0 - 5,50 ● 5,50 - 9,14 • 9,14 - 10,82 · 10,82 - 12,91 □ >= 12,91

Universities of Physical Education

	Name	1	2	3	4	5
1	E1	●	•	·	·	
2	E2	•	●	●	●	•
3	E4	·	●	●	●	·
4	E3	·	•	•	●	
5	E5		•	·		●

● 0 - 8,15 ● 8,15 - 8,75 • 8,75 - 9,66 · 9,66 - 12,18 □ >= 12,18

Universities of Economics

	Name	1	2	3
1	P1	●	•	
2	P3	•	●	•
3	P2		•	●

● 0 - 8,58 ● 8,58 - 8,58 • 8,58 - 13,77 · 13,77 - 13,77 □ >= 13,77

Pedagogical Universities

Source: Self-study with the usage of MaCzek programme authorised by A. Sołtysiak, P. Jaskulski

Another step in this study is a choice of representatives of typological groups on the basis of the result of a conducted classification. The representatives were distinguished again with the usage of centre of gravity method. To the obtained division in the category of universities the following values were indicated: values of correctness measuring instruments, a representative of a group and average values of all variables in grouping. The results are presented in Table 5 and 6.

Table 5

Values of grouping measuring instruments and representatives in universities grouping with the sage of orderly Czekanowski's method regarding costs structure

Group	University	Representative
General universities, Q = 0,9149		
Group 1	U1,U5,U6,U10,U11,U12	Uniwersytet w Białymstoku
Group 2	U2,U3,U7,U8,U13,U16	Uniwersytet Śląski w Katowicach
Group 3	U4	Uniwersytet Jagielloński w Krakowie
Group 4	U9	Uniwersytet Mikołaja Kopernika w Toruniu
Group 5	U14	Uniwersytet Warmińsko-Mazurski w Olsztynie
Group6	U15	Uniwersytet Warszawski
Group 7	U17	Uniwersytet Zielonogórski
Universities of Technology, Q = 0,8786		
Group 1	T7,T11	Politechnika Krakowska im. Tadeusza Kościuszki
Group 2	T3,T4,T8,T12,T13, T14,T16	Politechnika Lubelska
Group 3	T2,T6, T10	Politechnika Opolska
Group 4	T1	Akadamia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie
Group 5	T5	Politechnika Gdańska
Group 6	T9	Politechnika Łódzka
Group 7	T15	Politechnika Śląska w Gliwicach
Group8	T17	Politechnika Warszawska
Group 9	T18	Politechnika Wrocławska
Universities of Life Sciences, Q = 0,9200		
Group 1	R1,R3,R6	Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie
Group 2	R5	Uniwersytet Przyrodniczy we Wrocławiu
Group 3	R8	Uniwersytet Humanistyczno-Przyrodniczy Jana Kochanowskiego w Kielcach

Group	University	Representative
Group 4	R7	Uniwersytet Technologiczno-Przyrodniczy im. J.J.Śniadeckich w Bydgoszczy
Group5	R4	Uniwersytet Przyrodniczy im. Augusta Cieszkowskiego w Poznaniu
Group 6	R2	Szkoła Główna Gospodarstwa Wiejskiego w Warszawie
Universities of Economics, Q = 1,000		
Group 1	E1	Akademia Ekonomiczna im. Karola Adamieckiego w Katowicach
Group 2	E2,E4	Uniwersytet Ekonomiczny w Krakowie
Group 3	E3	Szkoła Główna Handlowa w Warszawie
Group4	E5	Uniwersytet Ekonomiczny we Wrocławiu
Universities of Physical Education, Q = 1,000		
Group 1	S1,S3	Akademia Wychowania Fizycznego im. Bronislawa Czecha w Krakowie
Group 2	S2,S5	Akademia Wychowania Fizycznego im. Eugeniusza Piaseckiego w Poznaniu
Group 3	S4	Akademia Wychowania Fizycznego Józefa Piłsudskiego w Warszawie
Group 4	S6	Akademia Wychowania Fizycznego we Wrocławiu
Pedagogical Universities, Q = 1,000		
Group 1	P1	Wyższa Szkoła Pedagogiczna w Częstochowie
Group 2	P2	Akademia Pedagogiczna im. Komisji Edukacji Narodowej w Krakowie
Group 3	P3	Akademia Pedagogiki Specjalnej im. Marii Grzegorzewskiej w Warszawie

Source: Self-study.

Additionally, to evaluate the conformity of results of the given classification another grouping of public universities was used regarding students number criterion with the usage of a value of conformity index calculated according to formula (6) on the basis of cross tabulation (table 8).Characteristics regarding the number of students included students of intramural studies and extramural (including evening) undergraduate and master's students and the number of intramural and extramural post graduate students. The results of public universities grouping according to additional criterion presented on the basis of orderly Czekanowski's diagram are shown in Figure 4.

Table 6

Average values of characteristics in particular groups of public universities in universities grouping with the usage of orderly Czekanowski's method regarding costs structure
(costs in thousand PLN)

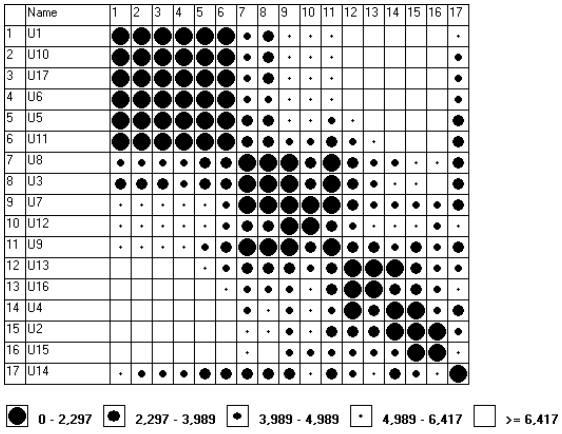
Group	Amortisation	Materials and energy	Services	Taxes and fees	Remuneration with overheads	Remaining costs	The value of sold goods and materials	Remaining operating costs	Financial costs	Average costs	Average number of students
General universities											
1.	2894,8	5371,9	5527,3	481,9	85125,3	3887,1	31,7	487,9	83,4	103891,4	18673,0
2.	10237,1	20142,8	22336,4	1385,0	223333,3	14844,9	2,6	812,4	363,3	293457,7	36457,8
3.	27745,0	43050,3	37393,2	6468,9	379337,6	45826,9	44,8	4439,9	1503,7	545810,3	44183,0
4.	14740,7	33336,7	16989,2	157,8	234379,6	10428,3	628,3	53457,7	255,6	364373,9	34689,0
5.	12437,8	26714,5	24603,1	479,4	186088,3	11832,5	2725,9	983,4	1195,8	267060,7	35886,0
6.	55163,7	35530,6	60814,1	42434,5	438045,2	65020,4	0,0	36860,6	1982,0	735851,1	52230,0
7.	5377,2	8285,4	7829,9	335,2	106543,2	4734,4	0,0	281,2	3024,3	136410,8	12117,0
Universities of Technology											
1.	9177,7	10230,0	14849,5	791,1	144000,1	6051,5	0,4	763,1	220,1	186083,4	16095,0
2.	4076,8	5981,1	5363,9	139,4	72249,8	4750,6	7,0	351,3	44,2	92964,2	11605,0
3.	1727,7	3457,0	5928,8	521,0	46295,0	2665,7	0,5	780,9	159,4	61535,9	9914,7
4.	17764,9	15489,9	22150,5	2235,7	273551,9	24851,5	21,7	3120,9	590,8	359777,8	27561,0
5.	14788,7	22143,8	21956,7	335,3	155339,3	11204,6	91,4	2160,2	256,6	228276,6	17116,0
6.	16949,5	13472,7	28471,3	6294,6	180107,4	15327,1	18,8	520,4	496,4	261658,2	19036,0
7.	11119,1	15573,7	15754,4	5099,2	249459,8	18605,3	3,5	605,2	79,7	316299,9	29193,0
8.	19137,2	32909,2	28142,3	846,8	369195,6	31086,9	659,6	23929,1	539,0	506445,7	28217,0
9.	25101,9	21265,5	36987,1	1331,7	268653,8	14044,7	30,9	4972,0	191,9	372579,5	32579,0
Universities of Life Sciences											
1.	3277,7	7387,7	6053,8	981,7	76206,0	5608,5	170,5	374,8	43,3	100104,1	11112,0
2.	4763,6	14735,5	15732,7	89,7	91255,4	4227,0	14,4	1819,1	22,2	132659,6	10847,0
3.	2912,5	5760,3	5438,3	48,5	107722,4	2086,7	0,0	520,9	292,2	124781,8	24210,0
4.	2999,8	8210,9	5762,3	97,1	71374,4	3075,2	563,2	221,2	363,7	92667,8	8953,0
5.	8485,0	11622,6	3966,8	3668,1	101626,9	11078,8	1,8	1943,0	538,5	142931,5	12057,0
6.	47067,8	36594,1	21591,9	579,0	177794,4	7567,8	32,9	3801,3	520,2	295549,4	21776,0
Universities of Economics											
1.	2684,1	4037,9	6691,2	2011,7	64960,5	3590,8	0,0	277,4	36,6	84290,2	12291,0
2.	2251,2	6393,2	7252,0	245,4	85608,5	5964,1	0,0	3476,5	63,6	111254,3	14849,0
3.	3036,7	7389,2	10105,5	343,8	120029,3	7020,8	0,0	123,8	95,1	148144,2	11173,0
4.	1721,9	6935,2	4739,0	404,6	89153,5	5924,7	625,7	1096,0	356,6	110957,2	15356,0

Group	Amortisation	Materials and energy	Services	Taxes and fees	Remuneration with overheads	Remaining costs	The value of sold goods and materials	Remaining operating costs	Financial costs	Average costs	Average number of students
Universities of Physical Education											
1.	694,5	2044,0	2183,3	64,6	29728,0	788,6	0,0	13184,3	33,6	48720,7	5339,5
2.	2229,3	3567,2	2136,8	62,3	32816,2	3079,5	0,0	125,0	25,9	44042,0	4367,5
3.	1582,8	7745,7	5676,8	177,5	50119,6	3267,5	0,0	7258,7	204,0	76032,6	6319,0
4.	534,5	3438,9	4003,1	839,9	36419,7	1260,2	25,1	184,7	1,0	46707,1	3993,0
Pedagogical Universities											
1.	810,9	2913,4	2362,9	588,6	47518,6	964,8	169,7	952,3	89,7	56370,9	9038,0
2.	2657,6	3596,5	5451,7	37,2	83730,2	2821,9	2,7	622,9	46,1	98966,8	16668,0
3.	1050,6	1370,3	1910,1	287,4	24758,9	668,2	0,0	402,1	69,7	30517,3	6541,0

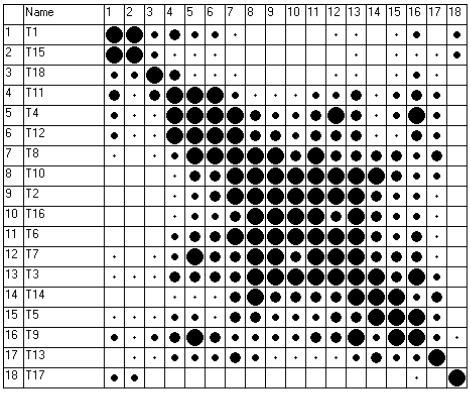
Source: Self-study.

Figure 4

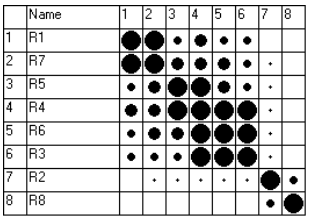
Orderly Czekanowski's diagram regarding the number of students' criterion



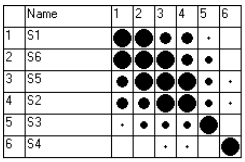
General Universities



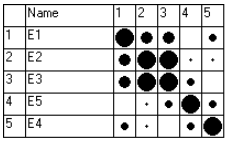
Universities of Technology



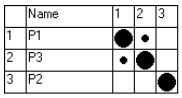
Universities of Life Sciences



Universities of Physical Education



Universities of Economics



Pedagogical Universities

Source: Self-study with the usage of MaCzek programme authorised by A. Sołtysiak, P. Jaskulski.

Because of grouping, after optimization of correctness measuring instrument for general universities and universities of life sciences we have received 5 groups of objects, for universities of technology 7 groups, for universities of economics and for universities of physical education 4 groups and 3 groups for pedagogical universities. A grouping of public universities in the mentioned categories and with a measuring instrument of grouping correctness was written down in Table 7.

Table 7

Universities grouping ordered on the basis of Czekanowski's method regarding the number of students and the value of measuring instrument of grouping correctness

Group	Universities
General Universities, Q = 0,9045	
Group 1	U1,U5,U6,U10,U11,U17
Group 2	U3,U7,U8,U9,U12
Group 3	U13, U16
Group 4	U2,U4,U15
Group 5	U14
Universities of Technology, Q = 0,7035	
Group 1	T1,T15
Group 2	T18
Group 3	T4,T11,T12
Group 4	T2,T3,T6,T7,T8,T10,T14, T16
Group 5	T5,T9
Group 6	T13
Group 7	T17

Group	Universities
Universities of Life Sciences, Q = 0,9583	
Group 1	R1,R7
Group 2	R5
Group 3	R3,R4,R6
Group 4	R2
Group 5	R8
Universities of Economics, Q = 1,000	
Group 1	E1
Group 2	E2,E4
Group 3	E3
Group 4	E5
Universities of Physical Education, Q = 0,9231	
Group 1	S1,S6
Group 2	S2,S5
Group3	S3
Group 4	S4
Pedagogical Universities, Q = 1,000	
Group 1	P1
Group 2	P2
Group 3	P3

Source: Self-study.

Conformity of grouping was researched on the basis of cross tabulation (table 8). All the given values of conformity index confirmed in case of universities of physical education that there is high level of grouping conformity. Similarly for universities of economics and universities of life sciences the value of conformity index indicated a good conformity of grouping in relation to both criterions. It demonstrates that in given groups the values of generated costs depend, to a great degree, on the number of students. The lowest level of conformity was found at general universities; however it is worth mentioning that this conformity compared to year 2004 has risen. The only group of universities were a decrease of conformity index was observed were universities of technology. Due to the character of these universities it can be assumed that there are other similarly important factors, different than number of students, that generate costs at particular groups of universities of technology.

Table 8

Cross tabulation and conformity index of grouping at public universities in 2006

students		costs							
		1	2	3	4	5	6	7	sum
	1	5	0	0	0	1	0	0	6
	2	1	3	1	0	0	0	0	5
	3	0	2	0	0	0	0	0	2
	4	0	1	0	0	0	1	1	3
	5	0	0	0	1	0	0	0	1
	sum	6	6	1	1	1	1	1	17

General Universities, *w = 0,5306*

students		costs									
		1	2	3	4	5	6	7	8	9	sum
	1	1	0	1	0	0	0	0	0	0	2
	2	0	0	0	0	0	0	0	1	0	1
	3	0	0	0	1	2	0	0	0	0	3
	4	0	0	0	1	3	3	0	0	0	7
	5	0	2	0	0	0	0	1	0	0	3
	6	0	0	0	0	1	0	0	0	0	1
	7	0	0	0	0	0	0	0	0	1	1
	sum	1	2	1	2	6	3	1	1	1	18

Universities of Technology, *w = 0,5804*

students		costs						
		1	2	3	4	5	6	sum
	1	1	0	0	1	0	0	2
	2	0	1	0	0	0	0	1
	3	2	0	0	0	1	0	3
	4	0	0	0	0	0	1	1
	5	0	0	1	0	0	0	1
	sum	3	1	1	1	1	1	8

Universities of Life Sciences, *w = 0,7879*

students		costs				
		1	2	3	4	sum
	1	1	0	0	0	1
	2	0	1	1	0	2
	3	0	0	0	1	1
	4	0	1	0	0	1
	sum	1	2	1	1	5

Universities of Economics, *w = 0,7500*

students		costs				
		1	2	3	4	sum
	1	1	0	0	1	2
	2	0	2	0	0	2
	3	1	0	0	0	1
	4	0	0	1	0	1
	sum	2	2	1	1	6

Universities of Physical Education, *w = 0,8750*

Source: Self-study.

4. Conclusion

Multifeature grouping of public universities is realized on the basis of cluster analysis with the usage of Czekanowski's diagram method and it gives significant quantitative and qualitative information both from research and general point of view. Diagram method has led to selection of object classes which are most similar to each other and in respect of taken characteristics and at the same time totally different objects from other cluster. Identification and characterisation of these clusters allows to reflect the phenomenon of object differentiation and to detect the following regularity between objects and its attributes and to make generalizing conclusions significant from the point of view of rational management politics of internal and external decision-makers at universities.

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Appendix

Table 9

A list of public universities

Symbol	University
U1	Uniwersytet w Białymstoku
U2	Uniwersytet im. Adama Mickiewicza w Poznaniu
U3	Uniwersytet Gdański
U4	Uniwersytet Jagielloński w Krakowie
U5	Uniwersytet Kardynała Stefana Wyszyńskiego w Warszawie
U6	Uniwersytet Kazimierza Wielkiego w Bydgoszczy
U7	Uniwersytet Łódzki
U8	Uniwersytet Marii Cure Skłodowskiej w Lublinie
U9	Uniwersytet Mikołaja Kopernika w Toruniu
U10	Uniwersytet Opolski
U11	Uniwersytet Rzeszowski
U12	Uniwersytet Szczeciński
U13	Uniwersytet Śląski w Katowicach
U14	Uniwersytet Warmińsko-Mazurski w Olsztynie
U15	Uniwersytet Warszawski

Symbol	University
U16	Uniwersytet Wrocławski
U17	Uniwersytet Zielonogórski
T1	Akademia Górniczo-Hutnicza im.Stanisława Staszica w Krakowie
T2	Akademia Techniczno-Humanistyczna w Bielsku-Białej
T3	Politechnika Białostocka
T4	Politechnika Częstochowska
T5	Politechnika Gdańska
T6	Politechnika Koszalińska
T7	Politechnika Krakowska im. Tadeusza Kościuszki
T8	Politechnika Lubelska
T9	Politechnika Łódzka
T10	Politechnika Opolska
T11	Politechnika Poznańska
T12	Politechnika Radomska im. Kazimierza Pułaskiego
T13	Politechnika Rzeszowska im. Ignacego Łukasiewicza
T14	Politechnika Szczecińska
T15	Politechnika Śląska w Gliwicach
T16	Politechnika Świętokrzyska w Kielcach
T17	Politechnika Warszawska
T18	Politechnika Wrocławska
E1	Akademia Ekonomiczna im. Karola Adamieckiego w Katowicach
E2	Akademia Ekonomiczna w Poznaniu
E3	Szkoła Główna Handlowa w Warszawie
E4	Uniwersytet Ekonomiczny w Krakowie
E5	Uniwersytet Ekonomiczny we Wrocławiu
R1	Akademia Rolnicza w Szczecinie
R2	Szkoła Główna Gospodarstwa Wiejskiego w Warszawie
R3	Uniwersytet Przyrodniczy w Lublinie
R4	Uniwersytet Przyrodniczy im. Augusta Cieszkowskiego w Poznaniu
R5	Uniwersytet Przyrodniczy we Wrocławiu
R6	Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie
R7	Uniwersytet Technologiczno-Przyrodniczy im. J. Śniadeckich w Bydgoszczy
R8	Uniwersytet Humanistyczno-Przyrodniczy Jana Kochanowskiego w Kielcach
S1	Akademia Wychowania Fizycznego im. Bronisława Czecha w Krakowie
S2	Akademia Wychowania Fizycznego im. Eugeniusza Piaseckiego w Poznaniu
S3	Akademia Wychowania Fizycznego im. Jerzego Kukuczki w Katowicach

Symbol	University
S4	Akademia Wychowania Fizycznego Józefa Piłsudskiego w Warszawie
S5	Akademia Wychowania Fizycznego i Sportu im. Jędrzeja Śniadeckiego w Gdańsku
S6	Akademia Wychowania Fizycznego we Wrocławiu
P1	Wyższa Szkoła Pedagogiczna w Częstochowie
P2	Akademia Pedagogiczna im. Komisji Edukacji Narodowej w Krakowie
P3	Akademia Pedagogiki Specjalnej im. Marii Grzegorzewskiej w Warszawie

Source: A. Ćwiąkała-Małys, M. Mościbrodzka, 'Hierarchiczne procedury aglomeracyjne w badaniu poziomu i struktury kosztów publicznych uczelni akademickich, paper in printing.

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