

GRAPH METHODS IN AN ANALYSIS OF A LEVEL AND A STRUCTURE OF PUBLIC COSTS OF UNIVERSITIES

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Abstract: In this article a usage of graph methods as a tool for a classification of polish public universities due to a generated level and a structure of costs is shown. The research was conducted in a spatial interpretation and referring to 57 public universities of an academic function. The usage of graph methods constitutes a tool which can be used by decision makers in a process of searching for ineffective usage of public sources. The outcomes should be a basis for further cause and effect analysis.

Keywords: taxonomic methods, public universities, an analysis of a level and a structure of costs

INTRODUCTION

Managing finances of a public university depends on efficient management of economic information. Its presentation should show clear and open financial data. The lack of proper presentation of a situation may lead to incorrect financial politics in relation with a public university and inside the university. Spatial analysis of a level and a structure of costs should be used as a tool in a process of an effective usage of a public source. The outcomes should be fully used in creating a strategy of higher education development and in internal cause and effect financial analysis of every university.

An article constitutes a continuation of researches of the authors in order to show the usefulness of the usage of chosen taxonomic methods in a process of checking a level and a structure of costs of public universities.¹

The aim of this article is to present the possibilities of the usage of graph methods in a process of public universities grouping due to a level and a structure of costs – in order to rationalize a politics of public universities financing.

THEORETICAL BASIS OF THE METHOD

A classification of public universities due to a level and a structure of costs in a spatial presentation was conducted with the usage of graph methods. By using graphs it is possible to show relations between researched objects [Nowak 1990].

One of the well known graph method is wroclaw taxonomy created by K. Florek, J. Łukasiewicz, J. Perkal, H. Steinhaus and S. Zubrzycki, a tree method by R.C. Prim and a graph method by W.Pluta .

In this article a taxonomic graph method was used (so called wrocławska taxonomy) which is also called a tree method. The rules of wroclaw taxonomy method were created by An Application Group of a Public Mathematical Institute in Wrocław [Florek and others 1951]. The basis for building a matrix of a distance between objects is calculated on the basis of Euklid certificate [Panek, Zwierzchowski 2013].

A base to divide a set of researched objects into typological groups is so called a tree which segregates them in a non-linear way [Nowak 1990, s. 69]. A process of creating a wroclaw tree in this method is a process of many stages. Apices of the graph correspond with the objects of a classification and edges (arcs and cords) – distances between the examined objects. A tree constitutes a broken line, continuous which can branch out but cannot include cycles (broken and completed) and combines all objects of the examined set, grouping them in a non-linear way [Nowak 1990, p. 70].

Building a tree consists of few stages (see Ćwiąkała-Małys, Nowak [2009]). Accumulation is understood as a coherent graph in which all the apices are connected by a continuous line of edges – a tree. There are many separate coherent graphs so creating a tree is continued and each accumulation is linked in places designated by the smallest distances. A process of creating a tree is assumed to be finished when all accumulations are linked and where is a coherent graph.

¹ Ćwiąkała-Małys A. (2009), Zastosowanie taksonomii wrocławskiej w analizie porównawczej publicznych uczelni akademickich, *Badania Operacyjne i Decyzje*, 1/2009.

Ćwiąkała-Małys A. Mościbrodzka M., Zastosowanie diagramu Czekanowskiego w grupowaniu publicznych uczelni wyższych ze względu na poziom i strukturę kosztów (w druku).

Ćwiąkała-Małys A., Mościbrodzka M. (2014), Hierarchiczne procedury aglomeracyjne w badaniu poziomu i struktury kosztów publicznych uczelni akademickich, *Metody ilościowe w badaniach ekonomicznych*, Vol. 15, no. 3, p. 30-41.

Another issue in this research was to indicate typological groups [Ćwiąkała-Małys, 2009]. It was obtained by cutting out edges from the longest tree. There are many different ways of a tree division. To separate from a T tree some typological groups you should divide it into T parts. So from a tree you eliminate T-1, it is the longest edge. Number T may be described in various ways, for instance according to the tips suggested by authors of wroclaw taxonomy [Florek i in. 1951].

Another way of separating typological groups on the basis of a tree was suggested by Z. Hellwig [1968], by using so called limited distance d^* , which was specified according to a formula [Nowak, 1990]:

$$d^* = d_1 + u \cdot (d_2 - d_1), \quad (1)$$

Where $d_1 = \min_i \min_j \{d_{ij}\}$, $d_2 = \max_i \max_j \{d_{ij}\}$ and d_{ij} defines a distance

between i and j typological object. In formula (1) an u value is determined by a researcher. It should belong to $[0,1]$ range. The smaller the value of a parameter the more typological groups we obtain.

Another step of the research was a choice of representatives of typological groups according to a result of a classification. In this situation we choose one object from each group, a choice should be made in such a way so that representatives are as similar as possible to the remaining elements from their group (a model object represents the remaining objects from the group) and least similar to the other elements outside the group (which enables to thoroughly learn about various structures of cost from researched objects). In this work a method of the centre of gravity was used [compare Pluta 1976] to choose representatives. While choosing representatives of the typological groups it is vital to aim at choosing such an object that will possibly be the most similar to the remaining objects which were not chosen as representatives.

EMPIRICAL MATERIAL AND RESEARCHES RESULTS

A subject of the research were public universities. The researched universities were initially divided into six groups according to the following structure: academic (U), technical (T), economic (E), environmental and life sciences (R), physical education (S), and pedagogical (P). Full names of the universities from all province were included in a table 5 (Annex). Data which were taken into consideration were taken from financial reports of the researched universities from 2006 [Ćwiąkała-Małys 2010]. The data included information according to the amount of costs of amortization, materials and energy, foreign services, taxes and fees, remunerations with margins, a value of sold goods and materials, financial costs and remaining costs including operational costs.

In the first step of grouping a structure of costs was taken into consideration. The usage of taxonomic methods to classify objects requires measures of structure

similarity of classified units. In this case as a measure of distance between the units due to a structure of costs a formula for a distance was used [Nowak 1990]:

$$d_{ij} = \sqrt{\frac{1}{2} \sum_{k=1}^K (u_{ik} - u_{jk})^2}, \quad (2)$$

where u_{ik} is an indicator of a structure of a k -element for an i -object.

A matrix of distances calculated according to (2) constituted a basis for further analysis. Due to the usage of such a distance with a regulated value [Szymanowicz 1977], similar objects according to a structure have a value of distance close to zero and values close to unity tell about huge diversity of researched structures.

On the basis of data pairs of universities were distinguished which are the most similar as a structure of costs is concerned (Table 1) and a tree was made which shows similarity of universities due to a structure of their costs (Figure 1).

It is visible that in respect of costs groups of universities do not exchange mutually which means that universities from a given group do not always have the most similar object in respect of a structure of costs from the same group of universities. It is also noticeable that in all cases a distance of a given university from its 'closest neighbour' is small (does not exceed 0,1) which indicates that there is close similarity of researched objects.

Table 1. A specification of pairs of universities which are the most similar due to a structure of costs

University	Distance	The most similar object	University	Distance	The most similar object	University	Distance	The most similar object
U1	0.0137	U8	T3	0.0141	T6	R4	0.0336	U4
U2	0.0157	T8	T4	0.0125	T1	R5	0.0264	U14
U3	0.0137	R6	T5	0.0198	U14	R6	0.0137	U3
U4	0.0336	R4	T6	0.0136	T8	R7	0.0228	U2
U5	0.0157	U10	T7	0.0198	T3	R8	0.0126	U6
U6	0.0126	R8	T8	0.0136	T6	E1	0.0226	U7
U7	0.0159	R1	T9	0.0331	T18	E2	0.0174	T8
U8	0.0137	U10	T10	0.0391	T9	E3	0.0159	T6
U9	0.0468	S4	T11	0.0176	U2	E4	0.0329	T2
U10	0.0196	P1	T12	0.0158	T3	E5	0.0183	U12
U11	0.0149	P3	T13	0.0271	U2	S1	0.1069	S3
U12	0.0183	E5	T14	0.0188	R6	S2	0.0203	T14
U13	0.0198	U16	T15	0.0171	T6	S3	0.0521	U9
U14	0.0198	T5	T16	0.0202	T5	S4	0.0468	U9
U15	0.0830	T9	T17	0.0320	T14	S5	0.0241	T11
U16	0.0198	U13	T18	0.0266	U16	S6	0.0242	U8
U17	0.0182	T3	R1	0.0141	R6	P1	0.0196	U9
T1	0.0125	T4	R2	0.0921	T5	P2	0.0149	U6
T2	0.0268	E1	R3	0.0174	T15	P3	0.0149	U11

Source: self-study

As the following step groups of universities similar in respect of a structure of costs were indicated, by using threshold value $d^*=0,024$, calculated on the basis of a formula (1) for a constant value $u=0,04$. (higher values made all universities to be accumulated in one place). Results of grouping with their representatives from particular groups were included in Table 2.

It is visible that one-element university groups are physical education universities which shows that there is diversification of costs in such universities and big academic centres with specific conditions following from a number of employees and students but also from a character and interdisciplinarity of the centres.

In the next step of the research the amount of costs in academic centres was taken into consideration. Costs data were standardized to make them comparable and homogenous due to changeability and location. On the basis of regulated values of features a matrix of Euklid distances between universities was distinguished. Then accumulations of first choice and pairs of universities the most similar in respect of value of costs according to groups were indicated (Table 3).

Although again there were mostly universities that did not have their similar object from the same group it is noticeable that there is common feature that appears between researched universities which should not surprise. Namely, it is visible that big academic centres have another big centre as their 'neighbour'. At the same time, it is worth noticing, that in some cases even the most similar object (so the one that has the smallest distance in respect of costs), was relatively far from its 'neighbour'. As an example we can name University of Warsaw, its distance from the closest university (Jagiellonian University in Kraków) in respect of value of costs was equal to 8,22 (which is 36 time higher than a distance of University of Bielsko-Biała from its most similar centre – University of Physical Education in Wrocław).

A tree obtained with the usage of wroclaw taxonomy method for public universities showing their diversification in respect of their value of costs was presented in Figure 2.

In another step groups of universities similar in respect of value of costs were distinguished with the usage of line value $d^*=0,7837$, calculated according to a formula (1) for a constant $u=0,04$. The result of grouping with the representatives was included in Table 4.

Figure 1. A tree obtained with the usage of wroclaw taxonomy method for a structure of costs of public universities

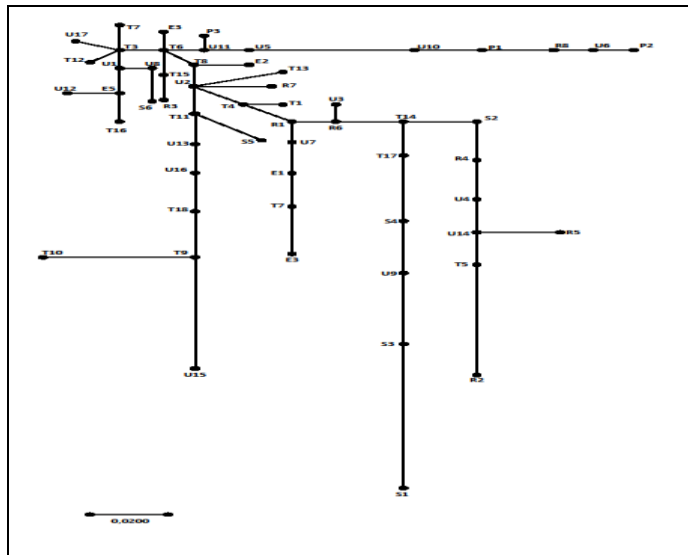
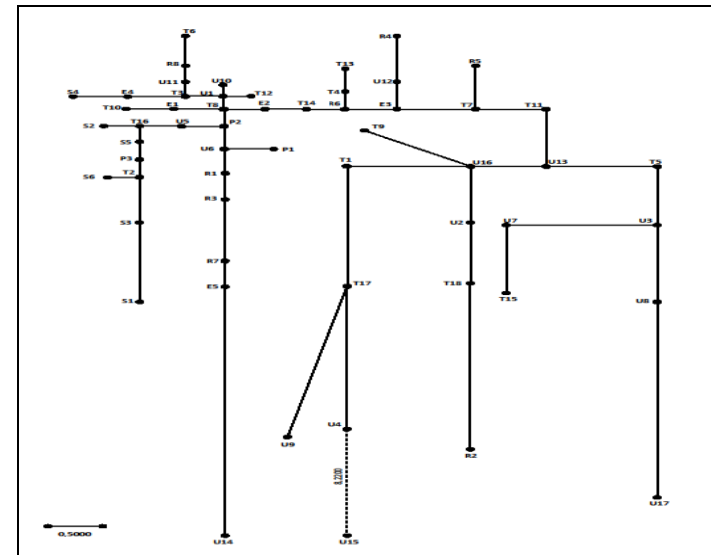


Figure 2. A tree obtained with the usage of wroclaw taxonomy method for the value of costs of public universities



Source: self-study

Table 2. A group of universities with a representatives in wroclaw taxonomy division due to a structure of costs

Group	University	Representative
group 1	U17,T12, T3, T7, U1, E5, U12, T16, U8, T6, E3, T15, R3, U11, P3, U5, T8, E2, U2, R7, T11, U13, U16, T4, T1, R1, R6, U3, T14 ,S2, U7, E1	Silesian University of Technology
group 2	E3	Warsaw School of Economics
group 3	T2	University of Bielsko-Biala
group 4	T9	Lodz University of Technology
group 5	T10	Opole University of Technology
group 6	T13	Rzeszów University of Technology
group 7	T17	Warsaw University of Technology
group 8	T18	Wrocław University of Technology
group 9	U9	Nicolaus Copernicus University of Toruń
group 10	U15	University of Warsaw
group 11	R2	Warsaw University of Life Sciences
group 12	R4	Poznań University of Life Sciences
group 13	R5	Wrocław University of Environmental and Life Sciences
group 14	U4, U14, T5	University of Warmia i Mazury in Olsztyn
group 15	U10, P1, R8, U6, P2	Kazimierz Wielki University in Bydgoszcz
group 16	S1	University of Physical Education in Cracow
group 17	S3	The Jerzy Kukuczka University of Physical Education in Katowice
group 18	S4	Józef Piłsudski University of Physical Education in Warsaw
group 19	S5	Gdansk University of Physical Education and Sport
group 20	S6	University of Physical Education in Wrocław

Source: self-study

Table 3. A specification of pairs of universities which are the most similar due to the amount of costs

University	Distance	The most similar object	University	Distance	The most similar object	University	Distance	The most similar object
U1	0.2444	U10	T3	0.3170	U1	R4	1.0553	U12
U2	1.3507	U16	T4	0.3544	T6	R5	0.8721	T7
U3	1.1080	T5	T5	0.9029	U13	R6	0.3236	T14
U4	3.9358	T17	T6	0.6884	R8	R7	0.4214	R5
U5	0.3297	T16	T7	0.6265	T11	R8	0.3919	U11
U6	0.4114	P1	T8	0.2520	U1	E1	0.3963	T8
U7	1.2463	T15	T9	1.4724	U16	E2	0.3640	T8
U8	1.5124	U3	T10	0.4398	E1	E3	0.4789	R6
U9	4.1577	T17	T11	0.6265	T7	E4	0.5423	S4
U10	0.2444	U1	T12	0.2660	U1	E5	0.4214	R7

University	Distance	The most similar object	University	Distance	The most similar object	University	Distance	The most similar object
U11	0.3204	T3	T13	0.4724	T4	S1	1.2712	S3
U12	0.5899	E3	T14	0.3236	R6	S2	0.2824	T16
U13	0.7805	U16	T15	1.2463	U7	S3	0.7326	T2
U14	6.4074	E5	T16	0.2693	S5	S4	0.5423	E4
U15	8.2200	U4	T17	3.5354	T1	S5	0.2486	P3
U16	0.7805	U13	T18	1.5160	U2	S6	0.2271	T2
U17	4.2856	U8	R1	0.4569	U6	P1	0.4114	U6
T1	1.4736	U16	R2	3.1891	T18	P2	0.3105	T8
T2	0.2271	S6	R3	0.5862	R1	P3	0.2486	S5

Source: self-study

Table 4. Groups of universities with representatives in wroclaw taxonomy division due to the amount of costs

Group	University	Representative
group 1	S4, E4, T3, U11, R8, T6, U1, U10, T12, T8, E1, T10, P2, U5, T16, S2, S5, P3, T2, S6, S3, U6, P1, R1, R3, E2, T14, R6, T4, T13, E3, U12, T7, T11	University of Bielsko-Biala
group 2	S1	University of Physical Education in Cracow
group 3	R7, E5	Wroclaw University of Economics
group 4	R2	Warsaw University of Life Sciences
group 5	R4	Poznań University of Life Sciences
group 6	R5	Wroclaw University of Environmental and Life Sciences
group 7	T1	University of Science and Technology in Cracow
group 8	T5	Gdańsk University of Technology
group 9	T9	Lodz University of Technology
group 10	T15	Silesian University of Technology
group 11	T17	Warsaw University of Technology
group 12	T18	Wroclaw University of Technology
group 13	U2	Adam Mickiewicz University in Poznań
group 14	U3	University of Gdańsk
group 15	U4	Jagiellonian University in Kraków
group 16	U7	University of Łódź
group 17	U8	Maria Curie-Skłodowska University in Lublin
group 18	U9	Nicolaus Copernicus University of Toruń
group 19	U13	Uniwersytet Śląski w Katowicach
group 20	U14	University of Warmia i Mazury in Olsztyn
group 21	U15	University of Warsaw
group 22	U16	University of Wrocław
group 23	U17	University of Zielona Góra

Source: self-study

It is noticeable that most of academic universities constituted a separate one-element group. Contrary to groups connected with a division according to a structure of costs, physical education universities had similar level of costs so they were allocated to groups of similar objects.

SUMMARY

The usage of graph methods in an analysis of researched objects is justified because it enables to classify them in a very detailed way. At the same time similar objects with the same characteristics are separated.

These methods should be used by Ministry of Science and Higher Education in an analysis of spending public sources by each university. Determining which universities are similar in the scope of a level and a structure of generated costs should constitute a basis for grants allocation.

ANNEX

Table 5. A list of public universities

Symbol	University
U1	University of Białystok
U2	Adam Mickiewicz University in Poznań
U3	University of Gdańsk
U4	Jagiellonian University in Kraków
U5	University of Warsaw
U6	Kazimierz Wielki University in Bydgoszcz
U7	University of Łódź
U8	Maria Curie-Skłodowska University in Lublin
U9	Nicolaus Copernicus University of Toruń
U10	University of Opole
U11	University of Rzeszów
U12	University of Szczecin
U13	Uniwersytet Śląski w Katowicach
U14	University of Warmia i Mazury in Olsztyn
U15	University of Warsaw
U16	University of Wrocław
U17	University of Zielona Góra
T1	University of Science and Technology in Cracow
T2	University of Bielsko-Biala
T3	Białystok University of Technology
T4	Częstochowa University of Technology
T5	Gdańsk University of Technology
T6	Koszalin University of Technology
T7	Tadeusz Kościuszko Cracow University of Technology
T8	Lublin University of Technology

Symbol	University
T9	Lodz University of Technology
T10	Opole University of Technology
T11	Poznań University of Technology
T12	Kazimierz Pulaski University of Technology and Humanities in Radom
T13	Rzeszów University of Technology
T14	West Pomeranian University of Technology in Szczecin
T15	Silesian University of Technology
T16	Kielce University of Technology
T17	Warsaw University of Technology
T18	Wrocław University of Technology
E1	University of Economics in Katowice
E2	Poznań University of Economics
E3	Warsaw School of Economics
E4	Cracow University of Economics
E5	Wrocław University of Economics
R1	Szczecin University of Life Sciences
R2	Warsaw University of Life Sciences
R3	University of Life Sciences in Lublin
R4	Poznań University of Life Sciences
R5	Wrocław University of Environmental and Life Sciences
R6	University of Agriculture in Cracow
R7	UTP University of Science and Technology in Bydgoszcz
R8	The Jan Kochanowski University in Kielce
S1	University of Physical Education in Cracow
S2	The Eugeniusz Piasecki University of Physical Education in Poznan
S3	The Jerzy Kukuczka University of Physical Education in Katowice
S4	Józef Piłsudski University of Physical Education in Warsaw
S5	Gdansk University of Physical Education and Sport
S6	University of Physical Education in Wrocław
P1	The Jan Długosz University in Częstochowa
P2	Pedagogical University of Cracow
P3	Akademia Pedagogiki Specjalnej im. Marii Grzegorzewskiej w Warszawie

Source: self-study

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