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## **MULTIDIMENSIONAL ANALYSIS IN THE CREATION OF MEDICAL CLUSTERS IN ŁÓDŹ – A CONCEPTUAL WORK**

### **1. INTRODUCTION**

The concept of a cluster has been driving new ways of thinking about competitive domestic and regional economies. At its heart lies fostering and stimulating collaboration between different entities, fast-tracking innovation and thus contributing to the improved competitive edge of a business within its cluster. Becoming part of an organisation such as a cluster is highly beneficial. This article aims at presenting a concept of the way entities that provide medical services should be selected for clusters.

### **2. CLUSTER – MEDICAL CLUSTER**

Michael Porter, who developed the cluster concept, defined clusters as: *“National industrial clusters are formed by firms and industries linked through vertical (buyer/supplier) or horizontal (common customers, technology etc.) relationships and with the main players located in a single nation/state. Geographic concentration of rivals, customers and suppliers in a region will promote innovation and competitiveness in a cluster”* (Porter 1990: 157). In 1998, Porter reviewed this definition and defined clusters as geographic concentrations of interconnected companies and institutions in a particular field.

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Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialised inputs such as components, machinery and services, and providers of specialised infrastructure. Clusters also often extend downstream to channels and customers, laterally to manufacturers of complementary products and to companies in industries related by skills, technologies or common inputs. Finally, many clusters include governmental and other institutions – such as universities, standards-setting agencies, think tanks, vocational training providers and trade associations – that provide specialised training, education, information, research and technical support (Porter 1998: 78).

Becoming part of an organisation (metaorganisation) such as cluster is highly beneficial and some of the pros of joining are:

- Access to knowledge (Klimas 2011: 84, 86):
  - information about novelties, latest trends,
  - information about competition,
  - information about prices, terms and conditions, suppliers,
  - new management techniques and solutions;
- Creating a common vision for the future (Nogalski, Białas, Dwojacki 2002: 100);
- Opening up to new markets (blue ocean strategy):
  - participation in creating comprehensive service,
  - personnel availability;
- Operational cost-cutting (predominantly logistics-related):
  - group procurement,
  - effective material flow;
- Efficient and effective services.

Benefits reaped from collaboration with a cluster are determined by success factors. One should not overlook, however, the factors that could jeopardise that collaboration (Table 1).

Table 1. Success and failure factors of in-cluster collaboration

<b>Success factors of collaboration</b> (Bryant 2003: 24-52)	<b>Failure factors of collaboration</b> (Kale, Dyer, Singh 2002: 762-764)
<ul style="list-style-type: none"> <li>– Continuous verification and analysis of inter-organisational relationships within a cluster;</li> <li>– Compatible technology enabling to exchange experiences;</li> <li>– Tailor-made organisational processes fostering collaboration;               <ul style="list-style-type: none"> <li>– Organisational structures assuring organisational conditions for collaboration.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>– Strategic mismatch between partners;</li> <li>– Organisational mismatch between partners;               <ul style="list-style-type: none"> <li>– No relevant experience;</li> <li>– Lack of trust;</li> </ul> </li> <li>– Inadequate management style (coordination, conflict resolution);</li> <li>– No inter-organisational exchange programmes.</li> </ul>

Source: own elaboration.

Becoming part of a cluster does not only profit the coming-in party, but also exposes it to threats (Niemczyk 2008: 176-178):

- Generation of extra cost related to network maintenance;
- Spiralling out of control number of relationships between members of the network;
- Cluster pathology – strategic concentration on longevity;
- Detachment of network members from market realities;
- Probability of losing knowledge and competences;
- Members losing their identity.

The concept of clusters is not limited to economic applications. Information about medical clusters is increasingly common. A *medical cluster* is a designated group of entities that represent complimentary competencies and that are connected by means of interdependencies of an organisational, legal, financial and scientific nature. A medical cluster is oriented to benefit from a synergy effect to support patients, the state budget and science.

### 3. DATA AND METHODOLOGY

Data collected by Regional Public Health Centre in Łódź (*pl. Wojewódzkie Centrum Zdrowia Publicznego w Łodzi*) found in in-patient health care institutions (*pl. działalność zakładów lecznictwa zamkniętego*) was used for the purposes of this paper. All data is as of 30 June 2013. The matrix of geographical distances between hospitals was prepared by the authors based on Google Maps. Visualisation on topographic maps was possible thanks to the Terrain Information System for Łódź (*pl. Łódzkiego Systemu Informacji o Terenie*).

This paper uses a hierarchical cluster analysis. Hierarchical cluster analysis enables the creation of classes of objects similar in terms of several variables, based on the distance matrix. Distances were determined using Ward's method, where dissimilarity between clusters is defined as the average root mean square of the distances between class' centres on mass (lack-of-fit sum of squares):

$$d_{AB} = \frac{n_A n_B}{n_A + n_B} d^2(\bar{x}_A, \bar{x}_B), \quad (1)$$

where:  $\bar{x}_j$  is the centre of cluster  $j$ ,  $n_j$  is the number of points in it and  $d_{AB}$  is called the merging cost of combining the clusters  $A$  and  $B$ .

The result of the method is a dendrogram, i.e.: a binary class tree where clusters are represented by nodes, while the leaves are classifiable objects. An optimum number of clusters return the highest ratio of between-groups variance and within-group variance. That criterion is referred to as the Calinski and Harabasz Index:

$$CH(k) = \frac{tr(M) / (k - 1)}{tr(W) / (N - k)}, \quad (2)$$

where:  $tr(M)$  is the overall between-cluster variance,  $tr(W)$  is the overall within-cluster variance,  $k$  is the number of clusters and  $n$  is the number of observations.

#### 4. RESULTS

In the following part, 40 hospitals were classified by 94 variables representing the number of hospital beds in each ward. Using that classification, the following could be identified: 3 big clusters and 2 isolated clusters and 1 two-element group of hospitals.

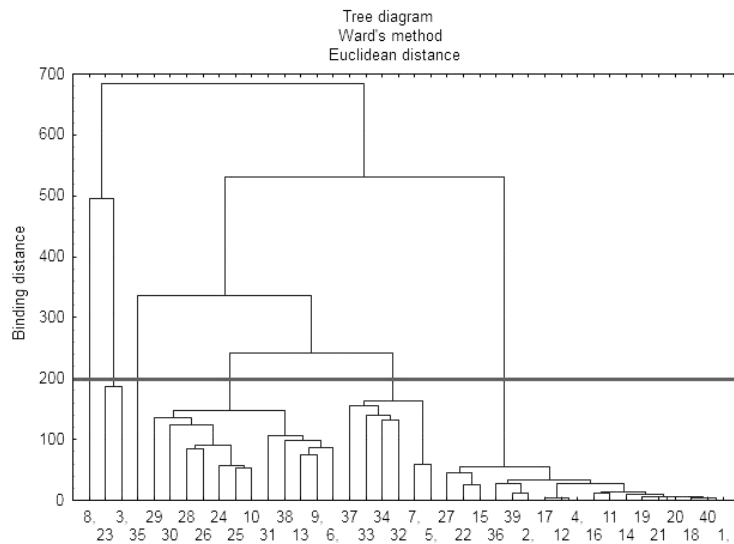


Figure 1. Dendrogram of hospitals produced using Ward's method with class demarcation line

Source: own elaboration.

**Cluster A** is made up of smaller hospitals (less than 200 beds) with various wards, and university hospitals. This group features the following hospitals:

- II Szpital Miejski im. L. Rydygiera (6),
- Instytut Medycyny Pracy (9),
- IV Szpital Miejski im. H. Jordana (10),
- Miejskie Centrum Zdrowia Publicznego im. Bł. R. Chylińskiego (13),
- Szpital MSWIA (24),
- Szpital Zakonu Ojców Bonifratrów im. Św. Jana Bożego (25),
- Uniwersytecki Szpital Kliniczny im. WAM, Centralny Szpital Weteranów (Hallera Square) (26),
- Uniwersytecki Szpital Kliniczny im. WAM, Centralny Szpital Weteranów (Żeromskiego Street) (28),
- Uniwersytecki Szpital Kliniczny im. WAM, Centralny Szpital Weteranów (Sterlinga Street) (29),
- Uniwersytecki Szpital Kliniczny nr 1 im. N. Barlickiego (30),
- Uniwersytecki Szpital Kliniczny nr 4 im. M. Konopnickiej (31),
- Wojewódzkie Centrum Ortopedii i Rehabilitacji Narządu Ruchu im. Z. Radlińskiego (38).

**Cluster B** is made up of big hospitals (200 hospital beds and more) offering a wide range of specialisations. It includes:

- I Szpital Miejski im. E. Sonnenberga (5),
- III Szpital Miejski im. K. Jonschera (7),
- Wojewódzki Specjalistyczny Szpital im. M. Pirogowa (Wileńska Street) (32),
- Wojewódzki Specjalistyczny Szpital im. Wł. Biegańskiego (33),
- Wojewódzki Specjalistyczny Szpital im. M. Pirogowa (Wólczańska Street) (34),
- Wojewódzki Zespół Zakładów Opieki Zdrowotnej – Centrum Leczenia Chorób Płuc i Rehabilitacji – Szpital Chorób Płuc im. bł. o. Rafała Chylińskiego w Łodzi (37).

**Cluster C** concentrates in majority non-public health centres which have very narrow specialisations and small number of beds. That cluster includes:

- Eskulap Usługi Medyczne Sobańska-Żurek (1),
- Centra Medyczne Medyceusz sp. z o.o. – szpital (2),
- Centrum Medyczne “Księży Młyn” (4),
- Klinika Okulistyczna “Jasne Błonia” sp. z o.o. Med.-Gastr Hospital sp. z o.o. (11),
- Niepubliczny Zakład Opieki Zdrowotnej Contact-Med. sp. z o.o. (12)
- Niepubliczny Zakład Opieki Zdrowotnej Medeor Plus Szpital Wielospecjalistyczny (14),

- Niepubliczny Zakład Opieki Zdrowotnej Olympus Endoterapia sp. z o.o (15),
- Niepubliczny Zespół Opieki Zdrowotnej Pulsmed sp. z o.o. Niepubliczny Zespół Opieki Zdrowotnej (16),
- Chirurgia Ortopedyczna Agamed (17),
- NZOZ All-Med. Centrum Medyczne (18),
- Specjalistyczne Gabinety Lekarskie w Łodzi (19),
- NZOZ Mikomed (20),
- NZOZ Klinika Chirurgii plastycznej Este L'arte (21),
- Salve Zakład Opieki Zdrowotnej (22),
- Uniwersytecki Szpital Kliniczny im. WAM, Centralny Szpital Weteranów (Krzemieniecka Street) (27),
- Wojewódzki Szpital Specjalistyczny im. M. Kopernika – Szpital im. J. Korczaka (36),
- Zakład Opieki Zdrowotnej Medical Magnus (39),
- Zakład Opieki Zdrowotnej Super-Med. s.c. (40).

**Isolated and two-element clusters** consist of very big hospitals with a wide range of specialisations:

- Wojewódzki Szpital Specjalistyczny im. M. Kopernika (35),
- Instytut centrum Zdrowia Matki Polki (8),

and very high specialisations:

- Centralny Szpital Kliniczny - Ogółem Instytut Stomatologii (3),
- Szpital dla Nerwowo i Psychiczenie Chorych im. Babińskiego (23).

Cluster analysis made it possible to distinguish groups of similar objects. In order to create medical clusters, i.e. platforms for collaboration, hospitals belonging to groups as explained by the diagram (Figure 2) were bundled together.

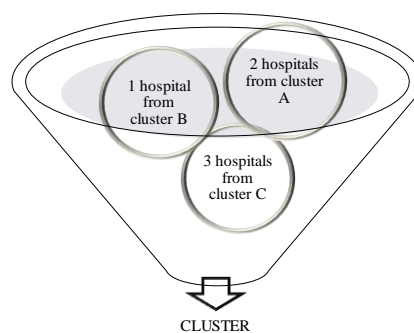


Figure 2. Hospitals creating the cluster

Source: own elaboration.

Consequently, 36 hospitals were used to create 6 clusters. The clusters were populated with objects based on the geographical distances between the objects. The algorithm for bundling hospitals based on criterion of least Euclidean distance between the objects is illustrated in Figure 3.

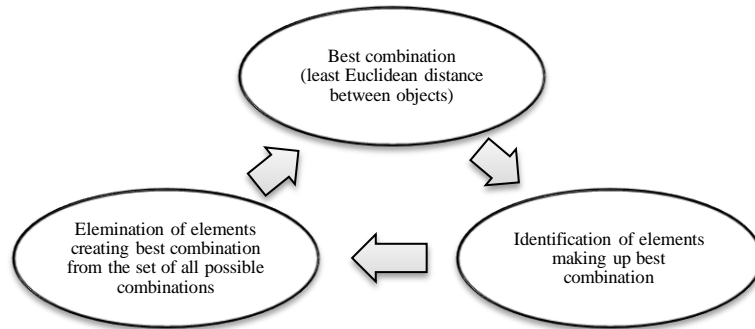


Figure 3. Algorithm for singling out cluster eligible hospitals based on the criterion of least geographical distance

Source: own elaboration.

Consequently, the objects most distant from each other end up in the last cluster. Six medical clusters were generated through the carried out analysis. The choropleth maps below illustrate the spatial distribution of these clusters (Figures 4–9).



Figure 4. Cluster 1 includes hospitals no. 26, 28, 34, 14, 16, 39

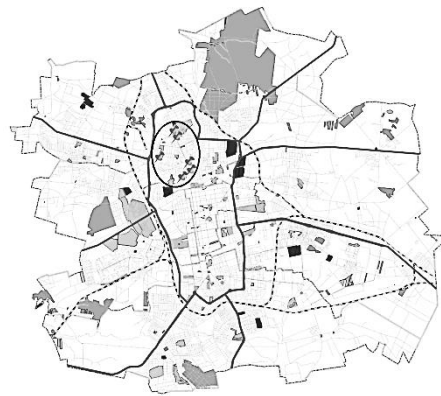


Figure 5. Cluster 2 includes hospitals no. 9, 38, 33, 2, 12, 15

Source: own elaboration.



Figure 6. Cluster 3 includes hospitals no. 6, 30, 7, 1, 17, 40

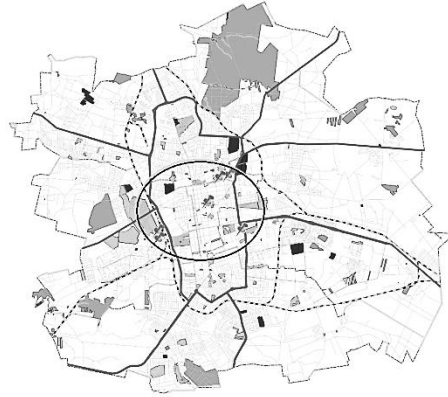


Figure 7. Cluster 4 includes hospitals number: 24, 29, 32, 4, 18, 27



Figure 8. Cluster 5 includes hospitals no. 10, 31, 5, 11, 20, 22



Figure 9. Cluster 6 includes hospitals no. 13, 25, 37, 19, 21, 36

Source: own elaboration.

## 5. CONCLUSIONS

The presented research points toward the following conclusions:

1. Criteria for classifying medical institutions under each cluster were developed.
2. In order to increase accuracy and eliminate irrelevant aspects, a multivariate analysis was employed.



3. The results were encouraging, showing that clustering consistent with the aforesaid criteria can lead to a lower probability of negative phenomena such as:
- excessive detachment of clustered entities from market realities;
  - probability of losing knowledge and competences;
  - generation of extra costs related to network maintenance.
- Furthermore, the results of this paper open a new research field.

## 6. RECOMMENDATIONS

The adopted classification criteria (94 variables) and selected statistical methods could be recommended as an effective tool for configuring medical clusters in Poland.

## 7. LIMITATIONS

It should be noticed that there are some limitations to this study:

1. Finding the correct number of clusters may prove tricky – it is a process heavily dependent on the experience and knowledge of the authors.
2. The Calinski-Harabasz index was used in this paper. In practise, knowledge of the researcher is a key alongside an in-depth understanding of the problem and goals the cluster analysis should help achieve.
3. The proposed hospital clustering algorithm based on geographical distances produces an outcome where the objects most distant from each other end up in the last cluster.

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#### ABSTRACT

This article aims at presenting a concept of the way entities that provide medical services should be selected for clusters. A medical cluster is a designated group of entities that represent complimentary competencies and are connected organisational, legal, financial and scientific interdependencies. A medical cluster is oriented to benefit from a synergy effect to support patients, the state budget and science. The research employed a multidimensional data analysis. Firstly, a hierarchical grouping procedure was used to distinguish groups of hospitals that have similar medical competencies. Then, division criteria that characterise competence differences within the groups in question were found. This way, groups of dissimilar (the most dissimilar) hospitals were obtained. Subsequently, on the basis of a minimal distance criterion, one entity was selected from each group to obtain new groups of entities that were decisively different in the context of medical services offered and simultaneously situated in the close vicinity to one another. These two aspects may offer some premises to initiate co-operation between the entities subject to the research within a given medical cluster.

#### WIELOWYMIAROWA ANALIZA W TWORZENIU KLASTERÓW MEDYCZNYCH W ŁODZI – PRACA KONCEPCYJNA

#### ABSTRAKT

Celem artykułu jest zaprezentowanie koncepcji doboru podmiotów świadczących usługi medyczne w województwie łódzkim do klastrów. Klastr medyczny to celowo dobrana grupa podmiotów o kompetencjach komplementarnych połączona zależnościami o charakterze organizacyjnym, prawnym, finansowym i naukowym, którego celem jest konsumpcja efektu synergii z korzyścią dla pacjentów, budżetu państwa i nauki. W badaniu wykorzystano metody wielowymiarowej analizy danych. W pierwszej kolejności za pomocą hierarchicznej procedury grupowania wyodrębniono grupy podobnych do siebie z punktu widzenia kompetencji medycznych szpitali. Następnie określono kryteria podziału charakteryzujące odrębności kompetencyjne w ramach grup. W ten sposób otrzymano grupy szpitali niepodobnych (najbardziej różnych od siebie). Następnie na podstawie kryterium minimalnej odległości z każdej grupy szpitali wybierano po jednym obiekcie, aby w ten sposób otrzymać nowe grupy obiektów, zdecydowanie różnych pod względem możliwości oferowanych usług medycznych, a jednocześnie znajdujących się w niedalekiej odległości od siebie. Te dwa aspekty mogą stanowić przesłankę do zainicjowania współpracy między tymi obiektami w ramach klastra medycznego.