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# Useing the Hierarchical Cluster Analysis and Fuzzy Cluster Analysis Methods for Classification of Some Hospitals in Basra

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## Abstract:

In general, the importance of cluster analysis is that one can evaluate elements by clustering multiple homogeneous data; the main objective of this analysis is to collect the elements of a single, homogeneous group into different divisions, depending on many variables. This method of analysis is used to reduce data, generate hypotheses and test them, as well as predict and match models. The research aims to evaluate the fuzzy cluster analysis, which is a special case of cluster analysis, as well as to compare the two methods—classical and fuzzy cluster analysis. The research topic has been allocated to the government and private hospitals. The sampling for this research was comprised of 288 patients being treated in 10 hospitals. As the similarity between hospitals of the study sample was measured according to the standards of quality of health services under fuzzy conditions (a case of uncertainty of the opinions of patients who were in the evaluation of health services provided to them, which was represented by a set of criteria and was measured in the form of a Likert five-point scale). Moreover, those criteria were organized into a questionnaire containing 31 items. The research found a number of conclusions, the most important is that both methods of hierarchical cluster analysis and fuzzy cluster analysis, classify the hospitals of the research sample into two clusters, each cluster comprises a group of hospitals that depend on applying health quality service standards. The second important conclusion is that the fuzzy cluster analysis is more suitable for the classification of the research sample compared to hierarchical cluster analysis.

**Keywords:** Cluster Analysis, Fuzziness, Quality of Health Services

## Introduction:

The health sector is one of the most important sectors in any country because it is closely linked to the health and life of human beings, Modern societies are paying great attention to the quality of health services to improve it in all health institutions. Health quality services has been defined in several ways including (continuous improvement of the health service provided to patients by reducing medical errors and keeping pace with scientific medical development). It's appears from the above definition that the satisfaction of patients is considered basic elements in the quality of health services. (1, 2)

There have been several studies concerning the quality of health services in hospitals, but our paper differs from these studies in the use of two methods of cluster analysis (hierarchical cluster analysis and fuzzy cluster analysis).

Cluster analysis is one of the statistical methods of multivariate analysis and is known by several definitions including the following:

A) An exploratory method of the most important data classification approaches, if the individuals are linked to each other according to the level of homogeneity, lessens the distance between them by clustering the individuals of the study population into categories that branch and end with a single cluster.

B) A different procedure designed aims to classify a group of situations or variables in a particular way and arrange them into clusters so that the situations within the cluster are homogeneous

(i.e. similar to each other) with respect to specific characteristics but different from the cases or other variables found in other clusters.

The purpose of the cluster analysis is not to estimate the extent to which the results obtained can be extended to the population, but rather the results of the analysis are specific to the sample, based on the variables studied. (3,4)

The observations of cluster analysis can be developed in a matrix form as follows: - (5)

$$X_{n*p} = \begin{pmatrix} X_{11} & \cdots & X_{1p} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{np} \end{pmatrix} \dots (1)$$

Where i = 1,2, ... n , j = 1,2, ..., p

Xij : represents the value of observations for unit i that belong to variable j

n: Number of variables under analysis

p: number of variables included in the study

The steps of the process of forming the clusters are summarized in the following steps:

1. Calculate the Euclidian distance between the different elements in order to determine the degree of kinship between them as in the mathematical formula below:

$$d_{ij} = \sqrt{\sum_{k=1}^{p} (x_{ik} - x_{jk})^2} \quad \dots (2)$$

Where as

$d_{ij}$: The Euclidean distance between elements

$x_{ik}$: The variable value of element i

$x_{jk}$: The value of the variable for element j

2. For the purpose of linking between the elements, the lowest Euclidean distance between the elements of the matrix is first searched, because the smaller the distance between any two elements indicates the degree of convergence between the two elements. Then the two closely related elements are combined into one cluster.
3. Continue the grouping process based on the degree of convergence until the last clusters are linked to form the final group, which is a tree form of clusters that are not similar to each other, but the elements in the cluster are highly convergent and homogenous.

## Methodology

### Hierarchical Cluster Analysis (2)

Hierarchical cluster analysis is one of the most widely used methods of cluster analysis because it is not complex, as it does not require prior knowledge of the number of clusters that have been categorized. Hierarchical analysis can be used with small samples and is divided into two parts:

A) Agglomerative technique: This method assumes that each unit describes its own subgroup, then groups subgroups of groups and notes together, and the result will be one group. The analysis begins with one group in each case, and then the closely related groups merge with each other until one group is obtained.

B) The a divisive technique (Fragmentation): The paper was based on clustering, which is based on the start of a single cluster that includes all the partial groups and units divided into smaller and smaller clusters. The elements are then grouped into clusters. The symmetry between the clusters must be calculated. There are many methods to calculate the symmetry: the method of Complete Linkage, the method of single linkage, and the centered linkage method. The methods of the single linkage and the method of Complete Linkage is one of the most important methods of measuring the symmetry between the clusters.

### Fuzzy Logic (6, 7)

Azerbaijani scientist Lotfi Zadeh, from the University of California, was the first to discuss fuzzy logic in 1965. He developed its use as the best method for data processing, but his theory did not receive significant attention until 1974. The application of fuzzy logic was then widely developed, and a fuzzy logic chip was used in many products, such as cameras. Furthermore, the development of computer systems and software has generated the desire to program systems that can deal with inaccurate information, which has led to the emergence of a problem: the computer's ability to deal only with specific and precise data. As a result, the trend is to what is known as expert systems or artificial intelligence, which is one of the theories of fuzzy logic through which such systems can be built. Thus, fuzzy logic can be defined as a logic system based on a generalization of traditional two-valued logic (0,1) with the aim of inferring the uncertain situation.

### Crisp Set, Fuzzy Set and α-Cut Set (8, 9)

The crisp group: A crisp or classical set can have an element that either belongs or does not belong. Let A and U have two groups, $\mu_A(x) = \begin{cases} 1, & x \in A \\ 0, & x \notin A \end{cases}$ ,the function of membership can be defined as follows:

$\mu_A(x): U \to \{0,1\}$

$x \to \mu_A(x)$

Fuzzy set (7): A set of elements with a degree of membership of $\mu_A(x)$, whose value is limited to [0,1] and represents the degree of membership of value (x) to set ($\check{A}$) in the form of arranged pairs:

$\check{A} = \{\mu_{\check{A}}(x_i), x_i \in X, i = 1,2,3, \dots, n\}$

$\mu_{\check{A}}(x) \in [0,1]$

The degree of membership to the shown fuzzy set can also be summarized in Table 1 as follows:

**Table 1. The membership function for elements of fuzzy set(8)**

| The membership function for fuzzy set | $\mu_{\tilde{A}}(x)$ |
|---|---|
| Does not belong to the set | 0 |
| Complete membership | 1 |
| High membership | 0.9 ، 0.7 ، 0.6 |
| Middle membership | 0.5 |
| Low membership | 0.4 ، 0.2,0.3 |

The α-cut set: it is one of the concepts related to the fuzzy set and symbolized by $A^{\alpha}$; It is defined as a set containing elements of x and having a degree of membership not less than the ratio of α to reflect the degree of membership to the important elements; Level set α is limited to important membership between the values of right and left (x, $x_r$) on the set. A line is otherwise insignificant and is often left out of scope, as shown in Fig.1:

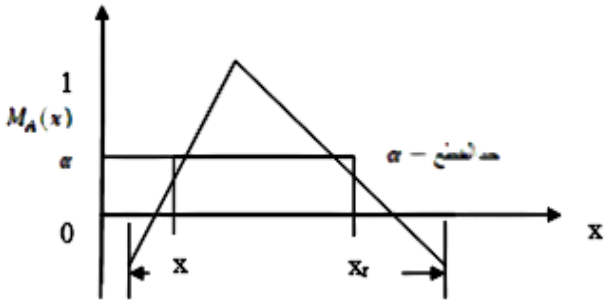


**Figure 1. $\alpha - cut$ set (6)**

**Fuzzy Cluster Analysis (10,11)**

The method of fuzzy cluster analysis differs from conventional cluster analysis in that the latter classifies observations (cases or variables) into a group of different clusters by giving them a degree of affiliation equal to one in the cluster to which it belongs and zero in the remaining clusters. On the other hand, the fuzzy cluster method is based on giving views a degree of membership between zero and one in one or more clusters. This is mathematically represented as follows:

$$\mu_{ik} \in [0,1], 1 \le i \le c\ , 1 \le k \le p$$

$$\sum_{i=1}^{c} \mu_{ik} = 1$$

$$0 < \sum_{k=1}^{p} \mu_{ik} < p \qquad \dots (3)$$

Where:

$\mu_{ik}$: represents the degree of membership of the unit k in cluster i

c: Number of clusters

p: Number of units

The algebraic algorithm that is used to infuse the NCSS program applied in the fuzzy process of search data is mathematically defined as follows:

$$Z = \sum_{k=1}^{c} \frac{\sum_{i=1}^{p}\sum_{j=1}^{p} \mu_{ik}^2\, \mu_{jk}^2\, d_{ij}}{2\ \sum_{j=1}^{p} \mu_{jk}^2}$$

$$subject\ to:\ \mu_{ik} \ge 0\ , \sum_{i=1}^{c} \mu_{ik} = 1 \qquad \dots (4)$$

$$d_{ij} = \sqrt{\sum_{k=1}^{p} (x_{ik} - x_{jk})^2} \qquad \dots (5)$$

**Goodness of Fit Coefficients (12)**

The process of determining the number of appropriate clusters is the most difficult in the cluster analysis method. Therefore, there is a set of coefficients used to select the number of suitable clusters for the classification of observations using the cluster analysis method, including the following

1. Dunn's Partition Coefficient

It is mathematically defined as:

$$F_c(U) = \frac{c \sum_{i=1}^{c}\sum_{k=1}^{p} \frac{\mu_{ik}^2}{p}}{\text{Cut level}} \qquad \dots (6)$$

The nn's partition coefficient, $\mathbf{F_c(U)}$, is, $0 < \mathbf{r_c(U)} < \mathbf{1}$ If $\mathbf{F_c(U) = 1}$;This indicates that there is no fuzziness in the data, while if $\mathbf{F_c(U) = 0}$, it means a complete fuzziness is in the data.

2. Kaufman partition coefficient is mathematically defined as:

$$D_c(U) = \frac{c\, D(U) - 1}{c - 1}\ ; D(U) = \frac{1}{p} \sum_{i=1}^{c}\sum_{k=1}^{p} (h_{ik} - \mu_{ik})^2 \qquad \dots (7)$$

3. Average Silhouette width is mathematically defined as:

$$s(i) = \frac{b(i) - a(i)}{\max(a(i), b(i))}\ ;\ -1 \le s(i) \le 1 \qquad \dots (8)$$

As $\mathbf{a(i)}$ represents the internal difference and **b (i)** the interstitial variation.

The optimal number of clusters is determined by the number of clusters with large $\mathbf{F_c(U)}$ And a small $\mathbf{D_c(U)}$.

## Real Data Analysis Side

To achieve the aim of the research, the researchers classified the hospitals under study using data obtained from table (5) in two ways and using the NCSS2007 program. The discussion of this method is as follows:

A - Hierarchical Cluster Analysis Method

The traditional hierarchical cluster analysis method was adopted according to the Euclidean distance method. Figure 2 shows the final clusters

in which the hospitals were clustered (c = 2) based on the degree of convergence of these hospitals in applying the standards of the quality of the health services.

The first cluster included the hospitals, Al Mosawi, Al Zuber, Praivet Child, Al Shifaa and Al Mawanaa, while the second cluster included Al Mowasat, Al Fayhaa, Al Basrah, Abn-Al Betar and Al Talimi.

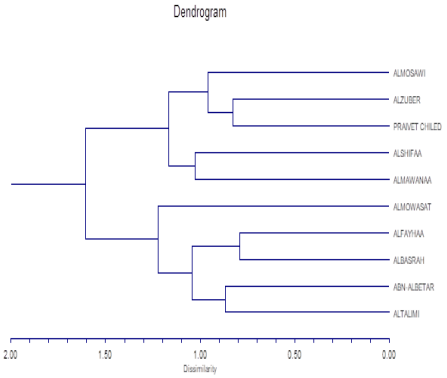


**Figure 2. Schema of the Hierarchical method of Cluster Analysis**

Source: - NCSS2007 Program Output

B- The fuzzy cluster method

In order to determine the optimal number of clusters, It was assumed equal to (5). The results of the fuzzy cluster analysis are summarized in Tables 2 and 3.

Table 2 shows the degree to which each hospital in the five clusters belongs, as well as the cluster in which the hospital has the highest degree of membership. Where some hospitals appeared in the clusters had a high degree of membership. The first cluster includes Al Talimi only; the second cluster includes Al Basrah and Al Fayhaa hospitals; the third cluster includes Al Mawanaa, Al Shifaa, Private Child, Al Mosawi, and Al Zuber hospitals; the fourth cluster includes Abn Al-Betar; and the fifth cluster includes Al Mowasat.

**Table 2. Classification of hospitals in five clusters with their degree of membership to the clusters**

| Hospital | Type of the hospital | Clusters 1 | 2 | 3 | 4 | 5 | The cluster of the largest membership |
|---|---|---|---|---|---|---|---|
| Al Talimi | Public | 0.9997 | 0.0001 | 0 | 0.0001 | 0.0001 | 1 |
| Al Basrah | Public | 0.1197 | 0.6648 | 0.0491 | 0.1040 | 0.0624 | 2 |
| Al Mawanaa | Public | 0.0854 | 0.2269 | 0.4094 | 0.1432 | 0.1351 | 3 |
| Al Fayhaa | Public | 0.0220 | 0.9327 | 0.0124 | 0.0214 | 0.0115 | 2 |
| Al Shifaa | Public | 0.0777 | 0.2301 | 0.3577 | 0.1871 | 0.1474 | 3 |
| Private Child | Public | 0.0189 | 0.0422 | 0.8720 | 0.0315 | 0.0354 | 3 |
| Abn Al-Betar | Private | 0.0010 | 0.0010 | 0.0004 | 0.9967 | 0.0009 | 4 |
| Al Mosawi | Private | 0.0375 | 0.0813 | 0.7114 | 0.0703 | 0.0995 | 3 |
| Al Mowasat | Private | 0.0003 | 0.0003 | 0.0003 | 0.0005 | 0.9986 | 5 |
| Al Zuber | Public | 0.0185 | 0.0486 | 0.8630 | 0.0349 | 0.0350 | 3 |

Table 3 shows the Goodness of fit coefficients for each of the clusters ($F_c(U), D_C(U), ASC$). Therefore, the number of clusters is equal to 2 because it has the largest $F_c(U)$, ASC and lowest $D_C(U)$ coefficients.

**Table 3. Goodness of fit coefficients**

| number of clusters | $ASC$ | $F_c(U)$ | $D_C(U)$ |
|---|---|---|---|
| 2 | 0.3179 | 0.5162 | 0.1142 |
| 3 | 0.2305 | 0.4671 | 0.1952 |
| 4 | 0.1778 | 0.5430 | 0.1795 |
| 5 | 0.1486 | 0.6108 | 0.1762 |

Accordingly, the hospitals in the research sample were divided into two clusters as shown in Table 4:
As it appeared that the hospitals (Al Talimi, Al Basrah, Al Fayhaa, Al Mosawi , Al Zuber)had the highest membership degree in the first cluster while the (Al Mawanaa, Al Shifaa, Private Child, Abn Al-Betar, Al Mowasat) had the highest degree of membership in the second cluster. Table (5) summarizes those criteria were organized into a questionnaire containing 31 items.

**Table 4. Classification of Hospitals in Two Clusters and Membership Degree**

| Hospital | Clusters 1 | 2 |
|---|---|---|
| Al Talimi | 0.9297 | 0.0703 |
| Al Basrah | 0.8943 | 0.1057 |
| Al Mawanaa | 0.2422 | 0.7578 |
| Al Fayhaa | 0.8487 | 0.1513 |
| Al Shifaa | 0.2739 | 0.7261 |
| Private Child | 0.0806 | 0.9194 |
| Abn Al-Betar | 0.0773 | 0.9227 |
| Al Mosawi | 0.8987 | 0.1013 |
| Al Mowasat | 0.1154 | 0.8846 |
| Al Zuber | 0.7231 | 0.2769 |

**Table 5. Quality standards for health services**

| Variable | Paragraph |
|---|---|
| $X_1$ | The hospital is committed to provid health services to patients on time |
| $X_2$ | The hospital is keen to provide health services in a proper manner |
| $X_3$ | The hospital provides all integrated work requirements to ensure that patients are served regardless of their social and political affiliations. |
| $X_4$ | The hospital is very interested in patients' problems and queries |
| $X_5$ | The hospital is keen to achieve confidence and the patient's appreciation through its health services and work on the development of procedures to upgrade this service. |
| $X_6$ | The hospital is meticulous in recording information about patients and their health manually and electronically. |
| $X_7$ | The hospital will inform the patients who are registered in advance of the exact time of service |
| $X_8$ | Hospital staffs are keen to provide medical and health assistance to patients. |
| $X_9$ | The hospital tries to make it as easy as possible to ensure fast and easy delivery of health services |
| $X_{10}$ | The hospital is keen to organize Khafarat to ensure continuous health services for 24 hours. |
| $X_{11}$ | The patients are trusted with the expertise and qualifications of the medical, nursing and administrative staff of the hospital. |
| $X_{12}$ | The patient feels safe when dealing with hospital management and staff. |
| $X_{13}$ | Hospital staffs are well treated with patients. |
| $X_{14}$ | The hospital ensures the confidentiality of patient information |
| $X_{15}$ | Hospital staff have knowledge, skills and experience. |
| $X_{16}$ | The hospital has a good reputation and status in patients |
| $X_{17}$ | The hospital features modern equipment and devices |
| $X_{18}$ | The hospital has adequate and appropriate physical facilities and facilities (corridors, courtyards, bathrooms, etc. ) |
| $X_{19}$ | The hospital is conveniently located and easily accessible. |
| $X_{20}$ | The hospital enjoys a high degree of cleanliness and good appearance for their employees. |
| $X_{21}$ | The hospital is keen to provide clean and air-conditioned waiting rooms. |
| $X_{22}$ | Hospital design is appropriate to provide health services. |
| $X_{23}$ | The hospital places signs and guidance boards to reach its wardrobes and departments. |
| $X_{24}$ | The hospital has wide corridors suitable for transporting patients without difficulty. |
| $X_{25}$ | The hospital seeks to reduce waiting times for patients in the emergency department. |
| $X_{26}$ | In the hospital radiology centers (x-ray, sonar, pulmonary resuscitation) are adequate and modern to meet the needs of patients. |
| $X_{27}$ | The hospital places patients' interests at the priorities of its concerns. |
| $X_{28}$ | Give staff time to take care of patients. |
| $X_{29}$ | The hospital takes into account the patient conditions. |
| $X_{30}$ | The hospital and supervisors have the knowledge and know-how of their patients. |
| $X_{31}$ | The hospital shall observe the customs, traditions and customs prevailing in the society and according to the medical interest of the patient and the deceased patients. |

## Conclusions:

This paper leads to a set of conclusions summarized by the following:

1. The method of hierarchical cluster analysis divides the hospitals of the research sample into two clusters according to the quality of their service criteria. The first cluster includes the hospitals Al Mosawi, Al Zuber, Praivet Child, Al Shifaa and Al Mawanaa. The second cluster includes Al Mowasat, Al Fayhaa, Al Basrah, Abn-Al Betar and Al Talimi.
2. The results of the fuzzy cluster analysis refer to the classification of hospitals of the research sample into two cluster with different membership degree.
3. By comparing the hierarchical cluster analysis and the fuzzy cluster analysis, therefore the fuzzy cluster analysis is more appropriate in the classification process due to its assumption that a hospital belongs to both clusters but with varying degrees of health service quality standards. Hierarchical cluster analysis, on the other hand, has classified on the assumption that the hospitals in the first cluster are completely different from those in the second cluster in terms of applying the standards of quality of health services—an assumption not valid in a practical situation.
4. Finally, The Heath Directorate must work hard to reduce the gap between hospitals in implementation of quality standards for health services. They also

should work on making all requirements available to improve the services that hospitals provide.

## Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Basrah University.

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# استخدام اسلوبي التحليل العنقودي الهرمي والتحليل العنقودي المضبب لتصنيف بعض مستشفيات محافظة البصرة

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**الخلاصة:**

تكمن اهمية اسلوب التحليل العنقودي بشكل عام في البحث عن تعنقد البيانات المتعددة والمتجانسة لغرض تجميع العناصر في مجاميع متجانسة فيما بينها (داخل المجموعة الواحدة) ومختلفة عن المجاميع الاخرى اعتماداً على العديد من المتغيرات ويستعمل في تقليص حجم البيانات وتوليد الفرضيات واختبارها وفي التنبؤ و مطابقة النماذج. وان البحث يهدف الى معرفة التحليل العنقودي المضبب وهو حالة خاصة من التحليل العنقودي فضلاً عن المفاضلة بين الاسلوبين ، ونظراً للدور الهام للمستشفيات وما له من علاقة وثيقة بصحة الانسان فقد تم تخصيص موضوع البحث لعنقدة المستشفيات الحكومية والاهلية لعينة من 288 مريض من المرضى الراقدين في 10 مستشفيات بناءاً على مدى تماثلها في تقديم الخدمات الصحية للمرضى الراقدين فيها حسب معايير جودة الخدمات الصحية في ظل ظروف مضببة ( حالة عدم التأكد لآراء المرضى الراقدين في تقييم الخدمات الصحية المقدمة لهم والتي مثلت بمجموعة من المعايير و قيست على شكل مقياس ليكرت الخماسي) وتلك المعايير نظمت في استمارة استبانة تضمنت 31 فقرة. وقد توصل البحث الى مجموعة من الاستنتاجات اهمها ان كلا اسلوبي التحليل العنقودي الهرمي والتحليل العنقودي المضبب صنف مستشفيات عينة البحث الى عنقودين كل عنقود يضم مجموعة من المستشفيات وان التحليل العنقودي المضبب اكثر ملائمة لتصنيف عينة البحث من التحليل العنقودي الهرمي نتيجة افتراضه ان المستشفى تنتمي لكلا العنقودين بدرجات انتماء متفاوتة في تطبيقها لمعايير جودة الخدمات الصحية بينما التحليل العنقودي الهرمي قد صنف المستشفيات اما تنتمي او لا تنتمي للعنقود اي افترض ان تلك المستشفيات في العنقود الاول مختلفة كليا" عن مستشفيات العنقود الثاني في تطبيقها لمعايير جودة الخدمات الصحية وهذا غير ممكن.

**الكلمات المفتاحية:** التحليل العنقودي، المنطق المضبب، جودة الخدمات الصحية