

Assessment of Higher Education Centers by Principal Components Analysis (a case study in Iran)Shahin Shahahmadi¹, Zahra Shayeste², Mahdi Bashiri³, T.H. Hejazi⁴¹. Department of Information Technology, Islamic Azad University, Tehran, Iran.². Planning office, State Tax Organization, Tehran, Iran.³. Department of Industrial Engineering, Shahed University, Tehran, Iran.⁴. Department of Industrial Engineering and Management, Amir Kabir University, Tehran, Iran.Shahahmadi@gmail.com

Abstract: For the prospective university student, obtaining information about the quality of information is of utmost importance. In recent decades, competition between universities has increased dramatically. Ranking universities based on various fields and by new scientific methods can provide interested students with helpful information that can be used to select a desirable university. The purpose of the ranking process is to evaluate the performance of a unit university within a given time span. For performance measurement we have to determine accurate criteria that can be used to evaluate all the influential aspects of the units (i.e. Universities). In this article, various popular measures have been selected for the assessment of units. A hybrid PCA and Custer Analysis method has been proposed for the ranking of universities. The PCA (Principal Component Analysis) method was used to make the new measures independent. A hypothetical unit of ideal scores was created for each year using the high scores obtained using the new independent measures. All the units were compared with this ideal series of scores. Finally, the AHP (Analytical Hierarchy Process) weighing method was used to find a combined score of four years, and cluster analysis was employed to cluster universities according to their scores.

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Key words: principal component analysis, ranking of the university, clustering analysis, hierarchical analysis process

1. Introduction

In today's competitive world, providing effective information about the quality of universities is of considerable importance. With the increase in the number of universities and higher education centers over the years, independent assessment of universities has grown in significance. In the last two decades, ranking has been conducted not only in the private sector but also in the public sector. Different ranking methods have been established worldwide. The main aim of these rankings is to provide prospective university students with sufficient information in order to choose higher education centers as well as to motive improved quality of universities. Ranking is aimed at university students, their parents, higher education centers, and public institutes responsible for education policies. Various ranking systems have been established according to different valuation indices. It seems that different approaches are selected based on who conducts the ranking: the universities themselves or a more independent commercial party. Nowadays, higher education centers have global competition. For this very reason, it is not enough for universities to know their status among national universities; rather they must have an idea of where they stand globally.

In this article, indices have been selected for the ranking of universities. Data related to these indices have been standardized and then with the help of one of the multivariate statistical techniques (i.e. Principal Component Analysis) new independent indices have been created. Among these new independent indices, the most inclusive of the desired qualities have been selected. Then, an ideal hypothetical university unit with the highest and lowest score of each index was created. This hypothetical unit contains the highest standard for each parameter. The difference between universities scores and the scores in this hypothetical unit has been calculated and annual ranking was done. Next, using cluster analysis these centers were classified into five different categories. Within these five categories, the universities were compared with each other. One general ranking was made for the four-year period with consideration to the priority of different years. The structure of this article is as follows: in the next section it deals with the literature review; in the third section, a brief explanation of techniques used in this article are given; the fourth section deals with weighing in hierarchical analysis process; the fifth section discusses the proposed

method used in this research, and the final section presents concluding remark.

2. Related work and background

There are numerous research projects available in the literature that has ranked the quality of higher education centers. Some of them are reviewed below. In [1], 39 clustered medical universities have been considered based on 3 indices: students-faculties ratio, staff number, healthcare facilities (e.g. number of hospitals, drugstores, x-ray units, laboratories, health care of citizens and villagers, and health house). The new clustering was compared with existing grouping of the universities. The result has showed that 8 universities were not in their suitable clusters. In [3], localization ranking of universities using EFQM method has been done based on actual weight and appropriate priority. To achieve this purpose, the authors use AHP analysis and SWA. In order to do this the authors have evaluated every criteria and sub criteria and then assigned a weight. In [5], in accordance with latest conceptual and methodological advances in academic ranking approaches, five selection criteria are defined and four international university rankings are selected. Comparative analysis of the four rankings is presented taking into account both the indicators' frequency and its weight.

Results show that, although some indicators differ considerably across selected rankings and even many indicators are unique, indicators referring to research and scientific productivity from university academic staff have a prominent role in all the approaches. The first-ever international meeting on these issues convened by European center for higher Education and held in Warsaw in 2002. Discussion included debatable issues such as what indicators can accurately measure quantity in higher education center, which methodology is more useful for the development of ranking systems. In [9], a method for university ranking was presented that has won many Nobel laureates, fields medals, and highly-cited researchers. In addition, major universities in the world with significant amount of articles indexed by Science Citation Index Expanded (SCIE) and Social Science Citation Index (SSCI) are also included. The institutes according to board subject fields, including Natural Sciences and Mathematics (SCI), Engineering Technology and Computer Sciences (ENG), Life and Agriculture Science (Life), Cliental Medicine and Pharmacy (med) and Social Science (Soc). For each indicator, the highest scoring institute is assigned a score of 100, and the score for other institutions are calculated as a percentage of top

score. Numerous research initiatives on the PCA method have been undertaken. Some of them are reviewed below.

In [8], the author shows that PCA has been numerously used to characterize processed meat. Thus, an important feature of processed food product quality is its reproducibility, i.e. a low variability of product characteristic. Evaluation of product variability requires an abundance of diverse data to be collected and results are often hard to analyze.

In [12], the author uses Principal Component Analysis to derive four measurements of a bank's performance, the core task of financial intermediate. This study then compares the performance of China's state banks and the city commercial banks. The study concludes that unlike other developing countries, in China the size of a bank is not correlated with its performance. Instead, economic and political condition has a greater role than the size of the bank and its owner.

In this study, we combined PCA methods and other statistical analysis methods like clustering, and AHP. First, we tried to choose an Evaluation variable from valid resources. Then, using PCA, 8 measures of a university's ability to perform the core tasks of higher education centers was derived. Next, we compared the performance of universities with each other. We further compared performance in different years. Ultimately, using AHP method and the help of expert's, we assigned a weight to each year's priority. The highest rank and lowest rank university in each year were identified. The following subsection provides a quick review of PCA, clustering and AHP, and entropy weighing method, respectively.

3. Multivariate technique

There are a number of statistical techniques that can be used to analyze data. Obviously, the objective of data analysis is to extract the relevant information contained in the data, which can then be used to solve a given problem. Any given problem is normally formulated into one or more null hypotheses. The collected sample data is used to statistically test for the rejection or no rejection of the hypotheses.

3.1 Principal Component Analysis (PCA)

The principal component analysis was first elaborated in 1901 by Karen Pearson. The purpose of this analysis is to create new independent indices (z_1, z_2, \dots, z_n) composite of n original variables (x_1, x_2, \dots, x_n) . The independent property of these indices shows that each index measures a different aspect of the data. Indices are ordered so that z_1 is

the most dominant or influential variable and z_2 is the next and so on. As such:

$$Var(z_1) > Var(z_2) > \dots > Var(z_n) \quad (3-1)$$

$Var(z)$ shows the variance of z in the sample data, so z is named principal component. Here, the hope is that a large number of the original variables can be eliminated due to their insignificant variance, leaving the most dominant or influential with the highest variances. This allows data analysis to become easier and more efficient. The new variables are not correlated among themselves and they are linear combinations of the original X_1, X_2, \dots, X_p variables. For example, the first pc is

$$Z_1 = a_{11}X_1 + a_{12}X_2 + \dots + a_{1p}X_p$$

This index contains the highest variance provided that the following relationship is valid.

$$a_{11}^2 + a_{12}^2 + \dots + a_{1p}^2 = 1 \quad (3-3)$$

However, if the above relationship does not prove to be valid, the variance of z_1 will increase proportionally to each value of a_{ij} .

And the next index is

$$Z_2 = a_{21}X_1 + a_{22}X_2 + \dots + a_{2p}X_p \quad (3-4)$$

Z_2 will have the next highest variance provided that the relationship below is valid.

$$a_{21}^2 + a_{22}^2 + \dots + a_{2p}^2 = 1 \quad (3-5)$$

Provided that z_1 and z_2 are not correlated with each other, the remaining PCs are calculated the same way. Note that the maximum number of new variables (i.e. PCs) is equal to the number of original variables. To utilize the results of the analysis of the original variables, it is not absolute necessary to know the exact details of how to derive the abovementioned relationships. However, it is helpful to understand the nature of the equation for the next step, in which the Eigen value must be found using a co-variance matrix.

The steps to obtain the principal component analysis are as follows.

Standardize the variables until the mean equals zero and the variance equals one.

Calculate the correlation matrix C . If step 1 has been properly followed, the correlation matrix and co-variance matrix will be the same.

Find the Eigen value $\lambda_1, \lambda_2, \dots, \lambda_p$ and the associated coefficient vectors a_1, a_2, \dots, a_p the i th

principal component coefficient is represented by a_i

and its variance by λ_i .

Delete any component that has a very small variance. As an example, if out of 20 variables up for analysis 20 PCs are produced, where 3 PCs are found to cover 90% of the variance, the remaining 17 PCs can logically be deleted.

3.2 Cluster Analysis

Cluster analysis is a technique used for combining observations into groups or clusters. Each group or cluster is homogeneous or compact with respect to certain characteristics. Also, each group should be different from other groups with respect to the same characteristic.

The literature offers a variety of algorithms for hierarchical clustering. Two main methods are considered below. We will consider two of them.

3.2.1 Cluster Analysis Algorithms

1- It begins by N clusters that include a series of common characteristics and a symmetric

Matrix of distances $D = \{d_{ij}\}$

2- Create the matrix for pairs with closest distance to form clusters. Suppose d_{uv} is the distance between the most similar uv cluster.

3- Combine the u and v clusters, entry of distance and update it. Mark the new cluster (uv), the member of distance matrix by deletion of related columns and rows with clusters u and v and then add a column and a row that is showed distance between (uv) and reminder clusters, then update them.

4- Repeat steps 2, 3 $n-1$ times until all of the objects are in one cluster.

3.2.3 Types of Hierarchical Cluster

- Nearest-neighbor or single-linkage method
- Farthest-neighbor or complete linkage-method
- Average-linkage method

4. Weight Calculation

4.1 AHP weighing method

There are two methods for AHP weighing

- Local priority
- Overall priority

Local priority weight can be obtained from a similarity matrix. Whereas, absolute weight is the final ranking of each choice that is obtained from the combination overall priority weights. methods of Calculating Local priority

In the hierarchical method, members of each pair are compared with each other to make a pair matrix. This matrix is used to calculate the relative weight of its members. Overall, a pair comparison matrix can be written as below, where a_{ij} grows the i th priority in relation to the j th priority.

Now we want to calculate the weight using a_{ij}

$$A = [a_{ij}] \quad i, j = 1, 2, \dots, n \quad (1-4)$$

This matrix may be consistent or inconsistent. If the matrix is consistent, calculating w_i is very simple and is done through normalizing of each columns member. Otherwise, weight calculation is not simple and is done through one of four methods:

Least squared method, logarithmic least squared method, eigenvector method, and approximation method.

5. Proposed Approach

In this paper, we intend to present an appropriate and integrated method for ranking of universities. As explained previously, performance evaluation measures are often correlated with each other which can lead to errors in calculation caused by conflict in dependency. To overcome this problem, indices will first be manipulated to become independent. These new indices will be used to evaluate the performance of universities.

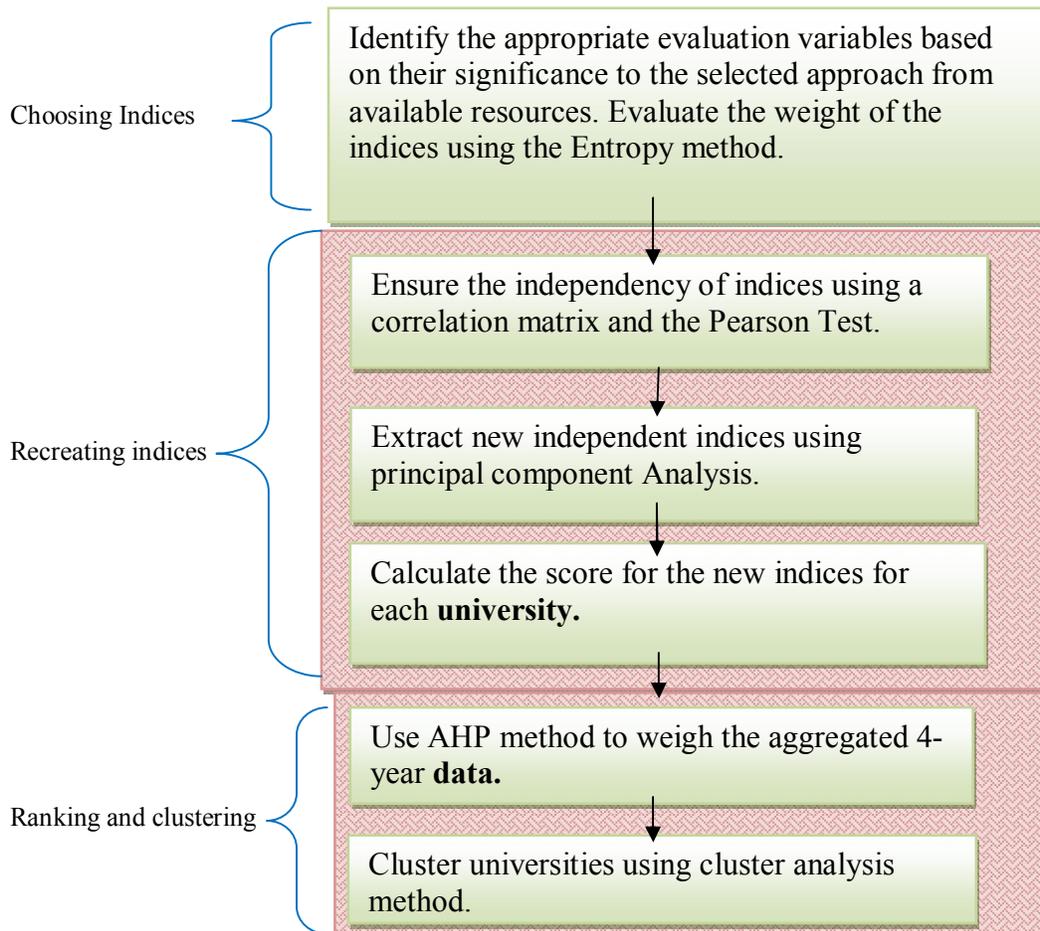


Figure 1. suggested approach

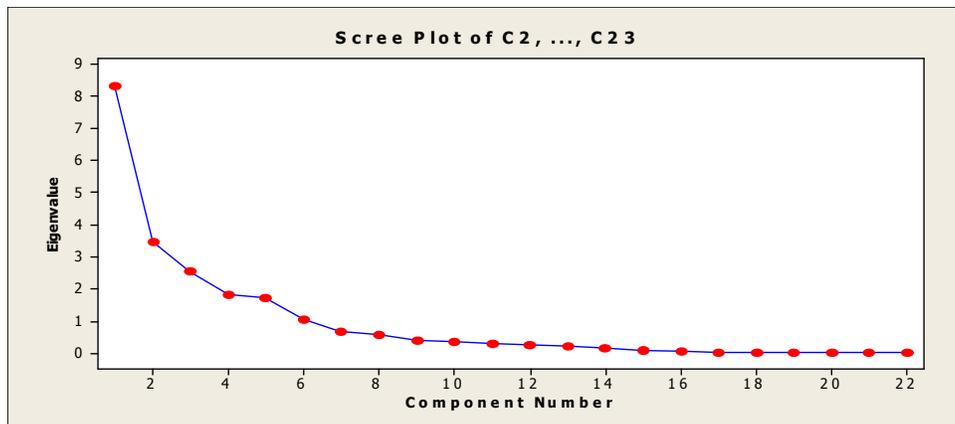
Some performance evaluation variables used to determine the performance of universities in a 4-year period (2003 -2006) include:

Total budget, number of students, number of full-time faculties, number of part-time faculties, number of laboratories, internet bandwidth, number of approved researches, number of completed projects, number of research papers, number of ISI

papers, number of other papers that have been published outside of the country, number of translated books, number of medical theses, number of PhD theses, number of M.Sc. theses, number of scientific journals, number of domestic invention, number of Persian books, number of non-Persian books, Persian current journals, number of Non-Persian journals, etc.

Table 1. The normalized results of performance evaluation indices of 27 academic units in 2003

The normalized core in 2003	Unit 1	Unit 2	Unit 3	Unit 15	Unit 16	...	Unit 25	Unit 26	Unit 27	
Total budget	-0.9673	-1.1096	1.4620	...	-0.3603	-0.1957	...	-1.0346	-0.1186	0.1108
Academic workshops	-0.0348	-0.3482	-0.3482	...	-0.3482	-0.0348	...	-0.0348	-0.3482	-0.3482
Number of sabbaticals granted	-0.4679	-0.4679	2.0587	...	-0.4679	-0.4679	...	-0.4679	-0.4679	-0.4679
...
Number of professional thesis	-0.4671	-0.4671	-0.4671	...	-0.4671	1.6907	...	-0.4671	-0.4671	1.012 5
Number of PhDs theses	-0.2460	-0.2460	-0.2460	...	-0.2460	-0.2460	...	-0.2460	-0.2460	-0.2460
Number of Ms Theses	-0.4661	-0.4661	4.3915	...	-0.3041	-0.1681	...	-0.4661	-0.2005	-0.3041
...
Total number of non- Persian books	-0.9818	-0.2790	1.6587	...	-0.5608	-0.4434	...	-1.0148	-0.5310	-0.3785
Number of published Persian journals	-0.6495	0.3386	0.2859	...	1.3267	1.5244	...	0.2596	1.1291	-0.3860
Number of published non-Persian journals	-0.2579	-0.6296	0.0801	...	-0.5958	1.4319	...	-0.6634	0.3167	0.1477



Graph 2. Scree plot for 2003 data

Table 2. Pc* in 2003

Component	First	Second	third	Fourth	fifth	sixth	seventh	eighth
Pc+	8.451009	4.788362	-3.31895	-1.15637	-1.59499	0.270369	0.064025	-4.40266
PC-	-2.54497	-0.53702	0.528982	0.092398	-0.38105	-0.94617	0.397788	0.258899

As we observe in the correlation matrix above, the indices are dependent on each other and this dependency may lead to an incorrect evaluation. Principal Component Analysis can be used to avoid this problem and to create new independent indices. This can be seen in the appendix. Out of these new independent indices, those with the highest Eigen value will be selected as new independent variables by which to evaluate the performance of universities. To clarify how this works, each selected PC accounts for a maximum variance that was not covered by any of the other PCs (i.e. the sum of the maximum variance of selected PCs is approximately 100%). As it can be seen in scree plot graph 1-4 (see appendix), the suitable PC number for years 2003 – 2006 is 8.

In addition, normalized correlation matrix data in 2003 is shown below.

0.407						
0.592	-0.042					
0.182	-0.004	0.038				
.	.	.	.			
0.828	0.288	0.544	...	0.747		
0.243	0.225	-0.286	...	0.309	0.275	
0.576	0.832	0.093	...	0.558	0.395	0.282

To achieve a suitable and accurate comparison, the highest and lowest PCs will be calculated.

$$PC_i^+ = \sum_i \max C_i \times \text{eigenvector}(PC_i) \quad \forall i = 1, 2, \dots, 8 \quad (1-5)$$

$$PC_i^- = \sum_i \min C_i \times \text{eigenvector}(PC_i) \quad \forall i = 1, 2, \dots, 8 \quad (2-5)$$

L shows number of PCs and **I** show primary variables according to the scree plot graph.

Table 2 shows the value relating to statements (1-5 and 2-5).

PC+ and PC- are the highest limit and the lowest limit of each PC for comparing universities with each other respectively.

$$D_i^+ = \frac{\sum_i w'_i |PC_i^+ - PC_i^-|}{\sum_i w'_i} \quad \forall i = 1, \dots \quad (3-5)$$

$$D_i^- = \frac{\sum_i w'_i |PC_i^- - PC_i^+|}{\sum_i w'_i} \quad \forall i = \dots \quad (4-5)$$

In the above equation, w' is the new index weight that can be obtained by substituting the primary variables' weight in the linear equation describing the relationship between PCs and primary variables. The most desirable situation is one where the the distance from the best PC will be highest and from the worst PC will be the lowest.

After calculating the positive and negative distances, the following equation will be used to drive an effective criteria that will serve as the overall evaluation index for each universities.

$$O_i = \frac{D_i^-}{D_i^- + D_i^+} \quad \forall i = 1, 2, \dots, 27 \quad (5-5)$$

The higher value of O , the more desirable the universities.

Table 3 shows the overall evaluation index for each university.

Table 3. Overall evaluation values between years (2003-2006)

Education center	1	2	3	...	26	27
Overall evacuation index 2003	0.091223	0.193195	0.413118	...	0.234163	0.518154
Overall evacuation index 2004	0.120313	0.190573	0.484191		0.265404	0.29903
Overall evacuation index 2005	0.157725	0.186802	0.467392		0.228765	0.396037
Overall evacuation index 2006	0.437205	0.448721	0.514293		0.456033	0.509245

To achieve the final ranking for aggregate (2003-2006) years, the annual data for each university will be merged. In this stage, we will consult academic experts to assign relative annual priority values. Next, AHP weighing method will be applied to compute the annual weight.

To derive the annual weight, the following steps will be completed.

A- The priority matrix is defined below according to the priority values as per AHP weighing method.

B- The weights will be achieved using columnar function on the priority matrix.

$$W = \begin{bmatrix} 0.11065 \\ 0.17167 \\ 0.26200 \\ 0.45400 \end{bmatrix}$$

C- Finally, weights obtained through AHP method will be applied to the following equation to achieve

the final ranking. The result can be seen in table 4 in the appendix.

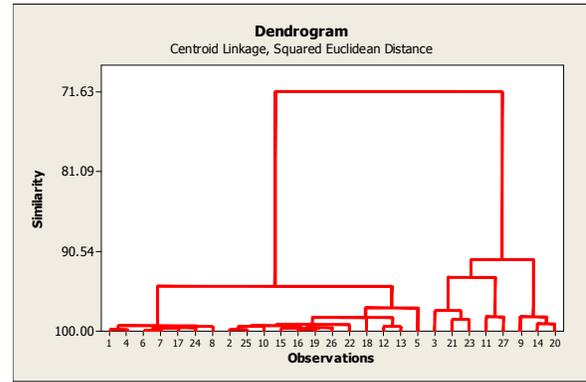
$$Ts_i = \sum_{k=82}^{85} W^k O_i^k \quad \forall i = 1, 2, \dots, 27$$

$$A = \begin{matrix} & \begin{matrix} 82 & 83 & 84 & 85 \end{matrix} \\ \begin{matrix} 82 \\ 83 \\ 84 \\ 85 \end{matrix} & \begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{3} & \frac{1}{3} \\ 2 & 1 & \frac{1}{2} & \frac{1}{3} \\ 2 & 2 & 1 & \frac{1}{2} \\ 3 & 3 & 2 & 1 \end{bmatrix} \end{matrix}$$

Table 4 Shows final ranking of education centers.

Table 4. Final ranking		
rank	Education centers	Ts
1	Education center21	0.556161
2	Education center23	0.512691
3	Education center3	0.48555
4	Education center11	0.474585
5	Education cente9	0.449809
.	.	.
.	.	.
.	.	.
14	Education center5	0.329179
15	Education center22	0.320904
16	Education center10	0.320319
17	Education cente15	0.312008
.	.	.
.	.	.
.	.	.
25	Education center17	0.253214
26	Education center6	0.249859
27	Education center7	0.243719

In addition, the clustering of similar universities in units as in table 3 simplifies policy and budgeting plans. The graph below shows the clustering results.



Graph 3. Cluster of education centers

6. Analysis

After ranking the universities for year 2003, it was found that the 11th unit has the highest rank and the 24th academic unit has the lowest rank. This is so because the 11th unit has the most number of maximum of indices (i.e. 5) and the 24th unit has the most number of minimum indices (i.e. 11) of all academic institutions measured. In year 2003, the 21st academic unit with 4 maximum indices has the highest rank and the 17th with the most minimum indices has the lowest rank. Again, in year 2004 the 21st academic unit with 5 maximum indices has the highest rank and the 17th with the most minimum indices has the lowest rank. Finally, the merged data for the aggregate years (2003-2006) revealed that the 21th has the top rank and the 7th the lowest rank. The detail of rankings is shown in table 7.

7. Conclusion

Considering the rapid growth in information gathering technology, and the rising expectations of university quality, in addition to the global attempt to increase university appeal, there is an escalating demand to know where universities stand on an international level. In Iran, this realization for such need has led to record keeping of several sought-after criteria for ranking of universities, as well as consideration given to their relative importance, which are ultimately used to derive a final rank for each university. In this paper, the evaluation indices were first identified. These indices were then manipulated to become independent and the most dominant of these were extracted with the help of Scree plot. The final ranking was done using these extracted variables.

The method utilized in this paper produces results with great confidence even in such situations where there may be a large number of units, a large number of indices, or where these indices may carry a great degree of dependency. The method in this paper is designed both to reduce the number of indices to those most influential, as well as to make effective use of loading to identify active groups of indices for each university.

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Corresponding Author:

Shahin Shahahmadi
Department of Information Technology,
Islamic Azad University, Tehran, Iran.
E-mail: Shahahmadi@gmail.com

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