International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:6, No:6, 2012

University Ranking Systems – From League table to Homogeneous Groups of Universities

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Abstract**—**The paper contains a review of the literature in terms of the critical analysis of methodologies of university ranking systems. Furthermore, the initiatives supported by the European Commission (U-Map, U-Multirank) and CHE Ranking are described. Special attention is paid to the tendencies in the development of ranking systems. According to the author, the ranking organizations should abandon the classic form of ranking, namely a hierarchical ordering of universities from "the best" to "the worse". In the empirical part of this paper, using one of the method of cluster analysis called k-means clustering, the author presents university classifications of the top universities from the Shanghai Jiao Tong University's (SJTU) Academic Ranking of World Universities (ARWU).

Keywords**—**classification, cluster analysis, ranking, university.

I. Introduction

ACCORDING to van Vught and Westerheijden [1], international discussions on higher education has given rise to a new concept called "transparency", which relates to the need to provide information about activities of universities. It is "perceived as a set activities intended to provide proof of quality to higher education institutions' external stakeholders, then creating transparency entails providing the information which these stakeholders need in order to form judgements and take decisions." [1]. It requires transparency tools such as rankings, classifications, league tables and benchmarking [2]

Nowadays there are many forms of evaluations and comparison of higher education institutions. All rankings, classifications and league tables can be analysed along different dimensions, included [3]:

- level: e.g. institutional vs. field-based,
- scope: e.g. national vs. international,
- focus: e.g. education vs. research,
- primary target group: e.g. students vs. institutional leaders vs. policy-makers,
- methodology and producers: methodological principles, sources of data, users.

For example, the experts of the European University Association, in the report *Global university rankings and their impact* divided the group of international rankings in the following way [4]:

- academic rankings with the main purpose of producing university league tables,
- rankings concentrating on research performance only,
- multirankings – university rankings and classifications using a number of indicators without the intention of producing league tables,
- web rankings,
- benchmarking based on learning outcomes.

Current university rankings are usually presented in the form of ranking list, so-called league table. The league tables, as given A. Usher and J. Medow, are "ranking systems that provide a single integrated score that allows an ordinal ranking of entire institutions" [5]. The main idea of the majority of university ranking systems is the creation of the aggregated indicator, also called synthetic variable, which is the basis of hierarchical ordering of analyzed universities. In Table I the most popular university ranking systems ordering universities from "the best" to "the worse" and their producers were presented.

TABLE I
THE MOST POPULAR UNIVERSITY RANKING SYSTEMS AND THEIR PRODUCERS

Global university ranking systems
Academic Ranking of World Universities (ARWU), *The Center for World-Class Uniwersities (CWCU), Graduate School of Education, Shanghai Jiao Tong University*
Times Higher Education World Reputation Ranking, *Times Higher Education (THE), Thomson Reuters*
QS World University Rankings, *Quacquarelli Symonds (QS)*
Performance Ranking of Scientific Papers for World Universities, *Higher Education Evaluation & Accreditation Council of Taiwan*
Webometrics Ranking of World Universities, *the Cybermetrics Lab, a research group belonging to the Consejo Superior de Investigaciones Científicas (CSIC)*
Leiden University Ranking, *Leiden University*
SIR (SCImago Institutions Rankings), SCImago
International Professional Ranking of Higher Education Institutions, *The École des Mines de Paris - MINES ParisTech*
World Academic ranking, *AcademyRank.com*
Top 200 Colleges and Universities in the world by University Web Ranking, *4 International Colleges & Universities*
University Ranking by Academic Performance, *Middle East Technical University, Informatics Institute*
National university ranking systems
U.S. News & World Report College and University rankings, *U.S. News & World Report* (USA)
America's Best College, *"Forbes" and The Center for College Affordability & Productivity* (USA)
The Top American Research Universities, *The Center for Measuring University Performance* (USA)
Washington Monthly College rankings, *"Washington Monthly"* (USA)
OEDb's Online College Rankings, *Online Education Database* (USA)

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University in China, *China Education Center Ltd.* (China)
The Good Universities Guide, *Hobsons* (Australia)
Maclean's University Ranking, "*Maclean's"* (Canada)
Ranking Szkół Wyższych "Perspektyw" i "Rzeczpospolitej", *"Perspektywy" i "Rzeczpospolita"* (Poland)
The Complete University Guide, "*The Independent"* (UK)
Ranking of Higher Education Institution of Kazakhstan, *The Independent Kazakhstan Quality Assurance Agency in Education* **(**Kazakhstan)
The Times Good University Guide, "*The Times"* (UK)

Most of the higher education institution rankings are ranking systems that provide a single integrated score that allows an ordinal ranking of universities. A different approach is taken by the Centre for Higher Education Development (CHE) in Germany, which issues annual rankings jointly with a media partner *Die Zeit*. The CHE Rankings do not rate universities form "the best" to "the worse". It is also not based on the total number of points. There are four initiatives of the CHE: The CHE University Ranking (ranking of higher education institutions in German-speaking countries for the first-year students), The CHE Research Ranking (ranking analyses the higher education institutions in Germany on the basis of their research performers), The CHE Excellence Ranking (ranking presents information about programme offerings and academic qualities of universities in Europe) and The CHE/dapm Employability Rating (assesses bachelor programmes in Germany on the basis of how well they promote qualifications and competencies that contribute to the professional capability of their graduates). These initiatives are created using methodological standards. The CHE rankings do not compare universities as a whole. They are based on the belief that each university has individual profiles with strengths and weaknesses in different subjects. Moreover stakeholders have varying preferences and they can decide themselves what is the most important to them. Therefore the CHE rankings do not assign weighting to individual indicators. They also give a picture of higher education institutions from different perspectives. The CHE University Ranking and the CHE Research Ranking assign objects to three rank groups, namely top group, middle group and bottom group. The producers want to avoid minor variations in the nominal value indicators, which are not always result from the differences in the level of performance and quality [6].

Another interesting ranking tool, created as a result of the initiative of the European Commission is U-Multirank – a multi-dimensional university ranking. It is "on-line instrument enables its users first to identify institutions that are sufficiently comparable to be ranked and, second, to design a personalized ranking by selecting the indicators of particular relevance to them. U-Multirank enables such comparisons to be made both at the level of institutions as a whole and in the broad disciplinary fields in which they are active." [3]. This new ranking system use the already designed and tested U-Map classification tool to create the user-selected groups of sufficiently comparable objects. U-Multirank uses a range of indicators representing five dimensions of higher education and research activities: (1) teaching and learning, (2) research, (3) knowledge transfer, (4) international orientation and (5) regional engagement. Its users can create two general types of rankings:

- focused institutional rankings: rankings at the level of institutions as a whole;
- field-based rankings: rankings in a specific field in which institutions are active.

Trends connected with preparation and publishing of university rankings have become the subject of many scientific discussions, which concern mainly issues related to the selection criteria and their weights, the presentation of results and the reliability of data. In bibliography there has been some criticism about the ranking systems. The best known and cited works are: [3], [7] – [16].

The paper discusses the critical views which regard the main steps of the construction of a league table from multiple criteria, including the following: (1) selection of data, (2) normalization of the data, (3) establishing the system of weights to the criteria and (4) aggregation of the weighted values.

Step 1. Selection of data

To a great extend the result of each ranking of higher education institution depend on the proper determining its criteria. Each ranking system uses a number of indicators, which renders it possible to create various classifications of the same objects. Van Dyke indicates that "the 10 report cards include a total of 72 different indicators spread across seven broad categories: Quality of Academic Staff/Faculty, Quality of Incoming Undergraduate Students, Quality of Undergraduate Program, Quality of Graduate Programs, Resources, Stakeholder Opinions, and Other" [9]. Additionally, in methodologies of current rankings selection of data are only theoretical character. According to van Vught and Ziegele „It seems that availability of quantitative data has precedence over their validity and reliability" [3]. While choosing data of university to create the ranking, the analyses of the statistical information from primary data are not carried out. A strong correlation between indicators often occurs. The ranking producers are not take into consideration the statistical characteristics of data. In addition, the differences in data are not statistically important [17], [18].

According to the author, the process of the selection of individual indicators should also include statistical procedures. The set of potential individual indicators prepared by group of experts ought to be verified according to their informative value. The indicators which have a low discrimination ability or repeat the information given by other indicators should be excluded from the set of potential data.

Step 2. Normalization of the data

In current university ranking systems different procedures of normalization of the data are used. Reference [19] presents various ways of normalization, including the following: dividing by the largest value, range normalization, z-scores

and dividing by the sum. According to CHERI [17], although the choice of the data normalization method has a big influence on the ranking, the ranking producers do not always explain it. Changing the method of normalization of the data has a dramatic effect on the results of rankings [19].

Step 3. Establishing the system of weights to the criteria

Some criticism about university ranking system has focused on choosing of weights. The choice of weights is arbitrary and subjective without theoretical or empirical basis [7], [9], [11], [18].

Step 4. Aggregation of the weighted values

Usually most university ranking systems add or average the indicators into a single number, sometimes ignoring that they use different scales or they are about different dimensions [3].

II. From League Table To Classification

Most rankings systems evaluate universities as a whole denying the fact that they are internally differentiated [9], [18]. There is no one definition of quality. Higher education institutions are very varied, they have different goals and missions, so they should not be evaluate together. Moreover, there are different stakeholders of university rankings (students, their parents, academics, governments, employers, etc.) and everyone needs different information. Reference [1] shows that individual users have different priorities and preference, so ranking systems should consider this heterogeneity. The most current rankings give only a single ranking. There are not specified target groups [3]. It is also worth paying attention to the fact that the main idea of the majority of ranking systems consists in ordering universities from "the best" to "the worse". Producers of all league tables do not explain differences in scores between universities. It often occurs the differences among universities one, two or three is significant in comparison with the universities occupying lower positions. In addition "the difference in scores between institutions placed several positions apart may not be statistically significant, even though the difference in positions suggests a disparity in quality or performance" [17].

Classification, i.e. grouping universities in homogenous clusters according to a given criterion, may be a solution to the above mentioned problems. In the paper the results of selected classifications are presented.

III. Cluster Analysis and the University Classifications

The data published on www.shanghajranking.com was used. In the research study. Classifications of 101 top universities from the Shanghai Jiao Tong University's (SJTU) Academic Ranking of World Universities (ARWU) were conducted. Table II shows the indicators and the weights used by ARWU.

TABLE II
Indicators and Weights for ARWU

Criteria	Indicator	Code	Weight
Quality of Education	Alumni of an institution winning Nobel Prizes and Fields Medals	alumni	10%
Quality of Faculty	Staff of an institution winning Nobel Prizes and Fields Medals	award	20%
	Highly cited researchers in 21 broad subject categories	hici	20%
Research Output	Papers published in Nature and Science	nas	20%
	Papers indexed in Science Citation Index-expanded and Social Science Citation Index	pub	20%
Per Capita Performance	Per capita academic performance of an institution	pcp	10%

The results of two selected classifications of universities are presented:
(1) classification of universities according to all criteria of ARWU ranking,
(2) classifications of universities according to one of the criteria: quality of faculty and research output.

The classifications were conducted by means of one of the method of cluster analysis called k-means clustering, using Statistica, 9.0. Because of a long description of the method, the author does not undertake to present it and refers to the following works [20], [21].

Firstly, before the classifications of universities, the statistical analysis of results of ARWU ranking were done. Fig. 1 shows the position of evaluated universities according to the value of indicators.

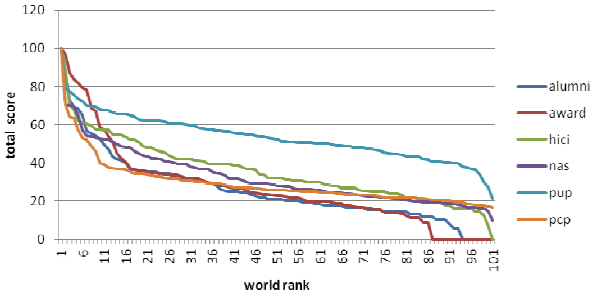

Fig. 1 Total scores of all indicators

It can be observed that analyzed ranking system differentiates universities in an uneven way. Depending on the indicator, a few first universities are far above the others. Additional, the data presented on the Figure 1 show that the few first universities are differentiated whereas the others are only to a small extent. It can be concluded that the cluster of universities is not homogenous, which is also corroborated by the values of coefficient of variation and asymmetry coefficient (Table III).

TABLE III
INDICATORS AND WEIGHTS FOR ARWU

Indicators	Coefficient of variation	Asymmetry coefficient
alumni	71,2	1,44
award	81,4	1,38
hici	46,3	0,98
nas	45,7	1,51
pup	22,3	0,46
pcp	41,8	2,9

Moreover, high values of asymmetry coefficient prove extreme level of right-sided asymmetry, i.e. there is a domination of universities in which the values of indicators are lower than the average.

Classification of universities according to all criteria of ARWU ranking

Using Ward's method and analyzing the process of agglomeration allows for distinguishing five clusters of universities (Fig. 2).

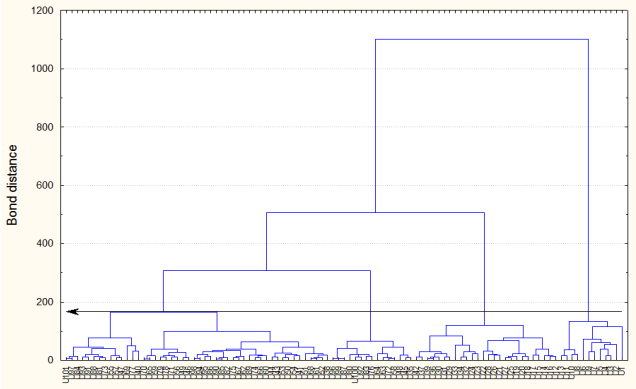

Fig. 2 Cluster dendogram

As the result of using k-means procedure five clusters of universities were singled out. The results of classification are presented in the Table IV. In order to avoid writing full name of universities the abbreviations U1, U2, U3, etc. corresponding to particular institutions in the ARWU ranking list in 2011 were introduced.

Each cluster is characterized by different level of indicators. One of the ways identifications of the cluster nature is the analysis of average values of indicators for each cluster. Table V shows average values of indicators for each group.

TABLE IV
CLUSTERS AND THEIR ELEMENTS

Cluster	University in the cluster	alumni	award	hici	nas	pup	pcp
1	U1	VH	VH	VH	VH	VH	H
2	U8, U9, U10, U11, U13	M	M/H	M	M	H	L
3	U2, U3, U4, U5, U6, U7	H	VH	H	H	M	H
4	U12, U14 – U32, U34, U35, U37, U39, U42, U45, U48	L	L	M	M	H	L
5	U33, U38, U40, U41, U43, U44, U46, U47, U49, U50 – U101	VL	VL	L	L	M	L

TABLE V
AVERAGE VALUES OF INDICATORS FOR EACH CLUSTER

Indicators	Average value of indicator				
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
alumni	100	56	63	23	19
award	100	60	82	24	18
hici	100	54	66	45	25
nas	100	49	62	41	23
pup	100	61	59	62	47
pcp	70	36	63	28	25

In order to distinguish basic characteristics of universities within each cluster, each of them is attribute a different symbol (dependent on the value of the average of indicators) in the following way:

- VH – very high value of indicator – average scores of indicators from 80 to 100
- H – high – average scores of indicators from 60 to 80
- M – medium - average scores of indicators from 40 to 60
- L – low - average scores of indicators from 20 to 40
- VL – very low - average scores of indicators from 0 to 20.

In order to present the nature of each cluster, a figure of average values of particular indicators for each cluster is given (Fig. 3).

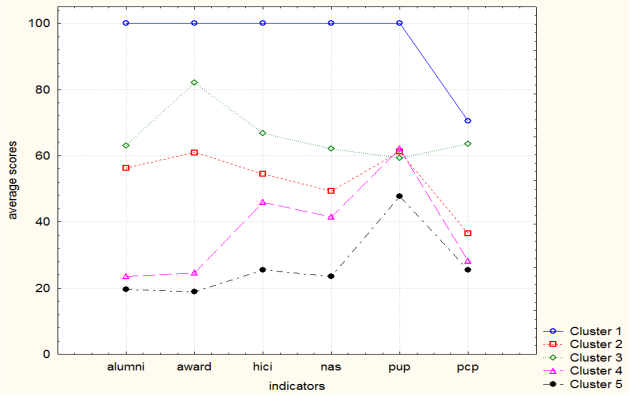

Fig. 3 Average scores for each cluster

In cluster 1 there is only one university – Harvard University. Such classification shows that the university is far above the others classified institutions. The university has top values for five indicators.

In cluster 2 there are only five universities. The average values of indicators range from 49 to 61, which proves very similar level of quality of education, quality of faculty and research output. A low value of pcp indicator and high values of others show that only very good but also big universities belong to this group.

In cluster 3 there are also five universities, which stand out from others because of a very high number of the staff winning

Nobel Prizes and high level of value of other indicators, but not sufficient to be in cluster 1 with Harvard University.

In cluster 4 there are 27 universities, characterized by a low level of the number of the staff and the alumni winning Nobel Prizes and low number of the alumni winning Fields Medals. The others are much higher.

In cluster 5 there are 63 universities. They are characterized by very similar and low level of each indicators in relation to the universities from other clusters.

From the classification conducted it result, that the group of all universities is not homogeneous group. It is proved by the fact that the clusters distinguished are not equinumerous. It is also corroborated by the coefficient of variation and the asymmetry coefficient, shown in Table VI.

TABLE VI
COEFFICIENT OF VARIATION AND ASYMMETRY COEFFICIENT

Indicators	Coefficient of variation				Asymmetry coefficient			
	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 2	Cluster 3	Cluster 4	Cluster 5
alumni	19,9	25,8	47,7	58,5	-0,08	0,20	-0,41	0,48
award	25,1	11,4	53,0	66,2	0,83	0,33	-0,80	0,45
hici	7,7	18,3	16,9	32,3	-0,16	1,25	0,54	-0,37
nas	12,3	17,6	16,9	23,5	-0,33	-1,20	0,32	0,72
pup	12,6	19,6	14,8	17,9	-0,33	-0,65	-0,26	-0,61
pcp	9,7	29,8	20,3	25,8	-0,99	1,86	1,33	2,03

There are not counted coefficient of variation and asymmetry coefficient for cluster 1, because there is only one university.

Thus, universities in particular clusters constitute more homogenous groups as to the indicators analyzed. The indicators within given clusters are characterized by as smaller discrimination ability and smaller asymmetry force than in the case described in Table III.

In the second part of research study all universities according to one of the criteria (quality of faculty and research output) were grouped. The same clustering procedures as in the previous classification were used.

The main purpose of the following classifications is indication of differences in its results.

Classification of universities according to quality of faculty

According to ARWU, the quality of faculty is represented by two indicators – the staff of an institution winning Nobel Prizes and Fields Medals (award) and highly cited researchers in 21 broad subject categories (hici).

Fig. 4 shows average values of analyzed indicators for each cluster.

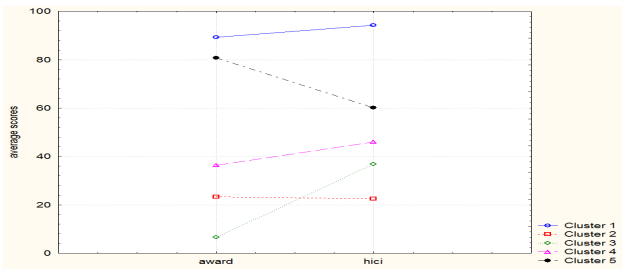

Fig. 4 Average scores for each cluster

In Table VII the universities of each cluster are presented.

TABLE VII
CLUSTERS AND THEIR ELEMENTS

Number of cluster	Elements of each cluster	award	hici
1	U1, U2	VH	VH
2	U37, U38, U40, U41, U43, U44, U47, U50, U51, U52, U53, U54, U55, U56, U57, U60, U61, U62, U66, U67, U68, U69, U71, U73, U74, U75, U77, U78, U81, U85, U86 U88, U89, U90, U91, U93, U94, U95, U97, U98, U101	L	VL/L
3	U21, U22, U26, U28, U35, U36, U39, U42, U45, U48, U58, U59, U63, U64, U65, U70, U72, U76, U79, U80, U83, U84, U87, U92, U96, U99, U100	VL	L/M
4	U10, U11, U12, U13, U14, U15, U16, U17, U18, U19, U20, U23, U24, U25, U27, U29, U30, U31, U32, U33, U34, U46, U49	L	M
5	U3, U4, U5, U6, U7, U8, U9	H/VH	M/H

Each cluster is characterized by different level of indicators. It is also worth paying attention to the fact that for example in cluster 3 there are universities from higher position in ARWU ranking (U21, U22, …) and from the end of the 101 top ranking list (U96, U99, U100). Therefore, they are very similar in terms of quality of faculty.

Classification of universities according to research output

According to ARWU, research output is also represented by two indicators – the papers published in Nature and Science (nas) and the papers indexed in Science Citation Index-expanded and Social Science Citation Index (pup).

Fig. 5 shows average values of analyzed indicators for each cluster.

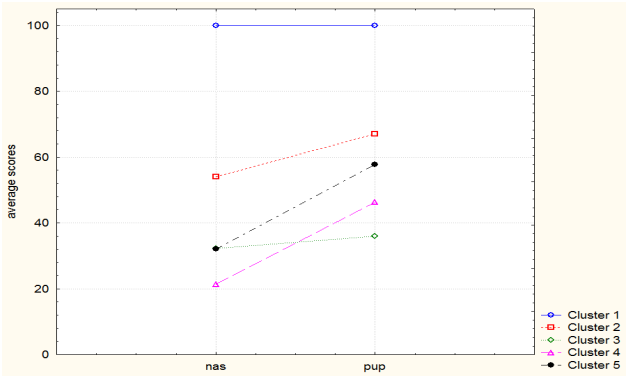

Fig. 5 Average scores for each cluster

TABLE VII
CLUSTERS AND THEIR ELEMENTS

Number	Elements of each cluster	nas	pup

of cluster			
1	U1	VH	VH
2	U2, U3, U4, U5, U6, U8, U10, U11, U12, U13, U14, U15, U16, U17, U18, U20, U21, U22, U26	M	H
3	U7, U32, U33, U34, U51, U65, U69, U73, U93	L	L
4	U40, U44, U47, U49, U50, U52, U55, U57, U59, U61, U62, U66, U67, U68, U70, U71, U74, U75, U76, U77, U78, U79, U80, U81, U82, U84, U85, U86, U88, U89, U90, U91, U92, U94, U95, U97, U98, U99, U100, U101	VL/L	M
5	U9, U19, U23, U24, U27, U28, U29, U30, U31, U35, U36, U37, U38, U39, U41, U42, U43, U45, U46, U48, U53, U54, U56, U58, U60, U63, U64, U72, U80, U83, U87, U96	L	M

In cluster 1 there is only one university – Harvard University. Moreover, Figure 5 shows that other universities have significantly lower values of analyzed indicators. Another fact worthy of note is that in cluster 3 there are universities, which are very distant in ARWU ranking. One of them is on the 7th position and another one on the 93th. These universities are very similar in terms of the number of papers published in Nature and Science and of papers indexed in Science Citation Index-expanded and Social Science Citation Index.

IV. Conclusion

Rankings of higher education institutions are – besides the reports of accreditation bodies assessing the quality of education – an important source of comparative information for various stakeholders. Year by year, they have an increasing impact on the universities and their environment, influencing, for example, the government policy of financing higher education institutions as well as the choices made by university candidates. Therefore, it is critical for the ranking organizations to present the public with the possibly most objective picture of the position of particular universities in relation to each other.

The proposed statistical procedure of the classification of universities allows for grouping higher education institutions into homogenous groups. It also renders it possible to describe and visualize the diversity of objects. Classification is a good tool for analyzing institutional profiles of universities. According to the results of conducted classifications, different criteria of clustering give different groups of universities. Using classification tools, stakeholders can decide which criteria of evaluation are the most important and interesting. It gives them possibility to find and compare similar institutions in terms of specific purposes.

Acknowledgment

This scientific research was financed from the resources of the National Centre for Science nr N N111 530140.

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