DOI: https://doi.org/10.30837/MMP.2020.281

APPROACH TO THE CALCULATION OF CONSOLIDATED RATINGS FOR THE TASKS OF MANAGING HIGHER EDUCATION INSTITUTIONS

Rossoshanskaya O., Biryukov O.

Since the beginning of the XXI century, more and more educational institutions began to pay attention to their representation in various regional and international ratings. This stimulated the emergence of new ratings and methods of calculating them. Educational institutions use ratings as one of the tools for managing their development, monitoring the correctness of the chosen path, promoting their image and increasing competitiveness. However, the unresolved issues of correct processing of the indicators used to calculate the ratings leads to the emergence of contradictions in the assessment of the quality of educational institutions, obtained from various ratings.

The article proposes an approach to the calculation of consolidated ratings, which is based on the application of the method of standardizing indicators and the operator of multiple layouts of four types of averages for these indicators. Based on the data of the consolidated rating of higher education institutions in Ukraine in 2020 on the example of the nomination "TOP 10 Best Private Universities of Ukraine", a significant difference in the structure of rating lists is shown, based on different approaches to calculating the rating. It was found that the proposed approach provides more reliable information for a holistic view of the level of activity of an educational institution. This allows us to recommend the proposed approach for constructing secondary and derived ratings based on existing ones to significantly reduce the likelihood of system errors inherent in each particular rating.

Introduction

The history of rating (ranking) of higher education institutions originates from the United States [1]. It can be divided into three main stages. The first stage (1870 - 1982) is characterized by a number of statistical studies, the results of which became available to the General public. First of all, it is the publication of annual reports with statistical information and classification of educational institutions, carried out by the US Bureau of education. Regularly, works began

to appear in which data related to the activities of educational institutions was analyzed. The emphasis was done on the staff, the achievements of leading scientists, the structure of the disciplines studied, the assessment of scientific results, the ranking of the reputation of universities and professional schools. The beginning of the second stage is considered the publication in 1983 of the list of the 50 best US universities in the US News & World Report, which continues to be published now. The appearance of the list initiated a number of studies on the independent assessment of universities by various organizations and the media [2]. Some of the research results began to be published systematically. Basically, these publications were aimed at applicants and their parents, who faced the question of choosing an educational institution. Therefore, in most cases, the ranking of universities was carried out at the sectoral or national levels. The practice of building individual international rankings, for example, universities in the Asia-Pacific region, was recorded [1]. The third stage in the development of the practice of ranking universities is associated with the construction of global (world) rankings. Since 2003, the Academic Ranking of World Universities - ARWU has been compiled annually. In 2004, the Webometrics rating appears, in 2005 - QS-THES, in 2006 - The Top 100 Global Universities, in 2007 - Performance Ranking of Scientific Papers for World Universities-PRSP, in 2010 as independent competing The World University Rankings (THE) and "Quacquarelli Symonds" (QS), etc. [1,2]. The information summarized in such ratings is focused to a greater extent not on potential applicants, but on decision-makers regarding the development of a strategy and the implementation of operational activities of educational institutions, as well as the formation of an environment for their activities within the framework of existing government policies. This situation is a logical consequence arising from the processes of economic globalization (including the market for educational services), informatization, and digitalization. Now it is possible to remotely

access educational resources at any time convenient for users. The transition of civilization to a higher technological order has increased the understanding of the role of universities as one of the most important links in the creation and implementation of innovative developments. This is reflected in the set of structural components of the ratings. They began to pay more and more attention to indicators that characterize not only the quality of educational (academic) activities, but also research, as well as international cooperation. Thus, today ratings, in essence, at various levels (national, global) describe the competitive environment of the education sector [3]. At the same time, the analytical processing of ratings helps to understand the place of a particular educational institution in it and to outline guidelines for its further development.

The constant change in competitive conditions also leads to a change in the format of universities' activities from "University 1", in which the key category is "learning," to "University 4" with the key categories "creativity, ecosystem, business" [4]. We have found that with the transition to higher formats, the share of process activities in universities decreases, while project activities increase. The increasing complexity of the context of activities, an increase in the number of multi-entity (in content and target orientation) projects implemented by universities, leads to the fact that within the framework of the formats "University 3, 4" requires a transition to the methodology of portfolio management of their activities. This statement is based on a significant number of publications in this direction, both theoretical and practical, by foreign [5, 6] and domestic authors [7-9]. In the formation of portfolios, an important role is played by the correct definition of strategic goals, key criteria and descriptors, for which the components of the rating components and their values for specific educational institutions can serve as benchmarks. However, at the same time, it is necessary to process a large number of ratings of a paEIE scale, differing both in the methodological basis and in the number of factors taken into account [10-12]. Today, to improve the quality of ratings, an International Group of Experts (International Ranking Experts Group - IREG) has

been created, which periodically holds conferences on topical issues related to the compilation of ratings. As part of the activities of this group, the principles of ranking educational institutions have been developed, recommendations are constantly being issued for consumers of academic ratings, and competitions are announced for conducting scientific research in the development of new rating systems [13].

Analytical processing of ratings is most often carried out in the direction of analyzing their components (factors). As a rule, they have different scales and units of measurement [14, 15]. The second direction is associated with the comparison of various ratings, their averaging (compilation of secondary, consolidated ratings), including taking into account changes in their structure in dynamics [1, 12, 16]. Today, the most controversial issues remain related to the procedures for standardizing and aggregating the data used [17-19], which determined the problematic of our study.

1. Approaches to data normalization and aggregation

The traditional algorithm for constructing ratings of educational institutions consists of sequentially performed operations of standardization, aggregation and ranking [18]. There are several different approaches to implementing each of these operations. Normalization is used to bring data to a dimensionless form within a single range. This makes it possible to compare and combine different types of data and indicators that characterize various aspects of the activities of educational institutions. Aggregation allows you to combine several indicators to obtain a complex indicator. Quite often, a weighting procedure is used for this - assigning different weight coefficients to indicator values. Ranking involves the distribution of indicators in ascending or descending order and assigning a corresponding rank to each position. In the process of constructing ratings based on multidimensional ranking (using a number of complex indicators), the standardization and aggregation procedures can be repeated several times at different

levels (the level of formation of complex indicators, groups of indicators, clusters, etc.) [1].

In [19], four mathematical models for data normalization are analyzed. The models are based on various ratios of current values to the maximum or minimum value from the studied data set. Based on the analysis of the advantages and disadvantages of the models, the authors recommend normalizing the data to a range that is determined by the difference between the maximum and minimum data values. When maximizing the normalized indicator, the normalized value of the indicator is calculated by the formula

$$\|X_i\| = (\max x_i - x_i) / (\max x_i - \min x_i), \quad (1)$$

and upon minimization – by the formula

$$\|X_i\| = 1 - (\max x_i - x_i) / (\max x_i - \min x_i). \quad (2).$$

A more complex method of standardization involves the use of the Z-aggregation procedure

$$\|_z X_i\| = (x_i - \bar{x}) / \sigma. \quad (3)$$

Based on the tables of the standard normal distribution, the values obtained by formula (3) are converted into a 100-point scale, equivalent to the percentage grading system [1].

There are several problems with weighted aggregation. The first is related to the justification of the values of the coefficients. The second is with the ability to compare and analyze the results of ratings calculated for different years. To take into account changes in the external environment, the calculation models are periodically updated.

To avoid the listed aggregation problems, we have proposed to use an approach based on the application of the operator of multiple collation of four types of means [20]. Mathematically, the operator can be represented as:

$$G_i = {}_{ij}\bar{Q}^k_{a,r,h,g}(\|X_{ij}\|), \quad (4)$$

where G_i is a final rating score for the *i*-th educational institution, *i* = 1, 2, … N; $\|X_{ij}\|$ - the normalized value of the *j* parameter for the *i*-th educational institution, which are used in the first step of the layout, *j* = 1, 2, … Q; ${}_{ij}\overline{Q}^{k}_{a,r,h,g}$ - operator of convolution of values of arithmetic mean (a), quadratic (r), harmonic (h), geometric (g); k- the number of layout iterations of the four averages that were obtained at the previous layout step.

The operator is based on the property of convergence of means when calculating their limits. For convergence, i.e. to obtain mean values that do not differ from each other, it is enough to carry out from three to five iterations. As practice has shown, the use of this operator allows one to obtain a single integrated assessment, which integrally reflects the features of changes in the studied data set and the nature of their scatter [21]. This approach, in our opinion, is more systemic and holistic in comparison with approaches based on the weighing operation during aggregation.

Based on this, to calculate the rating of educational institutions based on a known set of indicators and their values, we proposed using the method of data normalization to the range (formulas (1), (2)) and the method of multiple matching of four types of averages (formula (4)).

2. Calculation of the consolidated rating in the framework of various approaches

Let's check the applicability of the proposed approach on the example of the consolidated TOP-200 rating of the information and educational resource "Osvita.ua" (IER "Osvita.ua"). It is calculated on the basis of three national ratings of higher educational institutions of Ukraine - "Top-200 Ukraine", "Scopus", "EIE points per contract" [22]. To determine the advantages and disadvantages of different approaches to calculating the rating, we will restrict ourselves to a comparative analysis using the example of the nomination "TOP 10 Best Private Universities of Ukraine" (table 1).

Table 1

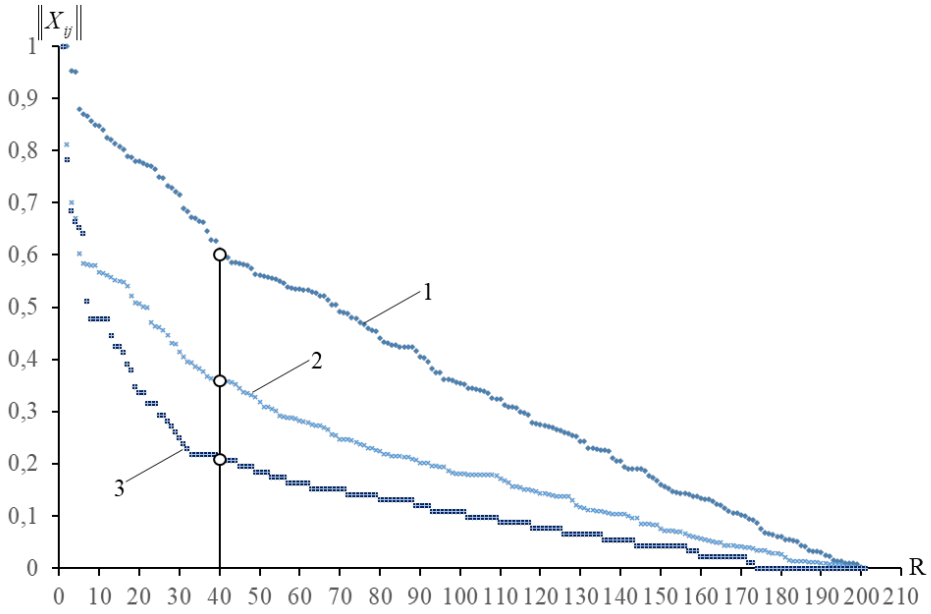
Consolidated rating in the nomination "TOP 10 Best Private Universities of Ukraine" IER "Osvita.ua"

Name of the educational institution	Place among private educational institutions	Place in the overall rating	Place in the overall rating Indicators for calculating the consolidated rating according to the method of IER "Osvita.ua"			
			TOP 200 Ukraine	EIE points per contract	Scopus	Final points
1	*2*	*3*	*4*	*5*	*6*	*7*
Ukrainian Catholic University (UCU)	1	82	129	1	177	307
Alfred Nobel University (UAN)	2	89-90	119	53	146	318
Lviv University of Trade and Economics (LTEU)	3	101-105	176	74	87	337
Poltava University of Economics and Trade (PUET)	4	106	117	102	128	347
Lviv Medical Institute (LMI)	5	111-112	201	11	148	360
Kyiv Medical University (KMU)	6	113-114	191	10	161	362
Kharkiv Humanities University "People's Ukrainian Academy" (KHU)	7	117	151	40	177	368
Interregional Academy of Personnel Management (IAPM)	8	120	106	158	109	373
University of Economics and Law "KROK" (KROK)	9	125	87	135	156	378
Concordia Ukrainian-American University (UAUC)	10	127	190	14	177	381

It should be noted that the methodology for constructing a consolidated rating (like some others on the basis of which it is calculated) does not provide for standardization operations, and aggregation is performed by simple summation of the ranks.

To normalize the values of the ratings included in the consolidated TOP-200 rating, we will normalize the data array of the Top-200 Ukraine, Scopus and EIE

points per contract for all educational institutions included in it. For this we use formulas (1) and (2). The normalization results are shown in fig. 1.



1 – "Top-200 Ukraine", 2 – "EIE points per contract", 3 – "Scopus"; N – number of educational institutions, $\|X\|$ – normalized values of indicators

Fig. 1. The nature of changes in the normalized values of indicators of the components of the consolidated rating of Ukraine TOP-2020

As can be seen from Fig. 1, the nature of rating changes is nonlinear and different. This is reflected in the normalized values of indicators $\|X\|$ (values) that correspond to the same place in different ratings. For example, for R40, the values $\|X\|$ for "Top-200 Ukraine", "Scopus" and "EIE points per contract" are 0.611, 0.3597 and 0.2065, respectively (Fig. 1). At the points on the curves that correspond to R40 (Fig. 1), the nature of the dependence of the values of normalized indicators on the number of places in the rating changes. R40 divides the entire rating scale in the proportion of 20: 80. This corresponds to the Paretto principle. The randomness or regularity of the appearance of such a place in the ratings requires additional research. Each rating has several (3-10) leaders, who have a much greater difference

between the indicators of nearby educational institutions than between others located lower in the rating.

To determine the normalized values of the components of the ratings "TOP 10 Best Private Universities of Ukraine", the values of their places in the overall rating and the corresponding normalized values of the indicator were used (table 2).

Table 2

Calculation of a consolidated rating based on normalized indicators in the nomination "TOP 10 Best Private Universities of Ukraine"

Name of the educational institution	Place among private educational institutions	Place in the overall rating	Normalized indicators for calculating the consolidated rating					max[4,5,6]-min [4,5,6]
			TOP 200 Ukraine	EIE points per contract	Scopus	Final points	Place	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
UCU	1	82	0,2526	1,0000	0,0000	1,2526	1	1,0000
UAN	2	89-90	0,2767	0,3059	0,0435	0,6261	2	0,2624
LTEU	3	101-105	0,0656	0,2407	0,1304	0,4367	10	0,1751
PUET	4	106	0,2945	0,1799	0,0652	0,5396	7	0,2293
LMI	5	111-112	0,0000	0,5659	0,0435	0,6094	4	0,5659
CMU	6	113-114	0,0226	0,5667	0,0217	0,6111	3	0,5450
KhHU	7	117	0,1535	0,3597	0,0000	0,5133	8	0,3597
IAPM	8	120	0,3392	0,0608	0,0978	0,4978	9	0,2784
KROK	9	125	0,4235	0,1094	0,0435	0,5763	5	0,3800
UAUC	10	127	0,0245	0,5516	0,0000	0,5761	6	0,5516

* Data of the information educational resource "Osvita.ua".

The final score in the consolidated rating (column 7 of table 2) (aggregation procedure) was determined by analogy with the methodology of IER "Osvita.ua", i.e. by summing up the points of the rating components. According to the analysis of the table 2, for eight out of ten educational institutions their places in the consolidated rating (column 8) have changed in comparison with the rating of IER "Osvita.ua"

(column 2). The correlation coefficient between the final scores (columns 7 of table 1 and table 2), equal to 0.62, indicates that there is no direct relationship between them. Therefore, it can be assumed that different calculation methods reflect different entities.

Based on the normalized values of the indicators (columns 4-6 of table 2) using the operator of layout of four averages (formula (4)), the final score of the consolidated rating was calculated (column 6 of table 3).

Table 3

Calculation of the consolidated rating with the performance of the aggregation operation based on the layout procedure for four averages within the nomination "TOP 10 Best Private Universities of Ukraine"

Name of the educational institution	Place among private educational institutions	Indicators for calculating the consolidated rating using the four-average layout procedure			
		TOP 200 Ukraine	EIE points per contract	Scopus	Final points
1	*2*	*3*	*4*	*5*	*6*
UAN	1	0,2767	0,3059	0,0435	0,131
PUET	2	0,2945	0,1799	0,0652	0,125
KROK	3	0,4235	0,1094	0,0435	0,122
IAPM	4	0,3392	0,0608	0,0978	0,113
KMU	5	0,0226	0,5667	0,0217	0,105
LTEU	6	0,0656	0,2407	0,1304	0,104
UCU	7	0,2526	1,0000	**0,0000**	0,100
LMI	8	**0,0000**	0,5659	0,0435	0,061
UAUC	9	0,0245	0,5516	**0,0000**	0,059
KhHU	10	0,1535	0,3597	**0,0000**	0,049

According to the value of the final score, a new order of arrangement of educational institutions in the rating "TOP 10 Best Private Universities of Ukraine" has been made.

3. Analysis of calculation results

For the convenience of analyzing the ranking results for three approaches, a table 4 was compiled. As you can see, the largest changes in the rating list, in accordance with the calculations, which used the four-averages matching procedure, were undergone by educational institutions that had a fairly large difference between the maximum and minimum values of the normalized indicators (column 8).

Table 4

Comparison of the places of educational institutions in the consolidated rating "TOP 10 Best private universities in Ukraine" calculated according to different approaches

Name of the educational institution	The place of the educational institution in the consolidated rating, calculated according to the methods:			Difference between places in the consolidated rating			From table 2 column 9 max [4,5,6]-min [4,5,6]
	"A" IER " Osvita.ua "	"B" by the sum of the normalized values of the indicators of the rating components	"C" using the four-average layout procedure	"A"-"B"	"A"-"C"	"B"-"C"	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
UCU	1	1	7	**0**	**-6**	-6	1,0000
UAN	2	2	1	0	1	1	0,2624
LTEU	3	10	6	-7	-3	4	0,1751
PUET	4	7	2	-3	2	5	0,2293
LMI	5	4	8	**1**	**-3**	-4	0,5659
KMU	6	3	5	3	1	-2	0,5450
KhHU	7	8	10	**-1**	**-3**	-2	0,3597
IAPM	8	9	4	-1	4	5	0,2784
KROK	9	5	3	4	6	2	0,3800
UAUC	10	6	9	4	1	-3	0,5516

The correlation coefficient between the deviation of the rating calculated according to the method of IER "Osvita.ua" and using the layout operator (column 6) and the inverse difference between the maximum and minimum values of the normalized indicators (column 8) is 0.86. Such a rather large value of the coefficient indicates that deviations are associated with the difference in indicators, which is well taken into account by the layout of the four averages. This is the advantage of the method and its distinctive feature. The method, unlike the others, is sensitive to educational institutions that have zero normalized values. Such educational institutions are located at the end of the rating list compiled with its use (table 3). Their initial entry into the leaders of the consolidated rating suggests the possibility of manipulating the calculation method.

Conclusions

The results of our research allow us to draw several particular conclusions.

Regional and international rankings are increasingly used in the management of institutions of higher education in almost all countries of the world. The emergence in the world of a new profession of ranker, (compiler of ratings), the active work of the guild of national and international appraisers of universities indicates that rating technologies will gradually enter the daily activities of all educational institutions. Therefore, it becomes necessary to radically improve the entire toolkit of rating technologies.

First of all, it is relevant to develop universal procedures for normalization and aggregation that could be used for any type of indicators and any kind of ratings. One of the options for solving this problem can be an approach to aggregation, which is based on the use of the multiple-set operator. This will allow to get away not only from the disadvantages of using weighting factors, targeted inclusion in the rating of indicators beneficial to certain stakeholders, but also will make it possible to establish the presence of links between different ratings.

Practical verification of the application of this approach on the example of the nomination "TOP 10 Best Private Universities of Ukraine" of the consolidated rating

of TOP-200 Ukraine of the information educational resource "Osvita.ua" showed the impossibility of manipulating the calculation method to improve the positions of educational institutions.

REFERENCES

1. Balatsky, E. V., Ekimova, N. A. (2011), "International University Rankings: Practice of Compilation and Use", available at : https://kapital-rus.ru/articles/article/globalnye_rejtingi_universitetov_praktika_sostavleniya_i_ispolzovaniya
2. Downing, K. (2018), "The history and development of higher education ranking systems", *QS Asia News Network*, available at : https://qswownews.com/history-development-higher-education-ranking-systems/
3. Levchenko, O. M., Tsarenko, I. O. (2016), "Competitiveness of Ukrainian higher education in measuring international ranking systems", *Economics and organization of management*, No. 3.
4. Neborskiy, E. V. (2017), "Reconstruction of the university model: transition to the 4.0 format", *Internet magazine "World of Science"*, Vol. 5, No. 4, available at : http://mir-nauki.com/PDF/26PDMN417.pdf
5. *Project, Programme and Portfolio Management Trends in Higher Education*, The Hanover Research Council – Academy Administration Practice, 2009, 33 p., available at : http://www.planning.salford.ac.uk/__data/assets/pdf_file/0013/20713/Project-Programme-and-Portfolio-Management-Trends-in-Higher-Education-Membership.pdf
6. Fei, Bi, Wenbing, Wu. (2017), "Research on portfolio management of university education funds taking Harvard university for example", *Conference: 2017 4th International Conference on Industrial Economics System and Industrial Security Engineering (IEIS)*. DOI: 10.1109/IEIS.2017.8078578
7. Rach, V. A., Borzenko-Miroshnichenko, A. Yu. (2009), "Project-oriented management models and evaluation of higher education institutions", *Project management and production development*, No. 1 (29).
8. Kolyada, O. P. (2011), *Portfolio planning in the process of implementing the development strategy of a higher educational institution* : author's ref. dis ... cand. tech. sciences: 05.13.22, Kyiv, Nat. University of Construction and Architecture, 20 p.
9. Пітерська В.М. (2019), "The mechanism of formation of a portfolio of research projects of higher education institutions within innovation programs", *Bulletin of NTU "KhPI". Series: Strategic Management, Portfolio, Program and Project Management*, No. 2 (1327). DOI: https://doi.org/10.20998/2413-3000.2019.1327.6
10. Marope, P. T. M., Wells, P. J., Hazelkorn, E. (2013), *Rankings and accountability in higher education: uses and misuses*, 305 p.

11. Zavarykina, L. V., Lopatina, A. S., Perfilieva, O. V. (2012), "Comparative analysis of international methodologies for ranking higher education institutions", *Bulletin of international organizations*, No. 1 (36).
12. Larionova, M. V. (2012), "Methodology for Comparative Analysis of International Approaches to Ranking Higher Education Institutions", *Bulletin of international organizations*, No. 1 (36).
13. "IREG Observatory on Academic Ranking and Excellence", available at : https://ireg-observatory.org/en/
14. Friso Selten, Cameron Neylon, Chun-Kai Huang, Paul Groth (2019), *A Longitudinal Analysis of University Rankings*, 29 p., available at : https://www.researchgate.net/publication/335462989_A_Longitudinal_Analysis_of_University_Rankings
15. Adina-Petruta, P. (2015), "Global University Rankings. A Comparative Analysis", *Procedia Economics and Finance*, No. 26, P. 54–63. DOI: https://doi.org/10.1016/S2212-5671(15)00838-2
16. Weiru, C. (2018), "Comparing University Rankings: Statistical Analysis of Four Global University Ranking Systems", *Conference, MAA MathFest 2018*, available at : https://www.researchgate.net/publication/327535648_Comparing_University_Rankings_Statistical_Analysis_of_Four_Global_University_Ranking_Systems
17. Klyushnikova, E. V., Shitova, E. M. (2016), "Methodological approaches to the calculation of the integral indicator, ranking methods", *Electronic scientific and practical journal "InnoCenter"*, No. 1 (10).
18. Arzhanova, I. V., Baryshnikova, M. Yu., Zhurakovsky, V. M. (2013), "Methodology of multidimensional ranking: the possibility of a comprehensive assessment of the activities of universities", *Bulletin of international organizations*, No. 1 (40), available at : https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2907265.
19. Rossoshanskiy, P. V., Graivoronskiy, S. A. "Analysis of methods for standardizing quality indicators of complex technical systems", available at : https://cyberleninka.ru/article/n/analiz-metodov-normirovaniya-pokazateley-kachestva-slozhnyh-tehnicheskih-sistem
20. Rach, V. A., Pilipenko, A. I. (2017), "Quantitative methods of resource-time evaluation in a flexible methodology of software development", *Project management and production development*, No. 1 (61), P. 62–71.
21. Rach, V., Rossoshanska, O., Medvedieva, O., Yevdokymova, A. (2019), "System Modeling of Development of Innovative Project-Oriented Enterprises", *Marketing and Management of Innovations*, No. 1, P. 105–131. DOI: http://doi.org/10.21272/mmi.2019.1-09
22. "Consolidated ranking of Ukrainian universities in 2020" ["Konsolidirovannyy reyting vuzov Ukrainy 2020 goda"], available at : https://ru.osvita.ua/vnz/rating/51741/