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PARAMETERS OF MONITORING THE COMPETITIVENESS OF HIGHER EDUCATION INSTITUTIONS

Abstract. *Six critical parameters of the competitiveness of a higher education institution were formed: scientific research and practical development, stability in the educational service market, adaptability to changes, cooperation and participation in alliances, projects, clusters, the level of competence of scientific and pedagogical employees, assessment of the financial condition of the higher education institution education. It includes the university's financial capacity for development and financial accessibility, i.e. providing the opportunity to study for students of different groups, inclusive education, etc. The formed list differs from the traditional one in that it allows consideration of both classical and specialized higher education institutions in the evaluation, regardless of the field of activity. It was determined that to analyze competitiveness, it is necessary to use methods based on pairwise comparison. Since the methods of assessing these parameters are different, one of the methods that can be suitable for assessing competitiveness is the DEA method. It was found that the interpretation of DEA results, considering the modifications of the optimization task of assessing the competitiveness of higher education institutions, still needs to be explored. It is indicated that to apply the model, it is necessary to collect input and output parameters and interpret the obtained results. To build a system for monitoring the competitiveness of a higher education institution, it is necessary to collect data on various types of activity of a higher education institution over a certain period and save them for processing. Data should be open, verifiable, transparent, and easy to verify. They should be free from the influence of the subjective factor. This is important to ensure an unbiased assessment of the institution's activities. The obtained results are essential for developers of systems for evaluating and monitoring the competitiveness of higher education institutions.*

Keywords: *monitoring; institution of higher education; competitiveness; data envelopment analysis*

Introduction

The effective functioning of higher education is the key to training high-level specialists. These specialists are the basis for ensuring the rapid development of society promoting development and innovation in various social spheres. High-quality higher education plays a significant role in increasing the country's and society's overall competitiveness. Therefore, the issue of evaluating the quality of higher education and the productivity of training specialists has always been relevant for research [1–4]. For evaluation, educational environments are created where universities function and interact with other universities within the framework of joint scientific and educational projects. Multi-criteria methods for selecting the best higher education institutions and scientists from among their employees are also being created [5–7].

Monitoring competitiveness is a higher-level task than simply evaluating the effectiveness of education. After all, the competition between higher education institutions for leadership in this field is an incentive for the training of high-quality specialists. In turn, this goal has scaled to the level of the state and the corresponding region. This is because trained specialists increase the state's competitiveness in the future. That is, monitoring and increasing the competitiveness of higher education institutions has excellent academic significance [8; 9].

The work [10] describes measures and strategies for improving the educational competitiveness of colleges and universities at the regional level. At the same time, these measures include the internationalization of scientific and educational activities. The work [11] identified the competitive advantages of higher education in China and proposed appropriate improvement strategies. Methods of increasing the competitiveness of higher education in cross-border regions based on an education audit are described in [12]. It was pointed out that audit is the only way to increase the competitiveness of higher education. In work [13], the issue of management of competencies and innovations for transforming higher education. In [14], an analysis of the competitiveness of higher education, a model for creating a competitiveness

index, was carried out. Then, based on this model and the corresponding index, a comparison of the competitiveness of China's higher education with other countries was made. The work [15] analyzed the impact of reputation in higher education on competitiveness. In [15], a fuzzy estimation method based on resource allocation is discussed. The work [16] analyzes the key factors affecting the educational competitiveness.

It should be noted that various higher education institutions provide training in various specialties (IT, humanities, mathematics, physics, etc.). All these directions can be completely heterogeneous, so it isn't easy to conceptually approach the monitoring of the competitiveness of such universities. There is also a different understanding of competitiveness. Scientists include various indicators in it. In general, for assessing competitors, opportunities are often traditionally distinguished: assessment of educational activity, scientific activity, international activity, financial activity, graduates' employment as an assessment of their qualification level, and existing university infrastructure.

However, the indicated list of indicators could be better. Due to the heterogeneity of international, scientific, and educational activities in various fields of knowledge, it is challenging to adequately evaluate universities that provide educational services in various fields. The author offers an improved list of indicators less dependent on this factor in this article.

Problem statement

Let $A = \{a_1, ..., a_n\}$ are higher education institutions, the competitiveness of which needs to be monitored. Each institution of higher education has been fully functioning for at least ten years. Accordingly, information on various aspects of activity, educational, scientific, financial, international, etc., has been preserved about the activities of such a higher education institution. Each pair of institutions of higher education (a_i, a_j), $i \neq j$, $i = \overline{1, n}$, $j = \overline{1, n}$ are competitors. Institutions of higher education compete if they offer similar programs of study and have similar academic resources. In addition to higher education institutions, competitors can be technical schools, training centers, and centers for advanced training, especially in information technology. Competition between higher education institutions can improve the quality of education and increase student choice. Still, it also challenges each institution of higher education to create an attractive learning experience and provide high-quality education and services for its students.

The task is to monitor the competitiveness of each institution of higher education a_i, $i = \overline{1, n}$, which takes into account the activities of competitors and is based on

the analysis of open performance indicators that do not depend on the main direction of the universities.

Data, terminology and methodology

Monitoring is a process of systematic observation, control, and data collection about particular objects, phenomena, or processes. The primary purpose of monitoring is to obtain up-to-date information about the state of the object or phenomenon to make informed decisions, detect anomalies in time, respond to them, and improve the control process.

The competitiveness of a higher education institution is the ability of a higher education institution to compete effectively in the market of educational services and gain a particular market share or increase its position relative to other players in this field, that is, other higher education institutions. Competitiveness is an essential factor for the successful operation of a higher education institution. The competitiveness of a higher education institution is essential for attracting students, ensuring their high-quality education, and preparing them for a successful career.

To organize monitoring of the competitiveness of a higher education institution, it is necessary to collect data on various types of activity of a higher education institution during a specific period and save them for processing. Data should be open, verifiable, transparent, and easy to verify. They should be free from the influence of the subjective factor. This is important to ensure an unbiased assessment of the activities.

The model for monitoring a higher education institution's competitiveness includes several steps and components that help analyze and evaluate the institution's effectiveness in competitive conditions. Here is the general model for monitoring the competitiveness of HEIs:

1. Determination of key performance indicators. These indicators include academic quality, reputation, foreign partnerships, number and quality of students, financial sustainability, etc.

2. Data collection. After collecting a list of key indicators, develop a data collection system for these indicators. This may include analysis of existing data, student surveys, alum surveys, financial statements, etc.

3. Data analysis and evaluation. After the data has been collected, it is necessary to conduct an analysis and evaluation to find out how the institution of higher education compares to its competitors. Determination of strengths and weaknesses of a universities.

4. Setting goals and strategies. Based on the analysis results, setting goals and developing strategies to improve competitiveness is necessary. These goals and strategies should be specific, measurable.

5. Implementation of measures. Implementation of strategies aimed at improving competitiveness. This may include modernization of programs, improvement

of the quality of education, development of marketing campaigns, improvement of financial stability, etc.

6. Monitoring and evaluation of results. Constantly monitor the impact of strategies on the institution's competitiveness. Use the metrics to determine whether you have achieved your goals and adjust your actions accordingly.

7. Reporting and communication. Reporting to stakeholders such as administration, faculty, students, parents, financial sponsors, etc.

8. Adaptation and improvement. Based on the obtained results, it is necessary to make adjustments in the strategy and activities to maintain or improve the competitiveness of the higher education institution.

Parameters of the competitiveness of higher education institutions

Aspects that a higher education institution should take into account to ensure competitiveness:

1. Academic quality. Ensuring high-quality education is the most critical aspect of competitiveness. This includes the quality of educational programs, the qualifications of teachers, research activities, and access to relevant educational resources and technologies.

2. Accessibility and financial availability. An institution of higher education should be accessible to various groups of students, including those with limited financial means. The availability of scholarships, financial support programs and flexibility in payment options can increase competitiveness.

3. Variety of programs. Providing various study programs and majors helps attract students with diverse interests and career goals.

4. International cooperation. A higher education institution can increase competitiveness by cooperating with other universities and taking educational programs abroad.

5. Infrastructure and technical support. Modernization of the campus, access to modern technologies, library resources and research laboratories help to increase competitiveness.

6. Career support. A higher education institution can provide career counseling services, internships and work with employers to prepare students for the labor market.

7. Involvement of students and the community. Active participation of students in various aspects of university life and cooperation with the community can increase the attractiveness of a higher education institution.

8. Reputation and ratings. A higher education institution can increase its competitiveness by gaining a good reputation and high places in world university rankings.

These aspects can be included in the following parameters:

1. Scientific research and practical development. It includes the research work of the employees of the institution of higher education, the scientific and technical implementation of the results of this work, the presence of scientific schools, etc.

2. Sustainability in the educational services market. It includes the quality of performance of the educational part of the work, the results of recruitment of new students, employment of graduates, etc.

3. Adaptability to changes. Availability of new programs, frequency of revision of educational programs, availability of elective courses in programs, modernization of study facilities and campus, research laboratories, etc.

4. Participation in alliances, projects, and clusters. Cooperation with other universities, including abroad, within joint projects, inclusion in university clusters in certain areas, etc.

5. The level of competence of scientific and pedagogical staff. Level of knowledge, certifications, indexes of scientific indicators of employees.

6. Assessment of financial status. It includes the university's financial capacity for development and financial accessibility, i.e., providing the opportunity to study for students of different groups, etc.

Thus, if a discrete time is given $\left(t_1, t_2, \ldots, t_T\right)$ for assessing competitiveness, a tuple can be formed:

$$O_j\left(a_i\right) = \left\langle S_i^j, Q_i^j, C_i^j, M_i^j, K_i^j, F_i^j \right\rangle, \ i = \overline{1, n}, \ t = \overline{1, T},$$

– $O_j\left(a_i\right)$ is a tuple with evaluations according to six parameters, which is defined for a higher education institution (HEI) a_i at a time moment t_j;

– S_i^j is an assessment of research work of employees of HEI a_i at a time moment t_j;

– Q_i^j is an assessment of the flow rate of HEI a_i at a time moment t_j in the educational services market;

– C_i^j is an assessment of the adaptability to changes of HEI a_i at a time moment t_j;

– M_i^j is an assessment of HEI a_i cooperation a_i at a time moment t_j with other universities, including abroad within joint projects, etc.;

– K_i^j is an assessment of the level of competence of scientific and pedagogical staff of HEI a_i at a time moment t_j;

– F_i^j is an assessment of the financial stability and financial condition of HEI a_i at a time moment t_j.

One of the methods that can help assess the competitiveness of higher education institutions is the

data coverage analysis (DEA) method. However, the application of this method to this problem has yet to be studied. In addition, the interpretation of DEA results, considering the modifications of the optimization task of assessing the competitiveness of higher education institutions, remains unexplored. Since the analysis of competitiveness consists of comparing the evaluations of different institutions of higher education on different criteria, the DEA method, which is a method of comparative analysis, should be well suited to this task. The main issues of constructing the DEA method are described in works [17, 18].

Let the set be given $D = \{D_1, D_2, ..., D_w\}$, where D_j, $j = \overline{1, w}$ are decision making units. Each decision making unit uses L_1 inputs x_r^j, $r = \overline{1, L_1}$ and generates L_2 outputs y_k^j, $k = \overline{1, L_2}$. Output y_k^j corresponds to price U_k^j, input x_r^j corresponds to price V_r^j, then:

$$\theta^j = \frac{\sum_{k=1}^{L_2} y_k^j U_k^j}{\sum_{r=1}^{L_1} x_r^j V_r^j},$$

where θ^j is a ratio of weighted inputs and outputs for each D_j, $j = \overline{1, w}$.

If the input and output prices are unknown, then a nonlinear programming problem needs to be solved:

$$\theta^j = \frac{\sum_{k=1}^{L_2} y_k^j U_k^j}{\sum_{r=1}^{L_1} x_r^j V_r^j} \to \max,$$

$$\sum_{k=1}^{L_2} y_k^j U_k^j \le \sum_{r=1}^{L_1} x_r^j V_r^j, \quad j = \overline{1, w},$$

$$U_k^j \ge E, \quad V_r^j \ge E, \quad E \ge 0, \quad r = \overline{1, L_1}, \quad k = \overline{1, L_2}.$$

This problem is reduced to a linear programming problem for a fixed j based on the substitution of variables: $s_k = tU_k$, $b_k = tV_r$, $t = \left(\sum_{r=1}^{L_1} x_r^j V_r^j \right)^{-1}$.

Then: $\theta^j = \sum_{k=1}^{L_2} y_k^j s_k \to \max$,

$$\sum_{r=1}^{L_1} x_r^j b_r = 1, \quad \sum_{k=1}^{L_2} y_k^j s_k \le \sum_{r=1}^{L_1} x_r^j b_r, \quad j = \overline{1, w},$$

$$s_k \ge E, \quad b_r \ge E, \quad E \ge 0, \quad r = \overline{1, L_1}, \quad k = \overline{1, L_2}.$$

To apply the DEA method, it is necessary to determine the input and output parameters for each of the competitiveness assessments described above. Implementing the model and calculating grades for higher education institutions is also necessary. Estimates of the specified six parameters for ten higher education institutions from the People's Republic of China have been collected. The data is entered into a database that is updated monthly. In this way, a time series of competitiveness assessments are formed. These estimates will be used to build a monitoring system.

Conclusions

1. The work forms six parameters of a higher education institution's competitiveness. They differ from the classical vision in that they do not depend on the direction of the university. In general, according to the proposed parameters, it is possible to compare classical higher education institutions and specialized ones, for example, technical, humanitarian, etc.

2. It was determined that to analyze competitiveness, it is necessary to use methods based on pairwise comparison. Since the methods of assessing these parameters are different, one of the methods that can be suitable for assessing competitiveness is the DEA method. It was found that the interpretation of DEA results, considering the modifications of the optimization task of assessing the competitiveness of higher education institutions, remains unexplored.

In the future, it is planned to develop this topic to build a system for monitoring the competitiveness of higher education institutions, in particular in the People's Republic of China.

References

1. Liu, Y. R. (2018). Innovation and practical exploration of teaching reform of continuing education guided by social competitiveness – Taking the practice of overseas Chinese higher education institutions as the research object. *Continuing Education,* 3, 7-10. https://doi.org/ 10.13981/j.cnki.cn11-3315/g4.2018.03.002.

2. Kang, K. & Gao, X. J. (2019). The Core of the Construction of Advanced Higher Education System in China: *Improving the Competitiveness of Higher Education. Journal of Adolescent Health*, 7, 8-13.

3. Kuchansky, A., Biloshchytskyi, A., Andrashko, Y., Biloshchytska, S. & Faizullin, A. (2022). The Scientific Productivity of Collective Subjects Based on the Time-Weighted PageRank Method with Citation Intensity. *Publications,* 10(4), 40, 1–17.

4. Andrashko, Y., Kuchanskyi, O., Biloshchytskyi, A., Pohoriliak, O., Gladka, M., Slyvka-Tylyshchak, G., Khlaponin, D. & Chychkan, I. (2023). A method for assessing the productivity trends of collective scientific subjects based on the modified PageRank algorithm. *Eastern-European Journal of Enterprise Technologies,* 1(4 (121), 41–47.

5. Biloshchytskyi, A., Biloshchytska, S., Kuchansky, A., Andrashko, Y., Toxanov, S. & Faizullin, A. (2022). Information-analytical system for evaluating the scientific performance of structural units of universities and research institutes based on the approach of constructing complex integral evaluation. *Scientific Journal of Astana IT University*, 11, 87–117.

6. Biloshchytskyi, A., Andrashko, Y., Kuchansky, A., Faizullin, A. & Toxanov, S. (2022). Model of multi-criteria selection of scientists and higher education institutions for the scientific organization. *Scientific Bulletin of Uzhhorod University. Series of Mathematics and Informatics,* 41(2), 7–15 (in Ukr.).

7. Biloshchytskyi, A., Kuchansky, A., Andrashko, Y. & Wang, Y. (2022). Devising a competence method to build information spaces for executors of educational projects in a dynamic environment. *Eastern-European Journal of Enterprise Technologies,* 1(3(115)), 66–73.

8. Raman, A. (2019). Potentials of fog computing in higher education. *International Journal of Emerging Technologies in Learning,* 14(18), 194-202. https://doi.org/10.3991/ijet.v14 i18.10765

9. Liu, N. N. (2017). A Study on the Competitiveness and Coordinated Development of the Provincial Graduate Education in China. *Modern Education Management,* 9, 102-107. https://doi.org/10.16697/j.cnki.xdjygl.2017.09.019.

10. Zhou, C. T. (2019). Research and Practice on the core competitiveness of Local Universities under the background of education internationalization. *Policy Research & Exploration,* 5, 52-53. https://doi.org/ 10.16324/j.cnki.jcts.2019.05.039.

11. Wen, X., Hu, Y. X. & Yin, Y. N. (2019). Individualized Evaluation and Promotion Strategy of Regional Higher Education Competitiveness. *Modern Education Management,* 12, 30-35. https://doi.org/10.16697/j.cnki.xdjygl.2019.12.005.

12. Dugarova, D., Kimova, S. & Kalinina, L. (2015). Educational Audit as an Imperative of Higher Education Program Competitiveness in the Trans-Border Region. *Procedia – Social and Behavioral Sciences*, 214, 192–200. https://doi.org/10.1016/j.sbspro.2015.11.661.

13. Nicole, C. J. (2019). Managing for competency with innovation change in higher education: Examining the pitfalls and pivots of digital transformation. *Business Horizons,* 62(6), 761- 772. https://doi.org/10.1016/j.bushor.2019.08.002.

14. Wang, S. & Fang, Y. (2012). Higher Education Competitiveness: Model, Index and International Comparison. *Educational Research,* 7, 122-129.

15. Plewa, C., Ho, J., Conduit, J. & Karpen, I.O. (2016). Reputation in higher education: A fuzzy set analysis of resource configurations. *Journal of Business Research,* 69(8), 3087-3095. https://doi.org/10.1016/j.jbusres.2016.01.024.

16. Lin, L. (2020). An Evaluation System and Its Model for Educational Competitiveness of Universities. *iJET*, 15(11), 188-201. https://doi.org/10.3991/ijet.v15i11.14521

17. Cooper, W. W., Li, S., Seiford, L. M., Tone. K., Thrall, R. M., & Zhu, J. (2001). Sensitivity and stability analysis in DEA: some recent developments. *Journal of productivity analysis*, 15(3), 217–246.

18. Charnes, A., Cooper, W. W. & Rhodes, E. L. (1978). Measuring the efficiency of decision making units. *European journal of operational research,* 2(6), 429–444.

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ПАРАМЕТРИ МОНІТОРИНГУ КОНКУРЕНТОСПРОМОЖНОСТІ ЗАКЛАДІВ ВИЩОЇ ОСВІТИ

Анотація. В роботі сформовано шість ключових параметрів конкурентоспроможності закладу вищої освіти: наукові дослідження та практична розробка; стійкість на освітньому ринку послуг; адаптивність до змін; співпраця та участь у альянсах, проєктах, кластерах; рівень компетентності науково-педагогічних співробітників. Оцінка фінансового стану закладу вищої освіти включає як фінансові можливості університету для розвитку, так і фінансову доступність, тобто забезпечення можливості навчання студентам різних груп, інклюзивна освіта тощо. Сформований перелік відрізняється від традиційного тим, що дає змогу врахувати в оцінці як класичні, так і спеціалізовані заклади вищої освіти незалежно від напряму діяльності. Визначено, що для аналізу конкурентоспроможності потрібно використовувати методи, які засновані на попартному порівнянні. Оскільки методики оцінювання цих параметрів різні, то одним з методів, що може підійти для оцінювання конкурентоспроможності, є метод DEA. Встановлено, що невивченими залишаються питання інтерпретації результатів DEA, враховуючи модифікації оптимізаційної задачі оцінки конкурентоспроможності закладів вищої освіти. Вказано, що для застосування моделі потрібно зібрати вхідні та вихідні параметри й інтерпретувати отримані результати. Для побудови системи моніторингу конкурентоспроможності закладу вищої освіти потрібно зібрати дані про різні види активності закладу вищої освіти протягом деякого періоду часу і зберегти їх для опрацювання. Дані мають бути відкриті, верифіковані та прозорі, їх має бути легко перевірити. Вони мають бути позбавлені впливу суб'єктивного фактору. Це важливо, щоб забезпечити неупереджену оцінку діяльності закладу вищої освіти. Отримані результати мають значення для розробників систем оцінювання і моніторингу конкурентоспроможності закладів вищої освіти.

Ключові слова: моніторинг; заклад вищої освіти; конкурентоспроможність; метод аналізу охоплення даних

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