PUBLISHER
**University of Belgrade – Faculty of Organizational Sciences**
Jove Ilića 154, Belgrade, Serbia
www.fon.bg.ac.rs

DEAN OF FACULTY OF ORGANIZATIONAL SCIENCES
**Milan Martić, Ph.D.**

DESIGNED BY
**Minja Marinović**

PRINTING
**NEWPRESS, Smederevo**

**ISBN: 978-86-7680-464-1**
**Tiraž: 50**

YEAR
**2024**

CONFERENCE ORGANIZER
**University of Belgrade – Faculty of Organizational Sciences**

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

005(082)(0.034.2)
004.738.5(082)(0.034.2)
007:004(082)(0.034.2)
330.341.1(082)(0.034.2)

**INTERNATIONAL symposium SymOrg 2024 (19 ; 2024 ; Zlatibor)**
Unlocking the hidden potentials of organization through merging of humans and digitals [Elektronski izvor] : symposium proceedings / XIX International symposium SymOrg 2024, Zlatibor, June 12-15, 2024 (hybrid) ; [conference organizer University of Belgrade, Faculty of Organizational Sciences] ; editors Milica Kostić-Stanković, Ivana Mijatović, Jovan Krivokapić. - Belgrade : University, Faculty of Organizational Sciences, 2024 (Smederevo : Newpress). - 1 elektronski optički disk (CD-ROM) : tekst, slika ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovnog ekrana. - Tiraž 50. - Bibliografija uz svaki rad.

ISBN 978-86-7680-464-1

1. Kostić-Stanković, Milica, 1971- [уредник] 2. Mijatović, Ivana, 1968- [уредник] 3. Krivokapić, Jovan, 1984- [уредник]
а) Менаџмент -- Зборници б) Информациони системи -- Зборници в) Информациона технологија -- Зборници г) Привредни развој -- Зборници

COBISS.SR-ID 148644617

# SENSITIVITY ANALYSIS OF THE ARWU RANKING: EFFECTS OF INDICATOR REMOVAL

Aleksandar Antić*[1], Milica Maričić[1], Veljko Jeremić[1]
[1]University of Belgrade – Faculty of Organizational Sciences, Jove Ilica 154, Belgrade, Serbia
*Corresponding author, e-mail: aleksandaran2001@gmail.com

***Abstract:*** *University rankings play a crucial role in shaping the perceptions of academic institutions and influencing decisions made by stakeholders. The Academic Ranking of World Universities (ARWU), known as the Shanghai Ranking, is one of the most influential global university rankings currently published. Due to that, the methodology behind this ranking often comes under scrutiny. Two methodological steps of the ARWU ranking that attract researchers' attention are the weighting scheme and indicator selection process. In this paper, we conduct a sensitivity analysis of the ARWU ranking by systematically removing individual indicators and distributing their weight to the remaining indicators. Our results show that the ranking is sensitive to the removal of the indicator related to the number of staff of an institution winning Nobel Prizes and Fields Medals (Award). At the same time, removing the indicator related to the institution's per capita academic performance (PCP) led to slight or no changes in the ranks.*

***Keywords****: University rankings, ARWU, weighting scheme, indicator selection process, sensitivity analysis*

## 1. INTRODUCTION

It is inherent in human nature to rank and be ranked (Marginson & Van der Wende, 2007). Therefore, rankings in fields such as sustainability, well-being, safety, and ease of doing business were created to rank institutions, cities, regions, and countries. One specific group of rankings which intrigues different stakeholders are the university rankings (Anowar et al., 2015). University rankings evaluate and rank higher education institutions based on various quantitative and qualitative criteria. University rankings offer a lens through which institutions and stakeholders can assess academic quality and reputation.

When it comes to university rankings, four main stakeholder groups can be identified (Goglio, 2016). The first group of stakeholders comprises students and their families, who often rely on university rankings as a criterion when selecting their academic pursuits. The reputation of a university is indisputably a crucial factor in making decisions about joining the academic community, and ranking lists certainly contribute to this reputation (Wut et al., 2022). The second stakeholder group involves universities, where top executives like vice chancellors and presidents are the main users of university rankings. These institutions anticipate advantages such as improved prestige, heightened student interest, and increased financial support, especially if they achieve high rankings. Universities also receive rankings as tools for self-assessment and improvement, allowing them to identify strengths and weaknesses. The problem that can arise when universities strive to position themselves higher on certain lists and achieve better rankings is that they may focus primarily on publishing research papers and engaging in external activities, neglecting the quality of teaching and student interaction in the process (Shin & Toutkoushian, 2011). The governmental sector constitutes the third stakeholder group. Governments derive benefits from university rankings through benchmarking for international comparisons and informed policy-making. Similar to universities, governments prioritise institutional autonomy and the use of reliable and transparent data rankings. Additionally, they consider broader university outcomes beyond research, such as graduate employability and technology transfer (Goglio, 2016). The fourth group of stakeholders includes ranking providers, such as companies or research centres, who are heavily invested in this domain. They benefit from the popularity and success of their rankings regarding business growth and revenue. However, they also prioritise maintaining independence and ensuring the transparency and reliability of their data to uphold their reputation. Recently, there has been increasing concern regarding the potential threat to institutions that create and publish rankings due to the varying nature of the relationship between them and the companies collecting, providing and analysing data for them (Chen & Chan, 2021). While dominant ranking providers currently set the standards, there is a need for critical oversight to address methodological shortcomings and misleading information. A large number of institutions developed methodologies for global university

rankings. In terms of relevance and public interest, three methodologies stand out: Academic Ranking of World Universities (ARWU), The Times Higher Education (THE) World University Rankings, and the QS World University Rankings (Johnes, 2018).

The ranking methodology we scrutinise in this paper is the ARWU ranking. In addition to ranking a large number of renowned universities, its popularity stems from being the first global methodology for ranking world universities. The ARWU ranking is calculated as the weighted sum of six indicators, taking into account the quality of education, quality of faculty, research output, and per capita performance. Besides attracting the attention of students, academia, and policy-makers, the ARWU ranking is captivating the attention of experts in the field of ranking. So far, numerous studies were written on the topic of ARWU methodology scrutinisation. The mentioned criticisms are fundamentally rooted in issues that generally arise with all composite indices (Greco et al., 2018), however, issues related to the weighting scheme and indicator selection are the ones which attract the most attention (Jeremic et al., 2011). One key problem is how the ARWU ranking (or any composite indicator) is calculated. The question arises about the transparency and comprehensibility of the methodology, which can impact its credibility. Additionally, since university rankings describe complex phenomena, it is important to appropriately select sub-indicators and determine their weighting coefficients. The weighting scheme should reflect the significance of each indicator within the ranking but approaches to its determination can often be subjective (Greco et al., 2018). The current AWRU methodological appendix does not provide any detail on the weighting scheme determination approach or the indicator selection process (ShanghaiRanking, 2024).

The analysis conducted in this paper focuses on the examination of the stability of ARWU rankings. The ARWU methodology should be insensitive to weight coefficient changes to ensure the rankings' reliability and credibility. Therefore, we strived to explore will and how the rankings change if an indicator is removed from the ranking and its weight distrubited among the remaining indicators. After the introduction, we outline the ARWU ranking methodology and its criticism. Next, we describe the research methodology and the sensitivity analysis that was conducted. In section four, we present the research results, while we finish the paper with the discussion and concluding remarks.

## 2. SHANGHAI RANKING'S ACADEMIC RANKING OF WORLD UNIVERSITIES (ARWU)

The Academic Ranking of World Universities, known as ShanghaiRanking or ARWU ranking, represents a ranking or a composite indicator developed by researchers at Shanghai Jiao Tong University. The first edition of the ARWU ranking was published in 2003, and since then, it has captured and attracted the attention of students, researchers, academics, and policymakers. Another proof is that despite more or less similar methodologies published, the ARWU Ranking remains among the most relevant. At first, the institution published just one ranking, the Academic Ranking of World Universities. In the years that came, they extended the scope and are currently providing four rankings: Academic Ranking of World Universities, Best Chinese Universities Ranking, Global Ranking of Sport Science Schools and Departments, and Global ranking of Academic subjects (ShanghaiRanking, 2024). As this paper focuses on ARWU ranking, we outline the structure and methodology in the following paragraphs.

For the year 2023, for which the data was collected, the ARWU ranked more than 2500 universities and the results for the best 1000 were published. Within its ranking, ARWU considers universities with notable achievements, such as Nobel Laureates, Fields Medalists, Highly Cited Researchers, and papers published in prestigious journals like Nature & Science. Additionally, institutions with a significant number of papers indexed by major citation databases are also included. Data for the ranking is sourced from reputable institutions and organisations, including Nobel Prize records, the Web of Science database, and national or regional agencies providing staff data (ShanghaiRanking, 2024).

The Shanghai Ranking (ARWU) evaluates academic performance using six criteria to provide a comprehensive assessment. Each criterion is assigned a benchmark score of 100 based on the best-performing university in that category. Universities are ranked according to their overall score, which is a weighted sum of their performance across these categories. The criteria include measures *Alumni* and *Award*, which track the number of Nobel prizes and Field medals awarded to a university's alumni or faculty members. The next there indicators (*HiCi, N&S,* and *PUB*) gauge research output, observing the number of highly cited researchers, publications in top journals (Nature and Science), and the number of articles published in the Science Citation Index Expanded and the Social Science Citation Index journals. The final indicator, *PCP*, calculates a weighted average of scores from the previous categories, divided by the number of full-time academic staff members. Each indicator contributes to the overall score according to the predefined weight (Jeremic et al., 2011). *Award*, *HiCi*, *N&S*, and *PUB* are weighted by 20%, while *Alumni* and *PCP* have slightly less importance with the weight of 10% (ShanghaiRanking, 2024).

## 2.1. Methodological issues with the ARWU ranking

Although the ARWU ranking is reputable and often cited in the media, its methodology has been criticised in the academic literature. Within this section, we provide a literature review of the papers which tackled the ARWU methodology, especially its weighting scheme. Maricic and co-authors (2017), in their study on the ARWU ranking, provide a useful timeline of research on the ARWU methodology. The first study they identified was the paper by Florian (2007), who pointed out that the results of the ARWU ranking were irreproducible and that reproduction attempts did not lead to the same results as official. Several years later, Jeremic and co-authors (2012) applied the I-distance to the ARWU ranking indicators to propose an alternative ranking and data-driven indicator weights. In their paper, Dobrota and Dobrota (2016) strived to assess the rank sensitivity of ARWU and proposed an alternative ARWU ranking using the Composite I-distance Indicator (CIDI). They concluded that the ARWU ranking is more sensitive to weight alterations than the alternative ranking. Maricic and co-authors (2019) applied the Hybrid Enhanced Scatter Search—Composite I-Distance Indicator (eSS-CIDI) methodology to the ARWU ranking. Their results showed that the weighting scheme of the ARWU ranking can be altered while improving the stability of the metric. Recently, Safon and Docampo (2020) considered the impact of reputation bias on the ARWU ranking and showed that bias exists in *N&S* but not in *HiCi*. Fernández-Cano and associates (2018) did a comprehensive literature review on the ARWU methodological issues and grouped them into the following segments: Omitted indicators, Supposed validity of the indicators used, Anomalous reliability, Questionable weighting of indicators, Confusing indicators, Over-emphasized citation indicator, Simplistic standardisation, as well as Selection bias or sample threat.

In conclusion, research on the ARWU ranking methodology has been ongoing throughout the years, with studies highlighting its issues with irreproducibility, sensitivity to weight alterations, and the impact of reputation bias. Various alternative approaches have been proposed, showing potential for improving the stability and accuracy of the ranking, signalling the ongoing need for critical evaluation and refinement in this domain.

## 3. RESEARCH METHODOLOGY

The JRC handbook on composite indicator creation states that there is no straightforward answer to the composite indicator methodology and that each of the ten methodological steps can be done by taking different approaches (Joint Research Centre, 2005). Therefore, the methodological frameworks of composite indicators are very often the subject of debate and discussion, as there is a whole series of choices to be made during their formation (Saltelli et al., 2007). Accordingly, it is necessary to determine the level of confidence in the formed methodological framework, representativeness and stability. The reliability of a composite indicator is measured through the analysis of the effects of changes in the methodological framework on the final ranks (Maricic et al., 2019). Regarding robustness analysis, uncertainty and sensitivity analysis are the most commonly applied (Paruolo et al., 2013). The uncertainty analysis includes the assessment of the impact of alternative methodological frameworks of the composite indicator on the ranking of the entity. Each alternative methodological framework is, in fact, a different composite indicator in which some of the methodological steps are changed within the defined scope and range (Dobrota, 2015). The uncertainty analysis can be done for just one methodological step (Dobrota et al., 2016) or several steps simultaneously (Cherchye et al., 2008). On the other hand, sensitivity analysis looks at how the uncertainty in the input factors affects the uncertainty in the output factors of the model (Saltelli et al., 2007).

The research methodology we employed in this paper is as follows. We wanted to explore whether and how ARWU university rankings change if an indicator is removed from the ranking methodology while the associated weight is distributed among the remaining indicators. For example, if the indicator *Awards* is removed from the ranking, its weight of 10% will be evenly distributed among the five remaining indicators. The precise distribution of weights for each run iteration is presented in Table 1. Within each iteration, new ARWU values and ranks were calculated. Spearman's correlation between the new and official ranks was calculated to assess the effects of indicator removal.

**Table 1:** Weights assigned to ARWU indicators within each iteration

| | Weight assigned to a particular indicator | | | | | |
|---|---|---|---|---|---|---|
| **Iteration** | **Alumni** | **Award** | **HiCi** | **N&S** | **PUB** | **PCP** |
| **Sin Alumni** | 0 | 0.22 | 0.22 | 0.22 | 0.22 | 0.12 |
| **Sin Award** | 0.14 | 0 | 0.24 | 0.24 | 0.24 | 0.14 |
| **Sin HiCi** | 0.14 | 0.24 | 0 | 0.24 | 0.24 | 0.14 |
| **Sin N&S** | 0.14 | 0.24 | 0.24 | 0 | 0.24 | 0.14 |
| **Sin PUB** | 0.14 | 0.24 | 0.24 | 0.24 | 0 | 0.14 |
| **Sin PCP** | 0.12 | 0.22 | 0.22 | 0.22 | 0.22 | 0 |

## 4. RESULTS

The approach presented in the section above was repeated six times for each ARWU indicator removal. We observed the top 100 universities ranked by ARWU for the year 2023. After each iteration, we calculated the new ARWU values and ranking and compared them with the official ARWU results. In Table 2, we present the top 10 universities on the original ARWU list and the rankings of these universities when individual indicators are removed. The label "Sin" in the column name indicates that the ranking shown in that column is calculated without that specific indicator, which was assigned a weight coefficient of 0, and its original weight is evenly distributed among the other indicators.

**Table 2:** Ranks for top 10 universities – original ranks and ranks after each indicator removal iteration

| University | ARWU rank | Sin Alumni | Sin Award | Sin HiCi | Sin N&S | Sin PUB | Sin PCP |
|---|---|---|---|---|---|---|---|
| Harvard University | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Stanford University | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Massachusetts Institute of Technology | 3 | 3 | 3 | 4 | 4 | 3 | 4 |
| University of Cambridge | 4 | 4 | 4 | 3 | 3 | 4 | 3 |
| University of California, Berkeley | 5 | 5 | 5 | 6 | 5 | 5 | 5 |
| Princeton University | 6 | 7 | 12 | 5 | 6 | 6 | 7 |
| University of Oxford | 7 | 6 | 6 | 8 | 7 | 8 | 6 |
| Columbia University | 8 | 9 | 7 | 10 | 9 | 10 | 8 |
| California Institute of Technology | 9 | 8 | 8 | 7 | 10 | 7 | 13 |
| University of Chicago | 10 | 10 | 19 | 9 | 8 | 9 | 9 |

The same university occupied the first position on the original list and throughout six iterations: Harvard University. This university's performance can also represent an outlier as the indicator values of Harvard University are much higher than those of the next best university. The second-ranked university, Stanford University, was also stable in all six iterations. Looking down the list, the largest change compared to the original rank is observed in the case of the University of Chicago, whose rank drops to nineteenth place when the indicator *Award* is removed, compared to its original 10$^{th}$ place on the list. This occurred because this university has a high value for *Award* indicator, while it has considerably lower values for other indicators than the neighbouring universities on the original ranking list. Similarly, a visible change in rank is observed for Princeton University (from the original 6$^{th}$ to 12$^{th}$ without the Award criterion).

We encounter a similar situation in the table below (Table 3) where we present the bottom 10 universities on the original ARWU list and the rankings of these universities when individual indicators are removed. However, we can notice that the oscillations are visibly larger, and the rankings of all ten universities differ after each iteration. The reasons for rank change are similar to those for the top ten, but we can conclude that the sensitivity is more pronounced. This is expected as the bottom ranked entities are more sensitive to methodological changes (Saisana et al., 2011). The values of individual indicators (criteria) in this part of the list vary among universities, which can be considered the cause of the mentioned oscillations. The largest change in rank is observed for McMaster University when the indicator *PUB* is removed. This university moved from its original last position to within the top 80 universities on the list. We can also see a big rank improvement for Stockholm University, which moved from rank 98 to 74 when the indicator *PUB* is excluded.

**Table 3:** Ranks for bottom 10 universities – original ranks and ranks after each indicator removal iteration

| University | ARWU rank | Sin Alumni | Sin Award | Sin HiCi | Sin N&S | Sin PUB | Sin PCP |
|---|---|---|---|---|---|---|---|
| University of Alberta | 91 | 90 | 91 | 86 | 82 | 91 | 85 |
| Huazhong University of Science and Technology | 92 | 81 | 69 | 89 | 87 | 99 | 81 |
| Nanyang Technological University | 93 | 82 | 68 | 100 | 90 | 88 | 95 |
| Seoul National University | 94 | 95 | 67 | 82 | 94 | 96 | 86 |
| Central South University | 95 | 87 | 73 | 98 | 80 | 100 | 94 |
| Nanjing University | 96 | 86 | 72 | 93 | 100 | 97 | 97 |
| Purdue University - West Lafayette | 97 | 96 | 98 | 84 | 96 | 86 | 91 |
| Stockholm University | 98 | 99 | 99 | 79 | 97 | 74 | 96 |
| Brown University | 99 | 100 | 94 | 76 | 93 | 78 | 99 |
| McMaster University | 100 | 97 | 95 | 96 | 81 | 79 | 98 |

Another way to analyse the effect of indicator removal is to calculate the correlations between official and newly obtained ranks. In Table 4, we provide the values of Spearman's correlation coefficient between ranks after each iteration and the official ARWU ranks.

**Table 4:** Correlation analysis between official ranks and ranks after each iteration

| | Sin Alumni | Sin Award | Sin HiCi | Sin N&S | Sin PCP | Sin PUB | ARWU |
|---|---|---|---|---|---|---|---|
| **Sin Alumni** | 1 | | | | | | |
| **Sin Award** | 0.896** | 1 | | | | | |
| **Sin HiCi** | 0.878** | 0.738** | 1 | | | | |
| **Sin N&S** | 0.924** | 0.835** | 0.929** | 1 | | | |
| **Sin PCP** | 0.951** | 0.866** | 0.946** | 0.968** | 1 | | |
| **Sin PUB** | 0.818** | 0.636** | 0.911** | 0.848** | 0.855** | 1 | |
| **ARWU** | 0.967** | 0.866** | 0.951** | 0.970** | 0.989** | 0.888** | 1 |

Note: **p<0.001

The table indicates that all obtained coefficients are positive, statistically significant, and above 0.83. Looking at the correlation between official ARWU ranks and alternative ranks, it can be noted that the smallest correlation is observed between the original rankings and those calculated without the *Award* indicator, 0.866. This might indicate that the ranking is highly dependent on the *Award* indicator. On the other hand, the highest correlation is measured between the original rankings and those calculated without the *PCP* indicator, 0.989. According to our analysis, removing this indicator would not significantly change or distort the rankings.

## 5. DISCUSSION AND CONCLUSION

The ARWU methodology has been extensively analysed and criticised since its first publication in 2003. Analyses and critiques can serve as assistance in refining the methodology and enabling more objective ranking. The aim of this paper was to closely observe how the university rankings change if an ARWU indicator is removed from the methodological framework.

The analysis showed that the rankings (especially the top-ranked universities) depend marginally on the chosen weights and indicators. Rolland and Cugliari (2019) came to the same conclusion by employing Ranking Sensitivity Index (RSI) analysis. However, more rank distortions can be seen in the lower part of the ranking, which can be expected (Saisana et al., 2011). The measured Spearmans' correlation coefficient between the official ARWU and alternative rankings indicated that removing the indicator *Award* leads to the largest rank changes. Previous studies signalled that if the indicator *Award* is removed, the ranking becomes more stable (Dobrota & Dobrota, 2016). Besides observing the impact of the indicator *Award* on the rankings, the measurement aspect should also be taken into account. For example, how accessible are the awards calculated within the *Award* and *Alumni* indicators to all university staff worldwide, are there certain barriers for university staff and alumni to receive them, do the received awards belong to the universities the winner completed or to the university the winner is affiliated to (Zornic et al., 2014).

Future directions of the study could be defined. First, the number of observed universities can be enlarged, having in mind that the ARWU ranking provides ranking for 1000 institutions. Such analysis would be useful, having in mind the results of a previous study which signaled that methodological differences should be implemented for different rank groups (Maricic et al., 2017). Within the presented sensitivity analysis only two methodological aspects were taken into account. Therefore, a more comprehensive sensitivity analysis should be conducted in the future to more comprehensively encapsulate the effect of methodological changes on the ARWU rankings. Nevertheless, it is hoped that the conducted analysis could help researchers as a starting point for deeper analysis on the ARWU uncertainty and sensitivity analysis.

## REFERENCES


[1] Anowar, F., Helal, M. A., Afroj, S., Sultana, S., Sarker, F., & Mamun, K. A. (2015). A critical review on world university ranking in terms of top four ranking systems. *New trends in networking, computing, e-learning, systems sciences, and engineering*, 559-566.

[2] Chen, G., & Chan, L. (2021). University rankings and governance by metrics and algorithms. In Research handbook on university rankings (pp. 425-443). Edward Elgar Publishing.

[3] Cherchye, L., Moesen, W., Rogge, N., Van Puyenbroeck, T., Saisana, M., Saltelli, A., ... & Tarantola, S. (2008). Creating composite indicators with DEA and robustness analysis: the case of the Technology Achievement Index. *Journal of the Operational Research Society, 59*, 239-251. doi:10.1057/palgrave.jors.2602445

[4] Dobrota, M. (2005). Statistički pristup formiranju kompozitnih indikatora zasnovan na Ivanovićevom odstojanju. PhD Thesis, Univerzitet u Beogradu - Fakultet organizacionih nauka.
[5] Dobrota, M., & Dobrota, M. (2016). ARWU ranking uncertainty and sensitivity: What if the award factor was excluded?. *Journal of the Association for Information Science and Technology, 67*(2), 480-482. doi:10.1002/asi.23527
[6] Dobrota, M., Bulajic, M., Bornmann, L., & Jeremic, V. (2016). A new approach to the QS university ranking using the composite I-distance indicator: Uncertainty and sensitivity analyses. *Journal of the Association for Information Science and Technology, 67*(1), 200-211. doi:10.1002/asi.23355
[7] Fernández-Cano, A., Curiel-Marín, E., Torralbo-Rodríguez, M., & Vallejo-Ruiz, M. (2018). Questioning the Shanghai Ranking methodology as a tool for the evaluation of universities: An integrative review. *Scientometrics, 116*, 2069-2083. doi:10.1007/s11192-018-2814-7
[8] Florian, R. V. (2007). Irreproducibility of the results of the Shanghai academic ranking of world universities. *Scientometrics, 72*(1), 25-32. doi:10.1007/s11192-007-1712-1
[9] Goglio, V. (2016). One size fits all? A different perspective on university rankings. *Journal of Higher Education Policy and Management, 38*(2), 212-226. doi:10.1080/1360080X.2016.1150553
[10] Greco, S., Ishizaka, A., Tasiou, M., & Torrisi, G. (2019). On the methodological framework of composite indices: A review of the issues of weighting, aggregation, and robustness. *Social indicators research, 141*, 61-94. doi:10.1007/s11205-017-1832-9
[11] Jeremic, V., Bulajic, M., Martic, M., & Radojicic, Z. (2011). A fresh approach to evaluating the academic ranking of world universities. *Scientometrics, 87*(3), 587-596. doi:10.1007/s11192-011-0361-6
[12] Johnes, J. (2018). University rankings: What do they really show?. *Scientometrics, 115*(1), 585-606. doi:10.1007/s11192-018-2666-1
[13] Joint Research Centre. (2008). Handbook on constructing composite indicators: methodology and user guide. OECD publishing.
[14] Jovanovic, M., Jeremic, V., Savic, G., Bulajic, M., & Martic, M. (2012). How does the normalization of data affect the ARWU ranking? *Scientometrics, 93*(2), 319–327. doi:10.1007/s11192-012-0674-0
[15] Marginson, S., & Van der Wende, M. (2007). To rank or to be ranked: The impact of global rankings in higher education. *Journal of studies in international education, 11*(3-4), 306-329. doi:10.1177/1028315307303544
[16] Maricic, M., Egea, J. A., & Jeremic, V. (2019). A hybrid enhanced Scatter Search—Composite I-Distance Indicator (eSS-CIDI) optimization approach for determining weights within composite indicators. *Social Indicators Research, 144*, 497-537. doi:10.1007/s11205-018-02056-x
[17] Maričić, M., Zornić, N., Pilčević, I., & Dačić-Pilčević, A. (2017). ARWU vs. alternative ARWU ranking: What are the consequences for lower ranked universities?. *Management: Journal of Sustainable Business and Management Solutions in Emerging Economies, 22*(1), 1-14. doi:10.7595/management.fon.2017.0002
[18] Paruolo, P., Saisana, M., & Saltelli, A. (2013). Ratings and rankings: voodoo or science?. *Journal of the Royal Statistical Society Series A: Statistics in Society, 176*(3), 609-634. doi:10.1111/j.1467-985X.2012.01059.x
[19] Pavel, Adina-Petruta (2015). Global university rankings – a comparative analysis. *Procedia Economics and Finance, 26*, 54–63. doi:10.1016/S2212-5671(15)00838-2
[20] Safón, V., & Docampo, D. (2020). Analyzing the impact of reputational bias on global university rankings based on objective research performance data: the case of the Shanghai Ranking (ARWU). *Scientometrics, 125*(3), 2199-2227. doi:10.1007/s11192-020-03722-z
[21] Saisana, M., D'Hombres, B., & Saltelli, A. (2011). Rickety numbers: Volatility of university rankings and policy implications. *Research Policy, 40*(1), 165–177. doi:10.1016/j.respo l.2010.09.003.
[22] Saltelli, A. (2007). Composite indicators between analysis and advocacy. *Social indicators research, 81*, 65-77. doi:10.1007/s11205-006-0024-9
[23] ShanghaiRanking. (2024). Shanghai Ranking Homepage. Available at: https://www.shanghairanking.com/, accessed April, 2024
[24] Shin, J. C., & Toutkoushian, R. K. (2011). The past, present, and future of university rankings. In University rankings: Theoretical basis, methodology and impacts on global higher education (pp. 1-16). Dordrecht: Springer Netherlands.
[25] Wut, T. M., Xu, J., & Lee, S. W. (2022). Does university ranking matter? Choosing a university in the digital era. *Education Sciences, 12*(4), 229. doi: 10.3390/educsci12040229
[26] Rolland, A., & Cugliari, J. (2020). Sensitivity index to measure dependence on parameters for rankings and top-k rankings. *Journal of Applied Statistics, 47*(7), 1191-1207. doi:10.1080/02664763.2019.1671963
[27] Zornic, N., Markovic, A., & Jeremic, V. (2014). How the top 500 ARWU can provide a misleading rank. *Journal of the Association for Information Science and Technology, 65*(6), 1303-1304. doi:10.1002/asi.23207