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APPLICATION OF LINEAR ORDERING METHODS TO ASSESS THE LEVEL OF INEQUALITY IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT GOAL 10 IN THE EUROPEAN UNION

Aneta MIKUŁA[1*], Małgorzata RACZKOWSKA[2]

[1] Warsaw University of Life Sciences; aneta_mikula@sggw.edu.pl, ORCID: 0000-0001-7129-6898
[2] Warsaw University of Life Sciences; malgorzata@raczkowska@sggw.edu.pl, ORCID: 0000-0002-8540-8958
* Correspondence author

Purpose: The purpose of this article is to compare the results of linear ordering conducted using various methods to assess the achievement level of the tenth sustainable development goal, i.e., reducing inequalities in European Union countries in 2022. A specific aim of the study is also to identify the technique that shows the greatest agreement with other forms of ordering.
Design/methodology/approach: In this study, three methods of linear ordering were used to assess the diversity of inequality levels in the European Union. The reference methods include Hellwig's development measure and the classical TOPSIS method. A non-reference method was also used based on the averaged values of normalized features. The synthetic variables were computed using indicators of the tenth sustainable development goal, which were applied to assess progress in goal achievement in EU countries. To assess the consistency of the obtained rankings, Kendall's rank correlation coefficients were calculated, and similarity measure vectors were computed.
Findings: The study addresses the issue of choosing a linear ordering method to determine the level of achievement of the 10th Sustainable Development Goal, which aims to reduce inequalities in the European Union countries in 2022. Based on the analysis, it can be concluded that the choice of synthetic variable construction procedure affects the ranking of the examined objects. Based on the similarity measure vectors of the rankings, it was found that the ranking constructed using the TOPSIS method with zero unitarization is the closest to all other rankings.
Research limitations/implications: The authors acknowledge that the choice of variables for the study does not fully capture the level of socio-economic inequalities in EU countries. The study used only the indicators of the 10th Sustainable Development Goal, monitored and published by Eurostat, to assess the level of inequality. Additionally, the final ordering of objects within linear ordering methods depends on the variable selection and normalization method adopted by the researchers.
Practical implications: The study's results may be useful for policymakers in the European Union countries. Using an aggregate synthetic measure to assess a multidimensional phenomenon can facilitate evaluating progress in achieving the goal. Additionally, the application of an appropriate method to identify the countries best achieving the goal provides an opportunity to identify processes contributing to success and apply them in countries with lower levels of goal achievement.

Originality/value: The study proposes the use of a multi-criteria analysis approach, which is currently considered an effective method for measuring and describing multifactor phenomena. Several methods of variable aggregation often yield different results. Therefore, it seems appropriate to compare several methods of evaluating a given phenomenon and choose the one with the greatest agreement with others. This procedure is not commonly used as a standard quantitative tool in assessing the diversity of inequality levels in EU countries.
Keywords: linear ordering, non-reference and reference methods, country ranking, inequalities, sustainable development.
Category of the paper: Research paper.

1. Introduction

Contemporary societies face many challenges, including the elimination of poverty and the reduction of social inequalities. These issues are closely linked to various global aspects such as debt, falling commodity prices, insufficient food production per capita, industrialization shortfalls, and growing economic disparities between different social strata (Utzig et al., 2023).

Poverty and social inequalities also constitute key obstacles to achieving sustainable development (SD), which aims for a lasting improvement in the quality of life for current and future generations through the appropriate balance of economic, human, and natural capital.

The Sustainable Development Goals (SDGs) are a set of seventeen global goals established in September 2015 by all member states of the United Nations (Sachs et al., 2018). Given the multifaceted nature of sustainable development, specific tasks have been defined for each goal to be achieved by 2030, totalling 169 tasks. Each of these tasks has been assigned indicators to measure progress, totalling 231 indicators. The responsibility for reporting progress rests with the governments of individual countries. This allows for systematic monitoring of progress worldwide in achieving the Goals (UN, 2015).

The European Union has developed its own set of indicators for the 2030 Agenda, tailored to the specifics of EU member states, with reporting conducted by Eurostat. This enables precise tracking of progress towards sustainable development at the European level.

It is worth noting that the diversity of indicators can help measure, monitor, and control various dimensions related to sustainable development. On the other hand, it can also make it difficult to assess overall progress towards sustainable development (Guijarro, Poyatos, 2018). A solution to this problem could be the application of a single aggregate synthetic measure. Such an integrated indicator is more accessible to interpret than a broad range of different indicators, and it also allows for country comparisons and assessment of changes over time. This is important because systematic progress monitoring in achieving sustainable development goals provides countries with significant feedback. It is believed that the key benefit of measuring and comparing international results is the ability to draw scientific conclusions from

the achievements of high-performing countries and focus on processes that have contributed to their success in improving one's level (Navarro, 2000).

Linear ordering methods are often used for evaluating multi-feature objects, enabling multidimensional comparative analysis. These methods allow for the ranking of objects from "best" to "worst" (Sompolska-Rzechuła, 2020). These methods are based on calculating a single value, called an aggregate or synthetic variable (Malina, 2004; Bąk, 2018b). There are several procedures for aggregating variables, which can be divided into non-reference and reference methods (using measures of distance from a reference point or anti-reference point). Descriptions of these procedures can be found in Kukuła, Luty (2015), Bąk (2018a), Ture, Dogan, Kocak (2019), Roszkowska, Filipowicz-Chomko (2021).

Reference methods for linear ordering are frequently used to assess the level of development of various phenomena. For example, TOPSIS has been used to assess good governance (Ardielli, 2019), economic and environmental energy efficiency (Vavrek, Chovancová, 2019), the implementation of the Europe 2020 strategy (Ture, Dogan, Kocak, 2019), differences in working conditions (Tutak, Brodny, 2022), the use of renewable energy sources in road transport (Kisielińska et al., 2021b), institutional quality (Balcerzak, 2020), the use of ICT in enterprises (Vasilić, Semenčenko, Popović-Pantić, 2020), and energy poverty (Zhou, Wang, Hussain, 2022). Meanwhile, Hellwig's method has been applied to assess education progress (Roszkowska, Filipowicz-Chomko, 2021), agricultural development levels (Reiff et al., 2016), macroeconomic stability and competitiveness (Roszko-Wójtowicz, Grzelak, 2020), and living conditions (Wawrzyniak, 2016). These methods are also used to evaluate progress in achieving sustainable development goals (Gavurova, Megyesiova, 2022; Roszkowska, Filipowicz-Chomko, 2020; Szymańska, 2021). Applying different methods often results in country rankings that differ from each other. Authors attribute differences in rankings to different standardization methods (Roszkowska, Filipowicz-Chomko, 2021). This means that the choice of method can affect a country's position in the ranking, which may influence the usefulness of conclusions drawn from these analyses.

This article aims to compare the results of linear ordering conducted using various methods to assess the diversity of inequality levels in European Union countries in 2022. A specific aim of the study is also to identify the method that shows the greatest agreement with other forms of ordering. The analyses are based on statistical data provided by Eurostat for the realization of the tenth Sustainable Development Goal, i.e., reducing inequalities in the European Union (SDG 10) in 2022. The calculations were performed using Statistica 13.1 and Microsoft Excel.

2. Research Method

The construction of a synthetic measure within the framework of linear ordering of objects proceeds through the following stages:

- Selection and screening of diagnostic variables.
- Determination of the nature of the variables.
- Normalization of the variables to bring them to a similar order of magnitude.
- Determination of the coordinates of the reference point, or the reference and anti-reference points in the case of reference aggregation.
- Construction of the synthetic measure and determination of the linear ordering of objects.

In this study, the reference methods used to assess the diversity of inequality levels in the European Union were Hellwig's measure of development (Hellwig, 1968) and the classic TOPSIS method (Hwang, Yoon, 1981). The method based on the averaged normalized values of features (Wypych, 1982) was applied as a non-reference method.

For all the linear ordering methods adopted in the study, both reference and non-reference, variables were normalised using zero unitarization. In the literature, this is considered a universal method for normalizing diagnostic features (Kukuła, 1999):

- for stimulant:

$$z_{ij} = \frac{x_{ij} - min_i\, x_{ij}}{max_i x_{ij} - min_i x_{ij}} \tag{1}$$

- for destimulant:

$$z_{ij} = \frac{max_i\, x_{ij} \quad - x_{ij}}{max_i x_{ij} - min_i x_{ij}} \tag{2}$$

where: z_{ij} – the normalized *i-th* observation of the *j-th* variable, for $i = 1, \ldots, n$, and $j = 1, \ldots, k$.

The formulas for the synthetic variables for the three selected linear ordering methods used in the study are presented in Table 1.

The synthetic variable q_i takes values from the interval [0;1]. The highest value of the aggregate variable indicates the best position of a given object, while the lowest value indicates that the object is in the worst situation in the analyzed area (Ulbrych, Lesiak, 2022). Normalized values of Hellwig's aggregate variable q_i may exceed the interval [0;1] if significantly outlying objects are in the set of ordered objects (Bąk, 2018a).

Kendall's rank correlation coefficients (1938) were determined to assess the consistency of the obtained rankings, and vectors of similarity measure values were calculated.

Table 1.
Synthetic Variables in Selected Linear Ordering Methods

Name of the Method	Synthetic Variable q_i
Hellwig's Measure of Development	$q_i = 1 - \frac{d_{i0}}{d_0}$, *(3)* where: $d_{i0} = \sqrt{\sum_{j=1}^{k}(z_{ij} - z_{0j}^{+})^2}$, *(4)* $d_0 = \bar{d}_0 + 2 \cdot s_d$, *(5)* $\bar{d}_0 = \frac{1}{n}\sum_{i=1}^{n} d_{i0}$, *(6)* $s_d = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(d_{i0} - \bar{d}_0)^2}$ *(7)*
Classic TOPSIS Method	$q_i = \frac{d_{i0}^{-}}{d_{i0}^{+} + d_{i0}^{-}}$, *(8)* where: $d_{i0}^{+} = \sqrt{\sum_{j=1}^{k}(z_{ij} - z_{0j}^{+})^2}$, *(9)* $d_{i0}^{-} = \sqrt{\sum_{j=1}^{k}(z_{ij} - z_{0j}^{-})^2}$. *(10)*
Non-Reference Method	$q_i = \frac{1}{k}\sum_{j=1}^{k} z_{ij}$. *(11)*

Source: Own elaboration based on: Mikuła (2016), Bąk (2018a), Sompolska-Rzechuła (2020), Kisielińska et al. (2021a).

3. Research results

Using Eurostat data, a set of 11 explanatory variables was preliminarily selected to assess the diversity of European Union (EU-27) countries regarding the level of inequality within SDG10, analyzed across three complementary dimensions (Szymańska, 2021):

- monitoring the reduction of inequalities between countries (indicators: adjusted GDP per capita (EU-27 = 100), adjusted gross household disposable income per capita (EU-27 = 100);
- monitoring the reduction of inequalities within countries (indicators: quintile share ratio; relative median poverty gap (% distance to poverty threshold), the share of disposable income held by the poorest 40% of the population (% of income), people at risk of poverty or social exclusion (% of the population);
- monitoring facilitation in migration and social integration (indicators: people at risk of income poverty after social transfers (% of population aged 18 years and over), young people not in employment, education, or training (NEET) (% of population aged 15 to 29 years), early leavers from education and training (% of population aged 18 to 24 years), employment rate (% of population aged 20 to 64 years), first-time asylum applications (number per million inhabitants).

Considering statistical criteria for variable selection, such as discriminatory power and degree of correlation with other characteristics (Kukuła, 2020), four indicators were excluded from the set: adjusted gross household disposable income per capita, quintile share ratio, people at risk of income poverty after social transfers, and employment rate. The first three indicators were eliminated due to a high level of Pearson's correlation coefficient ($r > 0.75$), while the employment rate was excluded due to a low coefficient of variation ($V < 0.1$).

As a result, seven diagnostic variables were adopted for assessing the diversity of EU countries in terms of inequality levels and constructing synthetic measures:

x_1 – adjusted GDP per capita (EU-27 = 100),

x_2 – relative median poverty gap (% distance to poverty threshold),

x_3 – share of disposable income held by the poorest 40% of the population (% of income),

x_4 – people at risk of poverty or social exclusion (% of the population),

x_5 – early leavers from education and training (% of population aged 18 to 24 years),

x_6 – young people not in employment, education, or training (% of the population aged 15 to 29 years),

x_7 – first-time asylum applications (number per million inhabitants).

Among the listed variables, only variables x_1 and x_3 are stimulants. The remaining variables are considered destimulants. No nominal variables were identified.

Table 2 presents the results of the linear ordering of European Union countries in 2022 obtained based on selected reference methods: Hellwig's measure of development and the classic TOPSIS method, as well as a non-reference method.

Considering the presented values of the synthetic measure, it can be concluded that the diversity of inequality levels among EU-27 countries in 2022 was significant (Table 2). The distance between the country with the highest level of the synthetic measure and the country with the lowest level was 0.681 for Hellwig's method, 0.409 for the TOPSIS method, and 0.475 for the non-reference method.

In each applied method, the top three places in the ranking were occupied by the same countries: Ireland, Luxembourg, and Slovenia. Spain, Italy, Romania, and Bulgaria ranked the lowest. In the case of the Hellwig method, Romania and Bulgaria swapped their positions. Romania was ranked last, and Bulgaria was second to last. Poland's position compared to other European Union countries was relatively high, as evidenced by its ranking (eighth, seventh, and sixth) in all constructed rankings.

Table 2.
The ranking of EU countries and the synthetic measure values describing the level of inequality in the context of the tenth Sustainable Development Goal in 2022 based on selected linear ordering methods

Country Position	Hellwig Method		TOPSIS Method		Non-reference Method	
	Country	q_i	Country	q_i	Country	q_i
1	Ireland	0,677	Ireland	0,762	Ireland	0,779
2	Luxembourg	0,602	Luxembourg	0,722	Luxembourg	0,763
3	Slovenia	0,539	Slovenia	0,694	Slovenia	0,753
4	Netherlands	0,536	Czech Republic	0,683	Czech Republic	0,741
5	Czech Republic	0,520	Netherlands	0,678	Netherlands	0,714
6	Finland	0,489	Finland	0,654	Poland	0,697
7	Sweden	0,476	Poland	0,645	Slovakia	0,695
8	Poland	0,455	Sweden	0,636	Finland	0,693
9	Denmark	0,449	Slovakia	0,632	Sweden	0,661
10	Slovakia	0,408	Denmark	0,614	Denmark	0,633
11	Portugal	0,377	Malta	0,590	Malta	0,622
12	Germany	0,371	Portugal	0,584	Portugal	0,608
13	Malta	0,369	Germany	0,575	Belgium	0,600
14	Belgium	0,340	Belgium	0,573	Germany	0,595
15	Hungary	0,332	Hungary	0,566	Hungary	0,591
16	France	0,329	Croatia	0,555	Croatia	0,575
17	Croatia	0,314	Lithuania	0,546	Lithuania	0,563
18	Lithuania	0,303	France	0,537	France	0,544
19	Austria	0,301	Cyprus	0,524	Cyprus	0,535
20	Cyprus	0,244	Austria	0,521	Austria	0,525
21	Latvia	0,198	Latvia	0,478	Latvia	0,470
22	Estonia	0,196	Greece	0,471	Greece	0,460
23	Greece	0,184	Estonia	0,450	Estonia	0,438
24	Spain	0,126	Spain	0,403	Spain	0,380
25	Italy	0,070	Italy	0,387	Italy	0,351
26	Bulgaria	0,015	Romania	0,372	Romania	0,311
27	Romania	-0,004	Bulgaria	0,353	Bulgaria	0,304

Source: own elaboration based on Eurostat, Sustainable Development Indicators.

The positions of individual countries in the prepared rankings vary. The position in all rankings was the same for seven countries (Ireland, Luxembourg, Slovenia, Hungary, Latvia, Spain, and Italy). However, the ranking differences for the remaining EU countries are insignificant, ranging within 1-3 places. Furthermore, there is a greater convergence between the TOPSIS benchmark ranking and the ranking obtained through the non-reference procedure - twenty countries achieved the same positions. The calculated value of the Kendall tau correlation coefficient $\tau = 0.98$ confirms this statement. Analysis of the Kendall tau correlation coefficients between the remaining rankings also confirms a high consistency in the ordering by different linear ordering methods (Table 3).

Table 3.
The Kendall tau correlation coefficients between the rankings ($p < 0.05$)

	Hellwig Method	TOPSIS Method	Non-reference Method
Hellwig Method	1,00	0,94	0,92
TOPSIS Method	0,94	1,00	0,98
Non-reference Method	0,92	0,98	1,00

Source: own study.

When analyzing the results of the linear ordering of objects obtained using different methods, choosing the ordering that shows the highest agreement with the other rankings is recommended. The procedure proposed by Kukuła and Luty (2015) was applied to select the results closest to the others.

For each pair of created orderings, the similarity measure of rankings was estimated, and then a vector of similarity measure values was calculated. The methods of variable selection were compared in the following order: non-reference, Hellwig, TOPSIS. The vector of similarity measure takes the form:

$$\left[\overline{u_p}\right] = [0{,}9506; 0{,}9341, 0{,}9615\ ].$$

Linear ranking of countries obtained using the TOPSIS method, with zero unitarization, is the closest to all other rankings. When this method was applied to assess the achievement level of the tenth sustainable development goal, i.e., reducing inequalities, Ireland took the first place, while Bulgaria took the last. The highest position in the ranking is primarily due to a very high level of adjusted GDP per capita and a low percentage of young people prematurely ending education and training in Ireland. Conversely, Bulgaria exhibited the lowest level of adjusted GDP per capita and a relatively high percentage of young, unemployed, uneducated, and untrained individuals.

4. Summary

Various methods of linear object ranking were applied to assess the achievement level of the tenth sustainable development goal, i.e., reducing inequalities. Two reference methods, Hellwig's and TOPSIS, as well as a non-reference method, were utilized. The use of both approaches is justified due to the different ways of determining rankings in these two groups of methods, often resulting in diverse outcomes. In all methods, zero unitarization was applied for variable standardization to eliminate differences in rankings caused by different standardization methods.

The results of the analyses indicate that the ranking obtained using the TOPSIS method with zero unitarization demonstrates the greatest consistency with other rankings.

The obtained results confirm significant diversity among European Union countries in terms of inequality levels in the context of sustainable development. It is anticipated that changes in these disparities will occur in the coming years. Differences between individual countries are expected to gradually diminish, mainly due to the implementation of European cohesion policy. However, this is a slow and long-term process.

The research area covered in this study is extremely extensive. Further expansion of the analysis is planned, utilizing linear ranking methods on other research objects, including all European countries. Future research goals using linear ranking methods will include other normalization algorithms and assigning variable weights.

References

1. Ardielli, E. (2019). Use of TOPSIS method for assessing of good governance in European Union countries. *Review of Economic Perspectives*, *Vol. 19, No. 3,* pp. 211-231, doi: 10.2478/revecp-2019-0012.
2. Bąk, A. (2018a). Analiza porównawcza wybranych metod porządkowania liniowego. *Research Papers of Wrocław University of Economics*, *Vol. 508*, pp. 19-28, doi: 10.15611/pn.2018.508.02.
3. Bąk, A. (2018b). Zastosowanie metod wielowymiarowej analizy porównawczej do oceny stanu środowiska w województwie dolnośląskim. *The Polish Statistician, Vol. 63(1),* pp. 7-20, doi: 10.5604/01.3001.0014.0521.
4. Balcerzak, A.P. (2020). Quality of institutions in the European Union countries. Application of TOPSIS based on entropy measure for objective weighting. *Acta Polytechnica Hungarica, Vol. 17, No. 1,* pp. 101-122, doi: 10.12700/APH.17.1.2020.1.6.
5. Eurostat. *Indicators of sustainable development*. Retrieved from: http://www.ec.europa.eu/eurostat/web/main/data/database, 12.01.2024.
6. Gavurova, B., Megyesiova, S. (2022). Sustainable health and wellbeing in the European Union. *Frontiers in Public Health, Vol. 10,* doi: 10.3389/fpubh.2022.851061.
7. Guijarro, F., Poyatos, J.A. (2018). Designing a sustainable development goal index through a goal programming model: The Case of EU-28 Countries. *Sustainability, Vol. 10, No. 9, 3167,* doi: 10.3390/su10093167.
8. Hellwig, Z. (1968). Zastosowanie metody taksonomicznej do typologicznego podziału krajów ze względu na poziom ich rozwoju oraz zasoby i strukturę wykwalifikowanych kadr. *Statistical Review, Vol. 4(1968),* pp. 307-326.
9. Hwang, C.L., Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications.* New York: Springer-Verlag.

10. Kendall, M.G. (1938). A new measure of rank correlation. *Biometrika, Vol. 30, No. 1/2,* pp. 81-93.
11. Kisielińska, J., Borkowski, B., Czech, K.A., Górska, A., Koszela, G., Krawiec, M., Zielińska-Sitkiewicz M. (2021a). *Wielowymiarowa analiza danych w ekonomice rolnictwa,* Warszawa: SGGW.
12. Kisielińska, J., Roman, M., Pietrzak, P., Roman, M., Łukasiewicz, K., Kacperska, E. (2021b). Utilization of Renewable Energy Sources in Road Transport in EU Countries–TOPSIS Results. *Energies, Vol. 14, No. 22, 7457*, doi: 10.3390/en14227457.
13. Kukuła, K. (1999). Metoda unitaryzacji zerowanej na tle wybranych metod normowania cech diagnostycznych. *Acta Scientifica Academiae Ostroviensis, Vol. 4*, pp. 5-31.
14. Kukuła, K. (2020). O pewnych dylematach związanych z budową rankingu obiektów ze względu na poziom zjawiska złożonego. *Scientific Journal Warsaw University of Life Sciences Problems of World Agriculture, Vol. 20(2),* pp. 12-21. doi:10.22630/PRS.2020.20.2.9.
15. Kukuła, K., Luty, L. (2015). Propozycja procedury wspomagającej wybór metody porządkowania liniowego. *Statistical Review, Vol. 62(2)*, pp. 219-231.
16. Malina, A. (2004). Wielowymiarowa analiza przestrzennego zróżnicowania struktury gospodarki Polski według województw. *Krakow Review of Economics and Management. Special Series, Monographs, Vol. 162.*
17. Mikuła, A. (2016). Nierówności społeczne w Polsce. *Social Inequalities and Economic Growth, Vol. 47*, pp. 442-453, doi: 10.15584/nsawg.2016.3.32.
18. Navarro, V. (2000). Assessment of the World Health Report 2000. *The Lancet, Vol. 356, No. 4*, pp. 1598-1601, doi: 10.1016/S0140-6736(00)03139-1.
19. Reiff, M., Surmanová, K., Balcerzak, A.P., Pietrzak, M.B. (2016). Multiple criteria analysis of European Union agriculture. *Journal of international studies, Vol. 9, No. 3,* pp. 62-74, doi: 10.14254/2071-8330.2016/9-3/5.
20. Roszko-Wójtowicz, E., Grzelak, M.M. (2020). Macroeconomic stability and the level of competitiveness in EU member states: a comparative dynamic approach. *Oeconomia Copernicana, Vol. 11, No. 4*, pp. 657-688, doi: 10.24136/oc.2020.027.
21. Roszkowska, E., Filipowicz-Chomko, M. (2020). Measuring sustainable development in the education area using multi-criteria methods: a case study. *Central European Journal of Operations Research, Vol. 28, No. 4*, pp. 1219-1241, doi: 10.1007/s10100-019-00641-0.
22. Roszkowska, E., Filipowicz-Chomko, M. (2021), Measuring sustainable development using an extended Hellwig method: A case study of education. *Social Indicators Research, Vol. 153, No. 1*, pp. 299-322, doi: 10.1007/s11205-020-02491-9.
23. Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G. (2018). *SDG index and dashboards report 2018: global responsibilities: implementing the goals.* New York: Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN).

24. Sompolska-Rzechuła, A. (2020). Zastosowanie liniowego porządkowania obiektów do oceny aktywności ekonomicznej ludności w ujęciu województw. *The Polish Statistician, Vol. 65(03),* pp. 46-61, doi: 10.5604/01.3001.0014.0456.
25. Szymańska, A. (2021), Reducing socioeconomic inequalities in the European Union in the context of the 2030 agenda for sustainable development. *Sustainability, Vol. 13, No. 13, 7409,* doi: 10.3390/su13137409.
26. Ture, H., Dogan, S., Kocak, D. (2019). Assessing Euro 2020 strategy using multi-criteria decision making methods: VIKOR and TOPSIS. *Social Indicators Research, Vol. 142,* pp. 645-665, doi: 10.1007/s11205-018-1938-8.
27. Tutak, M., Brodny, J. (2022). Evaluating differences in the Level of Working Conditions between the European Union Member States using TOPSIS method. *Decision Making: Applications in Management and Engineering, Vol. 5, No. 2*, pp. 1-29, doi: https://doi.org/10.31181/dmame0305102022t.
28. Ulbrych, M.A., Lesiak, J. (2022). Determinanty konkurencyjności produkcji przemysłowej krajów Grupy Wyszehradzkiej. *Optimum. Economic Studies, Vol. 4, No. 110,* 133-150, doi: 10.15290/oes.2022.04.110.09.
29. UN, (2015). Przekształcamy nasz świat: Agenda na rzecz zrównoważonego rozwoju 2030, A/RES/70/1. Retrieved from: https://www.unic.un.org.pl/files/164/Agenda%202030_pl_2016_ostateczna.pdf, 12.01.2024.
30. Utzig, M., Raczkowska, M., Mikuła, A. (2023). Wybrane aspekty zrównoważonego rozwoju w obszarze społecznym w powiatach województwa mazowieckiego. *Journal of Tourism and Regional Development, Vol. 19*, pp. 117-126, doi: 10.22630/TIRR.2023.19.11.
31. Vasilić, N., Semenčenko, D., Popović-Pantić, S. (2020). Evaluating ICT usage in enterprises in Europe: Topsis approach. *Economic Themes, Vol. 58, No. 4*, pp. 529-544, doi:10.2478/ethemes-2020-0030, DOI:10.2478/ethemes-2020-0030.
32. Vavrek, R., Chovancová, J. (2019). Assessment of economic and environmental energy performance of EU countries using CV-TOPSIS technique. *Ecological Indicators, Vol. 106, 105519*, doi:10.1016/j.ecolind.2019.105519.
33. Wawrzyniak, D. (2016). Standard of living in the European Union, Comparative Economic Research. *Central and Eastern Europe, Vol. 19, No. 1*, pp. 141-155, doi: 10.1515/cer-2016-0008.
34. Wypych, M. (1982). Syntetyczna miara rozwoju w badaniach ekonomiczno-przestrzennych. *Statistical Review, Vol. 3-4.*
35. Zhou, K., Wang, Y., Hussain, J. (2022). Energy poverty assessment in the Belt and Road Initiative countries: Based on entropy weight-TOPSIS approach. *Energy Efficiency, Vol. 15, No. 7,* 46, doi: 10.1007/s12053-022-10055-8.