Digital Economy in Visegrad Countries. Multiple-criteria Decision Analysis at Regional Level in The Years 2012 and 2015

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Abstract

Building effective digital economy infrastructure is currently a basic condition for improving international competitiveness of middle income countries that want to close their development gap and avoid the problem of a middle income trap. From the national perspective, investing in digital economy can be a tool which supports sustainable development and increases the speed of convergence process at regional level. In this context, comparative research on development of the digital economy, both at national and regional level, should be considered as an actual and important scientific task. Therefore, the main aim of the article is to assess and compare the development level of digital economy in Visegrad countries at regional level (NUTS 1). In the research, the digital economy is defined as a multiple-criteria phenomenon. As a result, in the empirical research, the TOPSIS method with application of generalized distance measure GDM was used. The data for diagnostic variables concerning digital infrastructure in the years 2012 and 2015 was provided by Eurostat. On the one hand, the analysis confirmed a relatively quick progress in building digital economy at regional level in Poland, the Czech Republic, Slovakia and Hungary. On the other hand, significant disparities between the analyzed regions can be seen, especially in case of Polish regions.

Keywords: digital economy, multiple-criteria decision analysis (MCDA), TOPSIS, generalized distance measure GDM, regions, NUTS 1

JEL Classification: P25, C38

1. INTRODUCTION

For the last two decades, the Visegrad countries have gone through the process of quick economic and socio-political modernization. They have successfully transferred their economies from ineffective central planed systems to modern market economies which are able to take advantage of convergence process with best-developed countries. However, the growth potential, which is related to the above-mentioned factors, has been utilized to high extent in recent years. Currently, the countries face the problem of building highly competitive knowledge-based economy which will result in closing a development gap with the economies at technological frontier. The experience of some countries, which have managed to reach the status of developed economies for the last decades, confirm that a technological leap forward is not possible without policies and institutional reforms resulting in building the effective digital economy (OECD, 1996; 2000; Piątkowski, 2002; Kondratiuk-Nierodzińska, 2016, 451-471; Balcerzak & Pietrzak, 2016a, pp. 66-81; Żelazny & Pietrucha, 2017, pp. 43-62).

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As a result, the main objective of the current article is to quantify and compare the development level of the digital economy tangible and intangible infrastructure in Poland, the Czech Republic, Slovakia, and Hungary in the years 2012 and 2015. In the article, the following research questions are asked:

1. In Visegrad countries, the changes in the digital economy infrastructure is characterized by high dynamics at NUTS 1 level.
2. The process of the digital economy development is characterized by significant regional disparities.

The research is conducted at regional NUTS 1 level. The choice of the economies is based not only on their geographic proximity, but especially on their historical path of economic transformation, a relatively close level of development and the challenges the economies face in the process of closing the development gap. The time span of the research is limited with the availability of data provided by Eurostat. As a result of taking into account regional approach, it is possible to conduct a comparative analysis for the object, which are characterized by comparable fundamental economic factors, such as geographical size and population potential. The present study is a continuation of previous research of the authors Balcerzak (2017) and Balcerzak and Pietrzak (2017).

The current article is constructed as follows. In the next section, an economic role of the digital economy investments in the process of improving micro and macro productivity is discussed. Then, in section 3, the method of the empirical research is characterized. In the article, the digital economy is treated as a multiple-criteria phenomenon which justifies the application of multiple-criteria decision analysis (MCDA) tools. In the current research, the TOPSIS method was used. However, the applied TOPSIS method is enriched with the application of general distance measure (GDM), developed by Walesiak (1999, pp. 167-173), for estimation of distance of the objects form negative and positive ideal solutions. Section 4 is devoted to presentation of empirical results. The article is ended with conclusions.

The main contribution of the article relates to two factors: its empirical and informative value relating to the current regional development of the Visegrad countries, and methodological input. To our best knowledge, the current contribution can be treated as a unique MCDA research devoted to the development of digital economy at NUTS 1 level in Central European countries. From the methodological perspective, the article presents the usefulness of potential modification of the TOPSIS method with the application of general distance measure GDM for MCDA analysis.

2. DIGITAL ECONOMY AS A MULTIVARIATE PHENOMENON OF MICRO AND MACROECONOMIC PRODUCTIVITY GROWTH

The experience of the last three decades indicates that the development of digital economy should be analyzed form the perspective of general purpose technologies concept (Bresnahan & Trajtenberg 1995, pp. 83-108). The general purpose technology is characterized by high dynamics based on its potential to be applied in many sectors of economy. First of all, it leads to a significant increase in the speed of microeconomic productivity growth which after a sufficient proliferation of the technology leads to a higher macroeconomic productivity growth in the long term. The general purpose technology can be considered as a platform that opens new possibilities in many applications. The potential of general purpose technologies can be utilized effectively under condition of development of complementary technologies. On the other hand, the general purpose technology to a high extent is a factor influencing development of the complementary innovations which generates positive spillover effects and network externalities of investment in the general purpose technology. This mechanism is the condition for reaching long-term growth, especially in case of economies at technological frontier (Bresnahan & Trajtenberg 1995, pp. 83-108). The historical analogies in favor the idea of analyzing the digital economy within the framework of general purpose technology development are provided by Dawid (1990, s. 355-361) and the empirical arguments in this regard are given by Brynjolfsson and Lorin Hitt (2003, p. 805; 2000, p. 24).

The microeconomic empirical research devoted to a potential influence of the digital economy infrastructure on higher productivity growth confirms that enterprises can obtain the highest benefits form "digitalization" when tangible investments in the digital economy infrastructure, such as information and communication technologies (ICT), are related to intangible investments in human capital and organizational resources, such as new business processes, decentralized and more elastic organizational structures or new strategies. The empirical literature confirms that the mentioned benefits are not automatic, but they depend on significant structural adjustments of enterprises which are influenced by their institutional environment.

In the above-mentioned context, Bloom et al. (2012, pp. 167-201) analyzed the sources of differences in utilizing the potential of the digital economy investments, in this case, the investment in ICT among American and non-American enterprises operating in the United Kingdom. The research confirmed that American multinationals operating in the United Kingdom tended to have a higher productivity than non-American companies, which was related to a higher productivity of ICT investment. As a potential explanation for these differences, the authors pointed to the importance of intangible factors, such as organization of companies that affects their abilities to take advantage of the digital economy potential.

The importance of competence and quality of human capital for utilizing the potential of the digital economy at microeconomic level was confirmed by Black and Lynch (2004, pp. 97; 2001, pp. 434-445). The research conducted in the United States confirmed that the companies, where majority of employees at non-managerial positions had a higher education tend to obtain higher productivity improvements related to ICT investments than the ones with less educated staff.

The importance of quality of human capital for obtaining benefits from the digital economy was also confirmed by Bresnahan et al. (2002, pp. 339-376). Their research showed that the enterprise investments in ICT that were related to improvements in quality of human capital and decentralization of the business processes resulted in a higher productivity of companies.

From the macroeconomic perspective, the relation between investments in the digital economy and productivity growth, thus long-term welfare benefits, is also complex. The same as in the case of microeconomic perspective the existence of the digital economy infrastructure is the permitting condition, but not the sufficient one for having the macroeconomic gains. Also, in that case the benefits can be obtained, when there are effective complementarities between the tangible digital economy infrastructure and the intangible factors, such as quality of human capital and effective institutional order. In case of the developed countries, the last two decades confirmed that the existence of the digital economy sectors in a given country cannot guarantee a significant improvement of the macroeconomic productivity growth. This benefit is obtained under condition that the digital economy sectors contribute to the process of significant reorganization of the whole economy, which is only possible when the complementary factors, such as effective governance, institutional policy and sufficient level of common digital competence among people, are present.

In this context, the research of Bart Van Ark et al. (2003, 56-63) confirmed that in the 90s of XX century, European economies were not able to utilize the potential of the digital economy so effectively as Canada or United States, mostly due to the restrictive regulations, that made the obstacles to a quick proliferation of the digital economy infrastructure in the sectors that were the users of ICT.

Also Salvatore (2003, pp. 531-540) confirmed empirically the importance of macroeconomic elasticity of the economy in the process of reaching benefits from the digital economy investments. In this context, such factors as labor markets regulations influencing the incentives to invest in competence of human capital are of crucial importance.

Moving to the developing economies, as it has been already mentioned after successful transformation, Central European countries face the problem of avoiding a middle income trap. The experience of East Asian economies, which are pointed as examples of successful policies resulting in escaping a middle income trap, indicate that investment in advanced infrastructure networks in the form of high-speed communication and broadband technology – so basic technological tangible infrastructure of the digital economy – are an important success determinant in the analyzed process (Gill et al, 2007; Langale, 1997, 235-249). Such experience encourage Agenor and Canuto to develop a theoretical two-period overlapping generations model of economic growth, where the development of advanced network infrastructure of the digital economy is one of conditions for avoiding a low-growth trap equilibrium (Agenor & Canuto, 2015, pp. 641-660).

The above mentioned empirical contributions, both at microeconomic and macroeconomic level, confirm that the digital economy development is a necessary condition for having higher growth in case of the developing and developed economies as well. Additionally, the presented research results indicate that the phenomenon of the digital economy cannot be treated only as the problem of investments in tangible infrastructure, but it should be analyzed as a multivariate phenomenon, where both tangible digital economy infrastructure and intangible factors, such as people competence and habits, are taken into consideration. As a result, in case of the current empirical research, these two factors were presented in section 4: the availability of tangible digital economy infrastructure and the competence and habits of society will be analyzed.

3. METHODOLOGY OF MULTIPLE-CRITERIA DECISION ANALYSIS: TOPSIS WITH GENERALIZED DISTANCE MEASURE GDM

In case of the current research, it is assumed that digital economy can be described by many aspects relating to technical infrastructure and intangible factors such as quality of human capital and habits of society (see Balcerzak, 2017). Thus, the phenomenon is of a multivariate character which can be analyzed with application of taxonomic or multiple-criteria decision analysis (MCDA) methods (Łyszczarz, 2016, pp. 169-185; Małkowska & Głuszak, 2016, pp. 269-283; Pietrzak & Balcerzak, 2016a, 1704-1712; 2016b, pp. 1492-1501; 2016c, pp. 120-129; Ali et al., 2017, pp. 257-278; Baykasoglu & Golcuk, 2017, 37-51; Arikan & Citak, 2017, 315-331). TOPSIS method can be a tool, which is not only applied for MCDA applications of choosing the best alternative, but also for description and evaluation of multivariate objects under consideration (see. Hwang & Yoon, 1981; Balcerzak & Pietrzak, 2016, pp. 66-81; Pietrzak, 2016, pp. 69-86.; Balcerzak, 2016a, pp. 7-17).

The TOPSIS method allows to calculate a synthetic measure of development (SMD), which describes an analyzed multivariate problem. Its commonly pointed important advantage relates to the fact that it is based on the distance of the object form pattern and anti-pattern (positive ideal solution and negative ideal solution). In case of the method, the analyzed phenomenon is broken down into separate economic aspects that enable to describe different parts of the analyzed economic phenomenon. Every separate aspect can be described by a set of diagnostic variables, which provides specific information on the stated aspect. Based on the accepted diagnostic variables a synthetic measure of development can be calculated. In case of the TOPSIS method, the values of the obtained measure of development are normalized and they range from 0 to 1. The values of the obtained measure which are close to 1 indicate a high level of development of the phenomenon under research.

To compare the objects with positive and negative ideal solutions, the distance must be determined based on a given metric. In case of the TOPSIS method, the choice of the metric is of crucial importance, as application of inappropriate metrics will significantly affect the obtained results. The choice of the metrics is primarily dependent on the type of data used for given diagnostic variables. One of the universal metrics, which can be applied for diagnostic variables from any measurement scale, is the generalized distance measure *GDM* proposed by Walesiak (see Jajuga et al., 2003, pp. 104-109; Walesiak, 1999, pp. 167-173; 2016). In order to construct generalized distance measure *GDM*, Walesiak used the concept of Kendall rank correlation coefficient (Kendall's tau coefficient) and the generalized correlation coefficient (see Kendall, 1955). The main advantage of that approach relates to the fact that it can be applied in case of variables measured on the ratio scale, interval scale, ordinal scale or the nominal scale. In the economic research regarding the evaluation of economic phenomena, the variables based on the ordinal scale are commonly used. In this case of the multiple-criteria analysis, the application of the *GDM* measure is necessary. GDM_{it} is described by equations 1 and 2. The measure *GDM* described by equations 2 and 3 should be applied for the variables measured on the interval scale or the ratio scale. There is also the version of the measure *GDM* for the variables measured on the ordinal scale (see Walesiak, 2016, Walesiak & Dudek, 2016).

$$GDM_{it}^{P} = \frac{1}{2} - \frac{\sum_{j=1}^{m}(z_{ijt} - P_{kj})(P_{kj} - z_{ijt}) + \sum_{j=1}^{m}\sum_{\substack{l=1 \\ l \neq i,k}}^{n}(z_{ijt} - z_{ljt})(P_{kj} - z_{ljt})}{2\left[\sum_{j=1}^{m}\sum_{l=1}^{n}(z_{ijt} - z_{ljt})^2 \cdot \sum_{j=1}^{m}\sum_{l=1}^{n}(P_{kj} - z_{ljt})^2\right]^{\frac{1}{2}}}, \quad (1)$$

$$GDM_{it}^{AP} = \frac{1}{2} - \frac{\sum_{j=1}^{m}(z_{ijt} - AP_{kj})(AP_{kj} - z_{ijt}) + \sum_{j=1}^{m}\sum_{\substack{l=1 \\ l \neq i,k}}^{n}(z_{ijt} - z_{ljt})(AP_{kj} - z_{ljt})}{2\left[\sum_{j=1}^{m}\sum_{l=1}^{n}(z_{ijt} - z_{ljt})^2 \cdot \sum_{j=1}^{m}\sum_{l=1}^{n}(AP_{kj} - z_{ljt})^2\right]^{\frac{1}{2}}}, \quad (2)$$

where:

GDM^{P}_{it} - a distance of the object form the positive ideal solution,

GDM^{AP}_{it} - a distance of the object from the negative ideal solution.

The whole procedure of calculating SMD with application of TOPSIS based on generalized distance measure GDM consists of seven steps (Walesiak 2016; Balcerzak & Pietrzak, 2016a, 66-81):

1. The choice of diagnostic variables X_j *(j=1,2,.., n)* describing a chosen phenomenon.
2. Establishing a set of economic objects O_i *(i=1,2,..., m)*, for which the value of the *SMD* will be assessed.
3. Determining the nature of diagnostic variables, whether they are stimulants or dis-stimulants. For stimulants X^S_j for every two values x^S_{ij} , x^S_{kj} that refer to objects O_i, O_k , the relation $x^S_{ij} > x^S_{kj} \rightarrow O_i \, \theta \, O_k$ is fulfilled, where θ means that object O_i is preferred to O_k. For dis-stimulants X^S_j for every two values x^S_{ij} , x^S_{kj} that refer to objects O_i, O_k, the relation $x^S_{ij} < x^S_{kj} \rightarrow O_i \, \pi \, O_k$ is fulfilled, where π means that object O_k is preferred to object *Oi.*
4. Normalization of the diagnostic variables which enables to obtain a set of variables Z_j is obtained. In case of the current research in the normalization process, zero unitarization method was applied (see Kukuła & Bogocz, 2014, pp. 5-13; Balcerzak, 2015, pp. 190-210).
5. For stimulants establishing positive ideal solution P_j with application of equation 3 and negative ideal solution AP_j with equation 4. For dis-stimulants, negative and positive ideal solutions are calculated the other way round, the positive ideal solution is obtained with equation 4 and the negative ideal solution with equation 3. In case of a dynamic research, the values of positive and negative ideal solutions should be constant for the whole period of the study, which is the condition of obtaining comparability of the obtained *SMD* in different periods t.

$$P_j = \max_{it} z_{ijt} \quad . \quad (3)$$

$$AP_j = \min_{it} z_{ijt} \quad (4)$$

6. For every object assessment of generalized distance measure *GDM* for positive ideal solution GDM^{P}_{it} and for dis-stimulant GDM^{AP}_{it} with equations 1 and 2.
7. Assessing the values of SMD_{it} with the formula 5:

$$SMD_{it} = 1 - \frac{GDM_{it}^{P}}{GDM_{it}^{AP} + GDM_{it}^{P}}; \quad (5)$$

4. ASSESMENT OF THE DIGITAL ECONOMY DEVELOPMENT IN VISEGRAD COUNTRIES

The experience of the last two decades confirmed that the development of digital economy depends on two economic aspects: a) availability of Internet infrastructure, which can be defined as a tangible component of the phenomenon; b) abilities and habits of society, which is considered to be as its intangible component. Therefore, the digital economy must be regarded as a multivariate phenomenon. The research is based on the variables relating to both aspects. The diagnostic variables with classification to stimulants and dis-stimulants are given in Table 1. The data aggregated at NUTS 1 level was obtained from the Eurostat service (http://ec.europa.eu/eurostat).

Based on the aims of the article, the values of SMD for the Visegrad countries was assessed for the years 2012 and 2015 with application of methodology described in a previous section. The estimations were done with application of R-Cran software with Package 'clusterSim' (see: Walesiak & Dudek, 2016).

Tab. 1 – Diagnostic variables for digital economy. Source: Eurostat Database

Diagnostic variable	Character of the variable
1. Tangible Aspect: digital economy infrastructure	stimulant
X_1 – Households with access to the internet at home (Percentage of households)	stimulant
X_2 – Households with broadband access (Percentage of individuals)	stimulant
X_3 – Individuals who accessed the internet away from home or work (Percentage of individuals)	stimulant
2. Intangible Aspect: competence and habits of society	stimulant
X_4 – Individuals who ordered goods or services over the internet for private use (Percentage of individuals)	stimulant
X_5 – Individuals who have never used a computer (Percentage of individuals)	dis-stimulant
X_6 – Individuals who used the internet, frequency of use and activities (Percentage of individuals)	stimulant

Based on the obtained SMD measure, the ranking of regions based on the level of development of digital economy was proposed. Additionally, with application of the natural breaks method, the regions were grouped to one of three classes. The concept of the natural breaks method consists of minimization of variance for objects from the chosen subsets and maximization of variance between the subsets (Jenks, 1967, 186–190). In the first class, the regions with the highest level of the digital economy development are present. In the third class, the regions with it the lowest level of development were grouped. The results are given in Table 2 and Figure 2.

Tab. 2 – Ranking and grouping of regions for Visegrad countries for the years 2011 and 2015. Source: own estimation.

Digital economy							
2012				**2015**			
Region	SMD	Rank	Class	Region	SMD	Rank	Class
Slovakia	0.881	1	1	Slovakia	0.983	1	1
Közép-Mag-yarország	0.667	2	1	Közép-Magyarország	0.969	2	1
Region Centralny	0.336	3	2	Czech Republic	0.965	3	1
Czech Republic	0.33	4	2	Dunántúl	0.935	4	1
Dunántúl	0.288	5	2	Region Centralny	0.724	5	2
Region Poludniowy	0.224	6	2	Region Poludniowo-Zachodni	0.626	6	2
Region Pólnocno-Zachodni	0.104	7	3	Region Pólnocno-Zachodni	0.52	7	3
Region Pólnocny	0.084	8	3	Region Poludniowy	0.483	8	3
Region Poludnio-wo-Zachodni	0.072	9	3	Region Wschodni	0.444	9	3
Region Wschodni	0.067	10	3	Alföld és Észak	0.414	10	3
Alföld és Észak	0.038	11	3	Region Pólnocny	0.389	11	3

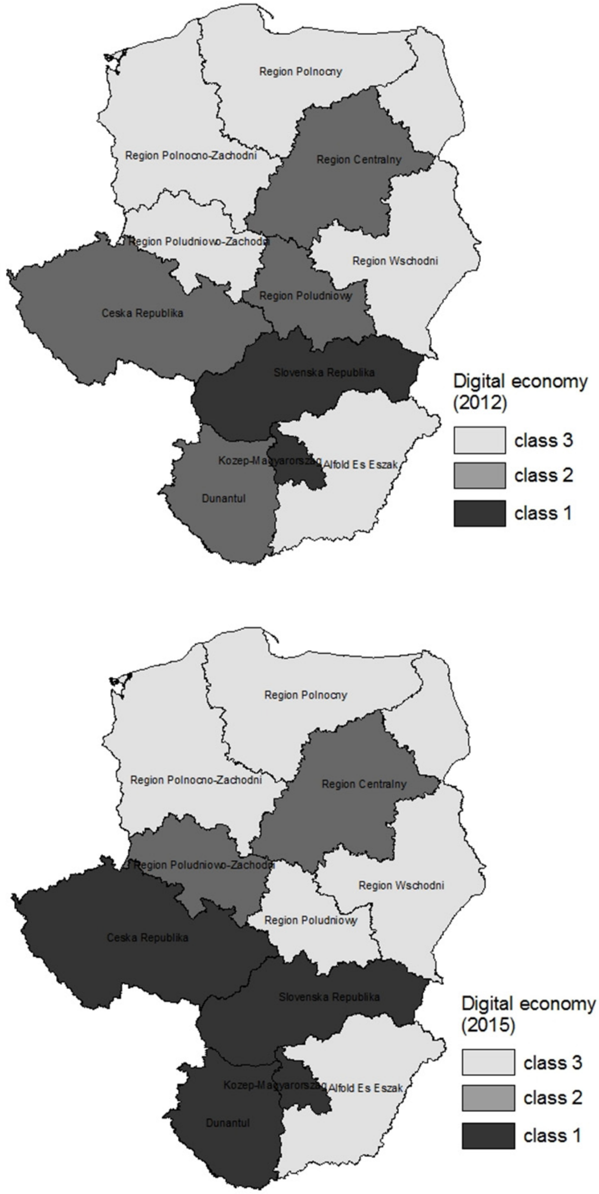

Fig. 1 – The level of digital economy in regions for Visegrad countries in the year 2012 and 2015.
Source: own estimation.

Taking into account the obtained results, it must be said that the situation of all the regions significantly improved between the years 2012 and 2015. It can be seen in the visible growth of the value of SMD for all the regions between the years 2012 and 2015. This result can be considered as an argument in favor of the first hypothesis of the article.

In the year 2012, in the first group with NUTS 1 regions characterized with the highest level of development of digital economy, one could find two regions Slovakia and Hungarian Közép-Magyarország. In the year 2015, additional two NUTS 1 regions joined the group: the Czech Republic and Dunántúl. As a result, Slovakia and Közép-Magyarország in the whole period of the research can be regarded as leaders who were able to keep their relative strong positions.

In the second class with NUTS 1 regions characterized with an average level of development in the year 2012, there were two Polish regions: Centralny and Południowy, the Czech Republic and Hungarian Dunántúl. On the other hand, in the year 2015 in the second class, one could find only two Polish regions: Centralny and Poludniowo-Zachodni. It should be stressed that due to a relatively lower growth rate of development of digital economy in Polish region Poludniowy, in the year 2015 it was degraded from the second class to the third class, grouping the regions with a relatively low level of development. On the contrary, Hungarian region Dunántúl managed to improve its relative position and moved from the second class in the year 2012 to the first class in the year 2015.

In the third class with the lowest relative development of digital economy in the first and last years of the research, one could find four Polish regions: Pólnocno-Zachodni, Północny, Poludniowo-Zachodni, Wschodni and Hungarian Alföld és Észak.

As a result, it can be concluded that in the analyzed years, the disparities between the Czech Republic, Slovakia and two Hungarian NUTS 1 regions got smaller. In the case of Hungary, the process of closing digital gap did not take over Alföld és Észak. In Poland, only two NUTS 1 regions were able to keep the pace with the best-developed NUTS 1 regions in Visegrad group. As a result, in the context of the second hypothesis of the research, it can be stated that it is partly confirmed, especially in the case of Polish NUTS 1 regions, which in spite of significant growth of the level of development, are not able to close a relative digital gap with the best regions in Central Europe.

5. CONCLUSION

The main empirical objective of the current research was to compare the level of development of digital economy at NUTS 1 level in Poland, the Czech Republic, Slovakia and Hungary in the years 2012 and 2015. In the article, two hypotheses were given.

The obtained results – high growth of values of synthetic measure of development for all the regions between 2012 and 2015 – provide arguments in favor of the first hypothesis, which related to a high speed of growth of digital economy in the analyzed regions.

In regard to the second hypothesis indicating significant regional disparities of growth between the analyzed NUTS 1 regions, the MCDA research confirmed its relevance mostly in regard to Polish NUTS 1 regions. In case of the Czech Republic, Slovakia and two Hungarian regions, the level of disparities in development of digital economy has decreased.

From the methodological perspective, the article presented possibilities of application of generalized distance measure GDM developed by Walesiak in MCDM research on the example of the TOPSIS method. The main advantage of the application of the method relates to its universality, as it can be used in case of variables based on the ratio scale, interval scale, ordinal scale or the nominal scale.

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