BJ O&PM Brazilian Journal of Operations & Production Management

ISSN 2237-8960 (Online)

ABEPRO ASSOCIAÇÃO BRASILEIRA DE ENGENHARIA DE PRODUÇÃO

RESEARCH PAPER

Global Innovation Indicators analysed by multicriteria decision

Marcela do Carmo Silva[1], Luiz Octávio Gavião[2], Carlos Francisco Simões Gomes[1], Gilson Brito Alves Lima[1]

[1]Production Engineering Graduate Program, Fluminense Federal University – UFF, Niterói, RJ, Brazil.
[2]Brazilian War College, Rio de Janeiro, RJ, Brazil.

How to cite: Silva, M.C., Gavião, L.O., Gomes, C.F.S. et al. (2020),"Global Innovation Indicators analysed by multicriteria decision", *Brazilian Journal of Operations & Production Management*, Vol. 17, No. 4, e2020907. https://doi.org/10.14488/BJOPM.2020.040

ABSTRACT

Goal: This paper analyses how European countries of Global Innovation Indicators (GII) present in the ranking by multicriteria support aid analysis.

Design / Methodology / Approach: The methodology uses Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for ranking countries and PROMETHÉE (Preference Ranking Organisation Method for Enrichment Evaluations) for outranking them.

Results: There was change in 30 ordered positions from 39 countries observed. At non-compensatory method the overrating become "easier" than the compensatory method, especially when there are many alternatives and criteria for computing with small difference among values.

Limitations of the investigation: It is only used the GII 2015 Europe for continuing investigations about MCDA realized for Latin America (2017) and Asia and Africa (2019).

Practical implications: The applications result in a different understanding about TOPSIS ranking application, from original score list at GII; and also the perception of organized groups at outranking application.

Originality / Value: Observing GII via MCDA is possible to see changing's in the ranking according to countries profiles different from GII raking. Although European profiles seem to be similar, it is important to observe other perspective of grouping by them; suggesting quantitative studies inclusion and innovative trends.

Keywords: Multicriteria Decision Aid; MCDA; Global Innovation Indicators; TOPSIS; PROMETHÉE.

INTRODUCTION

The innovation term alignment to whom creativity concepts, knowledge, change and rupture are timely to define the innovative process in the inputs and outputs - and why not during the production process, adoption, assimilation or export of products and/or services of aggregated values in macroeconomic and microeconomic terms, overcoming barriers of competitiveness (Fonseca and Lima, 2015). Advances in information technology are rapidly changing the market environment; the ability to innovate, combining internal and external knowledge is becoming one of the most critical components that lead to a sustainable competitive advantage (Lopes et al., 2016).

Developed countries tend to stimulate innovation policies through competitive strategies and practices, in order to promote research and development practices to cause disruption in production processes, adding value along the production chain, sustainability in production operations and their utilities (Lopes et al., 2016; Silva et al., 2019b; 2019c).

Financial support: None.
Conflict of interest: The authors have no conflict of interest to declare.
Corresponding author: marceladocarmo30@gmail.com
Received: 16 Nov 2019.
Approved: 10 Aug 2020.
Editor: Osvaldo L. G. Quelhas.

Frezatti et al. (2014) observe the organizations' management model absorbing the pressure of various external elements, such as: customer demands, international trade pressure and competitive advances, in a relevant way. This pressure is reflected in the dynamic tensions about the impact on the strategic decisions regarding the innovation process, affecting the time horizon, either the rigidity degree which a strategy is followed.

In this regard, there are different perspectives to consider the country development in the concept of innovation and intellectual property, since theories originating in the 1960s suggest a system of intellectual property development occurs as part of the evolution for countries to be considered social and economic development, as well as the construction of strong economic policies and systems promote innovation (Olwan, 2011; Oztaysi et al., 2017).

This paper's objective is to apply a Multicriteria Decision Aid (MCDA) method called TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), in an aggregation/ordering process using the Global Innovation Indicators' (GII) 2015 from 39 European countries, observing the ranking computed and the differences between this ranking and the original position from GII ranking list. European countries' list is also computed *via* PROMETHÉE (Preference Ranking Organisation Method for Enrichment Evaluations), an outranking MCDA computing other different rank and allow to understand formation of clusters at PROMETHÉE results. It occurs because European countries have similar profile; hence, grouping them *via* ranking might help to invest according to hubs and bridges led innovation by economic sectors.

This paper by suggesting quantitative studies inclusion and innovative trends aimed at understanding European innovation, so that GII can better categorize the indicators. This research is restricted to the practices observed by GII in its 2015 report without comparison with previous years, since there were changes in methodology (tendencies for observing innovation around the world change annually) and perception of indicators, items, subitems, innovation thresholds and correlation within the indicators score the countries in the ranking. Such changing's in methodology will not be cited in this paper because this is an operational research paper; not being a purpose to do a literature review about GII through its years, in this work as shown at Silva et al. in August, 2018.

Thus, this paper was organized in five sections where the second section presents the context of innovation and WIPO (World Intellectual Property Organisation), the third section exposes the practice of the TOPSIS and PROMETHÉE, the fourth observes the results and in the fifth this paper is concluded with the final considerations.

WIPO AND EUROPEAN INNOVATION INSTITUTIONALIZATION

Europe and some developing countries in the nineteenth century (*e.g.* Brazil as signatory, Ecuador, Guatemala, El Salvador and Tunisia) begun to understand intellectual property, when they formalize the system of registries of intellectual assets as a multilateral agreement by means of two treaties: initially the Paris Convention of 1883 and the Berne Convention of 1886, as an addition to the Paris Convention on the protection of literary and artistic works. The Paris Convention had other additions such as Brussels in 1900, Washington in 1911, The Hague 1925, London 1934, Lisbon 1958, 1967 Stockholm and at last in 1979 (Olwan, 2011).

However, the Berne Convention of 1886 promotes a subtle rupture in the fragmentation of understanding about innovation for countries development. In this regard, the sovereign Europe (France, Britain, Belgium, Italy, and Spain) adopts a legal process of intellectual property records in order to become independent and somewhat superior to the developing countries and their African colonies, Asian, Caribbean and South American colonies as well (Olwan, 2011).

European innovation institutionalization

Notoriously for decades, several countries have made the Berne Convention revision panels, mainly by the weakening of developing countries, colonies and former colonies,

subjugated to innovations protective envelope in the European continent, easily patented to the detriment of their interests. In 1971, The Paris Convention revised the alignment of the international intellectual property system structure and the scope (Olwan, 2011; Kwakwa and Talbott, 2013).

However, the concept and identification of a country as an innovator aims to analyse and document adaptations and innovations (even if they are benchmarked) so that best practices in innovative production processes in order to raise national intellectual property (Cornell University, 2015; Silva et al., 2017).

In this regard, Europe as a WIPO' stakeholder is consolidated as a member that has a strong influence on WIPO as a participant in the diplomatic corps and of the committees and general assembly's of the institution, but cannot speak for itself, only as a European Union. Each country fulfils its own demand and particularities, respecting the internal agreements between WIPO and European Union in which they separate the joint participation of the countries within the institution avoiding lobbies and maintaining isonomy. It should be noted that WIPO promotes attempts to demonstrate isonomy between countries with agreements and participation models signed with other institutions, such as the African Intellectual Property Organization (Kwakwa and Talbott, 2013; Silva et al., 2019c).

However, the paradox of European Union's intellectual property legal negotiations is absorbed within the WIPO's organizational context, albeit shows a strong influence of the block on the institution, with attempts to equalize and insert agencies, departments, committees, electronic rules and unified systems. Notwithstanding, WIPO's members caused the rupture of isonomy when it was suggested to use the patent law practiced worldwide; thus, with legal clarity the European Union was guaranteed in WIPO without principles linked to the sovereignty of the institution, without interconnectivity with the continent and the actions of its market (Silva et al., 2019c).

The understanding for European criteria studies belongs to a set of studies of how criteria behaviour by groups of countries. This paper presents such European issue; because countries have similar profiles regarding how they manage innovation issues. Hence, they might be observed by other perspective in order to decision-makers decide where they would like to invest, regarding innovation conditions, for improving economic sectors, specially when they are grouped into "hubs" and "bridges" (Silva et al., 2020).

World Intellectual Property Organization – WIPO

The World Intellectual Property Organization (WIPO) was set up in Stockholm on July 14, 1967 with the members' assignment to promote the global protection of intellectual property by focusing on innovation as a stimulus, creativity and contribution to economic development. In addition to promoting the intellectual property protection, its members were keen to accelerate the transfer of technology to their economies through business co-operation among them by multilateral agreements aligned with intellectual property law (Olwan, 2011). In order to identify the countries with the highest level of innovation, WIPO provokes a trend study, which reflects in a new methodological perception, developing indicators that are the result of countries with innovative intellectual assets: micro and macroeconomic aspects that characterize the country to economic-social evolution are analysed as well.

WIPO had to transnationalize itself with the expansion to other continents with regional offices and had to insert itself in anthropological causes as for example to observe intellectual property of the aboriginal culture in its drug treatments, its methods of cultural identity of works of art and their constitution and production processes specific to the native peoples – doing the institutional preservation to the creative economies.

Observing an WIPO's change of behaviour, in which its bureaucratic profile of intellectual assets of developed countries changed (because there was a need to show some institutional governance within the institution); to which its profile currently adapts pragmatic conditions for optimization of patent registration and identification software, alignment of registration

metrics to all countries, and actions to promote innovation potential technological development infrastructures in developing countries (Takagi and Czaijkowski, 2012).

METHODOLOGY

The nature of this research is an analysis to understand the GII European ranking list different from a TOPSIS either PROMETHÉE list for composing an innovation indicators rank list; which countries positions define the more innovative in each area. The exploratory character with the use of the TOPSIS tool analyses within the dimensions and its scenarios, for understanding the innovation in the national and international strategy and competitiveness environment (Martins et al., 2015); whilst PROMETHÉE computes results where it is possible to observe clusters formed by these countries.

Decisions are necessary when an opportunity or problem exists, either when something is not it should be or even when there is an opportunity for improvement or optimization. Many real situations of decision-making, several possible solutions may be considered, which requires decision makers to take into account different points of view (Bortoluzzi et al., 2017; Gomes et al., 2017; Vieira et al., 2017).

A MCDA can also be defined as a set of techniques which are designed to search for a number of alternatives within multiple criteria and conflicting objectives (Pujadas et al., 2017). Criteria must be consistent for decision proposed as result and alternatives must have the same conception and definition for being ordered at a MCDA tool. Hence, this study is centred on determining criterion of European countries' ranking by GII in its innovation indicators; presenting some aspects deemed essential by the decision-maker and makes up part of the element set that substantiates the dimensions that he has in mind when observing the context about the ranking and the possibility of groups formed by countries according to their behaviour through the computation (Bortoluzzi et al., 2017).

The first full exposition of the multicriteria decision support method's application was in 1976 by Keeney and Raiffa in a study named the "*Decisions with Multiple Objectives: Preferences and Value Tradeoffs*", which decision theory there were consequences in multi-attributes, integrating uncertain associations with long-term consequences in their multiple objectives (Office of Public Sector Information, 2009).

It is understood to solve a multicriteria decision support method, as a tool of an alternative - decision variant - correspond to the best option by the decision maker, combining at least two values as an orderly way of positioning, better for worse or less favourable; and by reaching the maximum values with respect to all criteria simultaneously - generally considered impossible. Solving a multicriteria decision support method application requires some combinations of information or preferences for criteria values being articulated by decision makers (Kaliszewski and Podkopaev, 2016; Labreuche and Grabisch, 2018; Silva et al., 2019b).

This paper method is built observing a MCDA compensatory method with simple application for understanding differences between GII 2015 list rank and the MCDA compensatory method rank. Then, an outranking method (PROMETHÉE) is applied also for understanding if the *surclassement* (outranking) offers other perspective of understanding, such as clustering formation among 39 countries. Both methods give informations about the data with differences from the original GII 2015 rank; being possible to observe more details about European countries regarding innovation indicators, supporting decision-makers to invest in European countries not only by their innovation scores, but also how the innovation indicators, after the computing at compensatory and non-compensatory methods might observe countries by other perspectives of investment, such as the "hubs" and "bridges" they design according methods result.

The seven innovation indicators used in this paper as criteria are: institutions (I_1), human capital and research (I_2), infrastructure (I_3), market sophistication (I_4), business sophistication (I_5), knowledge and technology outputs (I_6), creative outputs (I_7). Institutions are an innovation indicator for considering police and economy behaviour. Human capital and research is an

indicator for scoring how human capital has been developed and absorbed by society and economy. Infrastructure observes utilities and how they improve innovation and economy. Market sophistication considers how economy granting credit. Business sophistication is the indicator shows intellectual property as assets and royalties obtained from a high-technological goods insertion at economic sectors. Knowledge and technology outputs; and creative outputs are the last innovation indicators showing how society at that country deals with innovation and uses innovation in their social lifes (Cornell University, 2015; Silva et al., 2017).

Innovation indicators score is obtained from an arithmetic average about the scores in each item and subitem from each innovation indicators. The score number composed is from 0 up to 100.

TOPSIS

Multicriteria decision support methods are applied when there is a need to select, sort, classify or describe alternatives present in a complex decision-making process with multiple criteria and conflicting objectives (Corrente, Greco and Słowinski, 2016; Silva et al., 2018a). In a short explanation about MCDA methods, the most widely used MCDA methods, whether in real-life academic applications are: ELECTRE, PROMETHÉE, AHP, TOPSIS and VIKOR, as well as MACBETH and MAUT (Currente, Greco, and Słowinski, 2016). The VIKOR method is based on the aggregate function that represents the next of the ideal, using linear normalization; while the positioning provoked by the PROMETHÉE method (non-compensatory method) with the linear preference function has a similar result to that organized by VIKOR. The results of the ELECTRE family of non-compensatory method, with linear substitute function attributes are relatively similar to the results generated by VIKOR. Therefore, it is chosen after these methods observations, the TOPSIS method for its simplicity of computational process and systemic procedure with a solid logic, which represents the human rational choice (Zhang and Xu, 2015; Dong and Saaty, 2014; Longaray et al., 2015; Hashemi et al., 2016). TOPSIS is ideal when working with a large number of criteria and/or alterations (Silva et al., 2018a). It should be noted that TOPSIS is a compensatory method (Zyoud et al., 2016). Considering each method has its own strengths, weaknesses, and applicable situations; it is important to know "when to use what" (Gan et al., 2017); that's the reason why occurred the TOPSIS' choice, due to the compensatory nature of the method (Silva et al., 2019a).

The MCDA tool chosen for this paper is the TOPSIS because it is based on the concept of overcoming relation (or over classification). According to Kuo (2017), TOPSIS has been widely applied in the past decades, considerable efforts have been made either to modify, or extend TOPSIS and even though to compare, or hybridize it with other MCDM methods.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was a seminal study by Hwang and Yoon (1981) called *Multiple attribute decision making: Methods and applications*, becoming widely known and used as a support method for multicriteria decision support analysis (Caiado et al., 2017). The PIS is a solution maximizes the most "advantageous" criteria and minimizes all the cost criteria; while the NIS is a solution minimizes all de benefit criteria and maximizes all the cost criteria (Bhutia and Phipon, 2012; Bilbao-Terol et al., 2014). TOPSIS, therefore, results in more balance in the evaluation, placing the alternatives in relation to the two points of reference (Walczak and Rutkowska, 2017): Its basic principles are the rationality of alternative choices that should have the shortest distance to the positive ideal solution (PIS) and the longest distance to the negative ideal solution (NIS). TOPSIS also observes a multi-attribute decision analysis (MADA) with alternatives and criteria as a geometric system with points distributed in a spatial dimension (Chen, 2015; Zyoud et al., 2016).

PROMETHÉE

PROMETHÉE was first proposed in Brans and Mareschal in 1984, as method for ranking a finite set of alternatives (Brans et al., 1984; Bouyssou et al., 2000). The PROMETHÉE method involves concepts and parameters have some physical or economical interpretation that is easy for most Decision Makers (DM) to understand (Sarrazin and De Smet, 2015). It is based on their "net flow", means the difference in how much an alternative "a" is better than other one "b", and how much an alternative "b" is better than one "a" (Bogdanovic et al., 2012).

PROMETHÉE observes preferences and computing in software, illustrations support the results for obtaining a better perspective of all the preferences, if a cluster is done by the alternatives etc. The software GAIA is used to compute all the data showing outranking onward net flow results (GAIA, 1990).

Mareschal (2015) presented a procedure for calculating PROMETHÉE, where possible decisions and items to be evaluated with qualitative and quantitative criteria exist for supporting all the global decision. The goal is to optimize $\{g_1(a), g_2(a), ..., g_k(a) \mid a \in A\}$; however, it is necessary to understand the pairwise comparison via computation of differences to each pairwise considering the criteria where xiSxk, observed at Equation 1:

$$\delta_{ik} = \left| v_j(x_i) - v_j(x_k) \right| \tag{1}$$

After achieving the differences, it is necessary to apply the selected preference functions for deciding preference results between *a* and *b*. In the sequence, it is calculated a general preference index *Pi* (*a,b*) representing preference intensity of *a* over *b* (Equation 2):

$$\pi(a,b) = \sum_{j=1}^{n} w_j . P_j(a,b); \left(\sum_{j=1}^{n} w_j = 1 \right) \tag{2}$$

Then it is calculated outranking flows for each alternative a ϵ *A*, considering positive preference flows (Equation 3) and negative preference flows (Equation 4). As this paper works with PROMETHÉE II, it is calculated the net flow (Equation 5):

$$\phi_i^+ = \sum_k s_{ik} \tag{3}$$

$$\phi_i^- = \sum_k s_{ki} \tag{4}$$

and $\phi_i = \phi_i^+(a) - \phi_i^-(a)$ (5)

Concluding, PROMETHÉE II result is a complete ranking to solve the decision-making problem according to considered alternatives.

INNOVATION INDICATORS RESULTS DISCUSSION

TOPSIS's application

In order to define the multi-criterion method for WIPO's ranking of innovation indicators in 2015, it is particularly noted the thirty-nine European countries cited in the publication with their scores in their seven indicators, as listed in Table 1.

Table 1. European Innovation Indicators GII's 2015

Countries	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Switzerland	89.6	59.2	58.6	72.3	60	72.4	64.8
United Kingdom	87.3	57.5	63	74.3	53.6	54.9	60.5
Sweden	90	61.7	62.8	63.7	56.9	60.5	55.1
Netherlands	91.9	51.7	60.5	61.8	55.3	55.9	61.9
Finland	95.8	64.9	58.5	61.5	58.8	51.9	52.2
Ireland	87.2	50.1	54.9	64	58.4	55.7	55
Luxembourg	83.5	40.8	54.2	56.2	60.2	49.1	69
Denmark	93.1	62.4	55.7	68.4	49.7	46.1	53
Germany	83.2	56.6	56.7	59.2	49.2	53.4	52.8
Iceland	87.8	48.7	51.8	52.7	46.4	40.7	72.4
Austria	88.7	57.4	55.2	56.5	47	43	51.3
Norway	94	49.9	64.8	56.5	45.8	39.2	51.7
France	81.7	55.5	60.8	59	49.3	41.1	50.8
Estonia	80.8	44.2	60.9	54.6	43.4	42.1	55.6
Czech Republic	76.4	45.8	51	52.4	45.3	46.7	50.2
Belgium	83.3	51.4	52.5	54.9	51	36.1	50.4
Malta	80.6	39.3	48	50.3	40.8	38.5	59.8
Spain	75.2	45.9	61	64.7	38.2	39.9	42.4
Slovenia	79.5	48.3	49.4	46.9	42.1	38.1	49.4
Portugal	80.6	47.6	50.3	55.4	35.2	33.2	45.7
Italy	73.8	41.3	57.6	53.6	40.6	41.2	37.6
Latvia	77.7	33.1	50.6	52.4	38.2	34.9	46.3
Hungary	73.4	37.7	47.2	46	36.8	34.7	40.7
Slovakia	75.1	33.2	49.3	50.4	36.7	33.7	40.4
Lithuania	73.6	39.2	48.2	51.9	36.4	28.3	41
Bulgaria	69.7	32.2	43.3	48.9	36.4	35.4	41.1
Croatia	71.8	36.9	44.6	47.1	37.9	31	40.5
Montenegro	69.5	35.9	39.3	51	34	28.4	44.6
Moldova, Rep.	59	27.6	36	50.6	31.7	39.6	40.5
Greece	68.2	45.9	47.9	51.2	30.8	26	37.5
Poland	75.3	37.2	45.5	49	35.2	28.3	35.4
Russian Federation	56.6	47.5	40.6	43.5	38.4	36.6	30.1
Belarus	53.2	43	42	56.1	30.3	37.1	26
Romania	69.7	27.8	42.4	45.3	34.7	32.8	32.1
TFYR of Macedonia	67.7	32.7	31.4	52.3	35.9	26.3	37.9
Serbia	62.2	30.1	42.6	43.9	30.2	27.7	34.6
Ukraine	52.2	40.4	26.3	43.9	32.4	36.4	31.3
Bosnia and Herzegovina	59.6	39.9	30.9	61.6	40.1	23	13.4
Albania	60.1	21.8	39	59.1	26.2	18.5	22

Source: Cornell University (2015).

The Table 2 presents the normalized matrix according to the TOPSIS method.

Table 2. Innovation indicators normalized matrix

Countries	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Switzerland	0.18574	0.20890	0.18578	0.20876	0.22192	0.28309	0.21760
United Kingdom	0.18097	0.20290	0.19973	0.21454	0.19825	0.21466	0.20316
Sweden	0.18657	0.21772	0.19910	0.18393	0.21045	0.23656	0.18503
Netherlands	0.19051	0.18244	0.19180	0.17844	0.20454	0.21857	0.20786
Finland	0.19859	0.22902	0.18546	0.17758	0.21748	0.20293	0.17529
Ireland	0.18076	0.17679	0.17405	0.18480	0.21600	0.21779	0.18469
Luxembourg	0.17309	0.14397	0.17183	0.16227	0.22266	0.19198	0.23170
Denmark	0.19300	0.22019	0.17659	0.19750	0.18382	0.18025	0.17797
Germany	0.17247	0.19973	0.17976	0.17094	0.18197	0.20880	0.17730
Iceland	0.18201	0.17185	0.16422	0.15217	0.17162	0.15914	0.24312
Austria	0.18387	0.20255	0.17500	0.16314	0.17384	0.16813	0.17227
Norway	0.19486	0.17608	0.20544	0.16314	0.16940	0.15327	0.17361
France	0.16936	0.19584	0.19276	0.17036	0.18234	0.16070	0.17059
Estonia	0.16750	0.15597	0.19307	0.15765	0.16052	0.16461	0.18670
Czech Republic	0.15838	0.16162	0.16169	0.15130	0.16755	0.18260	0.16857
Belgium	0.17268	0.18138	0.16644	0.15852	0.18863	0.14115	0.16924
Malta	0.16708	0.13868	0.15218	0.14524	0.15091	0.15054	0.20081
Spain	0.15589	0.16197	0.19339	0.18682	0.14129	0.15601	0.14238
Slovenia	0.16480	0.17044	0.15661	0.13542	0.15571	0.14897	0.16589
Portugal	0.16708	0.16797	0.15947	0.15996	0.13019	0.12981	0.15346
Italy	0.15299	0.14574	0.18261	0.15477	0.15017	0.16109	0.12626
Latvia	0.16107	0.11680	0.16042	0.15130	0.14129	0.13646	0.15548
Hungary	0.15216	0.13303	0.14964	0.13282	0.13611	0.13568	0.13667
Slovakia	0.15568	0.11715	0.15630	0.14553	0.13574	0.13177	0.13566
Lithuania	0.15257	0.13833	0.15281	0.14986	0.13463	0.11065	0.13768
Bulgaria	0.14449	0.11363	0.13728	0.14120	0.13463	0.13842	0.13801
Croatia	0.14884	0.13021	0.14140	0.13600	0.14018	0.12121	0.13600
Montenegro	0.14407	0.12668	0.12459	0.14726	0.12575	0.11104	0.14977
Moldova, Rep.	0.12231	0.09739	0.11413	0.14610	0.11725	0.15484	0.13600
Greece	0.14138	0.16197	0.15186	0.14784	0.11392	0.10166	0.12593
Poland	0.15610	0.13127	0.14425	0.14148	0.13019	0.11065	0.11887
Russian Federation	0.11733	0.16761	0.12872	0.12560	0.14203	0.14311	0.10108
Belarus	0.11028	0.15174	0.13315	0.16198	0.11207	0.14506	0.08731
Romania	0.14449	0.09810	0.13442	0.13080	0.12834	0.12825	0.10779
TFYR of Macedonia	0.14034	0.11539	0.09955	0.15101	0.13278	0.10283	0.12727
Serbia	0.12894	0.10621	0.13506	0.12676	0.11170	0.10831	0.11619
Ukraine	0.10821	0.14256	0.08338	0.12676	0.11984	0.14233	0.10511
Bosnia and Herzegovina	0.12355	0.14080	0.09796	0.17787	0.14832	0.08993	0.04500
Albania	0.12459	0.07693	0.12364	0.17065	0.09690	0.07234	0.07388

The entropy was the attribution of weights applied, considering that to the weight value of each criterion is attributed a higher value to the criterion, in relation to a greater diversity of innovation indicators evaluations (Oliveira and Mello, 2009). Therefore, the weights were distributed according to Table 3.

Table 3. Weights by entropy of the seven innovation indicators

Weights	I_1	I_2	I_3	I_4	I_5	I_6	I_7
	0.1613	0.1796	0.1302	0.0519	0.0953	0.2763	0.1055

Among the innovation indicators alternatives for classification, it was observed their discrimination, and under this criterion the normalized and weighted matrix was calculated as observed in Table 4.

Table 4. Standardized and weighted matrix of innovation indicators

Countries	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Switzerland	0.02996	0.03752	0.02419	0.01083	0.02115	0.07822	0.02296
United Kingdom	0.02919	0.03644	0.02600	0.01113	0.01889	0.05931	0.02143
Sweden	0.03009	0.03910	0.02592	0.00955	0.02006	0.06536	0.01952
Netherlands	0.03073	0.03277	0.02497	0.00926	0.01949	0.06039	0.02193
Finland	0.03203	0.04113	0.02415	0.00922	0.02073	0.05607	0.01849
Ireland	0.02916	0.03175	0.02266	0.00959	0.02058	0.06018	0.01948
Luxembourg	0.02792	0.02586	0.02237	0.00842	0.02122	0.05304	0.02444
Denmark	0.03113	0.03955	0.02299	0.01025	0.01752	0.04980	0.01878
Germany	0.02782	0.03587	0.02340	0.00887	0.01734	0.05769	0.01871
Iceland	0.02936	0.03086	0.02138	0.00790	0.01636	0.04397	0.02565
Austria	0.02966	0.03638	0.02279	0.00847	0.01657	0.04645	0.01817
Norway	0.03143	0.03162	0.02675	0.00847	0.01614	0.04235	0.01832
France	0.02732	0.03517	0.02510	0.00884	0.01738	0.04440	0.01800
Estonia	0.02702	0.02801	0.02514	0.00818	0.01530	0.04548	0.01970
Czech Republic	0.02555	0.02903	0.02105	0.00785	0.01597	0.05045	0.01778
Belgium	0.02785	0.03258	0.02167	0.00823	0.01798	0.03900	0.01786
Malta	0.02695	0.02491	0.01981	0.00754	0.01438	0.04159	0.02119
Spain	0.02514	0.02909	0.02518	0.00970	0.01346	0.04311	0.01502
Slovenia	0.02658	0.03061	0.02039	0.00703	0.01484	0.04116	0.01750
Portugal	0.02695	0.03017	0.02076	0.00830	0.01241	0.03587	0.01619
Italy	0.02468	0.02617	0.02378	0.00803	0.01431	0.04451	0.01332
Latvia	0.02598	0.02098	0.02089	0.00785	0.01346	0.03770	0.01640
Hungary	0.02454	0.02389	0.01948	0.00689	0.01297	0.03749	0.01442
Slovakia	0.02511	0.02104	0.02035	0.00755	0.01294	0.03641	0.01431
Lithuania	0.02461	0.02484	0.01990	0.00778	0.01283	0.03057	0.01453
Bulgaria	0.02331	0.02041	0.01787	0.00733	0.01283	0.03824	0.01456
Croatia	0.02401	0.02339	0.01841	0.00706	0.01336	0.03349	0.01435
Montenegro	0.02324	0.02275	0.01622	0.00764	0.01198	0.03068	0.01580
Moldova, Rep.	0.01973	0.01749	0.01486	0.00758	0.01117	0.04278	0.01435
Greece	0.02280	0.02909	0.01977	0.00767	0.01086	0.02809	0.01329
Poland	0.02518	0.02358	0.01878	0.00734	0.01241	0.03057	0.01254
Russian Federation	0.01893	0.03010	0.01676	0.00652	0.01354	0.03954	0.01066
Belarus	0.01779	0.02725	0.01734	0.00841	0.01068	0.04008	0.00921
Romania	0.02331	0.01762	0.01750	0.00679	0.01223	0.03544	0.01137
TFYR of Macedonia	0.02264	0.02072	0.01296	0.00784	0.01265	0.02841	0.01343
Serbia	0.02080	0.01908	0.01758	0.00658	0.01064	0.02993	0.01226
Ukraine	0.01745	0.02560	0.01086	0.00658	0.01142	0.03932	0.01109
Bosnia and Herzegovina	0.01993	0.02529	0.01275	0.00923	0.01413	0.02485	0.00475
Albania	0.02010	0.01382	0.01610	0.00886	0.00924	0.01999	0.00779

Sequentially, the optimum positive solution points were identified, as the maximum of the classifications of each alternative in each criterion, in addition to the points of solution anti-ideal, observed in Table 5.

Table 5. Positive and Negative Ideal Solutions

Solutions	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Positive Ideal Solution	0.03203	0.04113	0.02675	0.01113	0.02122	0.07822	0.02565
Negative Ideal Solution	0.01745	0.01382	0.01086	0.00652	0.00924	0.01999	0.00475

The TOPSIS' method practice starts with the calculation of the Euclidean distances between A_i and A^+ and between A_i and A^-, realized by the equations: $D_i^+ = \sqrt{\sum_{j=1}^{n}\left(p_{ij} - p_j^+\right)^2}$ and $D_i^- = \sqrt{\sum_{j=1}^{n}\left(p_{ij} - p_j^-\right)^2}$; while the calculation of the relative proximity C_i for each alternative A_i in relation to the ideal solution A^+ is generated by the equation: $C_i = \frac{D_i^-}{D_i^+ - D_i^-}$, where i = 1,...,m. and the value of the index C_i ranges from 0 to 1.

Continuing with TOPSIS, the Euclidean Distances for each country were calculated within the ideal solution configuration and anti-ideal solution. Afterwards, the coefficients are calculated between the major and minor distances, and the alternatives are ordered, with the coefficients being calculated. Finally, by concluding the use of the method, the countries were organized and it is observed that they were changed in 30 of the positions analysed by GII, in the final comparison of the TOPSIS multicriteria method (the altered countries were shaded). The large number of countries, treated by TOPSIS as alternatives, confirms the applicability of the method in this type of situation, as shown at Table 6.

Table 6. Calculation of Euclidean Distances, calculation of coefficients and comparison of European countries in GII's and by TOPSIS

Euclidean Distances' Calculation			Calculation of Coefficients	GII's ranking	GII's ranking by TOPSIS
Countries	D+	D-			
Switzerland	0.00559	0.06913	0.92519	1	1
United Kingdom	0.02028	0.05309	0.72360	2	3
Sweden	0.01467	0.05856	0.79965	3	2
Netherlands	0.02032	0.05268	0.72164	4	4
Finland	0.02350	0.05259	0.69112	5	6
Ireland	0.02189	0.05068	0.69835	6	5
Luxembourg	0.03020	0.04489	0.59786	7	9
Denmark	0.02977	0.04653	0.60979	8	8
Germany	0.02337	0.04939	0.67876	9	7
Iceland	0.03672	0.04010	0.52199	10	13
Austria	0.03373	0.04170	0.55285	11	10
Norway	0.03826	0.03874	0.50311	12	15
France	0.03581	0.04000	0.52760	13	12
Estonia	0.03675	0.03755	0.50538	14	14
Czech Republic	0.03305	0.03932	0.54333	15	11
Belgium	0.04164	0.03449	0.45304	16	17
Malta	0.04193	0.03253	0.43686	17	20
Spain	0.04004	0.03414	0.46027	18	16
Slovenia	0.04096	0.03315	0.44731	19	19

Table 6. Continued...

Euclidean Distances' Calculation			Calculation of Coefficients	GII's ranking	GII's ranking by TOPSIS
Countries	D+	D-			
Portugal	0.04637	0.02919	0.38630	20	21
Italy	0.04040	0.03278	0.44797	21	18
Latvia	0.04770	0.02634	0.35582	22	23
Hungary	0.04772	0.02530	0.34650	23	24
Slovakia	0.04950	0.02402	0.32669	24	28
Lithuania	0.05332	0.02183	0.29054	25	31
Bulgaria	0.04889	0.02388	0.32815	26	27
Croatia	0.05153	0.02199	0.29907	27	30
Montenegro	0.05459	0.01968	0.26503	28	35
Moldova, Rep.	0.04846	0.02552	0.34498	29	26
Greece	0.05535	0.02200	0.28439	30	32
Poland	0.05434	0.02003	0.26937	31	33
Russian Federation	0.04684	0.02717	0.36711	32	22
Belarus	0.04824	0.02553	0.34611	33	25
Romania	0.05337	0.01961	0.26869	34	34
TFYR of Macedonia	0.05839	0.01545	0.20928	35	37
Serbia	0.05780	0.01553	0.21183	36	36
Ukraine	0.05047	0.02362	0.31879	37	29
Bosnia and Herzegovina	0.06271	0.01401	0.18263	38	38
Albania	0.06972	0.00701	0.09142	39	39

PROMETHÉE's application

PROMETHÉE outranking method is computed *via* GAIA software. The same data is computed at the software and the net phi generates the outranking list shown at Table 7 compared with TOPSIS ranking and GII's original ranking. At PROMETHÉE outranking, only 5 countries don't change their "place"; it means, only five countries are not outranked by other countries.

Table 7. PROMETHÉE net phi outranking result compared with TOPSIS and GII 2015

Countries	Net Phi	GII's ranking	GII's ranking by TOPSIS	PROMETHÉE outranking
Switzerland	0.8624	1	1	1
United Kingdom	0.777	2	3	3
Sweden	0.8463	3	2	2
Netherlands	0.7706	4	4	4
Finland	0.765	5	6	5
Ireland	0.626	6	5	7
Luxembourg	0.4657	7	9	11
Denmark	0.6718	8	8	6
Germany	0.5699	9	7	8
Iceland	0.3991	10	13	13
Austria	0.5127	11	10	9
Norway	0.4744	12	15	10
France	0.4473	13	12	12
Estonia	0.3565	14	14	14

Table 7. Continued...

Countries	Net Phi	GII's ranking	GII's ranking by TOPSIS	PROMETHÉE outranking
Czech Republic	0.218	15	11	16
Belgium	0.2195	16	17	15
Malta	0.0206	17	20	20
Spain	0.1945	18	16	17
Slovenia	0.0547	19	19	19
Portugal	-0.0984	20	21	21
Italy	0.0669	21	18	18
Latvia	-0.2086	22	23	22
Hungary	-0.3632	23	24	23
Slovakia	-0.368	24	28	24
Lithuania	-0.3989	25	31	26
Bulgaria	-0.4353	26	27	28
Croatia	-0.4604	27	30	29
Montenegro	-0.5491	28	35	33
Moldova, Rep.	-0.5051	29	26	31
Greece	-0.5089	30	32	32
Poland	-0.4871	31	33	30
Russian Federation	-0.3704	32	22	25
Belarus	-0.4277	33	25	27
Romania	-0.6352	34	34	36
TFYR of Macedonia	-0.6894	35	37	37
Serbia	-0.7585	36	36	38
Ukraine	-0.5742	37	29	34
Bosnia and Herzegovina	-0.6324	38	38	35
Albania	-0.8481	39	39	39

Figure 1 shows the non-compensatory method possibilities of grouping by countries according to their economic sectors behaviour. The innovation indicators show how the near countries scores might build "hubs" either "bridges" according to their similarities.

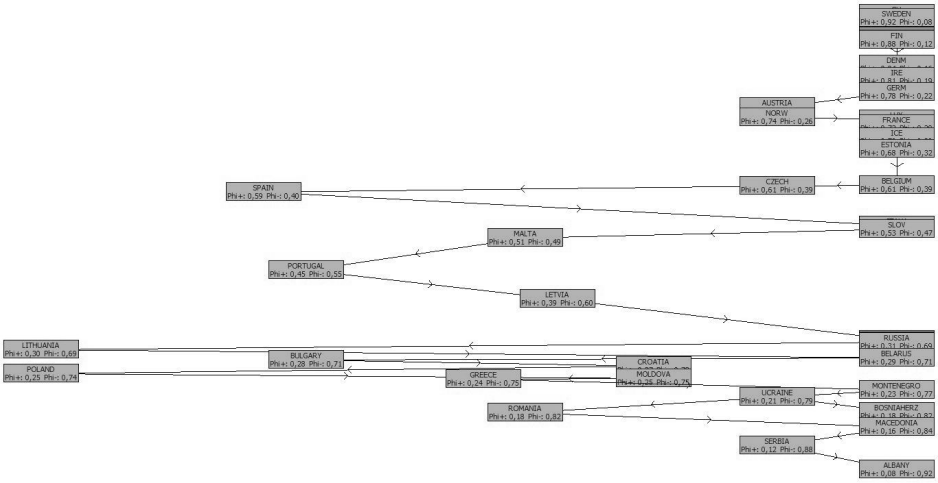

Figure 1 – Adaptation from GAIA screen graphs
Source: GAIA – Visual PROMETHÉE Academic

Figure 2 has an interesting perspective of strong and weak weights for the seven innovation indicators and a bar graph showing from which country the net phi becomes negative, being Portugal the first net phi negative up to Albany. From Switzerland (CH) up to Malta (MAL) there are positive net phi results.

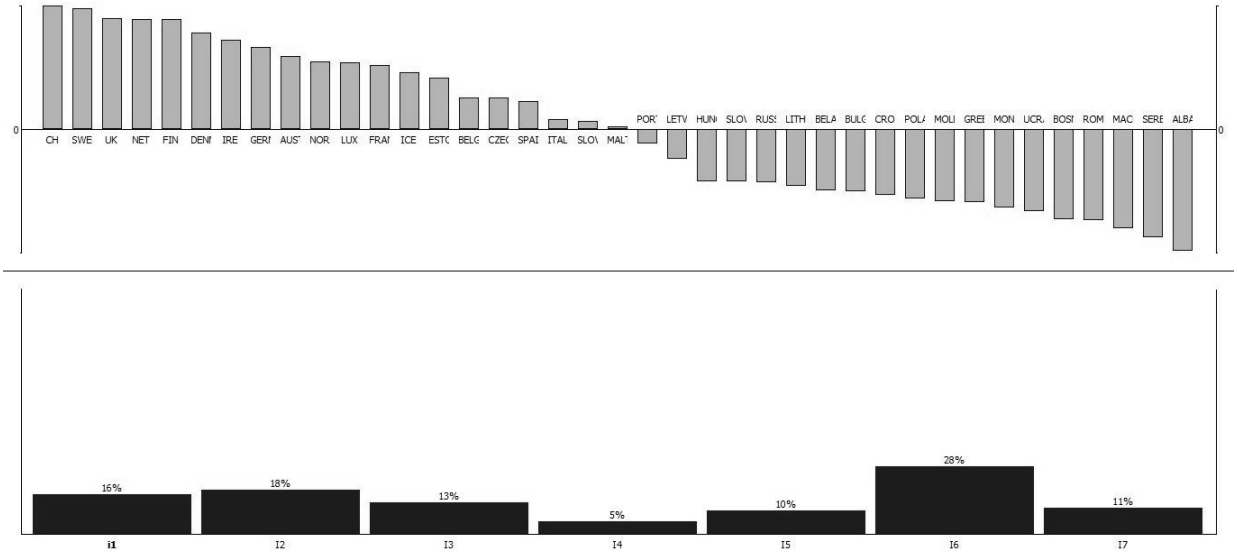

Figure 2 – Walking weights
Source: GAIA – Visual PROMETHÉE Academic

Applications results

GII's arrangements for 79 innovation indicators in the 2015 report were structured in 3 categories, 7 pillars in 2 sub-pillars showing a particular change in 30 positions, with only 9 planning stays in the same position. Despite the correlation in the correspondence analysis being 95% between categories, pillars and sub-pillars; the identification and aggregation of innovation indicators through TOPSIS' multicriteria decision analysis observes changes in the positions in two sorts downwards or upwards, according to the position of the indicators, as well as change of sorts in four positions down or up.

European innovation's leaders (e.g. Switzerland and Netherlands) created innovations aligned to ecosystems, where there were investments in human resources combined with infrastructure's innovation, contributing to increase the creativity level in productive process (Cornell University, 2015).

Robustness analysis is often used to evaluate AMD methods; hence at GII 2015, the correlation between rankings allows to evaluate the robustness of the results; where the degree of ordinal correlation is directly associated with the robustness of the GII method (Magdy and Jones, 2010).

Kendall's and Spearman's coefficients are non-parametric methods consider the positions that the variables values occupy when ordered; whose results may vary in the interval [-1, 1], characterizing high negative and positive correlation, respectively, and null coefficient indicates absence of correlation between the analysed methods rankings (Hauke and Kossowski, 2011). In these results, Kendall's tau index was 0.8461538 and the Spearman's rho was 0.9560729: Evans and Over (2013) observes indexes above 0.8 indicating a very strong positive correlation between the variables, represented by the method rankings. These values of the correlations were calculated from the "cor" function of software "R" (R-Core-Team, 2016).

TOPSIS' observations may show WIPO's indicators methodological construction can be altered in some of its pillars and sub-pillars, so that they are better grouped in the correlations - with the possibility of maintaining a 95% correlation - and to revise the applied methodology, that would be chosen and audited by the institution, through a multicriteria decision support analysis that observes the ordinances.

PROMETHÉE as an outranking method shows changings in 34 positions, only resting 5 countries not outranked by other countries. Using the same weights used at TOPSIS for computing the MCDA results; PROMETHÉE also shows in a graph the possibility of forming clusters where the outranking condition demonstrates some similarity among countries grouped.

Figure 1 above shows an adaptation from GAIA screen with a net flow graph result. It is possible to observe four clusters formed according to their profile: the first group involves the most developed countries regarding economy and intellectual property assets by royalties for their innovative products developed and registered. The second group appears at the middle of the graph with Czech Republic, Spain, Slovenia, Malta, Portugal and Latvia being considered the transition group, because they have agricultural economy but also a industrialized economy. The third group appears with Russia, Belarus, Lithuania, Poland, Hungary, Greece, Croatia, Moldova forming a group where the oil&gas sector generates a "hub" passing through these countries regarding logistics and regarding processing industries, where they are connected to improve their economies and their innovative process considering industries of capital goods. The fourth cluster starts with Montenegro, and then comes Ukraine, Romania, Bosnia and Herzegovina, Macedonia, Serbia and Albany. Observing the graph result is possible to understand these clusters because countries are grouped according to this representation to their similar countries about economy behaviour and production chain connected with other countries. These groups behaviour support the decision-maker's investment in how of economic sector regarding innovation development they would like to invest considering European countries, especially the groups formulate "hubs" either "bridges" to their regional economies.

CONCLUSIONS AND FINAL CONSIDERATIONS

The aim of this paper is to use the TOPSIS method to verify the positioning of the most innovative European countries identified by GII's methodology and to provoke for future work a better identification for compensatory methods, considering the use of the TOPSIS method by weights in entropy, as presented in this paper, as well as through the use of the TOPSIS method normalized by sum of criteria or normalization by the greater criterion, thus altering the understanding of positioning of the indicators ranking to be optimized in future for the new world-regional identifications for the innovative countries, since in Europe in 2015 there was change in 30 ordered positions from 39 countries observed.

Another issue is to observe compensatory and non-compensatory methods results whose perspective gave different ways of how to invest at European countries regarding innovation business, *e.g*. The similar scores provoked by innovation indicators were redefined when TOPSIS ranked European countries different from GII 2015 score and also when PROMETHÉE grouped them observing different adjusts for economic sectors integrated, as "hubs" either "bridges".

The suggestion of this paper is that the subsequent reports methodological reformulation should occur, regarding GII's global innovation indicators for analysis data, through multicriteria decision support, with the feasibility of using other formulas, or analysis calculations in TOPSIS and/or other compensatory methods, in the future, for observing different behaviours from these innovation indicators and how they might group aligned to their economic sectors rather not.

Regarding the use of an outranking method it was possible to see the changing of place being more difficult than in a compensatory method. Using PROMETHÉE only 5 countries were not outranked by others, whilst at TOPSIS 9 countries were not compensating by other countries. At non-compensatory method the overrating become "easier" than the compensatory method, especially when there are many alternatives and criteria for computing with small difference among values.

Although correlations between indicators, pillars and sub-pillars have a high percentage, the TOPSIS method showed that at some point there is still a failure in the classification

decision of the agents involved; suggesting quantitative studies inclusion and innovative trends aimed at understanding European innovation, so that GII can better categorize the indicators, including the opportunity to use other methods and analysis models to support multicriteria decision making in addition to TOPSIS and PROMETHÉE, respecting its combinatory and temporal parameters.

References

Bhutia, P.W. and Phipon, R. (2012), "Application of AHP and TOPSIS method for supplier selection problem", *IOSR Journal of Engineering*, Vol. 2, No. 10, pp. 43-50. http://dx.doi.org/10.9790/3021-021034350.

Bilbao-Terol, A., Arenas-Parra, M., Cañal-Fernández, V. et al. (2014), "Using TOPSIS for assessing the sustainability of government bond funds", *Omega*, Vol. 49, pp. 1-17. http://dx.doi.org/10.1016/j.omega.2014.04.005.

Bogdanovic, D., Nikolic, D. and Ilic, I. (2012), "Mining method selection by integrated AHP and PROMETHEE method", *Anais da Academia Brasileira de Ciências*, Vol. 84, No. 1, pp. 219-33. http://dx.doi.org/10.1590/S0001-37652012005000013.

Bortoluzzi, S.C., Ensslim, S.R., Ensslim, L. et al. (2017), "Multicriteria decision aid tool for the operational management of an industry: a constructivist case", *Brazilian Journal of Operations & Production Management*, Vol. 14, No. 1, pp. 165-82. http://dx.doi.org/10.14488/BJOPM.2017.v14.n2.a4.

Bouyssou, D., Marchant, T., Pirlot, M. et al. (2000). *Evaluation and decision models: a critical perspective*. Kluwer Academic Publishers, USA. viii + 274 pp.

Brans, J.P., Mareschal, B. and Vincke, P. (1984). *Promethee: a new family of outranking methods in multicriteria analysis*. North-Holland, Washington.

Caiado, R.G.G., Lima, G.B.A., Gavião, L.O. et al. (2017), "Sustainability analysis in electrical energy companies by similarity technique to ideal solution", *IEEE Latin America Transactions*, Vol. 15, No. 4, pp. 675-81. http://dx.doi.org/10.1109/TLA.2017.7896394.

Chen, T.Y. (2015), "An interval type-2 fuzzy technique for order preference by similarity to ideal solutions using a likelihood-based comparison approach for multiple criteria decision analysis", *Computers & Industrial Engineering*, Vol. 85, pp. 57-72. http://dx.doi.org/10.1016/j.cie.2015.03.005.

Cornell University, Institut Européen d'Administration des Affaires – INSEAD, World Intellectual Property Organization – WIPO (2015). *The Global Innovation Index 2015: effective innovation policies for development*, WIPO, Switzerland, Geneva.

Corrente, S., Greco, S. and Słowinski, R. (2016), "Multiple criteria hierarchy process for electre tri methods", *European Journal of Operational Research*, Vol. 252, pp. 191-203. http://dx.doi.org/10.1016/j.ejor.2015.12.053.

Dong, Q. and Saaty, T.L. (2014), "An analytic hierarchy process model of group consensus", *Journal of Systems Science and Systems Engineering*, Vol. 23, No. 3, pp. 362-74. http://dx.doi.org/10.1007/s11518-014-5247-8.

Evans, J.S.B.T. and Over, D.E. (2013). *Rationality and reasoning*, Psychology Press, Hove.

Fonseca, L.M. and Lima, V.M. (2015), "Countries three wise men: sustainability, innovation, and competitiveness", *Journal of Industrial Engineering and Management*, Vol. 8, No. 4, pp. 1288-302. http://dx.doi.org/10.3926/jiem.1525.

Frezatti, F., Bido, D.S., Cruz, A.P.C. et al. (2014), "O papel do balanced scorecard na gestão da inovação", *Revista de Administração de Empresas*, Vol. 54, No. 4, pp. 381-92. http://dx.doi.org/10.1590/S0034-759020140404.

GAIA (1990). *PROMETHEE-GAIA software*. Université Libre de Bruxelles, B. Mareschal, Bruxelles.

Gan, X., Fernandez, I.C., Guo, J. et al. (2017), "When to use what: methods for weighting and aggregating sustainability indicators", *Ecological Indicators*, Vol. 81, pp. 491-502. http://dx.doi.org/10.1016/j.ecolind.2017.05.068.

Gomes, C.F.S., Costa, H.G. and Barros, A.P. (2017), "Sensibility analysis of MCDA using prospective in Brazilian energy sector", *Journal of Modelling in Management*, Vol. 12, No. 3, pp. 475-97. http://dx.doi.org/10.1108/JM2-01-2016-0005.

Hashemi, S.S., Hajiagha, S.H.R., Zavadskas, E.K. et al. (2016), "Multicriteria group decision making with ELECTREIII method based on interval-valued intuitionistic fuzzy information", *Applied Mathematical Modelling*, Vol. 40, No. 2, pp. 1554-64. http://dx.doi.org/10.1016/j.apm.2015.08.011.

Hauke, J. and Kossowski, T. (2011), "Comparison of values of Pearson's and Spearman's correlation coefficients on the same sets of data", *Quaestiones Geographicae*, Vol. 30, No. 2, pp. 87-93. http://dx.doi.org/10.2478/v10117-011-0021-1.

Hwang, C.L. and Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications*, Springer-Verlag, New York. http://dx.doi.org/10.1007/978-3-642-48318-9.

Kaliszewski, I. and Podkopaev, D. (2016), "Simple additive weighting – A metamodel for multiple criteria decision analysis methods", *Expert Systems with Applications*, Vol. 54, No. C, pp. 155-61. http://dx.doi.org/10.1016/j.eswa.2016.01.042.

Kuo, T. (2017), "A modified TOPSIS with a different ranking index", *European Journal of Operational Research*, Vol. 260, No. 1, pp. 152-60. http://dx.doi.org/10.1016/j.ejor.2016.11.052.

Kwakwa, E. and Talbott, A. (2013). *The influence of the World Intellectual Property Organization on the European Union". Between autonomy and dependence: the EU legal order under the influence of international organisations*. Springer, The Netherlands, pp. 199-216. https://doi.org/10.1007/978-90-6704-903-0_9

Labreuche, C. and Grabisch, M. (2018), "Using multiple reference levels in multi-criteria decision aid: the generalized-additive independence model and the Choquet integral approaches", *European Journal of Operational Research*, Vol. 267, No. 2, pp. 598-611. http://dx.doi.org/10.1016/j.ejor.2017.11.052.

Longaray, A.A., Popiolek Junior, T.L., Munhoz, P.R. et al. (2015). "Caracterização da produção científica brasileira sobre a aplicação de métodos multicritério de apoio à decisão: uma análise das publicações entre 2004-2013", in *XXXV Encontro Nacional de Engenharia de Produção: ENEGEP*, ABEPRO, Rio de Janeiro.

Lopes, A.P.V.B.V., Kissimoto, K.O., Salerno, M.S. et al. (2016), "Innovation management: a systematic literature analysis of the innovation management evolution", *Brazilian Journal of Operations & Production Management*, Vol. 13, No. 1, pp. 16-30. http://dx.doi.org/10.14488/BJOPM.2016.v13.n1.a2.

Magdy, W. and Jones, G. (2010). "Examining the robustness of evaluation metrics for patent retrieval with incomplete relevance judgements", in *International Conference of the Cross-Language Evaluation Forum for European Languages*. Springer, Dublin, pp. 82-93. https://doi.org/10.1007/978-3-642-15998-5_10

Mareschal, B. (2015). "Modèles unicritères et multicritères", Université libre de Bruxelles, available at: http://homepages.ulb.ac.be/~bmaresc/assets/tqg-2015-6-ad.pdf (accessed 16 November 2019).

Martins, E.F., Lima, G.B.A. and Gomes, H.C. (2015), "Análise estratégica multicritério sócio-econômico-ambiental como ferramenta de apoio à decisão em uma empresa de distribuição de energia", *Revista Eletrônica Sistemas de Gestão*, Vol. 10, No. 1, pp. 96-106. http://dx.doi.org/10.7177/sg.2015.v10.n1.a8.

Office of Public Sector Information – OPSI (2009). *Multi-criteria analysis: a manual*. Office of Public Sector Information, United Kingdom.

Oliveira, A. V. and Mello, J. (2009). "Combinação de um método multicritério de auxílio à decisão subjetivo e outro objetivo e aplicação desse modelo híbrido na seleção de um imóvel", *Relatórios de Pesquisa em Engenharia de Produção*, Vol. 9, No. 9, pp. 1-25.

Olwan, R.M. (2011). *Intellectual Property and Development: Theory and Practice*, Doctor of Philosophy Thesis, Faculty of Law, Queensland University of Technology, Brisbane, Queensland.

Oztaysi, B., Onar, S.C., Goztepe, K. et al. (2017), "Evaluation of research proposals for grant funding using interval-valued intuitionistic fuzzy sets", *Soft Computing*, Vol. 21, pp. 1203-18. http://dx.doi.org/10.1007/s00500-015-1853-8.

Pujadas, P., Pardo-Bosch, F., Aguado-Renter, A. et al. (2017), "MIVES multi-criteria approach for the evaluation, prioritization, and selection of public investment projects. A case study in the city of Barcelona", *Land Use Policy*, Vol. 64, pp. 29-37. http://dx.doi.org/10.1016/j.landusepol.2017.02.014.

R-Core-Team (2016). "R: a language and environment for statistical computing", available at: http://www.r-project.org (accessed 16 November 2019).

Sarrazin, R. and De Smet, Y. (2015), "Applying multicriteria decision analysis to design safe road projects", *European Journal of Transport and Infrastructure Research*, Vol. 15, No. 4, pp. 613-34.

Silva, M.C., Gavião, L.O., Gomes, C.F.S. et al. (2017), "A proposal for the application of multicriteria analysis to rank countries according to innovation using the indicators provided by the WIPO", *Revista de Administração e Inovação*, Vol. 14, No. 3, pp. 188-98. http://dx.doi.org/10.1016/j.rai.2017.05.003.

Silva, M.C., Gomes, C.F.S. and Costa Junior, C.L. (2018a), "A hybrid multicriteria methodology TOPSIS-MACBETH-2N applied in the ordering of technology transfer offices", *Pesquisa Operacional*, Vol. 38, No. 3, pp. 413-39. http://dx.doi.org/10.1590/0101-7438.2018.038.03.0413.

Silva, M.C., Gomes, C.F.S. and Costa Junior, C.L. (2019a), "The use of TOPSIS for Ranking WIPO's Innovation Indicators", *Innovar*, Vol. 29, No. 73, pp. 133-48. http://dx.doi.org/10.15446/innovar.v29n73.78027.

Silva, M.C., Gomes, C.F.S. and Costa, H.G. (2019b). "Multicriteria decisions for investment in innovative upper-middle income countries GII 2016", in *Euro 2019*, EURO, United Kingdom, available at: https://www.euro-online.org/conf/euro30/treat_abstract?frompage=search&paperid=1307 (accessed 16 November 2019).

Silva, M.C., Gomes, C.F.S. and Lima, G.B.A. (2019c), "Utilities analysis for latin america and caribbean innovation indicators", *IEEE Latin America Transactions*, Vol. 16, No. 11, pp. 2834-40.

Silva, M.C., Lima, G.B.A., Gomes, C. F. S. et al. (2019d), "A SMARTS-Choquet's approach for multicriteria decision aid applied to the innovation indexes in sustainability dimensions", *Soft Computing*, Vol. 23, No. 16, pp. 7117-33. http://dx.doi.org/10.1007/s00500-018-3353-0.

Silva, M. C., Costa, H. G. and Gomes, C. F. S. (2020). "Multicriteria decision choices for investment in innovative upper-middle income countries", *Innovation & Management Review*, Vol. 17, No. 3, pp. 321-347. https://doi.org/10.1108/INMR-02-2019-0016.

Takagi, Y. and Czaijkowski, A. (2012), "WIPO services for access to patent information. Building patent information infrastructure and capacity in LDCs and developing countries", *World Patent Information*, Vol. 34, No. 1, pp. 30-6. http://dx.doi.org/10.1016/j.wpi.2011.08.002.

Vieira, J.A.M., Gomes, C.F.S. and Braga, I.E. (2017), "Development of a scenario prospecting model with the use of multicriteria decision aiding: importance of environmental variables", *Brazilian Journal of Operations & Production Management*, Vol. 14, No. 2, pp. 210-7. http://dx.doi.org/10.14488/BJOPM.2017.v14.n2.a9.

Walczak, D. and Rutkowska, A. (2017), "Project rankings for participatory budget based on the fuzzy TOPSIS method", *European Journal of Operational Research*, Vol. 260, No. 2, pp. 706-14. http://dx.doi.org/10.1016/j.ejor.2016.12.044.

Zhang, X. and Xu, Z. (2015), "Soft computing based on maximizing consensus and fuzzy TOPSIS approach to interval-valued intuitionistic fuzzy group decision making", *Applied Soft Computing*, Vol. 26, pp. 42-56. http://dx.doi.org/10.1016/j.asoc.2014.08.073.

Zyoud, S., Kaufmann, L., Shaheen, H. et al. (2016), "A framework for water loss management in developing countries under fuzzy environment: integration of Fuzzy AHP with Fuzzy TOPSIS", *Expert Systems with Applications*, Vol. 61, No. 1, pp. 86-105. http://dx.doi.org/10.1016/j.eswa.2016.05.016.

Author contributions: All the authors contributed equally to this paper.