Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company’s public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
The 8th International Conference on Information Technology and Quantitative Management (ITQM 2020 & 2021)

A Group Multi-Criteria approach for development of a country COVID-19 indicator

Rădulescu Constanța Zoie*, Rădulescu Mariusb, Zbăganu Gheorghităb, Bonecara

aNational Institute for Research and Development in Informatics, 8-10, Mareșal Averescu, Bucharest, 011455, Romania
b"Gheorghe Mihoc-Caius Iacob" Institute of Mathematical Statistics and Applied Mathematics of the Romanian Academy, Calea 13 Septembrie, No.13, Bucharest, 050711, Romania

Abstract

The pandemic generated by the Sars Cov 2 corona virus is monitored, at the level of each country, every day, by several COVID-19 indicators. The present paper proposes a Group Multi-Criteria (GMC) approach for the development of a country COVID-19 indicator called COPACOV (COuntry Performance Against COVID-19) indicator. It is calculated starting from several country COVID-19 indicators measured separately, in a set a countries. COPACOV can identify which countries are more vulnerable to COVID-19 illnesses from several points of view taken together. The GMC approach is based on a hybrid method composed from the Group Analytic Hierarchy Process (GAHP) weighting method and from the Multicriteria Optimization and Compromise Solution (VIKOR) multi-criteria method. The aggregation (consensus) of the experts’ opinions, in the GAHP method is calculated with the geometric mean method. The VIKOR method uses the weights calculated by the GAHP method and calculates the COPACOV’ indicators. The proposed GMC approach is applied in a case study for a set of COVID-19 indicators and a set of Eastern European countries.

© 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the The 8th International Conference on Information Technology and Quantitative Management (ITQM 2020 & 2021)

Keywords: COVID-19 indicators; Group Multi-Criteria approach; Group AHP weighting method; VIKOR multi-criteria method

1. Introduction

The evolution of the pandemic generated by the Sars Cov 2 corona virus in different countries and continents differs, with Europe being the hardest hit continent. On March 29, 2021 the total number of COVID-19 cases

* Corresponding author. Tel.: +40-75-585-7943.
E-mail address: radulescucz@yahoo.com; zoie.radulescu@ici.ro.

1877-0509 © 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the The 8th International Conference on Information Technology and Quantitative Management (ITQM 2020 & 2021)
10.1016/j.procs.2022.01.019
was in Europe 39,173,670 (31%), Nord America 35,716,598 (28%), Asia 28,149,060 (22%), South America 20,906,315 (16%), Africa 4,227,930 (3%) and Oceania 56,329. A similar situation is for total deaths, active cases, and serious, critical cases. This situation posed many new challenges to European healthcare systems.

An important contribution in the elaboration of European policies is the understanding of the situation generated by the coronavirus infection (COVID-19) taking into account several points of view. Good and global indicators can help to understand political trade-offs. Based on such global indicators it will be possible to establish, at country level, the most appropriate policies to follow.

Obtaining global COVID-19 indicators is a multi-criteria analysis problem.

Some examples of research on COVID-19 problems which are solved based on multi-criteria analysis are: the calibration of an index able to predict the risk of contagion in urban districts [1], a utility-based multicriteria model to support the physicians to deal with the screening decision problem, due to the COVID-19 pandemic [2], analysis of European countries’ vulnerability to the associated consequences [3], evaluation the available COVID-19 treatment options [4], evaluating and benchmarking the different diagnostic models for COVID-19 [5], the effects of the COVID-19 on OECD countries' sustainable development [6].

The present paper proposes a Group Multi-Criteria Approach (GMC) approach for development of a country COVID-19 indicator called COPACOV (COuntry Performance Against COVID-19) indicator that is based on several country COVID-19 indicators measured separately, in a set of countries. COPACOV depends on a given set of countries, a given set of COVID-19 indicators and a time period. It can identify which countries are more vulnerable to COVID-19 illnesses from several points of view taken together.

GMC approach is based on a hybrid method composed from the GAHP weighting method and the VIKOR multi-criteria method. The experts' opinions, in GAHP method, are formulated with the help of the comparison in pair matrices. The aggregation of the comparison in pair matrices and the individual weights calculated for each expert are solved with the geometric mean method. This method is used also for overall weights calculation. The VIKOR method uses the overall weights calculated by the GAHP method and calculates the COPACOV indicator for each considered country. The proposed GMC approach is applied, on a case study, to the analysis of a set of COVID-19 indicators in a group of Eastern European countries.

This paper is organized as follows. In second section a GMC approach for calculation of a country COPACOV indicator, in a set of countries, is proposed. In this section are described the input data in the GMC approach, the computation of the AHP criteria weights for each expert based on the comparison in pair matrix, the aggregation of criteria weights and the computation of overall criteria weights. In the third section the GMC approach is implemented for ranking a set of 12 Est-European Countries and 7 COVID-19 indicators (criteria). The paper ends with a section dedicated to conclusions.

2. The Group Multi-Criteria Approach

The pandemic generated by the Sars Cov 2 corona virus is monitored, at the level of each country, every day, by several COVID-19 indicators (criteria). The most used COVID-19 indicators, at country level are: total cases, daily cases, active cases, total deaths, daily deaths, deaths over 65 years, hospital beds occupied, tests performed, daily tests performed, total vaccinated people, number of daily vaccinated people, cases at ICU (Intensive Care Unit), etc. Considering the population of each country, each indicator can be calculated at the level of one million country population. Two types of indicators can be considered: those for which the decreasing values are better (example: daily new cases, daily deaths, etc.) and those for which the increasing values are better (example: the number of tests performed, number of vaccinated people, etc.). Each of these indicators give an order of the country’s performances against COVID-19.

The problem is to find a global COVID-19 indicator (COPACOV) that is based on several COVID-19 indicators obtained individually.
The above problem is a multi-criteria problem in which the set of COVID-19 indicators can be considered a set of criteria and the set of countries, for which the analysis is done, can be considered as a set of alternatives. When there are a lot of alternatives and several often-conflicting criteria, there is the problem of ranking these alternatives to consider all the criteria. A general score (COPACOV indicator) is thus calculated for each country. The calculation of such an overall score can be done by Multi-Criteria methods. As a result of applying a multi-criteria method, a ranking of the alternatives is obtained, and the best alternative is found.

A weight can be associated for each criterion considered. The criteria weights can be calculated by weighting methods. A summary of criteria weighting methods is presented in [7], [8].

The determination of the weights can be performed by an expert (evaluator, decision maker) or by a group of experts (evaluators, decision makers). When the determination of weights is done by a group of experts, there is a problem of consensus between experts in calculating weights [9].

The proposed approach combines a group weighting method with a multicriteria analysis method. The selected group weighting method is the Group Analytic Hierarchy Process (GAHP) [10-11] and the multi-criteria method is the VIKOR method [12]. GAHP and VIKOR are two widely used methods that have proven effective in many areas.

The proposed GMC approach has the following stages:
1. Construction of input data in the GAHP method.
2. GAHP criteria weights calculation for each expert from the experts group.
3. Obtaining the total criteria weights by aggregation.
4. Construction of input data in the VIKOR method.
5. Calculation of VIKOR alternatives ranks.

2.1. GMC approach input data

The input data in GMC approach are:
- **E** - the set of \( p \geq 1 \) experts \( E = \{E_1, E_2, ..., E_p\}, |E| = p \). When there is more than one expert, to each expert \( E_i, i=1,2,..., p \) can be assigned a coefficient of authority (expert weight). The set of experts’ coefficients of authority is: \( D = \{d_1, d_2, ..., d_p\} \).
- The expert’s weights have a numerical values in the range (0,1). A condition for weights is:
  \[ \sum_{r=1}^{p} d_r = 1 \]
- **C** - the set of \( n \) criteria (COVID-19 indicators) \( C = \{C_1, C_2, ..., C_n\}, |C| = n \). Examples of criteria: total cases, daily cases, active cases, total deaths, daily deaths, tests performed, total vaccinated people, daily vaccinated people, cases at ICU. A criterion \( C_i \) from the set \( C \) is measured using a measure unit and can be of max (benefit) type or of min (cost) type. To each criterion can be associated a weight (coefficient of importance). The set of overall criteria weights is denoted by \( W = \{w_1, w_2, ..., w_n\} \). The weights have a numerical value in the range (0,1). A weighting method can be used based on experts’ evaluations to determine the criteria weights. In our approach the GAHP weighting method is used. A condition for the criteria weights is that \( \sum_{i=1}^{n} w_i = 1 \).
- **A** - the set of \( m \) countries. Denote by \( A = \{A_1, A_2, ..., A_m\}, |A| = m \). The countries are monitored.
- **Q** - the matrix of selected measured COVID-19 indicators: \( Q = (q_{ij}), i = 1,2,..., m; j = 1,2,..., n \) where \( q_{ij} \) is the value of indicator \( j \) for the alternative \( i \).
3.2. GMC approach criteria weights and COPACOV indicator

Each expert from the set $E$ of $p$ experts makes sets of comparisons between criteria from the criteria set $C$ based on Saaty’s 1 - 9 fundamental scale. For each expert $E_r$ from the set $E$ of $p$ experts a $n \times n$ pair-wise comparison matrix:

$$G^E_r = (g^E_{ij}); r=1,2, ... , p; i,j=1,2, ... , n$$

is obtained.

The entry $g^E_{ij}$ denotes the pair-wise comparison of the $E_r$-th expert on the degree the $C_i$-th criterion influences the $C_j$-th criterion on the Saaty’s scale.

Each matrix $G^E_r$ is verified for consistency. The maximum eigenvalue $\lambda^E_{\text{max}}$ and the consistency index $CR^E_r$ of matrix $G^E_r$ are computed:

$$CI^E_r = \frac{\lambda^E_{\text{max}}-n}{n-1}; CR^E_r = \frac{CI^E_r}{RI}$$

RI - the Random Index is obtained from a predefined table [10]. If $CR^E_r \leq 0.1$ then the matrix $G^E_r$ is consistent that it is considered acceptable. If $CR^E_r > 0.1$ then the expert $E_r$ must correct the pair-wise comparison.

In the GMC approach the method for computing the weights is the geometric mean.

For each expert $E_r$ the criteria weights from the set:

$$W^E_r = \{w^E_{1r}, w^E_{2r}, ... , w^E_{nr}\}; r = 1,2, ... , p$$

are calculated as follows:

$$i^E_r = \left(\prod_{i=1}^{n} g^E_{ij} \right)^{1/n}, i = 1,2, ... , n; r = 1,2, ... , p$$

$$w^E_i = i^E_r / \sum_{j=1}^{n} i^E_{ij}, \quad i = 1,2, ... , n; r = 1,2, ... , p$$

There are several methods to obtain a experts group valuation. Some of them are: consensus between experts; compromise or voting when consensus cannot be reached; aggregation on individual judgements; aggregation of individual weights and consideration of interval judgements [13].

The aggregation in GAHP can be viewed from two points of view: (a) the aggregation of the comparison matrices in pairs and the calculation of the criteria weights and (b) the aggregation of the criteria weights calculated for each expert and then the calculation of the overall criteria weights.

If the authority coefficients $d_1, d_2, ... , d_p$ are considered then, in the first point of view, the comparison matrix in pairs for group of experts, $G = (g_{ij})$ will be calculated as follows:

$$g_{ij} = \prod_{r=1}^{p} (g^E_{ij})^{d_r}, i,j = 1,2, ... , n$$

For equal authority coefficients then:

$$g_{ij} = \prod_{r=1}^{p} (g^E_{ij})^{1/p}, i,j = 1,2, ... , n$$
Then total criteria weights are calculated using one of the existing weighting methods. In the second point of view, the criteria weights are first obtained for each expert and then they are aggregated to obtain the total criteria weights \( W = \{w_1, w_2, \ldots, w_n\} \) for the group of experts:

\[
    w_i = \prod_{r=1}^{p} (w_i^E)^{d_r}, \quad i = 1,2, \ldots, n
\]

For equal authority coefficients then:

\[
    w_i = \prod_{r=1}^{p} (w_i^E)^{1/p}, \quad i = 1,2, \ldots, n
\]

Then VIKOR solutions and ranks are calculated. Each VIKOR solution can be considered a COPACOV indicator.

### 3. Case Study

The problem is to find a ranking of a set of countries in context of the COVID-19 pandemic considering a set of indicators at the same time and computing COPACOV indicators.

The GMC approach is implemented for ranking and analysis of a set of 12 East-European Countries and 7 COVID-19 criteria. The COVID-19 data from the analyzed set are built from data taken from [14-15]. These databases contain real-time data about COVID-19 indicators from European countries.

The criteria considered are from the set \( C \): Active Cases / 1 Million population (\( C_1 \)), Serious-Critical/1 Million population (\( C_2 \)), Total Cases/1 Million population (\( C_3 \)), Total Deaths/1 Million population (\( C_4 \)), Total Tests/1 Million population (\( C_5 \)), New Deaths/1 Million population (\( C_6 \)), New Cases/ 1 Million population (\( C_7 \)). These criteria can be compared between them because they are calculated in relation 1 Million population of a country (per 1 million inhabitants).

For the calculation of the criteria weights, a group of 3 experts in the field \( E_r, r = 1,2,3 \) is selected. Each of them evaluates in pairs the criteria considered according to Saaty's scale and build three matrices in pairs comparison \( G_E^1, G_E^2, G_E^3 \). Each matrix is verified for consistency. All matrices \( G_E^1, G_E^2, G_E^3 \) are consistent. The consistency ratio for matrix \( G_E^1 \) is \( CR_E^1 = 10\% \), for matrix \( G_E^2 \) is \( CR_E^2 = 9\% \), and for matrix \( G_E^3 \) is \( CR_E^3 = 10\% \). Consistency rates are calculated based on the equation (1).

These comparison in pairs matrices are aggregated with the geometric mean method (equation (5)) and the aggregated in pairs comparison matrix are presented in Table 1.

Table I. The aggregated comparison in pairs matrix

| Criteria | \( C_1 \) | \( C_2 \) | \( C_3 \) | \( C_4 \) | \( C_5 \) | \( C_6 \) | \( C_7 \) |
|----------|----------|----------|----------|----------|----------|----------|----------|
| \( C_1 \) | 1        | 0.32183  | 2.289428 | 0.189479 | 1.44225  | 0.178781 | 0.281144 |
| \( C_2 \) | 3.107233 | 1        | 3.107233 | 0.333333 | 5        | 0.329317 | 0.522758 |
| \( C_3 \) | 0.43679  | 0.32183  | 1        | 0.142857 | 1.100642 | 0.36246  | 0.281144 |
| \( C_4 \) | 5.277632 | 3        | 7        | 1        | 3.556893 | 0.829827 | 1.957434 |
| \( C_5 \) | 0.693361 | 0.2      | 0.90856  | 0.281144 | 1        | 0.251316 | 0.281144 |
| \( C_6 \) | 5.593445 | 3.036589 | 2.758924 | 1.205071 | 3.979057 | 1        | 2.154435 |
| \( C_7 \) | 3.556893 | 1.912931 | 3.556893 | 0.510873 | 3.556893 | 0.464159 | 1        |
For each expert $E_r$, $r = 1, 2, 3$ the criteria weights $w^{E_r}_i$ and aggregated criteria weights are calculated based on geometric mean method (formula (7)). The results are presented in Table 2.

Table 2. Experts’ criteria weights

|     | $w^1$ | $w^2$ | $w^3$ | $w^4$ | $w^5$ | $w^6$ | $w^7$ |
|-----|-------|-------|-------|-------|-------|-------|-------|
| $W^1$ | 0.041 | 0.201 | 0.062 | 0.343 | 0.052 | 0.213 | 0.087 |
| $W^2$ | 0.063 | 0.117 | 0.052 | 0.34  | 0.046 | 0.201 | 0.18  |
| $W^3$ | 0.058 | 0.078 | 0.028 | 0.136 | 0.041 | 0.389 | 0.27  |
| $W$   | 0.058 | 0.131 | 0.048 | 0.276 | 0.048 | 0.273 | 0.167 |

The set of alternatives is a set of 12 Est-European countries (in alphabetic order): Bulgaria (A1), Croatia (A2), Czechia (A3), Hungary (A4), Moldova (A5), North Macedonia (A6), Poland (A7), Romania (A8), Serbia (A9), Slovakia (A10), Slovenia (A11), Ukraine (A12) (Fig. 1).

The period considered is from February 15, 2021 to March 28, 2021 (6 weeks). For each week the $Q$-matrix of selected measured COVID-19 indicators is build: $Q = (q_{ij})$, $i = 1, 2, \ldots, 12$; $j = 1, 2, \ldots, 7$ where $q_{ij}$ is the value of indicator $j$ for the country $i$.

They are two types of indicators: minimization indicators (those for which the decreasing values are better: Active Cases/1 Million population (C1), Serious-Critical/1 Million population (C2), Total Cases/1 Million population (C3), Total Deaths/1 Million population (C4), New Deaths/1 Million population (C6), New Cases/1 Million population (C7)) and maximization indicators (those for which the increasing values are better: Total Tests/1 Million population (C5)). Normalization of the matrix Q uniformizes the two types of indicators. As a result, all indicators will be of the same type.

The COPACOV indicators for each country and period, including all the criteria considered are calculated based on VIKOR method [12]. These VIKOR solutions can be considered COPACOV indicators.

The ranks of the obtained VIKOR solutions (COPACOV indicators) are calculated. This ranks are compared with the ranks for each criterion, for the sixth weeks (Table 3).
For each expert $E_{Err}, r = 1, 2, 3$ the criteria weights $w_{Erro}$ and aggregated criteria weights are calculated based on geometric mean method (formula (7)). The results are presented in Table 2.

Table 2. Experts’ criteria weights

|   | $w_1$ | $w_2$ | $w_3$ | $w_4$ | $w_5$ | $w_6$ | $w_7$ |
|---|--------|--------|--------|--------|--------|--------|--------|
| 1 | 0.41   | 0.20   | 0.06   | 0.34   | 0.05   | 0.21   | 0.09   |
| 2 | 0.06   | 0.11   | 0.05   | 0.34   | 0.04   | 0.20   | 0.18   |
| 3 | 0.06   | 0.07   | 0.02   | 0.13   | 0.04   | 0.39   | 0.27   |

The set of alternatives is a set of 12 Est-European countries (in alphabetic order): Bulgaria (A1), Croatia (A2), Czechia (A3), Hungary (A4), Moldova (A5), North Macedonia (A6), Poland (A7), Romania (A8), Serbia (A9), Slovakia (A10), Slovenia (A11), Ukraine (A12) (Fig. 1).

The period considered is from February 15, 2021 to March 28, 2021 (6 weeks). For each week the $Q$-matrix of selected measured COVID-19 indicators is built: $Q = (q_{ij}), i = 1, 2, \ldots, 12; j = 1, 2, \ldots, 7$ where $q_{ij}$ is the value of indicator $j$ for the country $i$.

They are two types of indicators: minimization indicators (those for which the decreasing values are better: Active Cases/1 Million population (C1), Serious-Critical/1 Million population (C2), Total Cases/1 Million population (C3), Total Deaths/1 Million population (C4), New Deaths/1 Million population (C6), New Cases/1 Million population (C7)) and maximization indicators (those for which the increasing values are better: Total Tests/1 Million population (C5)). Normalization of the matrix $Q$ uniformizes the two types of indicators. As a result, all indicators will be of the same type.

The COPACOV indicators for each country and period, including all the criteria considered are calculated based on VIKOR method [12]. These VIKOR solutions can be considered COPACOV indicators.

The ranks of the obtained VIKOR solutions (COPACOV indicators) are calculated. This ranks are compared with the ranks for each criterion, for the sixth weeks (Table 3).

Table 3. Comparison between ranks of COPACOV indicators and the ranks for each criterion

| Nr. | Countries     | COPACOV indicators Ranks | Ranks for C1 | Ranks for C2 | Ranks for C3 | Ranks for C4 | Ranks for C5 | Ranks for C6 | Ranks for C7 |
|-----|---------------|--------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1   | Bulgaria      | 12                       | 7            | 9            | 2            | 9            | 4            | 12           | 11           |
| 2   | Croatia       | 4                        | 1            | 3            | 7            | 6            | 6            | 4            | 2            |
| 3   | Czechia       | 10                       | 10           | 12           | 12           | 12           | 12           | 6            | 5            |
| 4   | Hungary       | 11                       | 12           | 11           | 9            | 11           | 10           | 10           | 12           |
| 5   | Moldova       | 5                        | 3            | 8            | 4            | 3            | 2            | 9            | 8            |
| 6   | North Macedonia | 9                        | 6            | 5            | 6            | 8            | 3            | 11           | 4            |
| 7   | Poland        | 6                        | 9            | 7            | 5            | 5            | 5            | 1            | 9            |
| 8   | Romania       | 2                        | 2            | 6            | 3            | 4            | 7            | 7            | 7            |
| 9   | Serbia        | 3                        | 8            | 2            | 10           | 1            | 8            | 5            | 10           |
| 10  | Slovakia      | 7                        | 11           | 10           | 8            | 7            | 9            | 8            | 1            |
| 11  | Slovenia      | 8                        | 4            | 4            | 11           | 10           | 11           | 2            | 3            |
| 12  | Ukraine       | 1                        | 5            | 1            | 1            | 2            | 1            | 3            | 6            |

One can easily see that the ranks, on each criterion taken separately, differ a lot. Compared to these, the COPACOV indicator considers all the criteria. For example, Romania has the rank 2 for Active Cases /1M pop (C1), the rank 7 for Serious-Critical/1M pop (C2), rank 3 for Tot Cases/1M pop (C3), rank 4 for Total Deaths/1M pop (C4), rank 7 for Total Tests/1M pop (C5), rank 2 for New Deaths/1M pop (C6) and rank 5 for New Cases/1M pop (C7). The COPACOV indicator for Romania is 2.
4. Conclusion

The paper proposes a new Group Multi-Criteria Approach for ranking of a set of Est European countries based on a calculated COPACOV indicator.

The main contributions of this research are described as follows: a group decision multi-criteria process is defined and formalized; a new GMC approach based on the hybrid method composed from GAHP and VIKOR methods is proposed; the GMC approach is applied in a case study for ranking of a set of Est European countries considering a COPACOV indicator. Matlab scripts were created to solve the hybrid method.

As far as we know, the approach proposed in this paper, that uses the COPACOV indicator is new. The GMC approach can identify which countries are more vulnerable to COVID-19 illnesses from several points of view taken together and can help decision makers to establish strategies for fighting against COVID-19.

Acknowledgements

The research reported in this paper was supported by project PN 19 37 04 01 “New solutions for complex problems in current ICT research fields based on modelling and optimization”, funded by the Romanian Core Program of the Ministry of Research and Innovation (MCI), 2019-2022.

References

[1] Sangiorgio V, Parisi F. A multicriteria approach for risk assessment of Covid-19 in urban district lockdown. Safety Science 2020;130, Article ID:104862.
[2] Roselli LRP, Frej EA, Ferreira RJP, Alberti AR, de Almeida AT. Utility-based multicriteria model for screening patients under the COVID-19 pandemic. Computational and Mathematical Methods in Medicine 2020; Article ID:9391251.
[3] Martí L, Puertas R. European countries’ vulnerability to COVID-19: multicriteria decision-making techniques. Economic Research-Ekonomska Istraživanja 2021;1-12.
[4] Yıldırım FS, Sayan M, Sanlidag T, Uzun B, Ozsahin DU, Ozsahin I. Comparative Evaluation of the Treatment of COVID-19 with Multicriteria Decision-Making Techniques. Journal of Healthcare Engineering 2021; Article ID 8864522.
[5] Arsalan M, Mubin O, Alnajjar F, Alsinglawi B. COVID-19 global risk: Expectation vs. reality. International journal of environmental research and public health 2020;17(15):5592.
[6] Abbey EJ, Khalifa BA, Oduwole MO, Ayeh SK, Nudotor RD, Salia EL, Lasisi O, Bennett S, Yusuf HE, Agwu AL, Karakousis PC. The Global Health Security Index is not predictive of coronavirus pandemic responses among Organization for Economic Cooperation and Development countries. PloS one 2020;15(10), Article ID:e0239398.
[7] Radulescu CZ, Radulescu M. Group decision support approach for cloud quality of service criteria weighting. Studies in Informatics and Control 2018;27(3):275-284.
[8] Zavadskas EK, Stević Z, Turskis Z, Tomasević M. A Novel Extended EDAS in Minkowski Space (EDAS-M) Method for Evaluating Autonomous Vehicles, Studies in Informatics and Control 2019, 28(3):255-264.
[9] Filip FG, Zamfirescu CB, Ciurea C. Computer-supported collaborative decision-making. Springer International Publishing; 2017.
[10] Saaty TL. The Analytic Hierarchy Process. NewYork: McGraw-Hill Press; 1980.
[11] Saaty TL. A scaling method for priorities in hierarchical structures, Journal of mathematical psychology 1977;15(3):234-281.
[12] Duckstein L, Serafin Opricovic S. Multiobjective Optimization in River Basin Development. Water Resources Research 1980;16(1):14–20.
[13] Escobar MT, Moreno-Jiménez JM. Aggregation of individual preference structures in AHP-group decision making. Group Decision and Negotiation 2007;16(4):287-301.
[14] Coronavirus Source Data, 2021, Available online: https://ourworldindata.org/coronavirus-source-data (Last accessed on 26 March 2021).
[15] Worldometer - Coronavirus Update (Live), 2021, Available online: https://www.worldometers.info/coronavirus/#countries, (Last accessed on 26 March 2021).