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Comparative analysis of TOPSIS, VIKOR and COPRAS methods for the COVID-19 Regional Safety Assessment

Seda Hezer[a], Emel Gelmez[b], Eren Özceylan[c,*]

[a] Department of Industrial Engineering, Konya Technical University, 42075 Konya, Turkey
[b] Department of Business Administration, Selçuk University, 42075 Konya, Turkey
[c] Department of Industrial Engineering, Gaziantep University, 27100 Gaziantep, Turkey

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ABSTRACT

COVID-19, which emerged in December 2019, has affected the entire world. Therefore, COVID-19 has been a subject of research in various disciplines, especially in the field of health. One of these studies was the report made by the Deep Knowledge Group (DKG) consortium in which safe regions for COVID-19 were determined. In the report, the main criteria of quarantine efficiency, government efficiency of risk management, monitoring and detection, health readiness, regional resilience, and emergency preparedness are used in the evaluation of countries and regions (alternatives). As the data and research structure used in this report are based on multi-criteria, the purpose of this study is to evaluate and analyse the safety levels of 100 regions in the world in terms of COVID-19 using Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), Vise Kriterijumsa Optimizacija I Kompromisno Resenje (VIKOR) and Complex Proportional Assessment (COPRAS) methods. The data and information required in the methods were obtained from a report prepared by the DKG. The results of the methods were compared with the ranking results presented in a report of the DKG. Accordingly, it has been observed that the method that provides the closest results to the results of the report is the COPRAS method, and the method that gives the most distant results is the VIKOR method.

Introduction

Coronavirus, or "COVID-19", emerged on 1 December 2019 in Wuhan, the capital of the Hubei region in China. This virus started to spread rapidly to China and other parts of the world at the beginning of 2020 [1], and the number of infected patients has increased exponentially [2]. Because the virus is highly contagious [3], effective treatment is urgently needed [4]. The effects of the novel coronavirus or the possible social consequences of this threat remain uncertain, and there is no vaccine yet [5]. As of 7 November 2020, 48,786,440 people have been diagnosed with COVID-19 in 219 regions worldwide, and 1,204,028 deaths have been reported [6]. The virus, which is spreading rapidly and affecting countries deeply, is the subject of numerous studies and is discussed in different disciplines.

One of the studies on COVID-19 was conducted by the DKG. The results of the research were presented in the "COVID-19 Regional Safety Assessment: Big Data Analysis of 200 Countries and Regions COVID-19 Safety Ranking and Risk Assessment" report [7]. The DKG report serves as a resource for governments to optimise security and stability during and after the pandemic. The DKG report enables governments to determine the best possible action plans to promote the health and economic well-being of the people in each region and reverse the damage indirectly caused by COVID-19 [7]. Accordingly, the report ranks 200 countries and regions using six main criteria. It was observed that multi-criteria decision-making (MCDM) methods can be applied to rank these countries and regions, and analyse these rankings, using the data presented in the DKG report. It is noted here that in the context of this study, the word "region" is used instead of "country".

MCDM is a technique designed to investigate several alternatives within multiple criteria and conflicting goals [8] and is used to solve complex problems [9] using different methods. These methods enable decision-makers to make a more logical and scientifically defensible decision by using a technical methodology employing technical knowledge [10]. Each method may produce equivalent results or different results. In this way, MCDM methods aid in solving a decision problem that often requires considering different perspectives [11].

* Corresponding author.
E-mail address: erenozceylan@gmail.com (E. Özceylan).

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Table 1
Regions by level [7].

Level type	Regions
Level 1	Australia, Austria, Canada, China, Denmark, Germany, Hong Kong, Hungary, Israel, Japan, New Zealand, Norway, Saudi Arabia, Singapore, South Korea, Switzerland, Taiwan, The Netherlands, United Arab Emirates, Vietnam.
Level 2	Bahrain, Croatia, Cyprus, Estonia, Finland, Georgia, Greece, Iceland, Ireland, Kuwait, Latvia, Liechtenstein, Lithuania, Luxembourg, Malaysia, Oman, Poland, Qatar, Slovenia, Turkey.
Level 3	Albania, Algeria, Andorra, Argentina, Armenia, Azerbaijan, Bahamas, Bangladesh, Belarus, Belgium, Bosnia and Herzegovina, Brazil, Bulgaria, Cambodia, Cayman Islands, Chile, Czech Republic, Ecuador, Egypt, France, Gibraltar, Greenland, Honduras, India, Indonesia, Iran, Italy, Jordan, Kazakhstan, Laos, Lebanon, Malta, Mexico, Moldova, Monaco, Mongolia, Montenegro, Morocco, Myanmar, Panama, Paraguay, Peru, Philippines, Portugal, Romania, Russia, San Marino, Serbia, Slovak Republic, South Africa, Spain, Sri Lanka, Sweden, Thailand, Tunisia, Ukraine, United Kingdom, United States, Uruguay, Vatican City.
Level 4	Afghanistan, Angola, Antigua and Barbuda, Aruba, Barbados, Belize, Benin, Bermuda, Bermuda, Bhutan, Bolivia, Botswana, British Virgin Islands, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Colombia, Comoros, Congo Rep., Costa Rica, Côte d'Ivoire, Cuba, Curaçao, Djibouti, Dominica, Dominican Republic, El Salvador, Equatorial Guinea, Eritrea, Ethiopia, Fiji, French Polynesia, Gabon, Gambia, Ghana, Grenada, Guam, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Iraq, Isle of Man, Jamaica, Kenya, Kyrgyzstan, Lesotho, Liberia, Libya, Madagascar, Malawi, Maldives, Mali, Mauritania, Mauritius, Micronesia Fed. Sts., Mozambique, Namibia, Nepal, New Caledonia, Nicaragua, Niger, Nigeria, North Korea, North Macedonia, Pakistan, Palau, Papua New Guinea, Rwanda, São Tomé and Principe, Senegal, Seychelles, Sierra Leone, Sint Maarten (Dutch part), Solomon Islands, Somalia, South Sudan, St. Kitts and Nevis, St. Lucia, St. Martin (French part), St. Vincent and Grenadines, Sudan, Suriname, Syrian Arab Republic, Tajikistan, Tanzania, Timor-Leste, Togo, Trinidad and Tobago, Turkmenistan, Uganda, Uzbekistan, Vanuatu, Venezuela RB, Yemen Rep., Zambia, Zimbabwe.

This study has two main aims. The first is to show that 100 regions presented in the DKG report can be solved using different MCDM methods. The second is to present different perspectives by diversifying the results about the rankings of the regions according to safety levels presented in the DKG report. In this study, region rankings were made using TOPSIS, VIKOR, and COPRAS methods to evaluate safe regions during the COVID-19 process. To the best of our knowledge, there have been no previous studies on the utilisation of MCDM techniques to determine safe regions within the scope of COVID-19.

The contributions of the study can be summarised as follows:

- Using the same data, multiple ranking alternatives within the same level are obtained, and these ranking alternatives will allow decision-makers to make different evaluations in terms of COVID-19.
- The measures taken by the upper-ranked regions in the fight against COVID-19 will guide the lower-ranked regions.
- The ranking results presented in this study will serve as a helpful resource to ensure stability and safety during and post-pandemic times.

Information about the research conducted by the DKG is provided in the second section of the paper. The third section presents the research methodology and information about the MCDM techniques to be used in this context. In the fourth section, we examine and evaluate the analyses. Finally, a general conclusion and further study suggestions are provided.

COVID-19 Regional Safety Assessment report

DKG is an organisation that includes commercial enterprises and companies together with non-governmental organisations. It works in the fields of artificial intelligence, investment technologies, financial technologies, and pharmaceuticals. In the report, published by the DKG on 3 June 2020, comprehensive research on COVID-19 in 200 countries and regions was conducted, and the regions were ranked under the title of "COVID-19 Regional Safety Assessment: Big Data Analysis of 200 Countries and Regions COVID-19 Safety Ranking and Risk Assessment" [7]. In the relevant research, 130 qualitative (exit strategy plan, state of emergency readiness, local vaccine development attempts, export-oriented region and other parameters) and quantitative (population density, number of cases, length of quarantine, literacy rate, number of hospital beds, number of doctors, and other parameters) parameters were used, and 200 regions were grouped into four different levels (Levels 1 to 4) according to the score value in terms of safe region. Level 1 consists of 20 regions with extremely high regional safety levels. Level 2 consists of 20 regions that do not have the same levels of security as the regions in Level 1 but score well in terms of regional safety. Level 3 consisted of 60 regions with fewer positive scores. The 100 regions with the least number of points constituted Level 4. The relevant levels and regions are listed in Table 1.

The 130 parameters used in the pre-analysis were classified under six main criteria: quarantine efficiency, government efficiency of risk management, monitoring and detection, health readiness, regional resilience, and emergency preparedness. *Quarantine efficiency* includes elements such as quarantine scale, quarantine timeline, and travel restriction. *The government efficiency of risk management* includes elements such as economic sustainability, the efficiency of the government structure, and preparedness for a pandemic. *Monitoring and detection* consist of elements such as monitoring systems and disaster management, the scope of diagnostic methods, and test efficiency. *Healthcare readiness* consists of elements such as COVID-19 equipment availability, mobilisation of new healthcare services, and the quantity and quality of medical staff. *Regional resilience* consists of factors such as the risk of infection spread, cultural characteristics and social discipline, and chronic diseases. *Emergency preparedness* consists of elements such as societal emergency resilience and emergency military mobilisation experience. The COVID-19 regional safety ranking hierarchy of the report is shown in Fig. 1.

As the report presents many criteria for decision-making, MCDM techniques can aid in making the rank list, considering the structure of the report and the determining criteria. Therefore, in this study, rankings were made using the data from the report [7] and MCDM techniques to determine the safe regions.

Methodologies

In this section, information about TOPSIS, VIKOR, and COPRAS methods are provided, which are MCDM techniques used in ranking the safe regions. Deterministic MCDM techniques are preferred because the data presented in the DKG report are deterministic. When the problem includes uncertainty, popular fuzzy MCDM methods [12–21] should be used to come with the imprecise data.

TOPSIS (Technique for Order Performance by Similarity to Ideal Solution)

Among the various MCDM techniques, the TOPSIS method has gained popularity because of its simple computational steps,

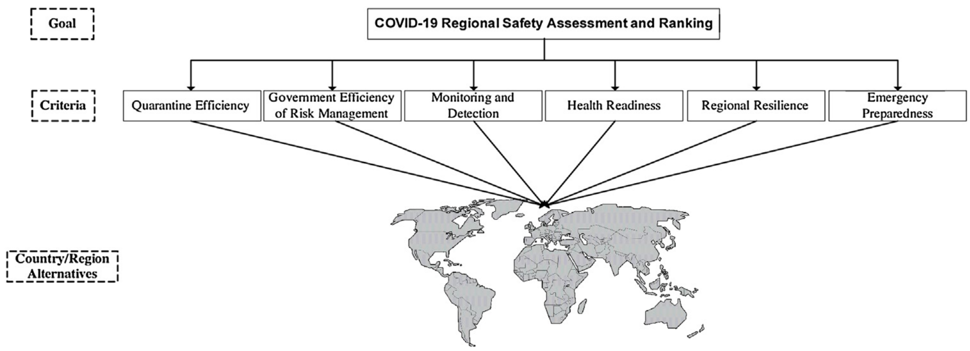


Fig. 1. COVID-19 regional safety ranking hierarchy.

solid mathematical foundations, and easy-to-understand method [22]. This method ranks the alternatives according to the distance between the positive and negative ideal solutions [23]. However, an alternative chosen while making a decision is expected to be close to the ideal solution and far from the non-ideal (negative ideal) solution [24]. The alternative that is closest to the positive ideal solution is also considered as the alternative that is the furthest from the negative ideal solution. The alternative closest to the positive ideal solution with the TOPSIS method is the best alternative [25]. The TOPSIS method can be used to evaluate decision-making units (DMUs). If m indicates the number of alternatives and n indicates the number of evaluation criteria, f_{ij} indicates the value of the jth alternative according to the ith criterion. The TOPSIS method consists of the following steps [23]:

Step 1. Decision matrix ($F = [f_{ij}]_{n\times m}$) is normalised.

$H = (h_{ij})_{n\times m}$ is defined as the normalised decision matrix, and the normalised criterion value h_{ij} is calculated using Eq. (1).

$$h_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{m}(f_{ij})^2}} \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, m \tag{1}$$

Step 2. The weighted normalised decision matrix is determined.

$V = (v_{ij})_{n\times m}$ is defined as the normalised weighted decision matrix of $H = (h_{ij})_{n\times m}$. When w_i is the weight of the ith criterion, the normalised weighted value is calculated using Eq. (2).

$$v_{ij} = w_i h_{ij} \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, m \tag{2}$$

Step 3. Positive-ideal and negative-ideal solutions are determined.

Positive-ideal and negative-ideal solutions were determined using Eqs. (3) and (4), respectively. Ω_b and Ω_c represent the sets of benefit type and cost type criteria, respectively.

$$A^* = \{v_1^*, \ldots, v_n^*\} = \left\{ \left(\max_i v_{ij} \middle| i \in \Omega_b \right), \left(\min_i v_{ij} \middle| i \in \Omega_c \right) \right\} \tag{3}$$

$$A^- = \{v_1^-, \ldots, v_n^-\} = \left\{ \left(\min_i v_{ij} \middle| i \in \Omega_b \right), \left(\max_i v_{ij} \middle| i \in \Omega_c \right) \right\} \tag{4}$$

Step 4. Euclidean distance is calculated from positive- and negative-ideal solutions.

The Euclidean distances of each alternative solution to the positive ideal (v_i^*) and negative ideal (v_i^-) solutions are calculated using Eqs. (5) and (6).

$$\beta_j^* = \sqrt{\sum_{i=1}^{n}(v_{ij} - v_i^*)^2} \quad j = 1, 2, \ldots, m \tag{5}$$

$$\beta_j^- = \sqrt{\sum_{i=1}^{n}(v_{ij} - v_i^-)^2} \quad j = 1, 2, \ldots, m \tag{6}$$

Step 5. Closeness to the ideal solution is calculated.

The closeness to the ideal solution formulated with Φ_j can be defined as shown in Eq. (7).

$$\Phi_j = \frac{\beta_j^-}{\beta_j^* + \beta_j^-} \quad j = 1, 2, \ldots, m \tag{7}$$

Step 6. The order of all alternatives is determined based on their relative closeness to the ideal solution. A larger Φ_j indicates a better A_j alternative. The best alternative is the one with the largest closeness to the ideal solutions.

The TOPSIS method can be applied with different evaluation criteria and is frequently used in practice. At this point, when the literature is examined, it is seen that the TOPSIS method is used in many areas such as the automotive sector [26], tourism [27], textiles [28], banking [29], the health sector [30], and the education sector [31].

VIKOR (Vise Kriterijumsa Optimizacija I Kompromisno Resenje)

The VIKOR method was developed for the multi-criteria optimisation of complex systems. It determines the compromise order list, the compromise solution, and the weight stability ranges for the preferred stability in the obtained compromise solution with the initial (given) weights. This method focuses on ordering and selecting a range of alternatives in the presence of conflicting criteria. It offers a multi-criteria ranking index based on the measure of "closeness" to the "ideal" solution [32]. This method is an effective tool used in MCDM, especially when the decision-maker cannot express their preferences at the beginning of the system design [33]. At the same time, this method focuses on ordering and choosing from a range of alternatives. It determines a compromise solution for problems with conflicting criteria that can help decision-makers reach a final solution [34]. The development of the VIKOR method starts with the $L_{p-metric}$ criterion form given by Eq. (8) [32]

$$L_{p,j} = \left\{ \sum_{i=1}^{n} \left[w_i (f_i^* - f_{ij}) / (f_i^* - f_i^-) \right]^p \right\}^{1/p} \quad 1 \le p \le \infty; \quad j = 1, 2, \ldots, m \tag{8}$$

In the VIKOR method, $L_{i,j}$ (S_j in Eq. (11)) and $L_{\infty,j}$ (R_j in Eq. (12)) ordering measurements were used by formulating. The aim is to obtain $\min_j S_j$ with maximum group utility ("majority" rule) and $\min_j R_j$ with minimal individual regret of the "opponent." The compromise solution F^c is the result closest to the ideal F^*. Compromise means an agreement with mutual concessions by $\Delta f_1 = f_1^* - f_1^c$ and $\Delta f_2 = f_2^* - f_2^c$ as shown in Fig. 2. The compromise ordering steps of VIKOR are as follows [32]:

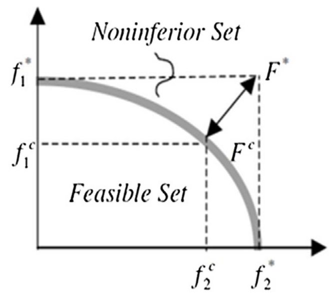


Fig. 2. Ideal and compromise solutions [32].

Step 1. The best (f_i^*) and worst (f_i^-) values of all the criteria functions were determined.

where $i = 1, 2, \ldots, n$, and the ith function represents a benefit. f_i^* and f_i^- are calculated using Eqs. (9) and (10), respectively, as follows:

$$f_i^* = \max_j f_{ij} \tag{9}$$

$$f_i^- = \min_j f_{ij} \tag{10}$$

Step 2. S_j and R_j values are calculated using Eqs. (11) and (12), respectively ($j = 1, 2, \ldots, m$).

$$S_j = \sum_{i=1}^{n} w_i (f_i^* - f_{ij})/(f_i^* - f_i^-) \tag{11}$$

$$R_j = \max_j \left[w_i (f_i^* - f_{ij})/(f_i^* - f_i^-) \right] \tag{12}$$

where w_i is the criterion weight, whose relative significance is expressed.

Step 3. The Q_j value is calculated using Eqs. (13)–(15) ($j = 1, 2, \ldots, m$):

$$S^* = \min_j S_j, \quad S^- = \max_j S_j \tag{13}$$

$$R^* = \min_j R_j, \quad S^- = \max_j R_j \tag{14}$$

$$Q_j = x(S_j - S^*)/(S^- - S^*) + (1 - v)(R_j - R^*)/(R^- - R^*) \tag{15}$$

where x represents the strategic weight of the majority of criteria (or maximum group utility). In this study, $x = 0.5$.

Step 4. Three ordering lists are created by arranging the S, R, and Q values of the alternatives in ascending order.

Step 5. If the two conditions stated below are met, alternative (a'), which ranks according to the best Q (minimum) values, is recommended as a compromise solution.

Condition 1. "Acceptable advantage"

a'' is the second alternative in the ranking list. Eqs. (16) and (17) need to be satisfied to fulfil Condition 1.

$$Q(a'') - Q(a') \geq DQ \tag{16}$$

$$DQ = \frac{1}{m - 1} \tag{17}$$

where m is the number of alternatives.

Condition 2. "Acceptable stability in decision making"

Alternative $a'$is the best alternative and must also be ranked according to the S and/or R values. This compromise solution is stable during the decision-making process. v is the weight of the decision-making strategy. If one of these conditions is not satisfied, a compromise set of solutions is suggested. This set of solutions includes the following:

- Alternative $a'$and a'' only if Condition 2 is not met.
- Alternatives $a', a'', \ldots, a^{(M)}$ if Condition 1 is not satisfied and $a^{(M)}$ is determined for the maximum M with $Q(a^{(M)}) - Q(a') < DQ$ relation (closeness to the positions of these alternatives).

The best alternative, ranked according to Q values, is the alternative with a minimum Q value. The main ranking result is a compromise solution with a compromise ranking list of alternatives and an "advantage ratio".

VIKOR is effective in a situation when the decision-maker is not aware of the design of the system. The compromise solution obtained is accepted by the decision-maker for the maximum group benefit of the majority (denoted by Eq. (11)) and the minimisation of the individual regrets of the opponents (denoted by Eq. (12)).

According to the literature, the VIKOR method is used in decision-making analyses in many studies in different disciplines, such as the automotive sector [35], the health sector [36], the banking sector [37], the textile sector [38], education sector [39], evaluation of countries in various ways [40], tourism sector [41], and evaluation of research and development performance [42].

COPRAS (Complex Proportional Assessment)

The "Complex Proportional Assessment" or COPRAS method was introduced by Zavadskas and Kaklauskas [43] and was used to evaluate the superiority of one alternative over another and makes it possible to compare alternatives [44]. This method can be applied to maximise or minimise criteria in an assessment where more than one criterion should be considered [45]. The COPRAS method ranks and evaluates alternatives step-by-step for their importance and utility degree [46]. The steps of the COPRAS method are as follows [47]:

Step 1. Decision matrix ($F = [f_{ij}]_{n \times m}$) is normalised using Eq. (18).

The normalised decision matrix is denoted by $G = [g_{ij}]_{n \times m}$. The purpose of normalisation is to obtain different dimensionless values to compare all criteria.

$$g_{ij} = f_{ij} / \sum_{j=1}^{m} f_{ij} \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, m \tag{18}$$

Step 2. The weighted normalised decision matrix $Y = [y_{ij}]_{n \times m}$ was determined using Eq. (19).

$$y_{ij} = w_i f_{ij} \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, m \tag{19}$$

Where g_{ij} is the normalised value of jth alternative according to ith criterion.

Step 3. The sums of the weighted normalised values were calculated for both the beneficial and non-beneficial criteria. These sums were calculated using Eqs. (20) and (21).

$$K_{+j} = \sum_{i=1}^{n} y_{+ij} \tag{20}$$

$$K_{-j} = \sum_{i=1}^{n} y_{-ij} \tag{21}$$

where y_{+ij} and y_{-ij} are the weighted normalised values of the beneficial and non-beneficial criteria, respectively. The larger the K_{+j} value and the lower the K_{-j} value, the better the alternative. The values of K_{+j} and K_{-j} indicate the degree of goals reached by each alternative.

Step 4. The significance of the alternatives is determined by defining the characteristics of the positive alternatives K_{+j} and negative alternatives K_{-j}.

Step 5. The relative significance or priorities of the alternatives were determined. The priorities of the candidate alternatives were calculated based on C_j. The higher the C_j value, the higher is the priority of the alternative. The relative significance of an alternative shows the degree to which it fulfils the demand provided by that alternative. The alternative with the highest relative significance value (C_max) is the best choice among the candidate alternatives. The relative significance value of the jth alternative, C_j, was calculated using Eq. (22).

$$C_j = K_{+j} + \left(\left(K_{-\min} \sum_{j=1}^{m} K_{-j} \right) / \left(K_{-j} \sum_{j=1}^{m} (K_{-\min}/K_{-j}) \right) \right) \quad j = 1, 2, \ldots, m \tag{22}$$

where $K_{-\min}$ is the minimum value of K_{-j}.

Step 6. The quantitative utility (U_j) was calculated for the j_{th} alternative. The utility level of an alternative is causally related to its relative significance value (C_j). The degree of utility of an alternative, determining the rank of the alternative, is determined by comparing the priorities of all alternatives for efficiency. It is calculated using Eq. (23).

$$U_j = \left[\frac{C_j}{C_{\max}} \right] \times 100 \tag{23}$$

where C_{max} is the maximum relative significance value. As the relative significance value increases or decreases for an alternative, its utility value also increases or decreases. The utility value ranges from 0 to 100%. For this reason, this approach allows the evaluation of direct and proportional significance and utility degrees of weight and performance values according to all criteria in a decision-making problem where more than one criterion is involved [47].

COPRAS is used in decision making analyses in various fields and subjects such as the construction sector [48], investment projects [49], prototyping system selection [50], supplier selection [51], material selection problem [52].

MCDM techniques can be used to solve problems related to the COVID-19 pandemic in health [53–56], education [57], and various fields [58,59]. The purpose and the methods used for some of these studies are summarised and presented in the subsequent paragraphs.

Albahri et al. [55] present a systematic approach to evaluate and compare various artificial intelligence techniques used to detect and classify medical images of the novel coronavirus. VIKOR methods were used for the process. Further, the analytic hierarchy process (AHP) was used in weighting.

In the study by Vinodhini [58], MCDM techniques such as Weighted Sum Model (WSM), Weighted Product Model (WPM), Weighted Aggregated Sum Product Assessment (WASPAS), and TOPSIS were used, and regions were listed according to control measures implemented to stop the spread of COVID-19.

Korzeb and Niedziółka [59] used the Hellwig and TOPSIS method to evaluate the preventive measure taken by Polish commercial banks to avoid the potential negative impact caused by the COVID-19 pandemic.

Sayan et al. [54] compared the existing SARS-CoV-2 diagnostic tests and determined the most effective test among them through enrichment evaluation (fuzzy PROMETHEE) and fuzzy TOPSIS methods.

Majumder et al. [53] used MCDM techniques to determine the most important risk factor in COVID-19 and continuously monitor deaths caused by the virus. The new TOPSIS method and group method of data handling (GMDH) were used in the study.

Alqahtani and Rajkhan [57] carried out their study to identify critical success factors for e-learning during COVID-19 using multi-criteria AHP and TOPSIS techniques to improve the education process.

Shirazi et al. [56] used the fuzzy AHP-PROMETHEE hybrid approach to evaluate hospitals for patient satisfaction during the COVID-19 pandemic in one of the cities in Iran. For this study, patient satisfaction factors were determined primarily under normal conditions. Patient satisfaction factors were then determined during the COVID-19 pandemic. Hospitals were ranked for patient satisfaction under normal conditions and the COVID-19 pandemic situation using the FAHP-PROMETHEE approach.

Based on the literature review, TOPSIS, VIKOR, and COPRAS methods, which are popular MCDM techniques, were chosen to determine the safety levels of 100 regions for COVID-19. Further, the results obtained were evaluated by comparing them with the report used to obtain the data. This study is unique as a limited number of studies have used MCDM techniques to determine safe regions study for COVID-19 pandemic. This study would be a significant contribution to the literature.

Application of methodologies

This section consists of three subsections. In the first subsection, brief information is provided regarding the alternatives considered. In the second subsection, information regarding the criteria and weights used in this study is presented in detail. In the concluding section, the results are presented.

Study region

A total of 100 regions in Level 1 (20 regions), Level 2 (20 regions), and Level 3 (60 regions), which are explained in detail in the second part, constitute the alternatives of the study. Regions in Level 4 (100 regions) are not considered because the data needed for the TOPSIS, VIKOR, and COPRAS methods are insufficient.

Evaluation criteria and data

The evaluation criteria used for the study were based on the six categories mentioned in the DKG report (2020). The values of each alternative for Level 1, Level 2, and Level 3 are presented in Table A1, Table A2, and Table A3, respectively, and the details are given in the Appendix.

Two different prioritizations are considered in this study. In the first prioritisation, the criterion weights suggested by the DKG are normalised, and in the second prioritisation, analyses are carried out with the assumption that all criteria weights are equal. In the applied methods, the criteria should be specified according to their orientation for benefit or cost. The criterion with the smallest (least cost) value in cost-oriented criteria and the criterion with the highest (the most benefit) value in benefit-oriented criteria should be determined as the best criterion. The six criteria used in this study are benefit-oriented in achieving the objective of the study (ensuring regional safety in terms of COVID-19). In other words, the high values of these criteria aid in determining the best alternative. The criteria used in this study and their weights are listed in Table 2.

Findings

In this section, the TOPSIS, VIKOR, and COPRAS methods are applied to compare and rank the alternatives. The ranking results obtained were analysed for methods used and compared with the ranking results given in the report presented by DKG [7].

Six applications (TOPSIS_NW, TOPSIS_EW, VIKOR_NW, VIKOR_EW, COPRAS_NW, and COPRAS_EW) were applied because

Table 2
The weights of criteria.

Criteria	Normalised weight (NW)	Equal weight (EW)
Quarantine Efficiency	0.22	0.16
Government Efficiency of Risk Management	0.22	0.16
Monitoring and Detection	0.15	0.16
Emergency Preparedness	0.15	0.16
Healthcare Readiness	0.13	0.16
Regional Resiliency	0.13	0.16

each method considers two prioritizations. Each application is applied by considering three levels (Level 1, Level 2, and Level 3) independent of each other. The results obtained for Level 1, Level 2, and Level 3 are given in Tables 3–5, respectively. Each of the three tables consists of 14 columns in which the ranking results of the DKG report [7] are given in the first 2 columns. Normalised results obtained by applying equal weights are presented for the TOPSIS method in the third, fourth, and fifth columns, for the VIKOR method in the next four columns, and the COPRAS method in the last four columns. In the rows, the alternatives included in Level 1 are given in Table 3, Level 2 is given in Table 4, and Level 3 is given in Table 5.

According to Table 3,

- As in the DKG report, *Switzerland* ranked first in all methods and prioritisation.
- The ranking of the six regions for normalised weights (Netherlands, Switzerland, New Zealand, South Korea, Republic of Korea, Norway, Vietnam) and four regions for equal weights (Switzerland, Norway, Denmark, Netherlands, Vietnam) using TOPSIS method, the ranking of the two regions for normalised weights (Switzerland, Australia) and two regions for

Table 3
Ranking of regions of Level 1 based on TOPSIS, VIKOR and COPRAS.

DKG report [7]		TOPSIS				VIKOR				COPRAS			
Rn	Alternatives	NW		EW		NW		EW		NW		EW	
		Φ_j	Rn	Φ_j	Rn	Q_j	Rn	Q_j	Rn	U_j	Rn	U_j	Rn
1	Switzerland	0.626	1	0.623	1	0.013	1	0.029	1	1.000	1	1.000	1
2	Germany	0.566	5	0.581	5	0.196	3	0.376	7	0.992	2	0.999	2
3	Israel	0.602	2	0.600	2	0.312	4	0.146	3	0.985	4	0.986	3
4	Singapore	0.560	7	0.555	8	0.036	2	0.088	2	0.985	3	0.986	4
5	Japan	0.568	4	0.593	3	0.386	6	0.220	4	0.975	5	0.984	5
6	Austria	0.570	3	0.590	4	0.590	11	0.510	9	0.961	6	0.966	6
7	China	0.549	8	0.560	6	0.712	14	0.663	11	0.945	9	0.949	8
8	Australia	0.560	6	0.555	7	0.431	8	0.736	15	0.951	8	0.949	9
9	New Zealand	0.521	9	0.510	11	0.406	7	0.260	6	0.953	7	0.950	7
10	South Korea	0.513	10	0.542	9	0.749	15	0.721	14	0.938	10	0.945	10
11	United Arab Emirates	0.464	12	0.511	10	0.777	16	0.693	13	0.923	12	0.940	11
12	Canada	0.445	13	0.444	13	0.440	9	0.236	5	0.923	11	0.922	12
13	Hong Kong	0.467	11	0.446	12	0.325	5	0.426	8	0.922	13	0.916	13
14	Norway	0.416	14	0.415	14	0.541	10	0.657	10	0.906	14	0.903	14
15	Denmark	0.370	17	0.390	17	0.640	12	0.678	12	0.891	15	0.892	15
16	Taiwan	0.389	15	0.373	18	0.910	18	0.922	19	0.877	16	0.869	18
17	Saudi Arabia	0.370	18	0.393	15	0.945	20	0.903	18	0.869	17	0.875	16
18	Hungary	0.379	16	0.392	16	0.914	19	0.856	16	0.868	18	0.869	17
19	Netherlands	0.333	19	0.361	19	0.689	13	0.922	20	0.863	19	0.862	19
20	Vietnam	0.275	20	0.274	20	0.886	17	0.859	17	0.844	20	0.837	20

*Rn: Rank.

Table 4
Ranking of regions of Level 2 based on TOPSIS, VIKOR and COPRAS.

DKG report [7]		TOPSIS				VIKOR				COPRAS			
Rn	Alternatives	NW		EW		NW		EW		NW		EW	
		Φ_j	Rn	Φ_j	Rn	Q_j	Rn	Q_j	Rn	U_j	Rn	U_j	Rn
1	Kuwait	0.722	1	0.712	1	0.004	1	0.000	1	1.000	1	1.000	1
2	Iceland	0.500	3	0.492	3	0.139	2	0.489	3	0.936	2	0.934	3
3	Bahrain	0.579	2	0.607	2	0.504	12	0.467	2	0.932	3	0.939	2
4	Finland	0.450	7	0.480	4	0.244	3	0.559	5	0.908	4	0.914	4
5	Luxembourg	0.408	10	0.432	6	0.271	4	0.577	6	0.896	6	0.900	5
6	Qatar	0.454	6	0.431	7	0.326	6	0.523	4	0.899	5	0.890	6
7	Liechtenstein	0.423	8	0.402	9	0.329	7	0.706	7	0.892	7	0.885	8
8	Poland	0.399	11	0.337	18	0.274	5	0.764	11	0.885	10	0.867	14
9	Lithuania	0.376	12	0.388	10	0.787	18	0.772	12	0.875	11	0.877	9
10	Malaysia	0.463	5	0.402	8	0.481	11	0.837	16	0.890	8	0.875	10
11	Latvia	0.367	13	0.325	19	0.335	8	0.720	8	0.874	13	0.861	17
12	Slovenia	0.359	16	0.379	11	0.735	17	0.744	10	0.872	14	0.874	11
13	Oman	0.464	4	0.469	5	0.626	14	0.848	18	0.886	9	0.885	7
14	Greece	0.365	14	0.362	14	0.455	10	0.843	17	0.870	15	0.865	15
15	Estonia	0.344	18	0.342	16	0.420	9	0.794	13	0.868	16	0.864	16
16	Croatia	0.342	19	0.377	12	0.790	19	0.826	14	0.862	17	0.867	12
17	Turkey	0.410	9	0.377	13	0.707	15	0.738	9	0.875	12	0.867	13
18	Ireland	0.328	20	0.345	15	0.526	13	0.894	19	0.856	19	0.856	18
19	Georgia	0.364	15	0.340	17	1.000	20	1.000	20	0.848	20	0.840	20
20	Cyprus	0.346	17	0.317	20	0.720	16	0.831	15	0.857	18	0.849	19

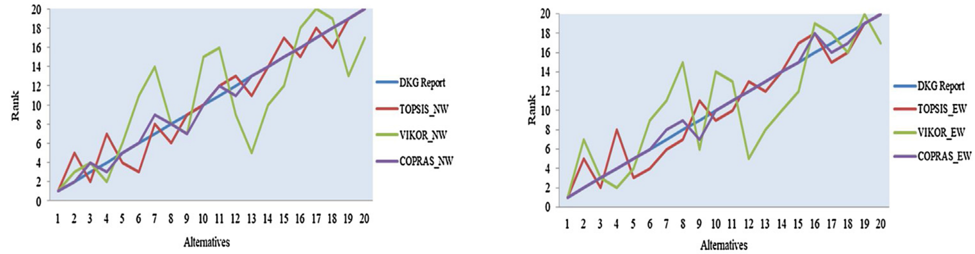
Table 5
Ranking of regions of Level 3 based on TOPSIS, VIKOR and COPRAS.

DKG report [7]		TOPSIS				VIKOR				COPRAS			
Rn	Alternatives	NW		EW		NW		EW		NW		EW	
		Φ_j	Rn	Φ_j	Rn	Q_j	Rn	Q_j	Rn	U_j	Rn	U_j	Rn
1	Chile	0.538	9	0.532	19	0.114	3	0.187	3	0.940	4	0.915	11
2	Montenegro	0.556	3	0.575	7	0.312	13	0.219	5	0.946	2	0.936	2
3	Czech Republic	0.548	5	0.585	6	0.181	6	0.227	7	0.941	3	0.936	4
4	Malta	0.538	10	0.538	16	0.249	7	0.553	29	0.936	5	0.912	13
5	Spain	0.548	6	0.598	5	0.267	9	0.129	2	0.933	7	0.934	6
6	Portugal	0.554	4	0.560	12	0.117	4	0.271	11	0.936	6	0.918	10
7	Thailand	0.500	19	0.527	22	0.292	12	0.265	9	0.923	10	0.911	14
8	Bulgaria	0.527	13	0.567	8	0.288	10	0.317	16	0.929	8	0.924	8
9	Greenland	0.545	7	0.616	2	0.575	31	0.487	23	0.924	9	0.936	3
10	Mexico	0.490	22	0.488	31	0.081	1	0.225	6	0.915	16	0.896	21
11	Uruguay	0.523	15	0.514	25	0.113	2	0.255	8	0.918	14	0.896	22
12	Vatican City	0.503	18	0.518	23	0.377	21	0.293	12	0.919	13	0.907	16
13	Italy	0.527	14	0.564	10	0.265	8	0.120	1	0.920	11	0.914	12
14	Serbia	0.490	21	0.557	13	0.375	20	0.335	17	0.911	18	0.918	9
15	Philippines	0.529	11	0.532	18	0.361	18	0.268	10	0.915	15	0.909	15
16	India	0.562	2	0.529	21	0.338	15	0.687	40	0.919	12	0.899	20
17	Romania	0.491	20	0.489	30	0.147	5	0.314	15	0.907	21	0.887	26
18	Slovakia	0.483	25	0.490	29	0.290	11	0.309	13	0.909	20	0.889	25
19	United States	0.542	8	0.615	3	0.731	48	0.680	39	0.911	19	0.931	7
20	France	0.655	1	0.691	1	0.500	26	0.500	26	1.000	1	1.000	1
21	Russia	0.528	12	0.613	4	0.697	44	0.636	36	0.912	17	0.936	5
22	Argentina	0.479	27	0.540	15	0.369	19	0.368	19	0.899	22	0.901	18
23	Belarus	0.484	24	0.530	20	0.436	24	0.337	18	0.899	23	0.893	23
24	Monaco	0.481	26	0.500	27	0.410	22	0.311	14	0.897	25	0.886	28
25	Sweden	0.476	29	0.555	14	0.589	32	0.490	25	0.892	27	0.904	17
26	Ukraine	0.477	28	0.518	24	0.332	14	0.435	22	0.894	26	0.886	27
27	Gibraltar	0.509	16	0.561	11	0.731	47	0.696	41	0.898	24	0.900	19
28	United Kingdom	0.508	17	0.566	9	0.749	50	0.698	42	0.888	28	0.892	24
29	South Africa	0.439	33	0.451	39	0.345	16	0.215	4	0.879	29	0.867	32
30	San Marino	0.455	31	0.465	36	0.361	17	0.371	20	0.879	30	0.861	33
31	Kazakhstan	0.465	30	0.514	26	0.597	34	0.506	27	0.872	32	0.874	30
32	Bosnia and Herzegovina	0.453	32	0.491	28	0.650	40	0.590	32	0.876	31	0.870	31
33	Iran	0.488	23	0.534	17	0.649	39	0.779	49	0.871	33	0.877	29
34	Ecuador	0.419	36	0.442	41	0.538	29	0.513	28	0.861	34	0.849	38
35	Azerbaijan	0.424	35	0.486	32	0.531	28	0.404	21	0.859	36	0.860	34
36	Mongolia	0.404	39	0.462	37	0.697	45	0.641	37	0.853	38	0.852	37
37	Lebanon	0.408	37	0.467	34	0.658	41	0.568	30	0.853	37	0.853	36
38	Belgium	0.435	34	0.484	33	0.645	38	0.701	43	0.860	35	0.855	35
39	Andorra	0.390	40	0.443	40	0.572	30	0.489	24	0.848	39	0.845	39
40	Cayman Islands	0.407	38	0.457	38	0.733	49	0.704	44	0.843	40	0.838	41
41	Armenia	0.383	41	0.466	35	0.821	54	0.737	47	0.827	43	0.838	40
42	Moldova	0.375	44	0.420	45	0.636	35	0.576	31	0.832	41	0.823	43
43	Myanmar	0.349	48	0.320	54	0.431	23	0.618	34	0.821	45	0.795	51
44	Bangladesh	0.380	43	0.370	49	0.516	27	0.628	35	0.830	42	0.808	46
45	Sri Lanka	0.352	47	0.339	51	0.471	25	0.653	38	0.823	44	0.796	50
46	Egypt	0.320	53	0.350	50	0.591	33	0.592	33	0.810	49	0.799	48
47	Tunisia	0.367	46	0.438	42	0.804	52	0.709	46	0.817	46	0.823	42
48	Albania	0.382	42	0.428	43	0.889	57	0.889	53	0.817	47	0.811	44
49	Jordan	0.330	51	0.392	47	0.857	55	0.802	50	0.807	50	0.809	45
50	Panama	0.344	49	0.391	48	0.721	46	0.897	54	0.805	51	0.796	49
51	Brazil	0.375	45	0.421	44	0.929	59	0.884	52	0.812	48	0.806	47
52	Morocco	0.315	55	0.292	55	0.690	43	0.706	45	0.797	52	0.771	53
53	Algeria	0.338	50	0.403	46	0.864	56	0.931	56	0.789	53	0.789	52
54	Honduras	0.298	56	0.284	56	0.812	53	0.765	48	0.785	54	0.762	55
55	Paraguay	0.316	54	0.332	52	0.986	60	0.953	58	0.780	55	0.765	54
56	Peru	0.298	57	0.328	53	0.919	58	0.966	59	0.774	56	0.761	56
57	Indonesia	0.252	59	0.262	58	0.777	51	0.810	51	0.768	57	0.749	57
58	Cambodia	0.273	58	0.270	57	0.640	36	0.920	55	0.767	58	0.739	58
59	Laos	0.246	60	0.205	60	0.642	37	0.934	57	0.752	60	0.713	60
60	Bahamas	0.326	52	0.248	59	0.683	42	1.000	60	0.765	59	0.717	59

equal weights using (Switzerland, Israel) the VIKOR method, and ranking of 14 regions for normalised weights (Switzerland, Germany, Japan, Austria, Australia, South Korea Republic of Korea, Hong Kong, Norway, Denmark, Taiwan, Saudi Arabia, Hungary, Netherlands, Vietnam) and 14 regions for equal weights (Switzerland, Germany, Israel, Singapore, Japan, Austria, South Korea Republic of Korea, United Arab Emirates, Canada, Hong Kong, Norway, Denmark, Netherlands, Vietnam) using the COPRAS method are the same as those in the DKG report.

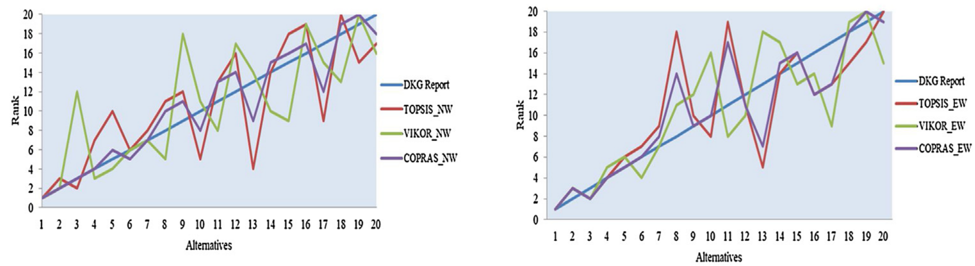
- The ranking of 13 regions (South Korea, Republic of Korea, Norway, the Netherlands, Vietnam, Germany, Japan, Austria, Australia, Hong Kong, Denmark, Taiwan, Saudi Arabia, and Hungary) is the same as the DKG report ranking in at least three methods.

According to Table 4,



a) Normalized weights b) Equal weights

Fig. 3. Evaluation of methods in terms of normalised and equal weights for Level 1.



a) Normalized weights b) Equal weights

Fig. 4. Evaluation of methods in terms of normalised and equal weights for Level 2.

- *Kuwait*, which ranks first in the report, maintains its place in all the methods.
- The ranking of the three regions for normalised weights (*Kuwait, Qatar, Greece*) and the two regions for equal weights (*Kuwait, Finland, Greece, Estonia, and Cyprus*) using the TOPSIS method, the ranking of four regions for normalised weights (*Kuwait, Iceland, Qatar, Liechtenstein*) and two regions for equal weights (*Kuwait, Liechtenstein*) using the VIKOR method, and the ranking of eight regions for normalised weights (*Kuwait, Iceland, Bahrain, Finland, Liechtenstein, Greece, Estonia, Croatia*) and nine regions for equal weights (*Kuwait, Finland, Luxembourg, Qatar, Lithuania, Malaysia, Greece, Estonia, Ireland*) using the COPRAS method are the same as the ranking in the report.
- The ranking of six regions (*Kuwait, Finland, Qatar, Liechtenstein, Greece, and Estonia*) is the same as the ranking in at least three methods.

According to Table 5,

- The ranking of four regions (*Bosnia and Herzegovina, Azerbaijan, Lebanon, Armenia*) for normalised weights and one region for equal weights (*Spain*) using the TOPSIS method, the ranking of one region for normalised weights (*Belgium*) and three regions for equal weights (*Vatican City, Sweden, Bosnia and Herzegovina, Portugal, Bulgaria*) using the VIKOR method, and the ranking of 22 regions for normalised weights (*Montenegro, Czech Republic, Greenland, Philippines, Argentina, Belarus, Ukraine, United Kingdom, South Africa, San Marino, Iran, Ecuador, Lebanon, Andorra, Cayman Islands, Morocco, Algeria, Honduras, Paraguay, Peru, Indonesia, Cambodia*) and eight regions for equal weights (*Montenegro, Bulgaria, Philippines, Belarus, Andorra, Peru, Indonesia, Cambodia*) using the COPRAS method are the same as the ranking of the report.
- The ranking of 31 regions (Montenegro, Czech Republic, Spain, Portugal, Bulgaria, Greenland, Vatican City, Philippines, Argentina, Belarus, Sweden, Ukraine, United Kingdom, South Africa, San Marino, Bosnia and Herzegovina, Iran, Ecuador, Azerbaijan, Lebanon, Belgium, Andorra, Cayman Islands, Armenia, Morocco, Algeria, Honduras, Paraguay, Peru, Indonesia, Cambodia) are the same as those in at least one application.
- While *Chile* takes first place in the report, *France* takes first place in six applications.

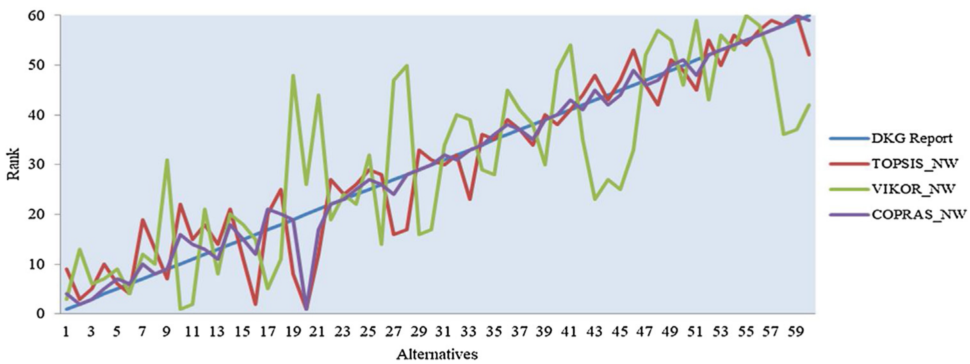
It can be seen that the success of the compromise solutions with reports provided by all three methods decreased from Level 1 to Level 3. When the methods are evaluated individually, it is observed that the ranking results are not exactly the same. Because the steps followed by each method after the weighting process are quite different, the success of the compromise solutions gradually decreases, and the ranking results are different.

The normalised and equal weights comparison graphs of Level 1, Level 2, Level 3 are presented in Figs. 3–5. From Figs. 3–5, it is seen that the criterion weights in all methods have a significant effect on the ranking. When the data in Figs. 3–5 are compared with Tables 3–5, it is found that for some regions, the ranking remains the same for the same method irrespective of the weight change. However, the ranking of many regions varies within the same method with weight change. For example, in the TOPSIS method, *Switzerland*, *German*y, and *Israel* maintain their rankings, while *Singapore* ranks seventh in the results obtained by applying normalised weights and eighth in the results obtained by applying equal weights, respectively, as shown in Fig. 3 and Table 3.

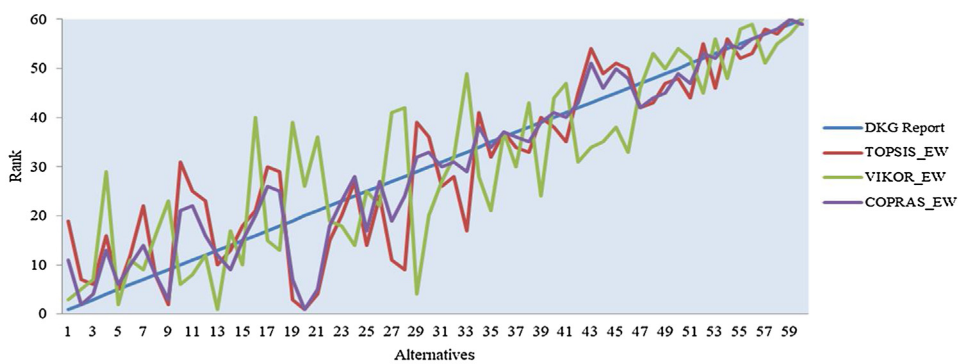
The evaluation of the results reveals that *Switzerland* ranks first for all methods and prioritisation. Similarly, *Kuwait*, which ranks first in the report in Level 2, maintains its ranking position in all methods and prioritizations. For Levels 1 and 2, it is determined that similarities and differences occur in rankings according to normalised and equal weights. In Level 3, while *Chile* ranked first in the report, *France* ranked first in six applications.

Conclusion and future directions

In this study, 100 regions of the world were analysed using TOPSIS, VIKOR, and COPRAS methods to determine their regional safety levels for COVID-19. The data used within the scope of the analysis were taken from the report [7] presented by the DKG, and evalua-



a) Normalized weights for Level 3



b) Equal weights for Level 3

Fig. 5. Evaluation of methods in terms of normalised and equal weights for Level 3.

tion was made by comparing the results obtained in this study with the report.

The regions Level 1, Level 2, and Level 3 constitute the alternatives. Unlike the DKG report used to obtain the data, Level 4 is not considered because the data required by the methods are insufficient. The six criteria used in this study were evaluated as benefit-oriented with the purpose of the study, which was determined to ensure regional safety in terms of COVID-19. Each region (Level 1, Level 2, and Level 3) is analysed comparatively with TOPSIS, VIKOR, and COPRAS methods, and the results are presented.

It was concluded that the COPRAS method obtained the most compatible results with the DKG report. The TOPSIS method gives a compromised result related to the report. It is observed that the VIKOR method provide the least compatible result. It has been observed that regions with an above-average score generally according to the government efficiency of risk management and quarantine efficiency criteria, which have the highest weight value, ranked high in the rankings.

Considering that MCDM techniques are auxiliary instruments for decision-makers, they are more appropriate to evaluate all methods than to suggest a single method. Decision-makers primarily evaluate the results of COPRAS. However, they should also consider the results of TOPSIS and VIKOR. In future studies, MCDM techniques that are different from the ones used in this study could be considered. By examining the procedures followed by the regions in their struggle against COVID-19 and their status, new criteria or sub-criteria presented in the DKG report [7] can be added to the criteria presented in this study, or MCDM methods can be applied by removing some criteria from the existing criteria. Further, fuzzy data that reflect the uncertainty of the real-life situation can be utilised. Therefore, fuzzy MCDM techniques can be used to solve the problem.

Funding

No funding sources.

Conflict of interest

None declared.

Ethical approval

Not required.

Appendix A

Table A1
The values of alternatives of Level 1 used in the study.

Region	Quarantine efficiency	Government efficiency	Monitoring and detection	Healthcare readiness	Regional resiliency	Emergency preparedness
Australia	59.59	82.21	77.03	62.18	68.70	78.83
Austria	55.62	85.52	81.16	68.26	73.50	73.17
Canada	58.92	78.02	88.96	57.58	69.25	66.42
China	54.63	78.02	88.33	61.53	56.68	92.33
Denmark	62.41	69.53	85.91	61.35	71.09	52.92
Germany	59.45	88.13	91.97	78.82	81.10	52.92
Hong Kong	61.61	75.40	88.84	53.45	59.06	77.92
Hungary	57.01	66.31	81.33	50.42	59.14	79.83
Israel	57.98	86.66	95.38	65.38	68.46	75.43
Japan	57.62	83.76	94.70	83.31	65.62	60.58
Netherlands	57.96	71.98	84.58	65.98	60.70	49.08
New Zealand	69.72	70.75	85.43	57.86	72.56	72.08
Norway	58.07	82.20	81.33	61.26	73.47	52.92
Saudi Arabia	56.66	64.84	80.50	39.91	81.39	74.08
Singapore	65.92	80.14	96.41	66.00	78.21	60.58
South Korea	53.82	79.88	88.85	64.92	68.28	74.08
Switzerland	65.26	85.56	87.67	77.75	71.66	63.04
Taiwan	53.90	78.97	83.85	52.44	52.98	74.08
United Arab Emirates	54.59	65.22	95.10	53.88	78.83	80.83
Vietnam	58.32	67.71	82.35	48.79	55.56	67.33

Table A2
The values of alternatives of Level 2 used in the study.

Region	Quarantine efficiency	Government efficiency	Monitoring and detection	Healthcare readiness	Regional resiliency	Emergency preparedness
Bahrain	49	58	61	59	66	68
Croatia	41	64	63	66	65	41
Cyprus	51	57	65	46	66	45
Estonia	47	63	62	59	64	42
Finland	47	63	62	74	65	45
Georgia	52	55	61	61	50	45
Greece	48	63	57	61	65	43
Iceland	53	63	69	68	67	44
Ireland	46	60	57	59	65	46
Kuwait	55	61	75	57	63	73
Latvia	50	64	67	47	65	43
Liechtenstein	52	63	58	62	66	43
Lithuania	40	70	62	64	66	42
Luxembourg	47	61	66	65	67	45
Malaysia	57	59	57	48	64	52
Oman	47	58	59	45	67	65
Poland	51	68	68	45	63	43
Qatar	46	68	61	51	62	57
Slovenia	41	67	63	63	67	42
Turkey	52	57	62	48	63	53

Table A3
The values of alternatives of Level 3 used in the study.

Region	Quarantine efficiency	Government efficiency	Monitoring and detection	Healthcare readiness	Regional resiliency	Emergency preparedness
Albania	44	46	53	51	59	36
Algeria	37	48	53	52	57	35
Andorra	41	50	63	47	65	38
Argentina	42	53	63	63	62	39
Armenia	34	48	62	58	61	38
Azerbaijan	40	51	62	55	55	43
Bahamas	52	52	53	20	44	34
Bangladesh	46	52	63	39	42	44
Belarus	40	60	60	61	56	41
Belgium	45	49	57	58	64	33
Bosnia and Herzegovina	48	47	63	53	62	38
Brazil	44	45	55	52	59	33
Bulgaria	48	53	64	65	60	39
Cambodia	42	52	63	38	37	32
Cayman	44	47	62	57	57	33
Chile	45	69	61	49	61	42

Table A3 (*Continued*)

Region	Quarantine efficiency	Government efficiency	Monitoring and detection	Healthcare readiness	Regional resiliency	Emergency preparedness
Czech Republic	48	55	63	64	62	41
Ecuador	47	50	63	46	61	37
Egypt	40	51	62	32	67	37
France	61	45	61	50	67	66
Gibraltar	49	45	60	59	58	47
Greenland	46	48	55	55	75	53
Honduras	46	47	62	29	55	35
India	50	60	53	28	58	66
Indonesia	41	49	61	34	50	34
Iran	42	49	53	40	60	64
Italy	47	54	62	54	62	46
Jordan	33	52	62	43	67	36
Kazakhstan	43	49	60	45	57	55
Laos	41	57	61	19	49	31
Lebanon	42	48	63	53	63	37
Malta	51	62	58	61	60	33
Mexico	48	58	67	41	67	41
Moldova	38	55	62	52	50	37
Monaco	49	51	65	47	61	43
Mongolia	35	57	61	50	59	43
Montenegro	54	51	65	55	68	41
Morocco	47	49	63	29	54	35
Myanmar	43	57	63	25	51	45
Panama	39	52	53	47	59	35
Paraguay	45	45	53	37	60	34
Peru	42	47	53	41	55	34
Philippines	49	51	65	32	64	61
Portugal	50	60	58	56	61	41
Romania	48	59	63	46	61	40
Russia	41	45	61	50	67	66
San Marino	48	53	66	51	48	40
Serbia	42	52	63	63	70	39
Slovakia	42	66	61	46	64	40
South Africa	46	53	65	37	66	44
Spain	46	53	64	51	66	52
Sri Lanka	43	58	58	37	53	36
Sweden	41	48	64	62	62	45
Thailand	41	65	63	52	66	40
Tunisia	36	49	55	47	63	44
UK United Kingdom	47	46	54	54	60	53
Ukraine	45	54	61	59	59	38
United States	43	45	57	50	62	69
Uruguay	49	61	59	47	61	42
Vatican City	52	50	69	49	66	39

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