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Published in:
Socio-Economic Planning Sciences

DOI:
10.1016/j.seps.2021.101198

Published: 01/06/2022

Document Version
Peer-reviewed accepted author manuscript, also known as Final accepted manuscript or Post-print

A Comparative Assessment of Air Quality across European Countries using an Integrated Decision Support Model

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Abstract

Reducing air pollution including greenhouse gas emissions originating from extensive use of fossil fuels is critical for European countries aiming at improving their environment and at carbon neutrality by the middle of this century. To optimally reduce the air pollutants and mitigate the climate change, not only national or EU level regulation need to be considered, but also international agreements such as the Sustainable Development Goals, Kyoto Protocol, and Paris Climate Agreement need to be included in these strategies. Managing such a complex framework would benefit from reliable multi-criteria decision-making approaches. Current models to enhance air quality often concentrate on one criterion at a time and focus on momentary improvements only, unable to offer longstanding enhancement. Therefore, comparative analysis of emissions of several air pollutants simultaneously is highly relevant empowering decision-makers with better tools for policy development. The focus of this study is on a decision support model based on the Best-Worst Method (BWM) and the Measurement of Alternatives and Ranking According to Compromise Solution (MARCOS) method to comparatively analyze air pollutants of 22 European countries. This study is the first in its kind to develop an integrated decision model for air quality assessment considering six air pollutants. Extensive sensitivity analyses were performed to highlight the impacts from different scenarios on the decision-making. The results indicate that Sweden, Latvia, France, Lithuania, Hungary, and Italy ranked as the top six countries with the lowest emission. However, Finland, Poland, the Czech Republic, Luxembourg, and Estonia had

the lowest overall ranking and the highest per capita emissions. The proposed methodology and evaluation framework can provide a helpful tool for developing regional and national strategies to minimize air pollutants and to improve environmental sustainability.

Keywords: Air Pollution; Greenhouse Gas Emissions; Multi-Criteria Decision-Making; Sustainable Development; Best Worst Method

Nomenclature

AAI	Anti-Ideal Solution
AI	Ideal Solution
AHP	Analytic Hierarchy Process
AQI	Air Quality Index
BWM	Best Worst Method
CoCoSo	Combined Comprise Solution
COPRAS	Complex Proportion Assessment
DEMATEL	Decision-Making Trial and Evaluation Laboratory
EDAS	Evaluation Based on Distance from Average Solution
EPM	Environmental Process Mapping
EU	European Union
GHG	Greenhouse Gases
MABAC	Multi-Attributive Border Approximation Area Comparison
MARCOS	Measurement of Alternatives and Ranking According to Compromise Solution
MCDM	Multi-Criteria Decision Making
N-DEMATEL	Neutrosophic Decision Making Trial and Evaluation Laboratory
IC-FSE	Integrated Constrained Fuzzy Shannon Entropy
OECD	Organization for Economic Co-operation and Development
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TOPSIS-F	Technique for Order of Preference by Similarity to Ideal Solution with fuzzy sets
WASPAS	Weighted Aggregated Sum Product Assessment

1. Introduction

Air quality is an essential part of the sustainable and environmental development goals, directly connected with emission control [1]. Air pollution is driven by several factors such as population growth, urbanism, industrialization, traffic, and inadequate waste management. In addition to environmental damage, e.g., to the soil [2] and atmosphere [3], air pollutants also harm economics [4], and cause health effects such as respiratory infections [5], heart diseases [6], chronic diseases, and lung cancer [7]. Due to the strong interconnection between environmental development, society and economics, and air pollution, its adverse effects extend to many sectors of society [8]. Similarly, national and international agreements to reduce air pollutant emissions have been established [9], such as the Kyoto Protocol on greenhouse-gas emissions [10], the ASEAN Agreement on Transboundary Haze Pollution [11], and United Nations Framework Convention on Climate Change (UNFCCC) [12].

The European Union (EU) has been active in creating a cleaner society by controlling air pollutants within different sectors such as transportation [13] and industrial activities [14]. Air pollution control in the EU and tracking of emission commitments of its member states is administered by the European Environment Agency [15], supporting policies aiming at enhancing green economics, sustainable industries, high environmental development, sustainable and smart societies, and cleaner agricultural activities [16].

Forming strategies and policies for air pollution control require addressing a multitude of factors and a reliable evaluation framework. MCDM provides valuable support to enable the simultaneous evaluation of several alternatives against a set of criteria [17]. MCDM has been extensively employed for air pollution-related studies, e.g., to assess various air pollutants [18], technological and economic factors [17], or the efficacy of clean air policies [19]. The literature of MCDM for green-house gas emission control is also extensive [20]. A detailed state-of-the-art review of the MCDM is given in Section 2.1.

The weighting of the decision-making criteria is a critical task for MCDM [21]. Integrated decision support models reduce human biasedness and enable two types of decisions: (i) evaluating the criteria by their importance and (ii) ranking the alternatives. In this paper, we will use the Best – Worst Method (BWM) [22] and the MARCOS method [23, 24] for criteria weights and prioritization of alternatives, respectively. The evaluation framework based on the integrated BWM and MARCOS method will be used to assess the air quality of 22 European countries by ranking them based on their air quality score considering emissions of six air pollutants. First, to determine the importance of each air pollutant to the total air pollution, the BWM is employed, which calculates the weight coefficients by selecting the best and worst indicators through an optimization model. Then, the MARCOS method is used to assess the countries based on the identified indicators. Finally, to verify the results of the BWM-MARCOS model, sensitivity analysis tests are performed based on data, weighting coefficients, and evaluation models. The outcome gives important insight into the countries' performance in terms of air pollutants which could help develop more effective solutions and strategies to control air pollutions according to the sustainability goals.

In general, the main motivations of conducting this study are to answer the following research questions:

- Why has air quality turned to be a vital sustainability problem?
- What are the major air pollutants contributing to a large proportion of air pollution?
- How to comparatively analyze the air quality of European countries considering all major air pollutants?
- Do all air pollutants contribute simultaneously to air pollution from a policy-maker's point of view?
- What are the valuable and reliable tools to determine air pollutants' contribution and importance level during an air quality analysis?
- How can the results of such tools be valuable and applicable for real-life practices?

According to the earlier discussions, the contributions of the current study are as follow. First, this study is among the first of its kind to study air quality based on six major air pollutants for 22 European countries. In order to quantify the air quality analysis, a decision support model is developed based on the BWM and MARCOS methods. Second, the developed decision support model is used to determine the importance of air pollutants and comparatively assess the performance of European countries on the emission of most common air pollutants. Since each air pollutant's determination of importance and contribution has a significant role in final results, the BWM is the most well-known optimization-based method to tackle this problem. Later, the MARCOS method, as a relatively new ranking MCDM model compared to traditional methods, is used to compare the performance of countries based on different utility functions. Finally, the quantitative air quality analysis based on six major air pollutants would generate helpful insights for real-life decision-makers and managers in sustainability, environmental science, energy transition, and climate change.

The rest of the paper is structured as follows. Section 2 presents a literature review and background of studies conducted on air quality assessment. The proposed model is presented in Section 3. The air quality assessment problem, case study, results, and sensitivity analysis are presented in Section 4. In Section 5, managerial and environmental insights are discussed. Finally, some conclusions are given in Section 6.

2. Literature Review

This section presents a literature review on the background of the air quality assessment with decision-making tools in the first part. In the second part, the most important and common indicators are identified based on the air pollutants.

2.1. Air Quality Assessment

Due to the high applicability of the MCDM methods for complex assessment and evaluations with straightforward soft computing methods, various forms of MCDM have been utilized to address similar problems in air quality assessment.

For example, some studies have used MCDM models to estimate the Air Quality Index (AQI). Sowlat et al. [25] developed a fuzzy algorithm to calculate the AQI. In another study, a Fuzzy MCDM model was developed for estimating the AQI in one location only using several pollutants. In addition, some studies also used integrated models [26]. Zhou et al. [27] integrated a Gaussian distribution model with a fuzzy relation model to provide a decision support tool for the power plant managers in designing an air pollution control platform that meets emission reduction goals. Hacıoğlu et al. [28] incorporated Elimination Et Choix Traduisant la Realité III (ELECTRE III) and AHP methods to choose the best air quality screening locations using various indicators such as distance, easy access, security, staff support, pollution levels, collaborations, availability of electricity. Banerjee et al. [29] developed an AHP-based spatial AQI estimation model to study the impact of air pollution caused by highway traffic. Piasecki and Kostyrko [30] developed an MCDM model to create a practical tool for ranking indoor air pollutants considering economic, technical, and health-related factors. They addressed the model's weighting scheme as an integrated model of the IAQ-based scheme and the MCDM model to make decisions with various criteria. Zavadskas et al. [31] proposed a Complex Proportion Assessment (COPRAS) method using criteria articulated in intervals for a multiple attribute evaluation of indoor air quality. Zavadskas et al. [32] also developed a model called Technique for Order of Preference by Similarity to Ideal Solution with fuzzy sets (TOPSIS-F), including attribute selection, assessment, calculating the chosen attributes of air pollution, and assessing air quality levels. A TOPSIS model was also used to identify the weights for the decision-making process to assess Guangzhou's air quality over the Asian Olympic Games [33]. Chen et al. [34] developed an integrated decision model based on ANP, DEMATEL, and VIKOR to analyze the key sources of urban air quality in Taiwan. The results were used to propose improvement strategies and recommendations. Zeydan and Pekkaya [35] used grey rational analysis for air quality monitoring stations in Turkey based on five major air pollutants as PM_{10}, SO_2, CO, NO_2, and O_3. Stević and Brković [36] developed a hybrid Full Consistency Method (FUCOM)-MARCOS model to assess the human resources in a transport system of an international transport company. Also, Đalić et al. [37] integrated two strategic decision-making methods, including Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, a matrix of Threats, Opportunities, Weaknesses, and Strengths (TOWS) into FUCOM and MARCOS methods. They evaluated different scenarios and made strategic decisions in a transportation firm in Bosnia and Herzegovina.

There is also extensive literature on using MCDM models for greenhouse gas emission reduction. For example, Çolak et al. [38] developed a fuzzy MCDM model integrating an AHP method using the hesitant fuzzy TOPSIS and the second type of interval fuzzy sets methods. Because the second and hesitant fuzzy sets enable assigning multiple membership values for a factor, this feature facilitates handling uncertainties in the decision-making process.

In some studies, air quality is assessed under sustainability indices. For example, Sitorus and Barito-Parada [39] developed an extended Shannon Entropy model as the Integrated Constrained Fuzzy Shannon Entropy (IC-FSE) model to obtain criteria weights for sustainability assessment and rank renewable energy technologies' sustainability criteria from uncertain input data. Kilic and Yasin [40] developed a hybrid model based on Neutrosophic Decision Making Trial and Evaluation Laboratory (N-DEMATEL) and TOPSIS to evaluate sustainability indices, including GHG emissions of different municipalities in Turkey. Roy et al. [41] proposed a hybrid model integrating AHP, DEMATEL, and environmental process mapping (EPM) methods. Air pollution and GHG emissions have been considered in the Indian textile industry to identify critical environmental performance indicators. Several studies analyzed the performance of the energy generation systems based on environmental sustainability [42]. More details on these studies can be found, e.g., [43].

2.2. Air quality indicators

The most crucial point in assessing air quality is identifying the most contributing air pollutants to air pollution. This part proposes a framework of indicators for the air quality assessment based on the most critical and practical air-related characteristics and environmental impacts of harmful gases on the climate. Table 1 presents complete information about the indicators, their units, definitions, and data sources. According to Table 1, we have six leading air quality indicators as CO_2, CO, greenhouse gas (GHG), NOx, SOx, and VOC. In addition, GHG includes Sulphur hexafluoride (SF6), chlorofluorocarbons (CFCs), perfluorocarbons (PFCs), methane (CH4), nitrous oxide (N2O), nitrogen trifluoride (NF3), and hydrofluorocarbons (HFCs) as well as CO_2. However, CO_2 is considered a separate indicator due to its high importance among all gases included in GHG.

Table 1. Air quality indicators.

Indicator	**Unit**	**Definition**	**Reference**
NOx	kg/capita	Nitrogen oxides	
CO_2	ton/capita	Gross direct carbon dioxide emissions from fuel combustion	
SO_x	kg/capita	Sulfur oxides	[44]
GHG	ton/capita	Greenhouse gases	
CO	kg/capita	Carbon monoxide	
VOC	kg/capita	Volatile organic compounds	
NO_x	kg/capita	Nitrogen oxides	

2.3. Contributions and novelties

European countries have been working on different environmental issues to prepare their infrastructures based on green and sustainable regulations and legislation for environmental and climate concerns. Air quality is one of the significant parts of such regulations and legislation that European countries have enacted many standards and laws to mitigate air pollutants. Paris agreement in 2015 was the peak of such regulations that many countries participated to decrease the role of air pollutants that contribute to global warming and climate change. Another crucial regulation is sustainable development goals by the United Nations, which included many targets regarding air quality and controlling air pollutants within its primary goals. One of the crucial points for European countries is to assess their progress and current situation on air quality considering major air pollutants. This would empower them to understand how well their programs and plans are going compared to other neighboring countries, bringing up many managerial and technical insights on their plans. However, performance assessment of several European countries considering different air pollutants is a highly complex task that cannot be conducted manually. MCDM methods are well-known reliable, straightforward tools that can be implemented in such cases to show which countries are doing well and which are not in good positions. One significant advantage of the MCDM methods is their simple mathematical structure, making it exceedingly more accessible for the public decision-makers and managers to adopt such methods. For this purpose, this study develops an integrated decision support model using two methods to determine the relative importance of air pollutants and assess countries based on the defined air pollutants. First, the Best-Worst Method (BWM) is a reliable, accurate, and well-known optimization-based MCDM method, and it is used to determine the importance of air pollutants. Later, the MARCOS method, as one of the recently developed ranking methods, is used to show the performance of countries against air pollutants. The developed decision support model results would show much helpful information for countries based on their final performance ranking. Based on the results, countries can also examine how well their plans and propositions have been working so far.

3. Methodology

This section presents individual steps of the research method applied in this study (Figure 1). Later, two separate subsections are presented to describe both applied MCDM methods in detail.

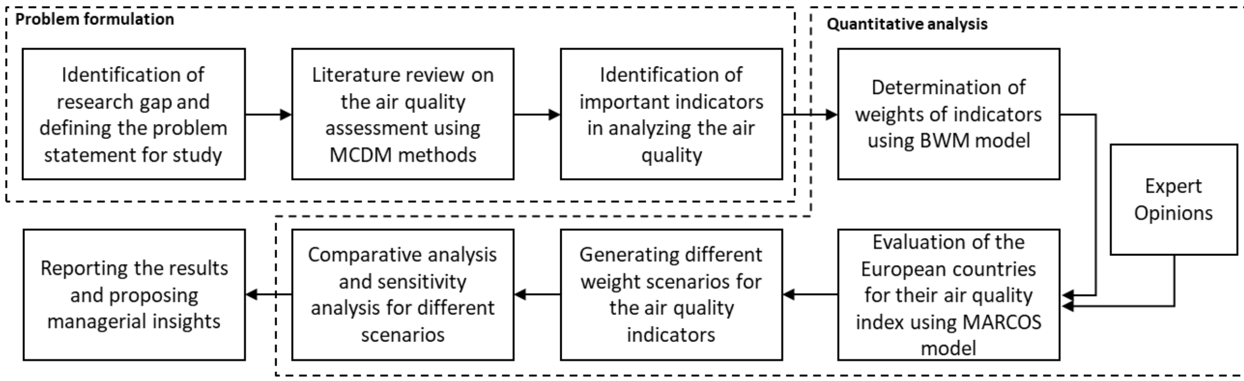

Figure 1. Flowchart of the proposed methodology.

3.1. Best – Worst Method (BWM)

The BWM [22] comprises a mathematical model to obtain the weight of criteria in an MCDM problem based on experts' opinions on the best and worst criteria. Due to the high applicability of the BWM in action, it has attracted the close attention of researchers in different fields such as sustainability [45], waste management [46], environmental management [47], supply chain management [48], and healthcare management [49].

The model is implemented through the following steps:

Step 1 – Defining criteria as $(c_i \, \forall \, i \in 1, 2, \ldots, n)$.

Step 2 – Identifying the worst and the best criteria.

Step 3 – Comparing all the criteria with the best one in a pairwise fashion using a scale from 1 to 9. Afterward, we derive the result of this comparison as a vector of $A_B = \left(a_{Bj}, \; \forall \, j \in 1, 2, \ldots, n\right)$, such that $a_{BB} = 1$ and a_{Bj} show that criterion B is considered the best over criterion *i*.

Step 4 – Decision-makers compare all the criteria with the worst one, similar to Step 4. Again, results are shown as a vector which shows the incline to the worst: $A_W = (a_{iW}, \forall \, i \in 1, 2, \ldots, n)^T$, such that $a_{WW} = 1$ and a_{jw} show that the criterion j is considered superior to W.

Step 5 – Calculate the optimum weights using the two weight vectors $(W_i^* \, \forall \, i \in 1, 2, \ldots, n)$. Some conditions should be met as $\frac{W_B}{W_j} = a_{Bj}$ and $\frac{W_j}{W_W} = a_{jW}$. To make these equations hold, the maximum

$\left| \frac{W_B}{W_j} - a_{Bj} \right|$ and $\left|\frac{W_j}{W_W} - a_{jW}\right|$ are minimized for all j. The weights accumulation constraint and the non-negativity constraint can be modeled for the BWM-model as.

$$\begin{aligned}
&\text{Min } \max_{j} \left| \frac{W_B}{W_j} - a_{Bj} \right|, \left| \frac{W_j}{W_W} - a_{jW} \right| \\
&\text{s.t:} \\
&\sum_j W_j = 1, \\
&W_j \geq 0 \text{ for all j}
\end{aligned} \tag{1}$$

The model is formulated as:

$$\begin{aligned}
&\min \xi \\
&\text{s.t:} \\
&\left| \frac{W_B}{W_j} - a_{Bj} \right| \leq \xi, \forall j \in 1, 2, \ldots, m \\
&\left|\frac{W_j}{W_W} - a_{jW}\right| \leq \xi, \ \forall j \in 1, 2, \ldots, m
\end{aligned} \tag{2}$$

(2)

$$\begin{aligned}
&\sum_j W_j = 1, \ \ W_j \geq 0, \forall j \in 1, 2, \ldots, m \\
&W_j \geq 0 \text{ for all j}
\end{aligned}$$

After obtaining the weights, the comparisons can be conducted considering different consistency levels. Then, the ratio of consistency for the Best-Worst-Method is presented through ξ^* and the corresponding index for the consistency levels in Eq. (3) and Table 2. It is observed that to obtain more consistent vectors, ξ^* and consistency ratio should be smaller. Therefore, the consistency ratio is defined as:

$$\text{Consistency Ratio} = \frac{\xi^*}{\text{Consistency index}} \tag{3}$$

Table 2. The obtained values for the consistency index (CI).

a_{BW}	1	2	3	4	5	6	7	8	9

CI	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

3.2. Measurement of Alternatives and Ranking according to COmpromise Solution -method (MARCOS)

In early 2020, a novel ranking method, so-called MARCOS, was developed, utilizing utility functions to determine a performance score for alternatives considering all criteria [23]. Since its development, MARCOS has been considered as a multi-criteria reliable ranking, sorting, assessment, and prioritization method in different fields such as supply chain management [50], landfill location selection [51], hospital location selection [52], transportation management [53], circular economy [54], and technology management [55].

The MARCOS method includes the following steps [23].

Step 1- An initial decision matrix with *n* criteria and *m* alternatives is constructed.

Step 2- The initial decision matrix is updated by adding the ideal (AI) and anti-ideal (AAI) values. AI and AAI values are determined based on the following equations.

$$\mathrm{AAI} = \min_i x_{ij} \ \text{ if } j \in B, \qquad \max_i x_{ij} \ \text{ if } j \in C \tag{4}$$

$$\mathrm{AI} = \max_i x_{ij} \ \text{ if } j \in B, \quad \min_i x_{ij} \ \text{ if } j \in C \tag{5}$$

where B involves benefit criteria, and C involves cost criteria;

Step 3- The initial decision matrix is normalized using Eqs. (6) and (7) based on the nature of the criteria.

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \ \text{ if } j \in C \tag{6}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \ \text{ if } j \in B \tag{7}$$

where C denotes cost criteria, and B shows benefit criteria.

Step 4- In this step, the normalized values are multiplied with the weight of each criterion to construct the matrix, which is weighted and normalized based on Eq. (8).

$$V_{ij} = n_{ij} w_{ij} \tag{8}$$

Step 5- Using Eq. (9), the sum of the weighted matrix elements is calculated.

$$S_i = \sum_{i=1}^{n} V_{ij} \quad (9)$$

Step 6- The utility degree of alternatives K_i is calculated using Eqs. (10)-(11).

$$M_{i^-} = \frac{S_i}{S_{aai}} \quad (10)$$

$$M_{i^+} = \frac{S_i}{S_{ai}} \quad (11)$$

Step 7- The utility function is determined concerning the anti-ideal solution $f(M_{i^-})$, and the utility function concerning the ideal solution $f(M_{i^+})$ based on Eqs. (12)-(13).

$$f(M_{i^-}) = \frac{M_{i^+}}{M_{i^+} + M_{i^-}} \quad (12)$$

$$f(M_{i^+}) = \frac{M_{i^-}}{M_{i^+} + M_{i^-}} \quad (13)$$

Step 8- The utility function of alternatives $f(M_i)$ is calculated based on Eq. (14). The ranking order of alternatives is based on their utility function values.

$$f(M_i) = \frac{M_{i^+} + M_{i^-}}{1 + \frac{1 - f(M_{i^+})}{f(M_{i^+})} + \frac{1 - f(M_{i^-})}{f(M_{i^-})}} \quad (14)$$

4. Computational Results

Based on the six indicators (air pollutants) presented in the previous section for the air quality assessment, the results of the MCDM approach are presented in the following subsections. First, the BWM and then the MARCOS results for 22 European countries are presented. After ranking the countries based on their air quality score, sensitivity analysis is implemented to show the reliability of the generated outcome of the BWM-MARCOS model.

3.1. Weights of the air pollutants

The BWM-model was applied to identify the criteria's optimum weights. Ten experts (six males and four females) were chosen to represent know-how in sustainability, climate, environmental, and social sciences for the weight determination process. An online platform was prepared for the experts to communicate and propose consensus scores for the air quality indicators within the BWM-model. CO_2 was selected as the most important indicator for air quality. The experts selected NO_x as the least important indicator. Pairwise comparisons of the criteria for the BWM-model are illustrated in Tables 3 and 4 using a scale from 1-9 where 1 expresses the equal preferred, 3 shows moderately preferred, 5 represents strongly preferred, 7 shows very strongly preferred, and 9 represents the highest preference. Other values represent the intermediate preference degrees. In Table 4, the best-to-other vector is constructed by comparing the best and other indicators against each other using the scale defined above. Table 5 shows the other-to-worst vector by comparing all indicators and the worst indicator using the scale above.

Table 3. Best-to-others vector of the indicators.

Best indicator	**CO_2**	**CO**	**GHG**	**NO_x**	**SO_x**	**VOC**
CO_2	1	5	4	8	7	6

Table 4. Others-to-worst vector.

Others to the worst	**NOx**
CO_2	8
CO	4
GHG	6
NO_x	1
SO_x	5
VOC	4

Based on the mathematical BWM- model (2), the final weights of the air quality indicators and the inconsistency rates are represented in Table 5. CO_2 has the highest weight value, 0.486, and NO_x has the lowest weight value, 0.044. Therefore, the inconsistency rate is calculated as 0.133.

Table 5. Weights of the indicators.

Indicators	**CO_2**	**CO**	**GHG**	**NO_x**	**SO_x**	**VOC**
Weight	0.486	0.124	0.155	0.044	0.088	0.103

Ksi*	0.133

3.2. Assessment of EU countries

In this part, the results of the MARCOS method are illustrated. In the first step, a data set (OECD, 2020) was used to build the preliminary decision matrix (Table 7). Next, the preliminary decision matrix is constructed for the six air quality indicators elaborated in Table 3. In this study, all air quality indicators are considered as cost criteria. Finally, to extend the initial decision matrix, AI and AAI values were identified for each criterion and add them to the decision matrix as represented at the bottom of Table 6.

Table 6. Initial decision matrix.

Countries		CO_2	CO	GHG	NO_x	SO_x	VOC
A1	**Austria**	7.4	59.799	9.327	16.195	1.441	13.603
A2	**Belgium**	8	25.543	10.030	15.024	3.271	9.533
A3	**Czech Republic**	9.6	76.964	12.092	15.284	10.333	19.484
A4	**Denmark**	5.4	41.969	8.587	19.36	1.777	17.825
A5	**Estonia**	12.1	104.692	15.825	25.104	29.29	16.85
A6	**Finland**	7.7	59.172	10.04	22.663	6.402	18.311
A7	**France**	4.6	41.484	7.264	12.411	2.223	9.43
A8	**Germany**	8.7	34.125	10.968	14.329	3.816	12.925
A9	**Greece**	5.9	34.675	9.028	25.523	6.541	14.384
A10	**Hungary**	4.7	43.41	6.556	12.205	2.846	14.54
A11	**Ireland**	7.4	18.366	12.779	22.933	2.764	23.814
A12	**Italy**	5.3	38.41	7.049	11.737	1.901	15.408
A13	**Latvia**	3.4	65.681	5.795	19.134	2.038	19.504
A14	**Lithuania**	3.8	48.92	7.176	18.292	4.061	16.067
A15	**Luxembourg**	14.5	36.997	17.293	30.938	1.708	20.437
A16	**Netherlands**	9.1	32.693	11.354	13.744	1.565	14.77
A17	**Poland**	8	67.122	10.902	21.146	15.35	18.2
A18	**Portugal**	4.9	34.322	6.878	16.376	4.764	16.274
A19	**Slovakia**	5.9	66.916	7.944	11.939	4.936	16.406

A20	**Slovenia**	6.5	50.405	8.4	16.548	2.338	14.325
A21	**Spain**	5.4	28.085	7.294	15.883	4.728	13.239
A22	**Sweden**	3.7	38.653	5.281	12.508	1.769	14.738
AAI		14.5	104.692	17.293	30.938	29.29	23.814
AI		3.4	18.366	5.281	11.737	1.441	9.43

Then, the initial decision matrix is normalized according to Eqs. (4) - (5) in Table 7.

Table 7. Normalized decision matrix.

Countries		**CO_2**	**CO**	**GHG**	**NO_x**	**SO_x**	**VOC**
A1	**Austria**	0.459	0.307	0.566	0.725	1.000	0.693
A2	**Belgium**	0.425	0.719	0.527	0.781	0.441	0.989
A3	**Czech Republic**	0.354	0.239	0.437	0.768	0.139	0.484
A4	**Denmark**	0.630	0.438	0.615	0.606	0.811	0.529
A5	**Estonia**	0.281	0.175	0.334	0.468	0.049	0.560
A6	**Finland**	0.442	0.310	0.526	0.518	0.225	0.515
A7	**France**	0.739	0.443	0.727	0.946	0.648	1.000
A8	**Germany**	0.391	0.538	0.481	0.819	0.378	0.730
A9	**Greece**	0.576	0.530	0.585	0.460	0.220	0.656
A10	**Hungary**	0.723	0.423	0.806	0.962	0.506	0.649
A11	**Ireland**	0.459	1.000	0.413	0.512	0.521	0.396
A12	**Italy**	0.642	0.478	0.749	1.000	0.758	0.612
A13	**Latvia**	1.000	0.280	0.911	0.613	0.707	0.483
A14	**Lithuania**	0.895	0.375	0.736	0.642	0.355	0.587
A15	**Luxembourg**	0.234	0.496	0.305	0.379	0.844	0.461
A16	**Netherlands**	0.374	0.562	0.465	0.854	0.921	0.638
A17	**Poland**	0.425	0.274	0.484	0.555	0.094	0.518
A18	**Portugal**	0.694	0.535	0.768	0.717	0.302	0.579
A19	**Slovakia**	0.576	0.274	0.665	0.983	0.292	0.575
A20	**Slovenia**	0.523	0.364	0.629	0.709	0.616	0.658
A21	**Spain**	0.630	0.654	0.724	0.739	0.305	0.712

A22	**Sweden**	0.919	0.475	1.000	0.938	0.815	0.640
AAI		0.234	0.175	0.305	0.379	0.049	0.396
AI		1.000	1.000	1.000	1.000	1.000	1.000

For example, the normalized value of Austria considering CO_2 is calculated as follows:

$$\frac{3.4}{59.799} = 0.459$$

The weighted decision matrix is constructed by multiplying the initial decision matrix and the weight vector obtained from the BWM-model after constructing the normalized decision matrix. The weighted decision matrix is presented in Table 8, calculated based on Eq. (6).

Table 8. Weighted decision matrix.

Countries		**CO_2**	**CO**	**GHG**	**NO_x**	**SO_x**	**VOC**
A1	**Austria**	0.223	0.038	0.088	0.032	0.088	0.071
A2	**Belgium**	0.207	0.089	0.082	0.034	0.039	0.102
A3	**Czech Republic**	0.172	0.030	0.068	0.034	0.012	0.050
A4	**Denmark**	0.306	0.054	0.095	0.027	0.071	0.054
A5	**Estonia**	0.137	0.022	0.052	0.021	0.004	0.058
A6	**Finland**	0.215	0.038	0.082	0.023	0.020	0.053
A7	**France**	0.359	0.055	0.113	0.042	0.057	0.103
A8	**Germany**	0.190	0.067	0.075	0.036	0.033	0.075
A9	**Greece**	0.280	0.066	0.091	0.020	0.019	0.068
A10	**Hungary**	0.352	0.052	0.125	0.042	0.045	0.067
A11	**Ireland**	0.223	0.124	0.064	0.023	0.046	0.041
A12	**Italy**	0.312	0.059	0.116	0.044	0.067	0.063
A13	**Latvia**	0.486	0.035	0.141	0.027	0.062	0.050
A14	**Lithuania**	0.435	0.047	0.114	0.028	0.031	0.060
A15	**Luxembourg**	0.114	0.062	0.047	0.017	0.074	0.048
A16	**Netherlands**	0.182	0.070	0.072	0.038	0.081	0.066
A17	**Poland**	0.207	0.034	0.075	0.024	0.008	0.053

Countries		CO_2	CO	GHG	NO_x	SO_x	VOC
A18	**Portugal**	0.337	0.066	0.119	0.032	0.027	0.060
A19	**Slovakia**	0.280	0.034	0.103	0.043	0.026	0.059
A20	**Slovenia**	0.254	0.045	0.097	0.031	0.054	0.068
A21	**Spain**	0.306	0.081	0.112	0.033	0.027	0.073
A22	**Sweden**	0.447	0.059	0.155	0.041	0.072	0.066
AAI		0.114	0.022	0.047	0.017	0.004	0.041
AI		0.486	0.124	0.155	0.044	0.088	0.103

For the same case, the weighted normalized value of Austria is calculated as follows:

0.459 * 0.486 = 0.223

The sum of weighted values for each alternative was first calculated according to Eq. (9), represented as S_i in Table 9. In the next step, the utility degree of alternatives is calculated based on Eqs. (10)-(11), which are represented as M_{i-} and M_{i+} in Table 9. Using the obtained values for the utility degree of alternatives, the utility function is calculated based on the ideal and anti-ideal solutions using Eqs. (12) -(13), which are represented as $f(M^{-})$ and $f(M^{+})$ in Table 9. The final utility function, $f(M_i)$, of each alternative is obtained through Eq. (14). Finally, the alternative ranking order is calculated based on the final utility function, shown as $f(K_i)$. The ranking of the MARCOS method is determined based on descending sequence, i.e., an alternative with the highest final utility function is ranked as a top alternative.

Table 9. Results of MARCOS method.

Countries		$\boldsymbol{S_i}$	$\boldsymbol{M_{i-}}$	$\boldsymbol{M_{i+}}$	$\boldsymbol{f(M^{-})}$	$\boldsymbol{f(M^{+})}$	$\boldsymbol{f(M_i)}$	Rank
A1	**Austria**	0.540	2.207	0.540	0.197	0.803	0.516	14
A2	**Belgium**	0.552	2.256	0.552	0.197	0.803	0.527	10
A3	**Czech Republic**	0.365	1.492	0.365	0.197	0.803	0.349	20
A4	**Denmark**	0.608	2.484	0.608	0.197	0.803	0.580	9
A5	**Estonia**	0.293	1.195	0.293	0.197	0.803	0.279	22
A6	**Finland**	0.430	1.757	0.430	0.197	0.803	0.410	18
A7	**France**	0.728	2.975	0.728	0.197	0.803	0.695	3

Countries		S_i	M_{i-}	M_{i+}	$f(M^-)$	$f(M^+)$	$f(M_i)$	Rank
A8	**Germany**	0.476	1.943	0.476	0.197	0.803	0.454	17
A9	**Greece**	0.544	2.220	0.544	0.197	0.803	0.519	13
A10	**Hungary**	0.683	2.788	0.683	0.197	0.803	0.651	5
A11	**Ireland**	0.521	2.126	0.521	0.197	0.803	0.497	15
A12	**Italy**	0.661	2.699	0.661	0.197	0.803	0.631	6
A13	**Latvia**	0.801	3.271	0.801	0.197	0.803	0.764	2
A14	**Lithuania**	0.715	2.922	0.715	0.197	0.803	0.683	4
A15	**Luxembourg**	0.361	1.476	0.361	0.197	0.803	0.345	21
A16	**Netherlands**	0.508	2.073	0.508	0.197	0.803	0.484	16
A17	**Poland**	0.402	1.640	0.402	0.197	0.803	0.383	19
A18	**Portugal**	0.640	2.616	0.640	0.197	0.803	0.611	7
A19	**Slovakia**	0.545	2.227	0.545	0.197	0.803	0.520	12
A20	**Slovenia**	0.550	2.247	0.550	0.197	0.803	0.525	11
A21	**Spain**	0.632	2.581	0.632	0.197	0.803	0.603	8
A22	**Sweden**	0.839	3.428	0.839	0.197	0.803	0.801	1
AAI		0.245	-	-	-	-	-	-
AI		1.000	-	-	-	-	-	-

For the ease of understanding, calculations of Austria are shown below as an example:

$S_i = 0.223 + 0.038 + 0.088 + 0.032 + 0.088 + 0.071 = 0.540$

$$M_{i-} = \frac{0.540}{0.245} = 2.207$$

$$M_{i+} = \frac{0.540}{1} = 0.540$$

$$\mathrm{f}(\mathrm{M}_{\mathrm{i}-}) = \frac{2.207}{0.540 + 2.207} = 0.197$$

$$\mathrm{f}(\mathrm{M}_{\mathrm{i}+}) = \frac{0.540}{0.540 + 2.207} = 0.803$$

$$f(\mathrm{M_i}) = \frac{2.207 + 0.540}{1 + \frac{1-0.803}{0.803} + \frac{1-0.197}{0.197}} = 0.516$$

The initial results from the MARCOS calculations indicate that Sweden, Latvia, France, Lithuania, and Hungary are the top five European countries with the highest air quality (least emissions). On the other hand, Estonia, Luxembourg, Czech Republic, Poland, and Finland had the lowest air quality performance. The results from the MARCOS method give broad and general insights about the air quality performance of the countries in comparison to each other and their ranking concerning their performance in producing air pollutants. The initial ranking of such countries would enable them to understand their performance among other countries; they would be able to re-evaluate their strategies to increase their air quality performance score and, therefore, their ranking order.

3.3. Sensitivity analysis & discussions

Experts' judgments for the weight determination process and the data source used here have a noticeable impact on the results of the decision-making model. Therefore, a comparative analysis of the results obtained from the decision-making model is helpful to demonstrate the utility, feasibility, and robustness of the introduced decision-making model. For this purpose, we designed two sensitivity analysis tests. First, we made a comparative analysis of the countries' ranking order using other well-known MCDM methods: Combined Comprise Solution (CoCoSo) [56], Evaluation Based on Distance from Average Solution (EDAS) [57], Weight Aggregated Sum Product Assessment [58] (WASPAS), Multi-Attributive Border Approximation area Comparison (MABAC) [59, 60] were selected here as the MCDM methods for comparison. The reason to use other MCDM methods for comparison is to analyze the changes in the ranking of countries based on the different types of normalization, score aggregation procedure, and decision-making structures in such methods. The results of the ranking order for the European countries obtained with the different MCDMs are presented in Figure 2. Sweden comes out as the top country in all the five MCDM methods.

On the other hand, Estonia is the lowest-ranked country in all the MCDM methods except for the CoCoSo, which gave a 21st out of 22 countries. However, as the second and third country, the MARCOS model selected Latvia and France, which did not obtain the same ranking order by the other methods. Austria was ranked 14th by all-new MCDM methods, while it was ranked 15th by EDAS. Belgium had more changes in its ranking among the methods; the differences were 1-3 ranks. Estonia ranked as the last country by most methods except for the CoCoSo, which improved the rank by one unit and placed it as the 21st.

Finland also stays at the 18th rank in all methods except for the CoCoSo, where it improved by one rank and placed as the 17th. The ranking of Germany stayed the same in EDAS, MARCOS, and WASPAS methods but improved in the CoCoSo and MABAC by two ranks. Unlike the MARCOS results, Greece obtained a better ranking in all other MCDM methods and raised from the 14th to the 10th in CoCoSo, EDAS, and MABAC. Hungary fluctuated between ranks third and fifth. Ireland got the same ranking in the MARCOS and WASPAS methods; however, four ranks worsened in the CoCoSo and MABAC methods. Rankings of Italy and Portugal changed slightly between the methods. Luxembourg obtained the same ranking in all methods except for the CoCoSo, whose ranking dropped to the 22nd. Poland also obtained the same ranking in all methods except for the CoCoSo, where its ranking improved by one rank. The EDAS and WASPAS methods worsened the ranking of Slovakia by one rank. Slovenia obtained the same ranking in MABAC, CoCoSo, and MARCOS, while the other methods showed a lower ranking. Spain experienced different ranking using the MCDM methods: CoCoSo and MABAC improved their ranking, but EDAS and WASPAS got the same ranking as MARCOS. Lithuania ranked as the 4th in most MCDMs except for the EDAS, ranked as the 5th country. The Czech Republic, Denmark, and Netherland yielded the same ranking in all the methods.

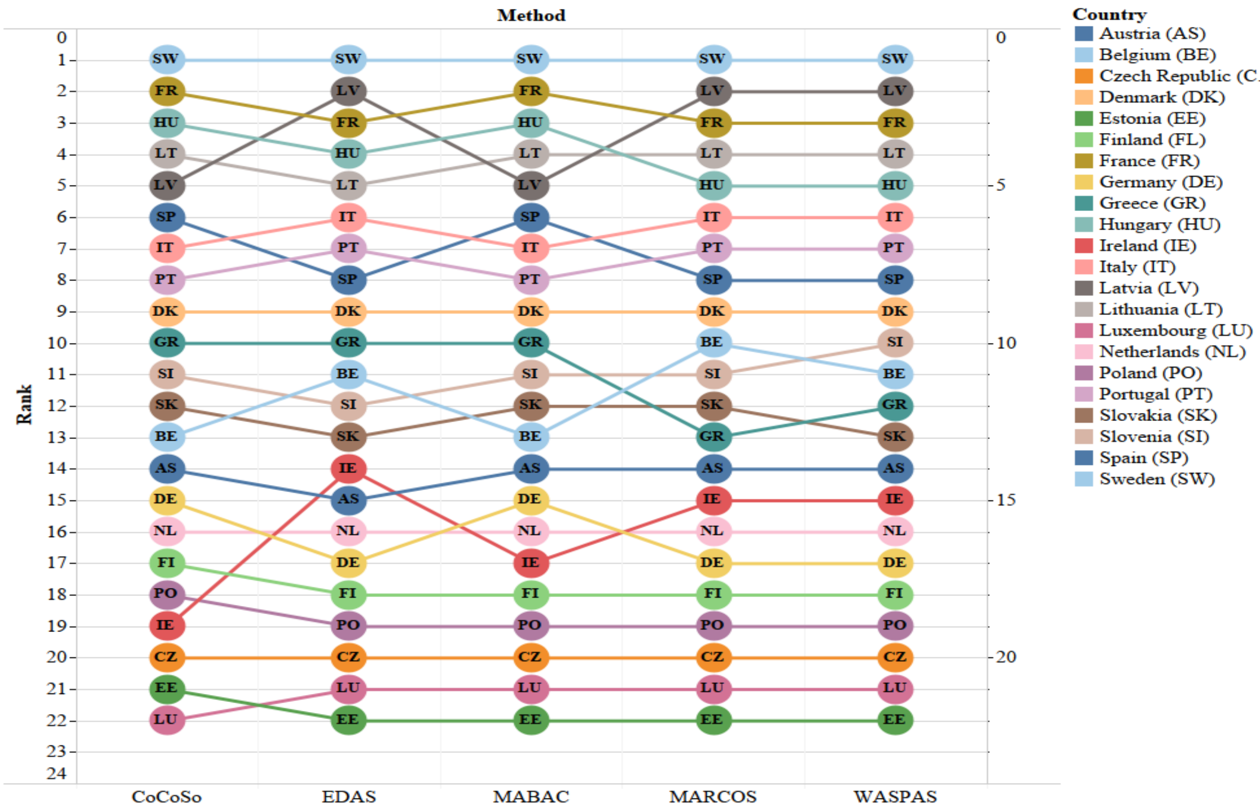

Figure 2. The ranking order of countries using other MCDM models.

In terms of correlation of computational analyses by different MCDM methods, Table 10 presents the correlation coefficient based on Spearman's correlation coefficient (SCC). Numerical values in Table 10 represent the SCC coefficient of results obtained by MARCOS against other MCDM methods. Based on the results, EDAS and WASPAS show a higher correlation with MARCOS rather than CoCoSo and MABAC.

Table 10. Correlation Coefficients.

MCDM methods	**EDAS**	**MABAC**	**CoCoSo**	**WASPAS**
WS Coefficient	0.9862	0.9798	0.9638	0.9934

In the second sensitivity analysis, the performance of the European countries in air pollutants over time was investigated using real data from the OECD database for 2008, 2010, 2012, 2014, and 2016. The results are represented in Figure 3. In 2014, 2016, and 2017, Sweden was the topperforming country and ranked as 3rd, 5th, and 2nd among all countries in 2008, 2010, 2012, respectively. Latvia ranked 1st in 2008-2012 but dropped to second place after 2014. Several countries, including Germany, Netherlands, and Austria, have dropped in their ranking over the years, while others such as France, Denmark, and Italy have clearly improved their air quality performance. Overall, Luxemburg, Estonia, Czech Republic, Finland and Portugal have the lowest ranking in all periods.

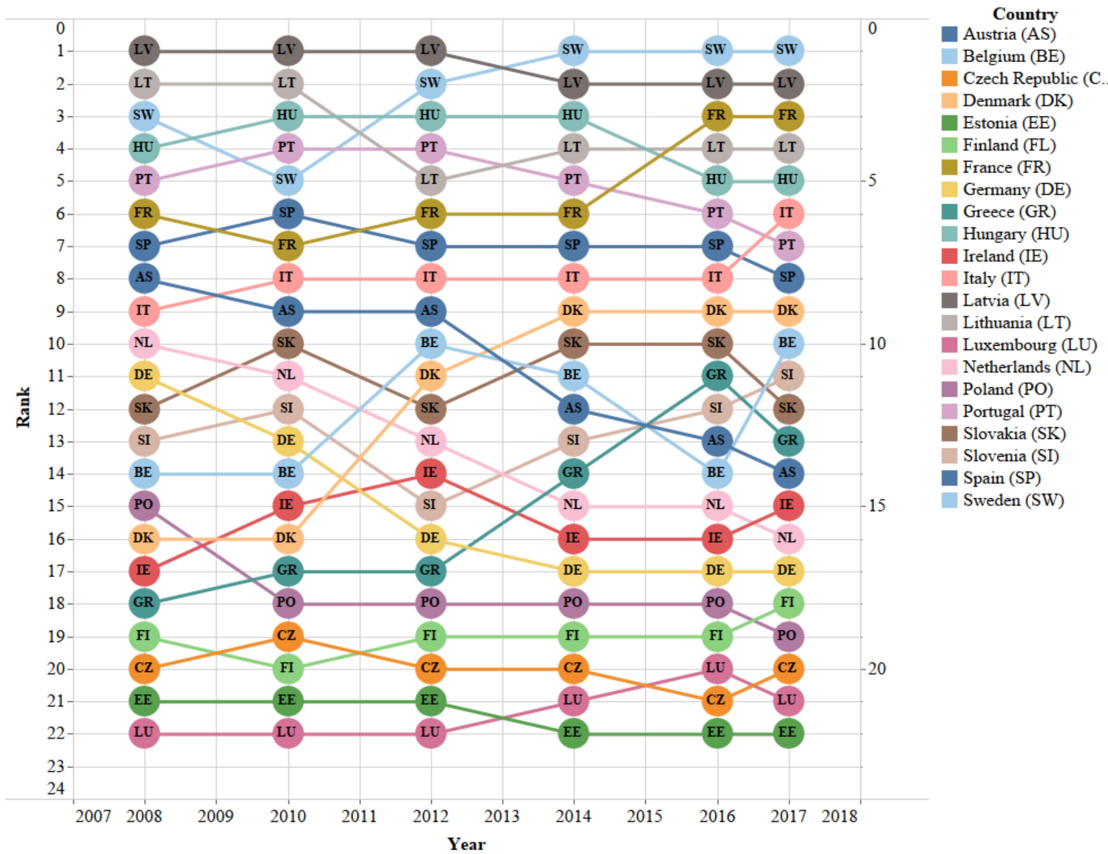

Figure 3. The ranking order of countries 2007-2018 using the MARCOS.

Regarding Luxemburg, air pollution is associated with emissions of CO, nitrogen oxide, Sulphur oxide, PM10, non-methane volatile organic compounds (NMVOC), and the reduction of non-renewables, including fossil fuels, metals, and minerals increasing. The reason for this increasing trend can be that while Luxembourg has altered its economy during 1970-1980, that resulted in mitigating the environmental burden of the businesses which are incredibly emission-intensive (for example, in steel manufacturing). However, several emission-intensive businesses are evolving recently as the significant causes of air pollution in Luxembourg like mobility, which its use of energy and resulted in emissions mainly control the non-renewable energy resources demand [61]. On the other hand, although manufacturing is the primary economic activity for Estonia based on employment, value-added, and exports, it stands behind the average productivity of the European countries and sustainability indices [62]. Low technology and less research-intensive innovations are added to this lack of productivity and integrated with the high pollutant manufacturing dominate in the Estonian manufacturing sector. In Addition, the low-tech businesses (for example, food and wood) create more considerable value-added than high tech businesses [63]. Manufacturing firms in Estonia are not rigorous enough to build and advance clean technologies, based on both in-house technologies and their networks or capable of empowering their production procedures. This results in making the majority of the manufacturers unable to realize new or upcoming clean business trends. Therefore these firms have significant hindrances in pursuing sustainability through higher-value activities in environmental sustainability indices [62].

In the Czech Republic, in 1990, a new Clean Air Act was introduced as a strict regulation conducted for polluters to reduce emission by 1998 as a response to the nation's bad air quality. This decreased the emissions of PM, SO2, and NOx by 90%, 86%, and 47%, respectively, in 1999 compared to their 1990 levels. Since then, energy consumption and associated CO_2 emissions and have not changed. Another regulation established in 2000 was ineffective because of low energy tax rates and allocating too many emission permits. This new regulation only caused a slight reduction in emission levels over the 2000s [64]. In the late 2000s, the Czech Ministry of the Environment raised almost ten times the tax rates for SO_2, NOx, PM, and VOC emissions fees; however, they would merely stand for three percent of pollutant-specific damage costs and, being well below the marginal expenses of mitigation, they did not result in any mitigation in emissions [65]. Nowadays, emission sources in the Czech Republic are regulated by various regulations such as an energy and emission tax, with insignificant and ineffective rates enforced with IPCC mitigation plans on pollutant concentration in flue gases. This historical record in the Czech Republic shows that air pollutant regulation has not been effective enough and has signs of being vague and burdensome [66].

In 1995, in Finland, and air quality enhancement act was developed. The act provided a long list of the necessary policies and national-level regulations conducted by the European Union (EU) to protect the air quality. These new legislations and restrictions were accordingly introduced in 1996

[67]. Because of these strict regulations, the re-evaluation of the Finland air quality became essential. One of the primary motives for the low air quality in Finland in the last years is the lack of stations for monitoring in urban areas [68]. Therefore, a suggestion to improve the air quality goes through addressing this problem. In other words, building stations within the urban background areas can indicate the general air quality, and the data collected by them would be helpful to evaluate population exposure to air pollution in urban regions. Thus, the assessment strategies must be altered to contain the stations for urban background air quality monitoring. This would also facilitate comparing the quality of air among cities. Another challenge identified is that each urban area's local authorities are responsible for quality control and quality assurance measurements. However, there is a lack of quality control documentation and archive [69]. Therefore, a well-documented quality assurance and control system must be employed immediately.

On the other hand, Latvia, Lithuania, Hungary, France, and Sweden have the best ranking overall. In France, the primary critical national guidelines for air quality protection were issued in 1961. Afterward, in 1996, French legislation identified the right to breathe clean and harmless air for the people. Since then, different legislative indicators have controlled air quality at the national and regional levels [70]. There are several air quality enhancement policies France has issued since then, which have had a significant impact on improving the overall air quality in France. For example, in 2015, authorities in regional areas have been authorized to limit traffic zones that require stickers on the cars showing the category of their emission during specific times. Also, it built tax motives for people, regional authorities, and car hire firms to buy clean cars [71].

Another very effective legislation was issued in 2011 for 2011-16 was feed-in-tariffs to generate green electricity using biofuel, including agricultural waste and vegetables to be consumed by power plants [72]. The Waste Control and Management Act has followed this legislation to decrease the amount of organic waste sent to landfills by demanding firms in the private sector to recycle it. In addition, France could encourage and force the firms not to generate more than ten tones per year [73].

According to the Greenpeace environmental campaign organization, Sweden has high-quality air worldwide [74]. It conducted research based on air quality assessment in seventy-three countries in the world in 2018. Several policies have been issued during recent years, which have effectively promoted the air quality in Sweden. A very successful task force was established in 2012 to deal with the open burning in Russia to decrease the unessential fires in a 3-year long period [75]. Another task force was created to develop and follow economic emission mitigation policies and design a national action policy in the same year. A year after, Sweden became the chair of the Arctic Council's task force on limited-time climate elements and published suggestions to decrease back carbon and methane emissions to mitigate the Arctic climate change. Then, in 2014, they decided to create a development program in rural and urban areas by encouraging biofuel productions [76].

Although Greece improved its ranking by seven places from 2008 to 2016, it dropped in the ranking for three places after this improvement, which could be traced back to the Greece economic crisis. For example, some studies believe that the amplified biomass burning because of its economic crisis has harmed air quality in some of the cities in Greece [77]. Other improvements in ranking belong to Sweden and France, and Slovenia from 2010 to 2017. These improvements are probably because of the successful implementation of the clean air policies issued in 2011, 2012, 2013, and 2015. For example, successful traffic zone categorization in crowded urban areas in France requires stickers on the cars showing the category of their emission during specific times [71]. Also, Sweden's effective regulations on cost-effective emission mitigation strategies and developing a national action plan for it and their efforts to decrease the black carbon and methane to slow down the Arctic climate change [76]. Slovenia's success in improving its rank is primarily because of the changes in waste control policies, changing from an almost complete landfilling (65 % in 2007) to a mainly recycling society. As a result, the municipal waste recycling rate in Slovenia is increasing faster than the average of EU-28. Slovenia has already With a 58 % recycling rate for 2017. Slovenia has already surpassed its 2020 waste recycling target of 50% and is now concentrating on the post-2020 targets [78].

Belgium and Slovakia improved their air quality performance over the years. The reason for this can be the halt in increasing the rate of recycling the municipal waste in Belgium where its success during 2012-14 with 55% compared to 44% of EU average and its rate of 25% in 2012 [79]. On the other hand, Poland and Lithuania's air quality performance decreased after 2008 and got to its lowest ranking in 2017. This reduction in performance is because of the growing household usage, which is the most critical contributor to the air pollution in these two countries. Between 2008 and 2017, $PM_{2.5}$ emissions of residential use remained about the same, having around 50% of the total pollutants [80]. Italy, Ireland, Greece, France, Finland, and Belgium are countries that slightly improved their air quality performance from 2008 to 2017. In 2008, Ireland joined the Climate and Clean Air Coalition (CCAC) to develop strategies to mitigate the short-lived contaminants at the national and sub-national levels, realizing the necessity for policy consistency among all the governmental levels. Ireland aims at sharing its experience in decreasing black carbon emissions and co-pollutants from heavy-duty vehicles and engines and production of brick to cope with the air pollution and climate change. The reasons for Belgium, France, and Finland have been explained earlier. Austria (AS), Estonia, and Germany did not improve their air quality performance over the years, and their ranking worsened year by year. Germany's unsuccessful implementation of the planned policies on tropospheric ozone precursors in NOx emission mitigation, volatile hydrocarbons reduction, methane, and CO mitigations plans [81]. Also, Austria failed to employ the pans of black carbon mitigation and soot emission reduction as part of particulate matter [82].

The final test analyzed the impact of using different weights for the most crucial criterion, CO_2. Eq. (14) was used to simulate 25 weight scenarios (s) concerning the CO_2 with the following algorithm:

$$\omega_{n\beta} = (1 - \omega_{na}) \frac{\omega_\beta}{(1 - \omega_n)} \tag{15}$$

where $\omega_{n\beta}$ denotes the adjusted value of the

criterion, ω_β denotes the original value of the criterion, ω_{na} denotes the reduced value of CO_2, ω_n denotes the original value of CO_2. The reductions in the value of the criterion CO_2 occur with 4% steps in each scenario. The weight scenarios are represented in Figure 4.

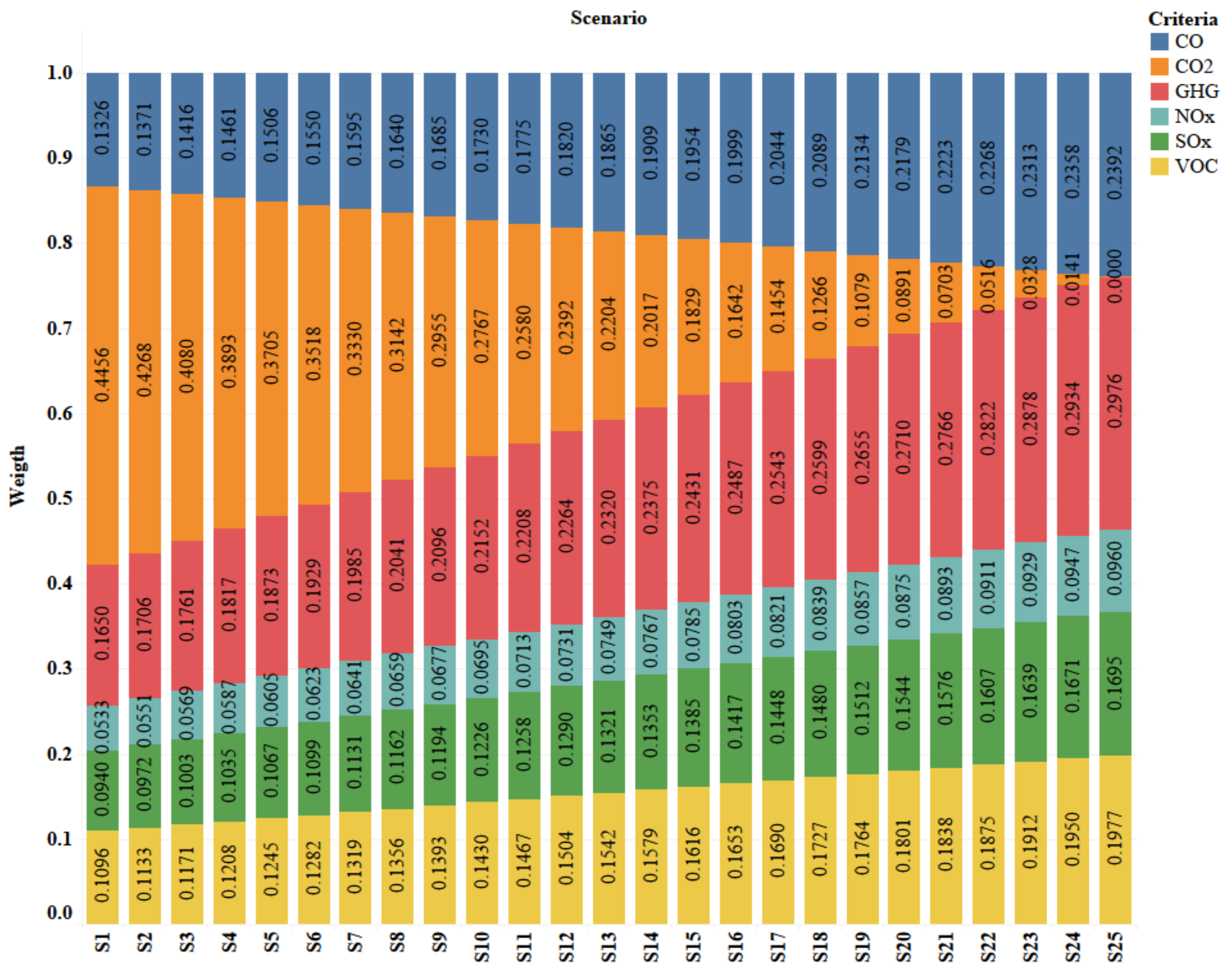

Figure 4. The weight factors for the air quality indicators in the 25 weight scenarios.

The ranking order of countries under the 25 weight scenarios is shown in Figure 5. We notice that Sweden resulted as the top-ranking country in all the weight scenarios. This indicates that the results obtained from the MARCOS method are reliable and robust for Sweden. On the other hand, Estonia, Luxembourg, and the Czech Republic placed among the lowest rankings with the slightest changes in their ranking under all weight scenarios. This means that air pollutants' weighting differently would not affect their ranking as they perform poorly against most criteria. Latvia, selected as the second country in initial results, keeps its place until S16; however, as the importance of CO_2 decreases from S16, Latvia drops to lower ranks gradually. This indicates that the air quality performance of Latvia is affected mainly by CO_2 among all air pollutants, and sensitivity analysis shows that unlike the initial results from the MARCOS method, Latvia cannot be counted as a country with an overall good air quality performance. These results give insights to policymakers that new and sustainable strategies should be proposed to improve Latvia's air quality performance. For the rest of the countries, we observe that some showing improvement in their performances and some show negative performance. France, Belgium, Austria, Denmark, Hungary, Ireland, Italy, Lithuania, Netherland, and Spain have shown improvement in their air quality performances by new weight scenarios. Italy was ranked as the sixth country in the initial weight scenarios, but as the importance of CO_2 decreases and GHG increases, Italy improves its ranking enormously after S8, where it places in fifth, fourth, later in S17 where it places in third ranks. Netherland improves its performance from 16^{th} place to 11^{th} place, and gradually as the importance of CO_2 decreases to its minimum value and GHG's importance increases, it ranks as the sixth country in the last weight scenario. Lithuania is one of the countries that shows negative performance as the importance of CO_2 decreases such that from fourth place in scenario 1, it drops to 9^{th} in scenario 16 and 15^{th} in the last scenario. This indicates that Lithuania does not show healthy air quality performance according to air quality indicators except CO_2. Therefore, its ranking decreases as CO_2 value decreases and other indicators increase. In other words, the air quality performance of Lithuania is strongly affected by CO_2, and it does not show healthy performance for other air pollutants. The rest of the countries showed slight changes in their ranking as the weight of air pollutants changes through weight scenarios.

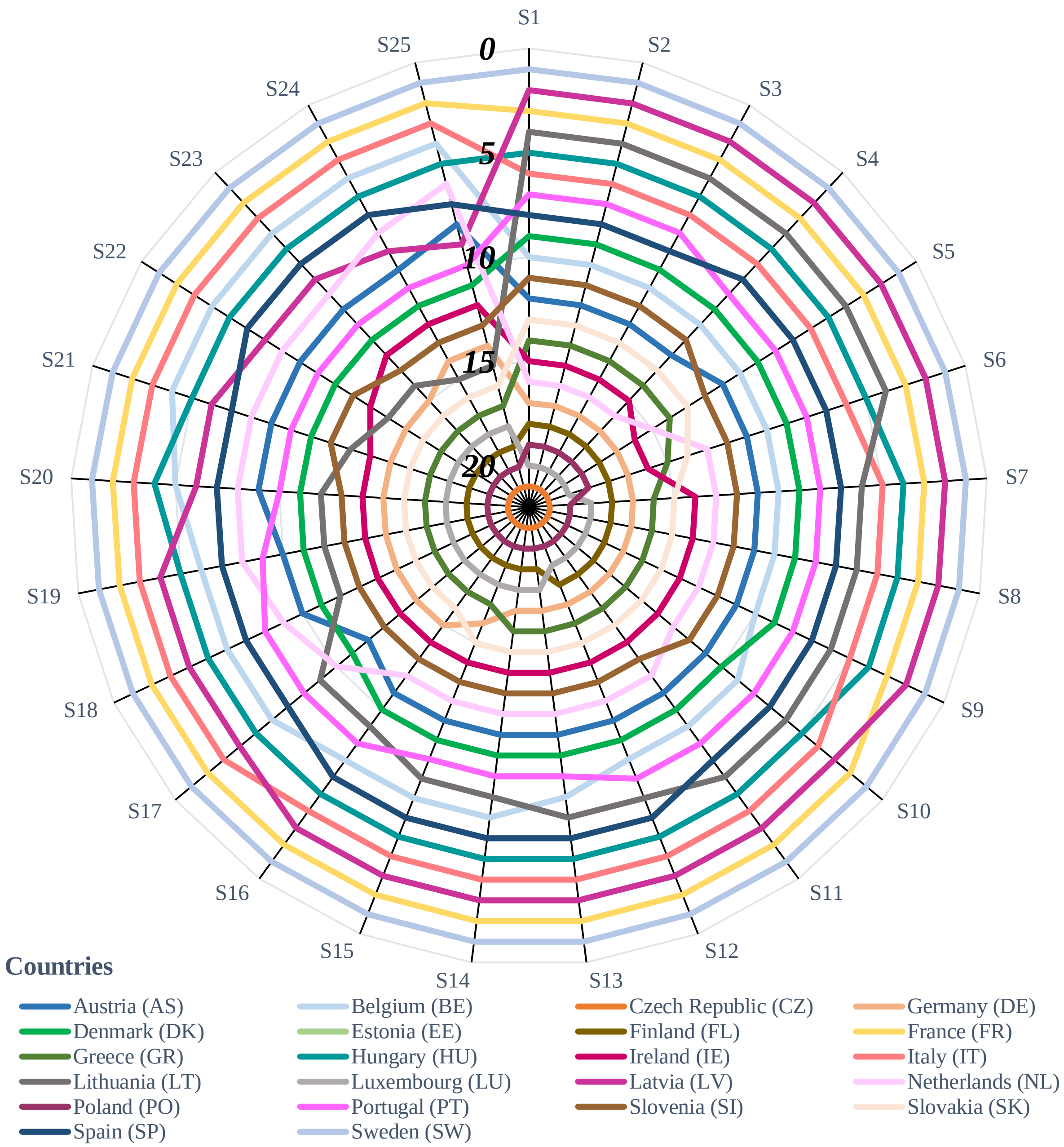

Figure 5. The ranking order of countries under 25 weight scenarios for CO_2.

4. Discussion

The results from the MARCOS method and the sensitivity analysis section present valuable insights on air pollution policies in Europe. Air quality and climate are essential in sustainable development principles and guidelines for all countries as air quality has noticeable effects on environmental, economic, and social aspects. In order to decrease the damages from air pollutants, countries must develop reliable tools for proposing strategies for improving air quality. In this study, we developed an evaluation framework for assessing the air quality of European countries using an integrated decision-making model constructed using the BWM and MARCOS methods. MCDM tools are complex evaluation frameworks that can help sustainability experts to evaluate the air quality performance considering all the necessary air pollutants. We considered six major air pollutants and assessed the performance of countries based on their recent data on the air pollutants emissions within all sectors. To evaluate the performance of countries regarding air pollutants, we first need to determine how vital each air pollutant is to the overall air quality. The BWM enables sustainability experts and policymakers to optimally determine the importance of air pollutants based on their judgments and through a mathematical model. In order to systematically calculate the performance score of each country, the MARCOS model enables to evaluation and rank of countries based on simple quantitative methods. Finally, the MARCOS method gives a value for ranking (0-1) for each country.

The proposed integrated decision support model produced practical implications in terms of the results from the MARCOS and the sensitivity analysis. Some concrete results are obtained based on the initial results from the proposed decision support model and sensitivity analysis. First, Sweden showed the best air quality performance in all tests, which indicates that Sweden has applied effective strategies to control its air pollution. Therefore, the best strategy for Sweden may be to continue its current policies related to controlling air pollutants as it seems to be along with sustainability guidelines and goals. Second, countries like Estonia and Luxembourg have shown the worst performance among all included countries in the case study. Therefore, these countries should modify their current strategies for controlling air pollutants and develop new and more sustainable plans and strategies to minimize emissions. Third, countries with a high population, such as France and Italy and Spain, have shown better performances in controlling air pollutants; however, countries like Germany and Poland have not shown very well performance. Therefore, sustainability and environmental experts in these countries must update their former preventive plans and develop new strategies which could be practical to mitigate the air pollutants. Fourth, countries in the middle rankings show mediocre performance in controlling air pollutants or maximizing air quality. However, it is recommended for such countries to update their plans to control air pollutants to maximize their economic, environmental, and social sustainability performance. Although air quality and air pollutants have direct relations with environmental development, they have dramatic effects on social and economic sides. A wrong strategy for controlling air pollutants would bring dramatic consequences for society and the economy regarding people's health and extra costs for such issues.

5. Conclusions

We have developed an evaluation framework for air quality performance of 22 European countries using CO_2, CO, GHG, NO_x, SO_x, and VOC as air quality indicators. The results indicate that countries such as Sweden, Latvia, and France have performed very well in overall control of air pollutants, whereas countries such as Estonia, Luxembourg, Finland, and the Czech Republic ranked lowest. The results suggest that countries with lower performance scores may need to develop more effective strategies and solutions to control and mitigate air pollutants to move toward more sustainable societies. In the last step, several sensitivity analysis tests were considered to verify the model results and propose new insights about the results of the MCDM model.

The air quality of European countries is studied using MCDM models in terms of six air pollutants. The proposed methodology would empower environmental decision-makers and policy-makers to perform evaluation tests for several countries or cities in terms of the production of air pollutants to help identify places with the highest urgency for improvements and those places that could act as best practice examples. Such comparisons could also help alert regions for increased actions if their ranking starts to drop.

This study can be expanded in some different directions. The introduced model could also be used to assess other countries with severe air pollution issues, for example, in China and the Middle East. The model could also be applied to other environmental problems, such as assessing sustainable waste management systems. In order to decrease the biasedness of experts in the weight determination process, the BWM model can be applied under uncertainty sets such as fuzzy logic.

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