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Assessing Green Transition Dynamics in Europe Through LOPCOW & CODAS Methods

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Abstract

The climate crisis is a result of human-caused global issues. Adopting the notion of sustainability is the key for surviving the repercussions of the climate crisis with minimal damage. Sustainability is a holistic approach to address the climate crisis. The green transition is a crucial strategy that can be used to promote sustainable global development. Measuring green transition performance enables countries to track their progress toward sustainability. This study aims to evaluate the green transition performances of 29 European countries through an integrated LOPCOW&CODAS method. The relative importance of performance indicators is calculated objectively by LOPCOW and then the overall performance scores are obtained by CODAS. The findings show that building energy efficiency, environmental impacts, and preserving and managing natural resources are considered the most critical factors in the green transition. Furthermore, this study explores the effects of applying different weight sets to set the robustness of the performances. Norway, the Netherlands, Estonia, and Austria are leading countries across multiple scenarios. By addressing these aspects, the findings provide deeper insights into green transition dynamics across Europe. Investments in the research and development of green transition should be given top priority by policy-makers who also support sustainable practices.

Keywords
Green transition, Sustainability, Performance analysis, LOPCOW, CODAS

JEL Classification
Q01, Q56, C00

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Avrupa'da Yeşil Dönüşüm Dinamiklerinin LOPCOW & CODAS Yöntemleriyle Değerlendirilmesi

Öz

İklim krizi, insan kaynaklı küresel sorunların bir sonucudur. Sürdürülebilirlik kavramının benimsenmesi, iklim krizinin yansımalarından en az zararla kurtulmanın anahtarıdır. Sürdürülebilirlik, iklim krizini ele almak için bütüncül bir yaklaşımdır. Yeşil dönüşüm, sürdürülebilir küresel kalkınmayı teşvik etmek için kullanılabilecek çok önemli bir stratejidir. Yeşil dönüşüm performansının ölçülmesi, ülkelerin sürdürülebilirlik yolunda kaydettikleri ilerlemeyi takip etmelerini sağlar. Bu çalışma, 29 Avrupa ülkesinin yeşil dönüşüm performanslarını entegre bir LOPCOW&CODAS yöntemiyle değerlendirmeyi amaçlamaktadır. Performans göstergelerinin göreli önemi LOPCOW ile objektif olarak hesaplanmakta ve ardından CODAS ile genel performans puanları elde edilmektedir. Bulgular, bina enerji verimliliği, çevresel etkiler ve doğal kaynakların korunması ve yönetiminin yeşil dönüşümde en kritik faktörler olduğunu göstermektedir. Ayrıca bu çalışma, ülkelerin performanslarının sağlamlığını belirlemek için farklı ağırlık setlerinin uygulanmasının etkisini araştırmaktadır. Norveç, Hollanda, Estonya ve Avusturya birden fazla senaryoda önde gelen ülkeler olarak elde edilmiştir. Bu hususların ele alınmasıyla, Avrupa genelinde yeşil dönüşüm dinamiklerine ilişkin daha derin bilgiler sağlanmıştır. Yeşil dönüşümün araştırılması ve geliştirilmesine yönelik yatırımlara, sürdürülebilir uygulamaları da destekleyen politika yapıcılar tarafından öncelik verilmelidir.

Anahtar Kelimeler
Yeşil dönüşüm, Sürdürülebilirlik, Performans analizi, LOPCOW, CODAS

JEL Kodu
Q01, Q56, C00

1. Introduction

Rising temperatures, sea level rise, air pollution, water scarcity, natural disasters, greenhouse gas emissions, and fossil fuel use are global problems caused by human activities and they lead to the climate crisis. According to the World Meteorological Organization (WMO), the warmest 10-year period occurs between 2014-2023. Therefore, the entire globe encounters with existential threats because of global warming and other detrimental effects of climate change. To combat these threads, some critical actions should be taken. Strategies and policies that recommend to utilize renewable energy sources, energy efficiency, forest protection and replanting, lowering carbon emissions, zero waste, and zero carbon targets should be developed and implemented to avert global catastrophe.

The key idea for surviving the effects of climate catastrophe with minimal damage is to embrace the concept of sustainability. Sustainability is the process of using today's resources effectively and efficiently without sacrificing the needs of future generations in order to achieve a balanced development in environmental, economic, and social factors (WCED, 1987).

Sustainability helps people to mitigate the impacts of climate catastrophe through sustainably managing natural sources, protecting the environment, and enhancing social well-being. Therefore, sustainability offers a comprehensive way forward for actions to tackle climate catastrophe.

In 2019, the European Commission published the European Green Deal including set of key laws and regulations to ensure sustainability. The European Green Deal comprehends a set of climate and environmental measures and aims to make the European Union a competitive economy that produces clean energy, uses resources efficiently, and does not emit greenhouse gases. In order to accomplish this change, countries need to rebuild their development plans with the concept of sustainability.

As Zhai et al. (2022) declared, sustainable global development can be achieved through an important strategy called green transition. Green transition is defined as a process in which unsustainable practices are transformed into environment-friendly methods. The opportunity to observe countries' progress towards sustainability is made possible by measuring green transition performances. For this purpose, countries should be subjected to a comprehensive performance analysis in which various dimensions such as reduction of greenhouse gas emissions and adoption of green technologies can be evaluated together. There are many organizations, institutions reporting green performances of countries with a holistic view. Environmental Performance Index (EPI) (Block et al., 2024), Global Green Economy Index (GGEI) (Dual Citizen LLC, 2024), Green Future Index (GFI) (O'Brien, 2023), Green Transition Index (GTI) (Fritz et al., 2024) are some of the indices developed for benchmarking. Based on the availability of the data, the GTI is selected as the data source for this study.

GTI evaluates 29 European countries based on key performance indicators including economy, nature, manufacturing, utilities, waste, buildings, and transport dimensions which are taken into account to create overall performances. Overall scores are calculated by aggregating subcategories evenly weighted. However, the possibility that seven different dimensions may have different levels of importance is an issue that needs to be focused on. From this point of view, it is useful to put forward the research questions that constitute the motivation of our study:

- Which indicator affects green transition performance more?
- What if the categories measuring a country's green transformation performance had different weights?

- Which European country outperforms in terms of green transition?
- How will the overall performance of countries be affected in light of categories with weights calculated by different weighting methodologies?

To address these questions, multi-criteria decision-making methodologies including LOPCOW and CODAS are applied. The reasons to determine and integrate LOPCOW&CODAS are as follows:

The LOPCOW (Logarithmic Percentage Change Operator Weighting) method is preferred for its ability to determine objective weights of criteria by considering the relative importance of each criterion. Its logarithmic approach ensures a robust and mathematically sound weighting process, making it highly suitable for decision-making problems where objectivity and precision are critical. The CODAS (Combinative Distance-Based Assessment) is a straightforward method yet effective approach to rank alternatives by calculating their distances from the ideal and anti-ideal solutions. The CODAS method provides a comprehensive evaluation of alternatives using Euclidean and Taxicab distances. In this way, this dual distance strategy which increases its sensitivity of differences between criteria, guarantees accurate and reliable findings. Furthermore, CODAS is particularly useful for addressing multi-criteria decision-making issues focusing on ranking and prioritization. LOPCOW, which provides objective weighting, and CODAS, which performs robust ranking procedures, are integrated to ensure methodological rigor and applicability to complex decision problems. The fact that LOPCOW and CODAS have not been used together in the field of green transition extends the scope of studies in the field of multi-criteria decision-making as well.

The study is organized as follows. In the literature review section, the studies focusing on the integration of green transition and MCDM methodology are compiled. Then, in the methodology section, LOPCOW and CODAS methods and their application areas are presented. In the application section, performance analysis and sensitivity analysis of the countries are provided. Finally, the study is concluded by discussing the findings.

2. Literature Review

Literature is reviewed in terms of three perspectives. First of all, the concept of green transition is handled and the studies focused on the performance evaluation of green transition are summarized. After that, the literature is addressed based on the methodologies. The studies applied

LOPCOW and CODAS are reviewed respectively. All studies are presented in tables to make them understandable and easy to follow.

2.1. Green Transition

Bak and Cheba (2023) conducted a detailed systematic literature review study. According to that study, "green transition" and "green transformation" concepts are used interchangeably in the literature. Additionally, especially as of 2021, there has been a major breakthrough in the number of studies on this subject. Therefore, it would be appropriate to underline that "green transition" is a trending topic nowadays. The top cited papers are presented in Bak and Cheba (2023). Since it would be beyond the scope of this study to review only green transition studies, this section will summarize studies that examine performance in green transition. Table 1 demonstrates the green transition performance-related studies.

Table 1

Studies Focused on Green Transition Performance

Author(s)	Topic	Methodology
Yin et al. (2020)	Evaluating green transition of Chinese cities	Three stage DEA
Zhai and An (2020)	Analyzing the influencing factors of green transformation	Structural Equation Modeling
Zhai et al. (2022)		Spatial Durbin model
Weichun et al. (2021)		DEA, Malmquist index, Tobit regression
Cui et al. (2021)		Total factor productivity
Wang and Cao (2022)	Evaluation of green strategies	ANP
Wu et al. (2022)	Evaluating the effect of green transition on ecological well-being	Spatial Durbin model
Long et al. (2022)	Evaluation of regional green transition	Spatiotemporal difference analysis
Cheba et al. (2022)	Evaluating green transformation of EU countries	Multivariate analysis, TOPSIS
Muciaccia (2023)	Evaluation of green transition efficiency of African countries	Linear regression, DEA
Muscillo et al. (2023)	Developing green transition index for Italian municipalities	-
Streimikiene (2023)	Assessing tourism destinations in terms of green digital transformations	TOPSIS, EDAS
Korucuk et al. (2022)	Evaluation of green approaches for twin transition	Fermatean Fuzzy SWARA&COPRAS
Ozdemir et al. (2024)	Evaluation of green deal performance	MEREC & MAIRCA
Radi and Westerhoff (2024)	Evaluation of green transition of firms	Evolutionary competition model
Xu et al. (2024)	Identifying key barriers to green transition	Fuzzy DEMATEL
Chen et al. (2024)	Developing decision-support system for industrial green transition	Prediction model, Cloud model, and Gray relational model (VBO-GM)
Yu et al. (2024)	Assessing green transition of Chinese cities	Entropy, TOPSIS

Sirin (2024)	Green transition effect in financial performance	Portfolio and firm level analysis
Cavalli et al. (2024)	Exploring effectiveness of green transition in terms of environmental quality	Evolutionary approach
Bănică et al. (2024)	Comparison of green and digital transition in terms of institutional quality	Multivariate analysis

When the literature is examined in detail, it is seen that Chinese cities (Yin et al., 2020; Yu et al., 2024), Italian municipalities (Muscillo et al., 2023), African countries (Muciaccia, 2023), tourism destinations (Streimikiene, 2023) were addressed in terms of green transformation performance. Additionally, Cheba et al. (2022) handled EU countries in terms of their way of green transformation. Although this study seems similar to our study, Cheba et al. (2022) analyzed the transition between 2004 and 2019 to observe the changes in the position. There are also a number of studies that commonly address firms and organizations in terms of green transformation (Radi and Westerhoff, 2024; Sirin, 2024; Bănică et al., 2024). In addition to performance analysis of units, there are also studies that examine the factors that have an impact on performance measurement (Zhai and An, 2020; Zhai et al., 2022; Weichun et al., 2021; Cui et al., 2021).

Consequently, although there are various studies that handle specific aspects of green transformation, none of them examine the performance evaluation in a comprehensive manner that integrates dimensions of environmental, economic, transportation, manufacturing, and utilities simultaneously. Furthermore, existing studies often employed conventional MCDM or statistical techniques, whereas our study applies an integrated LOPCOW&CODAS approach for the first time in the field of green transformation. Therefore, it is clear that our study will contribute to the literature.

2.2. LOPCOW Method

In addition to the studies focused on green transition, it would be better to review the studies applied LOPCOW and CODAS. Table 2 shows the studies utilized LOPCOW methodology.

Table 2

Studies Applied LOPCOW Method

Author(s)	**Topic**	**Methodology**
Biswas and Bandyopadhyay (2022)	The impact of COVID-19 on firm performances	LOPCOW, EDAS
Demir and Riaz (2023)	Evaluation of open data management in G20 countries	LMAW, LOPCOW, WASPAS

Ulutaş et al. (2023)	Material selection for common commercial buildings	PSI, MEREC, LOPCOW, MCRAT
Ecer et al. (2023)	Assessing sustainability of solutions in urban transportation	Interval valued fuzzy neutrosophic Delphi, LOPCOW, CoCoSo
Simic et al. (2023)	Assessing industry 4.0 based material handling technologies	Neutrosophic LOPCOW, ARAS
Nila (2023)	Selection of third-party logistics provider	Triangular fuzzy LOPCOW, FUCOM, DOBI
Jiang et al. (2024)	Evaluation of food supply chain performance	Intuitionistic fuzzy ERUNS, LOPCOW, SWARA
Dhruva et al. (2024)	Selection of Suitable Cloud Vendors	Fermatean Fuzzy Set, LOPCOW, and CoCoSo
Ulutaş et al. (2024)	Evaluating third-party logistics providers of car manufacturing firms	Grey LOPCOW, PSI, MACONT
Korucuk et al. (2024)	Selection of warehouse site	Inteval-valued fermatean fuzzy LOPCOW, RAFSI
Do (2024)	Evaluation of influencing factors in university ranking	LOPCOW, PIV, RAWEC, RAM, SRP
Riaz et al. (2024)	Evaluating AI-driven solutions for healthcare supply chain	Circular Intuitionistic fuzzy LOPCOW, AROMAN
Biswas et al. (2024)	Selection of sales personnel	Spherical fuzzy LOPCOW
Işık et al. (2024)	Assessing urban competitiveness in European cities	LOPCOW, CRITIC, ALWAS
Ecer et al. (2024)	Selection of aviation fuel supplier	Interval valued fuzzy neutrosophic LOPCOW, MARCOS
Sumrit and Keeratibhubordee (2025)	Developing risk assessment framework	Trapezoidal fuzzy AHP, LOPCOW, ARAS

Although LOPCOW was introduced recently by Ecer and Pamucar in 2022, it attracted a lot of attention from scholars. In particular, publications on supply chains stand out in the literature (Nila, 2023; Jiang et al., 2024; Ulutaş et al., 2024; Riaz et al., 2024; Ecer et al., 2024). In addition, it is also worth mentioning with which methods LOPCOW is used. Although it is not a prominent method, it has been applied together with current MCDM methods. It is also seen that LOPCOW is applied together with different fuzzy extensions such as triangular (Nila, 2023)), intuitionistic (Jiang et al., 2024; Riaz et al., 2024), neutrosophic (Ecer et al., 2023; Simic et al., 2023; Ecer et al., 2024), fermatean (Korucuk et al., 2024), spherical (Biswas et al., 2024).

2.3. CODAS Method

Table 3 demonstrates the studies applied CODAS method. The CODAS method which predates LOPCOW, is extensively preferred in the literature. The review is conducted based on the quality of the publications. Therefore, the outstanding studies published in between 2017 and 2025 are provided in Table 3.

Table 3

Studies Applied CODAS Method

Author(s)	**Topic**	**Methodology**
Ghorabaee et al. (2017)	Evaluation of market segment	Fuzzy CODAS, EDAS, TOPSIS
Bolturk and Kahraman (2018)	Selection of facility location	Pythagorean fuzzy CODAS
Mathew and Sahu (2018)	Selection of material handling equipment	CODAS, EDAS, WASPAS, MOORA
Laha and Biswas (2019)	Evaluation of Indian banks	CODAS, k-means clustering
Karasan et al. (2019)	Selection of residential construction site	Interval valued hesitant fuzzy CODAS
Yalçın and Yapıcı Pehlivan (2019)	Selection of personnel	Hesitant Fuzzy CODAS
Şeker and Aydın (2020)	Evaluation of sustainable public transportation system	Interval-Valued Intuitionistic AHP, CODAS
Xu (2021)	Evaluation of Blockchain industry performance	Intuitionistic Fuzzy CODAS
Aytaç Adalı and Tuş (2021)	Selection of hospital site	TOPSIS, EDAS, CODAS, CRITIC
Wang and Van Thanh (2022)	Selection of fertilizer supplier	Spherical Fuzzy AHP, CODAS
Candan and Cengiz Toklu (2022)	Evaluating circular economy performances of EU countries	SMART, CODAS
Gonzales et al. (2022)	Evaluation of barriers to implementing Education 4.0	Fermatean Fuzzy Entropy, CRITIC, CODAS, SORT
Tadić et al. (2022)	Evaluation of Smart City Logistics Solutions	Grey BWM, CODAS
Wątróbski et al. (2022)	Evaluation of sustainable electricity generation	COMET, CODAS
Afzali et al. (2022)	Selection of sustainable supplier	Interval-valued intuitionistic fuzzy CODAS
Remadi and Frikha (2023)	Selection of green material	Triangular intuitionistic fuzzy CODAS
Pamucar et al. (2023)	Route selection in freight transportation	Atanassov interval-valued intuitionistic fuzzy CODAS
Ghoushchi et al. (2023)	Evaluation of clean energy barriers	Spherical fuzzy SWARA, CODAS
Alkan et al. (2024)	Selection of automation degree	Intuitionistic fuzzy AHP, CODAS
Kamber and Baskak (2024)	Selection of green logistics park location	Circular intuitionistic fuzzy CODAS
Alkan (2024)	Evaluation of renewable energy systems	Interval valued picture fuzzy CRITIC, SWARA, CODAS
Alsalem et al. (2024)	Evaluation of AI healthcare applications	q-Rung Orthopair Fuzzy 2-Tuple Linguistic FWZIC and q-Rung Orthopair Fuzzy 2-Tuple Linguistic CODAS
Andukuri and Rao (2024)	Selection of condition monitoring equipment	Trapezoidal fuzzy CODAS
Amusan et al. (2024)	Selection of hybrid energy system	CRITIC, CODAS
Hezam et al. (2024)	Evaluation of supply chain risk for gas company	Spherical fuzzy CODAS
Leal et al. (2025)	Analyzing site suitability for green hydrogen production	ARAS, SAW, CODAS, TOPSIS, BWM
Zeng and Yang (2025)	Risk evaluation of livestream e-commerce platforms	q-Rung orthopair fuzzy CODAS

According to Table 3, CODAS is applied in diverse fields. Location selection (Bolturk and Kahraman, 2018; Karasan et al., 2019; Aytaç Adalı and Tuş, 2021; Kamber and Baskak, 2024; Leal et al., 2025), logistics (Şeker and Aydın, 2020; Tadić et al., 2022; Pamucar et al., 2023; Kamber and Baskak, 2024), sustainability (Wątróbski et al., 2022; Afzali et al., 2022; Remadi and Frikha, 2023; Ghoushchi et al., 2023; Alkan, 2024; Amusan et al., 2024) are prominent application areas for CODAS method. As in LOPCOW, CODAS method was also applied with various fuzzy extensions based on the problems handled. For instance, Pythagorean (Bolturk and Kahraman, 2018), hesitant (Karasan et al., 2019; Yalçın and Yapıcı Pehlivan, 2019), Intuitionistic (Şeker and Aydın, 2020; Xu, 2021; Afzali et al., 2022; Remadi and Frikha, 2023; Remadi and Frikha, 2023; Kamber and Baskak, 2024) are some of the outstanding fuzzy extensions. Furthermore, CODAS was preferred to apply with TOPSIS (Ghorabaee et al., 2017; Aytaç Adalı and Tuş, 2021; Leal et al., 2025), EDAS (Ghorabaee et al., 2017; Mathew and Sahu, 2018; Aytaç Adalı and Tuş, 2021), AHP (Şeker and Aydın, 2020; Wang and Van Thanh, 2022; Alkan et al., 2024) which are relatively earlier methods.

Considering Table 2 and Table 3, it is seen that the application areas of the LOPCOW and CODAS methods are still limited. There is no study in the field of green transition performance. Additionally, the literature review indicates that no applied studies have been conducted on the integrated LOPCOW&CODAS method. Based on the comprehensive review, our study contributes to the literature both in terms of application area and the methodology employed.

3. Methodology

This study employs an integrated LOPCOW&CODAS methodology. The LOPCOW is applied to calculate the weights while the CODAS is utilized to rank the alternatives. The process of integration is illustrated in Figure 1.

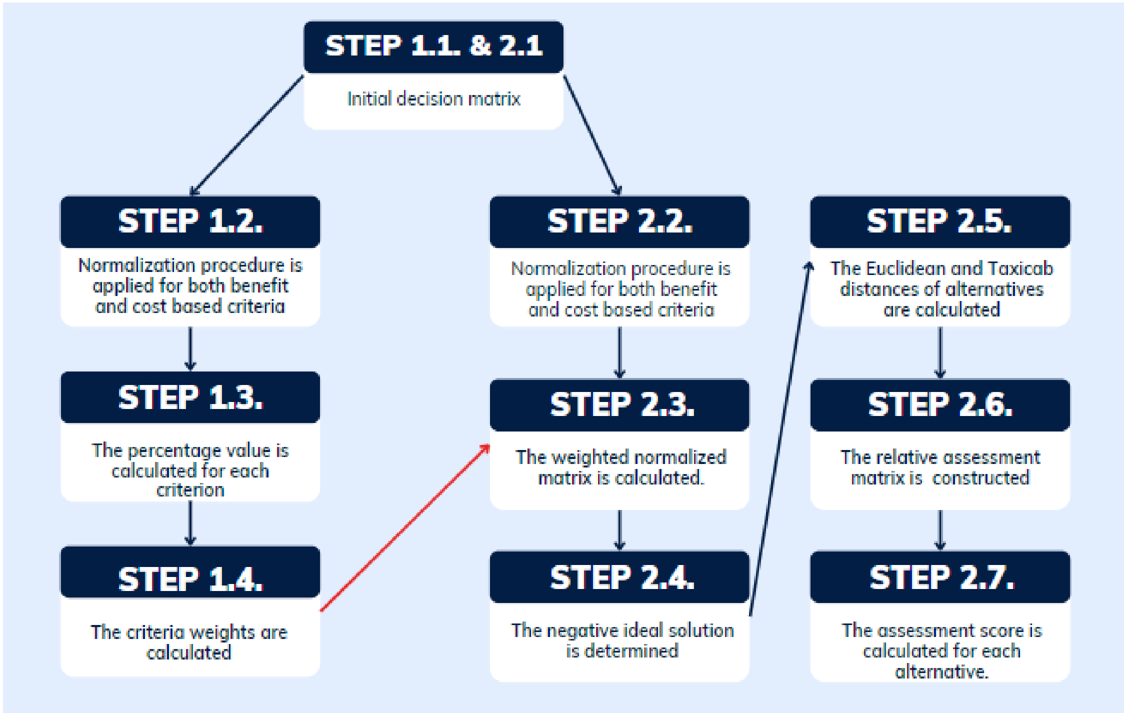

Figure 1. The flowchart of the integrated LOPCOW&CODAS

3.1. LOPCOW Method

LOPCOW developed by Ecer and Pamucar (2022) is a multi-criteria decision-making methodology. The logarithmic structure enables LOPCOW to provide accurate and mathematically sound weighting approach. Thus, LOPCOW method becomes suitable for problems where reliability and clarity are crucial. In addition, objective and balanced assessments are presented by correcting potential distortions due to the volume of data. The calculation steps are provided respectively (Ecer and Pamucar, 2022).

Step 1.1. The data with m alternatives and n criteria is structured as an initial decision matrix.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Step 1.2. Normalization procedure is applied. Equation (2) shows the normalization for the benefit-oriented criteria and Equation (3) shows cost-oriented normalization.

$$n_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}} \text{ (For benefit type criteria)} \quad (2)$$

$$n_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}} \text{ (For cost type criteria)} \quad (3)$$

Step 1.3. The percentage value (PV) is calculated for each criterion as shown in Equation (4).

$$PV_{ij} = \left| \ln \left(\frac{\sqrt{\frac{\sum_{i=1}^{m} n_{ij}^2}{m}}}{\sigma} \right) \times 100 \right| \quad (4)$$

Here σ denotes the standard deviation of the criterion, m is the number of alternatives.

Step 1.4. The criteria weights (w_j) are obtained using Equation (5).

$$w_j = \frac{PV_{ij}}{\sum_{i=1}^{n} PV_{ij}} \quad (5)$$

3.2. CODAS Method

The CODAS (Combinative Distance-Based Assessment) is a method developed to rank alternatives by evaluating their proximity to ideal and anti-ideal solutions. It is proposed by Keshavarz Ghorabaee et al. (2016). It provides a thorough evaluation of alternatives based on how well they perform based on numerous criteria by combining the Euclidean and Taxicab distances. CODAS is a flexible approach to evaluate complex decision-making problems involving prioritization and ranking because of its special dual-distance technique, that allows comprehensive evaluations. The application procedure is provided in the following (Keshavarz Ghorabaee et al., 2016).

Step 2.1. The initial decision matrix is shown in Equation (1) including m alternatives and n criteria.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{6}$$

Step 2.2. The data is normalized depending on whether the criteria are benefit-oriented or cost-oriented as given in Equation (7-8).

$$n_{ij} = \frac{x_{ij}}{x_{max}} \text{ (For benefit type criteria)} \tag{7}$$

$$n_{ij} = \frac{x_{min}}{x_{ij}} \text{ (For cost type criteria)} \tag{8}$$

Step 2.3. The weighted normalized matrix is calculated as given in Equation (9).

$$r_{ij} = w_j n_{ij} \tag{9}$$

Here w_j denotes the weight of the j^{th} criterion and $\sum_{j=1}^{n} w_j = 1$

Step 2.4. The negative ideal solution (point) is determined as given in Equation (10).

$$ns = \left[ns_j\right]_{1xm} \tag{10}$$

Here ns_j denotes min (r_{ij}).

Step 2.5. The Euclidean and Taxicab distances of alternatives from the negative-ideal solution are calculated as shown in Equation (11-12):

$$E_i = \sqrt{\sum_{j=1}^{m} (r_{ij} - ns_j)^2} \tag{11}$$

$$T_i = \sum_{j=1}^{m} \left|r_{ij} - ns_j\right| \tag{12}$$

Step 2.6. The relative assessment matrix is constructed.

$$Ra = [h_{ik}]_{nxn} \tag{13}$$

$$h_{ik} = (E_i - E_k) + (\psi(E_i - E_k) \times (T_i - T_k)) \tag{14}$$

Here $k \in \{1,2, \dots, n\}$ and ψ denotes a threshold function to recognize the equality of the Euclidean distances of two alternatives, and is defined as follows in Equation (15):

$$\psi(x) = \begin{Bmatrix} 1 \; if \; |x| \geq \tau \\ 0 \; if \; |x| < \tau \end{Bmatrix} \tag{15}$$

Here τ is the threshold parameter which is generally suggested to be set between 0.01 and 0.05 and it is determined by the decision maker.

Step 2.7. The assessment score is calculated for each alternative. According to the assessment score, the alternatives are ranked in descending order. The alternative with the highest score is defined as the best alternative.

$$H_i = \sum_{k=1}^{n} h_{ik} \tag{16}$$

4. Application

This study focuses on evaluating the green transition performances of countries. While various indices have been developed by different organizations, they often lack significant methodological contributions in performance analysis. To address this gap, this study aims to evaluate performance using different methodological approaches. This not only enriches the analysis but also provides an opportunity to validate the robustness and reliability of the evaluation indicators.

The Green Transition Index (GTI) is an index developed by Fritz et al. in 2024 under the heading of Oliver Wyman consulting firm. GTI assesses the green transition performance of 29 European countries across key dimensions, including economy, nature, manufacturing, utilities, waste, buildings, and transport. In calculating overall performance scores, these dimensions are aggregated with the assumption of equal weighting across subcategories. However, this presumption of uniform importance among the seven dimensions warrants critical examination, as their relative influence may vary significantly. This concern forms the primary motivation for our study. Driven by this motivation, our research aims to address the following key questions:

- Which performance indicators have the greatest impact on green transition performance?
- How would the overall scores differ if the dimensions contributing to a country's green transition performance were weighted unequally?
- Which European country demonstrates the highest level of success in green transition?
- How would countries' overall performances change if the weights of the dimensions were determined using alternative weight sets?

To address these research questions individually, the methodological workflow of our study will follow the structure illustrated in Figure 2.

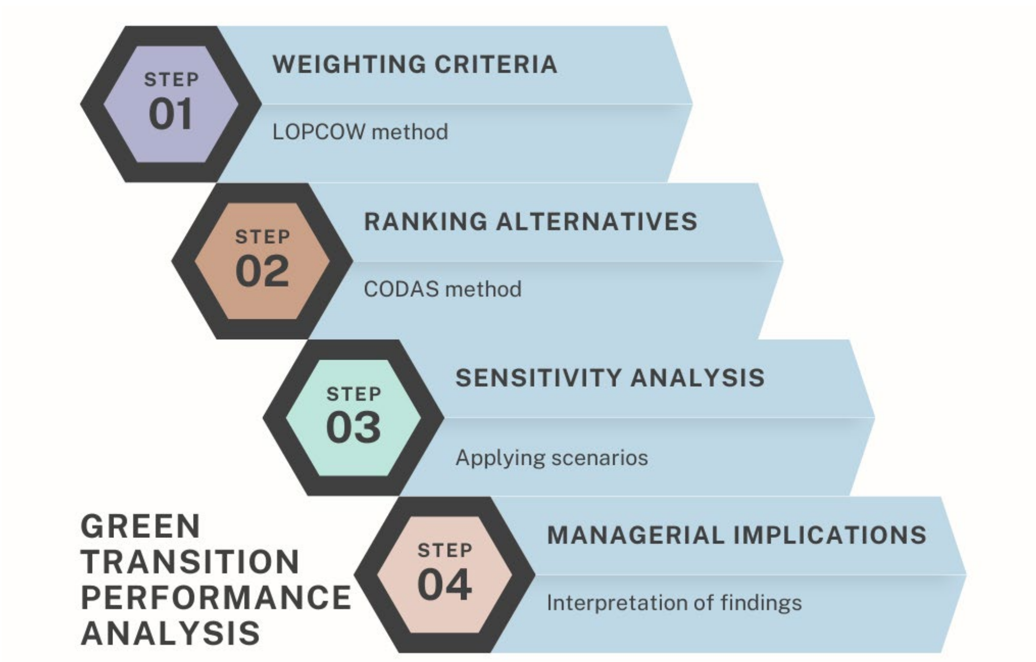

Figure 2. Application procedure

The data covers seven categories including economy, nature, manufacturing, utilities, transport, buildings, and waste. In GTI, the performances of countries are calculated based on the 28 key performance indicators under seven categories. The details are given in Table 4.

Table 4

Categories and Indicators

Criteria	Indicators
ECONOMY	*Greenhouse gas emissions intensity (Greenhouse gas emissions per unit of GDP)*
	Energy intensity (Primary energy consumption per unit of GDP)

	Track record in reducing greenhouse gas emissions and primary energy consumption
	Value-added in the environmental goods and services sector as % of total value-added
	Public research and development spending towards environmental objectives as % of GDP
	Eurostat Eco-Innovation Index
NATURE	*Protected terrestrial and marine area as % of total country area*
	Organic farming as % total utilized agricultural area
	Water exploitation index (Total freshwater use out of total renewable freshwater resources)
	Urban population exposure to air pollutants
MANUFACTURING	*Greenhouse gas emissions intensity in the manufacturing sector*
	Energy intensity in the manufacturing sector
	Hazardous waste intensity in the manufacturing sector
UTILITY	*Renewables and biofuels as % of total electricity production*
	Capacity of hydrogen projects for energy transition purposes about total GDP
	Capacity of carbon capture and storage projects in relation to total CO_2 emissions
	Capacity of battery-related storage projects in relation to total generation capacity
TRANSPORT	*Average CO_2 emissions from new passenger cars per km*
	Adoption and penetration of alternative fuels passenger cars (electric, hybrid, fuel cells, biofuels) as % of total vehicle stock
	CO_2 emissions from household transport activities per capita
	Public transport in total passenger transport
BUILDINGS	*Household electricity consumption per capita*
	Share of renewables in space and water heating of households
	Certified green building projects by leading standards in relation to GDP
WASTE	*Hazardous and non-hazardous household waste per capita*
	Circularity rate including recycling and reuse
	Municipal waste disposal in landfill per capita

* Source: The Green Transition Index

According to Fritz et al. (2024) who developed GTI, manufacturing, utilities, transport, and buildings are determined based on the main sources of emissions in the European economy. In addition, nature and waste categories are included since they help to evaluate countries' natural source management and waste generation and treatment practices. Lastly, the economy category evaluates overall performance in emissions and energy use while examining government efforts, such as public R&D funding and policies, to support the green transition. In GTI, the categories of economy, nature, manufacturing, utility, transport, buildings, and waste were analyzed. In this study, these categories are treated as criteria for further examination.

To address the research question, "Which performance indicators exert the greatest influence on green transition performance?", the LOPCOW method will be utilized to assign weights to the relevant criteria.

<u>Step 1. Weighting Criteria</u>

The data including 29 European countries and 7 criteria is structured as an initial decision matrix and presented in Table 5.

Table 5

Initial Decision Matrix

Country	Economy	Nature	Manufacturing	Utilities	Transport	Buildings	Waste
Austria	61.3	74.5	75.2	21.1	45	56.5	54
Belgium	49.7	52.4	58.3	17.6	46.7	42.1	72.8
Bulgaria	21.1	45.1	25.3	2.4	43.9	70.8	32.9
Croatia	35.2	46.1	53	16.4	30.7	75.7	47.8
Cyprus	39.3	14.4	31	0.3	18.8	60.8	23.7
Czechia	40.4	53.7	72.2	1.9	62.9	68.1	37
Denmark	63.6	60.4	93.2	51.5	37	52.9	40.2
Estonia	66.7	76.2	57	10.5	41.5	71.9	64.2
Finland	65.8	69.7	52.6	17	37.4	56.8	59
France	64.2	61.1	75.1	21.8	37.1	61.4	64.8
Germany	68.1	61.9	83.6	38.9	21.6	47.4	60.1
Greece	62.2	29.2	43.4	17.4	39.1	58.6	27.6
Hungary	28.2	51.2	63.8	2.4	54.3	61	58
Ireland	53.3	47.1	100	22.3	29.7	35.5	49.7
Italy	61.8	45.6	79.8	26	36.6	56.1	59
Latvia	42.2	59.1	52.8	15	35.3	76.4	47
Lithuania	26.8	50.8	62.6	14.9	6.6	73.5	40.8
Luxembourg	61.3	58.2	59.9	22.1	35.5	45.2	70
Malta	52.8	26.7	94.9	0	45.4	55.4	25.9
Netherlands	61.2	54.4	66.7	52	43.3	48.9	75.2
Norway	61.8	69.4	46.1	49.5	56.3	21.1	67.8
Poland	20.6	42.3	52.5	3.3	47.8	60.6	65.3
Portugal	56.3	42.9	57.2	39.2	36.7	77.5	26.5
Romania	36.5	46.8	57	11.1	49.3	82.3	53.3
Slovakia	40.5	67.4	48.6	8.7	54.2	61.1	42.1
Slovenia	44.9	72.7	76.4	6.6	18.8	71.1	68.9
Spain	64.3	47.8	65.8	36.2	30.8	62.3	40
Sweden	66.4	73.9	69.8	26.6	45.1	39.7	54
United Kingdom	60.9	49.7	78.6	47.6	26.2	56.9	64.1

Among the criteria, economy, nature, utilities, transport, buildings, and waste are benefits whereas manufacturing is a cost-based criterion. A normalization procedure is applied based on this information. The normalized decision matrix is presented in Table 6.

Table 6

Normalized Decision Matrix

Country	Economy	Nature	Manufacturing	Utilities	Transport	Buildings	Waste
Austria	0.857	0.972	0.332	0.406	0.682	0.578	0.588
Belgium	0.613	0.615	0.558	0.338	0.712	0.343	0.953
Bulgaria	0.011	0.497	1.000	0.046	0.663	0.812	0.179
Croatia	0.307	0.513	0.629	0.315	0.428	0.892	0.468
Cyprus	0.394	0.000	0.924	0.006	0.217	0.649	0.000
Czechia	0.417	0.636	0.372	0.037	1.000	0.768	0.258
Denmark	0.905	0.744	0.091	0.990	0.540	0.520	0.320
Estonia	0.971	1.000	0.576	0.202	0.620	0.830	0.786

Finland	0.952	0.895	0.635	0.327	0.547	0.583	0.685
France	0.918	0.756	0.333	0.419	0.542	0.658	0.798
Germany	1.000	0.769	0.220	0.748	0.266	0.430	0.707
Greece	0.876	0.239	0.758	0.335	0.577	0.613	0.076
Hungary	0.160	0.595	0.485	0.046	0.847	0.652	0.666
Ireland	0.688	0.529	0.000	0.429	0.410	0.235	0.505
Italy	0.867	0.505	0.270	0.500	0.533	0.572	0.685
Latvia	0.455	0.723	0.632	0.288	0.510	0.904	0.452
Lithuania	0.131	0.589	0.501	0.287	0.000	0.856	0.332
Luxembourg	0.857	0.709	0.537	0.425	0.513	0.394	0.899
Malta	0.678	0.199	0.068	0.000	0.689	0.560	0.043
Netherlands	0.855	0.647	0.446	1.000	0.652	0.454	1.000
Norway	0.867	0.890	0.722	0.952	0.883	0.000	0.856
Poland	0.000	0.451	0.636	0.063	0.732	0.645	0.808
Portugal	0.752	0.461	0.573	0.754	0.535	0.922	0.054
Romania	0.335	0.524	0.576	0.213	0.758	1.000	0.575
Slovakia	0.419	0.858	0.688	0.167	0.845	0.654	0.357
Slovenia	0.512	0.943	0.316	0.127	0.217	0.817	0.878
Spain	0.920	0.540	0.458	0.696	0.430	0.673	0.317
Sweden	0.964	0.963	0.404	0.512	0.684	0.304	0.588
United Kingdom	0.848	0.571	0.286	0.915	0.348	0.585	0.784

Thereafter, the standard deviation (σ) of each criterion is calculated. Using σ and the number of countries, the percentage value (PV) is calculated for each criterion. Finally, the criteria weights are calculated using the percentage value. The values are given in Table 7.

Table 7

σ, PV, and the Weights

	Economy	**Nature**	**Manufacturing**	**Utilities**	**Transport**	**Buildings**	**Waste**
σ	0.3126	0.2386	0.2365	0.3103	0.2210	0.2267	0.2967
PV	81.8684	103.8802	81.9282	47.9821	100.7448	106.2970	72.4678
w	0.1376	0.1745	0.1377	0.0806	0.1693	0.1786	0.1218

The criteria ranking is obtained as buildings, nature, transport, economy-manufacturing, waste, and utilities respectively. According to the findings, buildings (0.1786) and nature (0.1745) indicate that building energy efficiency, environmental impacts, and the preservation and management of natural resources are considered the most critical for environmental sustainability. On the other hand, the utilities criterion (0.0806) is viewed as less critical compared to other categories. These weights emphasize that buildings and natural resource management should be the primary focus of environmental sustainability strategies. At the same time, utilities are less prominent priorities but should not be overlooked. In addition, it can be noted that the weight differences among the criteria are not particularly dramatic.

Step 2. Ranking Alternatives

This step aims to address the following research questions: (*i*) How would the overall scores differ if the dimensions contributing to a country's green transition performance were weighted unequally? (*ii*) Which European country demonstrates the highest level of success in green transition? respectively.

The performance scores of countries are calculated by integrating the weights obtained in the first step. CODAS method is applied to the initial decision matrix which is demonstrated in Table 5. Thereafter, a normalization procedure is conducted and the normalized decision matrix is given in Table 8.

Table 8

Normalized Decision Matrix

Country	Economy	Nature	Manufacturing	Utilities	Transport	Buildings	Waste
Austria	0.900	0.978	0.336	0.406	0.715	0.687	0.718
Belgium	0.730	0.688	0.434	0.338	0.742	0.512	0.968
Bulgaria	0.310	0.592	1.000	0.046	0.698	0.860	0.438
Croatia	0.517	0.605	0.477	0.315	0.488	0.920	0.636
Cyprus	0.577	0.189	0.816	0.006	0.299	0.739	0.315
Czechia	0.593	0.705	0.350	0.037	1.000	0.827	0.492
Denmark	0.934	0.793	0.271	0.990	0.588	0.643	0.535
Estonia	0.979	1.000	0.444	0.202	0.660	0.874	0.854
Finland	0.966	0.915	0.481	0.327	0.595	0.690	0.785
France	0.943	0.802	0.337	0.419	0.590	0.746	0.862
Germany	1.000	0.812	0.303	0.748	0.343	0.576	0.799
Greece	0.913	0.383	0.583	0.335	0.622	0.712	0.367
Hungary	0.414	0.672	0.397	0.046	0.863	0.741	0.771
Ireland	0.783	0.618	0.253	0.429	0.472	0.431	0.661
Italy	0.907	0.598	0.317	0.500	0.582	0.682	0.785
Latvia	0.620	0.776	0.479	0.288	0.561	0.928	0.625
Lithuania	0.394	0.667	0.404	0.287	0.105	0.893	0.543
Luxembourg	0.900	0.764	0.422	0.425	0.564	0.549	0.931
Malta	0.775	0.350	0.267	0.000	0.722	0.673	0.344
Netherlands	0.899	0.714	0.379	1.000	0.688	0.594	1.000
Norway	0.907	0.911	0.549	0.952	0.895	0.256	0.902
Poland	0.302	0.555	0.482	0.063	0.760	0.736	0.868
Portugal	0.827	0.563	0.442	0.754	0.583	0.942	0.352
Romania	0.536	0.614	0.444	0.213	0.784	1.000	0.709
Slovakia	0.595	0.885	0.521	0.167	0.862	0.742	0.560
Slovenia	0.659	0.954	0.331	0.127	0.299	0.864	0.916
Spain	0.944	0.627	0.384	0.696	0.490	0.757	0.532
Sweden	0.975	0.970	0.362	0.512	0.717	0.482	0.718
United Kingdom	0.894	0.652	0.322	0.915	0.417	0.691	0.852

The weights calculated in LOPCOW method should be integrated into the decision matrix after normalization. Table 9 shows the weighted normalized decision matrix.

Table 9

Weighted Normalized Decision Matrix

Country	Economy	Nature	Manufacturing	Utilities	Transport	Buildings	Waste
Austria	0.12	0.13	0.05	0.06	0.10	0.09	0.10
Belgium	0.10	0.09	0.06	0.05	0.10	0.07	0.13
Bulgaria	0.04	0.08	0.14	0.01	0.10	0.12	0.06
Croatia	0.07	0.08	0.07	0.04	0.07	0.13	0.09
Cyprus	0.08	0.03	0.11	0.00	0.04	0.10	0.04
Czechia	0.08	0.10	0.05	0.01	0.14	0.11	0.07
Denmark	0.13	0.11	0.04	0.14	0.08	0.09	0.07
Estonia	0.13	0.14	0.06	0.03	0.09	0.12	0.12
Finland	0.13	0.13	0.07	0.04	0.08	0.09	0.11
France	0.13	0.11	0.05	0.06	0.08	0.10	0.12
Germany	0.14	0.11	0.04	0.10	0.05	0.08	0.11
Greece	0.13	0.05	0.08	0.05	0.09	0.10	0.05
Hungary	0.06	0.09	0.05	0.01	0.12	0.10	0.11
Ireland	0.11	0.09	0.03	0.06	0.06	0.06	0.09
Italy	0.12	0.08	0.04	0.07	0.08	0.09	0.11
Latvia	0.09	0.11	0.07	0.04	0.08	0.13	0.09
Lithuania	0.05	0.09	0.06	0.04	0.01	0.12	0.07
Luxembourg	0.12	0.11	0.06	0.06	0.08	0.08	0.13
Malta	0.11	0.05	0.04	0.00	0.10	0.09	0.05
Netherlands	0.12	0.10	0.05	0.14	0.09	0.08	0.14
Norway	0.12	0.13	0.08	0.13	0.12	0.04	0.12
Poland	0.04	0.08	0.07	0.01	0.10	0.10	0.12
Portugal	0.11	0.08	0.06	0.10	0.08	0.13	0.05
Romania	0.07	0.08	0.06	0.03	0.11	0.14	0.10
Slovakia	0.08	0.12	0.07	0.02	0.12	0.10	0.08
Slovenia	0.09	0.13	0.05	0.02	0.04	0.12	0.13
Spain	0.13	0.09	0.05	0.10	0.07	0.10	0.07
Sweden	0.13	0.13	0.05	0.07	0.10	0.07	0.10
United Kingdom	0.12	0.09	0.04	0.13	0.06	0.10	0.12

The negative ideal solution point is determined to calculate Euclidean and Taxicab distances for each alternative. Finally, the relative assessment matrix is constructed. Table 10 demonstrates the calculated parameters related to the counties. The relative assessment score for each alternative represents the performance score of the country. The country with the highest relative assessment score has the best performance among 29 countries.

Table 10

The Euclidean, Taxicab Distances and Assessment Scores

Country	E_i	T_i	H_i	Rank
Austria	0.188	0.457	2.283	7

Belgium	0.167	0.411	0.238	15
Bulgaria	0.166	0.347	-1.025	21
Croatia	0.142	0.349	-2.522	25
Cyprus	0.112	0.209	-7.064	29
Czechia	0.170	0.355	-0.406	19
Denmark	0.203	0.458	2.972	4
Estonia	0.203	0.494	3.740	3
Finland	0.183	0.459	1.744	8
France	0.182	0.451	1.491	10
Germany	0.186	0.435	1.737	9
Greece	0.145	0.343	-2.134	23
Hungary	0.156	0.342	-1.505	22
Ireland	0.129	0.306	-3.891	26
Italy	0.164	0.406	-0.058	17
Latvia	0.159	0.393	-0.612	20
Lithuania	0.123	0.257	-5.380	27
Luxembourg	0.173	0.431	0.774	12
Malta	0.123	0.235	-5.821	28
Netherlands	0.221	0.530	5.348	2
Norway	0.232	0.543	6.159	1
Poland	0.148	0.323	-2.466	24
Portugal	0.180	0.419	0.973	11
Romania	0.168	0.396	-0.020	16
Slovakia	0.171	0.400	0.255	14
Slovenia	0.169	0.375	-0.122	18
Spain	0.171	0.414	0.515	13
Sweden	0.191	0.456	2.304	6
United Kingdom	0.194	0.457	2.475	5

According to Table 10, Norway (1^{st}), the Netherlands (2^{nd}), and Estonia (3^{rd}) are the leading countries in the green transition. Countries such as Austria (7^{th}), Sweden (6^{th}), and the United Kingdom (5^{th}) are close to the top but do not reach the same level of environmental sustainability impact as the leaders. However, they still perform well in terms of transition. Major economies like France (10^{th}) and Germany (9^{th}) fall into the middle-upper range, showing moderate success in green transition despite their economic scale. Cyprus (29^{th}), Malta (28^{th}), and Lithuania (27^{th}) demonstrate the weakest performance in green transition.

Step 3. Sensitivity Analysis

As the answers to three research questions have already been determined, now we focus on addressing the final research question: “How would countries' overall performances change if the weights of the dimensions were determined using alternative weight sets?”.

By addressing this question, the study will determine whether the performance scores of countries are sensitive to the weighting of the criteria. For this reason, five different scenarios are generated to test overall performances. Scenario 1 has the original weights calculated by LOPCOW method. Scenario 2 is the case that assumed equal weights. Scenarios 3, 4, and 5 include the weights randomly generated. The various weight sets are demonstrated in Table 11.

Table 11

Scenarios Based on Different Weight Sets

Scenario	Economy	Nature	Manufacturing	Utilities	Transport	Buildings	Waste
Scenario 1	0.1376	0.1745	0.1377	0.0806	0.1693	0.1786	0.1218
Scenario 2	0.143	0.143	0.143	0.143	0.143	0.143	0.143
Scenario 3	0.003	0.101	0.402	0.057	0.328	0.075	0.034
Scenario 4	0.128	0.016	0.099	0.317	0.077	0.270	0.094
Scenario 5	0.120	0.180	0.100	0.150	0.200	0.080	0.170

According to Table 11, the rankings of the criteria are given in Table 12. When examining the table, it becomes evident that the values assigned to the criteria vary significantly across different scenarios.

Table 12

Rankings of Criteria Obtained from Different Scenarios

Scenario	Economy	Nature	Manufacturing	Utilities	Transport	Buildings	Waste
Scenario 1	5	2	4	7	3	1	6
Scenario 2	-	-	-	-	-	-	-
Scenario 3	7	3	1	5	2	4	6
Scenario 4	3	7	4	1	6	2	5
Scenario 5	5	2	6	4	1	7	3

Table 12 shows the rankings obtained from different scenarios. Upon initial observation, although the weights differ, the rankings do not exhibit any significant or dramatic variations. Except for scenario 3, the 1st, 2nd, 3rd, and 4th countries are identical. In addition, all scenarios have a common thread for Cyprus which is the worst performer. For the 2nd, 3rd, and 4th from the end, the same results are obtained except for the scenario 3. To strengthen this observation, it would be beneficial to examine the Spearman correlation coefficients. The rankings achieved in scenarios 2, 3, 4, and 5 are compared with the ranking obtained in scenario 1 (LOPCOW&CODAS methodology) by utilizing Spearman Correlation Coefficients. The correlation coefficients are found 0.99951, 0.94877, 0.99852, and 0.99754 respectively. The correlation coefficients indicate very high levels of correlation between the rankings across the different weighting scenarios which means that the green transition performances of countries are not sensitive to the weighting of the criteria. In other words, the performance scores are robust.

Table 13

Rankings of Countries Obtained from Different Scenarios

Country	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Austria	7	7	2	6	5
Belgium	14	14	9	14	14
Bulgaria	21	21	22	21	21
Croatia	24	24	26	25	25
Cyprus	29	29	29	29	29
Czechia	19	19	20	19	19
Denmark	4	4	3	4	4
Estonia	3	3	1	3	3
Finland	8	9	6	8	8
France	10	10	8	10	10
Germany	9	8	7	9	9
Greece	23	23	24	23	23
Hungary	22	22	21	22	22
Ireland	26	26	25	26	26
Italy	17	17	15	16	16
Latvia	20	20	19	20	20
Lithuania	27	27	28	27	27
Luxembourg	12	12	11	12	12
Malta	28	28	27	28	28
Netherlands	2	2	5	2	2
Norway	1	1	4	1	1
Poland	25	25	23	24	24
Portugal	11	11	10	11	11
Romania	16	16	17	17	17
Slovakia	15	15	16	15	15
Slovenia	18	18	18	18	18
Spain	13	13	14	13	13
Sweden	6	6	13	7	7
United Kingdom	5	5	12	5	6

Step 4. Managerial Implications

As the last step, the findings would better be interpreted by policymakers and benchmarking countries. Norway, Netherlands, Estonia, and Austria are leading countries across multiple scenarios. Through developing green transformation strategies with a holistic approach (including all criteria), policymakers ensure a more sustainable and comprehensive transformation. Countries consistently perform well, and likely benefit from advancements in green technologies and strong policy frameworks. Managers should prioritize investments in the research and development of green technologies and advocate for policies that promote sustainable practices.

Estonia demonstrates outstanding performance in scenario 3. This situation can be explained by the higher performance of Estonia in manufacturing and transport criteria which have higher weights in scenario 3. Strategies could be tailored to focus more on the sectors where a country or organization has the greatest potential (for instance, concentrating on manufacturing or transportation in certain regions), which may lead to better outcomes.

Cyprus, Malta, and Lithuania perform less successfully in green transition. They may encounter some challenges in implementing green transition strategies or they may not have adequate investment opportunities because of their economic drawbacks.

Since green transition performance is affected by various criteria (such as economic policies, environmental impact, and sector-specific strategies, etc.), countries should continuously monitor their sustainability efforts and adjust their strategies to align with evolving criteria and global standards. This adaptive approach will ensure long-term success in green transition and help to maintain a competitive edge in an increasingly sustainability-focused world.

5. Conclusion

This study focuses on performance analysis based on green transition. Green transition refers to shifting from unsustainable practices to environmentally friendly approaches. Assessing the performance of this transition allows countries to track their progress towards sustainability, taking into account various factors such as the reduction of greenhouse gas emissions and the adoption of green technologies. For this reason, four research questions are occurred as the motivation of this study.

Determining performance metrics that have the most significant influence on green transition was questioned through LOPCOW method. The findings show that buildings and nature are considered the most important criteria for environmental sustainability, highlighting the significance of building energy efficiency, environmental impacts, and the conservation and management of natural resources. In contrast, the utilities criterion is regarded as less important than the other categories. These findings assert that environmental sustainability strategies should primarily focus on buildings and natural resource management. Özdemir et al. (2024) supported this finding by asserting that energy consumption, freight transportation, and environmental tax revenues are the most three important factors in green deal performance.

In addition, the impact on overall rankings if the factors contributing to a country's green transition performance are assigned different weights and the European nation that reaches the greatest achievement in green transition and other performances were found out by utilizing

CODAS method. According to the results, Norway, Netherlands, Estonia serve as benchmarks for green transition success. Policymakers in around the world should be aware of best practices to ensure regulations. Cyprus, Malta, and Lithuania exhibit relatively poor performance in the green transition. To enhance their performances, these countries would benefit from adopting best practices from the leaders in this area, such as Norway, the Netherlands, and Estonia. By analyzing the strategies that have contributed to the success of these top performers, Cyprus, Malta, and Lithuania can identify key areas for improvement and implement effective measures to accelerate their green transition. Although supporting the findings with the studies published in the literature is important, the limited directly comparable research in the field of green transition restricts the possibility to comparison. This limitation, however, highlights the novelty of the study and serves it as a basis for future studies in the literature.

A comprehensive and adaptive policy framework that integrates technological innovation, strong regulatory mechanisms and sector-specific strategies should be adopted by policymakers. Through these efforts, nations are encouraged to enhance their green transition performances. Especially highly performed countries like Norway, the Netherlands, Estonia, and Austria give importance to targeted investments to employ green transition plans. Furthermore, nations should take advantage of sectoral strengths and monitor their sustainability performance to meet global standards. In addition, supportive financing mechanisms and international cooperation are essential to encourage inclusive progress in green transformation to address structural challenges in economically disadvantaged countries like Cyprus, Malta, and Lithuania.

Finally, the sensitivity analysis was conducted to examine how the overall performance of countries would be affected by criteria with different weights. These analyses contribute more accurate and comprehensive assessments of green transition performance. According to the rankings across different scenarios, the rankings remain largely consistent, with minimal variation, except for scenario 3. This indicates that the green transition performances of European countries are robust.

The performance of European countries in terms of green transitions is the main topic of this study. Research questions are restricted to 29 European nations due to the coverage of the index prepared by Fritz et al. (2024). Different methodologies can be applied based on the data.

Therefore, the findings represent only the provided information about the related countries. For instance, by introducing new factors about green transition, the performances may change.

For further studies, different country groups can be focused in terms of their level of development. Another MCDM methodologies or various statistical approaches can be utilized to calculate the green transition performances. In addition, the study can be repeated with green transition data including divergent factors or with the same factors for different countries.

Declaration of Research and Publication Ethics

This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement

Since the author is the sole author of the article, his contribution rate is 100%.

Declaration of Researcher's Conflict of Interest

There are no potential conflicts of interest in this study.

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