

doi: 10.52370/TISC2676DP

GREEN TRANSFORMATION PATTERNS IN EU TOURISM: A CLUSTER ANALYSIS OF EU GREEN PILLAR INDICATORS

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Abstract

This paper examines structural patterns of green transformation in EU tourism using 2023 data from the EU Tourism Dashboard. Three Green Pillar indicators were analyzed: air travel emission intensity, excellent bathing water quality and dependence on distant origin markets. Descriptive statistics and K-means cluster analysis were applied to identify sustainability profiles among EU Member States. The results reveal three distinct clusters. The first group combines high environmental quality with strong dependence on long-haul markets, indicating structural vulnerability despite strong natural assets. The second cluster is characterized by high emission intensity and lower environmental performance. The third group reflects a more balanced and relatively sustainable model with lower emissions and moderate market dependence. ANOVA results show that emission intensity and dependence on distant markets are the main differentiating factors. The findings highlight heterogeneous pathways of sustainable tourism transformation across the EU.

Key Words: *Green transformation, EU Tourism Dashboard, Green Pillar, Cluster analysis*

JEL classification: *L83, Q54*

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Introduction

Sustainable transformation has become a central objective of tourism policy within the European Union, driven by the "Transition Pathway for Tourism" to ensure green and digital, resilient growth. Within this policy framework, the European Commission (2023) has emphasized the need to measure sustainability indicators capable of supporting evidence based policymaking. In response, the EU Tourism Dashboard was developed as a monitoring tool integrating environmental, digital, and socio-economic indicators at the Member State level. The Green Pillar of the Dashboard specifically addresses environmental sustainability, enabling systematic cross country comparison. Despite growing availability of harmonized sustainability data, empirical research that examines structural differences in green transformation patterns among EU Member States remains limited. Existing studies often focus on single destinations or isolated indicators, while the transition toward sustainable tourism is understood as a systemic and multi-dimensional process (Niewiadomski & Brouder, 2024). Sustainable transformation involves not only environmental performance but also the structural characteristics of tourism demand, transport dependency, and market exposure.

This study addresses this research gap by analyzing three complementary Green Pillar indicators for 2023. These variables capture climate impact, environmental resource quality and structural exposure to long-haul tourism markets. By applying descriptive statistics and K-means cluster analysis, the research identifies distinct sustainability profiles among EU Member States and explores heterogeneous transformation pathways within the Union.

Literature review

Sustainable tourism development has become a central policy priority, reflecting the growing economic importance and ecological footprint of the tourism sector (Wasowicz, 2021). Taking into account the challenges of climate change, the priorities of sustainable tourism development should be redefined. The experience of the pandemic further reinforced the need for sustainable development, emphasizing the importance of economic-social resilience, as well as green and digital transformation of the tourism sector (Kó et al., 2022). The European Union plays a leading role in the development of sustainability strategies, especially through the European Green Deal, whose goal is to transform the EU into a modern,

competitive and climate-neutral economy by 2050, while separating economic growth from resource consumption and pollution, while respecting the principles of social equality. The new industrial strategy from 2020 further encourages the sustainable development of tourism through accelerating the green and digital transition and strengthening global competitiveness (Civelek et al., 2023; European Commission, 2022; Streimikiene, 2023).

Numerous studies have developed frameworks for assessing sustainability in tourism, including sustainability evaluation procedures (Ko, 2005), application of economic and investment indicators (Nesticò & Maselli, 2020), sustainability measurement in protected areas and cultural heritage (Latinopoulos & Vagiona, 2013; Spencer & Sargeant, 2024), as well as multi-model and systematic reviews of sustainable tourism indicators (Punzo et al., 2022; Miller & Torres-Delgado, 2023). However, these studies did not offer a universal framework for the sustainable development of tourism aligned with contemporary public policy priorities, such as economic and socio-cultural resistance to global pandemics or mitigation of climate change. Also, although there are studies that deal with comparative analyzes and benchmarking of certain dimensions of sustainability, such as the digitization of tourism in the EU, there is still a limited number of studies that integrate a wider set of sustainability indicators and conduct comprehensive empirical comparative analyzes of countries based on a multidimensional approach (González-Rodríguez & Díaz-Fernández, 2025). Contemporary literature increasingly applies territorial and composite approaches to assess tourism sustainability across European countries and destinations. Indicator-based frameworks and composite indices are developed to evaluate sustainability and identify territorial disparities (Cesarini & Terraglia, 2023; Mitrică et al., 2021). Particular emphasis is placed on the “green pillar,” comparing countries by ecological, emission, and resource management indicators, thereby revealing heterogeneity in Europe’s green transition (Davidović et al., 2023). In the digital dimension of tourism, recent studies develop models for measuring and benchmarking national-level digitization and competitiveness. González-Rodríguez and Díaz-Fernández (2025) apply a multi-criteria approach to assess tourism digitalization in the EU, while Liu et al. (2021) propose an evaluation model for monitoring national tourism competitiveness. Similarly, Allahverdi et al. (2025) employ cluster analysis within the Travel and Tourism Development Index to group destinations according to performance and competitiveness. Cesarini and Terraglia (2023) construct

a composite sustainability index for European destinations, while Claveria (2017) combines tourism and macroeconomic indicators through two-dimensional mapping. More recently, Kovacs-Györi et al. (2025) apply spatial-temporal clustering based on overnight stay data, highlighting the relevance of territorial and structural analysis.

Methodology

Research Area

The subject of the research includes the member states of the European Union (EU-27).. The research includes analyzes data for the year 2023, which represents the period of stabilization of tourist flows after the pandemic and enables a more realistic assessment of the structural characteristics of sustainability.

Data Used

The data used in the research were taken from the EU Tourism Dashboard platform for the reference year 2023. From the Green Pillar dimension, three indicators were selected that reflect different aspects of the ecological sustainability of tourism, which were available for all analyzed countries. Given the different measurement units, the data were standardized by applying the Z-score transformation before conducting the multivariate analysis.

Table 1: *Used indicators and data source (2023)*

Name of the indicator	Short description	Code	Unit of measure	Expected direction of sustainability	Data sources
Air travel emission intensity	Intensity of CO ₂ emissions per passenger in tourism-related air transport; indicator of climate impact of tourist trips	ATE I	kg CO ₂ per passenger	– (lower value = higher sustainability)	EU Tourism Dashboard
Excellent bathing water	Percentage of bathing waters rated "excellent quality"; an indicator of the preservation of natural resources and the quality of the environment	EBW	%	+ (higher value = higher sustainability)	EU Tourism Dashboard

Dependence on distant origins	Share of tourist arrivals from distant emitting markets; indicator of structural dependence on long-haul tourism	DDO	%	– (lower value = higher sustainability)	EU Tourism Dashboard
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Source: *European Commission, 2023*

The results of the cluster analysis were additionally interpreted through spatial visualization (mapping), which made it possible to see the geographical patterns of green transformation within the European Union. Statistical software SPSS v.23 was used for data processing.

Results

The number of clusters was determined based on interpretability and variance analysis (K-means clustering). Statistical significance of cluster differentiation was assessed using ANOVA tests.

Table 2: *Descriptive Statistics*

	N	Min.	Max.	Mean	Std. Deviation
ATEI	27	43.39	127.89	76.6752	21.82303
EBW	27	67.69	100.00	84.4004	10.26802
DDO	27	2.80	80.67	11.8881	15.23959

Source: *Authors*

Descriptive statistics reveal substantial cross country heterogeneity in 2023. ATEI shows wide dispersion (M = 76.68; SD = 21.82; range 43.39–127.89), indicating notable differences in climate related transport intensity. EBW is relatively high and more stable (M = 84.40%; SD = 10.27). In contrast, DDO demonstrates pronounced variability (M = 11.89%; SD = 15.24; range 2.80–80.67), highlighting structural differences in market dependence.

Table 3: *Initial Cluster Centers*

	Cluster		
	1	2	3
Zscore (ATEI)	0.00755	2.34682	-1.52523
Zscore (EBW)	1.51924	-0.73533	-0.56782
Zscore (DDO)	4.51337	-0.38506	-0.31682

Source: *Authors*

Table 3 shows the average standardized values (Z-scores) of the three indicators per cluster. Cluster 1 is characterized as environmentally strong but structurally exposed as it includes countries with a very high quality of natural resources (especially coastal waters), but with a pronounced structural dependence on distant emission markets. Cluster 2 is a carbon intensive tourism model because it includes countries with a pronounced climate burden in the tourism sector. High emission intensity is the dominant characteristic of this type. At the same time, the lower quality of bathing waters indicates weaker environmental performance. Cluster 3 presents a low-intensity and structurally balanced model because it is characterized by countries with relatively low emissions from air traffic and less structural dependence on distant markets. Although the water quality is not particularly high, the overall profile indicates a more stable and less climate-intensive model of tourism.

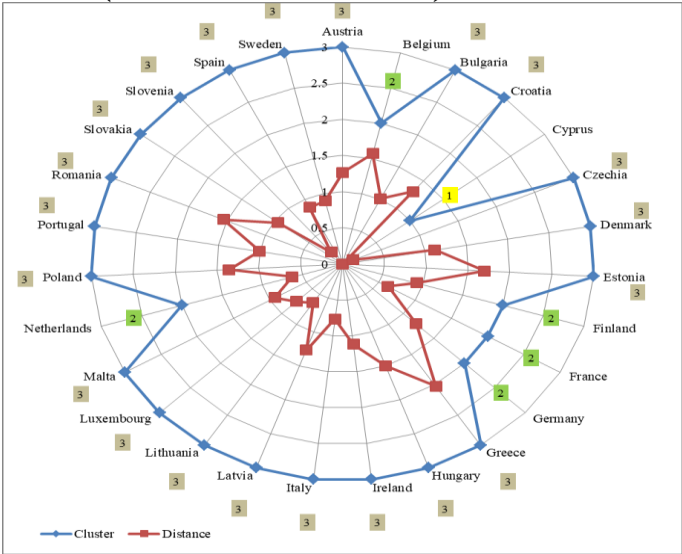
Table 4: ANOVA results

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Zscore (ATEI)	9.945	2	.255	24	39.062	.000
Zscore (EBW)	1.677	2	.944	24	1.778	.191
Zscore (DDO)	10.671	2	.194	24	54.987	.000

Source: *Authors*

ANOVA results (Table 4) within the K-means cluster analysis indicate statistically significant differences between the formed clusters for the variables ATEI ($F = 39.062$; $p < 0.001$) and DDO ($F = 54.987$; $p < 0.001$), while the differences for EBW are not statistically significant ($F = 1.778$; $p = 0.191$). The highest discriminating power is shown by DDO, which confirms that the dependence on distant emitting markets is a key factor of differentiation between groups of countries, while the emission intensity of air traffic also contributes significantly to the formation of the cluster structure. The bathing water quality indicator has a limited role in segmentation.

Figure 1: *Radar Diagram of Cluster Membership and Distance from Cluster Centroids (EU Member States, 2023)*



Source: *Authors*

The radar diagram confirms the structural asymmetry of cluster distribution. The dominance of Cluster 3, which includes the largest number of countries and forms an almost continuous outer ring is visually evident, indicating a prevailing but internally heterogeneous model of sustainability. Cluster 2 is significantly smaller and concentrated, suggesting a differentiated, emission-intensive pattern, while Cluster 1 is represented by one isolated case, confirming its structural specificity. Distance analysis shows variable internal cohesion: individual countries within the dominant cluster have larger deviations from the centroid, which implies the existence of substructures within that model.

Conclusion

The results reveal heterogeneity among the member states, confirming that the sustainable transformation of tourism in the EU does not follow a unique development path. Environmental indicators of resource quality, although significant, have less discriminating power compared to structural and transport factors. This confirms that the decarbonization of tourist mobility is the central challenge of the green transformation of the sector. From a policy perspective, the results call for differentiated strategies. Countries highly dependent on distant markets (such as Cyprus) require demand diversification, while emission intensive systems

(Belgium, Finland, France, Germany, Netherlands) should prioritize transport decarbonization. More balanced countries must preserve their relatively favorable climate profiles while enhancing ecological quality.

However, this research has certain limitations. The analysis refers to one reference year (2023), which limits the possibility of observing dynamic trends. Also, only three indicators are included, which do not cover the full multidimensionality of sustainable tourism. Future research should include a larger data set.

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