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TRENDS IN THE DEVELOPMENT OF OPEN GOVERNMENT DATA IN EUROPEAN COUNTRIES IN 2022-2024

ABSTRACT

This article investigates the trends in the development of open government data in European countries between 2022 and 2024, based on the Open Data Maturity Report. The relevance of the study is driven by the growing role of open data in ensuring transparency in public administration and supporting digital transformation. The main objective of the study is to classify European countries according to the dynamics of open government data development and to identify key differences in digital maturity.

The study applies the Time Series K-Means clustering method to normalized digital maturity indicators of countries for the period 2022–2024. As a result, three typical trajectories of open data development were identified: countries with an average starting point but dynamic growth; leading states with high and stable openness indicators; and countries with the lowest levels of digital openness and unstable progress. The analysis of average cluster indicators showed that the main differences between groups lie in the impact of open data on socio-economic processes and compliance with technical standards. At the same time, there is a trend toward narrowing the gap between countries in terms of political governance of open data.

The study concludes that structural inequalities persist among European countries in the development of open data policies, while common vectors of digital transformation are being confirmed. The findings may be used for comparative analyses of digital policies, improvement of national open data strategies, and assessment of the effectiveness of digital reforms. Promising directions for further research include a deeper analysis of the impact of open data on public governance, economic development, and social trust, as well as interregional comparisons of openness policy implementation.

Keywords: open data, digital governance, European countries, clustering, digital maturity, Time Series K-Means, public policy

JEL Classification: C38, H11, O33

INTRODUCTION

In today's digital transformation of society, open government data occupies a key place in the public administration system. For many countries, data has become a tool for government transparency and accountability and a driver of socio-economic development. Open data contributes to the development of digital services, innovative entrepreneurship, the effective use of public resources, and increased citizens' participation in management decisions. In this regard, open government data is considered not as an auxiliary function of the state apparatus, but as one of the fundamental elements of a digital state and a democratic society.

In recent years, European countries have significantly progressed in developing the legal, technical, and institutional infrastructure for open data. This is evidenced by the adoption of regulations such as EU Directive 2019/1024 (Directive EU 2019/1024 of the European Parliament and of the Council on open data and the re-use of public sector information), Data Act, and Data Governance Act, which provided an impetus for harmonizing approaches to the opening and re-use of public information within the Euro-

pean Union. In addition, the strategic initiative "A European Strategy for Data", presented by the European Commission in 2020, set out long-term guidelines for creating a single European data space based on the principles of trust, interoperability, security, and re-use.

However, despite regulatory support and political will, the practical implementation of open data policies in European countries remains uneven. Some countries demonstrate steady progress, consistently improving open data maturity indicators, while others face technical, organizational, or social barriers. Therefore, there is a need for a systematic analysis of the real state of data openness, identifying typical development trajectories and factors that determine the success of open data policies in different national contexts.

Thus, the article's relevance is due to the need for an in-depth understanding of how European countries implement open government principles in the context of digital transformation, which development models are the most effective, and which barriers should be overcome to ensure sustainable progress. Given the growing role of open data in shaping digital sovereignty, increasing trust in public institutions, and stimulating innovation, the results of this study may be helpful for policymakers, researchers, civil society representatives, and digital businesses.

LITERATURE REVIEW

Open government data is one of the key elements of the digital transformation of the public sector, so it is expected to be the subject of many research works. The scientific community's interest in this topic results from numerous scientific works in various fields of science, which allow us to characterize the achievements and challenges that countries face in implementing open data policies.

The dynamics of scientific publications in the scientometric database Scopus for the keywords "open AND government AND data" indicate the constant interest of the research community in the topic of open government data. Starting from 2015, the number of publications has grown every year; in general, over the past 10 years, the number of scientific studies on open government data has increased more than 2 times (Figure 1), which reflects both the increasing global interest in digital openness and the evolution of institutional open data strategies. The most significant number of studies is concentrated in computer science (20.4%) and social sciences (18.0%), which indicates the interdisciplinary nature of the issue – on the verge of technical implementation and social impact. Medicine, engineering, management, economics, and finance also significantly contribute to the study of open government data, emphasizing the broad application of open data in various areas of social development (Figure 2).

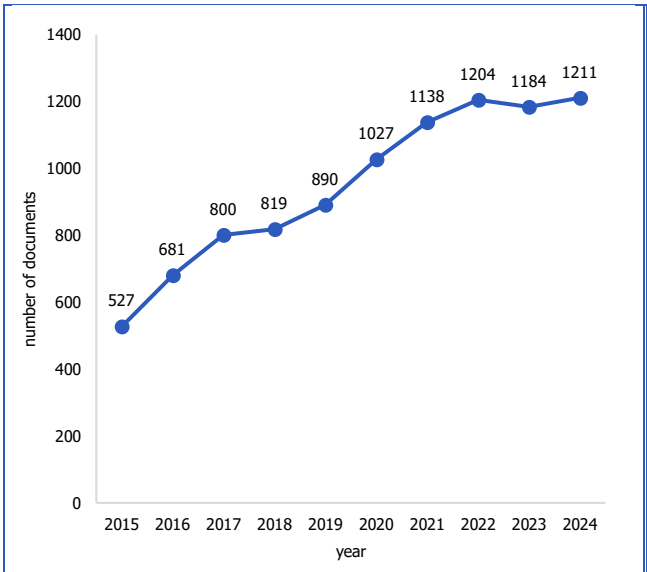

Figure 1. Dynamics of OGD-related publications in the Scopus database during 2015-2024. *(Source: built by the authors based on the Scopus, n.d.)*

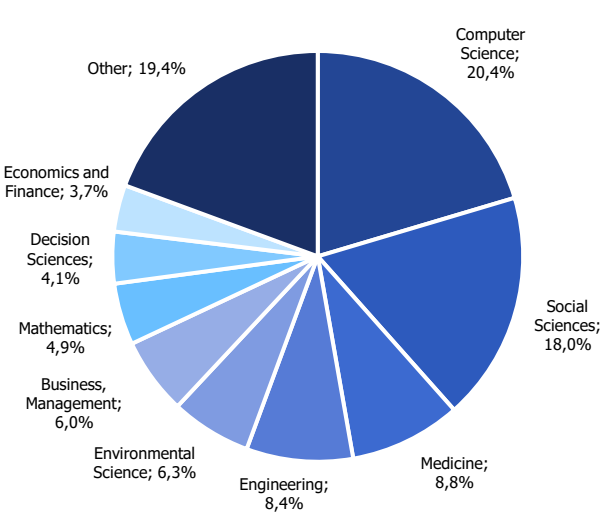

Figure 2. Distribution of OGD-related publications in the Scopus database by subject area. *(Source: built by the authors based on the Scopus, n.d.)*

One of the leading research directions is developing and accessing open data maturity models. Works related to open data maturity models are numerous, allowing us to understand better and systematize countries' approaches to digital transformation. Examples of such studies are the works of Alexopoulos et al. (2017), Macedo & da Silva Lemos (2024), and

Veljković et al. (2014), which focus on the evolution of open data portals and the creation of diagnostic tools that allow us to assess both quantitative and qualitative aspects of government data publication. However, Çaldağ & Gökalp (2022) concluded in a literature meta-analysis that existing models for evaluating the maturity of open government data do not fully cover all dimensions of open data and need to be expanded towards creating objective and multi-dimensional approaches. In this regard, works that propose new approaches to the assessment of open data are es-sential, in particular the studies of "big" government data analysis in the works of Okuyucu & Yavuz (2020) and Hujran et al. (2022), which emphasize the need to consider both micro and macro levels of data management and show a shift from traditional step-by-step modelling to more flexible, quantitative models.

The legal and regulatory requirements for open data are also becoming increasingly complex with the development of technology, so legal studies offer a slightly different perspective on the openness of government data. For example, Arisi (2022) examines the implementation of the EU Open Data Directive (EU Open Data Directive 2019/1024), particu-larly in scientific research, highlighting the complexities associated with intellectual property and personal data protec-tion. Meanwhile, Paparova et al. (2023) propose a legal concept of "data governance spaces" to trace how data powers change across multi-level governance.

Another area of research is the evolution of open government data projects. An example of such research is the work of Gao et al. (2021), which outlined four phases of developing open government data and foresees a trend towards sustainability and integrating artificial intelligence to create "smart" open data platforms. However, not all studies offer such an optimistic view of the future of open government data, in particular, Didas (2023) draws attention to the barri-ers to the implementation of big data analytics in the public sector and emphasizes that the potential of open data can only be realized if institutional and resource constraints are overcome.

Thus, despite the growing number of initiatives and national policies, open data remains underutilized. The lack of unified standards, limitations in interoperability, and political instability slow down progress, as confirmed by the works of Zeleti et al. (2016) and Quarati (2020), which show the limitations of scientific approaches to evaluating open data models and find that even high-quality metadata sets do not guarantee active use.

Thus, a literature review indicates the presence of numerous developments in concepts, models, policies, and technological solutions in the field of open government data. However, there is a lack of comprehensive studies focusing on current trends in individual regions, which is essential given the specifics of the work of world governments in recent years, which are marked by new challenges of the pandemic, military conflicts, and digital transformation. This gap justifies the study's novelty, which seeks to analyze the current state and dynamics of the development of government data openness in European countries in 2022-2024.

AIMS AND OBJECTIVES

The aim of the study is to analyze the trends in the development of government data openness in European countries during 2022-2024, to identify structural and dynamic patterns in the level of digital openness by clustering countries using the Time Series K-Means method according to similar development trajectories in this area. The study aims to understand how different EU countries implement open data policies in the context of the digital transformation of public administration.

Achieving the goal involves solving the following tasks:

1. Collect and benchmark government data openness indicators in Europe based on European Commission reports for 2022–2024.
2. Perform a cluster analysis of the dynamics of open data development in European countries using the Time Series K-Means method for countries in groups with similar development trajectories.
3. Analyze the modelling results and provide an interpretation of the identified clusters regarding digital maturity and strategic directions for the further development of open data.

METHODS

The research methodology is based on a quantitative analysis of panel data covering 35 European countries from 2022 to 2024. The primary data source is the annual Open Data Maturity Reports (Open Data Maturity, 2024), published on the European Open Data Portal. This source was chosen among other indicators of data openness (Open Data Barometer,

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Global Open Data Index, OURdata index, Open Data Inventory) because the Open Data Maturity Report provides a unified methodology for assessing the level of openness of government data in the EU countries and neighbouring countries, including Ukraine, which allows for comparative analysis and observation of the dynamics of changes over time.

The report assesses the openness of government data across four key dimensions:

1. Open data policy, i.e., the existence of national strategies and legal frameworks for open data.
2. Impact of open data – the level of monitoring and assessment of the impact of open data on the economy and society.
3. Open data portal, i.e., functionality and coverage of national open data portals.
4. Open data quality – metadata quality and its compliance with technical standards.

For each of the dimensions, appropriate quantitative indicators were selected, which, after normalization, formed the basis of a panel set, including 105 observations (35 countries over 3 years) and 18 variables. The complete list of variables is given in Table 1. Since the 2022–2024 reports use an updated assessment methodology, using this period allows for data consistency.

Table 1. List of variables of the government open data maturity dataset. *(Source: prepared by the researchers, based on Open data maturity, n. d.)*

Dimension	Label	Variable
Open Data Policy	$X1_1$	Policy framework
	$X1_2$	Governance of open data
	$X1_3$	Open data implementation
Open Data Impact	$X2_1$	Strategic awareness
	$X2_2$	Measuring re-use
	$X2_3$	Created impact
	$X2_{3a}$	Governmental impact
	$X2_{3b}$	Social impact
	$X2_{3c}$	Environmental impact
	$X2_{3d}$	Economic impact
Open Data Portal	$X3_1$	Portal features
	$X3_2$	Portal usage
	$X3_3$	Data provision
	$X3_4$	Portal sustainability
Open Data Quality	$X4_1$	Currency and completeness
	$X4_2$	Monitoring and measures
	$X4_3$	DCAT-AP (Data Catalogue Vocabulary Application Profile) Compliance
	$X4_4$	Deployment quality and linked data

Because the assessment methodology underwent minor changes during the study period, the maximum possible scores for individual indicators changed. Before performing the analysis, the indicator values were normalized using the formula (1) of the ratio of the actual value to the maximum possible in the corresponding year:

$$x'_{i,j,t} = \frac{x_{i,j,t}}{x_{j,t}^{max}}, \quad (1)$$

where $x'_{i,j,t}$ – the normalized value of the j-th feature (indicator) for the i-th country in year t; $x_{i,j,t}$ – the initial value of the jth feature (indicator) for the ith country in the year t; $x_{j,t}^{max}$ – the maximum possible value of the jth feature in year t, according to the Open Data Maturity Report methodology.

Descriptive statistics revealed that most countries demonstrate a high level of data openness, as evidenced by the concentration of values on the right side of the distribution and the presence of peaked distributions in several variables, which emphasized the need for standardization of variables, given the sensitivity of the chosen clustering method to mean values and the range of fluctuations (Kobylin & Lyashenko, 2020).

To standardize the time series before clustering, the TimeSeriesScalerMeanVariance class from the tslearn library of the Python language was used. Using this method performs calculations according to the formula (2) and allows for the elimination of the effect of data scale, ensuring the exact weight of each variable in the model, and performs transformations according to the formula (2):

$$x''_{i,j,t} = \frac{x'_{i,j,t} - \bar{x}_j}{\sigma_i}, \quad (2)$$

where $x''_{i,j,t}$ – the normalized value of the j-th feature (indicator) for the i-th country in year t; $x'_{i,j,t}$ – the initial value of the jth feature (indicator) for the ith country in the year t; $\bar{x}_j$ – mean of the j feature; σ_i – standard deviation of the i-th characteristic.

The Time Series K-Means time series clustering method was used to identify typical trajectories of data openness development. This method was chosen because, unlike the classical K-Means algorithm, Time Series K-Means allows for grouping countries by indicator values and by the similarity of the dynamics of their changes during the analyzed period (Huang et al.). Thus, using this method allows us to group observations and combine entities in a panel dataset based on the similarity of the dynamics of their indicators during the considered period.

The optimal number of clusters was determined using the Elbow Method, which is based on the analysis of the change in the average distance within clusters (inertia) depending on their number. For the collected data, a sharp decline in inertia is observed up to cluster 3, so for further modelling, three clusters were selected as the optimal solution for classifying observations.

In practice, the Time Series K-Means classification model is implemented using the tslearn library in Python. The Euclidean distance is used as the basis of the model to measure the similarity of time series, since all-time series in the collected dataset have the same length and structure (Amidon, 2020). The result of using this methodology is the classification of European countries according to three typical trajectories of the development of government data openness, which allows us to identify groups with similar trends in the digital transformation of public administration.

RESULTS

In modern conditions, open government data has become one of the key foundations of the digital transformation of public administration and society in general. With the development of information and communication technologies, more and more governments recognize the importance of transparency, accountability, and accessibility of public information as a tool for democratization and socio-economic development.

According to Geiger and von Lucke, open government data is all stored public sector data that can be provided by the government in the public interest without any restrictions on use and distribution (Geiger & von Lucke, 2012). In practice, data, open data can cover a wide variety of areas - from budget, health, and education to infrastructure, ecology, and transport. Thus, open data creates an information basis for decision-making, public control, and the development of digital tools.

The role of open data in digital development is multidimensional. The following reasons usually motivate governments to implement and develop open data:

1. Transparency, which means not only formal access to information, but also the real opportunity to use, reuse, and disseminate data to ensure the proper functioning of a democratic society, control and evaluation of government activities, and strengthen trust in state institutions.
2. Socio-economic value, which is manifested through the creation of conditions for innovation, as companies, scientific institutions, NGOs and startups can use open government data (from geological information and educational statistics to environmental indicators, budget reports or transport data) to create new products, services or analytical solutions that benefit the economy and citizens.
3. Citizen participation in governance, which involves not only participation in elections or referendums but also regular interaction with politics and government structures through specialized open data portals and other initiatives, thanks to which people have more information for decision-making, can participate in policy formation, submit proposals or analyze the effectiveness of government decisions (Attard et al., 2015).

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In addition, open data significantly increases the efficiency of government processes. Analytics based on public data allows for better planning of budget expenditures, identification of systemic risks, provision of interdepartmental data integration, and automating decisions. Research proves that governments that implement open data respond faster to social challenges, increase the effectiveness of policies, and are more successful in developing digital platforms for citizen participation (Didas, 2023).

Thus, the level of development of data openness indicates the state's ability to use digital tools to improve public administration and improve citizens' quality of life. Open government data is not an auxiliary function of digital transformation, but its central element. In the global context, open government data is one of the basic elements of digital government and open governance. Since 2011, the Open Government Partnership initiative has been established at the international level, to which dozens of countries worldwide (including Ukraine and most EU countries) have joined, committing to developing data openness as a form of public accountability.

Over the past decades, EU governments, responding to the needs of civil society, business, and the scientific community, have gradually moved towards open data policies. This approach strengthens the transparency and accountability of institutions, promotes innovative economic development, and deepens the interaction between the state and society. One of the key initiatives that defines strategic guidelines for EU member states in the data field is the "European Strategy for Data", presented by the European Commission in 2020. This strategy envisages the creation of a single European data space where public, private, personal, and industrial data could be safely used to create innovative digital services (European Data Strategy, 2020). In the context of open data, the approach emphasizes the importance of ensuring interoperability, reusability, high quality, and protection of data collected and published by public authorities (Franck, 2023). From a legal perspective, this strategy is supported by two main regulatory acts.

Firstly, the Data Governance Act (DGA) was adopted, as a comprehensive instrument for regulating and using public and protected data in different sectors. The DGA aims to facilitate data exchange by introducing rules for new entities – the so-called data intermediaries- and to support data exchange for altruistic reasons (A European Strategy for Data, 2025).

Secondly, the Data Act was adopted, which entered into force on 11 January 2024. Its main objective is to ensure Europe’s leadership in the digital economy by effectively using the growing volume of industrial data. The Data Act is designed to boost the use of data in business, industry and society, contributing to the creation of new digital services, the development of innovation and increasing the competitiveness of the European market (European Data Act enters into force, putting in place new rules for a fair and innovative data economy, 2024).

Together, these two documents form a legal infrastructure that combines the protection of personal information, the maintenance of user trust, and the development of an innovative environment for data exchange, which is critical for the digital sovereignty and economic growth of the European Union. In addition to the documents described, which relate to data management in general, European legislation has regulatory legal acts explicitly aimed at the openness of government data, among which it is worth noting Directive (EU) 2019/1024 of the European Parliament and the Council on open data and the re-use of public sector information. This document, adopted on 20 June 2019, establishes general rules for a unified approach to public data in the EU Member States. The directive establishes requirements for free access, open formats, machine readability, and non-discrimination in access to information (Arisi, 2022).

The Open Data Maturity Report 2024 analysis showed that most European countries have already achieved a high level of openness of government data (Figure 3). Of the 34 countries presented in the report, 29 received more than 60% of the maximum possible score for openness of government data (2520 points), which indicates the widespread implementation of openness policies and digital transformation of public administration.

The rating leader is France with a score of 2510 out of 2520 possible points, demonstrating almost complete compliance with the digital maturity criteria. In addition to France, the countries with the highest level of openness include Poland, Ukraine, Slovakia, Ireland, Spain, and Lithuania. These countries are distinguished by the active implementation of open data strategies, the development of portals, compliance with DCAT-AP (Data Catalogue Vocabulary Application Profile) standards, and the stimulation of data reuse. At the opposite end of the open data maturity scale are Bosnia and Herzegovina, Albania, and Malta, which scored less than 50% of the maximum score. This indicates the existence of systemic barriers to open data implementation, which may include technical limitations and a lack of political will.

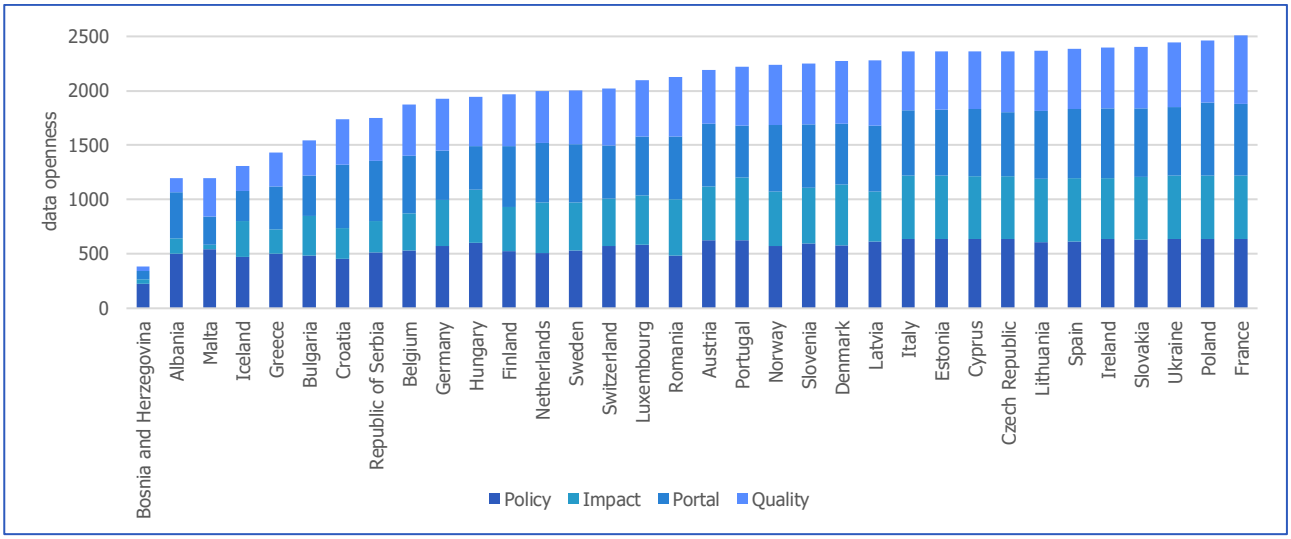

Figure 3. Open data maturity in Europe as of 2024. *(Source: prepared by the researchers, based on Page et al., 2024)*

In addition to the current state of openness of government data, the trajectory of recent changes in this area is of interest. To identify countries with similar trends in the development of open data, clustering models, in particular Time Series K-Means, allow us to build. Before proceeding to cluster analysis, the data were initially processed for 18 indicators, in particular, the values of the indicators were normalized relative to the maximum possible estimate in the corresponding year. Further descriptive analysis (Table 2) revealed the following key observations:

1. The average values of the variables in 2022-2024 range from 0,57-0,88, which indicates that most countries have high indicators.
2. The distribution of all variables has negative asymmetry, i.e., the concentration of values in the right part, which confirms the overall high level of data openness in the region.
3. Variables x12, x13, x32, x42 i x44 are characterized by high kurtosis (>3), which means a peaked distribution and concentration of values around the mode.

Table 2. Descriptive characteristics of the open data maturity dataset. *(Source: prepared by the researchers, based on Python outputs)*

Variable	Mean	Standard Deviation	Minimum	Maximum	Mode	Median	Skewness	Kurtosis
$X1_1$	0.86	0.14	0.44	1	1.00	0.91	-0.92	0.00
$X1_2$	0.86	0.18	0.13	1	1.00	0.92	-2.24	5.60
$X1_3$	0.83	0.20	0	1	1.00	0.90	-1.67	3.15
$X2_1$	0.78	0.26	0.09	1	1.00	0.86	-1.06	-0.04
$X2_2$	0.78	0.34	0	1	1.00	0.91	-1.48	0.65
$X2_3$	0.65	0.32	0	1	1.00	0.70	-0.71	-0.58
$X2_{3a}$	0.70	0.34	0	1	1.00	0.75	-1.05	-0.18
$X2_{3b}$	0.64	0.34	0	1	1.00	0.75	-0.66	-0.86
$X2_{3c}$	0.68	0.33	0	1	1.00	0.75	-0.96	-0.24
$X2_{3d}$	0.57	0.39	0	1	1.00	0.50	-0.22	-1.45
$X3_1$	0.75	0.22	0.08	1	0.91	0.82	-1.09	0.54
$X3_2$	0.88	0.19	0.10	1	1.00	0.93	-2.36	5.26
$X3_3$	0.74	0.21	0.1	1	0.87	0.80	-1.09	0.56
$X3_4$	0.81	0.23	0.07	1	1.00	0.91	-1.52	1.56
$X4_1$	0.68	0.20	0.13	1	0.79	0.71	-0.71	0.01
$X4_2$	0.82	0.22	0	1	1.00	0.89	-1.96	3.18
$X4_3$	0.76	0.29	0	1	1.00	0.88	-1.57	1.45
$X4_4$	0.69	0.21	0	1	0.83	0.72	-1.64	3.27

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The next step was to prepare the dataset for analysis, including confirming the absence of missing values and eliminating the influence of different scales of variables by standardizing the dataset using TimeSeriesScalerMeanVariance from the tslearn library.

The optimal number of clusters was determined using the elbow method. According to the obtained graph (Figure 4), it is noticeable that a sharp decline in inertia is observed up to cluster 3. After this point, the decrease in inertia becomes less sharp, which means a decrease in the information gained from additional clusters, therefore, for further modelling, it is advisable to choose exactly 3 clusters to balance the simplicity of the model and the quality of classification.

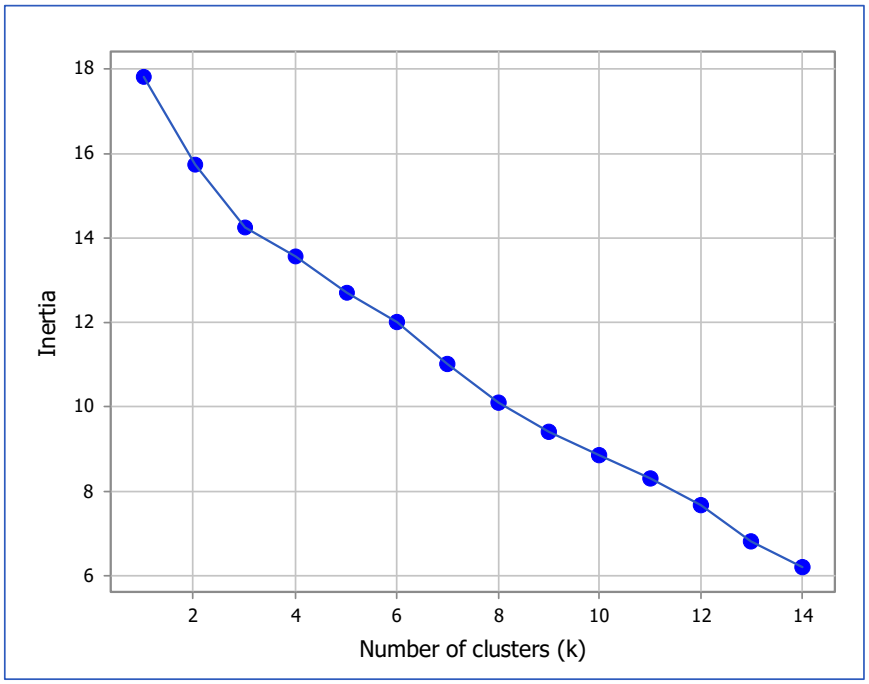

Figure 4. Selecting the optimal number of clusters using the elbow method. *(Source: prepared by the researchers, based on Python outputs)*

Thus, using the tslearn Python library, a Time Series K-Means model with three clusters and using Euclidean distance was built based on the collected and prepared data. As a result of using the model, all countries were divided into three groups according to the typical trajectory of the development of government data openness in Europe (Table 3).

Table 3. Clusters of countries by data openness trends. *(Source: prepared by the researchers, based on Python outputs)*

Cluster	Number of countries	List of countries
1	15	Austria, Belgium, Croatia, Finland, Germany, Greece, Ireland, Latvia, Luxembourg, Netherlands, Romania, Serbia, Slovakia, Slovenia, Switzerland
2	10	Cyprus, Czech Republic, Estonia, France, Hungary, Italy, Lithuania, Poland, Spain, Ukraine
3	10	Albania, Bosnia and Herzegovina, Bulgaria, Denmark, Iceland, Malta, Montenegro, Norway, Portugal, Sweden

The results of clustering European countries based on government data openness indicators made it possible to identify three countries with similar trends in digital openness development during 2022-2024.

Since all the features used for modelling have the same measurement scale after normalization, we can compare the average value of all features for countries in different clusters. The analysis of the average values of the features showed significant differences between them in terms of the level of openness and the dynamics of changes over time (Figure 5).

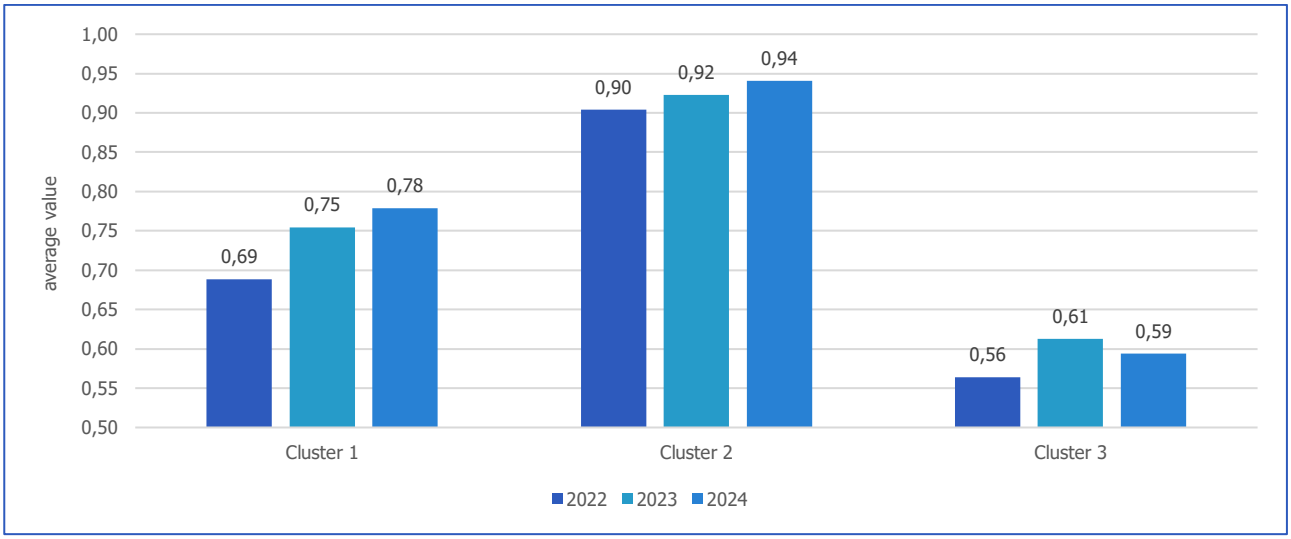

Figure 5. The average value of data openness indicators for clusters by year. *(Source: prepared by the researchers, based on Python outputs)*

From Figure 5, it is clear that the first cluster includes countries with an average level of openness but with monotonous growth. The average openness value in these countries increased from 0,69 in 2022 to 0,78 in 2024. This indicates the presence of political will for the development of open data and progress in digitalization.

The second cluster unites countries with the highest and consistently high openness indicators. This cluster's average index value increased from 0,90 to 0,94 over three years. Countries in this group have a developed legal and technical infrastructure, stable data reuse practices, and widespread implementation of DCAT-AP (Data Catalogue Vocabulary Application Profile) standards.

The third cluster includes countries with the lowest levels of openness (0,56–0,61), as well as characteristic instability of dynamics. This indicates the presence of obstacles or inconsistencies in digital development strategies. Such countries demonstrate fluctuations in the index without a stable upward trend, which indicates fragmented efforts in implementing open data. A deeper understanding of the specifics of each group of countries is provided by detailed average values of individual indicators by cluster (Table 4).

Table 4. The average value of certain indicators for clusters by year. *(Source: prepared by the researchers, based on Python outputs)*

Year	2022			2023			2024		
Cluster	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
$X1_1$	0.79	0.97	0.78	0.81	0.98	0.82	0.84	0.99	0.83
$X1_2$	0.88	0.94	0.60	0.91	0.97	0.74	0.90	0.99	0.74
$X1_3$	0.74	0.96	0.65	0.84	0.98	0.69	0.91	0.97	0.73
$X2_1$	0.69	0.97	0.49	0.75	0.98	0.62	0.85	1.00	0.70
$X2_2$	0.58	0.99	0.65	0.75	1.00	0.63	0.88	1.00	0.60
$X2_3$	0.50	0.90	0.42	0.60	0.94	0.49	0.64	0.97	0.48
$X2_{3a}$	0.61	0.95	0.48	0.70	0.94	0.51	0.71	1.00	0.46
$X2_{3b}$	0.55	0.86	0.40	0.60	0.95	0.49	0.60	0.98	0.45
$X2_{3c}$	0.50	0.88	0.44	0.65	0.94	0.53	0.72	0.98	0.58
$X2_{3d}$	0.35	0.93	0.35	0.45	0.93	0.43	0.54	0.94	0.44
$X3_1$	0.80	0.90	0.60	0.81	0.89	0.59	0.74	0.87	0.51
$X3_2$	0.88	0.92	0.80	0.94	0.92	0.85	0.93	0.97	0.69
$X3_3$	0.73	0.80	0.62	0.81	0.86	0.58	0.81	0.84	0.56
$X3_4$	0.81	0.92	0.65	0.88	0.92	0.66	0.84	0.94	0.66
$X4_1$	0.64	0.78	0.62	0.62	0.72	0.63	0.71	0.87	0.60
$X4_2$	0.83	0.91	0.61	0.89	0.98	0.70	0.85	0.94	0.60
$X4_3$	0.80	0.95	0.47	0.82	0.98	0.50	0.82	0.96	0.47
$X4_4$	0.71	0.72	0.51	0.73	0.75	0.59	0.75	0.73	0.61

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According to Table 4, it can be seen that countries in different clusters differ most in the impact of the digital system on government ($X2_3$), especially in economic ($X2_{3d}$) and social ($X2_{3b}$) impact. Also, countries in the first and second clusters have a significant gap in DCAT-AP (Data Catalogue Vocabulary Application Profile, $X4_3$). The gap between the average values of these indicators for different clusters mostly remains quite stable, for example, for DCAT-AP ($X4_3$) compliance, it fluctuated at the level of 0,48-0,49.

At the same time, it is noticeable from Table 4 that there are indicators in the dataset for which the difference between clusters is much less noticeable, in particular, the political governance of open data ($X1_1$) and the quality of open data deployment ($X4_4$). Over time, the gap between the average values of these indicators between clusters gradually decreases. For example, the gap between the average values of the quality of open data deployment ($X4_4$) between the countries of the second and third clusters was 0,21 in 2022 and decreased to 0,14 in 2024.

In summary, the study found that European countries demonstrated different trajectories of government data openness development from 2022 to 2024. Based on cluster analysis, three types of countries were identified:

1. Leaders (cluster 2) with high and stable openness.
2. Progressive countries (cluster 1) that demonstrate rapid growth.
3. Lagging countries (cluster 3), where the level of openness remains low and unstable.

The differences identified are most evident in the economic and social impact of open data and in technical compliance with European standards. At the same time, there is a gradual narrowing of the gap between clusters in specific characteristics (e.g., political governance).

DISCUSSION

The obtained clustering results allow us to understand better current trends in the openness of government data in European countries in 2022–2024. The analysis showed the presence of clear clusters of openness development, which indicates a different level of maturity of digital transformation, political will, and institutional readiness.

According to the cluster analysis results, the second cluster (leaders) includes countries with the highest, stable, and gradually increasing openness indicators. This, on the one hand, confirms the presence of successful models of open data management, and on the other hand, indicates limited potential for further rapid growth: countries have already approached the maximum indicators, so we can expect that further improvement will require systemic innovations.

The first cluster is countries that demonstrate positive dynamics and have the potential to move to the group of leaders in the future. Their trajectory may indicate effective learning from advanced countries, increased participation in international initiatives, and growing domestic demand for transparency and digital connectivity.

In contrast, the third cluster includes countries with low and unstable indicators, indicating the presence of systemic problems that may include a lack of financing for digital transformation, a lack of legislative incentives, weak technical capacity, or resistance of institutional structures to transparency. The unstable dynamics of data openness indicators in the third cluster countries indicate the need for increased technical assistance, international partnerships, and the formation of regional alignment strategies.

The findings are consistent with previous studies (including the Open Data Maturity Reports 2020-2023, Arisi, 2022, and Gao et al., 2021), which also show a gradual consolidation of countries around common digital standards. The study also confirms the findings of previous studies that emphasize the role of political leadership and the regulatory framework as key factors for success (e.g., Zeleti et al., 2016, and Quarati, 2020), by demonstrating that it is governance aspects ($X1_1$) that have relatively more minor gaps between countries, while technical and institutional factors ($X4_3$, $X2_3$) create the most significant stratification.

Unlike previous studies, the article uses the time series clustering method, which allows us to consider not only the static level of openness but also its dynamics, which provides a deeper understanding of the trajectories of digital development of individual countries and regions. Despite the relevance and novelty of the study, it has several limitations worth paying attention to.

First, the Time Series K-Means Method does not take into account the potential correlation of indicators with each other or external shocks (for example, the impact of a pandemic or military actions on digital infrastructure), which may, to some extent, complicate the interpretation of the constructed model. Second, the primary data source for the work is the

official Open Data Maturity report, the estimates of which may differ from alternative assessments of openness, for example, from civil society or independent research organizations.

CONCLUSIONS

The study analyzed the trends in developing government data openness in European countries in 2022-2024. Based on the latest reports on the digital maturity of open data and methods of cluster analysis of time series, three key development trajectories were identified, which allow us to systematically assess the state and dynamics of digital transformation in the region. It was found that most European countries demonstrate consistently high or increasing indicators of government data openness, which confirms the effectiveness of national open data strategies, the development of digital infrastructure, and the growing role of transparency in governance.

The application of the time series clustering method (Time Series K-Means) made it possible to consider not only the current state of openness but also the dynamics of changes, making this approach promising for a comparative analysis of digital policies in dynamics. European countries were classified into three clusters according to the dynamics of the level of government data openness in 2022-2024:

1. The first cluster - countries with mediocre openness indicators that demonstrate significant improvement in dynamics.
2. The second cluster – leaders with high stable indicators and small but steady growth.
3. The third cluster – countries with a low level of openness and unstable development rates, which may indicate the presence of barriers to the implementation of open data policies.

The most significant differences between clusters are observed in indicators of the socio-economic impact of open data and technical characteristics, such as compliance with DCAT-AP standards. At the same time, in managerial indicators, particularly political leadership and the quality of data deployment, the gaps between countries are gradually narrowing, indicating the formation of a common digital culture and the adaptation of best practices.

Thus, the results confirm the importance of a multidimensional approach to assessing the openness of government data, which combines the analysis of the current level, development dynamics, and impact on social processes. In this context, promising areas for further research are assessing the long-term effects of open data policies in the context of sustainable development and digital inclusion, comparing European experience with practices in other regions of the world to identify global patterns and regional specificities, investigating the role of civil society, business and academia in the creation and reuse of open data, and modelling the impact of external factors, including wars, pandemics and economic crises, on the pace of digital openness and the adaptability of digital strategies of states.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All Authors have contributed equally.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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ТЕНДЕНЦІЇ РОЗВИТКУ ВІДКРИТОСТІ УРЯДОВИХ ДАНИХ У КРАЇНАХ ЄВРОПИ У 2022-2024 РОКАХ

У роботі досліджено тенденції розвитку відкритості урядових даних у країнах Європи у 2022-2024 роках на основі даних звіту Open Data Maturity Report. Актуальність дослідження зумовлена зростанням ролі відкритих даних у забезпеченні прозорості державного управління, підтримці цифрової трансформації та формуванні інноваційних екосистем. Метою дослідження є класифікація європейських країн за динамікою розвитку відкритості урядових даних, а також виявлення ключових розбіжностей у цифровій зрілості.

У дослідженні застосовано метод кластеризації часових рядів (Time Series K-Means) до нормалізованих індикаторів цифрової зрілості країн за період 2022–2024 років. У результаті сформовано три типові траєкторії розвитку відкритості урядових даних: країни з посереднім стартовим рівнем, але динамічним зростанням; держави-лідери з високими та стабільними показниками відкритості й країни з найнижчим рівнем цифрової відкритості та нестабільною динамікою змін. Аналіз середніх значень показників за кластерами показав, що ключовими відмінностями між групами є вплив відкритих даних на соціально-економічні процеси та відповідність технічним стандартам, водночас спостерігається тенденція до зменшення розриву між країнами в царині політичного управління відкритими даними.

Основні висновки дослідження полягають у виявленні структурних нерівностей між країнами Європи щодо розвитку політик відкритих даних, а також у підтвердженні спільних векторів цифрової трансформації. Отримані результати можуть бути використані для порівняльного аналізу цифрової політики країн, удосконалення національних стратегій відкритих даних і оцінки ефективності цифрових реформ. Перспективними напрямами подальших досліджень є глибший аналіз впливу відкритих даних на публічне управління, розвиток економіки та соціальну довіру, а також міжрегіональне порівняння досвіду реалізації політик відкритості.

Ключові слова: відкриті дані, цифрове врядування, європейські країни, кластеризація, цифрова зрілість, Time Series K-Means, публічна політика

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