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Analysing the Relationship Between Postmodernism and Digital Age Governance with Entropy and Mabac Methods: The Case of the 2022 EU Digital Economy and Society Index (DESI) Report

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ABSTRACT

Postmodernism has affected institutions and systems with its rejection of traditional, macro, and hierarchical approaches. Accordingly, it has also affected the structuring of public administration by popularising two new concepts: new public management (NPM) and digital age governance (DAG). Public administration systems have sought to escape the rigid confines of modernism with the understanding of NPM, which has evolved into a system in which governance is strengthened together with an understanding of DAG. In this sense, data-based digital governance approaches are being adopted in the postmodernist era, and states, citizens, and the private sector actively participate in digital platforms. Information and communication technologies have become increasingly important for countries in the framework of DAG. Along these lines, the European Commission publishes its Digital Economy and Society Index (DESI) Report every year to evaluate the digital transformation performance of EU countries. The aim of this study is to examine the effects of postmodernism on public administration through NPM and DAG and to evaluate the digital governance performances of EU countries in the postmodern era using the entropy and MABAC methods. The dataset used in this research consists of 5 sub-criteria of the Digital Public Service (DPS) criterion included in the 2022 DESI Report. As a result of this analysis, the sub-criterion with the highest importance is found to be 'Digital Public Services for Business', while the sub-criterion with the least importance is 'Pre-Filled Forms'. It is seen that the EU countries with the strongest performance according to the DPS criterion are Estonia, the Netherlands, and Finland, respectively.

Keywords: Postmodernism, Digital Age Governance, DESI, Entropy, MABAC.

JEL Classification Codes: D73, N40, O38.

INTRODUCTION

Postmodernism, which inherently entails breaking away from modernism, has deeply affected social, economic, and political structures around the world. This process of change, which started with Lyotard (1984), has influenced thinkers and systems on a global scale. Postmodernism criticises modernism and offers a different perspective in contrast to institutions and structures built with a modernist perspective. Contrary to modernism, postmodernism advocates pluralism, micro versus macro perspectives, and innovation versus traditional approaches (Best & Kellner, 2011). In this way, postmodernism, which prioritises multiculturalism, the inclusion of differences, and the digitalisation of societies (Baudrillard, 1976), has had transformative effects on institutions and structures. Public administration structures have also been affected by these changes and, in many cases, they have undergone a two-stage transformation.

The first period of the postmodern approach to public administration began in the late 1970s and was shaped by the concept of 'new public management' (NPM). Prior to this period, the understanding of public administration was strictly hierarchical and centralised, far removed from active citizenship, and highly traditional in line with the teachings of modernism. However, with the understanding of NPM, concepts of governance and active citizenship began to come to the fore (Gruening, 2001; Greve, 2010). The second period of postmodern public administration has been driven by the concept of 'digital age governance' (DAG). DAG, which began exerting notable impacts after the beginning of the 2000s, brings with it digitalised democratic ideas such as accountability, transparency, open government, and e-participation. Citizens, the private sector, and other stakeholders have begun participating in public management without limitations of time or space thanks to the DAG approach. This has been made possible with the advancement of information and communication

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technologies (ICT) and the evolution of social structures into data-based digital platforms (Dunleavy et al., 2005).

The digitalisation of countries and the importance they place on governance have become evaluation criteria that are emphasised by the European Commission, which regularly evaluates EU countries with its annual reports and evaluation texts. The annual Digital Economy and Society Index (DESI) Report is one such report in which evaluations of the digitalisation processes of EU countries are published (European Commission, 2020, 2022). The aim of this study is to explore the effects of postmodernism on public administration within the dimensions of NPM and DAG and to analyse the digital governance performances of EU countries in the postmodern era using the entropy and multi-attributive border approximation area comparison (MABAC) methods. The data used in this analysis are taken from the DESI Report published by the European Commission for the year 2022 (European Commission, 2022). For the 27 EU Member States, the importance levels of the DESI criteria were evaluated using the entropy method for 5 sub-criteria ('E-Government Users', 'Pre-Filled Forms', 'Digital Public Services for Citizens', 'Digital Public Services for Business', and 'Open Data') that constitute the Digital Public Service (DPS) criterion. Subsequently, using the MABAC method, the performances of EU countries were analysed within the framework of the DPS criterion and countries were ranked according to their performance levels.

There are no studies in the literature to date that directly examine the relationship between DAG and postmodernism; this area of research is very limited. As the scarcity of relevant resources constitutes a limitation of the present study, the contributions that this study will make to the limited body of literature are all the more important. In this context, the usage of the 2022 DESI Report also increases the importance of the study in terms of allowing for a unique contribution via determination of the performance of EU countries in the framework of the DPS criterion.

In the next section of this study, postmodernism is explained in general terms together with the transformations it facilitated in public administration and the concept of NPM is emphasised. In the following section, DAG is explained and the transition from an understanding of NPM to the implementation of DAG is described. In the fourth section, different understandings of NPM and DAG are explained using a comparative method and they are evaluated within the framework of the concept of postmodernism. In the fifth section, the analytical procedures are presented and the entropy and MABAC methods are explained in detail. In the sixth section, the application steps and the dataset are introduced and the findings are presented. In the final section of the study, the findings are interpreted and suggestions are made.

POSTMODERNISM AND POSTMODERN PUBLIC ADMINISTRATION

Postmodernism was first defined in 1979 in a book by J.F. Lyotard titled *The Postmodern Situation*. For Lyotard, postmodernism meant 'the end of metanarratives'. Lyotard's view of postmodernism was shaped by a framework in which critiques of modernism were embodied. According to him, postmodernism does not contain metanarratives, such as ideologies or beliefs, that are outcomes of modernism. While modernism rationalises by standardising, postmodernism undermines those standards (Lyotard, 1984). Lyotard did not trust metanarratives because he found metanarratives to be legitimising. As he described it, metanarratives make the commodities that they legitimise become unshakable and rational. Metanarratives have emerged over time due to the nature of modernism, and they are legitimised and disseminated through modern science and institutions. Therefore, while fields such as science and education should foster liberation by enabling individuals to govern themselves, they instead become oppressive by legitimising metanarratives (Lyotard & Brugger, 2001).

It is seen that postmodernism criticises modernism, looking at it with suspicion and critiquing the establishment of legitimacy among individuals with metanarratives. Wallerstein (2001) criticised modernism in the same way, arguing that modernism leaves the individual sterile in the positivist paradigm of science; convinces him of material, empirical, and singular truths; and is anti-libertarian. According to Hayek (1937), individuals exist in rational states stemming from pure logic and can thus be thought to be completely rational. However, thoughts and actions are not based entirely on empirical elements; they are also related to the ways in which individuals perceive the outside world. According to Jameson (1984), modernism tried to gather individuals under an umbrella of universal thought by creating a universal framework. However, in the 'post-industrial' age, when postmodernism emerged, universality was fragmented and dispersed. Postmodernism created a major breaking point for modernism, reducing the big to the small and the central to the local. Along these lines, Lyotard (1984) explained that with postmodernism, the local started to come to the fore and the micro perspective rather than the macro gained importance.

Another thinker who questioned the universal nature of modernism was Foucault (1994), who criticised the production and dissemination of knowledge in association with the freedom of the individual. According to Foucault, knowledge is a tool that is valid only in the period to which it belongs and it serves the power relations of that specific period. It is not a truth, because it is created in and for the period to which it belongs. Knowledge becomes a tool with the power of control over the masses when it is applied by the power structure, functioning as a sort of power technology. For this reason, Foucault took scepticism and questioning in postmodernist thought to the extreme and rejected the common discourses, knowledge, massiveness, and centrism of the period. Deleuze and Guattari (1987), following Foucault, stated that in the postmodern era, capitalism has transitioned to a 'post-Fordist/post-industrial' digital society stage. In this society, the information and technology tools that spread throughout society are highly effective on the masses. Therefore, in digital societies, the singularity of individuals remains at risk in the face of the majority. Modernism acquired traditionally organised masses and institutions as a result of certain knowledge clusters, and according to Deleuze and Guattari (1987), postmodernism has deconstructed those stereotyped and fixed foundations.

Baudrillard, who dealt with the digital aspects of postmodern societies, criticised the structure of information society by emphasising the role of hyper-reality. Increasing innovation and technological developments in digital societies lead to changes in perceptions of reality (Baudrillard, 1976). While this situation is negative in terms of the inability of individuals to perceive their own realities, it also offers opportunities to create spaceless time and timeless space. For this reason, considering the 'decentralised' structure of postmodernism, it can be said that possibilities exist for areas in which individuals can act individually.

Table 1. Model of Change in Approaches to Public Administration

Criteria	Traditional (Modern) Administration	Innovative (Postmodern) Administration
Structures	Strict bureaucratic structure Hierarchy Strong centralisation	Narrow centre Wide, unlimited environment Localisation
Systems	Central control Detailed auditing	Performance targets Pricing centres Domestic markets
Staffing	Large volume of personnel Fixed, perpetual Centralised bargaining	Narrow, qualified personnel Flexible, wide environment Localised bargaining
Administrative Culture	Inflexible administration Legal and financial reliability Professionalism Quantity in service delivery	Flexible administration/ participants Cost-benefit analysis Customer/citizen demands Quality in service delivery

Source: Toprak Karaman, 1997.

When the qualities of a digital society come together with the benefits of postmodernism, it is inevitable that the evolving social structure will have an impact on public administration and bureaucracy. In contrast to the singularism, universalism, and traditionalism of modernism, postmodernism advocates pluralism and the rejection of the universal and traditional (Best & Kellner, 2011). This emphasis steers the structure of public administration away from traditional patterns. The modern understanding of public administration, which is centralised, macro-level, and hierarchical, has expanded to take into account micro-level perspectives and individuals within a decentralised framework. Public administration has undergone a postmodern transformation with the advancing of technology and increases in the availability of information/data-based platforms (Bogason, 2005; Fox & Miller, 1995). This has eliminated the restrictions of time and space and centralised administrative structures have been weakened with the help of technology (Harvey, 1992).

The characteristics of modern and postmodern public administration are given in Table 1. As detailed below, postmodern public administration, which we can describe as the exact opposite of the modernist approach to public administration, has adopted the characteristics of the postmodernist period and developed an understanding that is locally focused, decentralised, and governance-oriented and considers the individual.

The most important prerequisite for postmodern public administration to become individual-oriented is technology, which is the main actor of the postmodern period. With the spread of technology and broadband global network services in today's societies, hierarchical relations have changed in postmodern public administration and vertical, horizontal, and cross-cutting organisations have developed (Spicer, 1997; Demirel, 2014). Thus, the understanding of governance has also changed in comparison to traditional public administration approaches, and opportunities for individuals to participate directly in management processes via the internet, regardless of time or place, have emerged. With this micro-level network-type governance, hierarchical information flows have been disrupted and an interrogative/supervisory framework has emerged with service demands moving from the bottom up (Bogason, 2008; Şener, 2005).

Due to the fact that governance elements and communication technologies are at the centre in postmodern administration, communications between states and citizens have strengthened (Genç, 2015; Gül, 2018; Cavalcante & Lotta, 2022). The understanding of modern public administration, together with the post-Fordist economy model, renewed itself by giving up the central and cumbersome bureaucratic structuring of previous years in a process known as 'new public management' (NPM) (Gruening, 2001). Since the late 1970s, with the NPM model, the understanding of modern public administration has shifted away from state monopolies to take on a structure of governance that includes citizens, civil society, and market actors (Olsen, 2005). Public administration in the digital age shows similarities with private sector management styles in terms of NPM, as it aims to ensure that citizens actively participate in administrative processes. The focus of postmodernism on the individual has become increasingly effective in the structuring of public administration (Greve, 2010; Zanetti and Carr, 1999). At the same time, the understanding of inclusiveness of differences at the micro level, which is another result of the postmodernist paradigm, is reflected in the inclusion of differences in administration and governance by postmodern public administrations. For this reason, the traces of deliberative democracy in the Habermasian sense have begun to be seen in postmodern public administration (King, 2005; Beniger, 1986; Barber, 2003).

DIGITAL AGE GOVERNANCE

The understanding of 'good governance' has become globalised as a result of the state-level pressures of international organisations such as the World Bank and OECD. For this reason, certain characteristics of good governance have become global principles (Aguilera & Cuervo-Cazurra, 2009). Governance can be broadly defined as effective governmental actions that enable state or non-state actors to interact in relationship dynamics and decision-making processes (Howlett & Ramesh, 2014; Weiss, 2000; Grimmelmann, 2015; Rhodes, 1996). When it was first defined in this way, governance was discussed in terms of factors such as transparency, political stability, information sharing, open financial reports, government effectiveness, and corruption control (O'Shea, 2005; Fukuyama, 2013; Gavelin et al, 2009). However, in the postmodern period, the concept began to be expanded and discussed in light of different factors.

With the use of technology and telecommunication services in political and administrative systems, transitions from governance to meta-governance have become desirable, and local and central government bodies have been asked to make such transitions (Gjaltema et al., 2019; Fransen, 2015). NPM is pluralistic and has the aim of sharing public service and management processes among actors. Therefore, meta-governance fulfils the criteria specific to the NPM understanding (Osborne, 2006; Fukuyama, 2013). New public governance can accordingly be defined as comprising self-organising inter-organisational networks (Rhodes, 1997). Within this framework, it is desired to increase the extent of factors such as accountability, monitoring, and auditing of the public sector like that of the private sector, with increased transparency and participation (Grindle, 2004). At the same time, factors such as freedom of expression, political participation, and democratic governance have also gained importance in new public governance as aspects of digital communications (Gorwa, 2019).

The foundations of DAG were first put forward by Dunleavy and Margetts in 2000. In the most general terms, digital governance entails a digital management paradigm that has emerged as a result of the shift of information in the field of management to virtual networks based on data and technology and requiring technologically equipped governing bodies and a digitalised society (Dunleavy & Margetts, 2000). DAG aims to interact with citizens by developing user-centred services, building open government policies with crowdsourcing, and creating transparent, accountable, and effective digital administration structures (Aitken, 2018). The digitalisation of administrative bodies is based on administrative reintegration and needs-based integration efforts. The simplification of relations between different administrative actors is sought, as is the provision of wide participation opportunities, to prevent the time and cost losses of hierarchy and bureaucracy and to ensure fast and flexible governance (Dunleavy et al., 2005).

When governance and digital technology come together in public bodies, digital governance is born, and e-Government is becoming a particularly important tool of digital governance (Janowski, 2016; Stanimirovic & Vintar, 2013). As one of the most critical tools in the digitalisation of administrations, e-Government stands out in terms of facilitating sustainable growth, the integration of different actors, and the provision of public services. It is seen as the main driving force of digital transformation in terms of strengthening the principles of transparency, efficiency, and accountability and increasing the quality of governance (Castro & Lopes, 2021; von Haldenwang, 2004).

ICT technologies are a key factor at this point because they are necessary for both the development of e-Government technologies and for citizens to participate in administration digitally. Thus, in countries with well-developed ICT, the rate of digital governance is increasing together with the rate of digitalised citizens (Tianru, 2020; Simons et al, 2020). Within the framework of DAG, the private sector and citizens act together with the state. According to DAG, citizens are not only consumers; they are also producers of public policy (Dunleavy et al., 2005). Citizens need technology developed for this function in order to actively apply digital participation mechanisms (Chocan & Hu, 2020). Directives should be created by standardising the relevant policies and procedures, and these directives should be embedded in technological information spheres because this is also a type of 'network governance' with an understanding of open government (Melin & Wihlborg, 2018).

The technological process referred to as the second wave of DAG started in 2010, and the evolution of society to a more advanced form with virtual network structures has accelerated accordingly (Dunleavy & Margetts, 2010). With the development of ICT, investments in this field have been increased to enable the private sector and citizens to become digitally interactive. The hierarchical order has disappeared completely and the concept of 'do-it-yourself government' has come into play. As citizen are seen as customers, quality has started to gain more importance in public services (Scupola & Zanfei, 2016).

DAG, which swiftly followed the NPM understanding in the development of governance, requires states to be 'digital states'. In this context, countries have been involved in DAG processes by developing projects to gain momentum in this area. European Union Member States began being structured and organised together with Framework Programme projects (Daves, 2009). The European Union now gives importance to criteria such as the digitalisation of public administration and the strengthening of digital governance, the treatment of citizens as customers, the spread of ICT in all areas of society and administration, and the training of specialised personnel. In this context, a data repository for many criteria has been created from relevant reports and analyses (European Commission, 2013, 2020, 2022).

The rapid development and spread of DAG continues to increase. In particular, states that lagged behind in digitalisation processes have entered the stage of resolving the lack of technical knowledge and equipment with radical changes. Attempts are being made to ensure adaptation in this area by establishing digital transformation institutions and expanding their working areas up to the digital adaptation of citizens and other participation actors. In addition, governance processes are being enriched with applications such as e-Government and m-Government, and new structures are being developed in which citizen are both consumers and producers as data providers. Previous structures that were developed very rapidly underwent serious transformations with the experiences of the COVID-19 pandemic, which has constituted a trigger of transformation on a global scale. On a social basis, states, private sectors, non-governmental organisations, and citizens all began a rapid and compulsory adaptation to digitalisation. This situation shows that participation in DAG will continue to be increased and administrative structures will evolve with supportable dimensions.

POSTMODERN PUBLIC ADMINISTRATION AND DIGITAL AGE GOVERNANCE

DAG has created an administrative transformation based on democracy with characteristics such as accountability, transparency, open government, and e-participation. It has created a basis for actors such as citizens and the private sector to become participants in governance processes. These digital networks and data-based processes have begun to share responsibilities and duties among actors (Karvalics, 2008; He, 2020). It can be stated that postmodernism affects understandings of public administration firstly via the concept of NPM and then subsequently via DAG.

Postmodernism, with its sceptical approach, has caused technologies of power to be questioned (Foucault, 1994) and has strengthened principles such as openness, transparency, and accountability. Along with the rejection of traditional approaches, the idea of society as an actor on the digital plane, separated from the idea of the masses, is a product of postmodernism (Deleuze & Guattari, 1987). As stated above, postmodernist thought, in which the local gains importance, has continued to shake modernism and has launched discussions of the hyper-reality of digital societies with the transformation of hierarchical, centralised, and traditional concepts.

The understanding of governance in the digital age entails efforts to keep up with these processes of change and to include all actors in society (citizens, private sector, etc.) as major players. This allows everyone to exert control over themselves, each other, and their governing bodies. ICT, developed to help achieve all this, has facilitated a global network system that has gradually spread throughout society. As a result, society is increasingly digitalised and this process brings democracy to the forefront (Gil-Garcia et al., 2018). It can be said that the integration of democracy and pluralism with DAG is closely related to the establishment of postmodernist identities, so much so that individuals who are familiar with the pluralistic and multicultural structures of postmodernism are flexible, decentralised, and adaptable to change. They want to exist with their own identities and

Table 2. Relationship Between Postmodern Public Administration and Digital Age Governance

Postmodern Public Administration	**Digital Age Governance**
Horizontal (broad) organisation	Cross-cutting (horizontal-vertical) and temporary organisations
Horizontal, flexible hierarchy	Person-centred, flexible hierarchy
Decentralised	Decentralised (virtual network structures)
Participation: Private sector and civil society Governance after 1990: Individual participation	After 2000: Digital governance Involvement of all actors, from the state to the individual
The individual is the consumer of the service; individuals take part in the production of services without being aware of it (indirectly and partially) via participation in civil society	At the point where the individual is the consumer of the service, he or she also takes on a role as a (direct) service producer
Transparency and accountability are on the rise	
State control of self and individual	Control of the individual and the state

Source: Created by the authors.

do not want to be attached to a specific group or do not feel a sense of belonging to previously emphasised social categories (Kellner, 1992). Postmodernism, which broke away from time-and-space cycles in terms of accepting differences and Others, has contributed to the development of democracy in this regard (Harvey, 1989). This is one of the factors that contribute to the activeness of individuals in digital governance.

The determinativeness of postmodernism in DAG can be seen in the understanding of postmodern public administration. It is clear that there is an evolutionary relationship between understandings of postmodern public administration and DAG, and the existence of major differences in terms of period and method has also been revealed.

RELATED STUDIES

The entropy method is widely used for calculating criterion weights in applications of multi-criteria decision-making methods. In recent years, it has been observed that the entropy method is particularly popular in studies conducted in different fields of the social sciences. Although there is wide variety among multi-criteria decision-making methods, the entropy method can be used with almost all of them. For the present work, a literature review of studies using the entropy method supported by the MABAC method was conducted.

Yong et al. (2022) carried out a two-stage study to determine whether abandoned coal mines could be used as underground power storage stations and, in doing so, they applied SWARA and the entropy-based MABAC method. Altıntaş (2022a), on the other hand, identified the countries that contributed the most to energy innovation globally based on the 2021 Global Energy Innovation Index Report and using MABAC and MARCOS as multi-criteria decision-making methods. According to that study, while the European countries with the highest global energy innovation performances are Finland, Denmark, and Sweden, the ones with the lowest performance are Poland, Greece, and Estonia. In another study, Altıntaş (2022b) measured cyber security performances based on the 2020 Global Cyber Security Index parameters of the G7 countries with the entropy-supported MABAC method. He found that the cyber security performances of the USA and UK are far ahead of those of other countries. Çınaroğlu (2020) evaluated innovation activities on a sectoral basis using the entropy-supported MABAC method. In subsequent research, Çınaroğlu (2022) measured the digital transformation performances of EU countries in 2021 based on the EU Commission's DESI Report with the entropy-supported MABAC method. The EU countries with the highest digital transformation performances were found to be Denmark and Finland, and those with the lowest performance levels were Greece, Bulgaria, and Romania. Meng et al. (2021) used entropy and FDEMATEL-supported MABAC to determine high-risk factors in digging foundation pits. Biswas and Saha (2019) used the TOPSIS and MABAC methods as multi-criteria decision-making methods to evaluate the criteria that working women pay attention to when purchasing scooters. Biswas et al. (2019), on the other hand, carried out a two-stage research project to calculate the risk-return ratios of investments to be made in mutual funds, and they used the entropy-supported MABAC method in the second stage. Ayçin and Çakın (2019) calculated the innovation performance values of countries with the MABAC method in their study and determined the weights of selected variables such as innovation, financing and support, and intellectual assets using the entropy method. In that study, the European countries with the highest innovation performance levels were Switzerland, Sweden, and Denmark, while the countries with the lowest performances were Ukraine, Romania, and Macedonia. Ulutaş (2019), on the other hand, aimed to determine the most suitable marketing manager for a furniture workshop with the entropy-supported MABAC method. Biswas and Das (2018) evaluated the variables that hybrid vehicle users pay attention to in vehicle selection with the entropy-supported MABAC method.

The present study makes a unique contribution to the literature by using the entropy-supported MABAC method to evaluate DAG applications at the EU level in digital public services.

RESEARCH METHOD

In this study, the entropy and MABAC methods were used since the aim of the research was to analyse the performance of EU countries in terms of DAG according to the digitalisation rates of administrative mechanisms in order to offer digital governance in the postmodern era. More specifically, the entropy method was used because it allows criterion weights to be determined objectively over a decision matrix. The importance levels of the selected sub-criteria were determined together with criterion weights obtained by the entropy method. The MABAC method, on the other hand, was selected because it is a multi-criteria decision-making method used to determine the best criterion among various criteria using criterion weights.

The data used in this research were taken from the DESI Report published by the European Commission for the year 2022. The DESI Report is published annually

Table 3. Criteria and Codes

Digital Public Service (DPS) Sub-criteria	Sub-criteria Codes	Directions of Sub-criteria	Source of Data
E-Government Users	DPS-1	Maximisation	Digital Economy and Society Index (DESI), 2022 Report (available at https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2022)
Pre-Filled Forms	DPS-2	Maximisation	
Digital Public Services for Citizens	DPS-3	Maximisation	
Digital Public Services for Business	DPS-4	Maximisation	
Open Data	DPS-5	Maximisation	

by the European Commission to evaluate the digital transformation performances of EU Member States. Data are published for each EU country within the four main categories of 'Human Capital', 'Connectivity', 'Integration of Digital Technology', and 'Digital Public Services', with sub-criteria included for each of these criteria (European Commission, 2022). The main criterion considered in this research for each EU country is Digital Public Services (DPS), which has five sub-criteria. The reason for selecting DPS as the criterion of interest is that it encompasses data relevant to the concepts of digital transformation of administration and digital governance, as described above.

The entropy and MABAC methods were applied to determine the EU countries with the highest performances in this field by analysing the outcomes of EU countries for the five sub-criteria of DPS. In this process, it was aimed to determine the levels of importance given to the selected sub-criteria by the countries in question in the field of digitalisation of administration in the postmodern age. The main criterion, sub-criteria, directions, and codes used in this study are given in Table 3. Subsequently, the steps and application findings of the entropy and MABAC methods are given in detail.

Entropy Method

The entropy method, which was first defined by Rudolph Clausius in the middle of the nineteenth century, was originally used to express measures of uncertainty in systems (Zhang et al., 2011: 444). Today, the method is used for both qualitative and quantitative criteria, incorporating Shannon's adaptation to information theories from 1948 (Zou et al., 2006: 1020). The purpose of using the entropy method is to determine the weights of criteria. By using a decision matrix, the weights and importance levels of criteria are determined. For this reason, the obtained criteria importance levels are objective. The entropy method consists of a total of five steps as detailed below (Deng et al., 2020; Kapur, 1982; Yin, 2019; Wu et al., 2011).

Step 1: Creating the Decision Matrix

In the first step, $m \times n$ decision matrix tables are created with m criteria and n alternatives. In this matrix, i = alternative and j = criteria for $x_i(j)$. The decision matrix is shown in Eq. (1).

$$X = \begin{bmatrix} x_1(1) & x_1(2) & \dots & x_1(m) \\ x_2(1) & x_2(2) & \dots & x_2(m) \\ \vdots & \vdots & \ddots & \vdots \\ x_n(1) & x_n(2) & \dots & x_n(m) \end{bmatrix} \tag{1}$$

Step 2: Normalisation of Decision Matrix

Alternatives are calculated with i, criteria with j, utility values with a_{ij}, and normalised values with p_{ij}.

$$\mathbf{p_{ij}} = \frac{\mathbf{a_{ij}}}{\sum_{\mathbf{i=1}}^{\mathbf{m}} \mathbf{a_{ij}}}; \forall_{\mathbf{j}} \tag{2}$$

Step 3: Calculating Entropy Values

In the equation below, r_{ij} represents the normalised values, e_j represents the entropy value, and k represents the entropy coefficient.

$$\mathbf{e_{j}} = -\mathbf{k} \sum_{\mathbf{j=1}}^{\mathbf{m}} \mathbf{r_{ij}} \mathbf{ln}\left(\mathbf{r_{ij}}\right) \tag{3}$$

Step 4: Calculating Weight Values

The degree of importance of the criteria is calculated with Eq. (4). Significance weight levels w_j are then obtained using Eq. (5).

$$\mathbf{d_j} = 1 - \mathbf{e_j}\ ;\ \forall_j \tag{4}$$

$$\mathbf{w_j} = \frac{\mathbf{d_j}}{\sum_{j=1}^{n} \mathbf{d_j}};\forall_j \tag{5}$$

MABAC Method

The multi-attributive border approximation area comparison (MABAC) method is a multi-criteria decision-making method introduced in the literature by Pamučar and Ćirović (2015). The values of the functions of the criteria are calculated for each decision alternative and the distances of these values to the boundary proximity area are determined. Then, by determining the distances of the criterion functions, the decision alternatives are ranked and the best alternative is selected (Wei et al., 2019; Ji et al., 2018). The MABAC method consists of a total of seven steps, which are detailed below (Pamučar & Ćirović, 2015; Gigovic et al., 2017; Ayçin, 2018).

Step 1: Creating the Decision Matrix

An initial decision matrix with *m* decision alternatives and *n* criteria is created**.**

$$X = \begin{bmatrix} x_1(1) & x_1(2) & \dots & x_1(m) \\ x_2(1) & x_2(2) & \dots & x_2(m) \\ \vdots & \vdots & \ddots & \vdots \\ x_n(1) & x_n(2) & \dots & x_n(m) \end{bmatrix} \tag{6}$$

Step 2: Normalisation of Decision Matrix

$$\mathbf{n_{ij}} = \frac{\mathbf{x_{ij}} - \mathbf{x_i^-}}{\mathbf{x_i^+} - \mathbf{x_i^-}} \tag{7}$$

$$\mathbf{n_{ij}} = \frac{\mathbf{x_{ij}} - \mathbf{x_i^+}}{\mathbf{x_i^-} - \mathbf{x_i^+}} \tag{8}$$

Step 3: Weighting the Decision Matrix

The criterion weights, previously calculated by another method, are now calculated with the help of Eq. (9).

$$\mathbf{v_{ij}} = \mathbf{w_i} \cdot \left(\mathbf{n_{ij}} + 1\right) \tag{9}$$

Step 4: Creating the Boundary Proximity Field Matrix

Boundary proximity field values are calculated using Eq. (10). Thus, the g_i value for all considered criteria is obtained.

$$\mathbf{v_{ij}} = \mathbf{w_i} \cdot \left(\mathbf{n_{ij}} + 1\right) \tag{10}$$

Step 5: Calculating the Distances (Q) of the Decision Alternatives to the Boundary Proximity Area

The difference between the elements of the weighted decision matrix and the boundary proximity matrix elements is taken.

$$Q = V - G = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \dots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \dots & v_{2n} - g_n \\ \dots & \dots & \dots & \dots \\ v_{m1} - g_1 & v_{m2} - g_2 & \dots & v_{mn} - g_n \end{bmatrix} \tag{11}$$

Step 6: Determining the Status of Decision Alternatives According to the Boundary Proximity Area

For each decision alternative, situations are determined using Eq. (12) according to the border proximity area. The upper affinity is denoted by G^+ and the lower affinity by G^-.

$$\mathbf{A_i} = \begin{cases} \mathbf{G^+ \text{ if } q_{ij}} > 0 \\ \mathbf{G \text{ if } q_{ij}} = 0 \\ \mathbf{G^- \text{if } q_{ij}} < 0 \end{cases} \tag{12}$$

Step 7: Ranking of Decision Alternatives

The criterion functions of each decision alternative are calculated using Eq. (13).

$$\mathbf{v_{ij}} = \mathbf{w_i} \cdot \left(\mathbf{n_{ij}} + 1\right) \tag{13}$$

RESULTS

Table 4. Creating the Decision Matrix

Sub-criteria EU Countries	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5
Criterion Direction	Max.	Max.	Max.	Max.	Max.
Germany	55.000	42.000	76.000	80.000	89.000
Austria	79.000	71.000	76.000	81.000	92.000
Belgium	74.000	73.000	72.000	81.000	55.000
Bulgaria	34.000	58.000	59.000	76.000	78.000
Czechia	76.000	41.000	75.000	81.000	74.000
Denmark	93.000	86.000	83.000	89.000	91.000
Estonia	89.000	87.000	92.000	98.000	94.000
Finland	92.000	90.000	90.000	93.000	86.000
France	87.000	47.000	69.000	80.000	98.000
Croatia	55.000	38.000	69.000	68.000	84.000
Netherlands	92.000	94.000	85.000	88.000	92.000
Ireland	92.000	59.000	80.000	100.00	95.000
Spain	73.000	78.000	87.000	94.000	95.000
Sweden	93.000	85.000	85.000	88.000	84.000
Italy	40.000	48.000	67.000	79.000	92.000
Cyprus	63.000	31.000	56.000	86.000	91.000
Latvia	84.000	77.000	87.000	86.000	77.000
Lithuania	70.000	92.000	82.000	93.000	89.000
Luxembourg	79.000	69.000	93.000	97.000	66.000
Hungary	81.000	60.000	64.000	74.000	58.000
Malta	72.000	87.000	100.00	97.000	51.000
Poland	55.000	74.000	57.000	70.000	95.000
Portugal	59.000	76.000	79.000	82.000	66.000
Romania	17.000	19.000	44.000	42.000	76.000
Slovakia	62.000	45.000	65.000	75.000	50.000
Slovenia	77.000	68.000	69.000	84.000	92.000
Greece	69.000	45.000	52.000	48.000	82.000

Steps and Findings of the Entropy Method

The decision matrix used in the entropy and MABAC applications is shown in Table 4. The entropy weights of the sub-criteria were determined based on the decision matrix.

Table 5. Normalisation of Entropy Decision Matrix

Sub-criteria EU Countries	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5
Germany	0.0288	0.0241	0.0378	0.0362	0.0406
Austria	0.0413	0.0408	0.0378	0.0367	0.0420
Belgium	0.0387	0.0420	0.0358	0.0367	0.0251
Bulgaria	0.0178	0.0333	0.0293	0.0344	0.0356
Czechia	0.0397	0.0236	0.0373	0.0367	0.0338
Denmark	0.0486	0.0494	0.0412	0.0403	0.0415
Estonia	0.0465	0.0500	0.0457	0.0443	0.0429
Finland	0.0481	0.0517	0.0447	0.0421	0.0392
France	0.0455	0.0270	0.0343	0.0362	0.0447
Croatia	0.0329	0.0178	0.0278	0.0389	0.0415
Netherlands	0.0288	0.0218	0.0343	0.0308	0.0383
Ireland	0.0481	0.0540	0.0422	0.0398	0.0420
Spain	0.0481	0.0339	0.0397	0.0452	0.0433
Sweden	0.0382	0.0448	0.0432	0.0425	0.0433
Italy	0.0486	0.0489	0.0422	0.0398	0.0383
Cyprus	0.0209	0.0276	0.0333	0.0357	0.0420
Latvia	0.0439	0.0443	0.0432	0.0389	0.0351
Lithuania	0.0366	0.0529	0.0407	0.0421	0.0406
Luxembourg	0.0413	0.0397	0.0462	0.0439	0.0301
Hungary	0.0424	0.0345	0.0318	0.0335	0.0265
Malta	0.0377	0.0500	0.0497	0.0439	0.0233
Poland	0.0288	0.0425	0.0283	0.0317	0.0433
Portugal	0.0309	0.0437	0.0392	0.0371	0.0301
Romania	0.0089	0.0109	0.0219	0.0190	0.0347
Slovakia	0.0324	0.0259	0.0323	0.0339	0.0228
Slovenia	0.0403	0.0391	0.0343	0.0380	0.0420
Greece	0.0361	0.0259	0.0258	0.0217	0.0374

The entropy normalisation matrix was created using Eq. (2).

Table 6. Calculation of Entropy and *k* Values

Sub-criteria EU Countries	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5
Germany	-0.1021	-0.0899	-0.1237	-0.1201	-0.1301
Austria	-0.1317	-0.1305	-0.1237	-0.1212	-0.1331
Belgium	-0.1259	-0.1330	-0.1191	-0.1212	-0.0925
Bulgaria	-0.0717	-0.1134	-0.1035	-0.1159	-0.1187
Czechia	-0.1282	-0.0883	-0.1226	-0.1212	-0.1144
Denmark	-0.1471	-0.1486	-0.1315	-0.1294	-0.1321
Estonia	-0.1428	-0.1498	-0.1410	-0.1382	-0.1351
Finland	-0.1460	-0.1532	-0.1389	-0.1333	-0.1270
France	-0.1406	-0.0976	-0.1156	-0.1201	-0.1389
Croatia	-0.1125	-0.0718	-0.0996	-0.1263	-0.1321
Netherlands	-0.1021	-0.0835	-0.1156	-0.1071	-0.1250
Ireland	-0.1460	-0.1577	-0.1336	-0.1284	-0.1331
Spain	-0.1460	-0.1147	-0.1282	-0.1401	-0.1360
Sweden	-0.1247	-0.1392	-0.1358	-0.1343	-0.1360
Italy	-0.1471	-0.1475	-0.1336	-0.1284	-0.1250
Cyprus	-0.0809	-0.0990	-0.1133	-0.1191	-0.1331
Latvia	-0.1373	-0.1380	-0.1358	-0.1263	-0.1176
Lithuania	-0.1211	-0.1554	-0.1304	-0.1333	-0.1301
Luxembourg	-0.1317	-0.1280	-0.1421	-0.1372	-0.1055
Hungary	-0.1339	-0.1161	-0.1096	-0.1137	-0.0961
Malta	-0.1235	-0.1498	-0.1491	-0.1372	-0.0875
Poland	-0.1021	-0.1343	-0.1009	-0.1093	-0.1360
Portugal	-0.1073	-0.1368	-0.1271	-0.1222	-0.1055
Romania	-0.0420	-0.0493	-0.0836	-0.0753	-0.1166
Slovakia	-0.1112	-0.0945	-0.1109	-0.1148	-0.0862
Slovenia	-0.1294	-0.1267	-0.1156	-0.1243	-0.1331
Greece	-0.1199	-0.0945	-0.0944	-0.0832	-0.1229

The *k* value was determined using Eq. (3).

Table 7. Table of d_j Values

dj	1.0220	1.0138	1.0373	1.0387	1.0375

The criterion entropy values were calculated using Eq. (4).

Table 8. w_j Criterion Weight Coefficients Table

Sub-criteria	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5	TOTAL
wj	0.19847	0.19689	0.20144	0.20171	0.20149	1

The criterion weight coefficients were obtained using Eq. (5). According to the results, the sub-criterion with the highest level of importance among the DPS sub-criteria is DPS-4. In contrast, the sub-criterion with the least importance is DPS-2.

Steps and Findings of the MABAC Method

The initial decision matrix used for the entropy and MABAC applications is the same matrix, as shown in Table 4. Since it is necessary to determine and integrate the criteria weights in these applications, criteria weights were determined first and then the MABAC application was started. The application steps are given in detail below. In the first step of this application, the decision matrix (Table 4) was normalised.

Table 9. Normalisation of the Decision Matrix

Sub-criteria EU Countries	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5
Criterion Direction	Max.	Max.	Max.	Max.	Max.
Germany	0.5000	0.3067	0.5714	0.6552	0.8125
Austria	0.8158	0.6933	0.5714	0.6724	0.8750
Belgium	0.7500	0.7200	0.5000	0.6724	0.1042
Bulgaria	0.2237	0.5200	0.2679	0.5862	0.5833
Czechia	0.7763	0.2933	0.5536	0.6724	0.5000
Denmark	1.0000	0.8933	0.6964	0.8103	0.8542
Estonia	0.9474	0.9067	0.8571	0.9655	0.9167
Finland	0.9868	0.9467	0.8214	0.8793	0.7500
France	0.9211	0.3733	0.4464	0.6552	1.0000
Croatia	0.5000	0.2533	0.4464	0.4483	0.7083
Netherlands	0.9868	1.0000	0.7321	0.7931	0.8750
Ireland	0.9868	0.5333	0.6429	1.0000	0.9375
Spain	0.7368	0.7867	0.7679	0.8966	0.9375
Sweden	1.0000	0.8800	0.7321	0.7931	0.7083
Italy	0.3026	0.3867	0.4107	0.6379	0.8750
Cyprus	0.6053	0.1600	0.2143	0.7586	0.8542
Latvia	0.8816	0.7733	0.7679	0.7586	0.5625
Lithuania	0.6974	0.9733	0.6786	0.8793	0.8125
Luxembourg	0.8158	0.6667	0.8750	0.9483	0.3333
Hungary	0.8421	0.5467	0.3571	0.5517	0.1667
Malta	0.7237	0.9067	1.0000	0.9483	0.0208
Poland	0.5000	0.7333	0.2321	0.4828	0.9375
Portugal	0.5526	0.7600	0.6250	0.6897	0.3333
Romania	0.0000	0.0000	0.0000	0.0000	0.5417
Slovakia	0.5921	0.3467	0.3750	0.5690	0.0000
Slovenia	0.7895	0.6533	0.4464	0.7241	0.8750
Greece	0.6842	0.3467	0.1429	0.1034	0.6667

Since all considered sub-criteria are maximisation-oriented, a normalisation decision matrix was created using Eq. (7).

Table 10. Weighted Normalised Decision Matrix

Sub-criteria EU Countries	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5
Germany	0.2977	0.2573	0.3165	0.3339	0.3652
Austria	0.3604	0.3334	0.3165	0.3373	0.3778
Belgium	0.3473	0.3386	0.3022	0.3373	0.2225
Bulgaria	0.2429	0.2993	0.2554	0.3200	0.3190
Czechia	0.3526	0.2546	0.3130	0.3373	0.3022
Denmark	0.3969	0.3728	0.3417	0.3652	0.3736
Estonia	0.3865	0.3754	0.3741	0.3965	0.3862
Finland	0.3943	0.3833	0.3669	0.3791	0.3526
France	0.3813	0.2704	0.2914	0.3339	0.4030
Croatia	0.2977	0.2468	0.2914	0.2921	0.3442
Netherlands	0.3943	0.3938	0.3489	0.3617	0.3778
Ireland	0.3943	0.3019	0.3309	0.4034	0.3904
Spain	0.3447	0.3518	0.3561	0.3826	0.3904
Sweden	0.3969	0.3702	0.3489	0.3617	0.3442
Italy	0.2585	0.2730	0.2842	0.3304	0.3778
Cyprus	0.3186	0.2284	0.2446	0.3547	0.3736
Latvia	0.3734	0.3491	0.3561	0.3547	0.3148
Lithuania	0.3369	0.3885	0.3381	0.3791	0.3652
Luxembourg	0.3604	0.3281	0.3777	0.3930	0.2686
Hungary	0.3656	0.3045	0.2734	0.3130	0.2351
Malta	0.3421	0.3754	0.4029	0.3930	0.2057
Poland	0.2977	0.3413	0.2482	0.2991	0.3904
Portugal	0.3082	0.3465	0.3273	0.3408	0.2686
Romania	0.1985	0.1969	0.2014	0.2017	0.3106
Slovakia	0.3160	0.2651	0.2770	0.3165	0.2015
Slovenia	0.3552	0.3255	0.2914	0.3478	0.3778
Greece	0.3343	0.2651	0.2302	0.2226	0.3358

A weighted normalised decision matrix was created using Eq. (9).

Table 11. Table of *gi* Values

Sub-criteria	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5
gj	0.33490	0.31132	0.30733	0.33656	0.32612

The g_i values were calculated using Eq. (10). For each sub-criterion, the distance to the boundary proximity area was determined.

Table 12. Distance to Boundary Proximity Matrix, *Si* Criterion Functions, and Rankings of Countries

Sub-criteria EU Countries	DPS-1	DPS-2	DPS-3	DPS-4	DPS-5	Si	Ranking
Germany	-0.0372	-0.0541	0.0092	-0.0027	0.0391	-0.0456	17
Austria	0.0255	0.0221	0.0092	0.0008	0.0517	0.1092	11
Belgium	0.0124	0.0273	-0.0052	0.0008	-0.1036	-0.0683	19
Bulgaria	-0.0920	-0.0121	-0.0519	-0.0166	-0.0071	-0.1797	24
Czechia	0.0177	-0.0567	0.0056	0.0008	-0.0239	-0.0565	18
Denmark	0.0621	0.0615	0.0344	0.0286	0.0475	0.2340	4
Estonia	0.0516	0.0641	0.0668	0.0599	0.0601	0.3024	1
Finland	0.0594	0.0720	0.0596	0.0425	0.0265	0.2600	3
France	0.0464	-0.0409	-0.0160	-0.0027	0.0769	0.0637	14
Croatia	-0.0372	-0.0646	-0.0160	-0.0444	0.0181	-0.1440	23
Netherlands	0.0594	0.0825	0.0416	0.0251	0.0517	0.2603	2
Ireland	0.0594	-0.0094	0.0236	0.0669	0.0643	0.2047	7
Spain	0.0098	0.0405	0.0488	0.0460	0.0643	0.2093	5
Sweden	0.0621	0.0588	0.0416	0.0251	0.0181	0.2057	6
Italy	-0.0764	-0.0383	-0.0232	-0.0062	0.0517	-0.0923	20
Cyprus	-0.0163	-0.0829	-0.0627	0.0182	0.0475	-0.0963	21
Latvia	0.0385	0.0378	0.0488	0.0182	-0.0113	0.1320	9
Lithuania	0.0020	0.0772	0.0308	0.0425	0.0391	0.1916	8
Luxembourg	0.0255	0.0168	0.0704	0.0564	-0.0575	0.1116	10
Hungary	0.0307	-0.0068	-0.0340	-0.0236	-0.0910	-0.1246	22
Malta	0.0072	0.0641	0.0955	0.0564	-0.1204	0.1028	12
Poland	-0.0372	0.0300	-0.0591	-0.0375	0.0643	-0.0396	16
Portugal	-0.0267	0.0352	0.0200	0.0043	-0.0575	-0.0247	15
Romania	-0.1364	-0.1144	-0.1059	-0.1348	-0.0155	-0.5071	27
Slovakia	-0.0189	-0.0462	-0.0304	-0.0201	-0.1246	-0.2401	26
Slovenia	0.0203	0.0142	-0.0160	0.0112	0.0517	0.0814	13
Greece	-0.0006	-0.0462	-0.0771	-0.1140	0.0097	-0.2282	25

As shown in Eqs. (11) and (12), the matrix of distances to the boundary proximity area was obtained. Finally, the alternatives were ranked from 1 to 27 based on the *Si* values obtained by calculating sub-criterion functions using Eq. (13). The highest criterion value signifies the most preferred alternative. According to the results of the analysis, the countries with the highest DPS performance levels in 2022 were Estonia, the Netherlands, and Finland, respectively. The countries with the lowest performances were Romania, Slovakia, and Greece, respectively.

CONCLUSION

Postmodernism has affected the structure of public administration in two dimensions. First of all, it has changed the understanding of public administration, which was a product of modernism, by introducing the concept of 'new public management'. Subsequently, it yielded the concept of 'digital age governance'. The digitalisation of administration and the strengthening of governance mechanisms on the country-level have also been important issues for EU Member States. The DESI Report annually published by the European Commission on digitalisation performances of EU countries includes many criteria and sub-criteria for success in digitalisation.

In this study, the digitalisation performances of EU countries were evaluated based on the 'Digital Public Services' (DPS) criterion of the 2022 DESI Report. In this way, it was aimed to identify the EU country with the highest performance in terms of administrative digital transformation. The maximisation-oriented DPS sub-criteria of 'E-Government Users', 'Pre-Filled Forms', 'Digital Public Services for Citizens', 'Digital Public Services for Business', and 'Open Data' were included in the analysis. The weights of the listed sub-criteria were determined by the entropy method and their importance levels were calculated. The MABAC method, which is a multi-criteria decision-making method, was then used to rank the 27 EU Member States from 1 to 27 in line with the weighted sub-criteria.

As a result of the analysis, it was determined that the three EU countries with the highest levels of performance within the scope of the DPS sub-criteria are Estonia, the Netherlands, and Finland, respectively. The EU countries with the lowest levels of performance are Romania, Slovakia, and Greece, respectively. According to the entropy analysis, in which the importance levels of the considered sub-criteria were determined, the most important DPS sub-criterion is Digital Public Services for Business. The sub-criterion with the least importance is Pre-Filled Forms. The ranking of the sub-criteria according to their importance levels was obtained as follows, from most to least important: Digital Public Services for Business, Open Data, Digital Public Services for Citizens, E-Government Users, and Pre-Filled Forms.

In conclusion, the DPS sub-criteria are parameters that show how levels of communication are increasing between states and citizens with digitalisation. In this framework, it can be said that Estonia, the Netherlands, and Finland are the EU countries with the most successful applications of DAG today. This study could be repeated for different years or for different sub-criteria. The DESI criteria can also be considered together with other criteria in this field in the coming years and countries can be evaluated with multi-criteria decision-making methods in terms of their digital transformation performances.

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