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Resilient public governance and ecological transition: Systemic adaptation models and the role of Artificial Intelligence in modern administration

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Abstract: In a context marked by the overlapping of contemporary crises - climate emergency, geopolitical instability, and technological acceleration - public administration is faced with the need to rethink its operational models. This article examines the drivers of public governance adaptation to the challenges of the dual ecological and digital transitions, drawing on the conceptual frameworks of negentropy, institutional resilience, and the integration of Artificial Intelligence (AI), with a focus on the transition economies of Central and Eastern Europe, particularly Romania. The mixed-methods approach relates on triangulation between secondary macroeconomic data (DESI, World Bank WGI, Eurostat Eco-Innovation Scoreboard) and a document analysis of major public policies, especially the National Recovery and Resilience Plan (PNRR). The results reveal a stark contrast between high-performing digital infrastructures and a low rate of citizen adoption of digital public services, while the PNRR initiates a strategic shift towards integrated e-government. The analysis also highlights the central role of green public procurement as a driver of eco-innovation, hampered by a shortage of specialized skills. Based on this, the article proposes the Negentropic Eco-Digital Governance (NDG) Model, structured around three pillars – technological, eco-responsible, and managerial – and formulates recommendations for agile AI regulation, the widespread adoption of digitized green public procurement, and the strengthening of public servants' skills.

Keywords: Institutional resilience, negentropy, ecological transition, Artificial Intelligence, digitization.

Résumé : Dans un contexte marqué par le chevauchement des crises contemporaines – urgence climatique, instabilité géopolitique et accélération technologique –, l'administration publique est confrontée à la nécessité de repenser ses modèles opérationnels. Cet article examine les vecteurs d'adaptation de la gouvernance publique face aux défis de la double transition écologique et numérique, en mobilisant les cadres conceptuels de la négentropie, de la résilience institutionnelle et de l'intégration de l'Intelligence Artificielle (IA), avec un focus sur les économies en transition d'Europe centrale et orientale, notamment la Roumanie. La méthodologie mixte repose sur une triangulation entre données secondaires macroéconomiques (DESI, WGI de la Banque Mondiale, Eco-Innovation Scoreboard d'Eurostat) et une analyse documentaire des politiques publiques majeures, en particulier le Plan National de Reprise et de Résilience (PNRR). Les résultats révèlent un contraste marqué entre des infrastructures numériques performantes et un faible taux d'appropriation des services publics numériques par les citoyens, tandis que le PNRR amorce un basculement stratégique vers un e-Government intégré. L'analyse met également en évidence le rôle central des achats publics verts comme

levier d'éco-innovation, freiné par un déficit de compétences spécialisées. Sur cette base, l'article propose le Modèle de Gouvernance Néguentropique Éco-Digitale (GNED), articulé autour de trois piliers – technologique, éco-responsable et managérial – et formule des recommandations pour une régulation agile de l'IA, la généralisation des achats publics verts numérisés et le renforcement des compétences des agents publics.

Mots-clés : résilience institutionnelle, négentropie, transition écologique, Intelligence Artificielle, numérisation**.**

Classification JEL : H11, O33.

1. Introduction

Contemporary public administrations operate in an environment characterized by increasing complexity, heightened volatility, and frequent disruptions. Faced with the pressures of the climate emergency, the imperatives of decarbonization, and rapid digital transformation, traditional bureaucratic structures, based on hierarchical rigidity and passive reactivity, are revealing their structural limitations (Li et al., 2026; Lodge & Wegrich, 2014). The ability of public institutions to preserve their fundamental functionality while developing a capacity for proactive adaptation is now the central challenge of modern governance (Boin & Lodge, 2016; Christensen et al., 2016).

From this perspective, the dual transition - ecological and digital - necessitates a fundamental overhaul of public sector decision-making and operational mechanisms. On the one hand, the ecological transition requires the cross-cutting integration of sustainability into public policy development and territorial management (Jordan & Huitema, 2014; Massuga et al., 2024). On the other hand, the digital revolution, accelerated by the spread of Artificial Intelligence (AI) and process automation, offers unprecedented opportunities to rethink public service delivery, increase transparency, and reduce bureaucratic inertia (Janowski, 2015; Mergel et al., 2019; Wirtz et al., 2019).

However, the unconsidered introduction of technological or regulatory innovations within the administrative apparatus risks increasing institutional entropy—manifested as disorganization, information overload, and resistance to change (Mergel et al., 2026; Sun & Medaglia, 2019). It therefore becomes essential to analyze how the principles of negentropy (negative entropy) and organizational resilience can be combined to guide public administration toward a dynamic, eco-responsible, and proactive governance model (Duit, 2016; Rădulescu et al., 2020).

This article aims to examine the vectors of adaptation of public governance in the face of the challenges of the double transition, focusing particularly on the dynamics at work in the transition economies of Central and Eastern Europe, such as Romania (Burlacu et al., 2024; Burlacu et al., 2025).

This issue raises a central question: to what extent does public governance in the transition economies of Central and Eastern Europe succeed in converting investments in the dual ecological and digital transition into an effective reduction of institutional entropy and a strengthening of organizational resilience? Two hypotheses guide this research: (H1) the strategic integration of Artificial Intelligence into public decision-making processes constitutes a driver of negentropy likely to reduce the bureaucratic burden and improve the quality of regulations; (H2) the convergence between digitalization and eco-governance, particularly through green public procurement, only strengthens institutional resilience when it is accompanied by the development of appropriate managerial skills.

To answer this question, the study employs a non-invasive mixed-methods approach, based on triangulation between secondary macroeconomic data (DESI, World Bank WGI, Eurostat Eco-Innovation Scoreboard) and a document analysis of major public policies, particularly the National Recovery and Resilience Plan (PNRR). This methodological choice allows for the cross-referencing of quantitative indicators comparable at the European level with the qualitative content of the reforms

undertaken in Romania. The main findings reveal a marked contrast between high-performing digital infrastructure and low citizen appropriation of digital public services, a central role of green public procurement as a lever for eco-innovation hampered by a skills gap, and the need to articulate these dynamics within an integrated model. Based on this, the article proposes the Eco-Digital Negentropic Governance Model (GNED). The rest of the article is structured as follows: section 2 presents the theoretical and conceptual framework mobilizing negentropy, institutional resilience and the digital transformation of the public sector; section 3 details the methodology and data sources; section 4 presents the results and their discussion; section 5 proposes the GNED model; section 6 concludes and formulates public policy recommendations.

2. Theoretical and conceptual framework

The analysis of resilient public governance in the face of the dual ecological and digital transition mobilizes three complementary theoretical frameworks, whose progressive articulation - from the internal mechanisms of institutional entropy to the technological instruments of its reduction - structures this section.

2.1. Entropy and negentropy in administrative systems

Public organizations can be modeled as open, complex, and thermodynamically unstable systems, subject to continuous information flows and external shocks (Loorbach, 2010; Meuleman, 2013). In general systems theory applied to the public sector, entropy measures the degree of disorder, bureaucratic rigidity, and decision-making inefficiency. If left unchecked, entropy leads to the obsolescence of administrative processes and the erosion of public trust (Rădulescu et al., 2020).

To restore balance and maintain the development trajectory, institutions must inject negentropy (negative entropy) in the form of organizational innovations, high-level skills, and cutting-edge technologies (Burlacu et al., 2023; Voß & Bornemann, 2011). Negentropic governance thus relies on the ability to intercept weak environmental signals, restructure information flows, and simplify bureaucratic procedures (Rădulescu et al., 2025). This capacity to reduce entropy is, however, only a necessary condition; it must also be part of a sustainable institutional trajectory, which relates to the concept of resilience.

2.2. Institutional resilience and sustainability governance

Institutional resilience goes beyond the simple capacity for crisis management or a return to a previous state of equilibrium (*bounce-back*); it encompasses a capacity for proactive transformation and continuous learning (*bounce-forward*) (Duit, 2016; Li et al., 2026). Faced with environmental challenges, resilience must be embodied in sustainability governance *capable* of structuring local and national public policies around the circular economy and decarbonization (Bornemann & Christen, 2019; Massuga et al., 2024).

In this context, administrative instruments such as Green Public Procurement (GPP) act as concrete levers to steer markets towards sustainable solutions (Gelderman et al., 2017; Halonen, 2021). However, the implementation of environmental governance often generates tensions between stakeholders and requires a rigorous alignment between regulatory objectives and operational capabilities (Johnson & Klassen, 2022; Lundberg & Marklund, 2018; Ortega Carrasco et al., 2025). This alignment between regulatory ambition and operational capacity depends, to a large extent, on the tools available to public administrations for processing information and supporting decision-making - which leads us to examine the role of Artificial Intelligence.

2.3. Artificial Intelligence and the digital transformation of the public sector

The digitization of public administration has gradually shifted from simply computerizing data to a profound organizational transformation (*digital transformation*) and the emergence of smart government (Gil-Garcia et al., 2016; Janowski, 2015; Mergel et al., 2019). The introduction of Artificial Intelligence (AI) and intelligent automation technologies offers unprecedented potential at three levels. Operationally, it enables the automation of repetitive tasks and the streamlining of administrative processes (de Sousa et al., 2019; Wirtz et al., 2021). At the decision-making level, it supports complex decision-making through predictive analytics and cybernetic models (Madan & Ashok, 2023; Rădulescu et al., 2025). Finally, on a relational level, it contributes to improving the co-creation of public value with users, provided that the risks of value co-destruction linked to technological biases are avoided (Mergel et al., 2026; Sun & Medaglia, 2019). However, the adoption of AI requires overcoming structural, ethical, and cultural barriers, necessitating the development of new management and leadership skills (Wirtz et al., 2019).

2.4. Towards an integrated analytical framework

These three theoretical frameworks – organizational negentropics, sustainability-oriented institutional resilience, and AI-driven digital transformation – are not used in isolation but are structured around a shared logic of reducing systemic complexity. Negentropics provides the organizing principle (how to reduce institutional disorder), institutional resilience defines the objective (a *bounce-forward trajectory* towards sustainable governance), and Artificial Intelligence constitutes the operational vector (the concrete tools for implementation).

3. Methodology and data sources

To analyze the level of systemic adaptation of public administration to the dual ecological and digital transitions, this study employs a non-invasive mixed-methods approach, structured around the triangulation of macroeconomic secondary data and in-depth policy analysis. This methodological choice addresses two constraints. First, the lack of a single, readily available composite indicator to measure "institutional negentropy" necessitates constructing an empirical picture from several complementary sources. Second, a non-invasive approach, based on public data already collected and validated by European and international institutions (European Commission, World Bank, Eurostat), ensures the reproducibility and comparability of results at the European level, while avoiding the biases inherent in primary data collection from Romanian public administrations.

3.1. Secondary macroeconomic data

The quantitative analysis of governance and digitalization trends relies on three sets of aggregated data. The Digital Economy and Society Index (DESI) provides indicators related to digital public services (e-government availability, pre-filled forms, open data). The World Bank's Worldwide Governance Indicators (WGI) allow for a comparative analysis of *Government Effectiveness* and Regulatory Quality *scores*. Finally, Eurostat's Eco-Innovation Scoreboard assesses performance related to sustainable public procurement practices and eco-innovation.

3.2. Documentary corpus

The qualitative dimension examines the content of recent regulatory and strategic frameworks in Romania and at the European level (2021-2026), in particular the National Recovery and Resilience Plan (PNRR) - with an emphasis on component C7 (Digital Transformation) and ecological components C5 and C15 - as well as national strategies relating to the deployment of AI and the

modernization of public services in Central and Eastern Europe.

The comparison of these two data streams - quantitative and qualitative - makes it possible to cross-reference a comparative measure of Romania's position within the European Union with a detailed analysis of the reform mechanisms actually undertaken at the national level, with a view to the integrated assessment of resilience and institutional negentropy presented in the following section.

4. Results and discussion

4.1. Digitization, AI integration and bureaucracy reduction

An examination of secondary data reveals a striking contrast in the ECE region, and particularly in Romania. While the country boasts high-performing connectivity infrastructure, the rate of citizen use of digital public services lags structurally behind the European average (DESI, 2024). Table 1 summarizes this gap: with a score of 21/100 on the digital public services dimension - more than three times lower than the EU average and placing the country last in the European rankings - Romania illustrates a persistent deficit despite also lagging basic digital skills (27.7% compared to the EU average of 55.6%). Public administration remains characterized by bureaucratic practices and siloed databases.

However, a review of recent programs (PNRR) reveals a strategic shift in scale. The transition from a bureaucratic administration to integrated e-government is a major priority for ensuring long-term sustainability and efficiency (Burlacu et al., 2024; Burlacu et al., 2025). The deployment of the *Government Cloud* and the cybernetic framework for AI adoption (Rădulescu et al., 2025) lay the groundwork for a direct injection of negentropy at two complementary levels. At the operational level, the automation of document workflows via RPA and virtual assistants reduces repetitive administrative tasks (de Sousa et al., 2019; Madan & Ashok, 2023). At the decision-making level, the use of predictive AI promotes the optimization of public energy, fiscal, and environmental policies, based on evidence-based data (Rădulescu et al., 2025; Wirtz et al., 2021). The main indicators used to characterize Romania's relative position are summarized in Table 1 below.

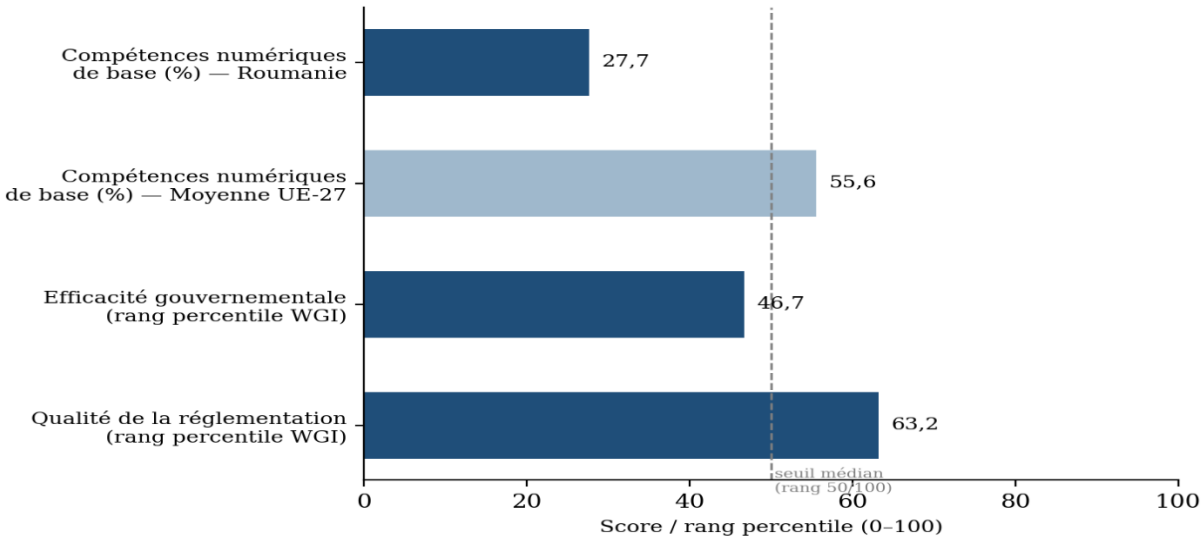
Table 1: Governance and Digitalization Indicators — Romania vs. European Union

Indicator	Romania	Reference EU-27
Digital public services for citizens (score /100)	21 (2024)	> 3× higher; Romania in last place
Basic digital skills (% of population)	27.7% (2024)	55.6%
Government efficiency (percentile rank, 0–100)	46.7 (2023)	—
Quality of regulation (percentile rank, 0–100)	63.2 (2023)	—
Eco-innovation index, evolution 2014–2024	The only member state to decline	+27.5% (EU-27 average)

Source: Bilouseac (2025) based on DESI/State of the Digital Decade 2024–2025 data; Worldwide Governance Indicators, World Bank (2023); European Environment Agency, Eco-innovation index (2024).

These discrepancies confirm, beyond institutional rhetoric, the extent of the operational gap that ongoing reforms must address. Figure 1 provides a complementary visual representation of these discrepancies for the two directly comparable indicators between Romania and the European Union average.

Figure 1: Digital skills and quality of governance - Romania (2023–2024)



Source: Digital Decade Report 2024, Comisia Europeană ; Worldwide Governance Indicators, World Bank (2023).

Taken together, these results indicate that Romania's room for improvement lies as much in citizen appropriation of digital tools as in the intrinsic quality of the regulatory framework.

4.2. Eco-governance and green public procurement

In terms of ecological transition, analysis shows that organizational resilience in public services requires a cross-cutting integration of sustainability (Bornemann & Christen, 2019; Burlacu et al., 2023). Green public procurement *appears* to be the most powerful regulatory lever for stimulating eco-innovation (Halonen, 2021; Ortega Carrasco et al., 2025) - a finding corroborated by the stagnation of the Romanian eco-innovation index, the only one to decline among the twenty-seven Member States between 2014 and 2024, while the European average increased by 27.5% over the same period (European Environment Agency, 2024).
However, analysis of public policies reveals major obstacles: a lack of specialized skills among public buyers and fears of legal risks associated with selecting complex environmental criteria (Gelderman et al., 2017; Johnson & Klassen, 2022). The convergence between the digitalization of public procurement and the simplification of environmental criteria offers a promising avenue for overcoming traditional trade-offs between cost and sustainability (Lundberg & Marklund, 2018).

4.3. Formalization: the Institutional Negentropy Index (INI)

In order to synthesize the three empirical dimensions mobilized in Table 1 into a single measure, consistent with the three pillars of the GNED Model (section 5), we propose an ***Institutional Negentropy Index (INI)***.

Since each raw indicator is expressed on a different scale (score/100, percentile rank, growth rate), prior min-max normalization is necessary:

$X^*_i = (X_i - Xmin) / (Xmax - Xmin) \times 100$ (1)

where X^*_i denotes the normalised value of the indicator for country i, brought to a common scale of 0 to 100, Xmin and Xmax correspond to the extreme values observed in the comparison sample (EU-27).

The Institutional Negentropy Index is then expressed as follows:

$INI_i = w_1 \cdot DPS_i + w_2 \cdot GE_i + w_3 \cdot EII^*_i$, with $w_1 + w_2 + w_3 = 1$ (2)

Or :

- DPS*$_i$ — normalized score of digital public services (proxy of the Technological and Algorithmic Pillar);
- GE*$_i$ — normalized score of government efficiency and regulatory quality, average of the two WGI indicators (proxy of the Managerial and Human Pillar);
- EII*$_i$ — normalized score of the evolution of the eco-innovation index (proxy of the Eco-responsible Pillar);
- **w_1 , w_2, w_3** — weightings assigned to each pillar.

In the absence of empirical justification favoring one dimension, an equal weighting ($w_1 = w_2 = w_3 = 1/3$) is retained as the reference hypothesis; a sensitivity analysis could, in subsequent research, test alternative weightings from a panel of experts (Delphi or AHP method).

5. Negentropic Eco-Digital Governance (NDG) Model

To conceptualize this synergy between negentropy, institutional resilience, and digital transformation - already outlined in the integrated analytical framework of section 2.4 and empirically operationalized by the Institutional Negentropy Index (section 4.3) - we propose the Eco-Digital Negentropic Governance Model (EDNG). This model articulates three inseparable pillars, the combination of which transforms bureaucratic inertia into a capacity for systemic adaptation.

The first pillar, technological and algorithmic, corresponds to operational negentropy. It is based on the integration of Artificial Intelligence and data interoperability to streamline internal processes and reduce transaction costs (Gil-Garcia et al., 2016; Rădulescu et al., 2025; Wirtz et al., 2019), as well as on the adoption of responsible digitization solutions to limit the environmental impact of public IT infrastructures.

The second pillar, eco-responsible, aims for systemic sustainability. It assumes the systematic generalization of sustainability criteria in administrative procedures and public procurement (Gelderman et al., 2017; Massuga et al., 2024), as well as the alignment of administrative strategies with decarbonization and circular economy objectives (Bornemann & Christen, 2019; Rădulescu et al., 2020).

The third pillar, managerial and human, supports organizational resilience. It involves the development of digital and ecological skills of the State's human capital (Burlacu et al., 2023; Lodge & Wegrich, 2014), as well as the promotion of adaptive leadership capable of managing complexity, preventing the co-destruction of value and strengthening citizen trust (Mergel et al., 2026; Voß & Bornemann, 2011).

These three pillars do not operate in isolation: it is precisely their simultaneous articulation - technological, environmental and human — that distinguishes the GNED model from a simple juxtaposition of sectoral reforms, and that makes it an operational framework that can be transposed to other economies in transition in Central and Eastern Europe facing similar structural challenges.

6. Conclusion and recommendations

6.1. Conclusions

Faced with the overlapping of contemporary crises, public administration can no longer rely on rigid or reactive structures. The resilience and adaptability of public institutions depend on the implementation of a negentropic governance capable of addressing complexity.

This research demonstrates that the true transformation of the public sector stems from the convergence of intelligent digitalization (driven by AI) and eco-governance. The empirical results - summarized by the Institutional Negentropy Index (section 4.3) - confirm the two hypotheses formulated in the introduction: the strategic integration of AI is indeed a driver of negentropy, but its effect on institutional resilience remains contingent on the parallel development of managerial skills; otherwise, digitalization risks remaining a purely technical investment without real organizational

impact. By leveraging strategic investments such as those of the PNRR, the transition economies of Central and Eastern Europe have a historic opportunity to modernize their administrative structures and build sustainable resilience (Burlacu et al., 2024; Burlacu et al., 2025; Rădulescu et al., 2025).

6.2. Public policy recommendations

Three concrete directions emerge from these results. First, it is necessary to promote ethical and agile regulation of AI in the public sector by structuring a clear framework that ensures the transparency of administrative algorithms while allowing for regulatory experimentation (*sandboxes*) (Madan & Ashok, 2023; Wirtz et al., 2021). Second, the widespread use of digitized green public procurement criteria, via automated decision-support platforms, would facilitate the integration of environmental criteria into public contracts (Halonen, 2021; Ortega Carrasco et al., 2025). Finally, it is necessary to invest in continuing education and adaptive leadership, equipping public officials with cross-cutting skills in data management and ecological transition, in order to reduce organizational resistance to change (Burlacu et al., 2023; Mergel et al., 2019).

6.3. Limitations of the research and perspectives

This research has several limitations, each of which opens up avenues for future work. Methodologically, the approach relies exclusively on secondary data and document analysis; it does not draw on interviews or field surveys with practitioners in the Romanian public administration, thus limiting a nuanced understanding of the observed organizational resistance. In terms of formalization, the Institutional Negentropy Index proposed in section 4.3 is based on equal weightings between components, due to a lack of empirical justification favoring a particular dimension; a sensitivity analysis using Delphi or AHP methods would allow for testing alternative weightings. This limitation is compounded by a constraint on data availability: since the eco-innovation index is published only as a relative change (EU-27 base = 100 in 2014) and not as a comparable absolute score, the third pillar of the GNED model could not be integrated into the illustrative calculation of the index. Finally, the study focuses primarily on the Romanian case; while the identified dynamics are likely shared by other transition economies in Central and Eastern Europe, systematic comparative validation at the regional level remains necessary to confirm the generalizable scope of the GNED model.

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