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Interoperable Governance Under Conditions of Digital Transformation and Crisis Constraints

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ABSTRACT

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The article examines interoperability as a fundamental principle of public governance under conditions of digital transformation and crisis constraints. The deepening of European integration processes drives the relevance of the topic, the growing complexity of governance interactions, and the need to ensure institutional resilience of the state amid wartime and socio-economic challenges. The purpose of the study is to provide a theoretical substantiation of interoperable governance as an integral architecture of public authority coordination and to determine the prospects for developing an adaptive-combined model for Ukraine. The research employs systemic, institutional, and comparative approaches, as well as methods of conceptual analysis, structural-functional modeling, and content analysis of regulatory documents of the European Union and Ukraine. The multidimensional structure of interoperability is revealed, encompassing political, legal, organizational, semantic, and technical levels of interaction. National interoperability frameworks of EU countries are analyzed and typologized into centralized, decentralized, transitional, and point-to-point interaction models. It is substantiated that the choice of architectural model determines the parameters of institutional resilience, governability, and resource efficiency. The current state of interoperability development in Ukraine is assessed, particularly in the fields of digital services, healthcare, and public finance, and the regulatory preconditions for its institutionalization are examined. An adaptive-combined model of interoperable governance is proposed, combining a centralized coordination contour with decentralized management of sectoral registries. The conclusions demonstrate that interoperability functions not merely as a technological instrument but as a strategic principle of organizing public authority, capable of enhancing policy coherence, reducing governance losses, and strengthening state resilience under conditions of crisis complexity. Further research should focus on developing methodologies for assessing interoperability as an indicator of governance quality and institutional maturity of public authorities.



KEYWORDS

interoperability, interoperable governance, digital transformation, institutional resilience, crisis constraints, adaptive-combined model.



Інтероперабельне врядування в умовах цифрової трансформації та кризових обмежень

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У статті досліджено інтероперабельність як засадничий принцип публічного врядування в умовах цифрової трансформації та кризових обмежень. Актуальність теми зумовлена поглибленням євроінтеграційних процесів, зростанням складності управлінських взаємодій і необхідністю забезпечення інституційної стійкості держави в умовах воєнних та соціально-економічних викликів. Метою дослідження є теоретичне обґрунтування інтероперабельного врядування як цілісної архітектури координації публічної влади та визначення перспектив формування адаптивно-комбінованої моделі для України. У роботі використано системний, інституційний і порівняльний підходи, методи концептуального аналізу, структурно-функціонального моделювання та контент-аналізу нормативних документів Європейського Союзу й України. Розкрито багатовимірну структуру інтероперабельності, що охоплює політичний, правовий, організаційний, семантичний і технічний рівні взаємодії. Проаналізовано національні рамки інтероперабельності країн ЄС та здійснено їх типологізацію за централізованою, децентралізованою, перехідною та моделлю взаємодії типу точка-точка. Обґрунтовано, що вибір архітектурної моделі визначає параметри інституційної стійкості, керованості та ресурсної ефективності. Оцінено сучасний стан розвитку інтероперабельності в Україні, зокрема у сфері цифрових послуг, охорони здоров'я та публічних фінансів, а також проаналізовано нормативні передумови її інституціоналізації. Запропоновано адаптивно-комбіновану модель інтероперабельного врядування, що поєднує централізований координаційний контур із децентралізованим управлінням галузевими реєстрами. У висновках доведено, що інтероперабельність виступає не технологічним інструментом, а стратегічним принципом організації публічної влади, здатним підвищити узгодженість політик, зменшити управлінські втрати та посилити стійкість держави в умовах кризової складності. Подальші дослідження доцільно спрямувати на розроблення методик оцінювання інтероперабельності як показника управлінської якості та інституційної зрілості органів публічної влади.



КЛЮЧОВІ СЛОВА

інтероперабельність, інтероперабельне врядування, цифрова трансформація, інституційна стійкість, кризові обмеження, адаптивно-комбінована модель.

1. Introduction

The contemporary evolution of public governance unfolds amid profound transformations driven by digitalization, the growing complexity of socio-economic processes, the acceleration of political cycles, and the spread of multidimensional crises. Under these circumstances, traditional administrative arrangements based on rigid hierarchy and departmental closure increasingly reveal their limitations in ensuring policy coherence and the consistency of managerial decisions. Governance is acquiring features of networked interaction, continuous coordination, data exchange, and the synchronization of actions among diverse public authorities, which necessitates a reconsideration of the fundamental principles of state organization. In this context, interoperability emerges as a systemic attribute of public governance that determines the state's capacity to secure institutional interaction, procedural compatibility, and the integration of political and administrative processes. Its meaning extends beyond the technical compatibility of information systems to include the alignment of legal, organizational, semantic, and technological components within a unified architecture of public authority, reflecting a transformation of managerial rationality and the emergence of a cooperative governance model grounded in shared standards, open data, and distributed responsibility.

In this regard, the experience of the European Union is particularly illustrative, as interoperability has acquired the status of an element of regulatory policy and an institutional principle of governance organization, especially amid intensifying crisis challenges related to the COVID-19 pandemic, energy instability, migration processes, and security threats. The adoption of Regulation (EU) 2024/903, known as the Interoperable Europe Act, demonstrated a systemic response to these challenges and marked a shift from fragmented digital initiatives toward the establishment of a common framework encompassing technical, legal, organizational, and semantic dimensions of interaction among public authorities [11]. Within this model, interoperability is understood as a prerequisite for the functioning of the Digital Single Market, the development of cross-border public services, and the provision of integrated governance within a multilevel system capable of maintaining policy coherence even under conditions of high uncertainty. Such an approach illustrates the potential for institutionalizing interoperability as a foundational principle of public administration in a crisis environment and provides an analytical basis for understanding its role in strengthening the resilience of public governance systems in countries undergoing profound transformations.

2. Literature Review

Within the European academic discourse, interoperability has long been conceptualized as a systemic characteristic of public governance that determines the degree of institutional integration and the coherence of interaction procedures within a multilevel structure of authority. Research by M. Janssen et al. [15] convincingly demonstrates that the integration of governmental data extends beyond purely technical solutions and requires the development of mechanisms for institutional coordination, regulatory alignment, and semantic compatibility [15, p. 261]. The works of T. Pardo et al. [20] emphasize the interdependence of the political, organizational, and technological dimensions of interoperability, which collectively shape a comprehensive ecosystem of digital governance [20, p. 12]. H. Scholl and R. Klischewski [22] interpret interoperability as a strategic prerequisite for the transition to integrated governance capable of ensuring the synchronization of processes, information flows, and responsibilities across different levels and actors of public authority [22, p. 903]. Thus, even before the formal regulatory consolidation of relevant frameworks, European scholarly thought had already established a theoretical foundation for understanding interoperability as a new model of governance associated with a reconsideration of the logic of state functioning in the context of digital transformation.

The European approach to interoperability has evolved as a conceptually and empirically grounded model of governance in which interoperability is interpreted not as mere technical compatibility of systems, but as a comprehensive characteristic of public authority that integrates technological, organizational, and political dimensions. Empirical studies of national interoperability frameworks in EU Member States demonstrate a positive correlation between their institutional implementation and the level of citizens' use of digital public services, thereby confirming the systemic impact of harmonized standards, coordination mechanisms, and semantic compatibility on the quality

of governance [3]. The 2024 analytical report of the European Commission and the Joint Research Centre is devoted to monitoring the implementation of interoperability frameworks across EU Member States and provides a comparative assessment of their institutional capacity, the level of data integration, and the degree of coordination among sectors of public administration, with particular emphasis on practical indicators of administrative digital maturity [8]. The 2025 publication of the European Commission in the format of Digital Public Administration Factsheets systematizes national profiles of digital governance, analyzes the state of cross-border interaction, the use of common standards, and the development of civil servants' competences, demonstrating the interconnection between the institutionalization of interoperability and the quality of public service delivery [10].

Contemporary research on digital transformation further demonstrates that data interoperability functions as a managerial resource that ensures the integrity of digital services, supports strategic planning, and contributes to enhancing transparency and performance in public administration [5]. Taken together, these approaches shape an understanding of interoperability as an institutional architecture of integrated governance capable of ensuring the continuity of administrative processes, reducing transaction costs, and strengthening trust in public decisions under conditions of digital and crisis-driven complexity.

Within the Ukrainian academic discourse, the issue of interoperable governance has long developed primarily in an applied and sectoral dimension, focusing on the technical aspects of information system compatibility, data standardization, and the integration of software and hardware solutions. In the study by A. Osmak et al. [18], interoperability is examined in the context of e-government functioning and the informational interaction of public authorities, with emphasis on the necessity of establishing unified approaches to the architecture of state information resources. The authors stress that without harmonized data exchange standards and clear regulatory frameworks for digital interaction, it is impossible to ensure the effectiveness of managerial decisions, as the fragmentation of the information environment leads to a decline in the controllability of the public administration system. At the same time, interoperability in this study is interpreted primarily as a tool for optimizing administrative procedures and enhancing the transparency of electronic services [18, p. 8].

In the article by N. Filipova et al. [13], the emphasis shifts toward a strategic interpretation of the state's digital transformation, where interoperability is presented as a necessary condition for the formation of an integrated ecosystem of public services. The authors highlight the importance of combining the technical compatibility of information systems with organizational and regulatory coordination, which makes it possible to create a coherent environment of interaction among public authorities, business entities, and citizens. Particular attention is devoted to the role of national digital platforms and registers as foundational elements of the interaction infrastructure, as well as to the need for harmonizing Ukrainian approaches with European standards [13, p. 15]. The works of Ukrainian scholars thus demonstrate a gradual transition from a purely technical and informational understanding of interoperability toward its recognition as an institutional principle of public administration modernization, although the paradigmatic dimension of this category remains insufficiently conceptualized.

3. Problem Statement

Despite the substantial body of research devoted to the technical, organizational, and regulatory aspects of interoperability, a gap persists in contemporary scholarship between its applied interpretation and its paradigmatic understanding within the system of public administration. Most studies focus on specific sectors or instruments of digital integration, whereas the consideration of interoperability as a system-forming principle of state activity under conditions of digital transformation and crisis complexity remains insufficiently conceptualized. In the Ukrainian context, this issue is further intensified by the simultaneous need for European integration adaptation, the modernization of the civil service, and the safeguarding of institutional resilience amid wartime and socio-economic challenges. In this regard, a key scholarly task emerges: to substantiate interoperability as a new paradigm of public administration, to define its structural dimensions and institutional

mechanisms of implementation, and to clarify its role in shaping an adaptive and coherent model of state governance.

The purpose of this article is to provide a theoretical substantiation of interoperability as a paradigm of public administration in the context of digital transformation and crisis-driven complexity, as well as to determine its institutional potential for enhancing the resilience and coherence of state governance. Achieving this objective requires reconsidering interoperability not as a purely technological instrument, but as a systemic principle of organizing public authority that influences the architecture of administrative processes, the nature of interagency interaction, and the logic of policy formation.

In accordance with the stated objective, the following tasks are defined: to conduct a conceptual analysis of approaches to understanding interoperability within European and Ukrainian academic discourse; to delineate the structural dimensions of interoperability as a multilevel characteristic of public administration; to analyze the institutional mechanisms of its regulatory consolidation and practical implementation; to determine the role of interoperability in shaping an integrated governance model under conditions of digitalization and crisis challenges; and to substantiate the directions for implementing the principles of interoperability in the Ukrainian system of public administration, taking into account European integration imperatives.

4. Methods and Materials

The methodological foundation of the study is based on a combination of systemic, institutional, and comparative approaches, which makes it possible to consider interoperability as a comprehensive characteristic of public administration under conditions of digital transformation and crisis complexity. The research employs methods of theoretical generalization and conceptual analysis to clarify the content of the category of interoperability and its paradigmatic dimension; comparative analysis to contrast European and Ukrainian practices of regulatory institutionalization; structural-functional analysis to identify the interrelations among technical, legal, organizational, and semantic components; as well as elements of content analysis of normative acts and analytical materials of the European Union and Ukraine to determine trends in the development of interoperable governance. The application of these methods ensures a comprehensive understanding of interoperability as an institutional resource for the modernization of public administration.

5. Results and Discussion

The European model of interoperability is grounded in a multidimensional approach that encompasses the technical dimension of standardized data exchange, the semantic level of aligning concepts and information structures, the organizational coordination of procedures and responsibilities among institutions, and the legal provision of regulatory compatibility and the protection of citizens' rights in the process of information interaction. The interaction of these components ensures the formation of integrated governance within which the state operates as a coherent system capable of maintaining policy consistency and the continuity of administrative processes.

An analysis of the institutional and architectural models implemented in the United Kingdom and the countries of the European Union demonstrates that such coherence is achieved not so much through isolated technological solutions as through a coordinated digitalization policy, stable administrative and legal support, and the alignment of infrastructural projects. Information technologies perform an instrumental function, whereas the level of effectiveness is determined by organizational and political factors, among which strategic coherence, the continuity of managerial decisions, and a clear distribution of responsibilities among public authorities are of particular importance. In this regard, the European Interoperability Framework serves as a normative and methodological framework that institutionalizes a multilevel approach and establishes a unified logic for the integration of systems and business processes at the political, legal, organizational, semantic, and technical levels.

The practical implementation of this logic is reflected in the national interoperability frameworks of European Union Member States, as well as in the British model of digital governance, which integrates open API standards, cloud architecture, and principles of data interoperability through the Government Digital Service. Their comparative analysis makes it possible to distinguish centralized, decentralized, transitional, and point-to-point interaction models as the basic options for organizing secure data

exchange (Table 1). The choice of architectural model determines the balance between manageability, autonomy, security, and resource efficiency, and thus functions as a strategic factor of institutional resilience. For states with a transformation economy, the most appropriate solutions are combined models that integrate centralized coordination mechanisms with distributed responsibility for data, which is of direct relevance for shaping the Ukrainian model of interoperable governance.

Table 1. Models for the Implementation of Interoperable Governance in the United Kingdom and EU Member States

Model of data exchange organization	Countries (current institutional mechanisms for model implementation)	Managerial logic of the model
Centralized	United Kingdom [23], France [21]	Provides for the existence of a centralized coordination framework that establishes mandatory standards, architectural principles, and rules for the integration of information systems. In the United Kingdom, the model is implemented through a system of compulsory digital standards and oversight by the Government Digital Service, while in France, it operates through the legally established RGI framework. Such an approach ensures a high level of manageability, architectural coherence, and security control; however, it requires substantial resources and clearly defined institutional responsibility.
Decentralized	Estonia [7], Germany [12], Switzerland [6]	Is based on automated data exchange between information systems without a permanent central operator. The state defines common technical and semantic standards, while each public authority retains autonomy in maintaining its own registers. The Estonian X-Road model serves as an example of a stable decentralized infrastructure. Its advantages include scalability and resilience to disruptions; however, the model requires a high level of interagency coordination.
Transitional (hybrid)	Belgium [1], Denmark [4]	Combines the centralized establishment of standards with the distributed management of registers. Central bodies develop service catalogs, architectural requirements, and rules of interaction, while responsibility for data remains with sectoral entities. This approach enables the gradual integration of systems without full centralization, ensuring flexibility and adaptability of the digital architecture.
Point-to-point interaction	Netherlands [14]	Provides for integration through open standards, APIs, and service interfaces without rigid centralized control over data exchange. Public authorities establish standardized access points to their own information resources and interact directly with one another. The model ensures autonomy and flexibility; however, it requires additional mechanisms for strategic coordination and the harmonization of standards.

Source: Author's development based on [1; 4; 6; 7; 12; 14; 21; 23].

The presented typology demonstrates that the architecture of interoperability in European Union Member States is not shaped according to a single template, but rather in accordance with the institutional structure of the state, the traditions of public administration, and the level of digital maturity. At the same time, all models are united by their orientation toward ensuring managed information interaction, within which data standardization, procedural coherence, and mechanisms of accountability are combined. This indicates that interoperability functions not as a technical attribute of individual information systems, but as an element of the strategic design of administrative architecture, where the choice of model determines the parameters of institutional resilience, the level of coordination among public authorities, and the state's capacity to adapt to complex and crisis-driven conditions of development.

For Ukraine, the concept of interoperability has a dual dimension of significance. On the one hand, it is linked to the European integration vector of development, as harmonization with European digital standards and regulatory approaches constitutes an integral part of the process of approximation to the EU acquis. On the other hand, interoperability represents an internal systemic necessity for a state

operating under conditions of prolonged multidimensional transformation and crisis-driven complexity. Institutional reforms in the areas of decentralization, healthcare, civil service, and public finance have led to a redistribution of powers, financial flows, and governance procedures, thereby increasing the requirements for coordination and data coherence. The COVID crisis highlighted the need for effective cross-sectoral coordination and rapid information exchange between national and local authorities. The full-scale war has further exacerbated the problem of institutional fragmentation and resource scarcity, intensifying the demand for integrated governance mechanisms. In such a context, interoperability emerges as a prerequisite for ensuring the integrity of state action, minimizing managerial losses, and maintaining the functional resilience of public administration.

Ukrainian practice demonstrates the presence of applied elements of interoperable governance. The digital ecosystem Diia functions as an integrated interface providing citizens with access to public services, while the interaction of numerous registers is ensured through the Trembita electronic data exchange system, which implements the principle of information reuse. A sectoral example of integration is represented by the activities of the National Health Service of Ukraine, within which the eHealth electronic system connects medical information systems of healthcare providers with a centralized database and financial mechanisms for the payment of medical services. In this case, interoperability ensures the alignment of clinical and financial processes within a unified financing model.

In the sphere of public finance, partial interoperability is implemented through the informational interaction of the State Treasury Service of Ukraine, the State Tax Service of Ukraine, and the National Bank of Ukraine, thereby creating a technical foundation for the coordination of budget revenues and payments. The ProZorro electronic procurement system represents an example of semantic and procedural coherence achieved through data standardization, information transparency, and the integration of market participants within a unified digital environment.

Ukrainian practice demonstrates not only the presence of applied digital solutions but also the gradual formation of a regulatory and legal foundation for interoperability across various sectors of public administration. The adoption of the Resolution of the Verkhovna Rada of Ukraine dated 17 December 2025, No. 4724-IX, concerning the draft law on railway transport safety and interoperability indicates an attempt to transpose European approaches to technical and procedural compatibility into the sphere of transport infrastructure [24]. The Order of the Cabinet of Ministers of Ukraine dated 13 August 2025 No. 854-r, approving the action plan for enhancing the interoperability of information systems, confirms the interagency nature of this process and recognizes interoperability as a distinct direction of state digital transformation policy [2]. Sectoral technical requirements, particularly in the fields of automated fare collection systems and geospatial data, establish a regulatory basis for the technical and semantic compatibility of information resources [16].

The implementation of European regulations in the field of electronic identification [17] and the harmonization of electronic signature standards indicate the gradual approximation of Ukraine's digital infrastructure to the requirements of the EU Digital Single Market [9]. At the same time, the current regulatory framework largely concentrates on technical parameters of compatibility and individual sectoral solutions, without ensuring the comprehensive consolidation of interoperability as a universal principle of organizing public authority. The existing legal and institutional developments form an important foundation; however, their potential can be fully realized only under conditions of strategic alignment, the integration of cross-sectoral approaches, and the formal recognition of interoperability as a systemic basis for interagency coordination and managerial resilience. In this context, particular importance is attached to the development of a system for assessing the capacity of public administration bodies for integrated interaction. The approach proposed by T. Pakhomova et al. [19] substantiates the formation of a comprehensive evaluation system for public authorities based on the combination of performance-related, organizational, and communicative parameters [19, p. 5]. Expanding such a model by incorporating indicators of semantic compatibility, the level of interagency integration, and data reuse makes it possible to consider interoperability as a dimension of managerial quality and institutional maturity.

The further development of interoperability in Ukraine requires a transition from a set of technical and sectoral solutions to a coherent architecture of managerial interaction. First and foremost, it is necessary to establish interoperability as a mandatory principle of public administration through regulatory consolidation, with clearly defined common definitions, basic data exchange standards, responsible entities, and coordination procedures. The semantic level requires strengthening through

the unification of classifiers, registers, data models, and metadata, without which technical integration cannot ensure full policy coherence. An important task is the creation of a centralized catalog of state information resources and services with a clear delineation of data ownership and access regulations. Particular attention should also be devoted to the formation of mechanisms for crisis management of information flows, including infrastructure redundancy, standardized protocols for operational exchange, and auditing of data access during states of emergency.

Given the institutional structure of Ukraine and the conditions of wartime and post-war transformation, an adaptive combined model appears to be the most appropriate, integrating a centralized regulatory and coordination framework with decentralized management of sectoral registers and services. Such a model makes it possible to ensure uniform rules, security, and strategic coherence at the national level, while preserving flexibility and sectoral autonomy. The integration infrastructure should be based on standardized interfaces, service catalogs, and interagency interaction mechanisms that can be scaled according to emerging needs and risks. It is precisely this combined approach that can establish a balance between manageability and system resilience, which is critically important for a state with a transformational economy and a high level of external and internal challenges.

6. Conclusions

In contemporary conditions, interoperability emerges not as an auxiliary instrument of digitalization but as a system-forming principle of public administration that ensures institutional integration, policy coherence, and the resilience of administrative processes within an environment of crisis-driven complexity. European experience demonstrates that the effectiveness of interoperable governance is determined by the combination of regulatory consolidation of a multilevel interaction architecture, strategic coordination of digital policy, and institutional responsibility for data and procedural compatibility. In the Ukrainian context, several applied and regulatory preconditions for the development of interoperability have already been established; however, they remain largely sectoral in nature and require integration into a unified governance logic. The substantiation of an adaptive combined model that integrates a centralized regulatory and coordination framework with decentralized management of registers and services makes it possible to consider interoperability as an institutional resource for state modernization and the strengthening of its crisis resilience. The transition to such a model presupposes the regulatory consolidation of the interoperability principle, the unification of semantic standards, the creation of a system of strategic data architecture management, and the introduction of mechanisms for assessing its maturity. As a result, interoperability may become the foundation for the formation of a coherent, adaptive, and coordinated model of public administration capable of ensuring the effective functioning of the state under conditions of digital transformation and prolonged crisis challenges.

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