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Information and Analytical Support of Tax Control in the Context of Digitalization of the Fiscal System

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Abstract: The research objective is to formalize the cognitive stratified framework of digital fiscal control through the unification of information and analytical tools based on decomposition, topological analysis, and Unified Modelling Language (UML). The study employed the following methods: SWOT analysis of solutions for the digitalization of fiscal tax control systems, decomposition and range analysis of digitalization technologies, topological analysis of digital information and analytical tools, and UML modelling of the framework for the digitalization of fiscal tax control systems. The developed framework is presented as a conceptual and architectural design structure that integrates artificial intelligence (AI)/machine learning (ML) risk stratification, Distributed Ledger Technology (DLT) traceability, autonomous compliance, and P2P interoperability to outline architectural integrity and procedural resilience as intended design properties rather than empirically demonstrated effects. SWOT, decomposition and range analysis, as well as topological analysis supported the identification of a unitary routing logic for risk, compliance, and verification flows that may contribute to fiscal transparency and evasion risk mitigation under subsequent pilot testing. The academic novelty is associated with the systemic identification, decomposition, structured organization, and topological mapping of information-analytical tools of fiscal control, which enabled the formal representation of a cognitively stratified architectural and functional topology of a digital fiscal control framework using UML modelling.

Index Terms: Taxes, AI-driven Risk Stratification, Distributed Ledger Technologies (DLT), Autonomous Compliance Systems, e-Invoicing Platforms, High-Frequency Audit Engines.

1. Introduction

The rapid digital transformation of fiscal systems raises the issue of integrating cognitive analytical tools into tax control mechanisms aimed at ensuring financial resilience and minimizing evasion risks [1]. Improving the information and analytical support of fiscal administration requires a synthesis of Big Data analytics methods, systematic verification of business processes, and cognitive compliance tools [2,3]

The aim of the research is to formalize a cognitive-stratified framework for the digitalization of fiscal tax control systems by identifying, structuring, and unifying information and analytical tools based on decomposition, topological analysis, and UML modelling. The framework is considered a conceptual-architectural construct intended to organize risk, verification, traceability, and compliance modules; its operational performance requires further empirical testing in real or simulated fiscal environments.

1.1. Research objectives

– Conduct a SWOT analysis of solutions for the digitalization of fiscal tax control systems to identify strengths and weaknesses, opportunities, and threats in the context of fiscal resilience.

– Perform a decomposition and range analysis of digital technologies in order to structure and form a unitary range of information and analytical tools for fiscal control.

– Perform a topological analysis of digital information and analytical tools to build an integration architectural topology of a cognitive stratified framework.

Implement UML modelling of the framework for the digitalization of fiscal tax control systems to formalize the conceptual and component structure and visualize information flows and procedural consistency.

2. Literature Review

In the context of the transformation of fiscal administration, the digitalization of tax control appears as a key vector for the functional rethinking of its analytical infrastructure. The expansion of digital capabilities is accompanied by the integration of intelligent data processing tools, automated verification systems and unified communication protocols, which necessitates a comprehensive rethinking of information and analytical support models. In this context, the issue of academic appropriateness of systematizing modern empirical work on the effectiveness of digital interventions in the tax sphere arises.

According to the focus of the research, the priority should be to focus on the strategic potential of high-level digitalization of tax frameworks, as substantiated by Dallhammer and Renelt [4]. They proved that the integration of high-level digitalization of TCF (automated auditing, cognitive analytics, AI modules) positively correlates with the perceptual quality of the framework and the level of aggressiveness of tax planning. The net benefit effect is driven by technological intensity, not the underlying IT infrastructure.

In support of this thesis, Ariani et al. [5] found that digital transformation of tax interaction (e-Filing, e-Billing), institutionalization of cybersecurity and regulatory deregulation significantly increase the level of tax compliance of individuals. The effect is determined by the increase in procedural transparency, service availability, and regulatory trust.

From the perspective of the regulatory impact of digitalization, Zhao and Wang [6] uniformly applied a quasi-natural experiment and a multi-point DID model, showing that the digitalization of tax administration significantly reduces profit management by reducing information opacity and tax evasion. The inhibitory effect is enhanced under high financial constraints and varies by enterprise typology.

In the context of fiscal transparency, Costa et al. [7] proved that institutionalized digitalization of the tax service (electronic invoicing, transaction validation, cross-system aggregation of financial data) intensifies fiscal transparency, increases compliance, and reduces the risks of fraud models. At the same time, there are still barriers to digital inclusion: cognitive resistance of customers, complexity of system architecture, and threats to cyber privacy. In the context of ensuring accounting reliability, Wu and Li [8] proved that institutionalized implementation of Golden Tax III as a digital fiscal regulator increases accounting information quality by strengthening endogenous controlling and exogenous audit supervision. The effect is determined by the structural ownership of the enterprise and affiliation with the Big Four, activating transparency and tax compliance.

Regarding the reduction of the shadow economy, Murodovich and Zafar [9] found that the implementation of digital fiscal tools (online PPO, e-invoicing, personalized tax offices) provides information and analytical transparency, reduces the level of the shadow economy, and increases fiscal mobilization. The use of cashback mechanisms activates behavioural tax engagement and strengthens the revenue-generating potential of the budget. Regarding macroeconomic effects, Fadipe et al. [10] empirically confirmed that the digitalization of tax administration positively correlated with sustainable development indicators – HDI and GDP – through increasing the efficiency of fiscal mobilization. Regression analysis showed a statistically significant impact of digital infrastructure on macroeconomic resilience.

As for indirect tax instrumental support, Ramkumar and Srinivasan [11] demonstrated that the implementation of analytical tools (EDA, anomaly detection, clustering) in the field of indirect tax administration provides increased procedural efficiency, transactional controlling, and fiscal fraud indication. The results of factor analysis confirmed the three-component model of analytical fiscalization in the context of digital transformation.

In the context of administrative institutionalization, Uygun [12] found that institutionalized e-Government infrastructure and the implementation of information and communication technologies (ICT) in tax inspection procedures increase the intensity of audit activities, procedural efficiency, transactional accuracy, and the level of voluntary compliance. The expansion of Public-to-Public Data Sharing reduces fiscal transaction costs and enhances regulatory transparency.

Concluding the review, it is appropriate to turn to a multi-innovation approach, where Iqbal et al. [13] found that the implementation of AI-driven risk analytics, immutable blockchain registries, and autonomous compliance automation increases cognitive detection of fiscal anomalies, guarantees transactional traceability, and provides continuous reporting update. The effectiveness of institutional diffusion of innovations is determined by regulatory specifics, cybersecurity protocols and polycentric stakeholder integration.

The analysis of the literature showed that the digital transformation of tax administration – through the implementation of AI modules, analytical systems, e-Government infrastructures, blockchain registries and automated controlling tools – increases accounting reliability, compliance, anti-corruption resistance, and macroeconomic stability. It was found that the effects of digitalization depend on the level of technological intensity, organizational structure, taxpayer typology, and regulatory specifics. These findings justify the need for targeted research into the information and analytical support of tax control, taking into account the variability of digital tools, their cognitive complexity, institutional integration, and regulatory interoperability.

3. Methods and Models

3.1. Research design

The sequence of the study is presented in a convenient graphical representation (Figure 1).

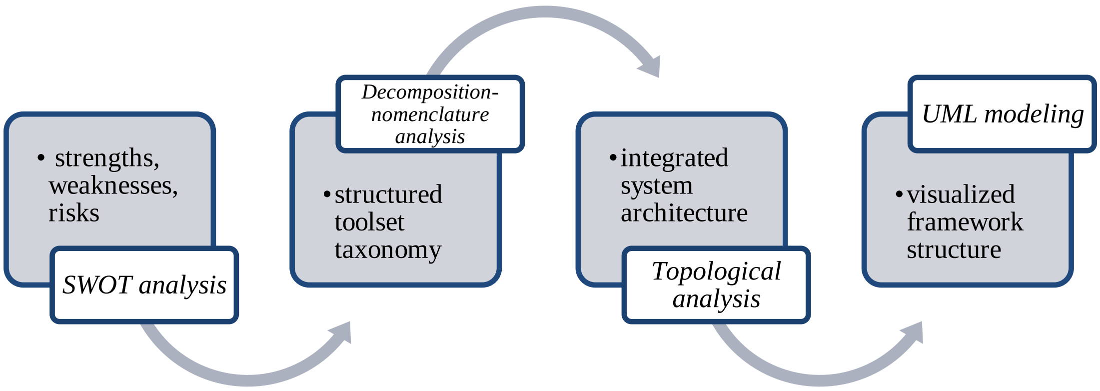

Fig. 1. Research stages.
Source: developed by the authors

3.2. Methods

The methodological framework of the study was developed as a structured and concept-oriented approach focused on the systematization, integration, and formal representation of digital fiscal control instruments. The selected methods were used to organize and formalize the architecture of the proposed framework, rather than to establish empirical superiority, scalability, or operational effectiveness.

1. SWOT analysis of solutions for the digitalization of fiscal tax control systems was applied to identify strengths, limitations, external opportunities, and potential risks of digital technologies in the context of fiscal resilience and procedural adaptability.

2. *Decomposition and range analysis of technologies for the digitalization of fiscal tax control systems* enabled the structural-functional disaggregation of digital technologies and the organization of their information-analytical tools into a coherent nomenclature.

3. *Topological analysis of digital information and analytical tools of fiscal tax control systems* facilitated the mapping of integration relationships among the identified tools, contributing to the construction of a cognitively stratified architectural topology of fiscal control processes.

4. *UML modelling of the framework for digitization of fiscal tax control systems* was employed to formalize the conceptual and component-level structure of the framework, ensuring visualization of information flows, module interactions, and procedural coherence across risk stratification, traceability, and compliance mechanisms.

Taken together, these methods provided a consistent analytical basis for structuring, integrating, and formally representing the proposed framework, while outlining its functional logic and architectural consistency without treating these design properties as empirically validated performance outcomes.

3.3. Sample

In the context of fiscal administration transformation, the analytical selection of digitally implemented technologies integrated into tax control systems is of key importance. The presented sample (Table 1) does not represent an empirical or statistically derived sample, but rather a purposively constructed analytical set of cases aimed at supporting the architectural synthesis of the proposed framework. The selection followed explicit inclusion criteria: (i) documented real-world implementation at the national or institutional level (OECD, IMF, World Bank, or official governmental reports), (ii) technological maturity and operational deployment, (iii) functional relevance to key modules of digital fiscal control (risk stratification, verification, compliance, interoperability, traceability), and (iv) representativeness across different jurisdictions and system architectures.

The selection procedure was based on structured cross-source screening and comparative analysis of publicly available cases, ensuring consistency of functional attributes rather than statistical representativeness. Accordingly, the sample should be interpreted as an analytical benchmark set used to identify, classify, and systematize core digital technologies and their information-analytical tools within the framework design. This approach supports the decomposition, topological mapping, and UML-based formalization stages, but does not imply reproducibility in a statistical sampling sense.

Table 1. Verified digital technologies implemented into fiscal tax control systems.

Name of digital technology	Brief description	Purpose of application	Verified examples of application	Academic research
AI-driven Risk Analytics	ML algorithms for detecting fiscal anomalies and predicting evasion	Automated screening, risk stratification, tax profile scoring	Estonia, 2020 – implemented in Tax and Customs Board; average number of manual checks reduced by 32% (OECD FTA 2020; Tax and Customs Board reports)	Adegbayibi and Ajape [14]; Sajid et al. [15]
Blockchain-based Audit Trails	Immutable cryptographically protected transaction logs available for verification by authorities	Account traceability, anti-corruption validation, automated audit	China, 2021 – Shenzhen Tax Office; VAT verification time reduced by 47% (PwC, OECD reports)	Larikaman et al. [16]; Liu [17]
e-Invoicing Platforms	Systems for electronic generation and circulation of standardized tax invoices	Eliminating fictitious VAT, increasing transaction reliability	Portugal, 2019 – e-Fatura; VAT gap reduced by 3.8 pps over two years (European Commission VAT Reports)	Kotsogiannis et al. [18]; Falah Alroud [19]
Autonomous Compliance Systems	Built-in self-reporting and self-control modules integrated into payers' ERPs	Automated reporting compliance, continuous tax data update	Singapore, 2021 – IRAS Smart Compliance; timely reporting increased by 26% (IRAS.gov.sg, OECD Singapore Profile)	Hussain [20]; Shah [21]
Public-to-Public Data Sharing (P2PDS)	Interdepartmental integration of tax, social, and banking registers	Multi-source verification, elimination of declaration discrepancies	Turkey, 2020 – Public Apps Center; double identification reduced by 41% (Digital Turkey Roadmap)	Almalı and Yıldırım [22]; Demirkıran [23]
Golden Tax III System	A single national platform for digital tax control and accounting in real time	Centralized inspection, control of reporting consistency, fight against transfer pricing	China, 2019 – State Taxation Administration; accounting accuracy increased by 34% (World Bank, IMF Tax Notes China 2020)	Xu et al. [24]; Su [25]
Cashback Monitoring Mechanisms	Electronic system for incentivizing buyers through cashback on official transactions	Determining the transparency of calculations, motivation for fiscal involvement	Uzbekistan, 2021 – Tax Service; the volume of non-cash transactions increased by 18% (uza.uz, minfin.uz)	Tohir o'g [26]; Nodirsho o'g'li [27]
Exploratory Data Analysis (EDA)	Statistical analytics for inductive pattern and risk detection	Building indicative models, risk assessment, operational interpretation of fiscal data	India, 2022 – GSTN Analytics Portal; over 12,000 suspicious transactions detected in first year (GST Council 2022, Indian Ministry of Finance)	Cheng et al. [28]; Kate et al. [29]
e-Filing and e-Billing Systems	Unified online reporting and payment services	Simplifying procedures, reducing transactional burden, increasing accessibility	Indonesia, 2020 – DJP Online; taxpayer coverage increased from 63% to 81% in two years (DJP reports, IMF e-Taxation case study)	Yanto and Girindratama [30]; Meilandri [31]

Name of digital technology	Brief description	Purpose of application	Verified examples of application	Academic research
High-Frequency Audit Engines (AI NTS / Robot Tax)	Real-time audit systems using AI for continuous scanning	Dynamic identification of violations, preventive action, automated risk escalation	South Korea, 2021 – National Tax Service AI System; risk response time reduced by 3.5 times (OECD FTA Korea Profile, NTS Annual Report 2022)	Win [32]; Oberson [33]

Source: developed by the authors

3.4. Instruments

The study used coding in the UML environment to formalize the conceptual, component, behavioural, and infrastructure architecture of the digital fiscal control framework. UML modelling tools were used to implement structural and functional visualization of cognitive risk stratification, DLT traceability, P2P interoperability, and compliance modules in the form of integrated Sequence, Component, Activity, and Deployment diagrams; these diagrams represent design logic rather than tested system performance.

4. Results

In view of the digital transformation of the fiscal system, a key task is the structured identification of digital tax control solutions, taking into account their functional-analytical roles, institutional integrability, and regulatory-risk sensitivity. SWOT analysis (Table 2) was applied as a structured comparative-analytical procedure to classify technologies based on consistently observed attributes across documented implementations (OECD, IMF, World Bank reports) and peer-reviewed studies.

The identification of strengths, weaknesses, opportunities, and threats was operationalized through predefined analytical criteria: (i) functional performance (e.g., scalability, analytical capacity, automation level), (ii) integration capability (interoperability with ERP/CRM, cross-agency compatibility), (iii) implementation constraints (data quality dependency, infrastructure requirements), and (iv) regulatory-risk exposure (compliance complexity, cybersecurity, jurisdictional limitations). Each attribute was derived through cross-case comparison and triangulation of multiple sources, ensuring that assigned characteristics reflect recurrent patterns rather than isolated observations.

Table 2. SWOT analysis of solutions for the digitalization of fiscal tax control systems.

Digital Technology	S (Strengths)	W (Weaknesses)	O (Opportunities)	T (Threats)
AI-driven Risk Analytics	High accuracy of risk stratification; reduction of manual checks; cognitive load of AI	Dependence on data quality; difficulty in interpreting models; risks of bias	Integration with ERP and CRM; scalability at the national level	Regulatory uncertainty regarding explainable AI; cyber threats
Blockchain-based Audit Trails	Irreversibility of records; full traceability; increased trust in the system	High energy and technical costs; limited adaptability in hybrid architectures	Use in VAT control and transfer pricing	Legal inconsistency in cross-border jurisdictions
e-Invoicing Platforms	Standardization of documentation; automated VAT control; reduction of the human factor	Dependence on payers' technical literacy; need for national coverage	Integration with POS and banking APIs; expansion to the SME sector	Small business resistance; threats of digital signature forgery
Autonomous Compliance Systems	Self-adaptability; continuous updating; integration into business processes	High complexity of setup; initial implementation costs	Deployment in multinational corporations	Distrust of autonomous systems in environments with low digital culture
Public-to-Public Data Sharing (P2PDS)	Multi-source verification; reduction of data fragmentation	Problems with registry compatibility; risks of duplication/discrepancies	Horizontal integration with social insurance systems	Threats of personal data leakage; imperfect data governance
Golden Tax III System	Centralized control; integration of B2B transactions; real-time	High complexity of updating; criticality to the stability of communication channels	Export of the framework to countries with centralized models	Provider monopolization; risks of technical vulnerability
Cashback Monitoring Mechanisms	Behavioural stimulation; improved non-cash discipline	Administrative complexity of reimbursement; need for mass coverage	Implementation in fiscal patriotism programmes	Operation simulation fraud; distortion of fiscal stimulus
Exploratory Data Analysis (EDA)	Inductive pattern detection; low-cost analytics	Focus only on historical data; need for experienced analysts	Integration with ML/AI; expansion to fraud detection	Incorrect interpretation of patterns; overfitting in models
e-Filing and e-Billing Systems	Simplification of interaction; increased accessibility and coverage	Digital inequality among users; risks of technical failures	Integration with banking platforms; expansion to mobile devices	Cyber threats; DDoS attacks during peak periods
High-Frequency Audit Engines (AI NTS / Robot Tax)	Real-time; automated response; reduced latency of control	Resource intensity; difficulty in setting up triggers	Scaling in continuous audit mode	False positives; overload of fiscal resources

Source: developed by the authors

To enhance analytical consistency, a qualitative coding approach was applied, where attributes were grouped and aligned with the dominant functional role of each technology within the emerging architecture. While no formal quantitative weighting scheme was introduced, the relative importance of factors was determined by their frequency of occurrence and systemic relevance across cases. Thus, SWOT analysis (Table 2) functioned as a structured screening and classification tool for identifying priority technologies to be further examined through decomposition and topological analysis.

SWOT analysis (Table 2) indicated the analytical priority of selected digital technologies – AI-driven Risk Analytics, Autonomous Compliance Systems, e-Invoicing Platforms, and High-Frequency Audit Engines (AI NTS / Robot Tax) – which were subsequently subjected to decomposition analysis to form a structured nomenclature of information-analytical tools for tax control (Table 3). This approach provides methodological support for the conceptual design of an adaptive cognitive model of fiscal informatization, the operational characteristics of which require further empirical or pilot-based verification.

Table 3. Decomposition and range analysis of technologies for digitalization of fiscal tax control systems.

Technology Title	Information and analytical tools	Application assessment in an optimized model
AI-driven Risk Analytics	ML algorithms, risk scoring engines, anomaly detection, rule-based classifiers	High potential – may support cognitive risk stratification and adaptive evasion detection under empirical calibration
Blockchain-based Audit Trails	Distributed ledger, cryptographic hashing, smart contracts, immutable logs	Medium potential – may support traceability and transparency, but analytical integration remains constrained
e-Invoicing Platforms	XML/UBL format, OCR modules, invoice validation engines, metadata extractors	High potential – may support transaction integrity and real-time registry verification after interoperability testing
Autonomous Compliance Systems	Self-updating rule engines, audit bots, compliance decision modules, API-based monitoring	High potential – may support continuous compliance and reduction of human error under controlled deployment
Public-to-Public Data Sharing (P2PDS)	Interoperability frameworks, data matching algorithms, federated queries, data validation services	Medium potential – may enable cross-departmental data reconciliation, but requires standard unification and governance alignment
Golden Tax III System	Centralized reporting engine, real-time tax data pipeline, transaction validators, audit logs	High potential – may support centralized B2B data processing and inspection logic, subject to scalability testing
Cashback Monitoring Mechanisms	Transaction tracking engines, digital incentive recorders, fraud pattern detectors	Low potential – behavioural efficiency is relevant, but analytical depth and integration capacity remain limited
Exploratory Data Analysis (EDA)	Descriptive statistics, correlation matrices, visual dashboards, clustering heuristics	Medium potential – may support preliminary interpretation and hypothesis generation, but does not independently validate risks
e-Filing and e-Billing Systems	Secure submission gateways, pre-filled forms engines, digital authentication services	High potential – may simplify access to control and reduce administrative burden after usability and coverage assessment
High-Frequency Audit Engines (AI NTS / Robot Tax)	Real-time scanning engines, risk signal aggregators, alerting systems, ML-driven rule triggers	High potential – may support proactive analytics and dynamic risk response, subject to false-positive and latency testing

Source: developed by the authors

Table 3 presents the results of the decomposition and range-based analysis of digital technologies for fiscal tax control, where each technology was disaggregated into its constituent information-analytical tools (n=37) based on functional roles (e.g., risk detection, validation, interoperability, compliance automation) identified across documented implementations and technical architectures. The classification of integration potential (high/medium/low) was derived through a criteria-based qualitative assessment, including: (i) degree of interoperability within multi-module architectures, (ii) scalability and adaptability to national fiscal systems, (iii) analytical contribution to risk stratification and compliance decision-making, and (iv) technological maturity and frequency of real-world application. Tools demonstrating multi-functional applicability, real-time processing capabilities, and compatibility with AI/ML-driven analytics and verification layers were categorized as having potentially high integration capacity. Conversely, tools with limited analytical depth or constrained interoperability (e.g., behavioural cashback mechanisms) were classified as medium or low. The decomposition and nomenclature analysis (Table 3) systematized 37 information-analytical tools, with approximately 60% classified as having high potential for integration according to the above qualitative criteria. These values should be interpreted as results of structured analytical classification, not as empirically measured performance indicators. Priority clusters were identified among cognitive-adaptive risk analytics, autonomous compliance systems, high-frequency audit engines, and e-Invoicing-based verification mechanisms, while comparatively lower integration capacity was observed in behavioural incentive systems and partially standardized inter-agency data exchange modules. This indicates the need to typify the identified tools according to differentiated criteria of primary functional role, level of analytical abstraction, and integration locus within the control process, in order to form a unitary nomenclature as a conceptual basis for the framework for the digitalization of fiscal tax control systems (Table 4).

Topological analysis (Table 4) enabled the formation of a unified range of digital information-analytical tools, classified into 9 categories with explicit differentiation based on primary functional dominance, stage within the control lifecycle, and type of analytical processing. The categories were delineated as follows: (i) cognitive risk inference (ex-ante analytical layer), (ii) compliance decision execution (rule-based and adaptive control layer), (iii) transaction-level validation (real-time verification layer), (iv) post-transaction traceability (ex-post registry and audit layer), (v) cross-domain data reconciliation (interoperability layer), (vi) real-time control activation (event-driven audit triggering layer), (vii) exploratory support analytics (auxiliary inductive analysis layer), (viii) user-system interaction (interface and submission layer), and (ix) behavioural modulation (incentive-driven compliance layer).

Table 4. Topological analysis of digital information and analytical tools of fiscal tax control systems (unified range).

Topology Category	**Information and Analytical Tools**	**Integration Type**	**Priority in the Framework**
1. Cognitive analytical risk stratification modules	ML algorithms, risk scoring engines, anomaly detection, clustering heuristics, risk signal aggregators	Intelligent Analytics (AI/ML)	High
2. Automated compliance control modules	Self-updating rule engines, audit bots, compliance decision modules, rule-based classifiers, API-based monitoring	Autonomous Self-Compliance Systems	High
3. Transaction verification platforms	XML/UBL formats, OCR modules, invoice validation engines, metadata extractors, smart contracts, transaction validators	Verification Analytics (B2B)	High
4. Registry tracing architectures	Distributed ledger, cryptographic hashing, immutable logs, centralized reporting engine, audit logs	Traceability and Transparency (DLT)	Medium
5. Interdepartmental interoperable modules (P2PDS)	Interoperability frameworks, data matching algorithms, federated queries, data validation services	Institutional Integration (GovData)	Medium
6. Real-time audit tools	Real-time scanning engines, alerting systems, ML-driven rule triggers	Dynamic Monitoring (AI)	High
7. Inductive analysis tools (EDA)	Descriptive statistics, correlation matrices, visual dashboards	Predictive Analytics (EDA)	Medium
8. Digital tax interaction tools	Secure submission gateways, pre-filled forms engines, digital authentication services	Administrative Automation	High
9. Behavioural incentive control mechanisms	Transaction tracking engines, digital incentive recorders, fraud pattern detectors	Incentive Analytics (Behavioural)	Low

Source: developed by the authors

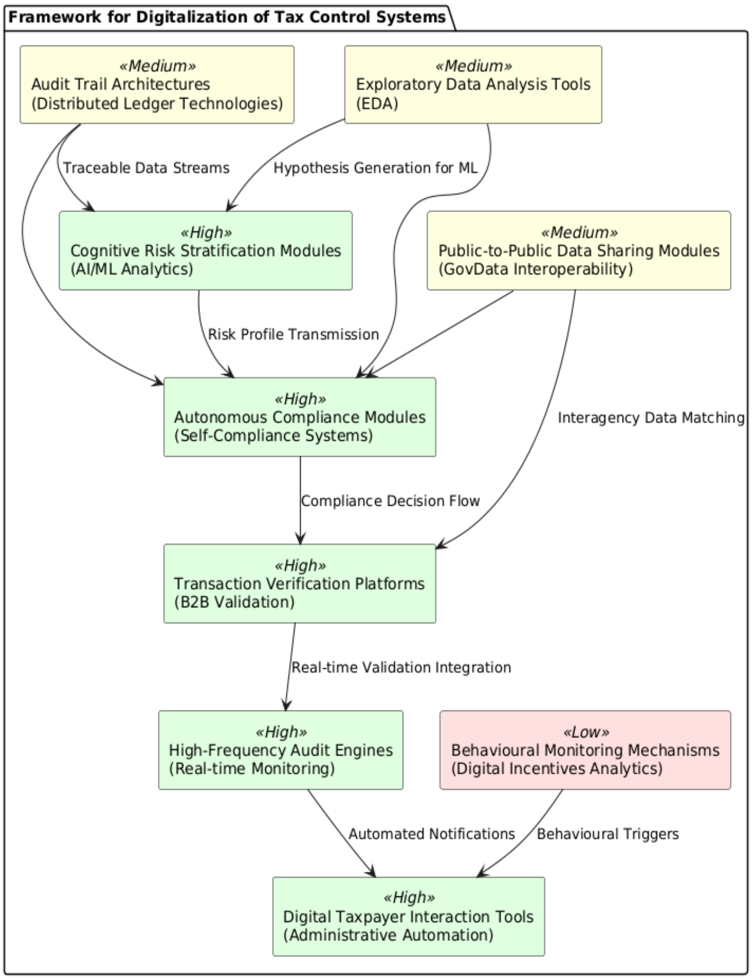

Fig. 2. UML model (concept) of the framework for digitalization of fiscal tax control systems.
Source: developed by the authors using UML

This multi-criteria delimitation reduces functional overlap by assigning each tool group to a dominant operational locus and temporal phase within the control process (ex-ante, in-process, ex-post). Analytically adjacent categories (e.g., risk inference vs. audit triggering; validation vs. traceability) are now explicitly distinguished by their decision role and execution timing. The structural priority within the framework is assigned to core modules – risk stratification, compliance execution, transaction validation, and real-time audit activation – while supporting layers provide traceability, interoperability, and auxiliary analytics (Figure 2 – Figure 6).

The UML framework model (Figure 2) represents a multi-level cognitively stratified architecture for the digitalization of fiscal tax control systems, where the core is formed by intelligent modules for risk stratification (AI/ML Analytics), autonomous compliance control, transactional verification (B2B Validation), real-time audit engines, and digital administrative automation. DLT architectures, interdepartmental P2PDS modules, and EDA tools are integrated as a supporting analytical layer intended to provide traceability, interoperability, and preliminary inductive analytics. Behavioural mechanisms function as auxiliary triggers for digital engagement. Structurally, the model outlines a vertically stratified information-analytical topology with proposed routing of risk, compliance, and verification data flows, forming the conceptual basis of the digital fiscal control framework rather than a validated operational system.

The Component Diagram (Figure 3) represents a modular-stratified architecture, where the core is formed by the Risk Engine (AI/ML), Compliance Core, B2B Verification Platform, Real-time Audit Engine, and Taxpayer Portal. Supporting subsystems (DLT Audit Trail, P2P Interoperability Hub, EDA Module, Behavioural Analytics) are designed to support traceability and integration. External interfaces (ERP/CRM, Banking APIs) ensure conceptual data input. The model illustrates logical interactions and functional dependencies rather than empirically validated system performance.

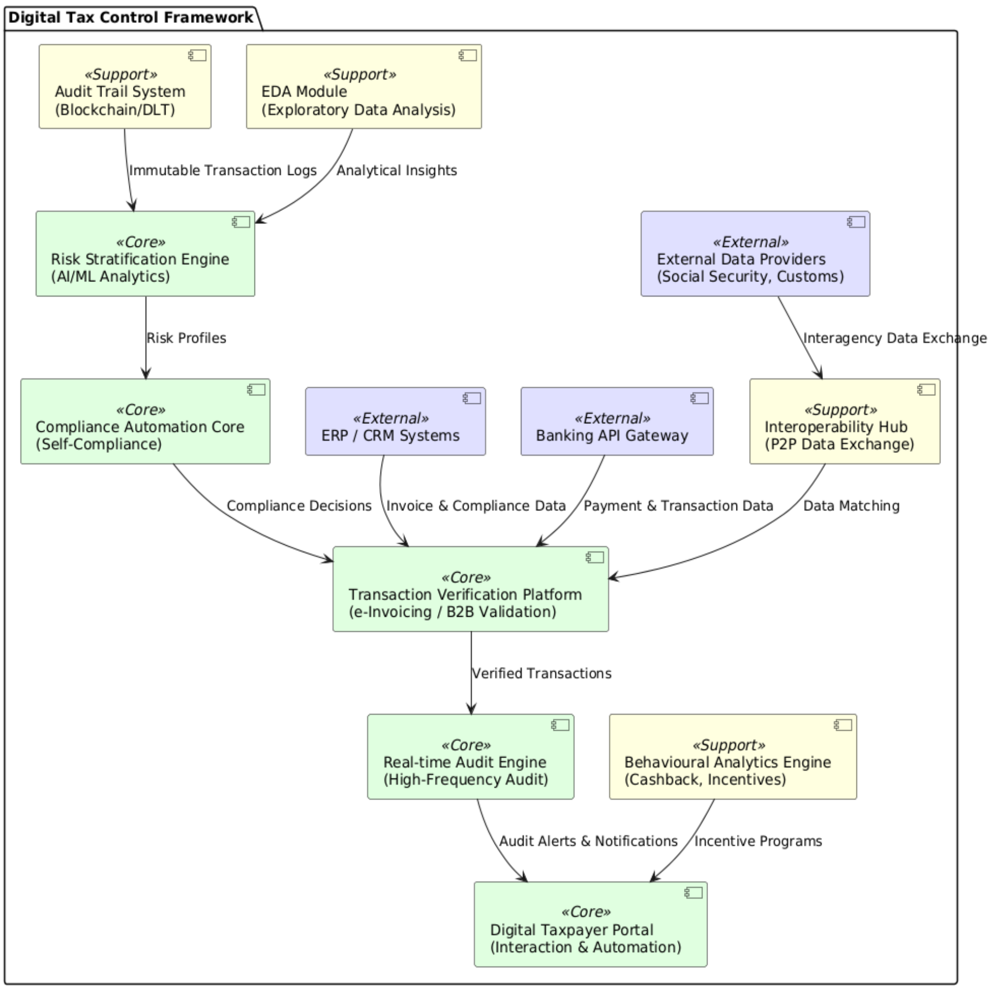

Fig. 3. UML model (Component Diagram) of the framework for digitalization of fiscal tax control systems.
Source: developed by the authors using UML

The Sequence Diagram (Figure 4) illustrates the logical sequence of risk-oriented transaction processing, including submission, verification, correlation, logging, risk stratification, and compliance decision-making. The diagram represents conditional process flows (high/low risk) and interaction logic without asserting operational efficiency, routing latency, or real-world throughput.

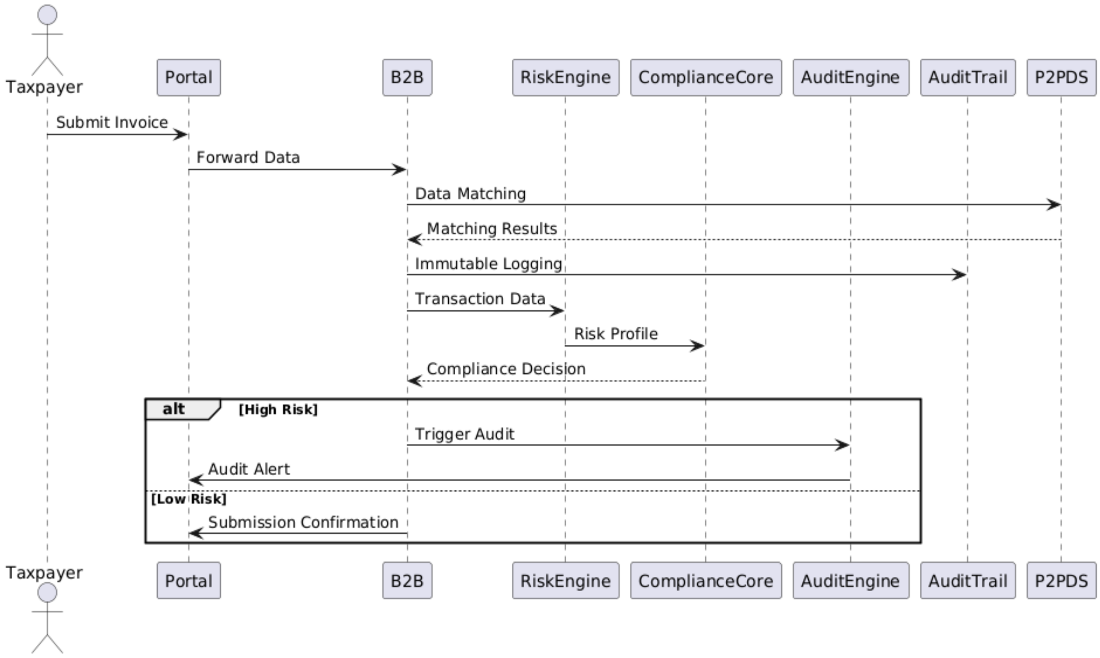

Fig. 4. UML model (Sequence Diagram) of the framework for digitalization of fiscal tax control systems.
Source: developed by the authors using UML

The Activity Diagram (Figure 5) models the procedural workflow of cognitive risk-oriented transaction processing, including verification, logging, and compliance decision points. It provides a formalized representation of process logic and control flow, without empirical validation of execution dynamics, robustness, or scalability.

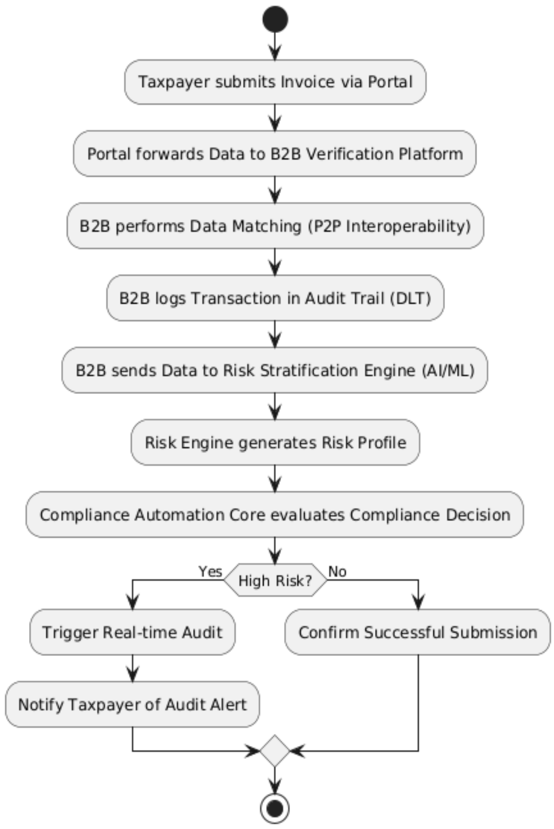

Fig. 5. UML model (Activity Diagram) of the framework for digitalization of fiscal tax control systems.
Source: developed by the authors using UML

The Deployment Diagram (Figure 6) presents a three-tier infrastructure architecture, including user interface, cloud-based processing modules, and external data systems. The model reflects conceptual deployment and integration logic rather than tested system robustness, interoperability efficiency, or scalability metrics.

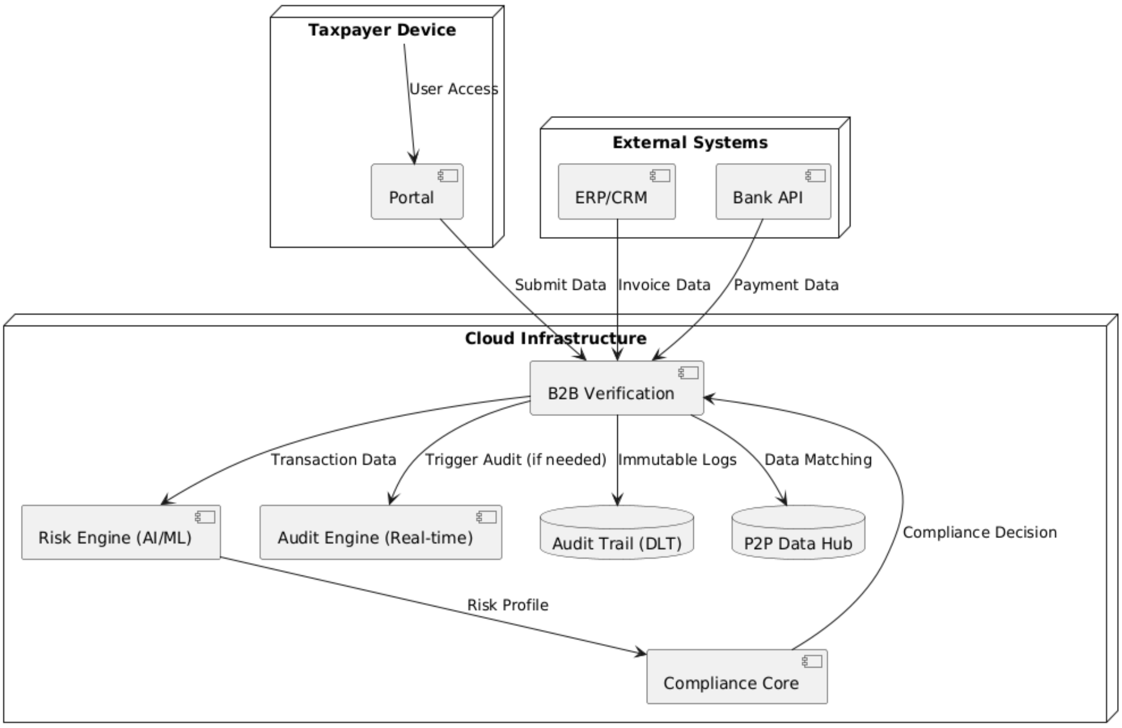

Fig. 6. UML model (Deployment Diagram) of the framework for digitalization of fiscal tax control systems.
Source: developed by the authors using UML

UML modeling (Figures 2–6) provided structural and functional formalization of the framework, enabling the design-level integration of cognitive risk routing, compliance logic, transaction traceability, and inter-agency interoperability into a unified architectural topology. The models serve as a conceptual and design-oriented representation of system architecture, outlining integration logic and functional relationships, rather than demonstrating validated performance characteristics such as interoperability efficiency, operational robustness, routing efficiency, or scalability.

5. Discussion

In the Discussion section, the primary emphasis is on the need for a critical comparison of conceptual, regulatory, organizational, and applied approaches to the digitalization of fiscal tax control systems. The discursive analysis is focused on verifying the architectural integrity, cognitive-risk stratification, procedural resilience, and interoperability of digital tools that ensure the integrative efficiency of fiscal administration in the context of digital transformation.

Vincent and Evans [34] conceptually defined the impact of digitalization on fiscal efficiency, focusing on the problems of tax presence and evasion. In the present study, these issues are addressed at the level of a proposed cognitive-stratified design logic that integrates AI/ML, DLT, and P2PDS modules, while its practical resilience remains subject to future implementation testing.

Garza de la Vega and Romero Jarrin [35] focused on the regulatory gaps of the digital economy, justifying the use of blockchain for fiscal transparency. In this study, blockchain is positioned as only one element within a broader conceptual routing framework formed through SWOT, range, and topological analysis, with architectural coherence treated as a design premise rather than a validated result.

Ikundi [36] focused on the regulatory and institutional gaps of digital taxation, particularly cross-border jurisdictional inconsistency. The present study complements this perspective by identifying analytical nodes and integrating them into a proposed cognitively stratified framework, although jurisdiction-specific legal heterogeneity remains a major constraint for practical deployment.

Zhang et al. [37] empirically investigated the impact of digital competence of knowledge and access channels on the innovative ambidexterity of tax organizations in the context of the TOE model. The present study shifts the focus from organizational capability measurement to structural-functional design of information-analytical tools within a cognitive fiscal control framework.

Qodirov [38] considered digitalization as a means of countering global profit shifting, focusing on strengthening overall fiscal control. The present study suggests that cognitive risk stratification and DLT traceability may support the mitigation of evasion schemes when embedded in a unified architectural topology, but this proposition requires empirical calibration and benchmark testing.

Li [39] identified data taxation as a challenge to fiscal classification, emphasizing normative approaches to their integration into tax regimes. In this study, the architectural integration of cognitive risk stratification and DLT traceability is proposed as a possible mechanism for reducing procedural opacity and supporting controlled data fiscalization.

Slimani [40] empirically confirmed the correlation between digitalization and modernization of tax administration, focusing on infrastructural and organizational aspects. The present study discusses modernization as a design problem of integrating risk stratification, autonomous compliance, and DLT traceability, while recognizing that functional strengthening remains dependent on empirical testing.

Rahmawati et al. [41] emphasized the legal gaps of digital taxation in Indonesia, justifying the need for harmonization of regulatory and compliance mechanisms. The present study conceptually links fiscal resilience with the integration of cognitive risk stratification, DLT traceability, P2P interoperability, and adaptive compliance within UML-based digital control architecture.

Heinemann and Stiller [42] empirically demonstrated the effectiveness of e-invoicing in reducing cross-border VAT fraud, using the trade data gap as a fraud indicator. The present study treats e-invoicing as a core verification component that may require complementary risk modules, traceability layers, and P2P interoperability to support broader fiscal control architecture.

Fodil and Khanoussa [43] focused on digitalization and AI as drivers of fiscal efficiency, with emphasis on taxpayers' information and competence. The present study broadens this perspective by systematizing digital fiscal control tools within a model framework, while acknowledging that systemic integrativeness and procedural resilience remain design-level properties pending practical testing.

Thus, the discussion indicates that, in contrast to predominantly conceptual and normative approaches focusing on discrete aspects of fiscal digitalization (e.g., transparency, regulatory harmonization, compliance), the proposed study advances a system-architectural integration of information-analytical tools within a cognitively stratified framework. At the same time, this integrative approach entails several trade-offs and limitations: increased architectural complexity, higher implementation and maintenance costs, dependence on data quality and interoperability standards, and potential risks associated with AI-driven decision opacity and cybersecurity vulnerabilities. In addition, partial functional overlap between modules (e.g., risk analytics and real-time audit triggering), legal heterogeneity across jurisdictions, and institutional constraints in cross-agency data exchange may affect the operational coherence of the framework. Therefore, while the proposed model improves the conceptual organization of fiscal control tools and clarifies integration logic, its practical effectiveness remains contingent upon regulatory alignment, data governance maturity, and controlled implementation conditions in real fiscal environments.

6. Research Limitations

A limitation of the study is the absence of empirical verification of the functional resilience and operational robustness of the developed cognitively stratified framework within real fiscal environments. The proposed architecture was constructed through conceptual-analytical synthesis, decomposition-nomenclature structuring, and topological integration of key modules, including AI/ML-based risk stratification, DLT-enabled traceability, and inter-agency P2P interoperability. However, the framework was not subjected to procedural-analytical testing, simulation modeling (e.g., agent-based or discrete-event simulation), or validation on real transactional datasets and administrative event logs. Consequently, the dynamic behavior of the system under varying load conditions, data heterogeneity, latency constraints, and regulatory compliance scenarios remains unverified. In addition, the absence of empirical calibration limits the assessment of predictive accuracy, false-positive rates in anomaly detection, routing efficiency, and automated compliance performance. Further limitations are associated with legal heterogeneity across fiscal jurisdictions, potential incompatibility of institutional data standards, data governance and privacy risks, explainability constraints of AI-driven decision-making, and cybersecurity vulnerabilities affecting DLT infrastructures, API gateways, and inter-agency data exchange. Therefore, the proposed framework should be interpreted as a conceptual-architectural basis for subsequent pilot implementation rather than as an empirically validated fiscal control system.

7. Recommendations

It is recommended to initiate a pilot project of fiscal control based on the proposed cognitive-stratified framework with the integration of risk scoring, DLT traceability, and inter-agency P2P interoperability modules. Controlled testing of the verification and compliance architecture in a test environment may allow assessment of procedural resilience, architectural integrity, functional-analytical stability, routing efficiency, and error profiles under realistic fiscal data conditions.

8. Conclusions

As an output of the research, a cognitively stratified framework for the digitalization of fiscal tax control systems was developed as a conceptual architectural configuration with functional-analytical coherence through the integration of AI/ML-based risk stratification, DLT-enabled traceability, autonomous compliance mechanisms, and inter-agency P2P interoperability. The application of SWOT, decomposition, range, and topological analyses enabled the identification and systematization of priority information-analytical tools, subsequently formalized through UML modeling. The proposed framework outlines a unified routing logic for risk, verification, and compliance data flows, offering a design-level basis for potential enhancement of fiscal transparency, adaptability, and evasion risk mitigation in the context of digital economic transformation.

The academic novelty of the research is associated with the formalization of a cognitively stratified framework for the digitalization of fiscal control, which integrates AI/ML-based risk scoring, DLT-enabled traceability, P2P interoperability, and procedural adaptive compliance within a unified architectural and functional topology. The study provides a systematic identification and structured organization of information-analytical tools of fiscal control based on decomposition and topological analysis, with their subsequent formal representation through UML modeling.

The practical significance of the research results lies in the creation of a unified architectural model of digital fiscal control that may support the integration of cognitive analytical modules into fiscal processes after controlled pilot testing. The developed framework can serve as a conceptual basis for pilot projects on the digitalization of fiscal systems, where structural-functional consistency, administrative burden, detection accuracy, and interoperability performance should be assessed empirically.

All the Declarations and Statements

Author Contributions Statement

Konon Bagrii – Conceptualization, Methodology, and Supervision: Proposed research ideas, Constructed the overall framework, supervised project execution, Review and Editing, and Project Management: Reviewed and edited the manuscript, ensured clarity and coherence, and helped coordinate project milestones and deadlines

Oleksii Maliarchuk – Data Curation and Software Implementation: Handled data acquisition, dataset preprocessing, and implementing the research model.

Serhii Rylieiev – Model Training, Validation, and Performance Evaluation: Led the model training process, validated results using standard metrics, and benchmarked performance against existing methods.

Volodymyr Yevdoshchak – Formal Analysis, Visualization, and Statistical Analysis: Performed in-depth analysis of experimental results, prepared performance charts, and ensured the statistical robustness of the evaluation.

Mykola Skrypnyk – Writing – Drafted the initial manuscript, contributed to the literature survey, and documented the technical background of the study.

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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None.

Data Availability Statement

This study analyzed publicly available datasets. The results obtained and datasets can be found from the correspondent author.

Ethical Declarations

None.

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Declaration of Generative AI in Scholarly Writing

None.

Abbreviations

The following abbreviations are used in this manuscript:

UML - Unified Modeling Language. UML is a standardized visual modeling language used for the formal representation, specification, visualization, and documentation of the structural, behavioral, and interactional components of systems. It enables the conceptual design of architectures, processes, information flows, and functional relationships through diagrams such as Component, Sequence, Activity, and Deployment, supporting systematic analysis and architectural formalization of complex systems.
SWOT - Strengths, Weaknesses, Opportunities, Threats. SWOT analysis is a strategic analytical method used to identify and evaluate internal factors (strengths, weaknesses) and external factors (opportunities, threats) that may influence the effectiveness, adaptability, risks, or development potential of a system, technology, or organizational process. It is commonly applied for comparative assessment, prioritization, and conceptual structuring of solutions under conditions of uncertainty and environmental variability.
AI - Artificial Intelligence. Artificial Intelligence (AI) refers to computational systems designed to perform tasks that typically require human cognitive capabilities, including pattern recognition, reasoning, decision-making, prediction, learning, and adaptive problem-solving. In digital fiscal control, AI is commonly applied to risk stratification, anomaly detection, fraud identification, predictive analytics, and automated compliance processes.
ML - Machine Learning. Machine Learning (ML) is a subfield of Artificial Intelligence focused on developing computational models and algorithms capable of learning patterns from data, generating predictions, identifying anomalies, and improving performance through iterative adaptation without explicit programming for each task. In digital fiscal control, ML is applied to risk scoring, anomaly detection, fraud prediction, taxpayer profiling, and adaptive compliance analytics.
DLT - Distributed Ledger Technology. Distributed Ledger Technology (DLT) refers to a decentralized digital infrastructure for recording, synchronizing, and validating transactions across multiple nodes without a central authority. DLT enables immutability, traceability, transparency, and integrity of records through distributed consensus mechanisms and cryptographic protection. In digital fiscal control systems, DLT is applied to transaction traceability, audit trails, fraud prevention, cross-agency verification, and enhancement of fiscal transparency and accountability.
P2P - Peer-to-Peer (in public administration contexts, often operationalized as Public-to-Public Data Sharing, P2PDS). P2P refers to a decentralized interaction model in which data, services, or information are exchanged directly between equivalent entities or institutional nodes without reliance on a centralized intermediary. In digital fiscal control systems, P2P architectures support inter-agency interoperability, multi-source verification, cross-domain data reconciliation, and distributed information exchange, enhancing coordination, transparency, and procedural continuity across public institutions.
Big Data - Big Data. Big Data refers to extremely large, complex, and rapidly generated datasets characterized by high volume, velocity, variety, veracity, and value (5V model), which exceed the processing capabilities of traditional data management systems. Big Data technologies enable real-time analytics, pattern recognition, predictive modeling, anomaly detection, and decision support through distributed storage and advanced computational methods. In digital fiscal control systems, Big Data is applied to taxpayer profiling, fraud detection, risk stratification, transaction monitoring, and large-scale compliance analytics.
Cognitive stratified architecture (framework) – a multi-layered architectural configuration of a digital fiscal control system in which functional modules are hierarchically organized according to their analytical roles: (i) data acquisition and preprocessing, (ii) cognitive analytics (AI/ML-based risk stratification), (iii) compliance decision-making, and (iv) execution and monitoring (audit, reporting). Each layer performs a distinct function within the end-to-end control pipeline, enabling structured data transformation and risk-oriented decision routing across modules.
TCF - Tax Control Framework. A structured system of policies, procedures, control mechanisms, and risk management tools designed to ensure tax compliance, regulatory conformity, transparency, and consistency in tax-related processes.
DiD - Difference-in-Differences. Difference-in-Differences (DiD) is a quasi-experimental econometric method used to estimate the causal effect of an intervention, policy, or treatment by comparing changes in outcomes over time between a treatment group and a control group. The method isolates the net effect of the intervention under the assumption of parallel trends, controlling for unobserved time-invariant differences between groups. In applied research, DiD is used for policy evaluation, impact assessment, institutional reform analysis, and causal inference in economics, public administration, and digital governance contexts.
PPO - Personalized Tax Office або Personalized Public Office. PPO refers to a personalized digital fiscal service environment designed to provide taxpayer-specific interaction, adaptive administrative support, customized reporting, automated compliance assistance, and individualized access to tax services. Such systems integrate user profiling, AI-supported recommendations, e-services, and digital communication channels to improve accessibility, responsiveness, and taxpayer engagement within digital fiscal administration.
HDI - Human Development Index. A composite statistical index developed to measure the overall level of human development based on three dimensions: life expectancy (health), education, and gross national income per capita. HDI is used to assess and compare socioeconomic development and quality of life across countries.

GDP - Gross Domestic Product. The total monetary value of all final goods and services produced within a country's economy during a specific period, typically measured annually or quarterly. GDP is used as a key macroeconomic indicator of economic activity, productivity, and overall economic performance.
EDA - Exploratory Data Analysis. An analytical approach used to summarize, visualize, and examine datasets in order to identify patterns, anomalies, relationships, and underlying structures before formal modeling or hypothesis testing. EDA commonly includes descriptive statistics, correlation analysis, clustering, and data visualization techniques.
ICTs - Information and Communication Technologies. A broad set of digital technologies, systems, and infrastructures used for the creation, storage, processing, transmission, and exchange of information, including computers, networks, software, telecommunications, cloud systems, and internet-based services. ICTs support automation, connectivity, data management, and digital transformation across sectors.
Procedural resilience - the capability of a fiscal control system to maintain continuity, consistency of decision-making, and regulatory compliance under conditions of data variability, operational load, and external disruptions, reflected in the stability and adaptability of control workflows.

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