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CONTENTS

RECONCEPTUALIZING HIGHER EDUCATION MARKETING IN THE ALGORITHMIC ERA: INSTITUTIONAL GENERATIVE AI AND MULTIDIMENSIONAL UNIVERSITY BRAND EQUITY	10
Nozima Zufarova	
DEVELOPMENT OF WAREHOUSE AND INVENTORY MANAGEMENT IN MANUFACTURING ENTERPRISES	16
Maxmidov Shirinboy Botirovich	
IMPROVING THE MECHANISM FOR ENHANCING THE POTENTIAL OF OIL AND GAS INDUSTRY ENTERPRISES IN UZBEKISTAN	25
Bekmuhamedova Malika Iskandarbekovna	
IMPROVING THE METHODOLOGY OF ARTIFICIAL INTELLIGENCE-BASED MARKETING DECISION-MAKING IN CONSTRUCTION MATERIALS MANUFACTURING ENTERPRISES	30
Uzakova Umida Ruzievna	
ORGANIZATIONAL AND ECONOMIC ASPECTS OF IMPROVING THE QUALITY OF DIGITAL SERVICES IN THE HIGHER EDUCATION SYSTEM	37
Berdiev Sunnatullo Alikulovich	
GLOBAL JUSTICE CODE AND GLOBAL JUSTICE INDEX: A CONCEPTUAL FRAMEWORK FOR GLOBAL GOVERNANCE AND SUSTAINABLE DEVELOPMENT	43
Alimov Nasimjon Hoshimovich	
IMPROVING THE MECHANISMS FOR MANAGING THE PROCESS OF DIVERSIFYING HOTEL SERVICES BASED ON INTERNATIONAL STANDARDS (USING THE FERGANA VALLEY AS AN EXAMPLE)	50
Sevarakhon Dehqonova Fatxitdin qizi	
DOES INVESTMENT SOURCE DIVERSIFICATION IMPROVE FARM PERFORMANCE? EVIDENCE FROM HORTICULTURAL PRODUCERS IN UZBEKISTAN	56
Jalilov Shohruh Zafar o'g'li	
SPECIFIC ASPECTS OF PREPARING AN AUDIT OPINION AND REPORT BASED ON ESG AUDIT RESULTS.....	65
Sayfullayev Mekhroj Sayfullayevich	
THE ROLE AND IMPORTANCE OF THE MULTIFACTOR DEVELOPMENT MODEL IN THE ECONOMIC DEVELOPMENT OF THE INDUSTRIAL SECTOR.....	70
Ne'matov Shokhruxbek Ma'murjon o'g'li	
IMPROVEMENT OF ACCOUNTING AND AUDITING OF ENVIRONMENTAL ACTIVITIES IN BUILDING MATERIALS INDUSTRY ENTERPRISES	75
Mirzaev Komiljon Abdullajonovich	
THEORETICAL EVOLUTION OF COMPETITIVENESS AND ISSUES OF THE TERRITORIAL COMPETITIVENESS OF SMALL BUSINESSES.....	82
Mamatkulova Kh. N.	
СОВРЕМЕННОЕ СОСТОЯНИЕ И АНАЛИЗ ЭКОНОМИЧЕСКОГО ПОТЕНЦИАЛА АО «УЗБЕКНЕФТЕГАЗ»	87
Бекмухамедова Малика Искандарбековна	
ОЦЕНКА ВЛИЯНИЯ ИННОВАЦИОННОЙ АКТИВНОСТИ НА РАЗВИТИЕ СОЦИАЛЬНОГО СЕКТОРА ЭКОНОМИКИ: ЭКОНОМЕТРИЧЕСКИЙ АНАЛИЗ.....	95
Холмуратов Жахонгир Салимбек ўғли	

FOREIGN EXPERIENCE IN SUPPORTING SMALL BUSINESS ENTITIES AND OPPORTUNITIES FOR ITS APPLICATION	104
Botir Baxtiyorovich Ganiyev	
STRATEGIES FOR THE DIVERSIFICATION OF INDUSTRIAL ENTERPRISES.....	108
Kalimullina Nargiza Vladimirovna	
CURRENT STATE AND CHALLENGES OF USING NATIONAL FASHION ELEMENTS IN UZBEKISTAN'S TOURISM MARKET	112
Yusupova Mokhinur Farkhod qizi	
IMPROVING THE ORGANIZATION, PLANNING, AND METHODOLOGICAL ASPECTS OF THE AUDIT OF BIOLOGICAL ASSETS	120
Akhmetova Salima Seytovna	
FACTORS DETERMINING THE DEVELOPMENT OF SMALL BUSINESS AND ENTREPRENEURSHIP	125
Imomnazarov Khurshid Ozodboevich	
SMART INCLUSIVE UNIVERSITY: A DIGITAL ECOSYSTEM MODEL FOR INCLUSIVE HIGHER EDUCATION.....	129
Kamola Makhkamova	
THEORETICAL FOUNDATIONS OF ORGANIZATIONAL AND ECONOMIC DEVELOPMENT OF THE FOOD INDUSTRY	137
Tleuov Nietulla Rakhmanovich	
SECTORAL ANALYSIS OF WATER RESOURCE USE EFFICIENCY UNDER CIRCULAR ECONOMY PRINCIPLES: EVIDENCE FROM UZBEKISTAN	143
Sotvoldiyeva Muslimaxon G'ayratjon qizi	
MECHANISMS FOR INCREASING THE IMPACT OF USING THE RESOURCES OF INTERNATIONAL FINANCIAL AND CREDIT INSTITUTIONS ON SUSTAINABLE ECONOMIC DEVELOPMENT	149
Qosimov Bobur Sobirovich	
IMPROVING ELECTRONIC SERVICES IN THE B2B AND B2G MARKET SEGMENTS OF THE REPUBLIC OF UZBEKISTAN	154
Otaboyev Nodirbek Oybek o'g'li	
MACROECONOMIC DETERMINANTS OF INDUSTRIAL DEVELOPMENT IN UZBEKISTAN: A TIME-SERIES ECONOMETRIC ANALYSIS AND SCENARIO FORECAST FOR 2026–2027	160
Khusniddin Nuriddin ugli Muydinov	
INSTITUTIONAL CHALLENGES AND DEVELOPMENT CONSTRAINTS IN SERVICE SECTOR MANAGEMENT	166
Dauletmuratov Adilbay Mirzabaevich	
ECONOMETRIC ANALYSIS OF THE FACTORS AFFECTING INTERBANK COMPETITION IN THE DIGITAL BANKING SERVICES MARKET	173
Karimov Odiljon Boqiyevich	
PRIORITY DIRECTIONS FOR ENHANCING FINANCIAL INCLUSION THROUGH INNOVATIVE BANKING SERVICES IN THE DIGITAL ECONOMY	185
Azlarova Aziza Axrorovna	
INTEGRATED INSTITUTIONAL MECHANISM OF FORMATION AND MANAGEMENT OF NATIONAL CRAFT CLUSTER.....	192
Yakhshilikov Sardor Rustam ugli	
IMPROVING THE METHODOLOGY OF PUBLIC AUDIT IN THE SYSTEM OF STATE FINANCIAL CONTROL.....	203
B. Sh. Mirzoyev	

PROSPECTS FOR THE DIGITAL TRANSFORMATION OF LOCAL GOVERNMENT AUTHORITIES	208
Achilova Firuza Kurbanovna	
Nurmurodov Zafarjon Nurmurod ugli	
A STUDY OF HOUSING STOCK MANAGEMENT ISSUES IN THE CONTEXT OF URBANIZATION BASED ON SWOT ANALYSIS.....	212
Mamanazarov Oybek Shomurodovich	
DETERMINING THE FORECAST PARAMETERS OF INDICATORS REPRESENTING AGRO-SERVICES AND THE POSSIBILITIES FOR POVERTY REDUCTION.....	217
Pardaev Mamayunus Karshibaevich	
Abilov Feruz Nematullaevich	
EVOLUTION OF PRODUCTION MANAGEMENT MODELS IN TEXTILE ENTERPRISES AND DIGITAL DIRECTIONS FOR IMPROVING EFFICIENCY.....	223
Kodirova Xurshida Ismoilovna	
DIRECTIONS FOR REDUCING POVERTY THROUGH THE USE OF DIGITAL TECHNOLOGIES IN THE SERVICE SECTOR	228
Saparov Murod Irgashovich	
FOREIGN EXPERIENCE IN HANDICRAFT MANAGEMENT AND OPPORTUNITIES FOR ITS APPLICATION IN UZBEKISTAN.....	233
Yakhshilikov Sardor Rustam Ugli	
REGIONAL INTERDEPENDENCIES AND CROSS-BORDER DYNAMICS: ASSESSING THE INFLUENCE OF NEIGHBOURING COUNTRIES ON THE DEVELOPMENT OF UZBEKISTAN'S TOURISM SECTOR	238
Khusniddin Egamnazarov	
THEORETICAL ISSUES OF DETERMINING THE QUALITY AND EFFICIENCY INDICATORS OF AGRO-SERVICES.....	246
Abilov Feruz Nematullaevich	
THE THREE-STEP INTERNAL QUALITY CONTROL MODEL FOR THE PREPARATION OF FINANCIAL STATEMENTS IN JOINT-STOCK COMPANIES IN ACCORDANCE WITH IFRS AND ITS IMPLEMENTATION MECHANISMS.....	251
Lutfullaev Sardorbek Utkur o'g'li	
CONCEPTUAL MODEL OF AN INTEGRATED ORGANIZATIONAL AND ECONOMIC MECHANISM FOR THE DEVELOPMENT OF RAILWAY INDUSTRIAL ENTERPRISES.....	260
Baymatov Atxam Axmadaliyevich	
INNOVATIVE MECHANISMS FOR THE STATISTICAL ASSESSMENT OF POPULATION QUALITY OF LIFE AND LIVING STANDARDS IN THE REPUBLIC OF UZBEKISTAN AND DIRECTIONS FOR THEIR IMPROVEMENT UNDER CONDITIONS OF SUSTAINABLE ECONOMIC GROWTH	266
Ostonaqulov Dilshod Ismatilla o'g'li	
THE IMPORTANCE OF CORPORATE CULTURE IN IMPROVING THE MANAGEMENT OF JOINT-STOCK COMPANIES	272
Nazokat Israilovna Akramova	
THE CURRENT STATE AND DEVELOPMENT PROSPECTS OF SPECIAL ECONOMIC ZONES IN UZBEKISTAN	280
Toshtemirova Malika Turg'un qizi	
IMPROVEMENT OF MECHANISMS FOR INCREASING THE EFFICIENCY OF FINANCIAL MANAGEMENT IN JOINT-STOCK COMPANIES.....	287
Abdubodiyev Muxammad Sharofitdinovich	
ANALYSIS OF THE CURRENT STATE AND ASSESSMENT MECHANISMS FOR THE DEVELOPMENT OF INTELLECTUAL AND TECHNOLOGICAL POTENTIAL IN THE KASHKADARYA REGION	294
Uralov Elshod Sirojiddin o'g'li	

IMPROVING MECHANISMS FOR CONTENT PLACEMENT AND MANAGEMENT BASED ON ARTIFICIAL INTELLIGENCE.....	303
Khujamatova Shakhlo Abdusalom qizi	
STATISTICAL MODEL FOR DETERMINING SAMPLE SIZE IN THE AUDIT OF BUDGETARY ORGANIZATIONS BASED ON AUDIT RISK, MATERIALITY, AND EXPECTED MISSTATEMENT	309
Jasur Bosimovich Muqumov	
ЭКСПЕРГООЭКОНОМИЧЕСКАЯ И ЭКСПЕРГООЭКОЛОГИЧЕСКАЯ ОЦЕНКА СОЛНЕЧНО-АККУМУЛЯТОРНОГО ХОЛОДОСНАБЖЕНИЯ ПРИ ДЛИТЕЛЬНОМ ХРАНЕНИИ ЯБЛОК	318
Мирзабаев Акрам Махкамovich	
Матчанов Нураддин Азадович	
Кулматов Хайрулло Хабибуллаевич	
Шодиев Бобур Тоир угли	
THE ESSENCE, SIGNIFICANCE, AND IMPORTANCE OF THE INTERCONNECTIVITY BETWEEN CENTRAL AND SOUTH ASIA, AND UZBEKISTAN'S ROLE IN DEEPENING REGIONAL COOPERATION WITH SOUTH ASIA	330
Yuldashev Anvar Ergashevich	
INTERNATIONAL EXPERIENCE IN STATE SUPPORT FOR FOOD INDUSTRY ENTERPRISES AND ITS ADAPTATION TO THE CONDITIONS OF UZBEKISTAN.....	341
Mamatojjeva Sarvinoz Dilshodjon qizi	
ОСОБЕННОСТИ ЭКОЛОГИЧЕСКОГО ТУРИЗМА ТАШКЕНТСКОЙ ОБЛАСТИ КАК ОСНОВЫ ЕЁ УСТОЙЧИВОГО ЭКОНОМИЧЕСКОГО РАЗВИТИЯ	346
Ахмедходжаев Равшан Темурович	
THE ROLE OF FOREIGN TRADE IN SHAPING SUSTAINABLE REGIONAL DEVELOPMENT: EVIDENCE FROM THE REGIONS OF UZBEKISTAN	352
Dilnoza Ochilova Ismoil qizi	
METHODOLOGICAL ASPECTS OF ACCOUNTING FOR CONSTRUCTION AND RENOVATION EXPENDITURES IN BUDGET ORGANIZATIONS: INTERNATIONAL PUBLIC SECTOR EXPERIENCE.....	364
Azizova Zilola Lochinovna	
ENDOGENOUS GROWTH FACTORS IN THE SUSTAINABLE ECONOMIC DEVELOPMENT OF THE REGIONS OF UZBEKISTAN: A CONCEPTUAL MODEL AND EMPIRICAL ASSESSMENT	369
Yuldashov Abdullo Abdugapparovich	
PROSPECTS FOR IMPLEMENTING STRATEGIC MANAGEMENT IN ENTERPRISES.....	377
Abdullaev Farkhod Ozodovich	
METHODOLOGICAL IMPROVEMENT OF LABOR MARKET STATISTICS IN UZBEKISTAN BASED ON INTERNATIONAL STATISTICAL STANDARDS	381
Abrayev Sherzod Xurromovich	
A COMPREHENSIVE METHODOLOGY FOR ASSESSING THE EFFICIENCY OF FINANCIAL INVESTMENTS AND CONDUCTING FORWARD-LOOKING ANALYSIS	391
Jumamurodov Tolibai Eldashbaevich	
CURRENT STATE OF INTERNAL AUDIT IN COMMERCIAL BANKS OF UZBEKISTAN: AN EMPIRICAL ANALYSIS OF SYSTEMIC CHALLENGES	396
Narziev Khayotjon Azamatovich	
VISUALIZATION OF RISKS IN PUBLIC FINANCIAL CONTROL: RISK MAP, RISK REGISTER AND ANALYSIS OF INTERZONAL MIGRATION	403
Gayimov Abdumalik Norbekovich	

ORGANISATIONAL AND METHODOLOGICAL MECHANISM FOR IMPLEMENTING CONTINUOUS AUDIT TOOLS IN THE INTERNAL AUDIT OF COMMERCIAL BANKS.....	408
Ismailov Azizbek Madaminovich	
IMPROVING THE RISK-BASED METHODOLOGY FOR PREPARING ANNUAL INTERNAL AUDIT PLANS IN THE PUBLIC SECTOR	415
Ismatillayev Baypolat Khushvaktovich	
ASSESSING THE MULTIDIMENSIONAL ECONOMIC POTENTIAL OF A TEXTILE ENTERPRISE: EVIDENCE FROM “YUSTEX” LLC (2021–2025)	424
Yuldashev Golibjon Turgunovich	
A DATA-DRIVEN APPROACH TO THE DIGITALIZATION OF PUBLIC PROCUREMENT AUDITING	431
Rajabov Shukhrat Ismayilovich	

A DATA-DRIVEN APPROACH TO THE DIGITALIZATION OF PUBLIC PROCUREMENT AUDITING

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Abstract. This article develops a data-driven digital approach to public procurement auditing. The author proposes an approach aimed at transitioning from periodic audits to continuous monitoring based on six risk indicators (red flags) automatically calculated from data obtained from information systems (the electronic public procurement system, treasury system, and accounting system), as well as a three-level risk signalling mechanism. The proposed approach enables early risk identification, automates the processes of assessing materiality and risk levels, and strengthens the preventive function of internal audit. The research findings contribute to advancing public procurement auditing towards a modern digital framework.

Keywords: public procurement, internal audit, digitalisation, data analytics, risk indicators, red flags, continuous auditing, preventive audit, electronic system, monitoring.

Аннотация. В статье разработан цифровой подход к аудиту государственных закупок, основанный на анализе данных. Автором предложен подход, направленный на переход от периодического аудита к непрерывному мониторингу на основе шести индикаторов риска (красных флагов), автоматически рассчитываемых на основе данных информационных систем (электронной системы государственных закупок, казначейской системы и системы бухгалтерского учёта), а также трёхуровневого механизма риск-сигнализации. Предлагаемый подход позволяет выявлять риски на ранних стадиях, автоматизировать процессы оценки существенности и уровня риска, а также усилить превентивную функцию внутреннего аудита. Результаты исследования способствуют развитию аудита государственных закупок в направлении современного цифрового формата.

Ключевые слова: государственные закупки, внутренний аудит, цифровизация, анализ данных, индикаторы риска, красные флаги, непрерывный аудит, превентивный аудит, электронная система, мониторинг.

INTRODUCTION

Under contemporary conditions, public procurement processes are becoming increasingly digitalised. The growing use of electronic procurement systems generates substantial volumes of data. The effective utilisation of these data creates opportunities to advance public procurement auditing to a new, digitally enabled level. In practice, however, audits are still frequently conducted using traditional manual methods, while the potential of digital technologies remains insufficiently utilised.

Digitalisation in public procurement involves not only the automation of procurement procedures but also the fundamental transformation of control and audit systems. Data stored in electronic systems constitute a valuable source of audit evidence, enabling the systematic analysis of procurement processes and the targeted identification of potential risks. Unlike traditional audit procedures, which are often significantly influenced by human judgement, data-driven auditing can enhance the objectivity, consistency and reliability of audit results.

Traditional auditing is generally periodic in nature and is conducted selectively within predetermined time intervals. Such an approach does not allow auditors to cover large volumes of procurement transactions in a timely manner and may result in the late detection of irregularities. In contrast, digitalisation and data analytics make it possible to continuously monitor procurement activities and identify emerging risks at an early stage.

In the Republic of Uzbekistan, the electronic public procurement system, including the kharid.uzex.uz platform, has been introduced, and measures are being implemented to digitalise public audit activities. Under these conditions, the digitalisation of public procurement auditing and the development of data-analytical tools have become increasingly relevant.

The purpose of this article is to develop an approach to the digitalisation of public procurement auditing based on risk indicators and continuous monitoring.

LITERATURE REVIEW

The application of data analytics and risk indicators in public procurement has received considerable attention in recent years. The Open Contracting Partnership (2024) systematises public procurement risk indicators, commonly referred to as red flags, and proposes methods for identifying potential corruption risks based on these indicators. A study published in *EPJ Data Science* (2025) provides a general overview of data-driven methods for detecting potential irregularities and risk patterns in public procurement.

In the field of internal auditing, Sawyer (2012) and Moeller (2016) identify continuous auditing as one of the most promising directions in the development of modern audit practice. Kazakova (2019) examines the role of data analytics in auditing, while INTOSAI GUID 5280 recommends the use of data analysis techniques in the audit of public procurement.

The concept of continuous auditing began to develop in audit theory in the late twentieth century. Its essence lies in the automation of audit procedures and the continuous analysis of data. The rapid development of digital technologies has created opportunities for the broader application of continuous auditing in the public sector, including public procurement.

The risk-indicator, or red-flag, approach is widely recognised as an important instrument for preventing and detecting corruption in public procurement. International organisations, including the World Bank and the Organisation for Economic Co-operation and Development, recommend the use of risk indicators in public procurement oversight. This method enables potentially high-risk transactions and circumstances to be identified rapidly within large datasets.

The specific characteristics of public procurement have been extensively examined in international studies, including the works of Arrowsmith (2014) and Thai (2009). The organisational foundations of internal audit have also been addressed in the studies of local researchers, including Ilhamov (2019) and Abdieva (2022). Nevertheless, an integrated approach combining the digitalisation of public procurement auditing, the automated calculation of risk indicators and the transition to continuous monitoring has not yet been sufficiently developed. This research gap determines the relevance of the present study.

RESEARCH METHODOLOGY

The study examines international practices and academic research relating to public procurement data analytics and risk indicators and adapts them to the institutional and technological conditions of Uzbekistan. A systems approach was employed to develop digital auditing as an integrated framework comprising interconnected data, analytical, monitoring and decision-making components.

Methods of analysis and synthesis were used to identify, classify and structure public procurement risk indicators. Comparative analysis was applied to assess the experiences of foreign electronic procurement and risk-analysis systems, including the Korean Online E-Procurement System (KONEPS), Brazil's Public Spending Observatory and risk-analysis mechanisms (BRIAS), and Ukraine's ProZorro system. Their potential applicability to the public procurement environment of Uzbekistan was subsequently evaluated.

Logical generalisation was used to formulate the main conclusions and recommendations. During the research, public procurement risk indicators were analysed and organised into a system of indicators that can be calculated using data obtained from electronic procurement platforms.

A signalling mechanism and the structure of an audit management dashboard were developed with due consideration of practical audit requirements. These instruments are intended to support the automated identification of risk events, the prioritisation of audit objects and the timely adoption of appropriate audit responses.

ANALYSIS AND RESULTS

The digitalisation of public procurement auditing refers to the organisation of audit activities through electronic systems and data-analytical technologies. The foundation of digital auditing consists of data obtained from various information systems. When these datasets are integrated and analysed collectively, it becomes possible to identify risks arising during public procurement procedures automatically.

The effective operation of a digital audit system requires the integration of procurement, treasury, tax, customs, budgetary and other relevant databases. Such integration allows auditors to evaluate procurement transactions comprehensively, identify inconsistencies between different sources of information and detect potentially high-risk transactions at an early stage.

The principal data sources required for the digitalisation of public procurement auditing are presented in Table 1.

Table 1
Main Information Sources for Digital Public Procurement Auditing¹

Source of information	Data to be obtained
State procurement electronic system (kharid.uzex.uz)	Announcements, offers, participants, winners, prices, contracts
Treasury system	Payments, budget execution, movement of funds
Accounting system	Expenses, calculations, movement of material assets
Registers and databases	Suppliers, contracts and blacklist information

Integration of data sources represents a fundamental requirement for the implementation of digital auditing. When data obtained from different information systems are consolidated within a unified analytical platform, auditors can obtain a comprehensive and integrated view of the public procurement process. For instance, cross-referencing contract information from electronic procurement systems with payment data from treasury systems enables the identification of potential risks, including payments for goods, works or services that have not been actually delivered or completed.

A major challenge in data integration is the diversity of formats, structures and technological environments in which information is stored. Therefore, effective digital auditing requires the standardisation of data formats and the establishment of reliable mechanisms for information exchange between different systems. Modern data analytics platforms provide opportunities for the automated collection, processing and integration of data from multiple sources, thereby creating the necessary technological foundation for digital audit procedures.

Data quality is a critical determinant of the effectiveness and reliability of digital auditing. For risk indicators to be calculated accurately, information recorded in electronic procurement systems must be complete, accurate, consistent and timely. Accordingly, standardised data-entry procedures and continuous data-quality control mechanisms are essential components of a digital audit framework. High-quality data ensure the reliability of analytical results and improve the effectiveness of risk identification.

Through the analysis of integrated data from various sources, procurement risk indicators (red flags) can be calculated automatically. These indicators serve as signals of potential irregularities, inefficiencies or integrity-related risks within procurement processes. The author proposes six key risk indicators for public procurement, which are presented in Table 2.

Table 2.
Key risk indicators (red flags) in public procurement audits²

Risk indicator	Description	Potential risk
Single-participant procurement	Only one participant submitted an offer	Limited competition and potential restriction of competitive conditions
Repeat winner	The same supplier repeatedly receives procurement contracts	Potential supplier concentration and preferential treatment risks
Price anomaly	The contract price significantly differs from market reference values	Possible price deviation from market conditions
Split procurement	A large procurement is divided into smaller transactions	Possible circumvention of established procurement thresholds
Multiple contract amendments	The contract is amended multiple times after signing	Potential changes to initial procurement conditions
Unusually short procurement period	The period for submitting offers is significantly shorter than expected	Potential limitation of supplier participation

The risk indicators presented in the table are calculated automatically based on data obtained from electronic procurement systems. For example, the system analyses the number of bidders participating in each procurement procedure to identify single-participant tenders and examines the frequency of contract awards to

¹ Source: Author's development.

² Source : author development based on Open Contracting Partnership (2024) .

particular suppliers in order to detect repeated winners. Such automation reduces the need for time-consuming manual analysis and allows auditors to focus on high-risk procurement activities.

Various analytical techniques are applied for the calculation of procurement risk indicators. Statistical methods are used to identify price anomalies and unusual transaction patterns; frequency analysis helps detect relationships between repeated contract winners and procurement participants; while rule-based approaches evaluate predefined risk conditions, such as compliance with established time limits or financial thresholds. The combined application of these methods improves the accuracy and reliability of risk identification.

Each risk indicator reflects a specific category of potential irregularity. Indicators related to single-participant procurement and unusually short procurement periods may signal artificial restrictions on competition. The repeated-winner indicator may indicate potential collusion or preferential treatment, while price anomaly indicators may reveal possible inefficient use or inefficient or inappropriate use of public funds. Split procurement indicators may suggest attempts to circumvent established procurement procedures or thresholds. The simultaneous presence of several risk indicators within a single procurement transaction significantly increases its overall risk level.

Based on the identified risk indicators, procurement transactions are classified using a three-level risk signalling mechanism. This mechanism enables auditors to prioritise procurement objects requiring further examination and allocate audit resources more effectively. The three-level signalling mechanism is presented in Table 3.

Table 3

A three-level risk signalling mechanism based on danger indicators³

Signal level	Danger indicators	Audit response
Green (low risk)	Indicators are absent or of little importance	Regular continuous monitoring
Yellow (medium risk)	One or two indicators have been identified	Additional inspection and monitoring
Red (high risk)	Several or serious indicators have been identified	Perform a detailed audit review

The risk signalling mechanism is closely integrated with the risk-based audit methodology and the materiality approach. Procurement transactions that generate risk indicators (red flags) are classified as high-risk objects and are subject to a lower materiality threshold and more detailed audit procedures. This integration transforms digital auditing into a comprehensive and systematic audit framework.

The practical operation of the system can be illustrated through the following example. Assume that the system simultaneously identifies indicators of single-participant procurement, price anomalies and multiple contract amendments within a single procurement transaction. In this case, the transaction receives a red-flag status and is automatically prioritised for detailed audit examination. The auditor then performs a targeted and focused audit based on the specific risk indicators identified by the system. Compared with traditional manual analysis, this approach significantly reduces the time and resources required for risk assessment.

A fundamental outcome of digitalisation is the transition from periodic auditing to continuous auditing. Continuous auditing enables the identification of risks through continuous and automated analysis of procurement data. Unlike traditional periodic audits, which evaluate transactions after a certain period, continuous auditing provides ongoing monitoring of procurement activities and allows potential irregularities to be detected at an early stage.

Another significant advantage of digital auditing is the ability to analyse the entire population of procurement transactions. Due to limitations in time and resources, traditional audit approaches usually rely on selective sampling. In contrast, digital auditing automatically processes all transactions recorded in electronic procurement systems. This approach reduces the likelihood that significant risks will remain undetected and substantially increases audit coverage.

The continuous audit mechanism consists of several interconnected components. These include automated data collection and updating, periodic recalculation of risk indicators (for example, on a daily or weekly basis), and automatic notifications to auditors regarding identified risk events. Such a mechanism enables continuous oversight of procurement processes without requiring constant manual intervention and significantly improves audit efficiency.

³ Source: Author's development.

Real-time monitoring represents one of the principal advantages of continuous auditing. While traditional audit procedures may identify irregularities only after a considerable period of time, continuous auditing detects risk events at the moment they occur or shortly thereafter. This not only reduces potential financial losses but also creates a preventive effect, as procurement participants are aware that transactions are subject to continuous monitoring.

Continuous auditing transforms public procurement auditing from a reactive control mechanism into a preventive risk-management instrument. Whereas traditional audits generally identify issues after the completion of procurement activities, digital continuous auditing enables risks to be detected during the procurement process and, in certain cases, before negative consequences arise. Consequently, the role of auditing expands from identifying deficiencies to preventing them.

The primary advantage of preventive auditing is the ability to minimise losses before they occur. In a traditional audit model, financial or operational damage may already have been incurred by the time irregularities are identified, making recovery difficult. Preventive auditing allows risks to be recognised at an early stage, appropriate corrective measures to be implemented, and potential losses to be avoided. This contributes to the efficient use of public funds and strengthens confidence in the procurement system.

The results of digital auditing can be presented through a visual analytical dashboard. The dashboard provides information on high-risk procurement transactions, identified risk indicators and corresponding signal levels, enabling auditors and management to make timely and informed decisions. This ensures that audit results are presented in a clear and actionable format.

The dashboard can be adapted to the information needs of different user groups. For auditors, it provides detailed risk profiles and analytical information, while management receives aggregated indicators, trends and overall risk assessments. Visual risk indicators allow users to focus attention on the most critical procurement areas, while historical analysis enables monitoring of changes in risk levels and audit outcomes over time.

International experience demonstrates the effectiveness of digital auditing approaches. The Korean Online E-Procurement System (**KONEPS**) and the Bid Rigging Indicator Analysis System (**BRIAS**) apply data analytics techniques to identify procurement risks automatically. Ukraine's **ProZorro** open-data procurement platform improves transparency and strengthens public oversight mechanisms. These practices provide valuable experience that can be adapted to the institutional environment of Uzbekistan.

The digitalisation of state audit activities in Uzbekistan is supported at the policy level. Current reforms aimed at improving public audit effectiveness include the introduction of digital technologies and the wider application of data analytics. The existing electronic public procurement infrastructure provides the necessary foundation for implementing the proposed digital audit approach.

The proposed approach provides several important advantages. First, it enables the early and automated identification of procurement risks. Second, it expands audit coverage by allowing continuous analysis of all procurement transactions. Third, it reduces the burden of manual analytical procedures and allows auditors to concentrate on complex and high-risk areas. Fourth, it strengthens the preventive function of auditing by enabling risks to be addressed before significant consequences occur.

One of the most promising future directions of digital auditing is the application of artificial intelligence and machine learning technologies. These technologies can identify hidden patterns, complex relationships and previously undetected anomalies within large datasets. Their further development will enhance the accuracy, adaptability and effectiveness of public procurement audit systems.

The proposed digital approach forms an integrated framework together with risk-based auditing, materiality assessment and audit procedures. Digital technologies provide mechanisms for automating these methodological approaches and applying them effectively in practical audit activities. Consequently, public procurement auditing can evolve into an integrated, modern and digitally enabled system.

Although the implementation of digital auditing requires initial investments in technological infrastructure and organisational development, it can generate significant long-term economic benefits. Automation of time-consuming analytical procedures reduces audit costs, improves auditor productivity and contributes to the preservation of public resources by preventing potential losses. Therefore, investment in digital auditing systems can be considered economically justified.

At the same time, several challenges should be considered in the digitalisation of public procurement auditing. First, the effectiveness of digital audit depends on the quality, completeness and reliability of available data, as inaccurate or incomplete information may reduce the accuracy of risk assessments. Second, successful implementation requires appropriate technological infrastructure and qualified specialists. Third, ensuring cybersecurity, data protection and confidentiality remains a critical requirement. Addressing these challenges is essential for the sustainable implementation of digital audit mechanisms.

CONCLUSIONS AND SUGGESTIONS

Based on the research findings, the following conclusions are formulated regarding the digitalisation of public procurement auditing.

First, the digitalisation of public procurement generates substantial volumes of structured data, and the effective utilisation of these data creates opportunities for continuous and more efficient audit procedures.

Second, the proposed approach enables the rapid identification of high-risk procurement transactions through six automatically calculated risk indicators (**red flags**) and a three-level risk signalling mechanism based on electronic procurement system data.

Third, digitalisation facilitates the transformation of public procurement auditing from a periodic control activity into a continuous monitoring system and from a reactive approach into a preventive mechanism aimed at early risk detection and mitigation.

Fourth, the proposed approach is compatible with risk-based auditing principles and materiality assessment methods. It is recommended that the research findings be considered in the development of methodological guidelines and practical programmes for the digitalisation of public procurement auditing.

Fifth, the digital transformation of public procurement auditing should be implemented gradually. The recommended sequence includes the integration of relevant data sources, the introduction of automated risk indicators and the subsequent transition to continuous monitoring. Such a phased approach will support effective, sustainable and institutionally appropriate implementation of digital audit systems.

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