INTEGRATION SMART MANUFACTURING TECHNOLOGIES INTO PUBLIC PROCURMENT SYSTEMS. A SYSTEMATIC LUTERATURE REVIEW

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Annotatsiya. Ushbu tadqiqot Industry 4.0 texnologiyalarini davlat xarid tizimlariga integratsiya qilish masalasini, ayniqsa O‘zbekistonda davlat xarid jarayonlarini modernizatsiya qilishga alohida e’tibor qaratgan holda o‘rganadi. Tadqiqotda Internet of Things, Artificial Intelligence, katta ma’lumotlar tahlili (big data analytics) va aqlli ishlab chiqarish tizimlari kabi ilg‘or raqamli texnologiyalar xarid jarayonlarining shaffofligi, samaradorligi, yetkazib beruvchilarni baholash va qaror qabul qilish jarayonlarini qanday yaxshilashi mumkinligi tahlil qilinadi. Tadqiqotda aralash usullar (mixed-methods) tadqiqot dizaynidan foydalanilib, xarid tranzaksiya ma’lumotlari, yetkazib beruvchilar faoliyati ko‘rsatkichlari va so‘rovnoma natijalarining miqdoriy tahlili sifatli intervyular hamda hujjatli tahlil bilan integratsiya qilindi. Tadqiqot pragmatik epistemologik yondashuvga asoslanib, obyektiv statistik dalillarni manfaatdor tomonlarning kontekstual qarashlari bilan uyg‘unlashtirishni maqsad qilgan.
Kalit so‘zlar: ta’minot xaridlari, Sanoat 4.0, Raqamlashtirish, Xarid 4.0, Buyumlar interneti (IoT), Elektron xarid tizimi.

Аннотация. Данное исследование рассматривает интеграцию технологий Industry 4.0 в системы государственных закупок с особым акцентом на модернизацию процессов государственных закупок в Узбекистане. Исследование анализирует, каким образом передовые цифровые технологии, включая Internet of Things, Artificial Intelligence, аналитику больших данных и системы умного производства, могут повысить прозрачность закупок, эффективность, качество оценки поставщиков и процессы принятия решений. В исследовании использован смешанный методологический подход (mixed-methods), объединяющий количественный анализ данных о закупочных транзакциях, показателей деятельности поставщиков и результатов опросов с качественными интервью и анализом документов. Исследование основывается на прагматистском эпистемологическом подходе, направленном на объединение объективных статистических данных с контекстуальными взглядами заинтересованных сторон.
Ключевые слова: процесс закупок, Индустрия 4.0, цифровизация, Закупки 4.0, Интернет вещей (IoT), электронные закупки.

Abstract. This study examines the integration of Industry 4.0 technologies into public procurement systems, with particular emphasis on the modernization of governmental

procurement processes in Uzbekistan. The research explores how advanced digital technologies, including Internet of Things, Artificial Intelligence, big data analytics, and smart manufacturing systems, can improve procurement transparency, efficiency, supplier evaluation, and decision-making processes. A mixed-methods research design was employed, integrating quantitative analysis of procurement transaction data, supplier performance records, and survey responses with qualitative interviews and documentary analysis. The study adopts a pragmatist epistemological approach to combine objective statistical evidence with contextual stakeholder perspectives.

Keywords: procurement, industry 4.0, digitalization, procurement 4.0, internet of things, e-procurement.

Introduction.

The 4th Industrial Revolution, otherwise referred to as Industry 4.0 (I4.0), is characterized by the convergence of information and communication technologies (ICT) and the automation of machinery and infrastructure [1, 2]. In the field of manufacturing, it signifies the process of digitalizing factories and their associated supply chain operations. Consequently, the advent of advanced digitalization in the manufacturing sector has given rise to a novel concept termed 'smart manufacturing'. The concept of smart manufacturing represents a paradigm shift in the coordination of manufacturing elements, with the integration of a data chain system facilitated by the Internet at its core. This development has been identified as a critical improvement in strategic supply chain management [3]. It is widely acknowledged that the function of procurement constitutes a critical component within the overarching framework of the supply chain, given its direct impact on the overall performance of the entire supply chain.

Procurement is defined broadly in terms of any form of the buying process, whether it is in the form of purchasing, leasing, renting, or otherwise acquiring supplies, services, or construction from external suppliers [4, 5]. This concept encompasses all management responsibilities that managers are expected to adhere to, including the identification, sourcing, access, and management of resources external to the company. Furthermore, it is posited that the fulfilment of the company's strategic objectives will engender significant business value and a substantial impact on profit. From the perspective of supply chain management, the role of procurement is considered indispensable, as it plays a crucial role in highlighting the importance of ongoing enhancements within the procurement division [1].

The objective of this study is to provide a comprehensive and methodically organized review of the extant literature on the subject, with a particular focus on the role of I4.0 technologies in the context of P4.0, as this aspect is of particular relevance to the current research. The article's principal contribution lies in its comprehensive overview of the extant state-of-the-art literature on the subject.

The article is outlined as follows. The second section delineates the methodology that was employed in conducting the literature review, as well as the criteria that were utilized to gather the publications that are listed. The review is divided into five sections. The categories are proposed and discussed in Section 5. The sixth section of the text is dedicated to the presentation of reflections and a conclusion.

Methodology.

The present study employs a mixed-methods research design, integrating both qualitative and quantitative approaches to provide a comprehensive understanding of the research problem. The rationale underpinning this design is rooted in the intricacy of the phenomenon under investigation. The assessment of the present state of a governmental procurement system, the identification of systemic inefficiencies, and the development of a technology-integration framework demand both numerical evidence and contextual depth, which neither approach can provide in isolation.

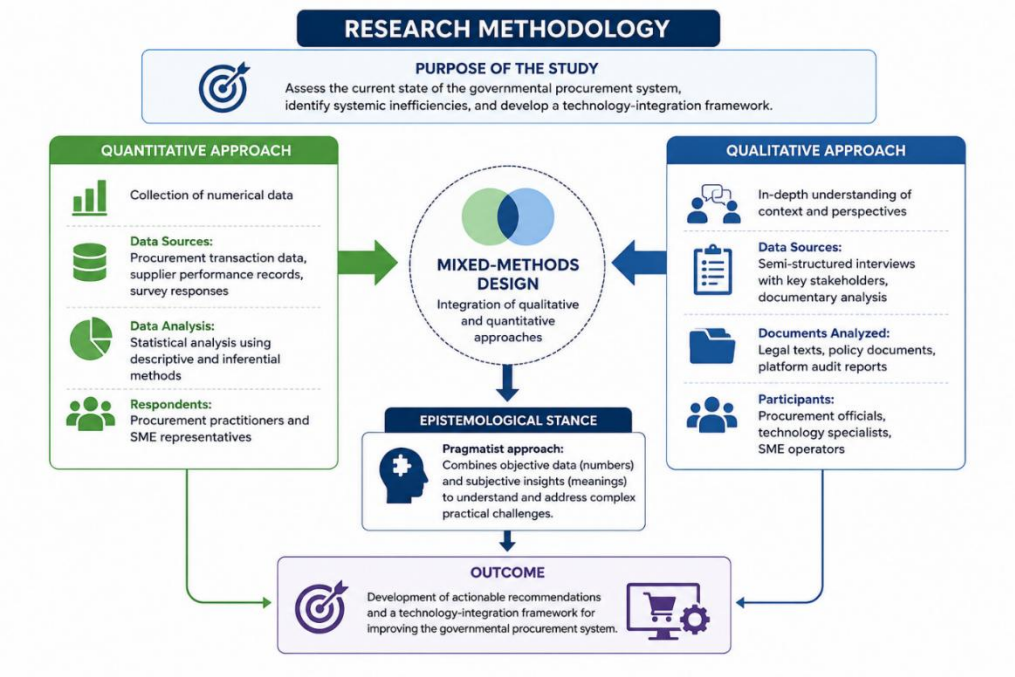


Figure 1. Mixed methods design methodology

The quantitative component of the study involves the collection and statistical analysis of procurement transaction data, supplier performance records, and survey responses from procurement practitioners and SME representatives. The qualitative component of the study involves the conduction of semi-structured interviews with key stakeholders, including procurement officials, technology specialists, and SME operators. In addition, a documentary analysis of legal texts, policy documents, and platform audit reports will be conducted.

The research adopts a pragmatic epistemological stance, acknowledging the necessity of both objective data and subjective interpretive insights to comprehensively understand and address the practical challenges within the study domain. This approach is consistent with the action-oriented objectives of the dissertation, which are directed towards the development of actionable recommendations for system improvement.

Literature review.

Public Procurement Systems: Global Practices and Standards.

Public procurement can be defined as the process by which governmental bodies acquire goods, services, and works from external suppliers using public funds. The field of study in question is one which intersects with a number of other academic disciplines, including public administration, economics, and law and supply chain management. Internationally, effective procurement systems are characterized by the following principles: transparency, competition, equal treatment, proportionality, and mutual recognition. These principles are enshrined in frameworks such as the World Trade Organization's Agreement on Government Procurement (GPA) and the European Union's procurement directives [6].

It is evident that there is a considerable body of literature pertaining to the correlation between the efficiency of procurement and the broader economic outcomes that ensue. As demonstrated in [7], competitive procurement markets have been shown to correlate with lower prices, higher quality outputs, and reduced fiscal waste. Conversely, systems characterised by weak competition, limited transparency, or inadequate supplier evaluation mechanisms tend to produce procurement at inflated costs and with greater incidence of contractor non-performance [8].

The advent of electronic procurement (e-procurement) in the early 2000s signified a transformative shift. The digitalization of procurement processes, encompassing tendering, supplier registration, bid evaluation, and contract management, has been demonstrated to engender a reduction in administrative costs, enhance transparency, and broaden the participation pool of suppliers [5]. Nations such as South Korea, Estonia, and Singapore have attained substantial success in the implementation of e-procurement, furnishing instructive exemplars for the development of economies.

Legal Framework in Uzbekistan.

Law O'RQ-684 Uzbekistan's procurement reforms gained significant legislative momentum with the adoption of the Law "On Public Procurement" O'RQ-684. This law established a unified legal framework governing procurement procedures across central and local government entities. It introduced mandatory competitive bidding requirements, defined thresholds for different procurement modalities, and established the legal basis for electronic procurement platforms.

The law mandates that procurement of goods, works, and services above specified value thresholds must be conducted through electronic platforms, primarily the unified e-procurement portal. Procurement entities are required to publish tender documentation, accept electronic bids, and conduct evaluation procedures according to standardized criteria. The Ministry of Finance serves as the primary regulatory authority overseeing compliance with these provisions.

While the law represents a substantial improvement over prior procurement arrangements, analysts have noted persistent challenges in its implementation. Enforcement capacity, digital infrastructure limitations, and low awareness among SMEs have been identified as barriers to full regulatory effectiveness [4].

Smart Manufacturing Systems: Definition and Principles

Smart manufacturing is broadly defined as a technology-driven approach to production that leverages connectivity, data, and intelligent automation to create adaptive, responsive,

and efficient manufacturing environments [6]. The concept is closely associated with the broader paradigm of Industry 4.0, first articulated in German industrial policy discussions and subsequently adopted as a global framework for understanding the next wave of industrial transformation.

Key technological pillars of smart manufacturing include cyber-physical systems (CPS), which integrate computational processes with physical operations; the Internet of Things (IoT), enabling real-time data collection from physical assets; artificial intelligence and machine learning, enabling pattern recognition and predictive modeling; big data analytics, facilitating the processing of large, complex datasets; and cloud computing, enabling scalable, accessible data storage and processing infrastructure [8].

Critically for the purposes of this dissertation, smart manufacturing principles are not restricted to factory environments. The same technological architectures that enable adaptive manufacturing systems can be applied to supply chain management, vendor evaluation, regulatory compliance monitoring, and procurement decision-making. The application of smart manufacturing thinking to procurement involves treating the procurement ecosystem as an interconnected, data-rich system amenable to optimization through intelligent algorithms and real-time monitoring.

Industry 4.0 Technologies in Supply Chain and Procurement

The application of Industry 4.0 technologies to supply chain management has attracted growing scholarly attention. Artificial intelligence has been applied to demand forecasting, inventory optimization, and supplier risk assessment [6]. IoT-enabled tracking systems have improved visibility across complex supply chains, enabling real-time monitoring of goods in transit and predictive alerting for potential delays [7].

Within procurement specifically, AI-based tools have been applied to automate vendor screening, detect bid manipulation, and optimize contract award decisions. Predictive analytics models trained on historical procurement data have demonstrated the ability to identify high-risk contracts before execution, enabling preventive intervention [7]. Natural language processing (NLP) tools have been applied to the automated review of technical specifications, reducing manual workload and improving consistency.

These applications suggest substantial potential for technology-driven improvements in procurement performance. However, the existing literature focuses predominantly on private sector or well-resourced public sector contexts in developed economies. Application within the specific institutional and infrastructure context of Uzbekistan remains an underexplored frontier.

Digital Transformation in the Public Sector

Digital transformation in the public sector is a multifaceted process involving not only the adoption of new technologies but also corresponding changes in organizational culture, administrative processes, and service delivery models [8]. Scholars distinguish between digitization (converting analog processes to digital formats), digitalization (using digital technologies to change existing processes), and digital transformation (fundamentally reimagining how public value is created through digital capabilities).

E-procurement represents an early stage of digitalization in public administration. More advanced digital transformation involves the integration of AI, data analytics, and automated decision-support systems that move beyond simple process automation toward genuine

intelligent governance. Countries at the forefront of public sector digital transformation — including Estonia, Singapore, and Denmark — have demonstrated that sophisticated use of data

and AI can dramatically improve government efficiency and service quality [8].

However, digital transformation in transitioning economies faces distinctive challenges. Infrastructure limitations, digital skills gaps, institutional inertia, and regulatory uncertainties can slow adoption and limit effectiveness. These contextual factors must be carefully accounted for in designing technology-driven reforms for procurement systems in countries like Uzbekistan.

E-Procurement Platforms: Benefits and Limitations

Electronic procurement platforms offer multiple potential benefits: reduced transaction costs, greater transparency through public information disclosure, wider supplier reach, and faster procurement cycles [9]. Empirical evidence from various country contexts demonstrates that e-procurement adoption is associated with lower procurement prices, shorter tender periods, and increased numbers of bidders [10].

However, the literature also documents significant limitations. Implementation challenges include resistance from incumbents who benefit from opaque processes, technical barriers for smaller suppliers, and inadequate training and support, and integration difficulties with existing administrative systems. Moreover, the mere existence of an electronic platform does not guarantee competition; if barriers to supplier registration and participation remain high, the platform may simply replicate existing market concentrations in a digital format.

Supplier Evaluation and Selection Models

Supplier evaluation and selection constitute one of the most critical activities within procurement management. The choice of supplier directly influences the quality, cost, and timeliness of procured goods and services. Traditional supplier evaluation methods include weighted scoring models, analytical hierarchy process (AHP), and total cost of ownership (TCO) analysis [8, 9]

These traditional approaches rely on pre-defined criteria sets and static evaluation at the point of contract award. They do not account for dynamic changes in supplier performance over time, nor do they leverage the predictive capabilities made possible by continuous data collection and machine learning.

AI-Based Approaches to Supplier Evaluation

The application of artificial intelligence to supplier evaluation represents a significant methodological advance. Machine learning models can be trained on historical performance data to predict the likelihood of supplier non-compliance, delivery delays, or quality failures. These predictive models incorporate a wider range of variables than traditional scoring methods, including financial health indicators, past contract performance records, industry-specific risk factors, and even social media and news sentiment analysis [6, 7].

Natural language processing tools have been applied to automated analysis of tender documents, comparing supplier-submitted technical specifications against procurement requirements to identify discrepancies before contract award. This approach significantly reduces manual review workload while improving consistency and thoroughness of evaluation.

Reinforcement learning algorithms have been explored in the context of dynamic procurement decision-making, where systems learn from outcomes of past procurement decisions to improve future award recommendations. Graph analytics approaches have been applied to detect collusion patterns among bidders by analyzing networks of corporate relationships and bidding behavior.

While the technical literature demonstrates the feasibility and effectiveness of these approaches in controlled settings, implementation within governmental procurement systems requires careful attention to legal compliance, algorithmic transparency, and procedural fairness. Public sector procurement must adhere to principles of non-discrimination and equal treatment that impose constraints on automated decision-making systems not present in private sector contexts.

Critical voices in the literature, however, challenge the uncritical adoption of AI in public procurement. [5] warn of the "automation of discretion," whereby the embedding of value judgments in algorithmic systems reduces the scope for contextual human reasoning that legitimate governance requires. This critique is particularly salient in procurement contexts: a machine learning model trained on historical award data will inevitably reflect the biases and structural inequalities encoded in that data, potentially perpetuating the exclusion of SMEs and minority-owned enterprises rather than addressing it. Algorithmic accountability frameworks, as proposed by [6], are therefore not merely technically desirable but ethically mandatory in public sector AI deployments.

A further limitation of the existing literature is its predominantly techno-optimistic orientation. Studies demonstrating AI efficacy in procurement are predominantly conducted in high-income, high-data-availability contexts (South Korea, Singapore, EU member states), where mature e-government infrastructures and robust data ecosystems pre-existed the AI implementations. The transferability of these findings to low- and middle-income transitioning economies with nascent data infrastructure, limited institutional capacity, and weak rule-of-law environments remains empirically underexplored [8,10]. This dissertation directly engages with this limitation by situating its framework development within the specific institutional constraints of Uzbekistan.

Results and Discussions.

A review of extant literature reveals a significant gap at the intersection of smart manufacturing systems and governmental procurement, particularly within the context of developing and transitioning economies. Although there is ample documentation regarding the application of artificial intelligence (AI) and digital technologies to private sector supply chains, the specific challenges of integrating these technologies within government procurement systems — with their distinctive legal requirements, institutional constraints, and equity objectives — remain underexplored.

Moreover, extant literature on procurement reform in post-Soviet Central Asia focuses predominantly on legal and institutional dimensions, with limited engagement with the technological dimension of reform. The present study aims to address this lacuna in the academic literature by examining the potential of smart manufacturing principles and AI-based tools to address procurement inefficiencies in Uzbekistan.

The present dissertation aims to address this gap by developing a context-specific framework for AI-driven procurement enhancement that is tailored to the institutional realities and developmental priorities of Uzbekistan. In doing so, it draws on international best practices and emerging technological capabilities.

Conclusion.

This study examined the role of Industry 4.0 technologies in transforming public procurement systems and evaluated their potential application within the institutional context of Uzbekistan. The research demonstrated that the integration of technologies such as Artificial Intelligence, Internet of Things, big data analytics, and intelligent automation can significantly improve procurement transparency, operational efficiency, supplier evaluation accuracy, and overall governance quality.

The findings from the literature review indicate that modern procurement systems are evolving from simple electronic platforms toward intelligent, data-driven ecosystems capable of predictive analysis and automated decision support. International experiences from digitally advanced economies show that smart procurement technologies can reduce transaction costs, improve competition, minimize corruption risks, and accelerate procurement cycles. However, the study also identified important implementation challenges, particularly in developing and transitioning economies, including infrastructure limitations, digital skills gaps, legal constraints, and institutional resistance to change.

A major contribution of this research is the development of a context-sensitive framework for integrating smart manufacturing principles into governmental procurement systems in Uzbekistan. The study highlights that technological modernization alone is insufficient without parallel improvements in regulatory enforcement, institutional capacity, data governance, and stakeholder engagement. Furthermore, ethical considerations such as algorithmic transparency, fairness, and accountability must remain central to the deployment of AI-driven procurement systems.

Overall, the research concludes that the future of public procurement lies in intelligent digital transformation supported by Industry 4.0 innovations. By adopting a strategic and phased approach to technological integration, Uzbekistan can strengthen procurement governance, enhance public sector efficiency, and create a more transparent and competitive procurement environment aligned with international best practices.

REFERENCES

1. Albano, G. L., & Ponti, M. (2008). Competitive selection in public procurement. In N. Dimitri, G. Piga & G. Spagnolo (Eds.), Handbook of Procurement (pp. 53-79). Cambridge University Press.
2. Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: A literature review. International Journal of Production Research, 57(15–16), 4719–4742.
3. Bovens, M., & Zouridis, S. (2002). From street-level to system-level bureaucracies: How information and communication technology is transforming administrative discretion and constitutional control. Public Administration Review, 62(2), 174–184.

4. Bof, F., & Previtali, P. (2007). Organisational pre-conditions for e-procurement in governments: The Italian experience in the public health care sector. Electronic Journal of e-Government, 5(1), 1–10.
5. Croom, S., & Brandon-Jones, A. (2007). Impact of e-procurement: Experiences from implementation in the UK public sector. Journal of Purchasing and Supply Management, 13(4), 294–303.
6. Davis, J., Edgar, T., Porter, J., Bernaden, J., & Sarli, M. (2015). Smart manufacturing, manufacturing intelligence and demand-dynamic performance. Computers & Chemical Engineering, 47, 145–156.
7. Fazekas, M., & Kocsis, G. (2020). Uncovering high-level corruption: Cross-national objective corruption risk indicators using public procurement data. British Journal of Political Science, 50(1), 155–164.
8. Ghadimi, P., Wang, C., Lim, M. K., & Nick, C. (2019). Intelligent sustainable supplier selection using multi-agent technology: Theory and application for industry 4.0 supply chains. Computers & Industrial Engineering, 127, 588–600.
9. Henriksen, H. Z., & Mahnke, V. (2005). E-procurement adoption in the Danish public sector: The influence of economic and political rationality. Scandinavian Journal of Information Systems, 17(2), 85–106.
10. Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. International Journal of Production Research, 57(3), 829–846.