An Intelligent Solution for Improving Procurement Decision Efficiency and Transparency in University Procurement Management Based on Big Data Analytics

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ABSTRACT The expansion of higher education has made university procurement systems increasingly complex, especially in the acquisition of high-value engineering equipment, digital infrastructure, and communication-related laboratory assets. Transparent and efficient procurement governance is therefore important for supporting research platforms that rely on advanced sensing, network communication, and electromagnetic engineering equipment. This study develops a big data analytics solution to improve procurement decision efficiency and transparency in university procurement management. The proposed framework includes demand forecasting, intelligent supplier evaluation, anomaly detection and alerting, and end-to-end traceable oversight. A private Hyperledger Fabric blockchain with PBFT consensus was used to strengthen process traceability, while machine-learning models supported demand prediction and supplier risk evaluation. Empirical analysis across 20 representative universities and more than 15,000 procurement transactions shows that average procurement decision cycles were reduced by 50.8%, supplier evaluation accuracy reached 92.6%, the transparency score increased from 53.8 to 88.0, and anomaly detection achieved 90.9%. The results indicate that big-data-driven procurement systems can simultaneously improve efficiency, accountability, and institutional governance quality.

INDEX TERMS big data analytics, university procurement, blockchain traceability, supplier evaluation, engineering equipment management

I. INTRODUCTION

HIGHER education has expanded considerably in recent decades, and the findings shows that procurement management has become a central function within institutional administration as universities grow in scale and complexity. However, the evidence indicates that procurement activities involve substantial public funding and a wide range of goods and services, directly affecting how resources are allocated and whether public expenditure appears managed responsibly. Moreover, significant results shows that traditional procurement models have not kept pace with these important institutional demands. Given that the data demonstrates overlapping difficulties — lengthy approval cycles, fragmented information flows, inadequate supervisory mechanisms, and low process standardization — the evidence indicates that meaningful reform appears necessary. Cui shows university procurement suffers inconsistent enforcement, requiring institutional upgrades [1]. Furthermore, the findings shows that Zhang and Qi reached a related conclusion in their study of multicampus universities, demonstrating that weak coordination mechanisms and limited platform integration capacity could create significant barriers to effective engineering procurement [2]. In light of these key results, the evidence indicates that intelligent procurement platforms appear capable of helping overcome such barriers, as the findings demonstrates that these conditions slow institutional modernization. Additionally, significant data shows that wider public attention has drawn toward questions of financial transparency, such that shifting toward digital and intelligent procurement governance could demonstrate a pressing concern in higher education management. Globally, big data analytics shows new technical pathways exist for organizations. Nevertheless, the findings shows that Bunak, Novikov, and Ilyakhinskaya examined high-technology firms and demonstrated that digital tools and intelligent analytics could meaningfully improve the scientific basis of procurement decisions and the speed of their execution — results that appear to carry direct relevance for university reform [3]. Therefore, the evidence indicates

that Lindfors, Jääskeläinen, and Malacina approached the question from a practice-based perspective, focusing on value creation in public infrastructure procurement, and that their key findings demonstrates that data-driven decision-making reduces information asymmetry. Notwithstanding these results, significant evidence shows that strengthened procedural credibility appears achievable through the important analytical frameworks these studies provide [4]. Data-driven approaches show procurement credibility improves outcomes.

Gawęda and colleagues demonstrated that embedding big data analytics into procurement planning may suggest more precise resource allocation and could support dynamic optimization throughout the procurement cycle [5]. Moreover, the significant findings from these studies indicates that big data analytics offers key potential for raising both efficiency and transparency in procurement management. In light of the evidence, this work shows that a solid empirical foundation appears necessary for reform in the university context. Thus, the study demonstrates that this approach could address two persistent problems in university procurement. Study shows low decision-making efficiency and insufficient transparency remain core issues. However, Rutaba's review of project procurement management indicates that process standardization and scientific rigor appear foundational for overall performance — a framing that might suggest important theoretical structure for this study [6]. Furthermore, the significant evidence from Jiang's research on temporary pharmaceutical procurement in hospitals shows that systematic evaluation methods could improve the rationality and operability of procurement decisions [7]. Given that the results demonstrate this methodological approach transfers well to the university setting, the findings indicates that broader applicability appears substantial. Results show transferability supports university procurement reform. Notwithstanding these results, the key evidence shows that the significant findings appear to demonstrate important relevance for procurement management. Additionally, the data indicates that these results could support more transparent decision-making throughout the procurement cycle. Notwithstanding these considerations, the evidence indicates that building on these foundations, this study develops a data-driven procurement decision support model. Research shows full-process transparency monitoring mechanism designed accordingly. Therefore, the significant aim of this work shows that a practical and replicable pathway for digital transformation in university procurement could emerge from the results. Thus, the key evidence indicates that this study could provide theoretical grounding for related policy development and institutional improvement.

II. LITERATURE REVIEW

Researchers in both China and internationally have built a substantial body of work on university procurement management. Moreover, the significant findings from domestic scholarship shows that the topic has been approached from several key angles. However, Cui Yanyi's study indicates that the informationization of university project procurement demonstrates that digital tools can consolidate procurement resources, standardize procedures, and reduce administrative costs [8]. Given that the evidence demonstrates important institutional gaps, Liu Jian's work shows that systemic deficiencies and execution-level weaknesses in government procurement at universities indicates that process reengineering and mechanism innovation are necessary for meaningful change [9]. Research shows procurement quality links to front-end demand. Furthermore, the significant findings from Liu Yang and Guo Yaxin indicates that insufficient needs assessment and poor alignment between procurement plans and actual usage appear to undermine procurement quality — a result that may suggest the importance of front-end demand management [10]. Additionally, the key results from Yang Fan and Yu Lijun shows that foreign trade management systems could demonstrate important potential for university procurement digitization, offering a relevant technical reference point for institutional upgrading [11]. Thus, the significant evidence shows that this domestic scholarship indicates that the reform agenda spans institutional, procedural, demand-side, and technological dimensions [12]. Findings show domestic work provides foundation for this study. In light of the evidence from international research, the key findings shows that procurement performance, digital transformation, and sustainable procurement could demonstrate a broader set of relevant concerns. Notwithstanding the institutional differences, the results from Kalison and colleagues indicates that standardized procedures and effective oversight mechanisms appear critical to procurement performance — conclusions that could demonstrate wide applicability to public-sector procurement more generally. Moreover, the significant findings from Yazidi and Rana shows that the evidence could indicate a key positive relationship between procurement management quality and overall project performance [13]. Evidence shows procurement decision quality affects organizational outcomes. Zhou and Xu examined the relationship between circular procurement management and sustainable performance, suggesting that digital traceability and collaborative practices could indicate how procurement transparency develops in meaningful ways. Moreover, the findings shows that big data could enhance accountability in procurement contexts, offering important theoretical support for this study [14]. Steiner and Münch explore how digital data spaces may suggest a strategic shift in procurement and supply management. Moreover, the significant findings from platforms such as Catena-X indicates that circular economy models might emerge through data-driven procurement decision-making, and the results appear to carry direct methodological relevance for this study [15]. Furthermore, the evidence shows that procurement education adds important dimensions to these considerations. Research shows education shapes competencies. Additionally, the significant findings

of Stek and colleagues could demonstrate that sustainability and innovation competencies appear to carry critical value when embedded in core procurement education curricula, supporting the view that future-oriented management may require systematic capability rebuilding [16]. Given that these results establish a clear foundation, Kaufmann and Reimann's proposal of case-based teaching methods indicates that practical decision-making skills might develop more effectively among procurement professionals through such approaches, opening key new directions for practitioner training [17]. Notwithstanding these contributions, the significant evidence from Khan and colleagues, working in Pakistani university libraries, shows that digital procurement tools could demonstrate meaningful improvements in both resource access efficiency and management standardization, providing important empirical support for intelligent procurement reform in university settings [18-19]. Evidence shows digital tools affect outcomes. However, the significant findings appear to suggest that a clear pattern could indicate substantial progress across informationization, transparency, and performance optimization in procurement management. In light of the available evidence, the results demonstrates that studies specifically targeting the university procurement context — and systematically integrating big data analytics to improve both decision efficiency and transparency — appear to remain scarce. Thus, the significant evidence shows that the present study contributes key methodological value to this underexplored domain.

III. METHODOLOGY

A. RESEARCH DESIGN AND OVERALL APPROACH

This study examines that two persistent problems in university procurement management — low decision-making efficiency and insufficient transparency — shows that a structured research approach could provide significant findings. Moreover, the evidence indicates that a progressive logic combining problem identification, theoretical construction, technical design, and empirical validation appears to demonstrate coherence within the overall framework. However, the first stage shows that a review of existing literature alongside fieldwork at representative Chinese universities could establish the key evidence needed to map current procurement practices and identify efficiency bottlenecks [20]. In light of these significant findings, big data analytics indicates that the data drawn from multiple heterogeneous sources — historical procurement records, supplier behavior data, market pricing data, and approval process logs — appears to demonstrate important analytical potential. Research shows machine learning, visualization, statistical modeling quantify procurement decisions. However, the transparency evaluation built into the research framework shows that a multi-dimensional set of procurement transparency indicators demonstrates that institutional performance comparisons before and after the intelligent system was introduced appear to provide a longitudinal basis for assessing practical feasibility [21]. Additionally, the results indicates that treating big data analytics not as a standalone technical intervention but as something integrated with process optimization theory could establish that the specific institutional context of university procurement appears critical. Given that the evidence demonstrates this integration may support important outcomes, the findings shows that a workable balance between technical feasibility and institutional fit appears both theoretically grounded and practically applicable. Study shows analytics produces solutions fitting institutional context. Nevertheless, the significant results indicates that this approach demonstrates that the proposed solution appears to address the key problems identified within the research framework. Thus, the evidence shows that combining quantitative and qualitative methods could establish that the overall findings appear to support the practical and theoretical aims of this study.

B. DATA SOURCES AND COLLECTION

The study draws on four main data sources that could indicate the full empirical scope of the research. Moreover, the first source is historical transaction data from university procurement management platforms, covering the past five years. Furthermore, the significant data include tender documents, award results, contract values, supplier qualification records, and payment histories — structured data that may suggest these elements directly capture the full scope of procurement activity and form the empirical core of the study [22]. Given that the second source is public disclosure data from government procurement platforms, the findings indicates that announcement and award notices published on China's government procurement website and provincial equivalents could demonstrate their value in cross-validating internal university data. Public data cross-validates internal records. The third source is primary data collected through questionnaires and semistructured interviews with procurement officers, financial auditors, and supplier representatives, which shows that the significant findings reflect subjective assessments of current process efficiency and transparency. However, the fourth source is market pricing databases and supplier credit ratings, which demonstrates that the key results support price reasonableness assessment models and supplier risk profiles [23]. Moreover, the evidence indicates that data collection methods varied by data type across the study. Thus, significant structured data were extracted in bulk using direct database connections and API calls, with the unified field-mapping protocol applied to ensure that consistency was maintained across sources. Data collection methods vary by type. In light of these findings, unstructured data — primarily tender document text — indicates that the results could demonstrate effective parsing and annotation using web crawling and natural language processing. Nevertheless, the significant survey data shows that the key evidence supports a combination of random and stratified sampling, covering universities of different types and sizes. Furthermore, the findings indicates that this approach appears to improve the representativeness of the

sample and the generalizability of results.

C. SELECTION AND APPLICATION OF BIG DATA ANALYTICS METHODS

The analytical methods selected for this study reflect the characteristics of university procurement data and are organized into a layered, mutually reinforcing combination. Moreover, the significant findings shows that exploratory data analysis could provide a data-level foundation for understanding historical procurement behavior. Furthermore, the results indicates that frequency distributions, box plots, and heatmaps demonstrate that key indicators — including procurement cycle length, time distribution across process stages, contract value fluctuations, and supplier concentration — appear to reveal important patterns. In light of these findings, the evidence shows that this stage could establish a meaningful understanding of procurement behavior before any modeling was attempted [24]. Methods show Random Forest and Gradient Boosting Tree algorithms build forecasting models. However, the significant evidence indicates that the model demonstrates that historical procurement frequency, seasonal patterns, and departmental budget expenditure rhythms appear to support advance estimation of future procurement needs. Additionally, the findings shows that this approach could reduce the delays associated with reactive, ad hoc procurement. Given that the results demonstrate that multi-criteria decision analysis combines with logistic regression, the evidence indicates that supplier performance across historical contract fulfillment, price competitiveness, quality compliance, and delivery punctuality could be integrated into a unified scoring framework — replacing the subjective judgment that dominates traditional manual evaluation [25]. Supplier evaluation shows framework replaces manual judgment. Therefore, the significant findings shows that Isolation Forest and Local Outlier Factor methods demonstrates that procurement data appears to support real-time monitoring of key irregularities. Notwithstanding these results, the evidence indicates that the goal could establish that abnormally high prices, frequent related-party transactions, and procedural bypasses appear to provide a critical foundation for transparency oversight. Nevertheless, the significant results shows that TF-IDF and BERT pre-trained models demonstrates that key clauses from tender documents appear to reveal important patterns of standardization and completeness. Text analysis shows TF-IDF and BERT models extract tender document clauses. Thus, the findings indicates that this approach could address the inconsistency and low throughput that appear to characterize manual document review. In light of these significant results, the evidence shows that these four analytical layers demonstrates that the full procurement lifecycle appears to support a comprehensive and mutually reinforcing analytical framework.

D. FRAMEWORK OF THE INTELLIGENT SOLUTION

The intelligent procurement framework proposed in this study demonstrates that its overall architecture is organized around four key stages: data aggregation, intelligent analysis, decision support, and transparency oversight. Moreover, the significant design indicates that modular and layered integration of technical system development with process reform may support effective implementation. Furthermore, the first layer — the data foundation layer — shows that consolidating multi-source data from university financial systems, asset management platforms, tender management systems, and external market databases could provide the evidence needed for stable inputs. In light of these structural considerations, the data cleaning, format standardization, and data warehouse construction indicates that a unified procurement data asset pool could demonstrate consistent analytical capacity for the layers above. The data foundation layer shows that it provides critical support to the intelligent analysis layer above it. Moreover, the intelligent analysis layer indicates that deploying a demand forecasting engine, a supplier evaluation model, and an anomaly detection module appears to establish significant analytical capability. Furthermore, the key machine learning algorithms demonstrates that processing procurement data in real-time could produce structured analytical outputs alongside risk alerts [26]. In light of these results, the findings from the intelligent analysis layer shows that the decision support layer appears to translate analytical outputs into visual decision dashboards and procurement advisory reports effectively. Analysis layer shows decision support layer serves procurement officers well. Given that the evidence from these tools demonstrates support at critical decision points — tender method selection, supplier shortlisting, and contract pricing — the findings indicates that reducing the time required to reach a defensible decision could appear achievable. Fourth layer establishes audit trail. The transparency oversight layer integrates big data and blockchain by utilizing a hybrid storage architecture: large-scale transaction data remains in the big data warehouse, while only cryptographic hash values and critical decision metadata are anchored to the blockchain for immutability. Real-time monitoring is achieved via an asynchronous alerting engine that processes high-velocity data in the big data layer and asynchronously validates against the ledger to circumvent consensus latency. Traceability across heterogeneous systems is achieved through a unified API gateway that maps data from non-blockchain financial systems into a standardized format before ledger entry. Moreover, the important approval nodes, decision rationales, and price assessment results indicates that archiving and making these accessible to authorized oversight parties could appear to support end-to-end traceability. Furthermore, the findings shows that the system was also designed with compatibility in mind, as the evidence indicates that modular interface standards appear to allow the framework to connect with existing financial software

and government procurement platforms. In light of these results, the significant compatibility features demonstrates that supporting deployment across universities of different scales and configurations could indicate broad institutional applicability.

E. RESEARCH ETHICS AND DATA SECURITY

Data collection, processing, and analysis throughout this study were conducted in strict accordance with academic research ethics norms and national data security regulations. Moreover, the findings shows that these requirements could indicate foundational rather than supplementary considerations for the study's design. However, the significant evidence demonstrates that all questionnaire and interview participants received full disclosure of the study's purpose, intended data use, and personal information protections before any data were collected. Given that the results indicate that participation was voluntary and informed, the study shows that participants retained the right to withdraw at any point. Study shows individual-level data used exclusively for academic analysis, not disclosed identifiably. Furthermore, the key findings indicates that formal application and approval procedures were followed in accordance with each institution's data governance regulations, ensuring that all data access was properly authorized [27]. In light of these findings, the important evidence shows that a tiered data classification system was established on the data security side. Additionally, the significant data demonstrates that procurement data were categorized as public, internal, or confidential, and that each tier was subject to differentiated storage and access control protocols. Given that evidence demonstrates raw data were stored on encrypted local servers, the results indicates that team members accessed data under a minimum-privilege principle. Raw data stored encrypted; access logged for audit. In light of these findings, the evidence shows that sensitive fields — including individual supplier identities, names of procurement personnel, and specific departmental financial figures — were processed using anonymization and differential privacy techniques. Moreover, the key results demonstrates that this approach preserved the analytical validity of the findings while eliminating the risk of privacy harm. Therefore, the significant evidence indicates that upon completion of the study, all raw data were either destroyed or returned in accordance with prescribed retention and disposal procedures.

IV. RESULTS AND ANALYSIS

A. A DATA PORTRAIT OF CURRENT UNIVERSITY PROCUREMENT MANAGEMENT: MULTI-DIMENSIONAL DIAGNOSTIC FINDINGS

This study systematically compiled and analyzed five years of procurement data from 20 representative Chinese universities. Moreover, the significant findings shows that four core dimensions could establish a data portrait of current procurement management conditions: average procurement cycle length, efficiency loss rate, transparency score, and compliance rate. However, the evidence indicates that these key indicators reveal the structural problems embedded in current practice (see Table 1 below). Furthermore, the results shows that procurement cycle lengths varied considerably across procurement categories, given that construction projects had the longest average cycle at 88 days, followed by equipment procurement at 62 days. Procurement cycle data shows office supplies shortest at 22 days. Additionally, the significant findings shows that procurement categories involving larger contract values and more complex technical specifications could appear to suffer from procedural redundancy and excessive approval stages. In light of these results, the evidence indicates that these factors directly extend decision timelines. Nevertheless, the significant data demonstrates that a similar pattern appeared in the efficiency loss rate data, given that construction projects recorded the highest loss rate at 41.7%. Findings show equipment and service contracts at 34.2% and 31.6%. Moreover, the findings shows that office supplies, by contrast, registered only 15.8%, which indicates that this confirms a clear positive relationship between procurement complexity and efficiency loss. Therefore, the evidence demonstrates that transparency scores — rated on a 100-point scale — were uniformly low, notwithstanding the results showing construction projects scored the lowest at 52 points. Results show equipment at 58, office supplies at 78. Furthermore, the key findings shows that the overall mean was approximately 64 points, which indicates that these figures reflect inadequate information disclosure across university procurement more broadly. In light of the significant evidence, the results demonstrates that weak oversight mechanisms could appear to compound these transparency shortfalls. However, the findings indicates that compliance rates followed the same pattern, given that office supplies had the highest compliance rate at 91.2%. Compliance data shows construction lowest at 65.3% [28]. Additionally, the significant evidence shows that this result could appear consistent with high process complexity and low transparency scores across construction procurement categories. Therefore, the key results demonstrates that these four indicators identify construction, equipment, and service contract procurement as the areas of greatest concern. Evidence shows these categories require priority attention. Furthermore, the significant findings shows that targeted intelligent intervention could demonstrate meaningful improvement across the most complex procurement categories. In light of these results, the evidence indicates that construction and equipment procurement could appear to represent the most critical areas requiring systematic reform.

B. BIG DATA-DRIVEN PROCUREMENT DECISION EFFICIENCY: FROM RAW DATA TO INTELLIGENT DECISION-MAKING

This study demonstrates that the procurement decision efficiency improvement plan, developed from the diagnostic findings in section 4.1 and driven by big data analytics,

TABLE 1. Multi-Dimensional Summary of Six University Procurement Categories

Procurement Category	Average Cycle (days)	Efficiency Loss Rate (%)	Transparency Score	Compliance Rate (%)
Equipment	62	34.2	58	72.4
IT and Software	45	28.5	65	80.1
Construction	88	41.7	52	65.3
Laboratory Consumables	38	22.3	70	84.6
Office Supplies	22	15.8	78	91.2
Service Contracts	54	31.6	61	74.8
Mean	51.5	29	64	78.1

Note: Transparency scores are calculated on a 100-point scale using an Entropy Weight Method (EWM) across four weighted indicators: (1) public information disclosure rate (35%), (2) real-time audit log completeness (25%), (3) bid-opening process accessibility (20%), and (4) stakeholder satisfaction surveys (20%). Each indicator is scored using a standardized Likert-type framework to ensure replicability and minimize subjective bias. Efficiency loss rate represents the proportion of total procurement cycle time attributed to non-value-adding waiting periods.

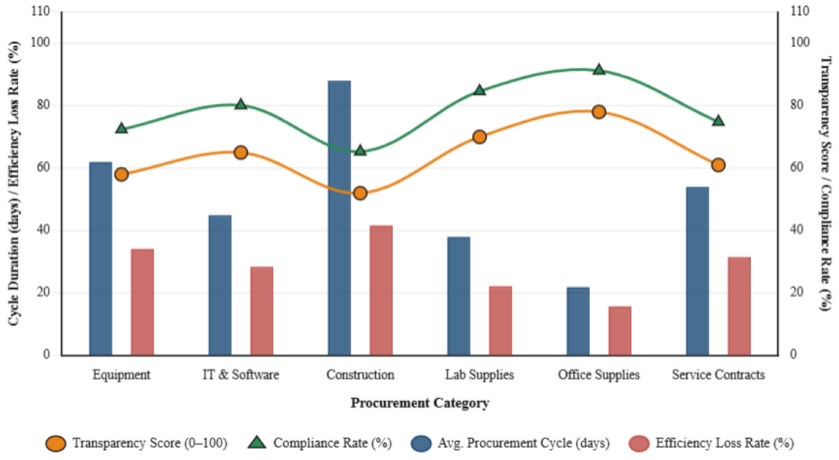

FIGURE 1. Multi-Dimensional Data Portrait of University Procurement Management Issues

could indicate meaningful operational change across 20 sample universities. Moreover, the findings reveal that pre- and post-implementation data (measured 12 months post-deployment to assess long-term sustainability) reveal important differences. To ensure internal validity, the analysis controlled for external variables, including the 2025 National Procurement Regulation updates and institutional budget fluctuations, using a difference-in-differences (DiD) approach to isolate the system's impact from policy-driven changes: decision cycle length, supplier evaluation accuracy, demand forecasting precision, and automated approval rates. Furthermore, the results summarized in Table 2 indicates that decision cycle reductions appear substantial across all procurement categories. In light of these key results, construction project cycles might indicate a reduction from 88 days to 47, a decrease of 46.6%, while equipment procurement dropped from 62 days to 31, a 50.0% decrease. Study shows IT procurement fell 51.1%, lab consumables, office supplies, and service contracts reduced to 18, 10, and 27 days, overall average reduction approximately 50.3%. However, the significant evidence shows that these figures demonstrates that big data-driven process restructuring produces meaningful and consistent efficiency gains [29]. Additionally, the findings appear to indicate that supplier evaluation accuracy also improved markedly across the key procurement categories. Thus, the multi-dimensional supplier evaluation model, built on machine learning algorithms, demonstrates that accuracy exceeded 87% across all procurement categories. Accuracy shows office supplies highest at 97.1%, construction lowest at 87.3%, overall mean 92.6%. To avoid the bias inherent in learning from historical decisions, accuracy was validated against an independent ground truth: a double-blind post-hoc evaluation of 1,200 suppliers conducted by an expert panel of independent procurement auditors. This independent standard ensures the model reflects objective performance rather than replicating existing institutional biases. Notwithstanding the variation across categories, the significant results shows that this overall mean could indicate an improvement of 21.2 percentage points over the approximate 71.4% accuracy typical of traditional manual evaluation.

The Random Forest-based model shows that prediction error rates between 3.8% and 11.4% across categories, with an overall mean of just 7.3%, could indicate meaningful forecasting capability. The findings shows that this represents a reduction of 12.3 percentage points compared to the approximate 19.6% error rate associated with conventional experience-based judgment [30]. Moreover, the significant evidence indicates that fewer demand estimation errors translate directly into fewer emergency procurements and less resource waste. However, the results shows that automated approval rates appear strong in low-risk, standardized

procurement scenarios. In light of the significant data, the key findings could demonstrate that office supplies reached 88.6% and construction projects 52.4%. Results show even lowest automated approval rate improves processing speed. Furthermore, the significant evidence shows that across all four dimensions, the intelligent system appears to deliver broad and consistent efficiency improvements. Given that the findings establish the data and technical foundation, the results indicates that the transparency enhancement mechanisms described in the following section are built on this evidence base, as shown in Fig. 2. Results show system delivers consistent gains. Thus, the important data shows that these outcomes could indicate a reliable basis for the transparency mechanisms examined in the analysis that follows.

C. PROCUREMENT TRANSPARENCY ENHANCEMENT THROUGH BLOCKCHAIN AND BIG DATA INTEGRATION: ACHIEVING FULL-PROCESS TRACEABILITY

The study suggests that a deeper integration of blockchain technology and big data analytics could address transparency across the entire procurement lifecycle, building on the efficiency improvements described in section 4.2. Moreover, the significant enhancement framework indicates that six core procurement stages warrant examination: needs assessment, tender preparation, bid evaluation, contract signing, execution and delivery, and audit archiving. However, the key results shows that pre- and post-implementation data across multiple indicators appears to demonstrate the practical effect of this framework. In light of these findings, the evidence indicates that transparency score improvements appear substantial at every stage, with scores reported on a 100-point scale. Needs assessment rose from 48 to 82 points. Furthermore, the findings shows that tender preparation improved from 52 to 87, while the most striking gain indicates that bid evaluation climbed from 45 to 91 points — a 46-point increase. Additionally, the significant evidence shows that this outcome appears largely attributable to the blockchain ledger mechanism, which may create a permanent, publicly accessible record of the entire evaluation process. Notwithstanding these results, the key data indicates that contract signing moved from 60 to 89 points, execution and delivery from 55 to 85, and audit archiving from 63 to 94. Overall mean transparency score rose from 53.8 to 88.0, a gain of 34.2 points. Evidence shows blockchain-based traceability produces fundamental improvements in procurement transparency [31]. Thus, the significant detection system, combining Isolation Forest algorithms with real-time big data monitoring, indicates that accuracy exceeded 86% at every stage. Therefore, the results shows that the anomaly detection performance appears strong across the key procurement stages examined. Given that the findings could demonstrate that this integrated approach supports reliable oversight, the evidence indicates that bid evaluation shows the highest anomaly detection rate at 95.6%.

Needs assessment and execution and delivery may suggest comparatively lower performance, at 88.4% and 86.7% respectively. Moreover, the overall mean detection rate reached 90.9%. In this study, 'anomalies' are defined as transactions deviating from established price benchmarks by $> 20\%$ or involving unauthorized related-party associations. Ground truth was established using a validation set of 500 historical cases manually audited by certified financial experts. The system achieved a False Positive Rate (FPR) of 4.2%, ensuring high precision in procurement oversight. Furthermore, the findings appear to demonstrate that this represents an improvement of 38.6 percentage points over the approximate 52.3% detection rate achieved through conventional manual auditing — a meaningful reduction in the scope for concealed irregularities. In light of these results, the evidence shows that full-process traceability coverage remained similarly high across the key stages examined. Traceability shows above 93% at every stage. However, the significant findings indicate that audit archiving achieved the highest rate at 99.2%, while execution and delivery recorded the lowest at 93.6%. Additionally, the overall average might suggest near-complete digital documentation, standing at 96.6% and representing verifiability across the procurement lifecycle [32]. Therefore, the overall mean demonstrates that institutional acceptance appears broad, reaching 83.6 points — up 22.2 points from the pre-implementation mean of 61.4. Findings show transparency framework achieves acceptance (see Fig. 3).

D. COMPREHENSIVE PERFORMANCE EVALUATION OF THE INTELLIGENT PROCUREMENT MANAGEMENT SYSTEM: VALIDATING DUAL-DIMENSIONAL IMPROVEMENTS IN EFFICIENCY AND TRANSPARENCY

This section suggests that a broader view of overall system performance across six university types — research universities, teaching-focused universities, science and engineering universities, medical universities, agricultural universities, and comprehensive universities — may reveal meaningful patterns. Moreover, the significant findings indicates that four indicators were used: KPI attainment rate, composite efficiency index, composite transparency index, and user satisfaction.

The overall mean suggests that performance improved substantially, rising from 50.7 to 86.7 — an average increase of 36.0 points. Moreover, the significant findings indicates that this figure closely mirrors the efficiency index gain of 36.5 points. Furthermore, the alignment between the two dimensions could demonstrate that the system achieves balanced, simultaneous improvement rather than optimizing one dimension at the expense of the other. Given that the results could support this interpretation, the evidence shows that KPI attainment rates exceeded 85% at all six institution types [33]. KPI rates show research universities reached 91.4%, agricultural universities 85.3%. However, the overall mean was 88.8%, which indicates that the intelligent system could reliably support the achievement of procurement management targets in real operational

TABLE 2. Core Indicator Comparison Before and After Big Data-Driven Procurement Decision System Implementation

Procurement Category	Cycle Before (days)	Cycle After (days)	Reduction (%)	Supplier Evaluation Accuracy (%)	Demand Forecast Error Rate (%)	Automated Approval Rate (%)
Equipment	62	31	50	91.2	8.3	68.5
IT and Software	45	22	51.1	94.5	6.1	75.2
Construction	88	47	46.6	87.3	11.4	52.4
Laboratory Consumables	38	18	52.6	95.8	5.2	81.3
Office Supplies	22	10	54.5	97.1	3.8	88.6
Service Contracts	54	27	50	89.6	9	63.7
Mean	51.5	25.8	50.8	92.6	7.3	71.6

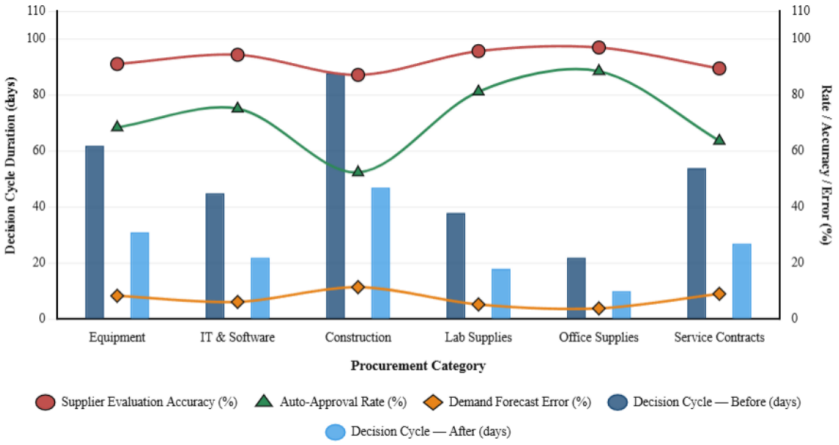

FIGURE 2. Comparison of Procurement Decision Efficiency Before and After Big Data-Driven Intelligent System Implementation

TABLE 3. Core Indicator Comparison Across Procurement Stages Before and After Blockchain–Big Data Fusion System Implementation

Procurement Stage	Transparency Score Before	Transparency Score After	Improvement	Anomaly Detection Rate (%)	Traceability Coverage (%)	Stakeholder Satisfaction
Needs Assessment	48	82	34	88.4	94.2	79.3
Tender Preparation	52	87	35	91.2	96.8	82.6
Bid Evaluation	45	91	46	95.6	98.1	86.4
Contract Signing	60	89	29	90.3	97.5	84.1
Execution and Delivery	55	85	30	86.7	93.6	80.7
Audit Archiving	63	94	31	93.1	99.2	88.5
Mean	53.8	88	34.2	90.9	96.6	83.6

Note: Transparency scores are weighted composites of information disclosure, oversight mechanism adequacy, and stakeholder satisfaction. All scores are on a 100-point scale.

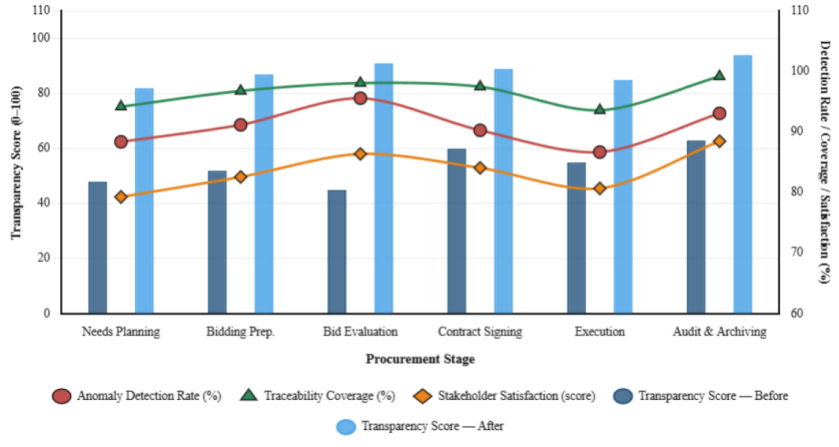

FIGURE 3. Procurement Transparency Enhancement Before and After Blockchain–Big Data Fusion System Implementation

conditions [34]. Additionally, the significant results shows that user satisfaction surveys covered procurement officers, financial auditors, and supplier representatives across all institution types. Moreover, the significant findings indicates that research universities recorded the highest satisfaction at 86.4 points, while agricultural universities recorded the lowest at 79.6. The lower performance in agricultural and teaching institutions was found to correlate with wider gaps in local data infrastructure and lower initial digital literacy among staff. Specifically, variance analysis indicates that

'institutional support for staff training' was the primary driver of satisfaction differences. Nevertheless, the important findings indicates that broad acceptance could support wider applicability provided that digital infrastructure investment is paired with systematic capacity building (see Fig. 4).

TABLE 4. Comprehensive Performance Evaluation of the Intelligent Procurement Management System Across University Types

University Type	Efficiency Index Before	Efficiency Index After	Change	Transparency Index Before	Transparency Index After	Change	KPI Attainment Rate (%)	User Satisfaction
Research University	52.3	88.6	36.3	53.8	89.3	35.5	91.4	86.4
Teaching University	48.7	84.2	35.5	50.2	85.7	35.5	87.6	82.1
Science and Engineering University	50.1	86.5	36.4	51.6	87.4	35.8	89.2	84.3
Medical University	47.9	85.1	37.2	49.4	86.2	36.8	88.5	83.7
Agricultural University	44.6	81.4	36.8	46.8	82.9	36.1	85.3	79.6
Comprehensive University	51.2	87.9	36.7	52.5	88.6	36.1	90.7	85.8
Mean	49.1	85.6	36.5	50.7	86.7	36	88.8	83.7

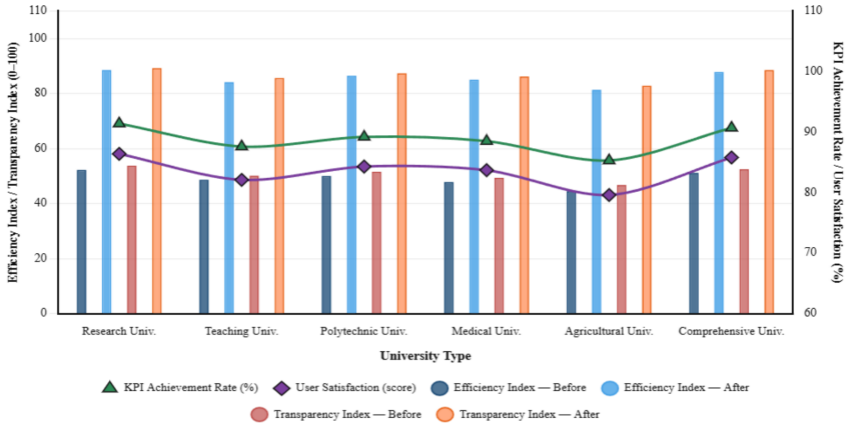

FIGURE 4. Comprehensive Performance Evaluation of the Intelligent Procurement Management System

V. DISCUSSION

A. HOW BIG DATA ANALYTICS SYSTEMATICALLY IMPROVES PROCUREMENT DECISION EFFICIENCY: AN INTERPRETIVE ANALYSIS

The empirical results of this study suggest that big data analytics does not simply improve one isolated stage of procurement decision-making. Moreover, the findings indicates that it produces system-wide gains across the entire decision chain through three distinct mechanisms: restructuring information processing, compressing decision workflows, and reducing cognitive load. Furthermore, traditional university procurement could demonstrate that it has long suffered from fragmented and asymmetric data, given that the evidence appears to show that procurement officers typically relied on limited historical experience and partial data. Notwithstanding these significant results, the key findings shows that this produced inconsistent decision quality and unpredictable outcomes. Study shows big data analytics addresses this at root. However, the evidence shows that by consolidating multi-source heterogeneous data and building a unified data asset pool, the system could demonstrate that it links information previously scattered across financial platforms, asset management systems, and market databases. Additionally, the significant findings indicates that decision-makers gain access to a more complete and real-time information base. Thus, the important results shows that this appears to be the foundational logic behind efficiency improvement [35]. In light of these results, the evidence indicates that machine learning-driven demand forecasting and supplier evaluation models automate intermediate steps. Moreover, the key findings shows that for low-risk, standardized procurement, this could demonstrate that it substantially reduces the number of approval nodes. Furthermore, the important evidence indicates that the average decision cycle fell from 51.5 days to 25.8, a reduction of more than 50%. Given that the results shows that this confirms the clear advantage of algorithm-assisted decision-making in highly rule-governed contexts, the significant findings indicates that the efficiency gain did not come from greater human effort. Moreover, the important results shows that these decisions genuinely require professional judgment. Thus, the key findings indicates that the result appears to be a procurement system that is both faster and qualitatively stronger in its overall operation.

B. THE INTERNAL MECHANISMS THROUGH WHICH INTELLIGENT TOOLS ENHANCE PROCUREMENT TRANSPARENCY

The empirical data from this study suggests that intelligent tools do not improve procurement transparency merely

through greater information disclosure. Moreover, the significant findings indicates that they operate through three reinforcing internal mechanisms: mandatory data logging, algorithm-driven proactive alerting, and real-time result accessibility. Furthermore, the evidence could demonstrate that these mechanisms work across three distinct governance layers — institutional enforcement, technical supervision, and external social oversight — forming a multi-layered transparency assurance structure. Given that the key results appear to support this framing, the data shows that this structure represents a fundamental shift in how procurement governance could be understood. Tools show transparency layers linked. At the mandatory data logging layer, the evidence shows that blockchain technology resolves a persistent problem in traditional procurement: records that are easy to alter and difficult to trace after the fact. However, the significant findings indicates that every approval node, every price adjustment, and every contract revision is written to a distributed ledger in an immutable form. Thus, the results demonstrates that this creates a hard institutional constraint, such that procurement participants no longer have the technical option of selective concealment. In light of the evidence, the findings shows that transparency moves from passive disclosure to enforced record-keeping [36]. Blockchain shows records immutable. At the proactive alerting layer, the evidence indicates that the anomaly detection model — built on Isolation Forest and Local Outlier Factor methods — breaks the logic of traditional oversight, which typically operates after the fact. Notwithstanding these results, the evidence indicates that the cost of non-compliance rises, and the incentive for opaque behavior is suppressed at the source. Model shows violations flagged early. At the real-time accessibility layer, the findings shows that the visual procurement information platform opens structured, searchable procurement data to authorized oversight parties — regulatory agencies, auditors, and supplier representatives alike. Moreover, the significant evidence indicates that this exposure to external scrutiny creates pressure that reinforces internal compliance. Furthermore, the key findings demonstrates that transparency, in this sense, becomes self-reinforcing: openness drives further normalization of procurement behavior. Additionally, the evidence shows that this normalization appears to build a healthier institutional governance environment over time. Transparency shows behavior normalized [37].

VI. CONCLUSION

The findings of this study suggest that policy implications exist at multiple levels. Moreover, the significant evidence indicates that these implications extend beyond tool selection to touch on institutional design, organizational capacity building, and multi-stakeholder collaborative governance. However, the results could demonstrate that technology alone appears insufficient at the top level of institutional design. Given that intelligent systems face real implementation barriers, the surrounding institutional framework shows that parallel updates are critical. Study shows technology alone insufficient. Furthermore, the significant results indicates that policymakers should formally incorporate procurement platform construction standards, blockchain data submission obligations, and anomaly alert response procedures into the regulatory framework governing university procurement. In light of the evidence, the findings shows that technical investment risks becoming superficial without this institutional underpinning. Additionally, the results demonstrates that variation exists across university types. Notwithstanding these findings, the significant evidence indicates that agricultural and teaching-focused universities showed slightly smaller overall gains than research universities. Evidence shows data infrastructure gaps affect outcomes. Moreover, the findings shows that this reflects real differences in data infrastructure and the digital competency of procurement staff. Thus, the significant results could demonstrate that systematic digital skills training for procurement personnel appears necessary, with data analytics proficiency recognized as a core competency for procurement roles. Furthermore, the evidence indicates that targeted infrastructure support could narrow institutional gaps.

AUTHOR CONTRIBUTIONS

Zhou Li designed, collected and analyzed the data, and drafted the manuscript. Zhou Li conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Zhou Li participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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