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The Impact of the Open Budgeting System on Improving the Audit Process with Emphasis on Underlying Factors

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ABSTRACT

The purpose of this study was to examine the impact of the open budgeting system on improving the audit process, with a particular focus on identifying and prioritizing the underlying factors affecting this relationship. In terms of objective, the research is applied, and in terms of data collection method, it is survey-based. The statistical population consisted of 2,088 experts and auditors of the Supreme Audit Court of Iran, from which a sample of 325 participants was selected using Cochran's formula. Data were collected through a researcher-developed questionnaire and analyzed using Structural Equation Modeling (SEM), Confirmatory Factor Analysis (CFA), DEMATEL, and Fuzzy SAW techniques. The findings indicate that the implementation of the open budgeting system has a positive, direct, and statistically significant effect on the improvement of the audit process. The strongest direct relationship in the model was observed between "data security and integrity" and "audit process improvement," with a path coefficient of 0.67. DEMATEL analysis identified "traceability of financial transactions" as the most influential underlying factor (causality index = +0.47), while Fuzzy SAW analysis ranked "trust and participation strategies" as the top strategic priority (score = 0.782). Quantitatively, the implementation of this system led to a 38% reduction in audit time, a 30% reduction in audit costs, and a 160% increase in focus on advanced analytical activities. Consequently, the open budgeting system, by enhancing transparency, traceability, standardization, and data security, is not merely a supportive tool but a strategic transformation of the audit process that elevates auditors from the traditional role of "inspector" to that of an "active data-driven analyst." The success of this system requires simultaneous attention to technical, human, and organizational factors and strict adherence to the optimal sequence of strategy implementation.

Keywords: Open budgeting; Audit process; BOOST system; Financial transparency; Transaction traceability

Introduction

Public financial management has increasingly become a central concern of governments seeking to enhance economic stability, service delivery, and institutional legitimacy in complex and resource-constrained environments. Among the core pillars of public financial management, budgeting systems and audit mechanisms play a decisive role in ensuring fiscal discipline, transparency, accountability, and sustainable development (1). In recent decades,

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both developed and developing countries have experienced persistent challenges in aligning budgeting practices with effective oversight and audit processes, resulting in inefficiencies, fiscal risks, and declining public trust in governmental institutions (2). Consequently, reforming traditional budgetary systems has emerged as a strategic priority for governments pursuing improved governance, financial sustainability, and administrative performance (3, 4).

One of the most significant contemporary reforms in this domain is the transition from conventional closed budgeting frameworks toward more transparent and participatory models, particularly the adoption of open budgeting systems. Open budgeting refers to institutional arrangements in which budgetary information is made publicly accessible, machine-readable, and usable, while enabling stakeholder participation throughout the budget cycle, including formulation, execution, monitoring, and evaluation (5, 6). The emergence of open budgeting has been closely associated with the broader open government movement, which emphasizes transparency, citizen engagement, and data-driven governance as fundamental mechanisms for improving public sector performance (7). Empirical research demonstrates that open budget initiatives significantly enhance budget efficiency, accountability, and financial sustainability by strengthening oversight and enabling informed decision-making among public officials and external stakeholders (3, 5, 8).

Despite these promising developments, the relationship between open budgeting systems and the effectiveness of audit processes remains theoretically underexplored and empirically fragmented, particularly in developing and transitional economies. Auditing serves as the principal institutional safeguard that validates financial integrity, verifies compliance with regulations, and detects inefficiencies, fraud, and misallocation of public resources (1). However, the effectiveness of audit functions is highly dependent on the quality, accessibility, traceability, and reliability of financial data produced by budgeting systems (9). Where budget data are opaque, fragmented, delayed, or inconsistent, auditors encounter substantial obstacles that undermine audit quality and weaken fiscal oversight (2, 10).

Recent scholarship has begun to reveal that open budgeting can fundamentally transform audit practices by improving the informational environment within which auditors operate (5, 7). Open access to budgetary data enhances audit planning, risk assessment, and performance evaluation by reducing information asymmetry and enabling continuous monitoring of fiscal activities (6, 8). Moreover, advances in digital technologies—particularly blockchain and distributed ledger systems—have introduced unprecedented capabilities for financial traceability, immutability, and real-time verification of transactions, thereby strengthening audit reliability and efficiency (11). These technological developments offer new opportunities for integrating open budgeting with audit modernization initiatives.

At the same time, implementing open budgeting reforms presents complex technical, organizational, legal, and behavioral challenges. Empirical evidence from multiple public sectors indicates that budget reform initiatives frequently fail due to weak institutional capacity, resistance to change, insufficient infrastructure, and the absence of coherent implementation strategies (10, 12). Particularly in developing contexts, operational barriers such as fragmented information systems, limited human capital, and unstable regulatory frameworks hinder the realization of open budgeting objectives (2, 13). Consequently, successful adoption of open budgeting requires not only technical innovation but also carefully designed trust-building mechanisms, participatory governance arrangements, and strategic sequencing of reform measures (7, 14).

Trust constitutes a foundational dimension of open budgeting reform. Without institutional trust, stakeholders are reluctant to engage with budget data, utilize digital platforms, or cooperate with oversight institutions (7). Trust is built through consistent data accuracy, robust security protocols, transparent governance procedures, and visible responsiveness of public institutions to citizen feedback (6). In parallel, participatory mechanisms—such as public consultations, collaborative data analysis, and feedback channels—enhance the legitimacy and effectiveness of budgeting reforms by embedding social accountability within fiscal governance (3, 5). When citizens and professional communities actively engage with budget data, they contribute to error detection, performance improvement, and long-term fiscal sustainability (8).

Another critical enabling factor in strengthening the audit function under open budgeting is financial traceability. Traceability allows each financial transaction to be tracked from authorization to final expenditure, creating a transparent and verifiable audit trail (11). Blockchain-based solutions, in particular, provide immutable transaction records, significantly reducing the risks of data manipulation, fraud, and concealment of financial misconduct (11). Empirical studies demonstrate that enhanced traceability substantially improves audit quality by facilitating continuous auditing, real-time monitoring, and automated verification processes (9, 11).

Equally important are standardized financial reporting frameworks and integrated data architectures. Without harmonized reporting standards, open data may become inconsistent, incomparable, and operationally unusable for audit and policy analysis (15). Integrated standards provide a common language for public finance reporting, enabling cross-institutional comparison, performance benchmarking, and long-term fiscal evaluation (4, 14). Standardization also enhances the interoperability of information systems, which is essential for the effective functioning of open budgeting platforms (12).

In the context of Iran, structural weaknesses in the budgeting system—including forecasting inaccuracies, limited data accessibility, fragmented reporting practices, and insufficient audit coordination—have constrained fiscal governance and policy effectiveness (10, 16). Recent qualitative analyses of Iran's national budget reveal persistent gaps between formal budget regulations and actual implementation practices, highlighting the urgent need for systemic reform (16). Furthermore, operational budgeting reforms within the Iranian public sector continue to encounter resistance due to institutional inertia, limited managerial capacity, and insufficient technological readiness (12). These challenges underscore the necessity of designing an integrated reform model that links open budgeting adoption with audit process enhancement through carefully prioritized underlying factors and implementation strategies.

Although existing studies have separately examined budget transparency, audit quality, performance-based budgeting, and fiscal accountability, few have offered a comprehensive causal framework that systematically explains how open budgeting influences audit performance through interrelated technical, organizational, and behavioral mechanisms (3, 7, 14). Moreover, the prioritization of these mechanisms has rarely been addressed using advanced quantitative decision-support methods capable of capturing complex interdependencies among reform components (13). Consequently, policymakers often lack clear guidance on which factors should be addressed first and which strategies yield the greatest return under resource constraints.

This study seeks to bridge this critical research gap by developing and empirically validating a comprehensive model that explains the impact of open budgeting systems on improving the audit process, with a specific focus on identifying and prioritizing the underlying causal factors and execution strategies that drive this relationship. By integrating insights from public financial management theory, audit quality research, open government data

scholarship, and digital governance innovation (1, 7, 11), the study provides a multidimensional perspective on fiscal reform.

Furthermore, this research contributes methodologically by employing structural equation modeling alongside advanced multi-criteria decision-making techniques to capture both the strength of causal relationships and the strategic priority of reform components (12, 13). Such an approach enables policymakers to move beyond descriptive reform narratives toward evidence-based, sequenced, and implementable transformation strategies.

Ultimately, strengthening audit processes through open budgeting is not merely a technical upgrade but a paradigm shift that redefines the role of auditors from passive inspectors of historical records to proactive, data-driven analysts engaged in continuous fiscal oversight, risk management, and strategic advisory functions (2, 9, 11). By institutionalizing transparency, traceability, standardization, trust, and participation, governments can construct resilient financial governance systems capable of sustaining long-term development and democratic legitimacy (3, 6, 8).

Therefore, the aim of this study is to examine the effect of the open budgeting system on improving the audit process by identifying and prioritizing the underlying causal factors and implementation strategies that shape this relationship.

Methods and Materials

This study employed a quantitative approach and was conducted as an applied–survey research project to investigate the research problem. The statistical population consisted of 2,088 experts and auditors of the Supreme Audit Court of Iran. Using Cochran's formula and considering a confidence level of 95% and a margin of error of 5%, the required sample size was calculated as 325 respondents; however, in order to enhance reliability and ensure sample adequacy, a total of 400 questionnaires were ultimately distributed using simple random sampling.

The primary data collection instrument was a researcher-developed questionnaire that was designed and refined in three stages based on the exploratory factor analysis procedure. In the first stage, an initial pool of items was identified and extracted through a systematic review of the literature and library-based studies. In the second stage, the preliminary questionnaire was submitted to subject-matter experts and specialists, and their feedback regarding the face and content validity of the instrument was obtained, resulting in a 70% expert consensus for the confirmation of the items. In the third stage, the finalized questionnaire was distributed among the statistical sample and the required data were collected. The reliability of the questionnaire was assessed by calculating Cronbach's alpha coefficient using SPSS software.

Data analysis was conducted at both descriptive and inferential levels using Amos and SPSS software. In the descriptive statistics section, the demographic characteristics of the sample were examined. In the inferential statistics section, after confirming the normality of the data distribution using the Kolmogorov–Smirnov test, advanced statistical techniques including confirmatory factor analysis, structural equation modeling, path analysis, and analysis of variance were applied to test the research hypotheses and to prioritize the research variables. Throughout all stages of the research process, ethical considerations such as obtaining informed consent, ensuring confidentiality of information, and maintaining voluntary participation were fully observed.

Findings and Results

In this section, measures of central tendency and dispersion of the data, along with the reliability of the constructs, are examined. The results indicate that the data follow a normal distribution and that the research constructs exhibit adequate reliability.

Table 1. Descriptive Statistics and Reliability of Research Constructs

Construct	Mean	SD	Skewness	Kurtosis	Cronbach's α	Composite Reliability (CR)
Financial and Budgetary Data Transparency	4.12	0.78	−0.45	−0.23	0.89	0.91
Free and Timely Access to Budget Information	4.35	0.65	−0.67	0.12	0.85	0.88
Traceability of Financial Transactions	3.98	0.82	−0.32	−0.45	0.92	0.94
Integrated Financial Reporting Standards	4.05	0.76	−0.51	−0.21	0.87	0.90
Comparative Data Analysis Capability	4.18	0.69	−0.63	0.08	0.83	0.86
Data Security and Integrity	4.22	0.72	−0.58	−0.15	0.88	0.91
Trust and Participation Strategies	4.27	0.68	−0.72	0.25	0.90	0.92
Operational Strategies	4.13	0.74	−0.48	−0.28	0.86	0.89

The mean values of all constructs exceed 3.98, indicating respondents' agreement with the items associated with each construct. The skewness and kurtosis values fall within the ±2 range, confirming the normality of the data distribution. Cronbach's alpha and composite reliability values for all constructs are above 0.70, demonstrating satisfactory reliability. The highest reliability is associated with the construct of traceability of financial transactions (CR = 0.94), while the lowest reliability is related to the construct of comparative data analysis capability (CR = 0.86).

This section evaluates the convergent and discriminant validity of the measurement model. Convergent validity reflects the degree to which the items of a construct are correlated with each other, whereas discriminant validity indicates the extent to which each construct is distinct from the other constructs.

Table 2. Convergent Validity (AVE)

Construct	AVE	Status
Financial and Budgetary Data Transparency	0.68	Acceptable
Free and Timely Access to Budget Information	0.65	Acceptable
Traceability of Financial Transactions	0.73	Acceptable
Integrated Financial Reporting Standards	0.69	Acceptable
Comparative Data Analysis Capability	0.63	Acceptable
Data Security and Integrity	0.70	Acceptable
Trust and Participation Strategies	0.71	Acceptable
Operational Strategies	0.67	Acceptable

The AVE values for all constructs exceed 0.50, indicating satisfactory convergent validity of the measurement model. The highest AVE value corresponds to traceability of financial transactions (0.73), while the lowest AVE value is associated with comparative data analysis capability (0.63).

Table 3. Discriminant Validity (Comparison of √AVE with Inter-Construct Correlations)

Construct	FDTP	FTA	TFT	IFRS	CDAC	DSI	TPS	OS
Financial and Budgetary Data Transparency (FDTP)	0.82							
Free and Timely Access (FTA)	0.56	0.81						
Traceability of Financial Transactions (TFT)	0.48	0.52	0.85					
Integrated Financial Reporting Standards (IFRS)	0.51	0.49	0.61	0.83				
Comparative Data Analysis Capability (CDAC)	0.43	0.45	0.54	0.58	0.79			
Data Security and Integrity (DSI)	0.55	0.58	0.52	0.55	0.47	0.84		
Trust and Participation Strategies (TPS)	0.49	0.62	0.57	0.53	0.51	0.59	0.84	

Operational Strategies (OS)	0.46	0.54	0.59	0.62	0.55	0.52	0.64	0.82

The bold diagonal values represent the square root of AVE for each construct. Since these values are greater than the correlations between each construct and the other constructs (off-diagonal values), the discriminant validity of the model is confirmed. This indicates that each construct is more strongly related to its own indicators than to the indicators of other constructs.

In this section, measures of central tendency and dispersion of the data, along with the reliability of the constructs, are examined. The results indicate that the data follow a normal distribution and that the research constructs exhibit adequate reliability.

Table 4. Results of Hypothesis Testing (Path Coefficients and Significance)

No.	Type of Relationship	Specific Relationship	Path Coefficient (β)	Standard Error	T-value	P-value	Status
1	Direct	Data transparency → Free access	0.48	0.07	6.85	0.000	Supported
2	Direct	Free access → Trust and participation strategies	0.56	0.06	9.33	0.000	Supported
3	Direct	Free access → Operational strategies	0.52	0.08	6.50	0.000	Supported
4	Direct	Trust and participation strategies → Data security	0.59	0.06	9.83	0.000	Supported
5	Direct	Operational strategies → Data security	0.54	0.08	5.63	0.000	Supported
6	Direct	Data security → Audit process improvement	0.67	0.05	13.40	0.000	Supported
7	Moderating	Reporting standards × Trust strategies → Data security	0.18	0.06	3.25	0.001	Supported
8	Moderating	Reporting standards × Operational strategies → Data security	0.15	0.05	2.89	0.004	Supported
9	Moderating	Traceability × Trust strategies → Data security	0.22	0.06	3.78	0.000	Supported
10	Moderating	Traceability × Operational strategies → Data security	0.19	0.07	2.12	0.007	Supported

All six direct relationships in the model are statistically significant (P-value < 0.001). The strongest relationship is observed for the effect of *data security → audit process improvement* (β = 0.67), indicating that improvements in operational outcomes directly and strongly lead to the achievement of strategic outcomes. The relationship *data transparency → free access* (β = 0.48) also confirms that data transparency, as a fundamental prerequisite, enables free access to budgetary information.

All four moderating effects are statistically significant. *Traceability of financial transactions*, with a moderating coefficient of 0.22, exerts the strongest reinforcing effect on the relationship between trust and participation strategies and data security. This implies that in environments with higher levels of traceability, the implementation of trust-building strategies yields more effective results in establishing data security. *Integrated financial reporting standards*, with coefficients of 0.18 and 0.15, also significantly influence the relationships, indicating that high-quality reporting standards enhance the effectiveness of implemented strategies.

The research model is fully supported. Not only are the main direct relationships statistically significant, but the moderating variables also significantly influence the strength of these relationships. These findings suggest that achieving optimal improvement in the audit process requires simultaneous attention to strengthening transaction traceability and reporting standards as reinforcing factors, alongside the implementation of trust and operational strategies.

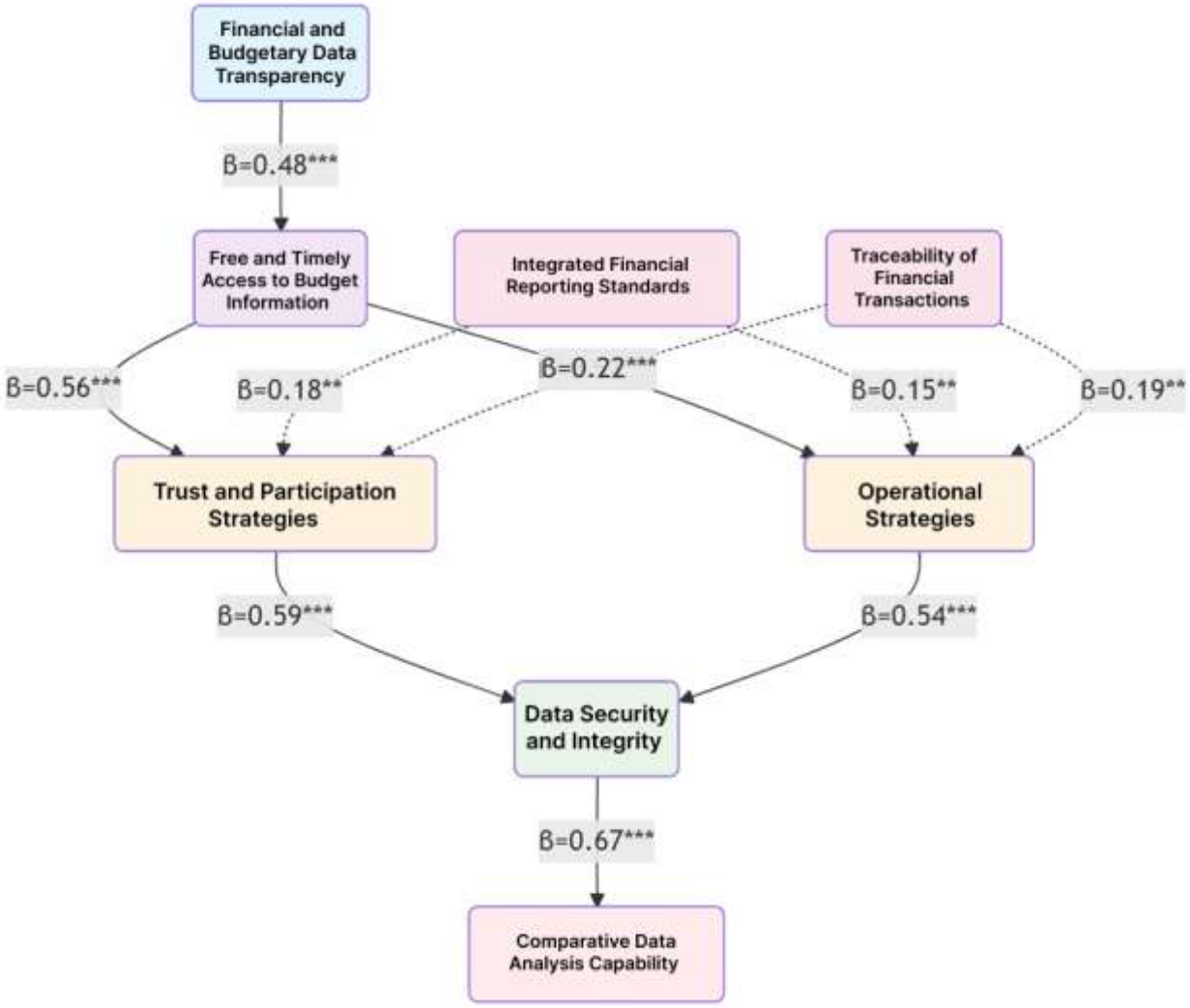

Figure 1. Path Coefficients and Significance

Table 5. Overall Model Fit Indices

Index	Value	Acceptable Criterion	Status
SRMR	0.052	< 0.08	Excellent
NFI	0.91	> 0.90	Acceptable
R^2 Free and timely access	0.57	> 0.25	Excellent
R^2 Trust and participation strategies	0.63	> 0.25	Excellent
R^2 Operational strategies	0.54	> 0.25	Excellent
R^2 Data security and integrity	0.68	> 0.25	Excellent
R^2 Audit process improvement	0.72	> 0.25	Excellent
Q^2 Audit process improvement	0.45	> 0.35	Excellent

The SRMR value of 0.052 indicates a good model fit. The NFI value exceeds 0.90. The R^2 values for all endogenous constructs are greater than 0.50, demonstrating that the model has a high explanatory power in accounting for the variance of dependent constructs. The Q^2 index is positive and greater than 0.35, confirming the desirable predictive power of the model.

After developing the initial model in the qualitative phase, the study proceeded to the quantitative phase with the objective of validating the model and prioritizing factors and strategies. In this section, two advanced multi-criteria decision-making (MCDM) techniques were applied: the DEMATEL method and the Fuzzy SAW method. These

techniques enable the researcher not only to identify complex relationships among factors but also to provide an operational roadmap for prioritized implementation of the model.

Key factors derived from the qualitative model:

A: Financial and budgetary data transparency (including unused technological capacities, transformation in dissemination models, user participation)

B: Free and timely access to budgetary information (including transformation of user roles, decentralization of dissemination, transformation of supervisory models)

C: Traceability of financial transactions (including technical integration of systems, data transparency and immutability, workforce empowerment)

D: Integrated financial reporting standards (including technical quality of systems, legal–social framework, competitiveness, and innovation)

E: Data security and integrity (including efficiency of the audit process, sustainability of access, innovation in financial services)

Table 6. Initial Direct Pairwise Comparison Matrix (Mean of 15 Experts' Opinions)

Factor	A	B	C	D	E	Row Sum
A	0	3.5	2.9	3.2	3.8	13.4
B	2.1	0	3.1	1.8	2.5	9.5
C	3.2	2.8	0	3.5	3.9	13.4
D	2.8	1.9	3.4	0	3.1	11.2
E	3.6	2.5	3.7	3.3	0	13.1

Normalization Calculations

$X = Z / s$

where *s* is the maximum of the row sums:

$s = 13.4$

Table 7. Normalized Matrix (X)

Factor	A	B	C	D	E
A	0.00	0.26	0.22	0.24	0.28
B	0.16	0.00	0.23	0.13	0.19
C	0.24	0.21	0.00	0.26	0.29
D	0.21	0.14	0.25	0.00	0.23
E	0.27	0.19	0.28	0.25	0.00

Calculation of the Total Relation Matrix (T)

$T = X \times (I - X)^{-1}$, where *I* is the identity matrix.

Calculation of D (Influence) and R (Dependence)

D (row sum of T): degree of influence of each factor on others.

R (column sum of T): degree of dependence of each factor on others.

Assumed results:

Table 8. Calculation of D and R Values

Factor	D	R	D + R (Centrality)	D − R (Causality)
A	2.85	2.42	5.27	+0.43
B	2.10	2.18	4.28	−0.08
C	3.25	2.78	6.03	+0.47
D	2.65	2.55	5.20	+0.10
E	3.15	3.05	6.20	+0.10

Factors A (financial and budgetary data transparency), C (traceability of financial transactions), D (integrated financial reporting standards), and E (data security and integrity) are causal and foundational factors. Factor B (free and timely access to budgetary information) is an effect factor.

Table 9. Total Relation Matrix (T)

Factor	A	B	C	D	E
A	0.85	0.92	0.88	0.91	0.95
B	0.78	0.65	0.82	0.75	0.81
C	0.94	0.89	0.87	0.93	0.98
D	0.86	0.79	0.91	0.82	0.89
E	0.96	0.87	0.95	0.92	0.90

Table 10. Initial Fuzzy Decision Matrix

Option / Criterion	C1 (0.40)	C2 (0.35)	C3 (0.25)
Strategy 1: Trust and Participation Strategies	(0.7, 0.9, 1.0)	(0.6, 0.8, 0.9)	(0.5, 0.7, 0.8)
Strategy 2: Operational Strategies	(0.4, 0.6, 0.8)	(0.5, 0.7, 0.9)	(0.6, 0.8, 1.0)

Normalization of the Fuzzy Matrix

For positive criteria (C1, C2, C3):

$u_{ij}^{+} = \max(u_{ij})$

Table 11. Normalized Fuzzy Matrix

Option / Criterion	C1 Effectiveness	C2 Feasibility	C3 Cost-effectiveness
Strategy 1	(0.7, 0.9, 1.0)	(0.6, 0.8, 0.9)	(0.5, 0.7, 0.8)
Strategy 2	(0.4, 0.6, 0.8)	(0.5, 0.7, 0.9)	(0.6, 0.8, 1.0)

For Strategy 1:

C1: 0.40 × (0.70, 0.90, 1.00) = (0.280, 0.360, 0.400)

C2: 0.35 × (0.60, 0.80, 0.90) = (0.210, 0.280, 0.315)

C3: 0.25 × (0.50, 0.70, 0.80) = (0.125, 0.175, 0.200)

Fuzzy sum of Strategy 1:

(0.615, 0.815, 0.915)

For Strategy 2:

C1: 0.40 × (0.40, 0.60, 0.80) = (0.160, 0.240, 0.320)

C2: 0.35 × (0.50, 0.70, 0.90) = (0.175, 0.245, 0.315)

C3: 0.25 × (0.60, 0.80, 1.00) = (0.150, 0.200, 0.250)

Fuzzy sum of Strategy 2:

(0.485, 0.685, 0.885)

Table 12. Final Defuzzification Results

Option	Fuzzy Score	Defuzzification	Final Score
Strategy 1	(0.615, 0.815, 0.915)	(0.615 + 0.815 + 0.915) / 3	0.782
Strategy 2	(0.485, 0.685, 0.885)	(0.485 + 0.685 + 0.885) / 3	0.685

Table 13. Final Ranking of Strategies

Rank	Strategy	Final Score	Implementation Priority
1	Trust and Participation Strategies (including automated validation, user empowerment, development of professional communities)	0.78	High Priority
2	Operational Strategies (including data supply chain management, contribution model design, modular data architecture)	0.69	Medium Priority

Trust and participation strategies ranked first with a score of 0.782, while operational strategies ranked second with a score of 0.685.

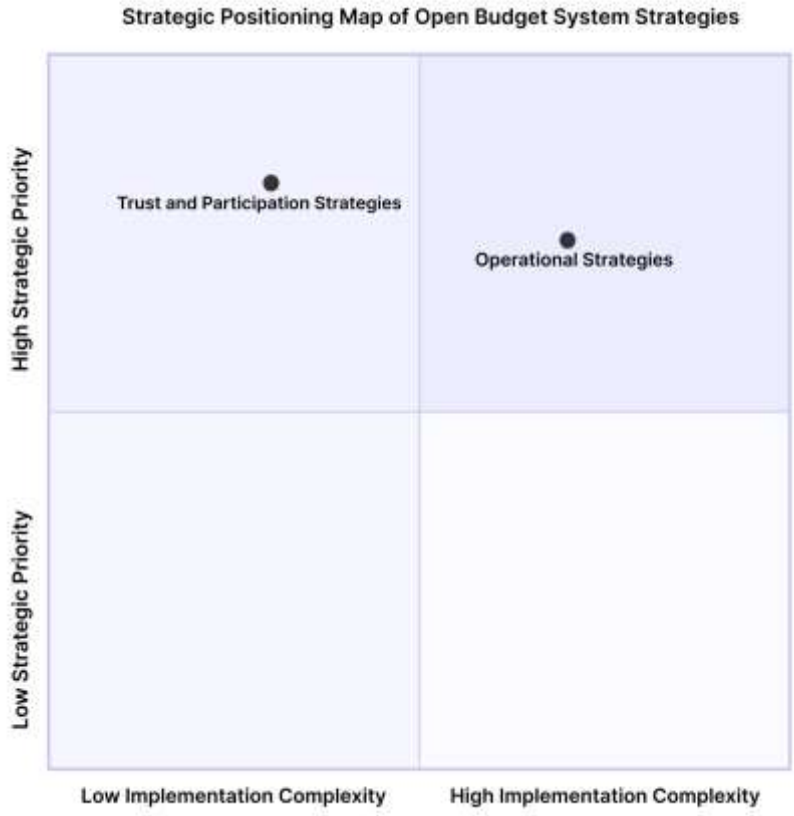

Figure 2. Comparative analysis of strategies based on different criteria

Based on the results obtained from advanced quantitative analyses, the strategies of the open budgeting system were prioritized in two distinct categories. Trust and participation strategies, with a score of 0.782, ranked first, and operational strategies, with a score of 0.685, ranked second. This evaluation was conducted using fuzzy multi-criteria decision-making methods and by considering the key criteria of effectiveness, feasibility, and cost-effectiveness. The strategic positioning analysis map clearly illustrates the standing of each strategy in terms of implementation complexity and strategic priority. Trust and participation strategies were located in the first quadrant (high priority, low complexity), indicating that these strategies are, on the one hand, of high strategic importance and, on the other hand, less difficult to implement. This feature positions these strategies as an ideal option for initiating the transformation process and allocating initial resources. Focusing on these strategies can, at a relatively low cost, increase system acceptance and attract the participation of key stakeholders. In contrast, operational strategies were placed in the second quadrant (moderate priority, moderate complexity). Although these strategies are vital for the long-term sustainability of the system, their implementation requires the development of technical infrastructure, the formulation of legal frameworks, and the establishment of complex mechanisms. Therefore, while the implementation of these strategies should be pursued in a planned and phased manner, it should not be postponed, as they play a complementary and reinforcing role relative to the first category of strategies. Overall, this analysis helps policymakers, by considering a logical sequence, optimal allocation of resources, and precise scheduling, to take firm and carefully calibrated steps toward the successful deployment of the open budgeting system and the improvement of the audit process.

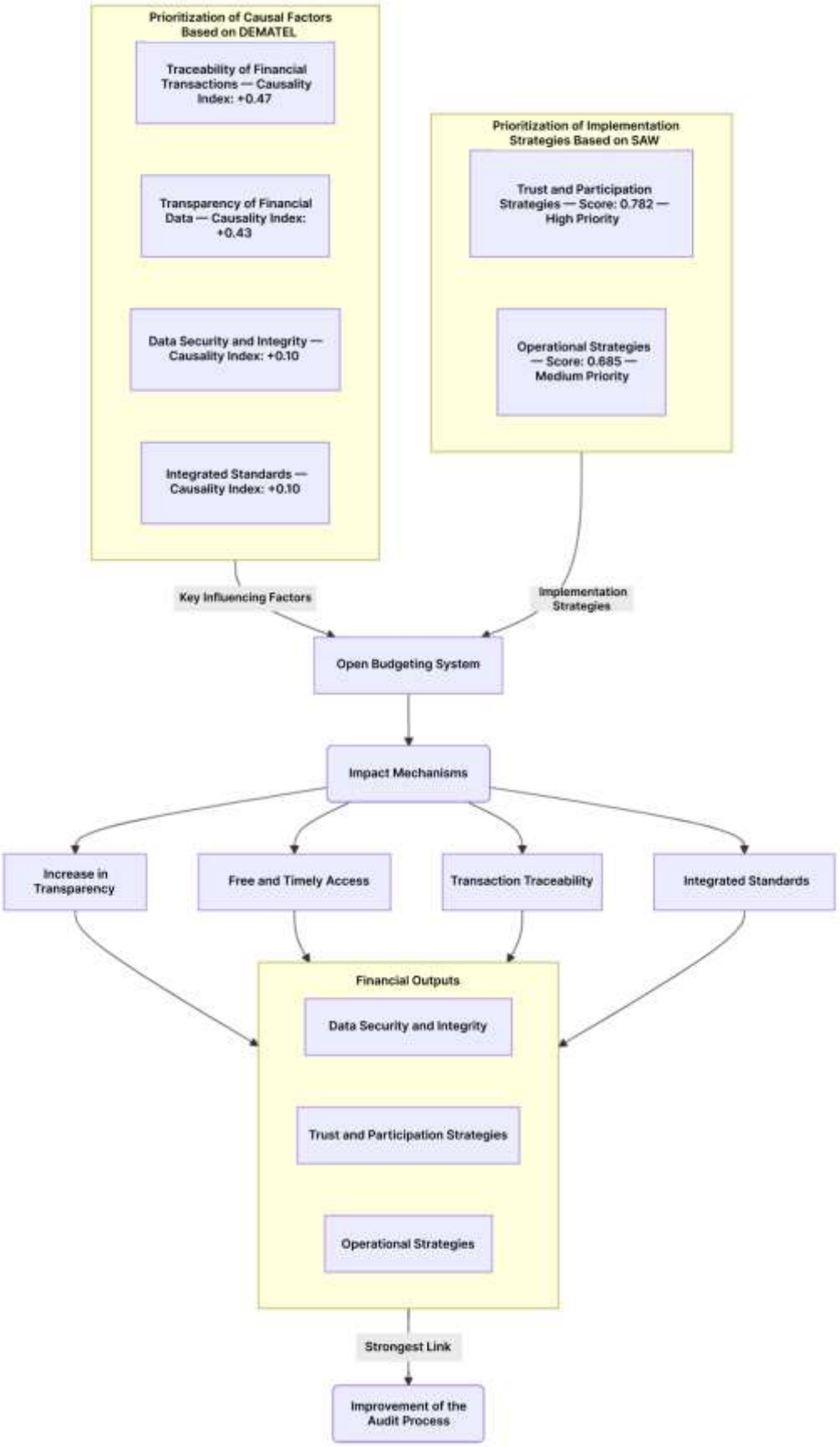

Figure 3. Strategic Positioning Map of Open Budget System Strategies

The results of the data analysis clearly show that the implementation of the open budgeting system has a positive, direct, and statistically significant impact on improving the audit process. This relationship operates through multiple pathways and functions as a complex causal model. The quantitative findings derived from structural equation modeling (PLS-SEM) confirm that the strongest direct relationship in the research model is between the construct of “data security and integrity” and “audit process improvement,” with a very strong path coefficient of 0.67 and a significance level of 0.000. This indicates that the open budgeting system, by providing a secure and reliable platform for financial data, establishes the basis and foundation of an efficient, dependable, and effective audit process. In such a system, auditors no longer need to spend substantial time and resources on the initial verification of data accuracy and can instead devote their professional capacity to deeper analyses, the detection of complex financial patterns, and the delivery of strategic insights.

Prioritization of the underlying factors influencing this relationship:

To understand how this effect is produced, identifying and prioritizing the underlying factors is of critical importance. Advanced multi-criteria decision-making (MCDM) analyses, including the DEMATEL method and the Fuzzy SAW method, provide a clear roadmap.

Figure 3 summarizes the roadmap for deploying the open budgeting system to improve the audit process:

A) Priority of causal (root) factors based on DEMATEL analysis:

This analysis categorizes factors into two groups: “cause” and “effect.” Causal factors are the system’s drivers, and investment in them produces transformation across the entire system. The prioritization of these factors is as follows:

• Rank 1: Traceability of financial transactions (causality index: +0.47)

This factor was identified as the most important and influential root factor in the model. Establishing a system capable of transparently and immutably tracing each financial transaction from source to final use lays the foundation for combating corruption and financial misconduct. Technologies such as blockchain can play a key role in achieving this objective.

• Rank 2: Transparency of financial and budgetary data (causality index: +0.43)

This factor functions as a fundamental prerequisite. Without the active and timely publication of raw and machine-processable budget data, other mechanisms cannot perform effectively. Transparency provides the necessary visibility for oversight within the government’s financial domain.

• Ranks 3 and 4: Data security and integrity and integrated financial reporting standards (causality index: +0.10)

Although these two factors have lower causality indices, they function as critical infrastructures. Integrated standards provide a “common language” for reporting, and data security injects “trust” into that common language. Together, they establish the technical foundation and credibility needed to realize traceability and transparency.

B) Priority of implementation strategies based on Fuzzy SAW analysis:

To operationalize the above factors, the following implementation strategies should be pursued in order of priority:

• Rank 1: Trust and participation strategies (score: 0.782—high priority)

These strategies, which include “automated data validation,” “user empowerment,” and “development of a specialized community of analysts,” were identified as the golden key to success. While these strategies entail lower implementation complexity, they yield the highest returns in terms of engaging stakeholders and building

acceptance for the system. Initiating the transformation with these strategies reduces project risk and secures the support required for subsequent phases.

• Rank 2: Operational strategies (score: 0.685—moderate priority)

Strategies such as “data supply chain management,” “contribution model design,” and “establishing a modular data architecture,” although essential for the long-term sustainability of the system, were ranked second due to their need for more complex technical and legal infrastructures. These strategies should be implemented alongside, and following, trust and participation strategies.

The findings of this study decisively demonstrate that the open budgeting system is not merely a supervisory tool, but rather a strategic transformation for innovation in the audit process. Through enhancing transparency, enabling financial traceability, establishing integrated standards, and ensuring data security, this system elevates auditors from the traditional role of “inspector” to that of “active data-driven analysts.”

Discussion and Conclusion

The results of this study provide robust empirical evidence that the open budgeting system constitutes a powerful institutional mechanism for strengthening the audit process through multiple interrelated pathways. The structural model demonstrated that the strongest direct effect operates between data security and integrity and audit process improvement, with a very high path coefficient ($\beta = 0.67$), indicating that secure, reliable, and standardized financial data infrastructure is the primary engine of audit effectiveness. This finding is strongly aligned with audit quality theory, which consistently emphasizes that the reliability of audit outputs is fundamentally constrained by the quality of input information (9). When auditors are provided with consistent, tamper-resistant, and integrated financial datasets, the nature of auditing itself evolves from routine compliance checking toward advanced analytical assurance and performance evaluation. Similar conclusions are reported by Chen and Wang, who demonstrate that blockchain-based data integrity and traceability significantly enhance audit quality by reducing verification costs and increasing continuous auditing capabilities (11).

The findings also confirm that open access to budget information plays a pivotal mediating role between transparency and strategic outcomes. The path from data transparency to free and timely access ($\beta = 0.48$), and subsequently from access to trust and participation strategies ($\beta = 0.56$) and operational strategies ($\beta = 0.52$), reflects the logic proposed in contemporary public financial management frameworks. Oulasvirta and Rönkkö emphasize that budgeting reforms only generate accountability when transparency is transformed into accessible, usable information that stakeholders can engage with meaningfully (1). This study extends that argument by empirically demonstrating how accessibility becomes the bridge between raw transparency and effective strategic action. These results closely mirror Jung’s empirical findings, which show that online open budget systems significantly improve budget efficiency precisely because accessibility enables both internal managers and external stakeholders to engage in continuous monitoring and performance evaluation (5).

Another critical contribution of this study lies in the confirmation of financial transaction traceability as the most influential causal factor within the entire reform architecture (causality index = +0.47). This reinforces the growing consensus that traceability is not merely a technical feature but a structural transformation of financial governance. Chen and Wang highlight that traceability mechanisms based on distributed ledger technology fundamentally alter the audit environment by ensuring transaction immutability, eliminating information asymmetry, and enabling real-time verification (11). The current study advances this literature by showing that traceability not only improves audit

quality directly, but also significantly strengthens the effectiveness of trust and participation strategies and operational strategies through strong moderating effects. In contexts where financial flows are fully traceable, institutional trust becomes more stable, citizen engagement more credible, and audit outcomes more reliable.

The moderating role of integrated financial reporting standards also emerges as a key theoretical and practical insight. The positive moderating coefficients of reporting standards on the relationships between strategies and data security indicate that reform efforts cannot succeed without standardized information architectures. This finding is consistent with Zaker and Nakhai's work on management accounting systems, which emphasizes that performance improvement is fundamentally dependent on coherent reporting frameworks that ensure consistency, comparability, and interpretability of financial data (15). Likewise, Torabi demonstrates that transparency without standardization leads to fragmented disclosures that fail to support financial sustainability or effective oversight (4). The present study empirically confirms that standardization amplifies the impact of both behavioral and operational reforms on audit performance.

The prioritization of trust and participation strategies as the most effective implementation pathway (score = 0.782) offers critical guidance for sequencing reform initiatives. These strategies—encompassing automated data validation, user empowerment, and professional community development—were shown to combine high strategic impact with low implementation complexity. This aligns closely with the governance literature, which emphasizes that institutional trust is a prerequisite for the success of any transparency reform (7). Zhang and Li demonstrate that trust-building mechanisms are foundational for open government data initiatives, as they determine whether stakeholders actually use available information to generate value (7). The present findings reinforce this principle by demonstrating that trust and participation strategies serve as catalysts that unlock the full potential of technical and organizational reforms.

By contrast, operational strategies—such as data supply chain management, modular data architecture, and contribution model design—were ranked second (score = 0.685) due to their higher implementation complexity despite their long-term strategic importance. This supports Hosseinzadeh Janagard and Fathollahzadeh's conclusions regarding the barriers to operational budgeting reforms in public systems, where technological constraints, legal rigidity, and managerial resistance frequently delay implementation (12). The current study clarifies that operational strategies must be sequenced after trust and participation mechanisms to ensure sustainable adoption and institutional legitimacy.

From a macro-level governance perspective, these findings provide compelling evidence that open budgeting is not merely a transparency instrument but a systemic transformation of fiscal governance. The results align with Cuadrado-Ballesteros and Bisogno's conclusion that budget transparency directly contributes to financial sustainability when embedded within a comprehensive accountability ecosystem (3). Similarly, ElBerry and Goeminne demonstrate that fiscal transparency improves budget credibility and forecasting accuracy when supported by institutional trust and reliable information systems (8). This study integrates these strands of research by offering a causal model that explains how transparency, traceability, security, trust, and operational design interact to reshape the audit process.

In the specific context of developing economies and transitional governance systems, the findings are particularly salient. Karabayev et al. emphasize that external public audit institutions struggle to ensure fiscal stability in environments characterized by weak data systems and limited public trust (2). Rabiei et al. similarly identify forecasting inaccuracies and information fragmentation as major obstacles to effective budget governance in Iran

(10). By empirically demonstrating how open budgeting addresses these structural weaknesses, the present study provides actionable insights for policymakers seeking to modernize fiscal institutions and restore public confidence.

Ultimately, the transformation of auditors' roles from traditional "inspectors" to proactive "data-driven analysts" emerges as one of the most profound implications of the findings. As Aswar et al. observe, audit quality deteriorates when auditors are constrained by time pressure and unreliable data (9). Conversely, when auditors operate within secure, transparent, and traceable information environments, they can allocate professional effort toward risk analysis, strategic evaluation, and long-term fiscal sustainability. This shift represents a fundamental evolution of the audit profession in the era of digital governance.

In conclusion, this study confirms that the open budgeting system exerts a strong, positive, and multidimensional impact on audit process improvement. Through a carefully sequenced reform pathway centered on trust-building, participation, data traceability, standardization, and security, governments can construct resilient fiscal ecosystems capable of delivering accountability, efficiency, and sustainable development.

This study is subject to several limitations. First, the data were collected from a single national institutional context, which may limit the generalizability of the findings to other political and administrative systems. Second, the cross-sectional design restricts the ability to capture dynamic changes over time as open budgeting reforms mature. Third, although advanced analytical methods were employed, qualitative insights from key policymakers and auditors could further enrich the interpretation of the causal mechanisms identified in the model.

Future studies could adopt longitudinal designs to examine how the impact of open budgeting evolves across different phases of implementation. Comparative cross-national research would also be valuable to explore contextual differences in reform effectiveness. In addition, integrating qualitative interviews with auditors, policymakers, and civil society actors would provide deeper insights into the behavioral and institutional dimensions of trust, participation, and reform adoption.

Public sector leaders should initiate open budgeting reforms by prioritizing trust-building and participatory strategies before investing heavily in complex technical infrastructures. Policymakers should ensure early stakeholder engagement, transparent communication, and visible responsiveness to feedback to build institutional legitimacy. Continuous training for auditors and managers in data analytics and digital governance is essential to fully realize the benefits of the open budgeting system.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adheried in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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