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Optimizing the Efficiency and Corporate Sustainability of E-Tendering Processes under Green Procurement Using Data Analytics Models

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Abstract This study proposes an optimization scheme for green procurement e-tendering system integrating distributed processing and cryptography theory, aiming to improve process efficiency and enterprise sustainability through data analysis model. The e-procurement business platform constructed based on the national bidding specification integrates procurement plan management, supplier evaluation and expert collaboration modules, and introduces the threshold secret sharing mechanism to reconfigure the security architecture, and realizes the distributed storage and disaster recovery of bids through the (t, n) threshold policy. The encryption time of the proposed threshold secret sharing algorithm is 262ms and decryption time is 362ms under 50MB data, which is significantly better than 1428ms and 1545ms of traditional RSA and 1297ms and 1549ms of ECC, and real-time performance is improved by more than 80%. In the performance evaluation, homomorphic encryption performs optimally with 93.51% resource utilization and 95.85% data accuracy, while data anonymization has the shortest processing time of 102ms but lower resource utilization of 74.96%. Through the empirical application of 198 enterprise users, the optimized platform has significantly increased efficiency from 16.67% to 58.08%, cost savings from 10.10% to 47.98%, and system stability (61.62% very stable) and user satisfaction (71.72% very satisfied).

Index Terms data analysis, green procurement, e-tendering, threshold secret sharing, cryptography

I. Introduction

In today's society, with the growing awareness of environmental protection, green procurement has become an important consideration for enterprises and organizations in procurement activities [1], [2]. Green purchasing is to fully consider the factors of environmental protection and sustainable development in the purchasing process, and to select products and services that have less impact on the environment, are more efficient in resource utilization, and comply with environmental standards [3]-[5]. It is not only buying “green” products, but also a concept and method throughout the entire procurement process, including the selection of suppliers, product design, production, transportation, use and disposal [6]-[9]. In the era of increasing environmental requirements and the background of circular economy and sustainable development, actively carrying out green procurement and green supply chain management is in line with the current economic development and long-term social development requirements, and helps to establish a good image of the company and sustainable development [10]-[13]. The data analysis model plays an important role in green procurement decision-making, which can help companies understand the efficiency and cost of the supply chain, identify potential risks and opportunities, and provide the basis for business decisions [14]-[16]. Based on this, it is of great significance to study the efficiency and corporate sustainability of the e-tendering process.

Bidding is an open competitive selection process conducted by a government or a business to select suppliers, contractors, or service providers with whom to work [17], [18]. The traditional bidding process usually faces time and space constraints, such as the time required for document delivery and the location limiting the participation of suppliers [19], [20]. In order to improve the efficiency and transparency of bidding, more and more organizations and companies have introduced e-tendering processes [21]. The e-tendering process is to transfer the traditional tendering process to be carried out online through the Internet and electronic technology [22], [23]. It transforms traditional paper documents and manual operations into electronic data and automated processes, which improves the efficiency and transparency of bidding and facilitates corporate sustainability [24]-[26].

A systematic solution integrating distributed processing and cryptography theory is proposed. Firstly, a fully functional e-procurement business platform is constructed, based on the national bidding standard, and the e-platform is designed to cover modules such as procurement plan management, supplier evaluation, and expert resource collaboration, so as to realize the improvement of procurement efficiency and full-cycle traceability through the standardized process and centralized analysis of data. On this basis, the system security architecture is reconstructed by introducing the threshold secret sharing mechanism, and a distributed threshold secret sharing model is proposed to address the inherent defects of the centralized architecture. Tenders are divided and stored in multiple servers, and the (t,n) threshold mechanism ensures data security and system disaster recovery capability. Shamir polynomial partitioning algorithm is adopted in the bid generation stage, and distributed reconfiguration is realized through Lagrange interpolation when opening bids to ensure that the business process strikes a balance between security and efficiency. Enhance fault tolerance and anti-attack capability. Finally, we combine classical cryptography theory, Shamir threshold sharing and China's residual theorem to construct the bid splitting and reconstruction algorithms, and introduce the identity-based encryption system (IBE) to strengthen the identity authentication and data transmission security, so as to provide multi-dimensional cryptographic protection for the system.

II. Research on Distributed Security Architecture Design and Cryptographic Support for E-Tendering System

II. A. Establishment of an e-procurement commerce platform through e-tendering

Relying on national bidding laws and norms and establishing a unified e-procurement business platform, enterprises can realize the information management of the whole process of project release, bidding, bid opening and evaluation to successful bidding based on bidding project management, such as centralized monitoring of procurement plans, standardized implementation of procurement activities, and comprehensive analysis of procurement data, so as to significantly improve the efficiency and standard of material management.

Generally speaking, the e-procurement business platform includes procurement plan management, procurement project management, expert resource management, supplier management and system management modules. Procurement plan management covers the submission of procurement application, the approval process of procurement plan, and the final plan implementation. Procurement program management is responsible for issuing tender notices, managing the bidding process, and executing the bid opening and evaluation process. For expert resource management, the accuracy and ease of use of evaluation expert information is ensured mainly through the continuous updating and maintenance of the expert database. For supplier management, the bidding unit will establish and manage supplier files and automatically update the status of suppliers to facilitate the auditing work during the selection and registration stage of winning bids. In terms of system management, it involves user management, role assignment and management of operation logs to ensure system security and traceability of user operations.

Through the above comprehensive management functions, the e-Procurement Business Platform provides strong support for each link of the procurement process and ensures the smooth running of the entire procurement activities. Its main results include: first, bidding project management as a key link ensures strong monitoring of the bidding execution process; second, each link of procurement activities is recorded on the platform, ensuring accurate information docking in each link; third, through the unified platform, enterprises can conveniently evaluate, select and manage suppliers; fourth, the platform process involves multiple departments, and the unified e-commerce platform promotes intra-enterprise synergy and cross-departmental cooperation.

II. B. Design of e-tendering system based on threshold secret sharing system

Although the e-procurement business platform significantly improves process standardization and collaboration efficiency, the centralized architecture it relies on still has security risks and reliability bottlenecks. Therefore, this section further proposes a distributed system design based on threshold secret sharing, which reconfigures the data storage and processing logic through cryptographic mechanisms, and injects fault-tolerance and anti-attack capability into the platform.

II. B. 1) Threshold Secret Sharing Design Ideas

Threshold secret sharing solves the problem of keeping an important secret by multiple people, which divides an important secret to multiple people for keeping, and several of these secret keepers must be present at the same time in order to recover the secret, which achieves the purpose of spreading the risk and tolerating the intrusion. The idea of threshold secret sharing is introduced into the design of e-tendering system to solve the problems of the existing e-tendering system and to improve the security and reliability of the e-tendering system.

Most of the existing e-tendering systems use centralized processing, i.e., all the operation processes are completed on a single server. The reliability of this centralized processing method is poor, and once the server is attacked or fails, the bidding activities cannot continue. Moreover, all information is stored on a single server, which is easy to be destroyed, tampered with, lost, and so on. In order to make up for the shortcomings of this centralized processing, some people design to add a standby server, when the main server fails or suffers an attack to switch to the standby server, although to a certain extent to alleviate the problem of a single point of failure, improve the reliability of the system, but can not fundamentally solve the drawbacks of the centralized processing.

The structure of the centralized processing system is shown in Figure 1.

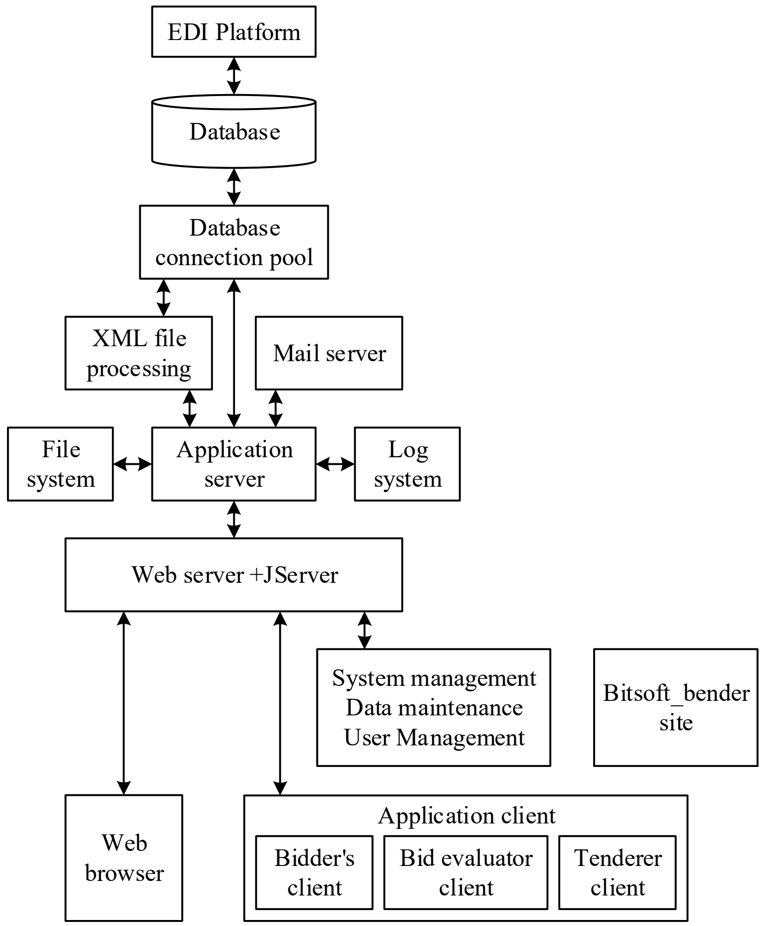

Figure 1: Structure diagram of the centralized processing system

In order to fundamentally solve the above problems, this paper introduces the idea of threshold secret sharing, i.e., distributed processing, into the design of the e-tendering system, and adopts the distributed processing method in which multiple bidding servers work together. It is described as follows: the secret distributor, i.e., the bidder of the e-tendering system, generates the secret, i.e., the bid, and then distributes the secret to n participants, i.e., the bidding servers, and $t(t<n)$ participants cooperate to reconstruct the secret. The bid is divided into n parts and stored in n different bidding servers, and any less than $t(t<n)$ bidding servers cannot reconstruct the bid, which ensures the security of the bid. Moreover, as long as $t(t<n)$ out of n bidding servers are working properly, the bid can still be reconstructed, which improves the reliability and fault tolerance of the system.

II. B. 2) Business process design

The e-tendering system optimizes the traditional bidding and tendering business process, i.e., taking the business process as the object and center, caring for the customer's needs and satisfaction as the goal, rethinking the traditional process fundamentally and re-designing it thoroughly, and making use of advanced information technology as well as modern management methods to maximize the efficiency of the business process and the user's satisfaction. The main contents of the business process optimization of this system are: whether the flow of business and data is smooth and reasonable; the relationship between data, business processes and management functions; and whether the traditional management mode and the realization of the management method of this system are feasible.

The basic business process of this system includes: the release of bidding information, the search and registration of bidders, bidding, the determination of bids, the opening of bids, the evaluation of bids, the determination of the successful bidder, and the announcement of the successful bid results.

(1) Tender information release: release tender information and solicit bidders.

(2) Bidder retrieval and registration: bidders retrieve the bidding information on the Internet and register to log into the system.

(3) Bidding: Bidders select projects, fill in the contents of the bid, and upload the bid.

(4) Finalizing bids: Bidding ends and each bidder stops uploading bids.

(5) Bid opening: Bids are regenerated through t bidding server.

(6) Evaluation of bids: Experts evaluate the bids according to the actual situation.

(7) Determine the winning bidder: Select the best solution according to the evaluation of experts.

(8) Announcing the winning bid: send the winning bidder's identity certificate to each bidding server.

The business process is shown in Figure 2.

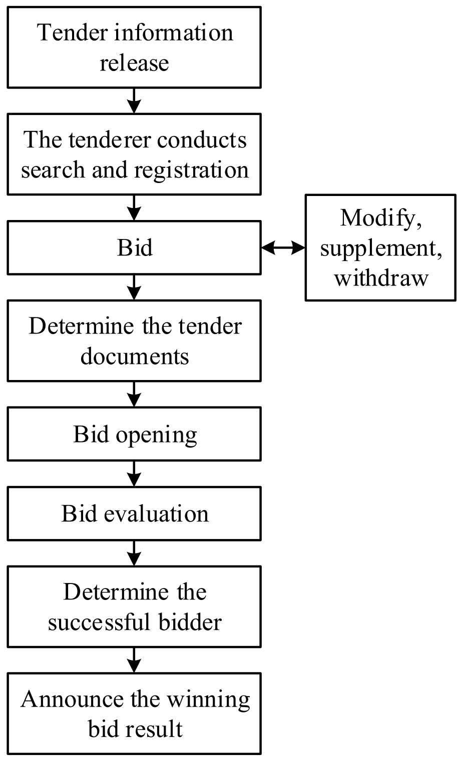

Figure 2: Business Flowchart

II. C. Theories related to classical cryptography

The landing of the threshold secret sharing model needs to rely on specific cryptographic algorithms to realize it. In this section, we will deeply explore the core theoretical tools supporting the system, including the classical secret sharing scheme and the lattice encryption regime, to ensure the security of the bid splitting, reconstruction and transmission process from the algorithmic level.

II. C. 1) Classical secret sharing

Classic (t,n)-threshold secret sharing consists of two core algorithms: a share generation algorithm and a secret reconstruction algorithm. The share generation algorithm divides a secret message into multiple shares and distributes these shares to n participants; the secret reconstruction algorithm collects shares from t or more than t participants and reconstructs the original secret. Typical schemes in classical (t,n)-threshold secret sharing contain Shamir-threshold secret sharing and Chinese Residual Theorem-based threshold secret sharing.

(1) Shamir threshold secret sharing

Assuming a trusted distributor Dealer and a set of n participants, the share generation algorithm for Shamir threshold secret sharing is described as:

The distributor Dealer randomly chooses a multinomial of degree $t-1$:

$$f(x)=(a_0+a_1x+a_2x^2+\cdots+a_{t-1}x^{t-1}) \bmod d \tag{1}$$

where $(a_0,a_1,a_2,...,a_{t-1})\in Z_d^t$, a_0 are secret information.

The distributor chooses n non-zero, mutually exclusive elements $(x_1,x_2,...,x_n)\in Z_d^n$ and first computes n shares $\{f(x_1),f(x_2),...,f(x_n)\}$ and then sends these n shares over a secure channel to n participants, each of whom holds a private share $f(x_i)(i=1,2,\ldots,n)$.

From the authorized subset consisting of any t of the n participants, if these t participants want to reconstruct the secret a_0, each of them takes out his private share $f(x_i)$, using the following Lagrange interpolation formula as the secret reconstruction algorithm:

$$a_0=f(x_0)=\left(\sum_{r=1}^{t} f(x_r)\prod_{1\le j\le t,j\ne r}\frac{x_j}{x_j-x_r}\right) \bmod d \tag{2}$$

In Equation (2), only t share is used for the secret reconstruction, and when the number of shares is $t+1,t+2,\ldots,n$, the following Equation (3) still holds.

$$\begin{aligned} a_0&=(\sum_{r=1}^{t} f(x_r)\prod_{1\le j\le t,j\ne r}\frac{x_j}{x_j-x_r}) \bmod d\\ &=(\sum_{r=1}^{t+1} f(x_r)\prod_{1\le j\le t+1,j\ne r}\frac{x_j}{x_j-x_r}) \bmod d\\ &=\cdots\\ &=(\sum_{r=1}^{n} f(x_r)\prod_{1\le j\le n,j\ne r}\frac{x_j}{x_j-x_r}) \bmod d \end{aligned} \tag{3}$$

When the number of shares collected is t or greater than t, the original secret can be reconstructed correctly. When the number of collected shares is less than t, i.e., when the number of exposed, lost or destroyed shares is more than $n-t$, the original secret cannot be reconstructed correctly, and similarly a collaboration with less than t participants is unlikely to obtain the shared secret.

(2) Threshold Secret Sharing Based on China's Remainder Theorem

Threshold secret sharing based on China's Remainder Theorem also includes two core algorithms: share generation algorithm and secret reconstruction algorithm.

The basic idea of the share generation algorithm is that the trusted distributor Dealer has a secret integer k that satisfies $m_nm_{n-1}\cdots m_{n-n+2}<k<m_1m_2\cdots m_i$, where $m_1,m_2,...,m_n$ is an integer greater than 1 and strictly increasing $m_1<m_2<\cdots<m_n$, m_i and m_q are mutually exclusive. The distributor Dealer first computes the product of n m_i $M=m_1m_2\cdots m_n$ and the sub-secret $k_i=k \bmod m_i$, and then the distributor takes (k_i,m_i,M) as a secret share and distributes it to the i th participant. When all shares have been distributed, each of the n participants has a secret share.

From the authorized subset consisting of any t participants chosen from n, if these t participants want to reconstruct the secret k, each of them takes out his private share (k_i,m_i,M), using the following Chinese remainder theorem as the secret reconstruction algorithm:

$$\begin{cases} M_j=M/m_j\\ N_j\equiv(M_j^{-1}) \bmod m_j \end{cases} \tag{4}$$

where $1\le j\le t$. Solving Equation (4) yields

$$k\equiv(\sum_{j=1}^{t} k_jM_jN_j) \bmod (\prod_{j=1}^{t} m_j) \tag{5}$$

Similar to Shamir's threshold secret sharing, in the threshold secret sharing based on China's Residual Theorem, the original secret can be solved when there are t or more than t participants present at the same time, or when there are t or more than t secret shares, but it cannot be solved when there are less than t participants.

II. C. 2) Identity-based encryption regimes on the grid

Identity-based encryption on the lattice: an identity-based encryption algorithm on the lattice is a probabilistic polynomial time (PPT) algorithmic quaternion (initial key generation algorithm $Setup(1^{\lambda})$, key extraction algorithm $Extract(msk, mpk, id)$, encryption algorithm $Enc(mpk, id, m)$, decryption algorithm $Dec(sk_{id}, c)$, defined as follows

Initial Key Generation Algorithm $Setup(1^{\lambda})$: Generate a one-way trapdoor function f for a lattice-hard problem, a master private l public key pair (msk, mpk) where λ is a security parameter.

Key Extraction Algorithm $Extract(msk, mpk, id)$: The key extraction algorithm $Extract(msk, mpk, id)$ takes as input a master private/public key pair (msk, mpk), an identifier $id \in \{0,1\}^{l}$, and returns a secret decryption key $sk_{id} = f_{msk}^{-1}(H(id))$ corresponding to that identifier id, where l is the length of the string of 0, 1, and H is a mapping function which maps the identifier id to the public key pk_{id}.

Encryption Algorithm $Enc(mpk, id, m)$: Encryption Algorithm $Enc(mpk, id, m)$ inputs master public key mpk, identity id and plaintext m, outputs ciphertext c.

Decryption Algorithm $Dec(sk_i d, c)$: Decryption Algorithm $Dec(sk_{id}, c)$ inputs secret decryption key sk_{id} and ciphertext c, outputs plaintext m.

In the above four algorithms, parameter $(msk, mpk, sk_{id}, pk_{id})$ belongs to the key space K, m belongs to the plaintext space M, c belongs to the ciphertext space C, $Extract()$ belongs to the set of key extraction algorithms Ex, $Enc()$ belongs to the set of encryption algorithms E, $Dec()$ belongs to the set of decryption algorithms D. at least one element in the set $\{M, C, K\}$ lies in the Hilbert space, and algorithms E, D belong to the family of quantum transformations.

III. Performance validation and optimization effect score of e-tendering system based on threshold secret sharing

Chapter 2 provides a theoretical guarantee for the green procurement e-tendering system by constructing a distributed security architecture and cryptographic support model. In order to further verify the practical effectiveness of the model, Chapter 3 combines the data analysis method to carry out empirical research from the dimensions of algorithm performance, process efficiency, cost saving and user satisfaction, to quantitatively evaluate the comprehensive performance of the system after optimization.

III. A. Performance Validation of Data Analytics Models in Green Procurement Bidding

In order to verify the optimization effect of the data analysis model on the efficiency of the green procurement bidding process, the following experiments were designed in this study.

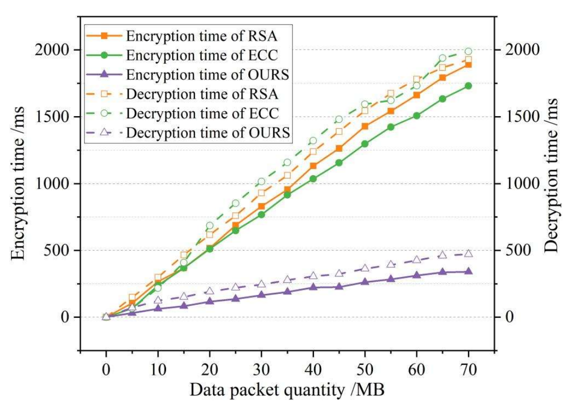

Figure 3: The encryption times of different algorithms

III. A. 1) Performance analysis

In further verifying the performance of threshold-based secret sharing algorithm when applied to the e-tendering process, this experiment is analyzed in terms of data encryption time and decryption time. With the number of network packets of 50MB, the proposed algorithm, the protection algorithm based on RSA encryption, and the protection algorithm based on ECC encryption are used for green procurement bidding data security and privacy protection, and the encryption time and decryption time of different algorithms are recorded as shown in Fig. 3.

As can be seen from Fig. 3, the encryption time of the three algorithms increases as the number of packets increases. When the number of packets is 50MB, the encryption time of RSA encryption algorithm and ECC encryption algorithm is 1428ms and 1297ms respectively, while the encryption time of this paper's encryption algorithm based on the threshold secret sharing is only 262ms. the decryption time of the three algorithms under the number of 50MB packets is 1545ms, 1549ms and 362ms respectively; when the number of packets is When the number of packets is 70MB, the encryption and decryption times of the three algorithms are 1889, 1730, 340ms and 1928, 1988 and 470ms, respectively.The synthesis of the above analysis shows that the proposed algorithms can effectively improve the real-time data security and privacy protection.

III. A. 2) Performance evaluation

Performance assessment is the process of analyzing and validating the efficiency, accuracy, resource utilization and response time of e-tendering technologies in the practical application of green procurement. The purpose of the evaluation is to ensure that the selected technology can protect data privacy without significantly degrading the performance of the system bidding. Figure 4 illustrates the performance of data anonymization, differential privacy, homomorphic encryption and federated learning in terms of processing time, resource utilization and data accuracy.

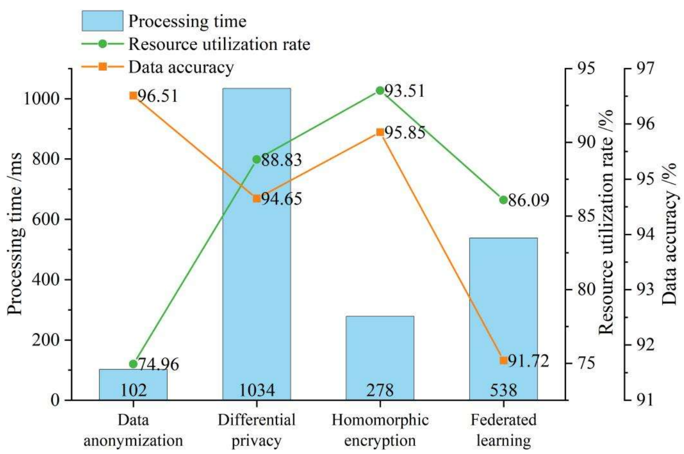

Figure 4: Performance Evaluation of Electronic Bidding and Tendering in Procurement

Figure 4 demonstrates the performance comparison of the four aspects (data anonymization, differential privacy, homomorphic encryption, and federated learning) in the green procurement e-tendering scenario. In terms of processing time, data anonymization performs best at 102ms, followed by homomorphic encryption at 278ms and federated learning at 538ms, while differential privacy significantly lags behind the other techniques due to its high computational complexity resulting in a processing time of 1034ms. In terms of resource utilization, homomorphic encryption ranks first with 93.51%, indicating its efficient use of system resources; differential privacy and federated learning follow with 88.83% and 86.09%, respectively, while data anonymization is at the bottom with 74.96%. In terms of data accuracy, data anonymization leads with 96.51% accuracy, homomorphic encryption 95.85% and differential privacy 94.65% follow, and federated learning is slightly less accurate due to its distributed learning characteristics, at 91.72%. Taken together, homomorphic encryption strikes a better balance between resource efficiency and accuracy, while data anonymization, although fast in processing, has low resource utilization, which may affect system scalability.

III. B. Optimization and implementation of bidding and trading platforms

Based on the theoretical validation of the algorithm performance, this section puts the optimized system into the actual application of the enterprise, and through the questionnaire survey and user feedback, it comprehensively examines the practical value of the technology optimization on the green procurement bidding process from the perspectives of efficiency enhancement, cost saving, system stability and user satisfaction.

The platform optimized based on the data analysis model of green procurement under the electronic bidding put into the enterprise application, the total number of enterprise users involved in the test is 207, in order to control the variables to facilitate to do the control reference, to test the application of the platform of the interviewed users issued a questionnaire, the recovery of the questionnaire 198 copies. The result data of this questionnaire survey is rounded up, and most of the digits after the decimal point are rounded up to the far side, and because the whole is 100%, so there may be 1%-3% data error in each part of the data.

III. B. 1) Efficiency gains

The results of the questionnaire survey on whether the e-platform bidding before and after optimization has improved efficiency are shown in Figure 5.

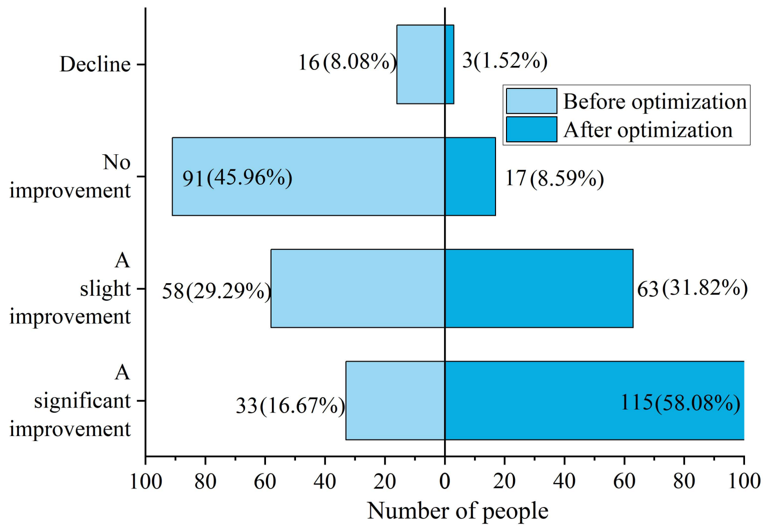

Figure 5: Investigation on Improving the Efficiency of Bidding and Tendering

After optimization, the proportion of those who greatly improved efficiency increased from 16.67% to 58.08%; the proportion of those who slightly improved increased from 29.29% to 31.82%; the rest of those who thought that there was no prompting decreased from 45.96% to 8.59%, and those who felt that the efficiency of the bidding decreased instead decreased from 8.08% to 1.52%. It can be seen that the study for the process of upgrading, for the operation manual optimization, for the optimization of the system functions of the overall effect.

III. B. 2) Cost savings

The results of the questionnaire survey on whether there were cost savings in e-platform bidding before and after optimization are shown in Figure 6.

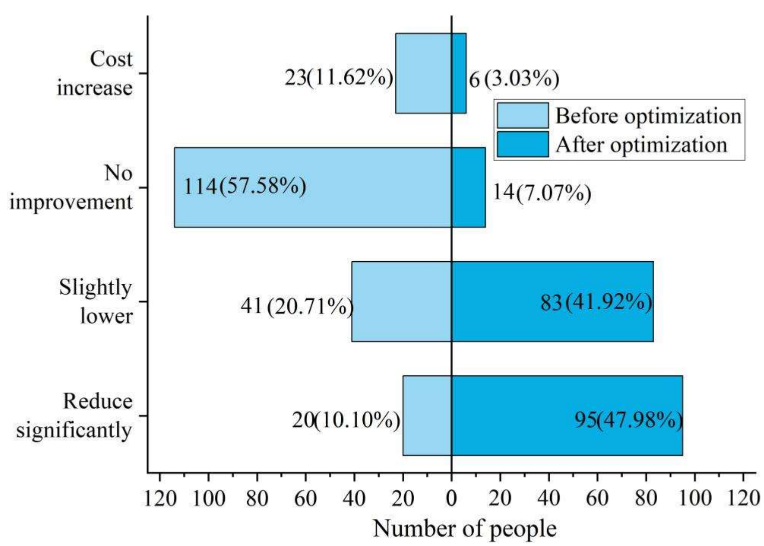

Figure 6: Investigation on Cost Savings in Electronic Bidding and Tendering

After using the optimized e-bidding platform, most of the respondents believe that the bidding cost has been greatly reduced, accounting for 47.98% from 10.10%. the proportion decreased slightly from 20.71% to 41.92%; The proportion of those who believe that it is basically the same as before has decreased from 58.58% to 7.07%, and the proportion of those who believe that the cost has increased has increased from 23 people before the optimization, and only 6 people think so after the optimization. It can be seen that the increase in supporting services has helped users save costs. For bidders, supporting services can facilitate online application for electronic guarantees and credit reports and can save processing costs. For bidding agents, expanding the server can reduce the occurrence of system errors, save the time of bid evaluation and save costs.

III. B. 3) Degree of stability

The results of the questionnaire survey on the system stability of the e-tendering platform before and after optimization are shown in Figure 7.

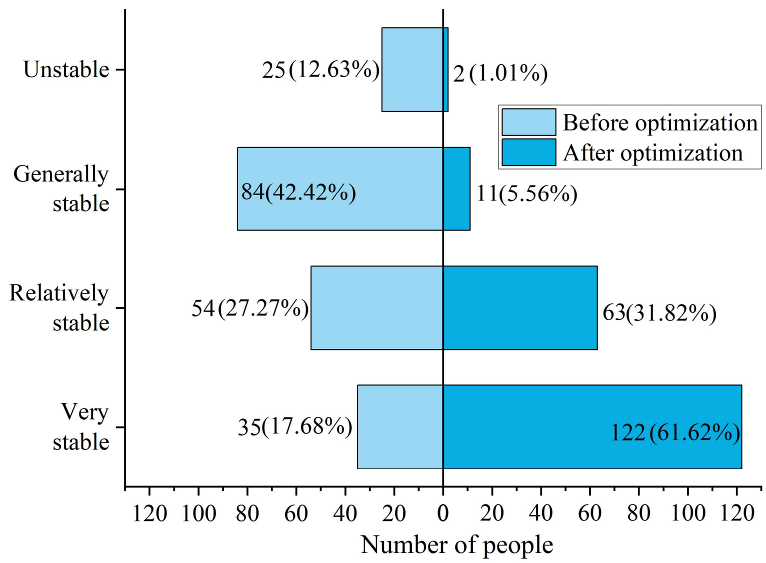

Figure 7: Investigation on the Stability of the Electronic Bidding and Tendering

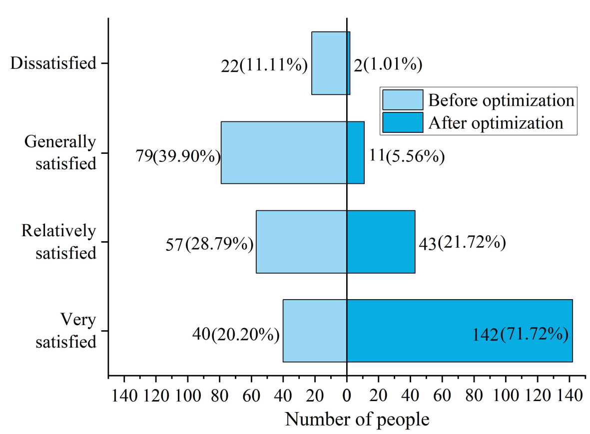

Figure 8: Satisfaction Survey of the Electronic bidding and tendering Platform

The percentage of respondents who think that the system is very stable has increased from 17.68% to 61.62%; the percentage of respondents who think that the system is more stable with a high probability has decreased from 27.27% to 31.82%; the percentage of respondents who think that the system is average in terms of stability has decreased from 42.42% to 5.56%; and the percentage of respondents who think that the system is unstable has decreased from 12.63% to 1.01%. It can be seen that the effect of the study on the expansion of the server is obvious.

III. B. 4) Satisfaction analysis

The results of the questionnaire survey on user satisfaction with the e-tendering platform before and after optimization are shown in Figure 8.

The percentage of respondents who are very satisfied has increased from 20.20% to 71.72%, the percentage of those who are more satisfied has decreased from 28.79% to 21.72%, the percentage of those who are generally satisfied has decreased from 39.90% to 5.56%, and only 1.01% of respondents are dissatisfied with the optimized e-tendering platform. Overall satisfaction has improved to a certain extent or can be seen to be effective.

IV. Conclusion

In this study, we reconstruct the e-tendering system through distributed threshold secret sharing and cryptography theory, and verify its optimization effect in green procurement by combining the data analysis model. Experimental data show that the encryption and decryption time of the threshold secret sharing algorithm is only 262ms and 362ms under 50MB data volume, which improves the efficiency of the traditional algorithm by more than 80%, and the resource utilization rate reaches 93.51%, which achieves the balance between security and real-time performance. In the empirical evidence of enterprise application, the proportion of respondents that the optimized platform has greatly improved the efficiency reaches 58.08%, the proportion of cost savings is increased to 47.98%, 61.62% of users think that the optimized system is very stable, and the proportion of users who are very satisfied is increased to 71.72%. The study proves that the optimization solution based on distributed architecture and data analysis can effectively solve the risk of single-point failure of the centralized system, reduce the bidding cost and improve the transparency of the whole process.

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