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Cloud-based internal audit quality improvement path under new quality productivity empowerment

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Abstract Improving the level of enterprise internal audit is the focus of reducing the business risk of enterprises. This paper is based on the hierarchical analysis method to mine the indicators affecting the quality of enterprise internal audit work, and construct the indicator system. Combined with big data cloud computing and K-Means algorithm, it carries out clustering analysis and character portrait of enterprise employee behavior data to find the types that need to be focused on by auditors. Take procurement approval behavior as an example to study the specific operation of internal audit quality optimization based on cloud computing. Compare the scores before and after the digital transformation of internal auditing to determine its quality improvement effect. The results show that through cloud computing statistics and cluster analysis, it is found that there is procurement fraud within the enterprise where the unit price of procurement is higher than the market price by 400 yuan, and it is necessary to focus on rectifying the internal auditing process in all aspects of procurement. The score after the digital transformation of internal audit is 81.25 points, much higher than the 63.38 points before the transformation, and the audit quality is improved greatly.

Index Terms internal audit, cloud computing, K-Means algorithm, audit character portrait, digital transformation

I. Introduction

In today's era of digitalization and informationization, the operational efficiency and risk management ability of enterprises, as an important pillar of the country's economic development, are particularly critical [1], [2]. As an important part of enterprise management, the traditional working mode of internal audit has been difficult to adapt to the rapidly developing business environment and technological changes [3]. Therefore, exploring the digital transformation path of enterprise internal auditing is not only an inevitable choice to enhance the effectiveness of auditing, but also a key step for enterprises to realize sustainable development [4], [5].

With the rapid development of intelligent technology, digital transformation has become an important driving force for innovation and development in all industries. For enterprise internal auditing, digital transformation means a shift from traditional manual auditing to data-driven intelligent auditing, which will greatly improve the accuracy, efficiency and coverage of auditing [6]-[8]. Among them, cloud computing is a tool for pooling information technology resources, improving performance, reducing costs, and simplifying management, which provides rich services for industrial digital transformation [9]. Utilizing various production and market resources integrated by the cloud platform can promote efficient docking and collaborative innovation in the upstream and downstream of the industrial chain, significantly reducing the threshold of enterprise digital transformation and accelerating the development of the digital economy [10]-[12]. As the business departments of enterprises “go to the cloud”, everyone will become the creator and user of data, and all data come from the same data source and the same database [13], [14]. Therefore, internal auditing based on the cloud platform works in the same shared data pool with the audit object, which requires the focus of auditing to shift to the data source and platform system errors and fraud, and strive to realize the improvement of the quality of internal auditing of enterprises under the support of cloud computing [15]-[18].

In order to improve the quality of enterprise internal audit, this paper constructs the internal audit quality impact evaluation system based on the 5M1E (Man, Machine, Material, Method, Measurement, Environment) management hierarchy analysis method, which includes 6 first-level indicators and 16 second-level indicators. Experts are invited to score and consistency test the indicators. Calculate and cluster analyze the behaviors of enterprise personnel through the classical unsupervised cluster analysis method K-Means algorithm, highlighting the abnormal behavior data and facilitating internal auditors to quickly locate possible violations. Digital transformation is carried out to improve the quality of internal auditing in response to the problems of internal auditing.

II. Analysis of internal audit quality improvement methods based on cloud computing

This chapter combines the hierarchical analysis method to analyze the relevant indicators that affect the audit quality within the enterprise and construct the indicator system. The K-Means algorithm based on cloud computing is utilized to cluster the purchasers to be audited, assisting internal auditors to find possible violations, thereby improving the quality of internal auditing.

II. A.Hierarchical Analysis

In 2024, the Chinese Institute of Internal Auditors (CIIA) revised the Internal Audit Quality Evaluation Manual. The manual evaluates the quality of an organization's internal audit work through a series of evaluation criteria to assess whether it adds value to the enterprise's value. The manual divides the evaluation criteria into two categories, namely, internal audit environment and internal audit operations. The internal audit environment mainly examines the overall internal and external control environment of the enterprise where the internal audit takes place, and the internal audit operation is mainly based on the audit operation itself. The two items have a total of 2 evaluation elements and 32 evaluation points, including 18 evaluation points for the internal audit environment and 14 evaluation points for the internal audit operations, which explain in detail the impact indicators affecting the quality of internal audit. This paper combines this evaluation standard with the situation of Company A. For the method of 5M1E (Man, Machine, Material, Method, Measurement, and Environment), it designs 6 major level 1 indicators and 16 major level 2 indicators. Table 1 shows the specific indicators. 6 primary indicators cover internal audit environment, internal audit personnel, internal audit tools, internal audit materials, internal audit methods and internal audit measurements. There are two to four secondary indicators under each level 1 indicator, covering a full range of internal audit quality influencing factors from “management attention” to “cost control”.

Table 1: Indicator system

First-level indicator	Secondary indicator
Internal audit environment(A1)	Degree of attention from the management(B1)
	Soundness of institutional setup(B2)
	Completeness of institutional norms(B3)
Internal auditor(A2)	Number of auditors(B4)
	Professional ability level(B5)
	Performance evaluation criteria(B6)
Internal audit tools(A3)	Degree of hardware configuration(B7)
	Degree of software usage(B8)
Internal audit materials(A4)	Standardization of working papers(B9)
	Persuasive evidence(B10)
Internal audit method(A5)	Audit method compatibility(B11)
	Audit process standardization(B12)
Internal audit measurement(A6)	Audit coverage rate(B13)
	Problem rectification rate(B14)
	Report timeliness(B15)
	Cost control degree(B16)

II. B.Hierarchical analysis based on 5M1E

II. B. 1) Hierarchical Analysis Basic Concepts

Hierarchical analysis refers to the method of dividing all the data into levels, with the goal of the decision as the objective level, the influencing factors of the decision as the criterion level, and the options of the decision as the scenario level, and then analyzing the weights of the influencing factors on the basis of this method.

II. B. 2) Basic Steps of Hierarchical Analysis

(1) Establishment of hierarchical structure model

A graphical approach can be used to visualize the goals of the decision, the influencing factors and the object of the decision in order of the top level, the middle level and the lowest level. The top level is the purpose of the decision and and the problem to be solved. The lowest level is the alternatives for making the decision, that is, the object of the decision. The middle level refers to the factors affecting the top and bottom levels, that is, the influencing factors for making decisions.

(2) Construction of judgment (pairwise comparison) matrix

The selected factor indicators are compared pairwise and rated according to their importance. For the results of the comparison of the importance of the elements with the elements, nine importance levels and their assigned values are generally given. The matrix formed by the two-by-two comparison results is called the judgment matrix.

(3) Hierarchical single sorting and its consistency test

The eigenvector $\lambda_{\max}$ corresponding to the largest eigenroot of the judgment matrix, and letting the sum of the elements of the vector be equal to (also known as normalization) is recorded as W. The elements of W are the ranked weights of the same hierarchical factor with respect to the relative importance of a factor of the previous hierarchical factor, which can also be called the hierarchical single ordering. This hierarchical single ordering needs to be tested for consistency, by which is meant the determination of the permissible range of inconsistency for A. The consistency of the ordering is determined by the following formula where the unique non-zero characteristic root of the n-order consistent array is n; the largest characteristic root of the n-order positive inverse array A, when and only when, A is a consistent matrix.

Denote the consistency index by CI, the smaller CI is, the greater the consistency is. The eigenvector corresponding to the largest eigenvalue is used as the weighting of the degree of influence of the compared factors on a factor in the upper layer, and the larger its individual degree of consistency is, the larger the judgment error caused. Thus, the magnitude of the value of $\lambda - n$ can be used to measure the degree of inconsistency of A. Define the consistency indicator as:

$$CI = \frac{\lambda - n}{n - 1} \tag{1}$$

To measure the size of the CI, the random consistency indicator RI was introduced:

$$RI = \frac{CI_1 + CI_2 + \ldots + CI_n}{n} \tag{2}$$

In order to exclude deviations from consistency due to random reasons, when testing for consistency, it is also necessary to divide the CI by the RI for comparison to derive the test coefficient CR, which is given by the following formula:

$$CR = \frac{CI}{RI} \tag{3}$$

Generally, if CR<0.15, the judgment matrix is considered to pass the consistency test, and vice versa, it does not have satisfactory consistency.

(4) Hierarchical total ranking and its consistency test

Calculating the weights of all factors at a certain level with respect to the relative importance of the highest decision-making target level is called hierarchical total sorting. This process is carried out sequentially from the highest level to the lowest level.

II. C. Study on the weighting of internal audit quality control issues in enterprises

II. C. 1) Calculation of the weighting of indicators

Decision-making experts are invited to evaluate the importance of the indicators, followed by the use of EXCEL forms for decision-making experts to process the data, through the evaluation of each expert on the degree of importance of the two-by-two comparisons between the various indicators into the judgment matrix embodied in the matrix and the resulting matrix with the weights accounted for the results. Table 2 shows the quality management 5M1E analytical method of internal audit factors affecting the proportionate weights of the enterprise. The above has passed the consistency ratio test. From Table 2, it can be concluded that the internal audit quality control dimensions accounted for the largest proportion of internal audit measurement (A6) 30%, the high importance of this level of indicators shows that the experts believe that for enterprises internal audit measurement is a key point of internal audit quality control, internal audit as a result-oriented work of a kind, and its internal audit measurement is to represent the results of the internal audit, in the six areas than the highest. Secondly, the internal audit environment (A1) is 27%, the high importance of this level of indicators shows that in the enterprise, the quality of the internal audit environment is a good foundation for the internal audit work, so as to facilitate the performance of internal audit in the risk management and control and enhance the value of the operation of the functions of the internal audit; internal audit methodology (A5) and personnel (A2) in the first level of indicators ranked third and fourth, accounting for 15 and 13%, indicating that experts believe that the enterprise in the internal audit quality control is the key point. 13%, indicating that experts believe that enterprises in the current people-centered era, in the internal audit quality control of internal audit personnel is also a key influence factor, should focus on talent training and team building, to facilitate the internal audit work and its quality management and control can be further deepened; internal auditing tools (A3) and internal audit materials (A4) compared to the first four first-level indicators accounted for a lower proportion, accounting for 5%, 10%; indicating that experts believe that relative to other factors, these two level 1 indicators are less important in terms of internal audit quality control, but they also have a certain impact on internal audit quality control. Meanwhile, CI=0.04<0.15, passing the consistency test.

Table 2: Proportion weight result

First-level indicator	A2	A3	A4	A5	A6	A1	W	CM
A2	0.15	0.13	0.14	0.15	0.12	0.13	0.13	6.07
A3	0.05	0.05	0.04	0.03	0.05	0.06	0.05	6.03
A4	0.07	0.04	0.10	0.08	0.05	0.10	0.10	6.03
A5	0.12	0.16	0.17	0.18	0.14	0.13	0.15	6.07
A6	0.30	0.31	0.25	0.28	0.36	0.30	0.30	6.11
A1	0.30	0.31	0.30	0.28	0.28	0.28	0.27	6.09
CR < 0.15,indicates that the consistency test has been passed							CI	0.04
							RI	1.22
							CR	0.03

II. C. 2) Ranking of the weight of factors affecting internal audit quality control

According to the above 5M1E analysis method in the weight of the six aspects of the calculation, respectively, to get in the enterprise internal audit quality control of each indicator weight, that is, the weight of each issue on the enterprise internal audit quality control proportion. Table 3 shows the results of the weight ranking of each factor affecting internal audit quality control. As can be seen from Table 3, the factors that affect the weight of the former are mainly in the internal audit environment, internal audit personnel, internal audit methodology and internal audit measurement of these four aspects, internal audit tools and internal audit materials are relatively less important to influence the weight of internal audit quality control in the enterprise. Therefore, this paper, in accordance with the quality management 5M1E analysis method classified 6 dimensions, selects the 4 aspects of the current conclusion of the weight of the 4 indicators ranked in the top as the key issues under the quality control of the enterprise's internal audit to analyze, looking for ways to improve the quality of the audit. Specifically: internal audit measurement (A6) - issue rectification rate (B14) (0.16); internal audit environment (A1) - system specification integrity (B3) (0.15); internal audit measurement (A6) - Audit Coverage (B13) (0.09); Internal Audit Methodology (A5) - Audit Process Normality (B12) (0.08).

Table 3: Quality control affects the ranking of weights of various factors

Target layer	First-level indicator layer		Secondary indicator layer			
	Specific indicators	Weight proportion	Specific indicators	Weight proportion	Overall weight	Sorting
Quality control of internal audit in enterprises	A1	0.27	B1	0.14	0.05	9
			B2	0.31	0.07	6
			B3	0.55	0.15	2
	A2	0.13	B4	0.23	0.02	13
			B5	0.54	0.09	3
			B6	0.23	0.02	14
	A3	0.05	B7	0.35	0.02	15
			B8	0.65	0.03	11
	A4	0.10	B9	0.39	0.04	10
			B10	0.61	0.06	8
	A5	0.15	B11	0.40	0.07	7
			B12	0.60	0.08	5
	A6	0.30	B13	0.31	0.09	4
			B14	0.39	0.16	1
			B15	0.15	0.03	12
			B16	0.15	0.02	16

II. D.Cloud-based internal personnel profiling model design

Procurement personnel within the enterprise can be categorized into two main groups: compliance procurement personnel and non-compliance procurement personnel. The amount of pending approvals for compliance procurement personnel fluctuates with changes in procurement operations, while the amount of pending approvals for non-compliance procurement personnel does not fluctuate with changes in procurement operations. Based on the fluctuation of the amount, it can be assumed that the non-compliant purchasing personnel may have behaviors that jeopardize the interests of the company. Therefore, the K-Means clustering algorithm can be used to cluster the sample procurement personnel according to the fluctuation amplitude of the amount to be approved by the big data cloud computing method, to find out the class of procurement personnel with the smallest fluctuation amplitude, and intersect with the class of procurement personnel with the largest fluctuation amplitude, so as to identify the procurement personnel who may be in violation of the law for the re-internal auditing process.

The K-Means algorithm, which is also known as the K-means algorithm or K-mean algorithm due to different translations, is a classical and most widely used unsupervised clustering analysis method, which has achieved good results in many practical applications. Clustering is the cloud computing to find the subset of data of the same kind in a given set of data, each of which forms a cluster of classes in order to have a high degree of similarity within the clusters and a low degree of similarity between the clusters.In machine learning, clustering algorithms belong to unsupervised learning algorithms, i.e., the class of the sample data is unknown, and samples are computed and categorized based on the similarity between the samples.

Assuming that there are n sample objects and each sample describes an attribute with at most p variables, each sample object x_i can be described by a p-dimensional vector $x_i = [x_{i1}, x_{i2}, \cdots, x_{ip}]$, then the sample containing n objects can be be represented as the following matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \cdots & \cdots & & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} \quad (4)$$

When calculating the distance between data samples, one of Euclidean distance, Manhattan distance or Chebyshev distance can be chosen as the similarity metric according to the actual needs, of which the most commonly used is Euclidean distance:

$$d_2(x_i, x_j) = \left(\sum_{k=1}^{p} | x_{ik} - x_{jk} |^2 \right)^{\frac{1}{2}} \quad (5)$$

Each class cluster consists of a number of points, and the interval between class clusters, also known as the distance between clusters, is generally expressed as the distance between the cluster centers of mass (the geometric centers of all data in the class).The K-Means algorithm begins by randomly selecting k objects (the k values are defined manually), each representing the center of mass of a cluster. For each of the remaining objects, the distance between the object and the center of mass of each cluster is computed, and it is assigned to the most similar cluster to it accordingly. The new center of mass for each cluster is then calculated. The process is repeated until the criterion function converges.

The criterion function generally employs the mean square deviation as a standardized measure function, which is used to evaluate the clustering performance:

$$E = \sum_{i=1}^{k} \sum_{p \in p - m_i|^2 Ci} | p - m_i |^2 \quad (6)$$

where E is the sum of the mean squared deviations of all objects in the database, p represents a point of a spatial object i.e., a sample point, and m_i is the class cluster mean point of the class cluster c_i. The criterion function aims to make the clusters themselves as compact as possible and the clusters as separate as possible from each other.

The K-Means algorithm is described as shown below:

Input: sample dataset D, number of class clusters k

Output: set of class cluster representatives C, vector of class cluster members m.

(1) Initialize the set of class cluster representatives C
Randomly select k data points from the sample dataset D
Use these k data points to form an initial set of cluster representatives C
Repeat the following steps
(2) Proceed to assign the data
Reassign each sample point in D to its nearest class cluster mean
Update m (m_i denotes the cluster identification of the i th point in D)
(3) Redetermine the mean value
Update C (C_j denotes the cluster mean of the j th point)
Until the objective function converges

K-Means algorithm, specify the number of clusters is one of the core steps, the construction of K-Means clustering model, you can be based on the elbow rule, calculated in each clustering results of each cluster's prime point and the square distance error of the sample points in the cluster and the SSE (i.e., the degree of aberration), to get the horizontal coordinate for the number of clusters, the vertical coordinate for the aberration degree of the curve, take the point of inflection (the elbow) as the optimal number of clusters. After determining the number of clusters, you can use the cleaned sample data to start clustering, if the clustering results meet the validity of the audit requirements, you can use this method to deal with unaudited data for the audit as a reference.

III. Internal Audit Quality Improvement Practices Based on Cloud Computing

In this chapter, we take “procurement fraud” as an example to analyze whether the cloud-based internal audit method can successfully cluster business people with abnormal fluctuations in procurement amounts, and the effect of digital transformation of internal audit based on this.

III. A. Feasibility Validation of Internal Audit Quality Improvement Based on Cloud Computing

III. A. 1) Procurement approval compliance analysis

In the internal procurement business, there are cases where the approval authority is different due to the different prices of materials, and some business personnel may dismember the project to avoid high-level approval and split the purchase order to gain profit. Therefore, it is necessary to examine whether there are cases of splitting procurement projects in order to avoid the approval of higher-level leaders. For manual raw review, it is not possible to see the full picture of the data, and by summarizing the procurement data through cloud computing, the amounts that are very close to the approval authority are listed separately, and internal auditors should pay attention to these employees who often have purchase orders with amounts just below the approval authority, which may be a clue to their splitting of orders. Figure 1 shows a summary of cloud-based purchase amounts. If a single purchase price higher than 150,000 yuan requires the approval of the vice general manager in charge of procurement, and when operations below 150,000 yuan only require the approval of the head of the procurement department, it is necessary to focus on whether there is a risk of order splitting for purchases close to 150,000 yuan. From the distribution of the amount to be approved, it can be seen that there are more than 10 businessmen whose amount to be approved hovers around 150,000 yuan, and for the summarized results of cloud computing, internal auditors should focus on the procurement data of this part of the businessmen.

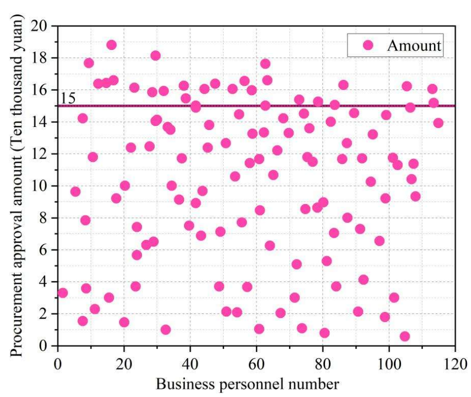

Figure 1: Summary of procurement amounts based on cloud computing

III. A. 2) Procurement audit quality improvement program

Based on the results of the procurement approval data cloud, internal auditors identified deficiencies in all aspects of procurement and the need to further improve the quality of internal audits and reduce irregularities in the operations staff. Summarize the internal audit quality control design effectiveness, implementation effectiveness evaluation, and internal audit control deficiencies identified by testing, and propose targeted modifications. First, the internal audit control deficiencies existing in each process of procurement are counted. Figure 2 shows the distribution of the number of audit deficiencies that exist in each part of procurement. In each approval process of procurement, including procurement planning and budget management, internal auditors have approval deficiencies, of which the highest number of deficiencies are in supplier management and payment management, both amounting to five deficiencies. The reason for this may be that internal auditors do not often interface with vendors, thus making it difficult to identify approval loopholes for this type of issue, and targeted solutions need to be explored in the future.

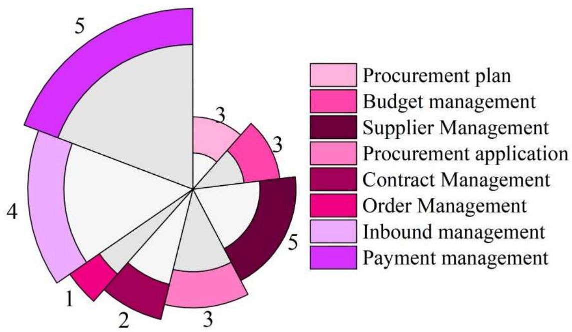

Figure 2: Quantity distribution of procurement with audit deficiencies

After analyzing the deficiencies, through the big data cloud computing audit platform, according to the key position personnel K-Means clustering portrait analysis, extract the business handled by the business personnel more in line with the “Fraud Triangle Theory”, and use excel to count the price fluctuations of the following five material codes over a period of time. Figure 3 shows the price fluctuations. From the price fluctuation situation, in addition to individual points higher or lower, the individual salesperson's procurement unit price fluctuation is not significant, and can not be effectively determined. At this time, the method of external price comparison can be used to determine the procurement price by inquiring and comparing prices with competitive supplier enterprises in the industry. Combined with the results of the price comparison found that the five materials within the enterprise are different degrees of the existence of high procurement prices, the same period of the material unit price should be in the 400 yuan, but the enterprise within the five items of material procurement price in five periods of time most of the unit price of more than 400 yuan. It indicates that procurement fraud does exist within the enterprise, and the image clustering method based on big data cloud computing can assist internal auditors to dig out the existing problems and improve the quality of internal auditing of the enterprise. The follow-up can be carried out through in-depth investigation and analysis, market research, supplier interviews and other forms of further implementation of internal audit transformation should focus on.

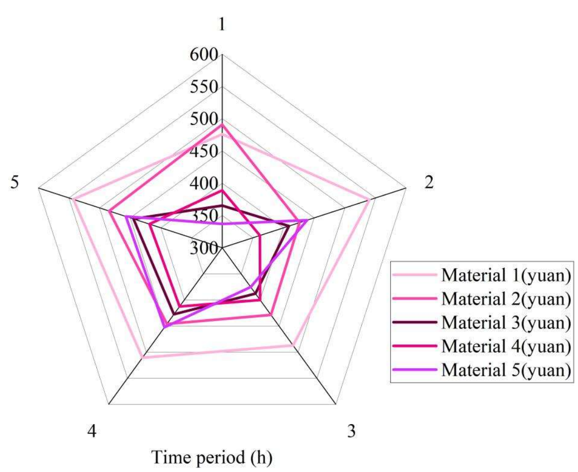

Figure 3: Price fluctuation situation

III. B. Before and After Cloud-Based Internal Audit Transformation

III. B. 1) Internal audit pre-digital transformation score

Relying on the big data cloud computing audit platform, the digital transformation of enterprise internal audit is realized. In order to judge the effect of the transformation, the scores of the indicators before and after the internal audit are combined. By organizing and summarizing the results of interviews, questionnaire surveys, and data from internal audit departments over the years, the actual values and importance levels of each indicator are collected. The actual values of the indicators are consistent, and after analysis, the qualitative indicators are scored directly, and the quantitative indicators are scored according to different threshold intervals. The evaluation scores before and after the digital transformation of internal audit were finally derived.

Table 4 shows the scores before the digital transformation of internal audit. From the scores of the indicators in Table 4, the average score of the enterprise's internal audit before digital transformation is 63.38, which does not break the passing line of 65. This also highlights the necessity of internal audit digital transformation based on cloud computing.

Table 4: Score situation of Internal Audit before Digital transformation

First-level indicator	Secondary indicator	Weight	Actual value	Score
A1	B1	0.05	61%	61
	B2	0.07	65%	65
	B3	0.15	70%	70
A2	B4	0.02	30	30
	B5	0.09	70%	70
	B6	0.02	65%	65
A3	B7	0.02	60%	60
	B8	0.03	78%	78
A4	B9	0.04	70%	70
	B10	0.06	65%	65
A5	B11	0.07	60%	60
	B12	0.08	60%	60
A6	B13	0.09	55%	55
	B14	0.16	50%	50
	B15	0.03	48h	50
	B16	0.02	150000 yuan	45
Scoring result		1.00	-	63.38

Table 5: Score situation of Internal Audit after Digital transformation

First-level indicator	Secondary indicator	Weight	Actual value	Score
A1	B1	0.05	70%	70
	B2	0.07	75%	75
	B3	0.15	76%	76
A2	B4	0.02	50	50
	B5	0.09	81%	81
	B6	0.02	70%	70
A3	B7	0.02	72%	72
	B8	0.03	86%	86
A4	B9	0.04	81%	81
	B10	0.06	75%	75
A5	B11	0.07	79%	79
	B12	0.08	80%	80
A6	B13	0.09	83%	83
	B14	0.16	79%	79
	B15	0.03	24h	75
	B16	0.02	100000 yuan	80
Scoring result		1.00	-	81.25

III. B. 2) Internal audit score after digital transformation

Table 5 shows the scores of internal audit after digital transformation. After the digital transformation based on cloud computing, the average value of the internal audit quality score of the enterprise is 81.25 points, which is 17.87 points higher than the 63.38 points before the transformation. And it is worth noting that the scores of all the indicators after the transformation have been greatly improved, indicating that the internal audit quality has been comprehensively optimized after combining the assistance of cloud computing. In particular, the scores of the high-impact internal audit measurement indicators are all above 75, indicating that the internal audit results after the transformation are also more excellent.

IV. Conclusion

This paper combines cloud computing and K-Means algorithm to explore the audit deficiencies within the enterprise, targeted to realize digital transformation and improve the quality of internal audit. The internal score of the enterprise before transformation is only 63.38 points, which is lower than the passing line of 65 points, indicating that there are more problems in the internal audit of the enterprise. After the transformation, the score increased to 81.25, and the individual scores of the measurement factors that have a greater impact on the internal audit of the enterprise are all over 75, which is an excellent effect of quality improvement. In the future, we can continue to study how to improve the computational efficiency of cloud computing, which in turn can better enhance the productivity level of internal auditors and promote the modernization of enterprise development.

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