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Article

Research on the Application of Big Data Analysis Technology in Financial Management Innovation in the Digital Economy Era

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Abstract: In the context of the digital economy era, traditional financial management has been difficult to meet the requirements of modern enterprises for data processing speed, depth of analysis and precision of decision-making. Combined with the guiding ideology and principles of indicator system design, 98 evaluation indicators are initially selected, and after a series of evaluation indicator screening, 30 evaluation indicators are finally determined to finalize the design of the evaluation indicator system for financial management innovation in the era of digital economy. Starting from the scope of big data analysis technology, it is proposed to use entropy weight method and TOPSIS method to construct enterprise financial management evaluation model. Finally, with the support of research data, the model is used to evaluate and analyze the financial management of an enterprise from 2014 to 2023. It is obtained that the Euclidean distance of 0.5405 of the enterprise's financial management level during 2014~2023 is reduced to 0.4497, indicating that the model in this paper can intuitively react to the current enterprise's financial management problems. In order to better face the challenges and opportunities of the digital economy, it proposes an innovative strategy for financial management in the economic era that integrates big data analysis technology.

Keywords: entropy weight method; TOPSIS method; big data analysis technology; financial management

1. Introduction

Under the dual impetus of economic globalization and digital transformation, enterprises are facing increasingly complex financial management needs [1]. The traditional financial management model has been difficult to meet the requirements of high efficiency and transparency, and there is an urgent need for the support of new technologies to improve the quality of decision-making and operational efficiency. Big data analytics technology, which utilizes distributed storage and computing frameworks (e.g., Hadoop, Spark) for rapid processing of massive data [2]. It helps companies to accurately control their financial situation, optimize resource allocation, and effectively manage risks by providing in-depth insights and predictions [3]. However, although big data analytics demonstrates great potential in enterprise financial management, its implementation faces many technical and managerial challenges [4]. Therefore, studying the innovative application of big data analysis technology in enterprise financial management is of great theoretical and practical significance for improving enterprise operational efficiency, preventing financial risks, and optimizing decision-making processes [5-6].

Data collection is the first step in the application of big data, which involves collecting relevant data from various internal and external sources [7]. In the field of financial management, data collection is not only simply recording transactions and financial activities, but also includes capturing multi-dimensional information such as market dynamics, customer behavior, supply chain situation, etc. Ren [8] faced with the huge amount of financial data through the application of big data technology, which helped the enterprise to achieve higher economic efficiency in procurement management, production control, capital budgeting, and investment decision-making, etc., which is attributed to the influence of big data on the financial decision-making mechanism. Yang [9] combined several big data analysis techniques to extract corporate financial data in a timely and complete manner, accelerated the efficiency of the corporate finance department, and then realized the financial management intelligence through the optimization of the financial process to improve the level of corporate financial management. Cheng [10] used big data analysis techniques based on the weighted simple Bayesian algorithm and the decision tree algorithm in financial risk prediction to increase the effectiveness of data mining for financial companies by 2%, proving the feasibility of big data technology in enterprise management from economic and technical perspectives. Through these advanced data processing and analyzing techniques, enterprises are able to extract valuable information from huge data and provide scientific basis for financial decision-making [11].

The utilization of big data technology in the budgeting process can simplify and accelerate the collection, processing and analysis of data, making the budget more accurate and timely. Wang et al [12] tested the repayment rate of customers after using data mining technology, and the experimental results showed that the technology had a higher accuracy in analyzing the repayment ability of customers, which helped to improve the enterprise's ability to analyze financial data. Shang et al [13] mined the potential connection between financial indicators and used fuzzy clustering algorithm, parallel rules and parallel mining algorithm to obtain fuzzy association rules that satisfy the minimum fuzzy credibility, and the study pointed out that big data technology can improve the financial data processing ability of enterprises. Liu, Y [14] explored the application effect of big data-driven technology in the collation of enterprise financial information, intelligent analysis, risk monitoring, decision support and internal control management and other aspects of the application effect, combined with practical cases to confirm its effectiveness in financial management, the enterprise can quickly and accurately deal with financial information.

Financial risk management is an important part of the enterprise risk management system, involving risk identification, assessment and control [15]. In the era of big data, risk management using big data technology has become a key strategy for enterprises to enhance their risk prevention and control capabilities and improve their financial health [16]. Chiang et al [17] used big data classification algorithms to predict corporate financial crises, and found that predicting corporate crises using the use of the variables in the financial crisis model worked well. Rauf et al [18] pointed out in a literature review that Big data analytics simplifies the enterprise financial process, can reduce the possibility of financial risks in enterprises, and significantly improves the efficiency of enterprise financial management. Yue et al [19] compared the prediction effect of three big data technologies including support vector machine, logistic regression, and information fusion methods in enterprise financial risk management, and the classification accuracy of the three methods on enterprise financial risk was higher than 90%, which It shows that big data technology can be applied to major enterprises as an effective solution for financial risk management. Edwards [20] used neural network method to predict potential problems of enterprise financial risk, and found that the data mining method can have a good prediction effect in detecting the actual financial performance of the enterprise, and the difference between the real condition and the predicted performance is minimal. Zhou et al [21] proposed a particle swarm-based Optimization of big data analysis technology, through nonlinear parallel optimization, accelerates the convergence speed of enterprise risk management model at the same time enhances its risk prediction ability, and solves the problem of the poor accuracy of risk assessment under diverse data situations. Liu, J et al. [22] designed a financial control strategy based on big data technology according to the actual situation of the ZH Group, in order to achieve the financial management and risk warning, continuous financial management tracking, and the financial management of the ZH Group. Risk early warning, continuous financial management tracking found that big data technology significantly improved the comprehensive business capabilities of ZH Group. Yan et al [23] demonstrated that both natural language processing and data mining algorithms based on natural language processing and data mining algorithms are able to obtain sufficient real-time data to assess and predict the financial risk management and control, and the quality of the collected data is high.

Although financial informatization and the use of financial software have improved the efficiency of enterprise work and made enterprise management more refined, however, there are also many problems, and many scholars have made research on this [24-25]. Some enterprises in the use of big data technology to deal with the process of enterprise financial information, the existence of information technology application is not broad enough. In addition, although many enterprises use big data technology in financial management, but the subsequent supporting system does not follow up, resulting in the lack of security of enterprise data, poor implementation, etc., can not give full play to the advantages of enterprise use of big data technology. At present, the study of big data application in enterprise financial management has to be further improved and developed, so as to provide theoretical guidance for financial management innovation in the era of big data.

In this paper, according to the index system design ideas and principles, 98 evaluation indicators were initially selected, and the pre-selected index system set was screened through the questionnaire, and the representative and wide evaluation scope indicators were selected, and 30 evaluation indicators were finally determined, from which the financial management evaluation index system was composed. Starting from the definition of big data analysis technology, it is proposed to use entropy weight method and TOPSIS method to construct the financial management evaluation model, and according to the model evaluation results, it is proposed to integrate the financial management innovation strategy of economic era with big data analysis technology.

2. Exploration of Financial Management Innovation in the Age of Digital Economy

2.1. Design of financial management evaluation index system

2.1.1. Guidelines for the design of the indicator system

Financial management is a unit enterprise in the process of digital economic activities, relying on human subjective initiative to reduce or even eliminate financial management does not meet the organization's expectations of financial behavior, artificial design of capital factor allocation plan, to achieve digital economic and social benefits maximization. Unit enterprise in the process of economic activities in a specific period of time, around the solution of the core problem carried out by the capital factor allocation plan and human subjective initiative induced behavior and results, is the embodiment of the level of enterprise financial management. Specifically, the first evaluation of the enterprise “what to do” that is, whether the digital economy theme and enterprise financial management innovation strategy, followed by the evaluation of the enterprise “how to do” that is, the evaluation of the key control points in the process of enterprise financial management, and finally according to the output of the unit enterprise that is, the evaluation of the financial management level. Finally, the output of the enterprise unit is calculated and evaluated according to the financial contribution performance.

2.1.2. Principles for the design of the indicator system

(1) Principle of scientificity: firstly, the content of the indicators should be consistent with the connotation of financial management innovation, taking into account various influencing factors, and reflecting the digital economy and financial management innovation at the same time. Secondly, the interpretation and expression of the indicators should be scientific and standardized.

(2) Principle of operability: the selection of evaluation indicators should take into account the difficulty of calculation and information collection, the indicators are too complicated to cause difficulties in application, and too brief to scientifically reflect the situation of the evaluation subject.

(3) Principle of comparability: the comparability of indicators reflects the significance of the indicators, the same unit of the enterprise in different spaces comparable and different units of the subject in the same space comparable.

(4) The principle of combining quantitative and non-quantitative indicators: comprehensive consideration of the interests of the holders of different capital elements, many factors affecting the innovation of corporate financial management. Maximum selection of quantitative indicators, but quantitative and qualitative methods should be used in conjunction with each other in order to achieve the objective evaluation purpose.

2.1.3. Basic ideas for the construction of indicators

The steps of this paper in designing the harmonious financial evaluation index system are as follows:

(1) Firstly, this paper comprehensively analyzes the interest needs of different capital element holders and the characteristics of enterprise financial management innovation, on the basis of which combining with the existing scientific research results, the body of the paper pre-selects the set of enterprise financial management indicator evaluation system using theoretical analysis method and frequency statistics method.

(2) The second pre-selected indicator system set is screened by questionnaire survey, on the basis of the existing financial indicator evaluation system, the connotation of enterprise financial management innovation is fully understood, and the screened evaluation indicators are categorized according to their nature.

(3) After the indicators are determined, the indicators should be empowered, and there are many factors affecting the harmonious management of finance, and the selected indicator system has a certain degree of complexity, and the indicator evaluation system should be equipped with the external evaluation of the unit enterprise and the need for self-assessment and rectification of the enterprise at the

same time. This paper selects the entropy weight method of big data analysis technology to evaluate the indicators, determine the specific weights of the indicators, and finally calculate the scores of the indicators through the dimensionless index.

(4) On the basis of the empowerment and assignment of the indicators, the criteria for evaluating the level of financial management innovation are formulated and practically applied to set up a set of systematic indicator evaluation system, which is an important reference value for the development of financial management innovation in the era of digital economy.

2.1.4. Pre-selection of evaluation indicators

This paper evaluates the whole process of enterprise financial management innovation by decomposing and categorizing it in four aspects: financial environment governance ability, financial activity management ability, financial information management ability, and financial contribution performance. In this paper, by reading 30 papers and reports on the evaluation system of financial management innovation indexes and the evaluation of the application of big data analysis in the digital economy, consulting the teachers of colleges and universities and senior managers of enterprises in the design and screening of the indexes, and finally selecting 98 evaluation indexes through the theoretical analysis and comparison, which are classified into four categories according to the content of the evaluation.

2.1.5. Screening of evaluation indicators

The pre-selected indicator system set is screened by distributing questionnaires to experts, and representative indicators with wide evaluation scope are selected. In the design process of this paper, 100 financial workers with senior experience and theoretical accumulation are contacted to screen the indicators by means of questionnaires. Mainly through the mail to send connotation or face-to-face interviews, experts are invited to select representative indicators and give reasonable modification opinions. The cumulative number of indicators selected in the questionnaire is more than half of the number of experts, it is designated as part of the evaluation index system. Finally, 30 indicators were identified, and the selected indicators are shown in Table 1.

Table 1. Selected indicators.

First-level indicator	Symbol	Secondary indicators	Symbol	Third-level indicators	Symbol
Financial environment governance capability	A1	Corporate governance and corporate culture	B1	Equity composition and checks and balances	C1
				The establishment of the "Three Meetings and One High" and the extent to which they play their roles	C2
		Optimization of the financial environment	B2	The organization and setting of financial strategies	C3
				Financial control mode and functions	C4
		Financial organizational structure and functions	B3	The setup of the financial organizational structure	C5
				Job allocation and implementation status	C6
		Financial personnel allocation	B4	Financial personnel training mechanism	C7
				Incentive mechanism for financial personnel	C8
		Construction of financial information system	B5	Implementation of the financial information system	C9
Financial activity management ability	A2	Financial decision-making ability	B6	Financial decision-making and auditing authority setting	C10
				Major matters responsibility mechanism.	C11
		Financial forecasting ability	B7	The formulation of budget management	C12
				Assessment of budget management	C13

		Financial risk management and control capabilities	B8	Tax administration	C14
		Financial supervision mechanism	B9	Internal control mechanism	C15
		Stakeholder relationship maintenance	B10	The formulation and implementation of dividend distribution policies.	C16
				Ratio of creditors to supervisors	C17
				Financial statement disclosure mechanism and its implementation	C18
				Consumer complaint rate	C19
				Government income rate	C20
Financial information management capability	A3	Accounting calculation ability	B11	Accounting calculation policy	C21
				Basic data management	C22
		External financial report	B12	Financial statement disclosure mechanism and its implementation	C23
Financial contribution performance	A4	Debt-paying ability	B13	Cash flow to debt ratio	C24
				Asset-liability ratio	C25
		Operational capacity	B14	Accounts receivable turnover ratio	C26
				Total asset turnover ratio	C27
		Profitability	B15	Return on net assets	C28
				Earnings per share	C29
		Development capacity	B16	Net profit growth rate	C30

2.2. Evaluation models based on big data analysis techniques

2.2.1. Big Data Analytics Technology Definition

"Big data" is defined as information assets that require new processing models to enable greater decision-making, insight discovery and process optimization, and is characterized by massive scale, high growth rates and diversity. McKinsey Global Institute pointed out that a scale in the acquisition, storage, management, analysis of the traditional database software tools greatly exceed the scope of the ability of the collection of data, with massive data scale, rapid data flow, diverse data types and low value density of the four characteristics. Big data and cloud computing are inseparable, must use distributed architecture, using cloud computing distributed processing, distributed database and cloud storage, virtualization technology. It is also characterized by distributed data mining of massive data. Currently, big data has attracted more and more attention, research and use. IBM proposes that big data is characterized by large volume, high speed, variety, low value density, and authenticity. Big data analytics is often associated with cloud computing, where real-time analysis of large datasets requires, for example, MapReduce frameworks to get the job done to hundreds or thousands of computers. Big data analytics techniques refer to the use of advanced algorithms (statistics and machine learning, etc.), tools, and methods to extract valuable information and knowledge from large, complex, and rapidly changing data.

2.2.2. Indicator assignment based on entropy weight method

(1) The basic principle of entropy weighting method

Entropy weighting method determines the indicator weights with the objective raw indicator data as the observation value, the assignment has a high degree of objectivity, is not subject to the interference of human subjective judgment, and the results obtained are more in line with the objective reality [26]. As a representative objective assignment method, compared with other objective assignment methods such as factor analysis, difference coefficient method, etc., the calculation is relatively simple, there is no requirement for the distribution state of the original data, the original data do not need to obey the normal distribution as required by the factor analysis and other methods, and the utilization of the original data is more adequate.

(2) Entropy weight method steps

(a) Determine the original data matrix

According to the various types of data information of the evaluation object, calculate the evaluation value under each evaluation index of the evaluation object, and form the original data matrix of the evaluation system. The greater the difference between the indicators in the original data matrix, the more information the indicator contains and the greater the role it plays in the evaluation.

(b) Data standardization

As the nature of the indicators in the original data matrix is not the same, and the scale and order of magnitude are also different, it is not possible to use the original indicator data directly for analysis, and standardization must be carried out first, i.e., the standardization of data. For indicators with different properties, different standardization methods should be used, so that the data are comparable and operable, i.e., the standardization methods of positive indicators, negative indicators, and moderate indicators are different, and they should be uniformly converted into positive indicators. Commonly used standardization methods include Min-max method, Z-score method and homogenization method. The standardized matrix is obtained after the data are standardized.

(c) Formation of normalized matrix

After the standardized matrix is obtained by the standardized processing of the original indicator data, due to the logarithm of the data in the subsequent calculation process, if there is a value of 0, a suitable processing method should be selected according to the actual situation and the purpose of evaluation. At present, there are three main processing methods: assuming that the logarithmic product of 0 and 0 is 0, taking the value of 0 as a minimal value, and translating the matrix.

(d) Calculation of the weighting of evaluation indicators

Let P_{ij} be the weight of the i th indicator of the i th evaluation object in the sum of the indicators. The greater the weight of the indicator, the greater the contribution of the evaluation object under this indicator. Let there be a total of m evaluation objects and n evaluation indicators. Then $\left(i=1,2,3\cdots\cdots m\right)$, $\left(j=1,2,3\cdots\cdots n\right)$. The method of calculating the weight of evaluation indicators is shown in formula (1):

$$P_{ij}=x_{ij}\Big/\sum_{i=1}^{m}x_{ij} \tag{1}$$

(e) Calculating the entropy value of evaluation indicators

According to the degree of difference of each evaluation indicator and the importance of each evaluation indicator to the comprehensive evaluation decision, the entropy value of each indicator is calculated using the formula of information entropy. The larger the entropy value of the indicator, the smaller the utility value of the information provided. Let e_j be the entropy value of indicator j. The method of calculating the entropy value of indicators is shown in formula (2):

$$e_j=-\frac{1}{\ln m}\sum_{i=1}^{m}P_{ij}\ln P_{ij} \tag{2}$$

(f) Calculate the coefficient of variation of evaluation indicators

Let g_j be the coefficient of variation of indicator j. For the j th indicator, the greater the difference between the values of the same indicator for different evaluation objects, the greater the evaluation effect on each research object, and the smaller the entropy value. The method of calculating the coefficient of variation of indicators is shown in formula (3).

$$g_j=1-e_j \tag{3}$$

(g) Determine the entropy right of evaluation indicators

Calculate the indicator difference coefficient (i.e., the utility value of information) according to the entropy value of the indicator, and do normalization according to the difference coefficient to derive the entropy right of the indicator. According to the principle of entropy weight method, when the entropy value is 1, the difference coefficient is 0, and the entropy weight is also 0, that is, this indicator has no contribution to the whole evaluation, and there is no evaluation role. Let W_j be the entropy weight of indicator j, and normalize the difference coefficient g_j to get the weight of each indicator W_j. The calculation formula of indicator entropy weight is shown in formula (4):

$$W_j=\frac{g_j}{\sum_{j=1}^{n}g_j} \tag{4}$$

2.2.3. Calculation of evaluation results based on the TOPSIS method

(1) The basic principle of TOPSIS method

The advantage of TOPSIS method for evaluation is that it makes the best use of the information of raw data, and its results can accurately reflect the gaps and quantitatively reflect the advantages and disadvantages of the evaluation programs. TOPSIS method does not have strict limitations on the distribution of raw data, the number of samples, and the number of indexes, and it is highly universal, and the calculation is simple and easy to use. TOPSIS is suitable for the comprehensive evaluation of digital economic efficiency and enterprise financial management, especially for the analysis of numerical efficiency indicators, and has been widely used in various fields. The disadvantage of TOPSIS lies in the fact that it does not take into account the weights of the indicators in the process of evaluating and ranking the evaluation objects, and the weights of the indicators have to be combined with the indicator weighting method according to the purpose of the evaluation in order to arrive at a more reasonable evaluation result. The practical application of TOPSIS should be based on the evaluation purpose and other factors combined with the indicator weighting method, so as to arrive at more reasonable evaluation results.

(2) Steps of TOPSIS method

(a) Construct the weighting matrix

TOPSIS method should be combined with the indicator assignment method in order to produce effective evaluation results, multiply the indicator weight vector with the standardized matrix obtained after standardizing the original data to obtain the weighted decision matrix. Set the standardized matrix as $\left(x_{ij}\right)_{m*n}$, the corresponding weight of each indicator as W_j, multiply the two to get the weighted decision matrix $\left(Z_{ij}\right)_{m*n}$, as shown in equation (5):

$$\left(Z_{ij}\right)_{m*n} = \left(x_{ij} * W_{ij}\right)_{m*n} \tag{5}$$

(b) Determination of positive and negative ideal solutions

In the weighted decision matrix, the optimal vector composed of the maximum value of each indicator, i.e., each column, is the positive ideal solution; the worst vector composed of the minimum value of each indicator, i.e., each column, is the negative ideal solution. The method of determining the positive and negative ideal solutions of each indicator is shown in Equation (6) and Equation (7):

$$Z^+ = \left(\max zi_1, \max zi_2, \max zi_3, \dots \max zi_n\right), \left(i = 1,2,3 \dots m\right) \tag{6}$$

$$Z^- = \left(\min zi_1, \min zi_2, \min zi_3, \dots \min zi_n\right), \left(i = 1,2,3 \dots m\right) \tag{7}$$

(c) Calculate the Euclidean distance of each evaluation object's index value to the positive and negative ideal solutions

Calculate the Euclidean distance of each evaluation object's index value to the positive and negative ideal solutions by using the Euclidean spatial distance formula to derive the degree of proximity of each evaluation object to the positive ideal solution and the degree of proximity of each evaluation object to the negative ideal solution, respectively. D_i^+ is the distance of the index value of the i th evaluation object to the positive ideal solution, and D_i^- is the distance of the index value of the i th evaluation object to the negative ideal solution. The calculation method is shown in Equation (8) and Equation (9):

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_j^+\right)^2} \tag{8}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_j^-\right)^2} \tag{9}$$

(d) Calculate and rank the relative closeness of each evaluation object to the positive ideal solution

Using the distance of each evaluation object to the positive ideal solution and the distance to the negative ideal solution, calculate its relative closeness to the positive ideal solution. The smaller the distance to the positive ideal solution and the larger the distance to the negative ideal solution, the better the performance of the evaluation object and the higher the performance ranking. Let the relative closeness be C_i, the calculation method is shown in formula (10):

$$C_i = D_i^- / (D_i^- + D_i^+) * 100 \tag{10}$$

3. Research and analysis

3.1. Analysis of the results of indicator assignment based on the entropy weight method

3.1.1. Data Selection and Data Sources

The indicators involved in this paper are the four dimensions constructed above totaling 30 indicators. The raw data of all indicators are derived from the annual reports of enterprises and Wind database, and the time span of the financial indicator data is from 2014 to 2023, and the raw data of each indicator of a certain enterprise from 2014 to 2023 are shown in Table 2, which shows that the data of each indicator are distributed in the range of 0 to 10, which provides solid data support for the following research results.

Table 2. The original data of each evaluation index of the enterprise from 2014 to 2023.

Index	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
C1	6.503	6.152	8.273	5.518	3.279	3.306	9.049	9.062	9.758	8.16
C2	5.069	9.705	8.946	7.873	4.686	3.632	4.955	3.339	6.379	5.594
C3	4.598	9.694	7.868	5.347	6.344	7.151	9.963	5.291	7.809	7.326
C4	8.881	5.863	3.756	5.528	9.639	9.983	6.932	4.489	6.377	7.736
C5	9.947	4.122	3.86	8.212	9.321	7.773	9.386	8.858	9.713	6.935
C6	8.74	5.226	8.315	6.912	8.864	5.472	6.814	8.87	8.494	3.304
C7	4.123	6.457	8.259	6.488	6.528	6.969	5.581	5.035	3.842	9.105
C8	4.562	9.311	4.89	4.949	8.583	4.458	8.655	4.814	3.4	3.512
C9	3.335	8.379	6.413	5.016	8.635	8.892	5.121	8.607	4.447	7.474
C10	3.544	7.62	9.795	7.444	3.117	7.198	7.793	5.404	9.002	7.582
C11	5.286	3.15	4.216	6.671	7.325	7.896	8.689	8.766	9.971	9.563
C12	7.993	9.054	5.469	4.494	5.924	8.307	6.692	9.588	7.754	8.075
C13	9.783	7.141	4.417	7.66	6.886	6.617	7.428	8.003	4.733	7.253
C14	8.187	6.609	8.465	3.259	4.051	4.419	3.77	9.978	6.247	3.651
C15	3.549	7.637	6.59	3.03	6.01	8.382	3.605	7.366	9.579	6.149
C16	7.129	9.873	3.666	9.981	5.78	9.902	4.234	4.131	5.618	4.095
C17	8.345	5.199	7.959	8.714	3.741	5.476	9.25	3.072	4	9.443
C18	8.042	7.271	3.878	8.045	6.836	8.65	5.017	4.927	3.91	5.487
C19	9.802	6.034	9.345	8.825	7.207	5.738	4.272	8.833	4.939	5.652
C20	5.598	8.691	4.172	4.589	6.37	7.749	9.803	8.563	3.83	6.154
C21	7.608	8.647	3.611	7.829	8.592	5.502	4.558	8.83	9.667	4.035
C22	8.263	6.481	8.024	5.226	3.04	8.037	7.943	3.372	8.501	3.865
C23	9.803	5.334	9.455	8.902	8.255	7.883	5.047	4.598	4.324	9.174
C24	6.015	4.774	4.41	8.457	6.537	7.358	3.472	4.975	4.948	8.187
C25	7.896	4.476	5.544	4.543	5.352	7.876	3.797	9.184	4.815	6.432
C26	8.555	3.342	6.265	3.286	7.555	6.061	5.774	4.686	7.901	8.527
C27	8.156	9.683	6.94	6.684	4.257	4.907	9.576	6.329	7.557	4.822
C28	6.508	3.543	6.032	7.762	4.728	4.212	9.804	9.494	9.911	8.828
C29	8.04	8.122	7.964	8.632	5.978	5.353	7.594	3.196	4.957	7.799
C30	7.39	4.922	7.059	3.511	9.552	6.941	7.568	8.367	3.12	4.725

3.1.2. Numerical preprocessing and dimensionless processing of indicators

In order to eliminate the influence of different magnitudes on data comparison, this paper adopts the extreme value method to preprocess the data. In addition, in order for the entropy value and weight calculated by the entropy weight method to have practical significance, it is necessary to exclude the influence of negative values and zeros on the results. After the dimensionless processing, in order to the intrinsic regularity of the data, the data were shifted to the minimum unit value as a whole, and the shifting unit in this paper is 0.00001, and Table 3 demonstrates the results of the dimensionless processing of each evaluation index of an enterprise from 2014 to 2023. After the indicator value preprocessing and dimensionless processing, the data of each indicator are located in the range of 0 to 1, thus forming a normalization matrix. Take the 2014 C1 indicator as an example:

$$x_{ij}^{'} = \frac{x_{ij} - \min_j}{\max_j - \max_j} = \frac{6.503 - 3.279}{9.758 - 3.279} = 0.498$$

Others are the same and will not be repeated.

Table 3. The results after dimensionless processing of evaluation indicators.

Index	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
C1	0.498	0.443	0.771	0.346	0.000	0.004	0.891	0.893	1.000	0.753
C2	0.272	1.000	0.881	0.712	0.212	0.046	0.254	0.000	0.478	0.354
C3	0.000	0.950	0.610	0.140	0.325	0.476	1.000	0.129	0.599	0.508
C4	0.823	0.338	0.000	0.285	0.945	1.000	0.510	0.118	0.421	0.639
C5	1.000	0.043	0.000	0.715	0.897	0.643	0.908	0.821	0.962	0.505
C6	0.977	0.345	0.900	0.648	0.999	0.390	0.631	1.000	0.932	0.000
C7	0.053	0.497	0.839	0.503	0.510	0.594	0.330	0.227	0.000	1.000
C8	0.197	1.000	0.252	0.262	0.877	0.179	0.889	0.239	0.000	0.019
C9	0.000	0.908	0.554	0.303	0.954	1.000	0.321	0.949	0.200	0.745
C10	0.064	0.674	1.000	0.648	0.000	0.611	0.700	0.342	0.881	0.669
C11	0.313	0.000	0.156	0.516	0.612	0.696	0.812	0.823	1.000	0.940
C12	0.687	0.895	0.191	0.000	0.281	0.749	0.431	1.000	0.640	0.703
C13	1.000	0.508	0.000	0.604	0.460	0.410	0.561	0.668	0.059	0.529
C14	0.733	0.499	0.775	0.000	0.118	0.173	0.076	1.000	0.445	0.058
C15	0.079	0.703	0.544	0.000	0.455	0.817	0.088	0.662	1.000	0.476
C16	0.548	0.983	0.000	1.000	0.335	0.987	0.090	0.074	0.309	0.068
C17	0.828	0.334	0.767	0.886	0.105	0.377	0.970	0.000	0.146	1.000
C18	0.873	0.711	0.000	0.873	0.620	1.000	0.239	0.220	0.007	0.337
C19	1.000	0.319	0.917	0.823	0.531	0.265	0.000	0.825	0.121	0.250
C20	0.296	0.814	0.057	0.127	0.425	0.656	1.000	0.792	0.000	0.389
C21	0.660	0.832	0.000	0.696	0.822	0.312	0.156	0.862	1.000	0.070
C22	0.956	0.630	0.913	0.400	0.000	0.915	0.898	0.061	1.000	0.151
C23	1.000	0.184	0.936	0.836	0.717	0.650	0.132	0.050	0.000	0.885
C24	0.510	0.261	0.188	1.000	0.615	0.780	0.000	0.302	0.296	0.946
C25	0.761	0.126	0.324	0.138	0.289	0.757	0.000	1.000	0.189	0.489
C26	1.000	0.011	0.565	0.000	0.810	0.527	0.472	0.266	0.876	0.995
C27	0.719	1.000	0.494	0.447	0.000	0.120	0.980	0.382	0.608	0.104
C28	0.466	0.000	0.391	0.663	0.186	0.105	0.983	0.935	1.000	0.830
C29	0.891	0.906	0.877	1.000	0.512	0.397	0.809	0.000	0.324	0.847
C30	0.664	0.280	0.612	0.061	1.000	0.594	0.692	0.816	0.000	0.250

3.1.3. Calculation of the weighting of evaluation indicators

On the basis of Table 3, the weight of each evaluation indicator is calculated by applying the formula, and the results of the weight of the evaluation indicators are shown in Table 4. Also take 2014 evaluation indicator C1 as an example, other indicators are the same. The specific calculation results are as follows:

$$P_{ij} = x_{ij}^{'} / \sum_{i=2014}^{2023} x_{ij}^{'} = \frac{0.498}{5.598} = 0.089$$

Table 4. The results of the proportion of evaluation indicators.

Index	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
C1	0.089	0.079	0.138	0.062	0.000	0.001	0.159	0.159	0.179	0.135
C2	0.065	0.238	0.209	0.169	0.050	0.011	0.060	0.000	0.113	0.084
C3	0.000	0.201	0.129	0.029	0.069	0.100	0.211	0.027	0.126	0.107
C4	0.162	0.067	0.000	0.056	0.186	0.197	0.100	0.023	0.083	0.126
C5	0.154	0.007	0.000	0.110	0.138	0.099	0.140	0.126	0.148	0.078
C6	0.143	0.051	0.132	0.095	0.146	0.057	0.092	0.147	0.137	0.000
C7	0.012	0.109	0.184	0.110	0.112	0.130	0.073	0.050	0.000	0.220
C8	0.050	0.256	0.064	0.067	0.224	0.046	0.227	0.061	0.000	0.005
C9	0.000	0.153	0.093	0.051	0.161	0.169	0.054	0.160	0.034	0.126
C10	0.011	0.121	0.179	0.116	0.000	0.109	0.125	0.061	0.158	0.120
C11	0.053	0.000	0.027	0.088	0.104	0.119	0.138	0.140	0.170	0.160
C12	0.123	0.161	0.034	0.000	0.050	0.134	0.077	0.179	0.115	0.126
C13	0.208	0.106	0.000	0.126	0.096	0.085	0.117	0.139	0.012	0.110
C14	0.189	0.129	0.200	0.000	0.030	0.045	0.020	0.258	0.115	0.015
C15	0.016	0.146	0.113	0.000	0.094	0.169	0.018	0.137	0.207	0.099
C16	0.125	0.224	0.000	0.228	0.076	0.225	0.020	0.017	0.070	0.015
C17	0.153	0.062	0.142	0.164	0.019	0.070	0.179	0.000	0.027	0.185
C18	0.179	0.146	0.000	0.179	0.127	0.205	0.049	0.045	0.001	0.069
C19	0.198	0.063	0.182	0.163	0.105	0.052	0.000	0.163	0.024	0.049
C20	0.065	0.179	0.013	0.028	0.093	0.144	0.219	0.174	0.000	0.085
C21	0.122	0.154	0.000	0.129	0.152	0.058	0.029	0.159	0.185	0.013
C22	0.161	0.106	0.154	0.068	0.000	0.154	0.152	0.010	0.169	0.026
C23	0.186	0.034	0.174	0.155	0.133	0.121	0.024	0.009	0.000	0.164
C24	0.104	0.053	0.038	0.204	0.126	0.159	0.000	0.062	0.060	0.193
C25	0.187	0.031	0.080	0.034	0.071	0.186	0.000	0.245	0.046	0.120
C26	0.181	0.002	0.102	0.000	0.147	0.095	0.086	0.048	0.159	0.180
C27	0.148	0.206	0.102	0.092	0.000	0.025	0.202	0.079	0.125	0.021
C28	0.084	0.000	0.070	0.119	0.033	0.019	0.177	0.168	0.180	0.149
C29	0.136	0.138	0.134	0.152	0.078	0.060	0.123	0.000	0.049	0.129
C30	0.134	0.056	0.123	0.012	0.201	0.120	0.139	0.164	0.000	0.050

3.1.4. Calculate entropy value, coefficient of variation, entropy weights

Under the premise of knowing the weight of financial management indicators of an enterprise from 2014 to 2023, the entropy value, coefficient of variance and entropy weight are calculated by applying the above formula, and the results of entropy value, coefficient of variance and entropy weight are shown in Table 5. Taking C1 as an example, the remaining 29 indicators are the same. The specific calculation process is shown below:

$$e_j = \frac{1}{\ln n}\sum_{i=2014}^{2023} p_{ij}\ln\left(p_{ij}\right) = \frac{1}{\ln 10}\sum_{i=2014}^{2023} 0.089\ln\left(0.089\right) = 0.881$$

$$d_j = 1 - e_j = 1 - 0.881 = 0.119$$

$$w_{ij} = \frac{d_{ij}}{\sum_{j=1}^{30} d_j} = \frac{0.119}{3.633} = 0.0327$$

Referring to related studies, n is usually taken as 10.

Table 5. Entropy value, difference coefficient, entropy weight result.

Index	Entropy value	Coefficient of difference	Entropy weight
C1	0.881	0.119	0.0327
C2	0.856	0.144	0.0396
C3	0.883	0.117	0.0323
C4	0.893	0.107	0.0296
C5	0.905	0.095	0.0260

C6	0.929	0.071	0.0196
C7	0.883	0.117	0.0323
C8	0.810	0.190	0.0522
C9	0.903	0.097	0.0266
C10	0.904	0.096	0.0263
C11	0.912	0.088	0.0243
C12	0.913	0.087	0.0239
C13	0.905	0.095	0.0263
C14	0.818	0.182	0.0501
C15	0.876	0.124	0.0340
C16	0.809	0.191	0.0526
C17	0.874	0.126	0.0348
C18	0.853	0.147	0.0404
C19	0.880	0.120	0.0331
C20	0.863	0.137	0.0377
C21	0.878	0.122	0.0335
C22	0.877	0.123	0.0340
C23	0.858	0.142	0.0391
C24	0.892	0.108	0.0298
C25	0.860	0.140	0.0386
C26	0.876	0.124	0.0340
C27	0.876	0.124	0.0341
C28	0.884	0.116	0.0319
C29	0.929	0.071	0.0195
C30	0.886	0.114	0.0313

3.1.5. Results of weighting of evaluation indicators

The entropy weights in the fifth column of Table 5 are summarized to finally obtain the weights of each evaluation index, and the results of the weights of each evaluation index are shown in Table 6. Taking the first-level indicators as an example, A2 (financial activity management ability: 0.3833) > A1 (financial environment governance: 0.2909) > A4 (financial contribution performance: 0.2192) > A3 (financial information management ability: 0.1066), which indicates that the influence of financial activity management ability on financial management innovation in the digital economy era is greater than that of the financial environment governance ability, financial contribution performance, and financial information management ability. The rest of the secondary indicators are the same as the tertiary indicators and will not be explained in detail.

Table 6. The weight results of each evaluation index.

First-level indicator	Weight	Secondary indicators	Weight	Third-level indicators	Weight
A1	0.2909	B1	0.0723	C1	0.0327
				C2	0.0396
		B2	0.0619	C3	0.0323
				C4	0.0296
		B3	0.0456	C5	0.026
				C6	0.0196
		B4	0.0845	C7	0.0323
				C8	0.0522
		B5	0.0266	C9	0.0266
A2	0.3833	B6	0.0506	C10	0.0263
				C11	0.0243
		B7	0.0502	C12	0.0239
				C13	0.0263
		B8	0.0501	C14	0.0501
		B9	0.0338	C15	0.0338
		B10	0.1986	C16	0.0526
				C17	0.0348
				C18	0.0404

				C19	0.0331
				C20	0.0377
A3	0.1066	B11	0.0675	C21	0.0335
				C22	0.034
		B12	0.0391	C23	0.0391
A4	0.2192	B13	0.0684	C24	0.0298
				C25	0.0386
		B14	0.0681	C26	0.034
				C27	0.0341
		B15	0.0514	C28	0.0319
				C29	0.0195
		B16	0.0313	C30	0.0313

3.2. Analysis of evaluation results based on the TOPSIS method

3.2.1. Constructing a weighting matrix

Using the weights obtained through the formula in the previous section and the corresponding multiplication of each vector in the original data matrix to obtain the weighting matrix, the weighting matrix of the evaluation indicators is shown in Table 7. Also take C1 in the evaluation index of enterprise financial management in 2014 as an example, and the rest of the indicators are the same. Calculated as follows:

$$\left(Z_{i,j}\right)_{m*n} = \left(x_{ij} * W_{ij}\right)_{m*n} = 6.503 * 0.0327 = 0.2126$$

Table 7. Weighted normalization matrix of evaluation indicators.

Index	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
C1	0.2126	0.2012	0.2705	0.1804	0.1072	0.1081	0.2959	0.2963	0.3191	0.2668
C2	0.2007	0.3843	0.3543	0.3118	0.1856	0.1438	0.1962	0.1322	0.2526	0.2215
C3	0.1485	0.3131	0.2541	0.1727	0.2049	0.2310	0.3218	0.1709	0.2522	0.2366
C4	0.2629	0.1735	0.1112	0.1636	0.2853	0.2955	0.2052	0.1329	0.1888	0.2290
C5	0.2586	0.1072	0.1004	0.2135	0.2423	0.2021	0.2440	0.2303	0.2525	0.1803
C6	0.1713	0.1024	0.1630	0.1355	0.1737	0.1073	0.1336	0.1739	0.1665	0.0648
C7	0.1332	0.2086	0.2668	0.2096	0.2109	0.2251	0.1803	0.1626	0.1241	0.2941
C8	0.2381	0.4860	0.2553	0.2583	0.4480	0.2327	0.4518	0.2513	0.1775	0.1833
C9	0.0887	0.2229	0.1706	0.1334	0.2297	0.2365	0.1362	0.2289	0.1183	0.1988
C10	0.0932	0.2004	0.2576	0.1958	0.0820	0.1893	0.2050	0.1421	0.2368	0.1994
C11	0.1284	0.0765	0.1024	0.1621	0.1780	0.1919	0.2111	0.2130	0.2423	0.2324
C12	0.1910	0.2164	0.1307	0.1074	0.1416	0.1985	0.1599	0.2292	0.1853	0.1930
C13	0.2573	0.1878	0.1162	0.2015	0.1811	0.1740	0.1954	0.2105	0.1245	0.1908
C14	0.4102	0.3311	0.4241	0.1633	0.2030	0.2214	0.1889	0.4999	0.3130	0.1829
C15	0.1200	0.2581	0.2227	0.1024	0.2031	0.2833	0.1218	0.2490	0.3238	0.2078
C16	0.3750	0.5193	0.1928	0.5250	0.3040	0.5208	0.2227	0.2173	0.2955	0.2154
C17	0.2904	0.1809	0.2770	0.3032	0.1302	0.1906	0.3219	0.1069	0.1392	0.3286
C18	0.3249	0.2937	0.1567	0.3250	0.2762	0.3495	0.2027	0.1991	0.1580	0.2217
C19	0.3244	0.1997	0.3093	0.2921	0.2386	0.1899	0.1414	0.2924	0.1635	0.1871
C20	0.2110	0.3277	0.1573	0.1730	0.2401	0.2921	0.3696	0.3228	0.1444	0.2320
C21	0.2549	0.2897	0.1210	0.2623	0.2878	0.1843	0.1527	0.2958	0.3238	0.1352
C22	0.2809	0.2204	0.2728	0.1777	0.1034	0.2733	0.2701	0.1146	0.2890	0.1314
C23	0.3833	0.2086	0.3697	0.3481	0.3228	0.3082	0.1973	0.1798	0.1691	0.3587
C24	0.1792	0.1423	0.1314	0.2520	0.1948	0.2193	0.1035	0.1483	0.1475	0.2440
C25	0.3048	0.1728	0.2140	0.1754	0.2066	0.3040	0.1466	0.3545	0.1859	0.2483
C26	0.2909	0.1136	0.2130	0.1117	0.2569	0.2061	0.1963	0.1593	0.2686	0.2899
C27	0.2781	0.3302	0.2367	0.2279	0.1452	0.1673	0.3265	0.2158	0.2577	0.1644
C28	0.2076	0.1130	0.1924	0.2476	0.1508	0.1344	0.3127	0.3029	0.3162	0.2816
C29	0.1568	0.1584	0.1553	0.1683	0.1166	0.1044	0.1481	0.0623	0.0967	0.1521
C30	0.2313	0.1541	0.2209	0.1099	0.2990	0.2173	0.2369	0.2619	0.0977	0.1479

3.2.2. Determining positive and negative ideal solutions

On the basis of Table 7, the positive and negative ideal solutions are determined by the formula, and the results of positive and negative ideal solutions of each index are shown in Table 8. Taking C1 in the evaluation index of enterprise financial management as an example, the positive and negative ideal solutions are 0.3191 and 0.1072 respectively. its calculation is as follows:

$$Z^{+} = \max(Z) = 0.3191$$

$$Z^{-} = \max(Z) = 0.1072$$

Table 8. The positive and negative ideal solution results of each indicator.

Index	Negative ideal solution	Positive ideal solution
C1	0.1072	0.3191
C2	0.1322	0.3843
C3	0.1485	0.3218
C4	0.1112	0.2955
C5	0.1004	0.2586
C6	0.0648	0.1739
C7	0.1241	0.2941
C8	0.1775	0.4860
C9	0.0887	0.2365
C10	0.0820	0.2576
C11	0.0765	0.2423
C12	0.1074	0.2292
C13	0.1162	0.2573
C14	0.1633	0.4999
C15	0.1024	0.3238
C16	0.1928	0.5250
C17	0.1069	0.3286
C18	0.1567	0.3495
C19	0.1414	0.3244
C20	0.1444	0.3696
C21	0.1210	0.3238
C22	0.1034	0.2890
C23	0.1691	0.3833
C24	0.1035	0.2520
C25	0.1466	0.3545
C26	0.1117	0.2909
C27	0.1452	0.3302
C28	0.1130	0.3162
C29	0.0623	0.1683
C30	0.0977	0.2990

3.2.3. Calculate the relative fit as well as the Euclidean distance

Combining the data in Table 8 and the formula in the TOPSIS method, the relative closeness of the evaluation object as well as the Euclidean distance are calculated, and the relative closeness and the Euclidean distance for the period from 2014 to 2023 are shown in Table 9. Taking 2014 in the evaluation index of enterprise financial management as an example, the Euclidean distance is 0.5405. the calculation is as follows:

$$D_{2014}^{+} = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_{j}^{+}\right)^{2}} = \sqrt{\sum_{j=1}^{30}\left(z_{2014j} - z_{j}^{+}\right)^{2}} = 0.59822$$

$$D_{2014}^{-} = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_{j}^{-}\right)^{2}} = \sqrt{\sum_{j=1}^{30}\left(z_{2014j} - z_{j}^{-}\right)^{2}} = 0.71743$$

$$C_i = D_i^{-} / \left(D_i^{-} + D_i^{+}\right) = 0.71743 / \left(0.59822 + 0.71743\right) = 0.5453$$

From the table, it can be seen that during the period from 2014 to 2023, the level of financial management of an enterprise has declined significantly, in order to better face the challenges and opportunities of the digital economy, enterprise financial management innovation is imperative.

Table 9. The relative proximity and European-style distance from 2014 to 2023.

Year	D_i^+	D_i^-	C_j	Rank
2014	0.59822	0.71743	0.5453	2
2015	0.59199	0.75433	0.5603	1
2016	0.70583	0.65177	0.4801	6
2017	0.70795	0.64781	0.4778	7
2018	0.71114	0.60956	0.4615	8
2019	0.6566	0.67309	0.5062	3
2020	0.7136	0.68126	0.4884	5
2021	0.71046	0.69009	0.4927	4
2022	0.75181	0.64065	0.4601	9
2023	0.74113	0.60566	0.4497	10

3.2.4. Enterprise financial management innovation strategy

Enterprise management evaluation model based on big data analysis technology can intuitively react to the current enterprise financial management problems, help management predict market changes, and develop a more reasonable financial strategy. Specific strategies are as follows:

(1) Build a data governance system

Enterprises need to establish a comprehensive data governance framework to develop unified data standards and management specifications. The data hosting system should cover the full life cycle management of data, including data collection, storage, processing, analysis, application of each link. Establish a data quality management system, set data quality assessment indicators, and implement a regularized data quality monitoring mechanism. Set up a special data governance committee, clarify the data management responsibilities of each department, implement data asset management, establish a data asset catalog, and realize unified management and value assessment of data resources. Formulate data standardization specifications, unify data definitions, formats and coding standards, and improve data consistency and usability. Establish a metadata management system, strengthen data lineage management, and realize data traceability and impact analysis. Optimize the data collection process, establish a data collection quality control mechanism, and reduce errors and redundancy in the data collection process. Implement master data management, unify the definition and attributes of key business entities, and ensure the accuracy and consistency of core data. Establish a data sharing mechanism to break “data silos” and promote the full utilization of data resources. A data quality evaluation system has been constructed, and data quality assessments are conducted on a regular basis to continuously improve data quality.

(2) Promote technological innovation and integration

Enterprises should formulate technological innovation strategies and continuously promote the innovative application of big data analysis technologies. Establish a technology innovation mechanism to encourage the development and application of new technologies and methods. Implement system architecture upgrading, adopt microservice architecture, and improve system flexibility and scalability. Promote the construction of technical standardization, unify technical platforms and development frameworks, and reduce the difficulty of system integration. Establish a technology evaluation mechanism to scientifically assess the applicability and value of new technologies and avoid blind introduction. Implement progressive system transformation and promote system upgrading step by step to reduce the risk of upgrading. Establish a technology innovation fund to support the research and development of key technologies and enhance the capability of independent innovation. Promote the application of cloud computing technology and build a hybrid cloud architecture to improve system elasticity and efficiency. Establish a technology cooperation mechanism, strengthen strategic cooperation with technology suppliers, and jointly promote technological innovation. Implement agile development methods to improve system development efficiency and accelerate technological innovation. Establish a technology monitoring mechanism to track technology development trends and grasp innovation opportunities in a timely manner. Promote the application of blockchain technology to enhance data credibility and security. Establish a technology risk assessment mechanism to prevent technology innovation risks and ensure the controllability of innovation projects.

4. Conclusion

With the rapid development of digital technology, the application of financial big data analysis technology in the financial management of enterprises in the digital economy era is becoming more and more widespread. For this reason, starting from the evaluation index system of enterprise financial management, with the help of entropy weight method and TOPSIS method in the big data analysis technology, we constructed a financial management evaluation model in the era of digital economy, and used the model to evaluate and analyze the financial management work of an enterprise from 2014 to 2023. The research results of this paper are as follows:

(1) In the results of the weighting of the enterprise financial management evaluation index system, it is found that A2 (financial activity management ability: 0.3833) > A1 (financial environment governance: 0.2909) > A4 (financial contribution performance: 0.2192) > A3 (financial information management ability: 0.1066), which reveals the importance of the financial activity management ability to financial management in the digital economy era.

(2) In the period from 2014 to 2023, the level of financial management of the enterprise shows a substantial decline, the corresponding Euclidean distance decreases from 0.5453 to 0.4497, which reacts to the financial management problems of the enterprise, and in order to better face the challenges and opportunities of the digital economy, it puts forward the innovation strategy for the financial management of the enterprise based on the big data analyzing technology.

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