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Article

Optimization analysis of financial resource allocation using linear programming algorithm

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Abstract: Reasonable financial resource allocation is an important factor in enhancing the core competitiveness of small businesses. In this regard, this paper studies the comprehensive deployment of time cost, financial resources opportunity cost, penalty cost and deferred cost objective functions, and constructs a mixed integer linear programming model under relevant constraints. Validated by the PSPLIB standard problem library, the results show that the integrated optimization can achieve the smooth use of financial resources than the single-objective optimization. The study selects 45 Shanghai and Shenzhen A-share listed real estate companies as research objects, integrates the entropy weight method and TOPSIS method, constructs the company's financial performance evaluation index system, and analyzes and explores the specific performance of the sample companies in terms of profitability, solvency, operating ability, growth ability, cash flow ability, and comprehensive financial performance in the years of 2021~2023. Through empirical analysis, it is found that after applying the financial resource allocation optimization model designed in this paper, the financial performance of enterprises is steadily improved. The research in this paper can satisfy the optimal allocation of financial resources when the enterprise is running.

Keywords: linear programming; PSPLIB; entropy weight TOPSIS method; resource allocation optimization

1. Introduction

Financial resource allocation refers to the combination of capital in different ways of formation and the distribution between different economic uses [1]. Optimization of corporate financial resource allocation project aims to find out the deficiencies and gaps and establish a new resource allocation system through the analysis of the use, distribution and income of the existing financial resources and cash flow status of the enterprise, and to realize the investment of the enterprise's financial resources to the advantageous areas and high-quality enterprises in line with the company's development strategy under the premise of controllable risk [2-4]. Good financial management can not only improve the efficiency of the use of funds, but also can cohesion and stimulate the enthusiasm of the members of the organization, and enhance the competitive strength of the enterprise [5]. However, for a long time, enterprise financial management generally exists such as unscientific budgets, imperfect performance assessment, poor incentive mechanism and other problems, which urgently need to be systematically optimized and reformed [6].

The linear programming algorithm consists of three parts, including variables, linear objective function and linear constraints [7]. The linear objective function and linear constraints are linear expressions of the variables, the linear objective function can be expressed as a maximum or minimum value, and the linear constraints can be expressed as a set of equations or a set of inequalities [8-9]. A set of assignments of the variables that satisfy the linear constraints is the solution of linear programming, and the value of the linear objective function obtained through this set of assignments is the objective of linear programming [10]. In simple terms, a linear programming optimization problem is to find a set of decision variables that maximizes or minimizes a linear objective function subject to a set of linear constraints [11]. The use of linear programming algorithms can effectively deal with multivariate, multi-constraint complex financial decision-making problems under the conditions of limited resources, to achieve the optimal allocation of resources [12].

For the allocation of financial resources, solving the related problems can make the enterprise go more stable, faster and better. Pinto et al. developed an intelligent optimization system for studying the financial performance of the enterprise, which determines the optimization strategy for achieving the highest risk-return and allocation of financial resources through the autonomous analysis of financial data, and the implementation of the optimization system improves the efficiency of the enterprise's decision-making [13]. Wang and Mansoor used the optimization characteristics of genetic algorithm to optimize the parameters and structure of the back-propagation neural network, so as to improve the decision-making ability of the model and optimize the utilization of financial resources, and the evaluation experiments show that the hybrid model is superior in analyzing financial management information [14]. Guo comprehensively analyzes the problems faced by financial resource management in colleges and universities, compares the performance of multiple intelligent optimization algorithms for optimizing financial resource allocation in different situations, and selects the best intelligent optimization algorithms according to the comparison results to ensure the smooth development of financial work in colleges and universities [15]. Wu et al.'s study confirms that regional integration has a positive moderating effect on the efficiency of enterprise resource allocation, which reduces the degree of resource mismatch of enterprises, and eases the financing constraints of enterprises, improves the degree of talent aggregation, as well as reduces the operating costs of enterprises [16].

The research on optimization of financial resource allocation using linear programming is relatively novel and lacks previous research in this area, but the research on resource allocation of the technology's deferred algorithms in the fields of electric power, cloud computing and other areas has yielded fruitful results, which are equally informative for the research in this paper [17-18]. For the optimal allocation of power resources, Özcan and Erol developed a multi-objective mixed integer linear programming model for optimal allocation of the most basic energy resources based on the usage and demand of energy for power generation in Turkey in order to achieve local sustainable development goals [19]. Zhu et al. successfully achieved regional load minimization scheduling during peak electricity consumption by scheduling adjustable power appliances and adjustable time appliances with optimal power and optimal operation time based on integer linear programming algorithm [20]. Nemati et al. constructed a power resource scheduling optimizer with the fusion of genetic algorithm and mixed integer linear programming algorithm, and verified its effectiveness in resource allocation under microgrid models with different operating strategies through evaluation and comparison experiments [21]. For optimal allocation of cloud resources, Liu and Fan proposed a resource allocation model based on mixed integer linear programming to solve the problem of optimizing resource allocation while satisfying user demands in cloud computing environment, and the access latency, optimization rewards, and resource allocation of the used model outperform the existing methods [22]. Kandi et al. compared the performance of integer linear programming algorithms with greedy algorithms for cloud computing resource allocation optimization, and they found that the linear model can be implemented in any fast integer linear programming solver, and the provided cloud resource allocation solution strikes a good balance between quality and cost [23]. Rezvani et al. proposed an algorithm based on integer linear programming in order to achieve efficient resource utilization in cloud environments, and the resource allocation performance of the used algorithm outperforms the comparative algorithms in the case of highly heterogeneous loads and maximizes the utilization of physical resources [24].

In this paper, a model for optimal allocation of financial resources based on linear programming algorithm is constructed in the research process. The model comprehensively considers the integrated financial resource allocation time cost, financial resource opportunity cost, penalty cost and extension cost. Through linear weighting, the four objectives are optimized and unified, and the model is built under the constraints of relevant conditions such as resource demand, enterprise resource pool, and project group with the highest priority. Matlab software is used to realize the solution of the model and analyze the impact of the model on enterprise performance based on the entropy weight TOPSIS method, so as to have a better understanding of the overall performance of the enterprise's financial resource allocation.

2. Modeling optimization of financial resource allocation

2.1. Financial resourcing

Financial resources refer to the capital owned by the enterprise and the unique, exclusive and specialized financial assets formed in the process of investment and financing, such as the financial management system, financial relationship network and financial personnel with unique skills. Generally speaking, the more homogeneous the financial resources, the greater the liquidity, but the lower the specialization, not conducive to enhance the core competitiveness of enterprises. On the contrary, higher specialization can strongly enhance the core competitiveness of the enterprise, but lower mobility. Therefore, in order to reduce risk, firms in the early stage of business need to maintain the liquidity of financial resources without overemphasizing their specialization. For mature enterprises, they need to have specialized resources to increase their differentiation in order to consolidate and expand their market position.

Financial resource allocation is a basic and important element of modern financial management. Financial resource allocation mainly involves two aspects: on the one hand, it is the arrangement of enterprise capital raising method and period, including the arrangement of long and short-term capital, equity capital and debt capital. On the other hand, the arrangements for the use of financial resources, including the direction of resource use and the amount of arrangements. The fundamental reason for enterprises to allocate financial resources is the scarcity of resources [25]. The scarcity of resources requires enterprises to allocate limited financial resources to the most needed places, improve the input-output efficiency of resources, and ensure the sustainable and stable development of enterprises.

2.2. Linear Programming Algorithms

Linear programming (LP) is an important branch of operations research, for which the research is relatively early, the development is also very fast, and now it has been widely used, it is a kind of mathematical method to assist people in daily scientific management. Linear programming method focuses on the mathematical theory and methods of linear objective function extreme value problems under linear constraints [26]. Linear programming method is widely used in military warfare, business management, economic analysis and engineering technology, etc. It provides a scientific configuration method for organizations to make optimal decisions when making rational use of their limited human, material and financial resources.

(1) The format of the linear programming model:

A linear function that requires a great value:

$$c_1x_1 + c_2x_2 \tag{1}$$

Problem constraints of the following form:

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 &\le b_1 \\ a_{21}x_1 + a_{22}x_2 &\le b_2 \\ a_{31}x_1 + a_{32}x_2 &\le b_3 \end{aligned} \tag{2}$$

And non-negative variables:

$$\begin{aligned} x_1 &\ge 0 \\ x_2 &\ge 0 \end{aligned} \tag{3}$$

(2) Steps in constructing a linear programming model:

1) Analyze the relevant factors to find the decision variables.

2) Determine the objective function based on the functional relationship between the decision variables and the purpose to be achieved.

3) Determine the constraints to be satisfied by the decision variable according to the constraints to which the decision variable is subject.

The mathematical model of linear programming can be expressed as follows:

Objective function:

$$\max(\min)Z = \sum_{j=1}^{n} c_j x_j \tag{4}$$

Constraints:

$$\begin{cases} \sum_{j=1}^{n} a_{ij}x_j \le (\ge, =) b_j, i = 1, 2, 3\cdots, m \\ x_j \ge 0, \qquad\qquad j = 1, 2, 3\cdots, n \end{cases} \tag{5}$$

2.3. Financial resource allocation optimization model construction

2.3.1. Model notation and definition of relevant variables

Enterprise financial resource deployment management involves a number of independent of each other in the enterprise, let the set of financial within the enterprise as $Q = \{Q_i \mid i = 1, 2, \cdots, n\}$, the enterprise has the deployment of financial resources repository (resource pool) set as $G = \{G_j \mid j = 1, 2, \cdots, m\}$, and the set of key financial resource types the firm has $R = \{R_k \mid k = 1, 2, \cdots, q\}$.

The relevant symbolic variables of the model and their definitions are given below:

$d_i^{\ k}$ denotes the financial Q_i demand for the R_k class of resources.

$s_j^{\ k}$ denotes the amount of G_j available to be deployed for the R_k class of resources after the start of resource deployment.

t_{ji} denotes the minimum time for G_j to deploy resources to financial Q_i after the start of resource deployment.

α_k R_k denotes the unit cost of redeployment for the class of resources.

β_k R_z denotes the unit penalty cost when the class resource is underdeployed.

$x_{ij}^{\ k}$ denotes the amount of R_k class resources that are redeployed from the resource pool G_j to the financial Q_i during the resource deployment process.

ω denotes the prioritized relative importance weighting factor for finance, where $\omega = \{\omega_i \mid i = 1, 2, \cdots, n\}$.

λ_{ki} means $\lambda_{ki} = \begin{cases} 1 & \text{Critical resources } R_k \text{ are ultimately redeployed to project cluster } Q_i \\ 0 & \text{Other} \end{cases}$.

R_i^* denotes the amount of critical resources actually allocated to the financial Q_i, where $R_i^* = \sum_{k=1}^{R} \lambda_k$.

δ_i denotes the amount of tasks that need to be accomplished during a certain period of time in finance (for the sake of research convenience, this paper assumes that this amount of tasks has been determined in the project planning stage).

t_{sk} denotes the deployment competition among multiple finances of the firm at the same time at the moment t_s for resources of class R_k.

$t_i^{\ h}$ t_S denotes the expected time after the moment when the finance Q_i needs the R_k class resources to have accomplished a certain task, i.e., the time required for the finance Q_t to accomplish a certain task assuming that the resources have been satisfied.

t_i^H indicates that after the enterprise multiple financial for R_k class resource competition deployment, in the moment t_s after financial Q_i also need to complete the actual completion of a task required time, i.e., the financial full life cycle = financial workload / amount of resources, in which $t_i^H = \delta_i / R_i^*$.

The Δc_i represents the cost of a one-day delay in the financial Q_i schedule due to untimely resource deployment.

Δt_i denotes the time interval between the actual time taken by finance Q_i to complete a task and the expected time, where $\Delta t_i = t_i^H - t_i^h$.

C_i denotes the cost of project delays due to untimely resource deployment and financial Q_i, where

$C_i = \Delta t_i \cdot \Delta c_i$.

φ_i denotes the time-cost conversion factor.

2.3.2. Model objective function

Based on the enterprise finance due to key financial resources deployment is not in place and the direct economic losses arising from the conditions of the construction of the financial resources deployment model principles, should take into account the financial resources from the enterprise financial resources pool deployment to the financial urgency of the deployment time to deployment time (this paper is called the cost of deployment time) as the core factor of the shortest. At the same time, in the study of enterprise financial resources deployment, should also take into account the deployment of financial resources when the financial resources themselves have the value of the cost (this paper is called the opportunity cost of financial resources). Due to the financial resources deployed to the financial enterprise can not meet the full amount of financial implementation needs and thus caused by the cost (this paper is called the cost of penalties). As well as due to the deployment of financial resources are not in place, resulting in the financial project schedule extension of the loss incurred (in this paper called extension costs). Therefore, in summary, the model constructed the objective function is shown below:

Objective function 1: The financial resource deployment time cost F_1 is:

$$F_1 = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{q} \omega_i x_{ij}{}^{k} t_{ji}{}^{T} \tag{6}$$

Objective function 2: The opportunity cost of financial resources F_2 is:

$$F_2 = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{q} \omega_i x_{ij}^{k} \alpha_k^{T} \tag{7}$$

Objective function 3: The financial resource deployment penalty cost F_3 is:

$$F_3 = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{q} \omega_i \left(d_i^k - x_{ij}^k\right) \beta_k^T \tag{8}$$

Objective function 4: The financial resource deployment deferral cost F_4 is:

$$F_4 = \sum_{i=1}^{n}\sum_{i=1}^{n} \omega_i C_i = \sum_{i=1}^{n}\sum_{i=1}^{n} \omega_i \Delta t_i \cdot \Delta c_i = \sum_{i=1}^{n}\sum_{i=1}^{n} \omega_i \left(\frac{\delta_i}{\sum_{k=1}^{R} \lambda_{ki}} - t_i^h \right) \cdot \Delta c_i^T \tag{9}$$

2.3.3. Constraints

The constraints related to them in the objective function of the model constructed above are mainly considered from the following aspects:

(1) The total amount of resources received by the financial set Q_i within the enterprise cannot exceed the resource requirements requested by the program cluster, i.e., there:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{q} x_{ij}^k \le d_i{}^k \tag{10}$$

(2) The total amount of financial resources that can be deployed from the enterprise's resource pool G_j cannot be greater than the amount it has, i.e:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{q} x_{ij}^k \le s_j{}^k \tag{11}$$

(3) For the project group with the highest priority, if the project is delayed due to financial resource

deployment, it will not only directly affect the economic objectives of the enterprise, but also negatively affect the strategic objectives of the enterprise and the enterprise's reputation in the market, so it should be prioritized to ensure that the project group with the highest priority will not be delayed due to the competition for financial resources or try to reduce the probability of the project being delayed, so there is:

$$\omega_i = \max\left(\omega_p\right), (i = 1, 2, \cdots, p, \cdots, n) \tag{12}$$

$$0 \le \sum_{i=1}^{n} \sum_{k=1}^{R} \lambda_{ki} = R \tag{13}$$

2.3.4. Model construction

Based on the above analysis and the central idea of this research paper, the optimization model of enterprise financial resource allocation constructed is shown below:

$$\min F = \varphi_i F_1^T + F_2 + F_3 + F_4 \tag{14}$$

$s.t.\ \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{q} x_{ij}^k \le d_i^k$, $\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{q} x_{ij}^k \le s_j^k$, $\omega_i = \max\left(\omega_p\right), (i = 1, 2, \cdots, p, \cdots, n)$,

$0 \le \sum_{i=1}^{n} \sum_{k=1}^{R} \lambda_{ki} = R$.

$x_{ij}^k \ge 0$ and are all integers.

$t_{ji} \ge 0$, $\alpha_k \ge 0$, $\beta_k \ge 0$, $i = 1, 2, \cdots, n; j = 1, 2, \cdots, m; k = 1, 2, \cdots, q$.

3. Analysis of examples

Project Scheduling Problems (PSPLIB) is designed using the software ProGen to set various parameters for project scheduling problems. The software generates scheduling problems with different objectives that meet the parameter requirements, including 500 scheduling problems, each containing 32 tasks and involving five types of renewable resources. At the same time, a set of scheduling problems involving multiple task modes is generated by extending ProGen to form PSPLIB.In this paper, the set of active multimodal j10 test problems from the PSPLIB standard problem library is used for validation and analysis. Matlab is utilized for programming calculations. For simplicity of calculation, only the 1st mode data of the activity is selected for reference.

The calculation example includes 10 processes, including 2 virtual processes and 8 real processes, and the construction process involves 2 renewable resources.

Calculate the earliest start time for each activity, using the rule of priority of maximum total financial resource requirements: $\{0, 2, 0, 3, 2, 6, 8, 9, 13, 16\}$. Latest Start Time: $\{0, 1, 0, 0, 0, 5, 16, 14, 17, 2, 19\}$. Activity Total Time Difference $\{0, 0, 0, 0, 2, 3, 0, 1, 3, 0, 0\}$. Free Time Difference $\{0, 0, 0, 0, 0, 0, 3, 1, 0, 3, 0, 0, 0\}$.

The financial resource profile for scheduling with the earliest start time is shown in Figure 1. Starting at the moment t = 1, determine the demand for financial resources at each moment. Determine the optimal scheduling plan when the objective function takes the minimum value:

$$\min F = \{0, 1, 0, 0, 3, 6, 10, 14, 0, 20\} \tag{15}$$

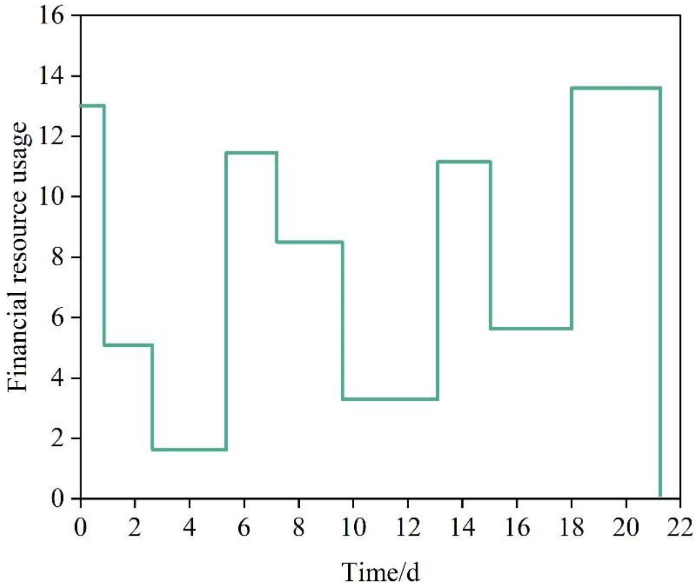

Figure 1. Financial resources profile (earliest start time).

The corresponding financial resources contour map is output, and the deviation of financial resources fluctuation is 163, and the comprehensive optimized financial resources contour map is shown in Figure 2. In this paper, the optimization considering four objectives of deployment time cost, opportunity cost of financial resources, penalty cost and postponement cost is smoother than the optimization when only financial resources balance is considered as the objective, and the financial resources fluctuation is reduced by 2.3%.

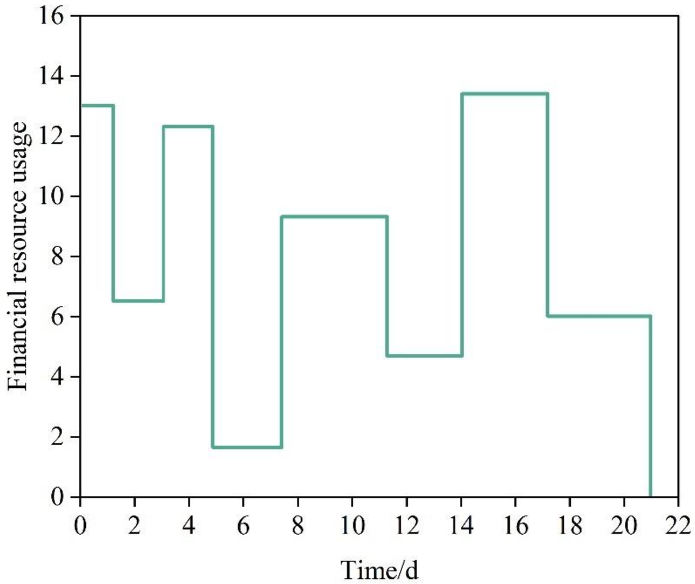

Figure 2. Comprehensive optimization of financial resources profile.

4. Analysis of the results of the optimization of the allocation of financial resources

This chapter analyzes the results of financial resource allocation optimization by entropy weight TOPSIS method. By constructing the enterprise financial performance evaluation index system and performance evaluation model, it analyzes the impact of the financial resource allocation optimization model on the enterprise financial performance.

4.1. Entropy weight TOPSIS method of performance evaluation modeling

Entropy weight TOPSIS method is a statistical analysis method that avoids subjectivity due to low-level, multi-factor weight determination [27]. The main research of this paper is to use entropy weight TOPSIS method to evaluate the financial performance of enterprises specific evaluation model calculation steps are as follows:

(1) Construct the original decision matrix

First, assuming that the number of sample companies is m, the number of evaluation indicators of financial performance is n, and the raw value of each financial performance evaluation indicator is $x_{ij}(i=1,2,\cdots,m; j=1,2,\cdots,n)$, the company's financial performance evaluation of the original decision matrix is: $X=\left(x_{ij}\right)_{n\times m}$.

(2) Standardization of raw data of evaluation indicators

Different indicators of different dimensions may be affected by the order of magnitude and scale, making them unsuitable for comparison in one dimension. In order to eliminate this influence, it is necessary to standardize the original decision matrix X to obtain the standardized decision matrix for the evaluation of the company's financial performance $Y_{mn}=\left\{y_{ij}\right\}(0\le i\le m, 0\le j\le n)$, where y_{ij} denotes the standardized values of the various performance evaluation indicators. Generally speaking, there are three kinds of relationships between the indicators for evaluating performance in a set of evaluation index system and the performance itself, either the indicators for evaluating performance are in the same direction as the performance growth, which is called positive indicators. Either it is opposite to the direction of performance growth, called negative indicator. Either they remain neutral, neither growing nor decreasing with performance, called moderate indicators. There are standardization formulas for different indicators:

The standardization formula for positive indicator data is:

$$y_{ij}=\frac{x_{ij}-x_j^{\min}}{x_j^{\max}-x_j^{\min}} \tag{16}$$

Normalization formula for the raw data of the inverse indicator:

$$y_{ij}=\frac{x_j^{\max}-x_{ij}}{x_j^{\max}-x_j^{\min}} \tag{17}$$

The normalization formula for the raw data of the suitability indicator is:

$$y_{ij}=\begin{cases}1-\dfrac{q_1-x_{ij}}{\max\left(q_1-x_j^{\min}, x_j^{\max}\right)}, x_{ij}<q_1\\ 1, q_1\le x_{ij}\le q_2\\ 1-\dfrac{x_{ij}-q_2}{\max\left(q_1-x_j^{\min}, x_j^{\max}\right)}, x_{ij}>q_2\end{cases} \tag{18}$$

Where x_{ij} denotes the raw data for each performance evaluation indicator. $i=1,2,\cdots,m$ (m is the number of sample companies). $j=1,2,\cdots,n$ (n is the number of performance evaluation indicators). $\left[q_1, q_2\right]$ is the moderation interval of x_{ij}.

(3) Determination of evaluation index weights

First, determine the entropy value of each financial indicator, and calculate the output entropy of the jth indicator in the evaluation matrix Y:

$$E_j=-(\ln m)^{-1}\sum_{i=1}^{m} p_{ij}\ln p_{ij} \tag{19}$$

where $p_{ij}=y_{ij}/\sum_{i=1}^{m} y_{ij}, j=1,2,\cdots,n$.

Second, the degree of variation of the jth indicator is calculated:

$$D_j=1-E_j; j=1,2,\cdots,n \tag{20}$$

Finally, the weight of the jth indicator is calculated:

$$w_j = D_j / \sum^{n} D_j ; j = 1, 2, \cdots n \tag{21}$$

(4) TOPSIS calculation of comprehensive assessment value

1) Constructing a standardized decision matrix for weighted financial performance assessment Z_{ij}

Multiply the standardized decision matrix $Y_{mn} = \left\{ y_{ij} \right\}_{n \times m}$ with the entropy weight vector of the company's financial performance evaluation indexes $\mathrm{w} = \left(w_1, w_2, \ldots, w_j \right)$ one by one, and obtain the weighted standardized decision matrix for corporate financial performance evaluation, $Z_{ij} = \left\{ z_{ij} \right\}_{n \times m}$, where $z_{ij} = w_j \times y_{ij}$.

2) Determine the optimal solution vector and the worst solution vector for each year's sample set

After obtaining the weighted normalized matrix, then obtain the positive ideal solution and negative ideal solution of the sample.

Positive ideal solution:

$$Z^{+} = \left(z_1^{+}, z_2^{+}, \ldots, z_n^{+} \right) \tag{22}$$

where $z_j^{+} = \max\left(z_{1j}, z_{2j}, \ldots, z_{ij} \right)$.

Negative ideal solutions:

$$Z^{-} = \left(z_1^{-}, z_2^{-}, \ldots, z_n^{-} \right) \tag{23}$$

where $z_j^{-} = \min\left(z_{1j}, z_{2j}, \ldots, z_{ij} \right)$.

3) Calculate the Euclidean distance between the target value of each evaluation index and the positive ideal solution and the negative ideal solution, respectively:

$$d_i^{+} = \sqrt{\sum_{j=1}^{n} \left(z_{ij} - z_j^{+} \right)^2} \tag{24}$$

$$d_i^{-} = \sqrt{\sum_{j=1}^{n} \left(z_{ij} - z_j^{-} \right)^2} \tag{25}$$

4) Calculate and rank the relative closeness between each of the secondary financial evaluation indicators and the ideal value, and calculate the relative closeness using the following formula:

$$D = \frac{d_i^{-}}{d_i^{-} + d_i^{+}} \tag{26}$$

The greater the relative closeness, the better the company's financial performance.

4.2. Construction of Financial Performance Evaluation Indicator System

The study refers to related literature [28], and the financial performance evaluation index system constructed is shown in Table 1. The results of the optimization of financial resource allocation are analyzed in five aspects, namely, profitability, solvency, operating capacity, growth capacity and cash flow capacity.

Table 1. Enterprise financial performance evaluation index system.

Evaluation index classification	Index name	Label quality
Profitability	Revenue per share X1	Forward indicator
	Net assets yield X2	Forward indicator
	Net profit ratio X3	Forward indicator
	Cost profit X4	Forward indicator

Solvency	Fixed speed ratio X5	Moderate indicator
	Amendment of property ratio X6	Moderate indicator
	Revised asset ratio X7	Moderate indicator
Operational capacity	Inventory turnover X8	Forward indicator
	Receivable turnover rate X9	Forward indicator
	Revised turnover of current assets X10	Forward indicator
	Fixed turnover rate X11	Forward indicator
Growth ability	Revenue growth of operating income X12	Forward indicator
	Net profit growth X13	Forward indicator
	Fixed asset investment expansion rate X14	Forward indicator
Cash flow capacity	Cash current liability ratio X15	Forward indicator
	Total asset cash recovery X16	Forward indicator
	Profit cash ratio X17	Forward indicator

4.3. Empirical analysis

4.3.1. Sample data sources and sample selection

The research samples selected for this paper are 50 companies listed in China's Shanghai and Shenzhen A-shares and whose main business income is real estate development and operation. All 50 listed real estate companies did not optimize financial resource allocation in 2021, and put into use the financial resource allocation optimization model in 2022 and 2023. After excluding some listed real estate companies with incomplete data, the final research object of this paper is the 45 listed real estate companies with more complete data, and the financial data comes from the Flush iFinD database.

4.3.2. Descriptive statistics of sample data

The assessment indicators of 45 listed real estate companies in the five dimensions are selected and their data in 2021~2023 are subjected to simple descriptive statistics, and the mean and standard deviation are shown in Table 2. First look at the situation of profitability, reflecting the profitability of the four assessment indicators (X1 ~ X4) the average value of its year-on-year increase, but the standard deviation is larger, which indicates that the average profitability of the sample of listed real estate companies in the last three years in the stronger, but different listed real estate companies between the profitability of the difference is large. Looking at the situation of solvency, the modified quick ratio (X5), modified equity ratio (X6) and modified gearing ratio (X7), which reflect the real solvency, show very little fluctuation in the average value during the three years, indicating that there is no significant change in solvency within the industry during the three years. The standard deviation of operating income growth rate (X12) and net profit growth rate (X13) under the dimension of growth ability exceeds 100 during the three years from 2021 to 2023, and the highest value even reaches 476.75, which shows that the status of these two indicators is not uniform throughout the market, and that the growth ability of each company is not the same. Lastly, the standard deviation of the indicators representing the cash flow ability of listed real estate companies (X15~X17) is not large during the three years, with the highest value not exceeding 11.95, which indicates that there is not much difference in the cash flow management ability of the sample companies.

Table 2. The average and standard deviation of each evaluation index.

Year / Index		Mean			SD		
		2021	2022	2023	2021	2022	2023
Profitability	X1	0.34	0.47	0.42	0.53	0.44	0.57
	X2	5.29	8.77	10	15.97	9.08	11.56
	X3	4.48	5.99	12.09	26.17	38.87	42.78

	X4	13.1	16.65	24.3	24.25	24.97	29.71
Solvency	X5	0.62	1.01	0.83	0.49	0.77	0.65
	X6	2.29	2.24	2.26	1.8	1.87	1.78
	X7	53.49	50.24	50.62	15.76	15.61	15.52
Operational capacity	X8	1.43	2.67	1.33	7.93	19.09	5.99
	X9	425.87	293.56	239.24	1890.07	1013.67	680.32
	X10	0.45	0.4	0.39	0.38	0.42	0.25
	X11	0.03	0.42	0.09	0.14	0.18	0.11
Growth ability	X12	22.65	62.84	32.35	107.45	186.2	202.16
	X13	-63.73	65.5	48.41	476.75	222.54	240.59
	X14	784.16	104.71	43.91	7302.73	544.18	166.63
Cash flow capacity	X15	-0.06	0.2	0	0.24	0.27	0.25
	X16	-0.13	0.03	0.04	0.09	0.11	0.09
	X17	-0.59	3.05	-0.63	9.17	11.39	11.95

In addition to the simple descriptive statistics of the mean and standard deviation of the sample listed real estate companies, it is still necessary to study the maximum and minimum values of the various assessment indicators to seek for the specific reasons leading to the large gap between enterprises to facilitate the subsequent study. Therefore, the maximum and minimum values of each evaluation index in the research sample from 2021 to 2023 are shown in Table 3. The indexes with large differences in the maximum values in the three years from 2021 to 2023 include accounts receivable turnover (X9), fixed asset investment expansion rate (X14), operating income growth rate (X15) and net profit growth rate (X16), which reflect the actual ability of the listed real estate companies in terms of operation and growth. These indicators precisely reflect the actual ability of listed real estate companies in terms of operation and growth, and the large difference between these indicators shows that there is a big gap between the sample companies in terms of operation and growth ability, and the level of each company is relatively decentralized. The relatively small differences in the maximum values of the indicators in the three years are the modified current asset turnover ratio (X10), modified total asset turnover ratio (X11) and total asset cash recovery ratio (X16), which reflect the ability of listed real estate companies in operation and cash flow, respectively.

Table 3. The most value table for the evaluation indexes of 2021~2023.

Year / Index		2021		2022		2023	
		Max	Min	Max	Min	Max	Min
Profitability	X1	2.19	-1.28	2.17	-0.64	2.92	-0.42
	X2	41.06	-74.25	49.74	-27.42	48.8	-48.79
	X3	53.88	-122.53	62.3	-325.4	150.55	-384.04
	X4	86.81	-89.21	138.16	-117.56	223.67	-86.14
Solvency	X5	3.59	0.22	6.2	0.27	3.99	0.09
	X6	10.44	0.25	12.21	-0.05	10.97	0.17
	X7	82.6	11.28	84.08	8.92	84.79	11.07
Operational capacity	X8	68.75	0.14	192.98	0.06	56.17	0.02
	X9	18205.32	0.67	9131.06	1.36	5292.21	1.2
	X10	3.41	0.21	3.65	0.12	2.16	0.13
	X11	0.65	0.21	1.45	-0.03	0.48	-0.02

Growth ability	X12	885.18	-75.27	1415.34	-87.82	1976.52	-92.47
	X13	1323.39	-3514.06	1329.07	-742.32	977.33	-1679.62
	X14	75549.02	-96.8	5260.91	-91.64	1431.97	-60.36
Cash flow capacity	X15	0.56	-0.81	0.93	-1.03	0.73	-1.23
	X16	0.3	-0.37	0.46	-0.33	0.29	-0.27
	X17	35.23	-58.58	98.24	-24.71	38.18	-73.83

4.3.3. Financial performance assessment based on entropy weight TOPSIS method

The mean values in Table 2 are normalized, and the entropy value (E), the degree of variability (D), and the entropy weight (w) of the comprehensive financial performance are calculated by using formulas (19), (20), and (21) as shown in Figure 3. Among them, those with higher weights are: cash current liability ratio (X15), fixed asset investment expansion rate (X14), cost and expense margin (X4), and net profit growth rate (X13), which accounted for 9.72%, 9.44%, 9.4% and 9.28%, respectively.

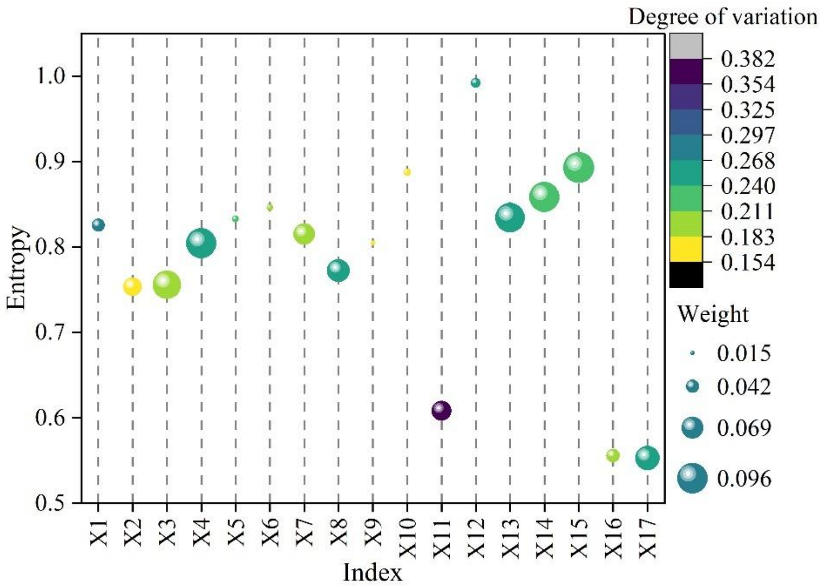

Figure 3. Comprehensive financial performance E , D and w .

Based on formula (22)~equation (26), the performance scores of the enterprise's indicators in each dimension are calculated, and the results are shown in Figure 4.From 2021 to 2023, the average values of the enterprise's comprehensive performance scores are 0.267, 0.426, and 0.742, respectively, and the enterprise's performance increases year by year. It shows that the optimization of financial resource allocation with the four objectives of deployment time cost, financial resource opportunity cost, penalty cost and deferral cost can achieve the optimal allocation of corporate financial resources and significantly improve corporate financial performance.

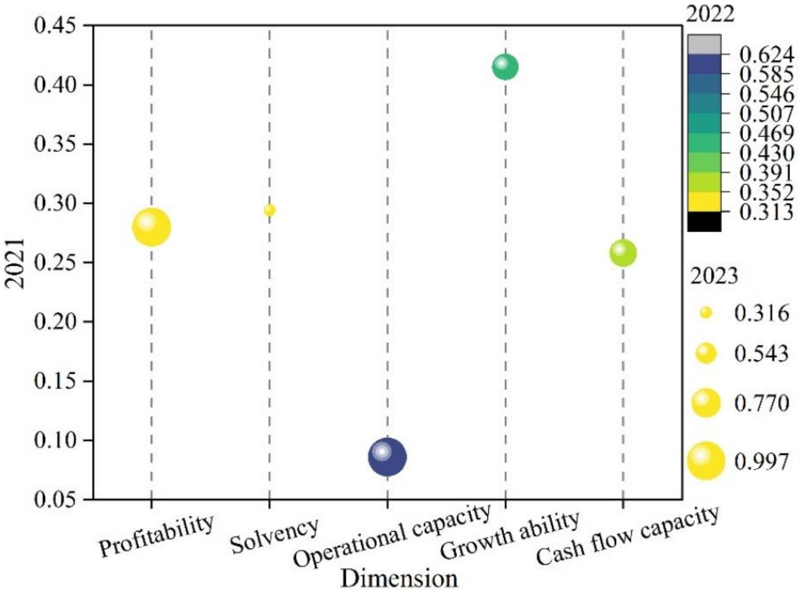

Figure 4. Performance scores for each dimension of the enterprise.

5. Conclusion

The study constructed a model for optimal allocation of financial resources through linear programming algorithm and used Matlab software to implement the model solution. The PSPLIB standard problem library is validated. The results show that, compared with single-objective optimization, the comprehensive optimized scheduling plan can ensure both smooth fluctuation of financial resources. Using the entropy weight TOPSIS method performance evaluation model to assess the profitability, solvency, operating capacity, growth capacity and cash flow capacity of 45 listed real estate companies from 2021 to 2023, the mean values of the comprehensive corporate performance scores were 0.267, 0.426 and 0.742, respectively. It shows that the model in this paper can realize the optimal allocation of corporate financial resources.

Of course, this study also has certain limitations:

(1) The model of optimal allocation of financial resources constructed in this paper is validated for large listed enterprise groups, and there are limitations in the research conclusions obtained. In the follow-up study should also be more comprehensive and in-depth research.

(2) The dimensions of the indicators selected in this paper for the construction of the enterprise performance evaluation index system have relative limitations. More relevant literature can be referred to in the later study so as to meet the needs of enterprise performance evaluation.

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