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Research on Warehouse KPI Evaluation System based on K-means++ and Fuzzy Comprehensive Evaluation

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Abstract

This project first investigates field research, excavation of the index system of current warehouse performance evaluation. Secondly, the corresponding indicators are selected from the aspects of business, finance, transportation, etc. Then by K-Means cluster analysis, classify the current logistics warehouse type is classified to obtain clustering centers of different warehouses. Finally, the fuzzy comprehensive evaluation is used. It is reasonable to empower different warehouse species, explore a reasonable and effective performance evaluation system of a warehouse, and the new evaluation system will provide new decision-making plans for the warehouse management system. The research results of this program can provide important decision support for warehouse management. For warehouse management issues facing other logistics enterprises, such as the existing deposit repository KPI evaluation system is not comprehensive, employee management model has to be improved, and it also has a reference significance. In the warehouse KPI assessment, the method of applying mathematics is used, and the KPI comprehensive evaluation model is used. According to the data establishment model, the differential warehouse KPI evaluation system is obtained. Finally, economics, technology, and environmental feasibility analysis of various optimization programs, discovery that the plan can be implemented, but also improve the efficiency of warehouse management.

Keywords

Warehouse KPI; K-means++; Fuzzy Comprehensive Evaluation; AHP.

1. Introduction

With the development of the logistics industry, the warehousing of modern enterprises has become an important logistics node for enterprises. There is a big difference in the responsibility to be undertaken by different warehouses, especially for the professional logistics enterprises of China's foreign transport companies, precise warehouse management is a key to control and guarantee that effectively control and reduce logistics costs. However, the existing repository KPI evaluation system has no comprehensive range of applications, and the employee management model has to improve and other phenomena.

With the development of technology, warehousing has gradually developed in the world, until the production of intelligent warehousing. Li Juan et al [1] for various factors that may affect intelligent warehousing performance, using the AHP method to determine the weight of each indicator, combined with fuzzy comprehensive evaluation method to establish a smart warehouse performance evaluation model. Zhang Lihua et al [2] constructed the index system for performance evaluation in the balanced catalysis, and the qualitative indictors of partially impossible quantization, the empirical analysis of the fuzzy comprehensive evaluation method evaluate the performance status of warehouse logistics enterprises. Chen Jie [3] Research on the Internet of Things Intelligent Warehouse Management System, combined with wireless network systems, RFID radio frequency identification, wireless sensing techniques, etc, for improved wireless network systems. Cao Mengru[4] proposed RFID-based warehouse management methods to study RFID-based warehouse management systems. Zhang Hai[5] Based on the Internet of Warehouse management system, its basic principle is to use electronic gas as a technology linkage for item identification and information collection, and read the EPC code in the Item RFID electronic tag in the reader and middleware to automatically identify the objects to automate management. Zhang Wenjun[6] the performance evaluation index of warehousing logistics enterprises combined with the investment output of warehousing logistics enterprises was established.

2. Issue and Optimization Plan Design Ideas in Evaluation System

We have improved in the original AHP analysis method, using three different ways to calculate weight, and use the K-Means++ clustering method to use different types of warehouse KPI to use different processing methods. Finally, based on the process of treatment, the fuzzy comprehensive evaluation method is used, and the difference warehouse KPI evaluation system is established. In the model application and testing phase, the team does not specifically analyze each warehouse, but is based on the data in Annex 1, a unified grading simulation demo, verify the rationality and practicality of the model.

3. Selection of Indicators

We have integrated consideration of the current warehouse's KPI indicators, including the use of 16 variables, monthly stack , monthly operation, warehousing business income, project warehouse gross profit, etc. ultimately the three types of indicators, operational indicators, and financial indicators are determined as a primary indicator, select the unit area stack, project warehouse gross profit margin, unit area business income, inventory turnover, 5 indicators of per capita as secondary indicators, consider these indicators to judge the warehouse KPI.

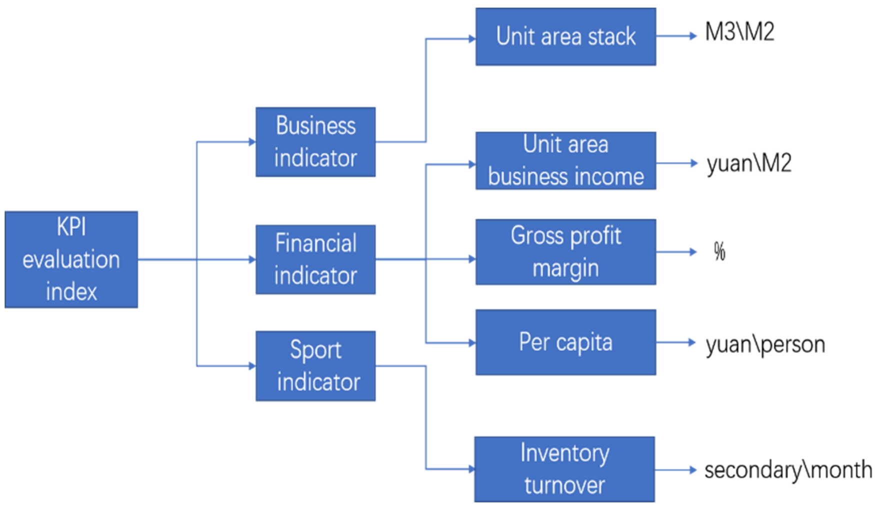

Figure 1. KPI evaluation index

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4. Extract based on K-means++ Clustering Center

4.1. Extraction of the Three Types of Warehouse Clustering Center

We are based on different nature of China's foreign warehouse, and all warehouse are divided into three categories of self-establishment positions, foreign rent storage, and distribution. Different types of warehouse KPI evaluation use different processing methods to achieve no differentiation of the warehouse KPI evaluation. We use the highly accurate K-Means++ clustering method, using SPSS software to divide the above warehouse into three categories, by clustering center table:

Table 1. Clustering center

	Category		
Variable	1	2	3
Unit area bulk quantity	0.52	0.44	0.47
Project warehousing gross profit margin	0.4	0.19	-0.08
Unit area business income	2.42	0.91	0.81
Inventory turnover	1.5	0.98	0.9
Per capita	10909.09	3054.83	-1289.19

(1) The five indicator centers of the first category are: the unit area stack 0.52, the project warehouse gross profit margin 0.4, the unit area business income 2.42, the inventory turnover 1.5, per capita Yuli 10909.09, five indicators occupy the forefront, representing foreign rental. There is a low operating cost of the rental, no need to configure warehouse personnel and hardware facilities.

(2) The five indicator centers of the second category are: the unit area stack 0.44, the project warehouse gross profit margin 0.19, the unit area business income 2.42, the inventory turnover 1.5, per capita Yuli 10909.09, the five indicators belong to the intermediate value in the three categories, representing"self-construction". Self-built warehouse warehousing is the company's own warehouse for warehousing. It can be seen that there is still a progressive space compared to professional storage.

(3) The five indicator centers of the third category are: the unit area stack 0.47, the project warehouse gross profit margin -0.08, the unit area business income 0.81, the inventory turnover 0.9, per capita Yuli -1289.19, the five indicators are located at the lowest in the three categories representing "generation management warehouse". The bin is a gap between the warehouse is submitted to other company enterprises or organizational regulations, and the natural indicators and China and foreign foreign transport are a certain gap between the warehouse and the outgoing bin.

4.2. Data Positive Correction Processing based on Clustering Center

In the established index system, the indicator set may also contain "extremely large", "minimal" or "intermediate" indicators. Therefore, the evaluation index must be consistency before evaluation. Here we unify all indicators into maximum indicators. We depart from the clustering center of the above, with its standard for each data to obtain each data, and obtain one of the best intervals, the above five variables, with ① unit area stack stock, a forwardized formula is as follows:

$$M=\max\{0.53-\min\{X_i\},\max\{X_i\}-0.51\},\widetilde{X}_i=\begin{cases}1-\frac{0.53-X_i}{M}, X_i<0.53\\ 1, 0.51\leq X_i\leq 0.53\\ 1-\frac{X_i-0.51}{M}, X_i>0.51\end{cases}$$

$$M=\max\{0.45-\min\{X_i\},\max\{X_i\}-0.43\},\widetilde{X}_i=\begin{cases}1-\frac{0.45-X_i}{M}, X_i<0.45\\ 1, 0.43\leq X_i\leq 0.45\\ 1-\frac{X_i-0.51}{M}, X_i>0.43\end{cases}$$

$$M=\max\{0.48-\min\{X_i\},\max\{X_i\}-0.46\},\widetilde{X}_i=\begin{cases}1-\frac{0.53-X_i}{M}, X_i<0.48\\ 1, 0.46\leq X_i\leq 0.48\\ 1-\frac{X_i-0.51}{M}, X_i>0.46\end{cases}$$

In the same manner, the same forwarding formula is constructed in a total of 12 intervals for the four variables of ②-⑤, and the data obtained by FIG.X is forwarded.

5. Differential Warehouse KPI Evaluation Model

5.1. Quantity of Forward Data

There is a deviation between metric units between the various evaluation indicators, which will result in the final calculated differential warehouse KPI index is not in the same order, resulting in unreasonable results of comprehensive evaluation. Therefore, we have the data of the data after consistency treatment to eliminate the differences between the original indicator data. The forward-direction matrix and the standardization process are as follows:

$$\mathbf{W}=\begin{bmatrix}\mathbf{w}_{11} & \mathbf{w}_{12} & \cdots & \mathbf{w}_{1\mathbf{m}}\\ \mathbf{w}_{21} & \mathbf{w}_{22} & \cdots & \mathbf{w}_{2\mathbf{m}}\\ \cdots & \cdots & \cdots & \cdots\\ \mathbf{w}_{\mathbf{n}1} & \mathbf{w}_{\mathbf{n}2} & \cdots & \mathbf{w}_{\mathbf{nm}}\end{bmatrix}_{16\times 5}$$

$$Z_{ij}=\frac{w_{ij}}{\sqrt{\sum_{i=1}^{n} w_{ij}^2}}$$

Where W is a standardized matrix. In the 8 different regional warehouses, the warehouse is used as a forwardization matrix constituted by 5 evaluation indicators such as unit area deposits, and the EXCEL statement is used.

5.2. Determination of Evaluation Index Weights based on AHP

Six secondary indicators selected above are: profitability, the influence of upstream and downstream enterprises, the stability of supply and demand, the credibility score, the difference warehouse KPI evaluation is ultimately determined by these six indicators. Here we use a hierarchical analysis (AHP) to determine the specific weight of each second-level index for the difference warehouse KPI, using a level analysis method and a comprehensive evaluation method to performed the evaluation of differential warehouse KPI.

For the judgment matrix in the hierarchical analysis, we get the following judgment matrix table based on the relative importance of each indicator, where M_{ij} is importance of the i element compared with the j column elements, and the judgment matrix table can be obtained:

Table 2. Judgment matrix

	factor1	factor2	factor3	factor4	factor5
factor1	1	1/7	1/5	1/2	1/4
factor2	7	1	2	5	3
factor3	5	1/2	1	4	2
factor4	2	1/5	1/4	1	1/2
factor5	4	1/3	1/2	2	1

After obtaining the judgment matrix, we first use MATLAB to consistency the judgment matrix, random consistency index CI=0.0494, finding the RI=1.26 according to the random consistency indicator table. Finally, the consistency ratio is 0.0886<0.1, which can be considered that the consistency of the matrix can be accepted. That is, the determination matrix is tested by a consistency.

The weight results for different methods are also different. In order to make weight settings more reasonable, we use the calculated average method, the geometric average method, and the characteristic method three methods for solving, And use the average method of calculating average, the result of the three methods is average, and the average method of calculation is obtained, and the specific results are shown in Table 3.

Table 3. Indicator average weight list

Model	Arithmetic average method	Geometric average method	Feature value method	Average weight
Unit area stack	0.0486	0.0492	0.0488	0.0488
Project warehousing gross profit margin	0.437	0.4357	0.4375	0.4367
Unit area business income	0.2731	0.2725	0.2733	0.2729
Inventory turnover	0.0824	0.0829	0.0821	0.0824
Per capita	0.1589	0.1597	0.1583	0.1589

n=(0.0489,0.4367,0.2730,0.0825,0.1590)

5.3. Introduction of Green Factors δ

Green warehousing refers to a warehouse characterized by small environmental pollution, less loss of goods, low transportation costs. The storage itself has an impact on the surrounding environment. For example, the storage and improper operation caused damage, deterioration, leak, etc. In addition, the warehouse layout is unreasonable, and the number of transportation is increased or transported. The so-called green warehouse management is to require reasonable warehouse layout, reduce transport mileage, save transportation costs. Therefore, we continue to excavate the above indicators, and incorporate the comprehensive consideration of the environmental factors in the warehouse.

The evaluation method of the above-mentioned evaluation method we carry out the evaluation of the green factor of the domestic foreign transport of the warehouse in different parts of China, the evaluation results of the specific area are as follows:

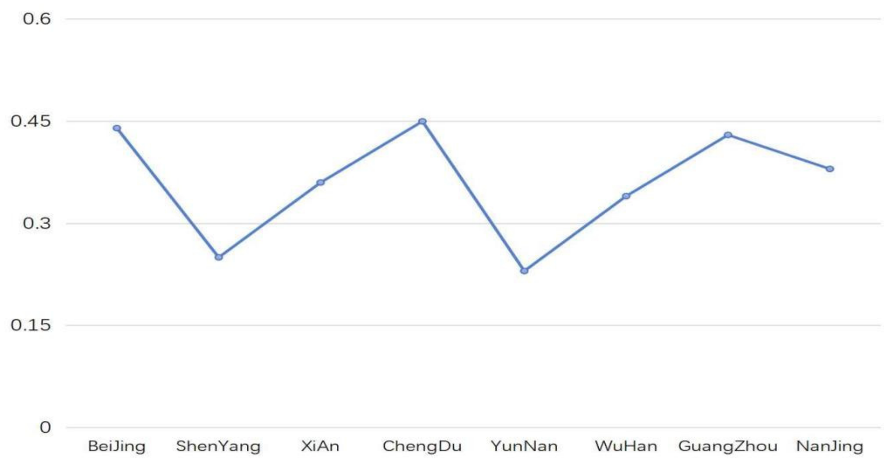

Figure 2. Green factor value

5.4. Establishment of Comprehensive Evaluation Model

A comprehensive evaluation value of the KPI comprehensive evaluation model is "synthesized" by a certain mathematical model or algorithm to achieve comprehensive evaluation of differential warehouses KPI [7]. Using hierarchical analysis, use line weighted computational synthesis index. Set F_p for the evaluation value of the p first-level evaluation index, F_{pq} is the evaluation value of the q second-level evaluation index of the p first-level evaluation index. The evaluation value of different levels of comprehensive evaluation indicators is weighted with respective weight coefficients, and its weighting and comprehensive evaluation value of differential warehouse KPI:

$$Y = \sum W_p(X_p)X_p;$$

$$X_p=\sum W_{pq}\left(X_{pq}\right) X_{pq};$$

In summary, the differential warehouse KPI comprehensive evaluation model is:

$$\begin{cases} y = \sum W_p\,(X_p)X_p \\ X_P=\sum W_{pq}(X_{pq})X_{pq} \\ X_p=f(R_p) \\ X_{pq}=f(R_{pq}) \end{cases}$$

Where $W_p(X_p)$ is the weight value of the p first-level evaluation, $W_{pq}(X_{pq})$ is the weight value of the q second-level evaluation index of the p first-level evaluation. Depending on the differential warehouse KPI evaluation index system framework:

$$y = W_1(X_1)f(R_1)+W_1(X_2)f(R_2)$$
$$=\sum_{q=1}^{10} W_{1q}\,(X_{1q})f(R_{1q})+\sum_{q=1}^{17} W_{2q}\,(X_{2q})f(R_{2q})$$

The size of the comprehensive evaluation value y is positively correlated with the level of the warehouse KPI, that is, the greater the comprehensive evaluation value, the higher the warehouse KPI, the better performance.

We divide the difference warehouse according to the KPI evaluation value of different warehouses. The higher the value of the KPI evaluation value of the warehouse, the stronger the business capabilities of the warehouse, the more the number of the levels obtained after the grading, the more excellent the performance of the warehouse. On the other hand, the lower the KPI evaluation value of the warehouse, the weaker financial capacity, the more the number of levels, the more dragged the repository. Thus, we first establish a comprehensive indicator of the differential warehouse KPI to map f(y), as shown in Table 4:

Table 4. A comprehensive indicator of the differential warehouse KPI to map f(y)

Grade number Level	1st	2sec	3rd	4th
Warehouse KPI evaluation value y	[0.3-0.4)	[0.2-0.3)	[0.1-0.2)	[0-0.1)

According to the established differential warehouse grading step model, the comprehensive evaluation value is divided into four levels from 0 to 0.4, divided into the first grade, the second grade, the third grade, the fourth level with 0.1 to fall gradient. With the increase in the value of the warehouse KPI, the warehouse performance level is, that is, the performance of the warehouse is more excellent. Using the Excel statistics software, the warehouse KPI comprehensive evaluation value and grading of 16 data in Annex 1, are shown in Figure 3.

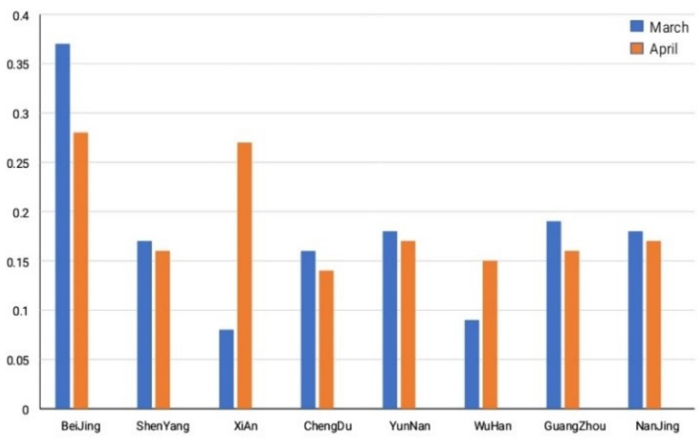

Figure 3. Comprehensive evaluation index value

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