Research and Implementation of Digital Transformation Methods for Process Manufacturing Enterprises Based on Employee Performance

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Abstract. Process manufacturing enterprises usually adopt KPI (Key Performance Indicator) or OKR (Objectives and Key Results) methods to assess the performance of employees. The collection of assessment indicators is difficult and complex, and it is difficult to meet the requirements of objectivity, accuracy and timeliness. With the deepening of digital transformation of process manufacturing enterprises in China, this paper proposes a performance appraisal method for digital employees in process manufacturing based on industrial big data technology. First of all, the comprehensive digital enterprise strategic objectives, combined with daily management needs and production norms, establish a comprehensive index database, and these indicators are divided into different dimensions, decomposed into the implementation of all levels of employees; Through the budget and plan management system to set the periodic indicators and index budget values of each position in the enterprise; The performance indicators of each employee are collected from each business system in real time, and the assessment score is calculated according to the assessment method of the corresponding indicators. Fuzzy Number (FN) -DEMATEL (Decision-making Trial and Evaluation Laboratory) -ANP (Analytic Network Process) method is used to determine the index weight objectively. The real-time performance scores of employees can be obtained by using indicator weights and presented in the form of digital performance cards. Employees may appeal against disputed performance scores. By applying the performance software platform designed by this method to a chemical enterprise, the operation efficiency of the enterprise can be effectively improved and the process of digital transformation can be promoted.

Keywords: Performance Evaluation; Indicator Library; Indicator Weight; ANP

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1 INTRODUCTION

In today's digital era, Chinese enterprises are experiencing an unprecedented wave of digital transformation[1]. Made in China 2025 proposes to promote the transformation of China's industrial enterprises to intelligent manufacturing and high-quality development. However, the progress of digital transformation of many enterprises is slow, and many of them are facing the dilemma of "unwilling to turn, afraid to turn, and unable to turn"[2]. In such an environment, digital enterprise employee performance appraisal is a grip, but also one of the challenges that need to be faced in the digital transformation.

At present, the process manufacturing industry performance appraisal mainly exists in the following aspects of the status quo. First, the assessment indicators are not comprehensive. Traditional models tend to focus only on certain specific indicators, ignoring the comprehensive ability and development potential of employees. Gu, Z.J [3] et al. used Smart PLS3 to analyse the data from a survey through Structural Equation Model (SEM). It was proved that positive work environment improves employee performance. Safitri, SR [4] et al. analysed the effect of leadership understanding, communication and motivation on employee performance. It was proved that these factors have a positive and significant impact on employee performance. Secondly, it is more subjective. Kaur, J [5] et al. proposed a framework for automated employee performance evaluation based on IoT sensory data, where employees and activities are put together to calculate the impact of the employee and then cognitive decisions are executed using fuzzy logic. Rahmati, A [6] et al. addressed the existing problem of the influence of individual emotions and employee judgement on the evaluation process, which reduces the bias in the results by proposing a method based on fuzzy Hierarchical Analysis and Fuzzy TOPSIS for employee performance evaluation. This subjectivity can easily lead to unfairness and bias in the evaluation results, and it is also difficult to provide employees with specific improvement directions and development suggestions [7]. Finally, using the whole organisation as the subject of performance appraisal may raise fairness issues and lead to a decrease in employee motivation and autonomy. Cagno, E [8] et al. developed a new framework for assessing the performance of industrial sustainability performance, which provides industrial decision makers with a scalable framework for different environments and better addresses sustainability performance across the industry. Ma, FS [9] et al. used improved neural network algorithms and parameter optimisation techniques to simulate the relevant data indicators of enterprise performance evaluation, so as to achieve intelligent analysis and accurate prediction of enterprise performance evaluation.

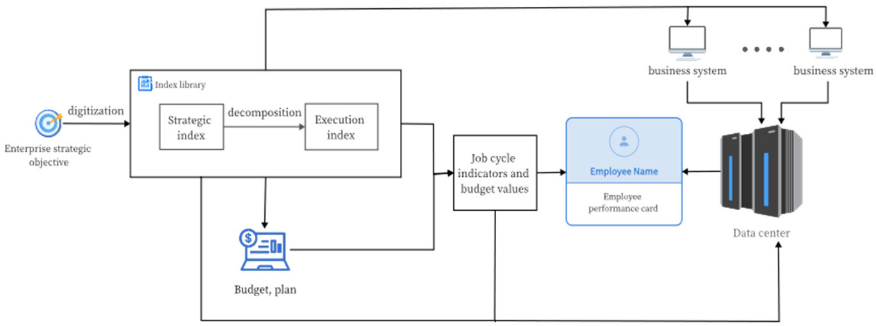

Fig. 1. Digital performance model diagram

Overall, although the research on enterprise performance appraisal at home and abroad has provided theoretical frameworks and practical methods, there are still some limitations. In this paper, a digital employee performance appraisal model for process manufacturing enterprises is proposed to address the above problems, in order to improve the objectivity, real-time and accuracy of performance scores of enterprise performance appraisal, to improve the problems existing in the traditional process manufacturing industry's employee performance assessment, and thus to improve the efficiency of employees and the competitiveness of enterprises.

2 DIGITAL EMPLOYEE PERFORMANCE MODELLING

In today's digital era, enterprise employee performance is an important part of long-term development and competitiveness enhancement of enterprises. Therefore, how to scientifically conduct employee performance appraisal, improve management and optimise operations has always been a hot issue for business managers.

Determining the company's strategic objectives is the key starting point of the employee digital performance appraisal model. Developing a proper strategic plan can help companies crystallise strategic objectives into executable plans to achieve desired performance outcomes. In this digital employee performance appraisal model, metrics are digitally formed through the company's strategic objectives, the company's day-to-day management needs and production norms. The strategic objectives provide a clear direction and vision, while the daily management needs and production norms constrain employee behaviour to ensure safe and environmentally friendly production as well as quality and efficiency. Initially, the digitised strategic targets need to be broken down into enforceable targets for all staff at all levels. When breaking down the indicators, it is necessary to set up the corresponding indicator type, calculation method and assessment cycle and other information. Through budget and programme management, employees are assigned cyclical targets and budget values. In the performance card, these metrics are displayed by type for easy observation of the employee's performance. The data centre is used to centrally manage and calculate the performance data of the whole enterprise, not only storing the indicator library and the budget value of the indicator cycle for each position, but also capturing the task completion situation in real time and converting it into corresponding scores according to the calculation method of the indicators. When assessing employee performance, it is necessary to calculate the score and weight of the employee indicators to get the final performance score, and the data centre will update the employee performance card after calculation. The performance card can objectively show the employee's performance in the target tasks and help judge the employee's contribution to the company's goals. If an employee disagrees with the performance score, he or she can file a performance appeal, which is verified by the data centre, and if the appeal is approved, the performance card score will be changed accordingly. This performance model is shown in Figure 1.

In conclusion, the digital employee performance model is based on the enterprise strategic objectives, through the daily management needs and production norms of the constraints, and then form all levels of sub-staff indicators and tasks, through the support of the data platform to achieve the quantitative, visual and supervised management of employee performance.

3 DIGITAL EMPLOYEE PERFORMANCE MODELLING PROCESS

3.1 Index base establishment

The indicator bank is digitally formed from the strategic objectives of the enterprise. Only by clearly defining and digitising the strategic objectives of the enterprise can we ensure that the performance indicators can have a direct or indirect impact on the strategic objectives of the enterprise.

In the process of digitising the strategic objectives, the strategic objectives need to be translated into core performance indicators for each business and functional area. Core performance indicators are important indicators for measuring and assessing the realisation of strategic objectives, which can directly or indirectly reflect the realisation of corporate strategic objectives and their practical effects. Each strategic goal usually requires one or more core performance indicators to measure and monitor.

In process manufacturing production, by regulating and standardising the six aspects of the 5M1E [10], the repeatability and stability of the production process can be ensured. The aspects of production, sales, supply, transport, inventory and energy consumption of a company cover all aspects of production and operations and are related to business planning, production management, sales management and logistics management of the company. Therefore, all these aspects should be factors that company decision-makers need to consider when digitising their strategic objectives, and they also need to ensure that these core performance indicators are aligned with the company's strategic objectives. By establishing a strategic indicator system, companies can monitor and evaluate the implementation of strategic objectives more effectively and make timely strategic adjustments and optimisation.

After determining the core performance indicators, these indicators are decomposed into specific indicators that can be implemented by all staff at all levels, according to the company's organisational structure and the functions of each department. employee performance can be examined more comprehensively by breaking down the core performance indicators into multiple execution indicators, which have different dimensions. The following principles need to be considered when determining these executive indicators: the first principle is measurability. The second principle is to ensure that targets are challenging and achievable to inspire the company to better achieve its strategic goals and motivate employees to improve their performance levels. Finally, metrics need to be real-time, i.e., able to provide timely feedback and be updated and adjusted over time. It is also necessary to determine the assessment algorithm, budget source, assessment cycle and other information of the indicators when creating the indicator library, which can provide the necessary support for the subsequent implementation of performance management.

In the whole model, in order to ensure a comprehensive assessment of all aspects of the employee's performance, the decomposed executable indicators in the indicator library need to be assessed according to different dimensions. In this way, the goals and standards that employees need to achieve in each dimension can be clearly defined, thus helping employees to fully understand their requirements and expectations in all aspects.

3.2 Target planning budget

After setting up the indicators, it is necessary to allocate periodic target budget values to different indicators and distribute them to various positions. In this model, budgeting and planning are used for the periodic budgeting and allocation of indicators. Prior to generating the periodic budget, budget submission and budget review need to be conducted.

Firstly, this module allows each department to fill in periodic budget requests according to their own needs and plans. Departments can plan and allocate financial resources reasonably based on their business and goals, ensuring the rationality and accuracy of the budget. Secondly, there is budget review, which allows superiors to review the budgets of subordinate departments. They can evaluate and make decisions on budget requests based on the organization's strategic goals and existing resources. If the budget submitted by a subordinate department is deemed unreasonable, the reviewing personnel can send it back for revision. They can also provide feedback and suggestions to help the subordinate department optimize the budget plan, ensuring its rationality and feasibility.

After obtaining the budget for each indicator, it is necessary to allocate the periodic budget of each indicator to various positions within the company. This process is usually determined based on the responsibilities and functions of different positions. Each position may be assigned a different budget value to reflect its importance and role in achieving the indicator's goals. When allocating budget values, factors such as resource requirements, abilities, and contributions of each position need to be considered.

The final audited periodic indicator budget belongs to the entire organization. According to the organizational hierarchical structure and the responsibilities and scope of work of employees at each level, the budget is progressively allocated. Firstly, the budget value is allocated to senior-level employees, who then distribute the budget to the middle-level employees they manage, and the middle-level employees further allocate it to frontline employees. The budget value at each level should be derived from the budget value of the previous level.

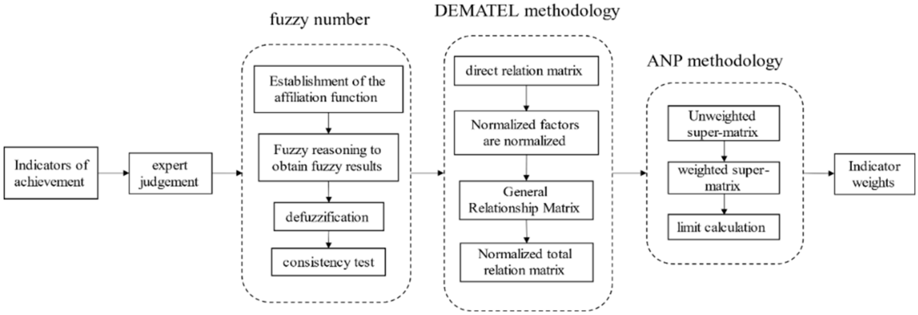

Fig. 2. FN-DEMATEL-ANP method flow

3.3 Performance card design

The initial performance card is formed by assigning periodic targets and target budget values to each position through budget and programme management. Subsequently, weights need to be calculated and assigned to each performance indicator of the performance card. These weights reflect the importance of the organisation for the different performance indicators and will be used for subsequent score calculation. After capturing the indicator data from each business system and performing the score calculation, the score of the performance card and the status of each indicator are updated.

Firstly, to evaluate performance more accurately, the FN-DEMATEL-ANP method is used to calculate indicator weights. This method is an analysis method for performance indicator weights that combines fuzzy number theory (FN), the Decision-Making Trial and Evaluation Laboratory (DEMATEL), and the Analytic Network Process (ANP). The method process is shown in Figure 2.

Step1. Fuzzy number

Fuzzy numbers [11] reflect the essence of uncertainty and vagueness. Among them, the trapezoidal fuzzy number is defined as follows:

$$\alpha = (a, b, c, d) \tag{1}$$

In this method, the input variables are the relationship matrix of performance indicators. Experts evaluate each indicator based on their professional knowledge and experience, and then convert their ratings into trapezoidal fuzzy numbers. The evaluation matrix is as follows:

$$\tilde{\beta}^{k} = \begin{bmatrix} \tilde{\beta}^{k}_{1,1} & \tilde{\beta}^{k}_{1,2} & \cdots & \tilde{\beta}^{k}_{1,n} \\ \tilde{\beta}^{k}_{2,1} & \tilde{\beta}^{k}_{2,2} & \cdots & \tilde{\beta}^{k}_{2,n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{\beta}^{k}_{n,1} & \tilde{\beta}^{k}_{n,2} & \cdots & \tilde{\beta}^{k}_{n,n} \end{bmatrix} \tag{2}$$

Where $\tilde{\beta}^{k}_{i,j}$ represents the impact value of indicator i relative to indicator j by expert k. The centroid method is used to defuzzify the trapezoidal fuzzy numbers, and the formula is as follows:

$$\odot\tilde{\alpha} = \frac{\left(c^2 + d^2 - a^2 - b^2\right) + \left(c^2 \bullet d^2 - a^2 \bullet b^2\right)}{3\left(a + b - c - d\right)} \tag{3}$$

The transformed matrix is represented as β^k, and a consistency check is performed on β^k. The consistency index of β^k is denoted as CI^k:

$$CI^k = \frac{\left(\lambda_{max}\right)^k - n}{n - 1} \tag{4}$$

Here, λ_{max} is the maximum eigenvalue of β^k, and CR^k is used to judge the consistency of the matrix. For β^k, CR^k is denoted by:

$$CR^k = \frac{CI^k}{RI^k} \tag{5}$$

where RI^k is a random number that depends on β^k and has dimension n. Finally when $CR^k > 0.1$ the judgements on the indicators are inconsistent and β^k fails the consistency check. The expert needs to adjust his judgement process to give a new judgement matrix.

Step2: The DEMATEL method

After the expert evaluates the weight data of performance indicators and performs fuzzy set calculations, a direct relationship matrix $A = [a_{ij}]_{n\times n}$ is formed as the input for the DEMATEL [12] method. Here, a_{ij}represents the impact of indicator a_i on indicator a_j. After obtaining the direct relationship matrix, it needs to be normalized. The matrix is normalized using the normalization factor method, and the normalization factor is as follows:

$$s = Min\left[\frac{1}{Max_{1\le i\le n}\left(\sum_{j=1}^{n} a_{ij}\right)}, \frac{1}{Max_{1\le j\le n}\left(\sum_{i=1}^{n} a_{ij}\right)}\right] \tag{6}$$

The normalized direct relationship matrix is as follows:

$$X = s \times A \tag{7}$$

Based on the normalized direct relationship matrix, we can further calculate the direct/indirect relationship matrix, also known as the total relationship matrix. The calculation formula is as follows:

$$\begin{aligned} TDM &= \lim_{k\to\infty}\left(X + X^2 + X^3 + \cdots + X^{k-1} + X^k\right) \\ &= X\left(1-X\right)^{-1} \end{aligned} \tag{8}$$

The final total relationship matrix is obtained and represented by TDM_C as follows:

$$TDM_C = \begin{array}{c} \\ c_{11} \\ D_1 \;\vdots \\ c_{1m_1} \\ \vdots \\ c_{n1} \\ D_3 \;\vdots \\ c_{nm_n} \end{array} \overset{\begin{array}{ccc} D_1 & D_j & D_n \\ c_{11} \cdots c_{1m_1} & c_{j1} \cdots c_{jm_j} & c_{n1} \cdots c_{nm_n} \end{array}}{\begin{bmatrix} TDM_C^{11} & \cdots & TDM_C^{1n} \\ \vdots & \vdots & \vdots \\ TDM_C^{n1} & \cdots & TDM_C^{nn} \end{bmatrix}} \tag{9}$$

Then, to calculate the normalized total relationship matrix, denoted by TDM_C^a, we need to calculate the row sums of the submatrices in TDM_C and normalize them. For example, for a submatrix TDM_C^{11}, let $d_i^{11} = \sum_{j=1}^{m_1} T_{ij}^{11}$ be the sum of the ith row of matrix TDM_C^{11}. Then, we normalize TDM_C^{11} by dividing each element in the matrix by the total sum of elements in its corresponding row. The normalized matrix TDM_C^{11} is represented as TDM_C^{a11}, and the matrix is shown below:

$$TMD_C^{a11} = \begin{bmatrix} T_{11}^{11} \Big/ \sum_{j=1}^{m_1} T_{1j}^{11} & \cdots & T_{1m_1}^{11} \Big/ \sum_{j=1}^{m_1} T_{1j}^{11} \\ \vdots & \vdots & \vdots \\ T_{m_1 1}^{11} \Big/ \sum_{j=1}^{m_1} T_{m_1 j}^{11} & \cdots & T_{m_1 m_1}^{11} \Big/ \sum_{j=1}^{m_1} T_{m_1 j}^{11} \end{bmatrix} \tag{10}$$

Step 3 ANP method

The Analytic Network Process (ANP) method offers greater flexibility in considering complex interactions between different elements due to the use of super-matrices [13].

The unweighted super-matrix can be formed by transposing the normalized total relation matrix TDM_C^a. Here, let C_n represent the nth cluster, e_{ij} represent the jth element in the ith cluster, and W_{ij} represent the weight vector of the jth cluster relative to the ith cluster.

$$W = \left(TDM_C^a\right)' = \begin{array}{c} \\ C_1 \begin{array}{c} e_{11} \\ \vdots \\ e_{1m_1} \end{array} \\ \vdots \\ C_n \begin{array}{c} e_{n1} \\ \vdots \\ e_{nm_n} \end{array} \end{array} \overset{\begin{array}{ccccc} C_1 & & C_j & & C_n \\ e_{11} \cdots e_{1m_1} & \cdots & e_{j1} \cdots e_{jm_j} & \cdots & e_{n1} \cdots e_{nm_n} \end{array}}{\begin{bmatrix} W_{11} & \cdots & W_{1j} & \cdots & W_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_{i1} & \cdots & W_{ij} & \cdots & W_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_{i1} & \cdots & W_{nj} & \cdots & W_{nn} \end{bmatrix}} \tag{11}$$

After obtaining the total relation matrix in the DEMATEL method, a threshold is set to ignore elements with small influences. The threshold is applied to the total relation matrix, and elements smaller than the threshold are set to 0, resulting in matrix TDM_D, where T_{ij}^D represents the degree of influence of cluster i on cluster j. Matrix TDM_D is then normalized and obtained as follows:

$$TDM_D^a = \begin{bmatrix} \frac{T_{11}^D}{\sum_{j=1}^n T_{1j}^D} = T_{11}^{aD} & \cdots & \frac{T_{1n}^D}{\sum_{j=1}^n T_{1j}^D} = T_{1n}^{aD} \\ \vdots & \vdots & \vdots \\ \frac{T_{n1}^D}{\sum_{j=1}^n T_{nj}^D} = T_{n1}^{aD} & \cdots & \frac{T_{nn}^D}{\sum_{j=1}^n T_{nj}^D} = T_{nn}^{aD} \end{bmatrix} \tag{12}$$

In matrix $T_{ij}^{aD} = T_{ij}^D / d_i$, the final normalized matrix TDM_D^a is used for weighted calculations. The calculation formula is as follows:

$$W = \begin{bmatrix} T_{11}^{aD} \times W_{11} & \cdots & T_{n1}^{aD} \times W_{1n} \\ \vdots & \vdots & \vdots \\ T_{1i}^{aD} \times W_{i1} & \cdots & T_{nn}^{aD} \times W_{nn} \end{bmatrix} \tag{13}$$

Finally, the super-matrix is subjected to limit calculations to obtain the global weight vector. The calculation formula is as follows:

$$\overline{W}^{\infty} = \lim_{k \to \infty} \overline{W}^k \tag{14}$$

After determining the weights of performance indicators, they are used in calculating employee performance score, which enhances the objectivity of employee performance evaluations. By utilizing industrial big data technology, companies can capture data in real-time from various business systems. However, different business systems may use different data formats and structures, so data processing and transformation are necessary before data capture to ensure consistency and usability of the data.

In order to facilitate the calculation of scores for each indicator, reasonable assessment algorithms have been set for different indicators when establishing the indicator library. Real-time values, periodic indicator budget values, and benchmark scores obtained in real-time are used as inputs. The scores are calculated according to the assessment algorithm of each indicator to obtain the employee's score on that indicator. To better evaluate employee performance, the scores in the performance scorecard are calculated and updated based on the weights and scores of the indicators. The performance scorecard not only allows viewing of the total performance score and completion status of each task, but also the completion status and scores of each dimension.

Lastly, regarding the performance scorecard, employees may have objections to their assessment results or performance scores. In order to ensure accuracy and fairness in performance evaluation, this model allows for employee appeals. Employees can appeal against any deduction items, clearly stating their objections to the performance evaluation results and providing relevant evidence or reasons to support their claims. After submission, the appeal needs to be audited, investigated, and verified. If the case is found to be true, the appeal will be approved. Once approved, the appeal by the employee will be successful, and the performance scorecard scores will change accordingly. If the appeal is not approved, the evidence will be feedback to the employee.

4 RESULTS

In this section, the performance of employees in a chemical company will be analysed using the employee performance model proposed in this thesis. Fifty people at different levels were selected from this company, and in this model, an indicator library was established based on the strategic objectives of this enterprise, and the indicator budget was decomposed to each employee's position through budget and plan management, and each employee was examined in terms of dimensions and indicator configurations. The weights of each indicator are assigned through the FN-DEMATEL-ANP method. The model allows real-time monitoring of employee performance, and five employees, A-E, were selected to track their performance changes in November. The performance score fluctuation graph for these five employees is shown in Figure 3.

Based on the performance data of the five employees mentioned above, the results generated by the model are consistent with the actual monthly performance score changes of the employees. The scores gradually increase or decrease based on the baseline score and overall maintain an upward trend, which is consistent with the employees' work each month. It can be seen from the graph that employee B's performance score had a significant decrease. Upon reviewing the performance card, it was found that the employee's product qualification rate was low in the first half of the month, there were production process problems, and the compliance rate with production standards was also low. After targeted adjustments were made, the employee's performance score gradually improved.

In order to better validate the effectiveness of our methodology, we have tracked and recorded the performance of an employee from January 2022 to December 2023. We will compare the results of our approach using this model with those obtained from traditional performance evaluation methods. The comparison chart is shown in Figure 4.

From the graph, it can be observed that compared to traditional performance evaluation methods, the employee performance scores using our model show an overall upward trend. This result indicates that the use of this model can effectively enhance employee motivation.

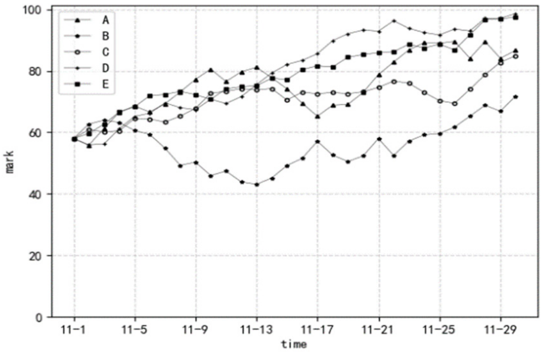

Fig. 3. Performance scores of five employees of the company in November 2023

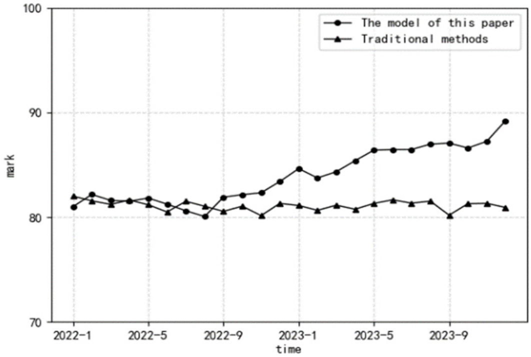

Fig. 4. The comparison of this model and the traditional evaluation method for an employee

5 DISCUSSION

This paper introduces a digital employee digital performance appraisal model for process manufacturing enterprises, in which the employee performance appraisal model realises the enterprise's performance to be decomposed into the performance of the whole staff step by step, changes the traditional mode of employee performance assessment, enhances the objectivity and accuracy of the performance appraisal, and realises the automation of employee performance assessment in the process manufacturing industry. Through the observation in the actual application of the enterprise, it is found that the model can not only effectively enhance employee motivation but also improve the operational efficiency of the enterprise.

It is important to note that the digital employee performance card assessment model is not a panacea, it is only a business optimisation tool rather than a total solution for employee management, so it requires an in-depth understanding of how to effectively apply this model and flexible management practices, so that it can give full play to its potential and realise the organisation's strategic objectives in terms of talent.

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