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Markov-Based Forecasting Model for Enterprise Human Resources Internal Supply

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***Abstract*—With the enhanced competition of enterprises on the talent, the rational manpower planning in enterprises to protect the human resources needs of enterprises becomes an important driving force to promote the development of enterprises. Human resources forecast is the premise and basis of manpower planning, which is of great significance to the sustainable development of enterprises. This paper focuses on the human resource internal supply forecast and establishes the forecasting model based on Markov chain. Firstly, this paper analyzes the factors that affect the internal human resource supply and compare the methods of human resources internal supply forecast. Then, this paper provides the steps of the human resource internal supply forecast in enterprises, determines the construction method of the forecasting model, and establishes the Markov forecast model. Finally, this paper uses the proposed model to predict the human resources within the M enterprise and gives suggestions for the internal supply of the M enterprise which have certain practical significance.**

Keywords—human resource supply; markov chain; forecasting

I INTRODUCTION

Human resources forecast is mainly to predict the supply and demand of employees. In terms of human resources supply forecast, the external supply is affected by various environmental and market factors in most enterprises, which is difficult to forecast. And the supply of employees is mainly from the internal supply. Therefore, the forecast of internal supply in the enterprise has become the main aspect of human resources supply forecast. Shanshi Liu and Lingquan Wen [1] used Delphi method to forecast human resources. Zhiqiang Li et al. [2] introduced and reviewed the characteristics and applicable conditions of the four quantitative forecasting methods, such as, nonlinear regression forecasting, gray system prediction, Markov model and neural network prediction. Songyuan Li, Dechong Wang et al. [3] further explored the methods of supply and forecast, and these methods were more detailed classification and comparison. Through the study of these literatures, we can find that the Markov method becomes the main research method of human resources supply forecast with the advantages of non-aftereffect property, accessible data, simple and scientific method and wide application range.

In the application of human resources forecast research, Markov method has a wide range of applications and taken on good effect. Lagarde and Cairns [4] have modeled the movements of medical workers to solve the problems of human resources policies. Saad and Adnan et al. [5] used the Markov chain to forecast the flow of university lecturers in order to advise on the recruitment and budget of university lecturers. Feyter [6], Dimitriou and Georgiou et al. [7] divided the staff into several groups, taking into account the flow of staff within and between departments. Raghavendra, Sankaran and Nilakantan [8], Nilakantan [9] extended the model to the organization of labor outsourcing, among which Nilakantan [9] also evaluated the different HR policies. In domestic, Hongli Sun and Yonggui He et al. [10] took the power plant as an example to validate the Markov model in practical application. Ying Yan and Juan Li [11], Siping Fang [12], Lu Zhang and Liyun Liu [13] and others also use the Markov model to study Human resource forecast.

In the view of human resource internal supply forecast, this paper uses the Markov chain to establish the forecasting model. And it also provides detailed steps and formulas which enable enterprises to more effectively predict the internal supply. The reasonable internal supply is of positive significance to the flow of the internal staff, the construction of the staff echelon, the development of the employee's career and the control of the labor cost.

II THE MARKOV FORECAST MODEL OF HUMAN RESOURCES INTERNAL SUPPLY

A. Modeling Idea

The Markov chain is a method of modeling the human resource internal supply using statistical principles. The basic idea is to calculate the transition probability of all types of employees through statistical analysis of historical data, and thus forecasts the future trend of employee turnover. The greatest feature of the application of Markov chain is the non-aftereffect property of Markov chain, that is, in a random process, the future state of the system is independent of the past state and is only related to the present state. Meanwhile, the application model of Markov chain also requires the smoothness of the transition trend, that is, the factors that affect the current state of the enterprise don't change greatly, and the flow of the staff has certain regularity, otherwise it needs to be recalculated [19].

III MARKOV CHAIN

If the state of the stochastic process is known at a particular time t_0, the conditional probability distribution of the state at

time $t > t_0$ is independent of the state before time t_0 and only with the time t_0. The process is called Markov process.

The Markov process is defined as follows:

Assuming that $\{X(t), t \in T\}$ is a stochastic process, I is state space, and for any positive integer $n \geq 3$, any time $t_1 < t_2 < \cdots < t_n \in T$, and any state $x_1, x_2, \cdots, x_n \in I$, when $P\{X(t_1) = x_1, X(t_2) = x_2, \cdots X(t_n) = x_n\} > 0$,

$$P\{X(t_n) = x_n \mid X(t_1) = x_1, X(t_1) = x_1, \cdots X(t_{n-1}) = x_{n-1}\}$$
$$= P\{X(t_n) = x_n \mid X(t_{n-1}) = x_{n-1}\}$$

It is said that the stochastic process $\{X(t), t \in T\}$ has Markov property, and the process is called the Markov process [20].

Assuming that the random sequence $\{X_n, n \in T\}$ has the parameter set $T = \{0, 1, 2, \cdots\}$ and the discrete state space I. If for any integer $n \in T$ and any state $i_0, i_1, \cdots, i_{n+1} \in I$,

$$P\{X_{n+1} = i_{n+1} \mid X_0 = i_0, X_1 = i_1, \cdots X_n = i_n\}$$
$$= P\{X_{n+1} = i_{n+1} \mid X_n = i_n\}$$

The random sequence $\{X_n, n \in T\}$ is called Markov chain [15].

The conditional probability $p_{ij}(n) = P\{X_{n+1} = j \mid X_n = i\}$ is called the one-step transition probability of the Markov chain $\{X_n, n \in T\}$ at time n, referred to as the transition probability. The conditional probability $p_{ij}^{(k)}(n) = P\{X_{n+k} = j \mid X_n = i\}$ is called the k -step transition probability of the Markov chain $\{X_n, n \in T\}$ at time n [16].

One-step transition probability makes up the matrix P

$$P = (p_{ij}) = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1j} & \cdots \\ p_{21} & p_{22} & \cdots & p_{1j} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_{i1} & p_{i1} & \cdots & p_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \cdots \end{bmatrix}$$

It is called one-step transition probability matrix. The one-step transition probability p_{ij} has the following basic properties:

(1) $p_{ii} \geq 0, i, j \in I$

(2) $\sum_{i \in I} p_{ij} = 1, i \in I$ [20-21]

If the transition probability $p_{ij}(n)$ of the Markov chain $\{X_n, n \in T\}$ is independent of the time n for any $i, j \in I$, the Markov chain is the homogeneous Markov chain and $p_{ij}(n)$ as p_{ij} [20].

The transition probability of the homogeneous Markov chain is independent of the time n, that is, the transition probability is independent of the starting point of the transfer, which means that the transition probability is stationary. In this paper, the study of the internal supply forecast of human resources is based on the premise that human resources management policy remains unchanged, which is consistent with the requirements of Homogeneous Markov chain.

The construction of this model is as follows:

Supposed that x_n is the time t_n, usually in years as a unit;

Assuming that there are $n+1$ position categories in the enterprise, where the $n+1$th category is the separation, the position state of each category is $A_i (i = 1, 2, 3, \cdots, n)$. Each category has r position levels, so the position state of a certain level of category can be expressed as $A_{ir} (r = 1, 2, 3, \cdots, n)$.

The transition probability $p_{A_{ir}A_{js}}$ represents the probability that the employees who are in the r th level of the i th category at time t_n are transferred to the s th level of the j th category in time t_{n+1}. The formula is $p_{A_{ir}A_{js}} = P\{x_{n+1} = A_{js} \mid x_n = A_{ir}\}$.

The construction of human resources internal supply forecasting model based on Markov chain is as follows:

(1) On the basis of thorough understanding of the enterprise, the positions are divided into different categories and levels to get the initial distribution matrix, i.e. $(p_{A_{11}}, \cdots, p_{A_{1n}}, p_{A_{21}}, \cdots, p_{A_{2n}}, p_{A_{i1}}, \cdots, p_{A_{in}}, \cdots, p_{A_{m1}}, \cdots, p_{A_{mn}})$. Generally, there are three categories of positions within the enterprise, i.e. managers, technicians and ordinary staff, and the level is divided into grassroots staff, middle staff and senior staff.

(2) Collect and analyze the historical data of personnel changes in the enterprise, estimate the frequency and mode of the position transfer, and pay attention to the position category and the level of each position category to be consistent in each cycle. If the frequency and mode of transfer are definite and stable, the annual transition probability can be calculated, and

then the average transition probability can be calculated, such as Eq. (1). In Eq. (1), we assume that each year has the same weight.

$$p_{A_{ir}A_{js}} = \frac{1}{T}\sum_{t=0}^{T}\frac{n_{A_{ir}A_{js}}(t+1)}{n_{A_{ir}}(t)} \quad (1)$$

$i=1,2,3,\cdots,n \quad j=1,2,3,\cdots,n \quad r=1,2,3,\cdots,n \quad s=1,2,3,\cdots,n$

And $0 < p_{A_{ir}A_{js}} < 1$. T is the time range of the historical data, generally in years as a unit. $n_{A_{ir}A_{js}}(t+1)$ is the number of employees who moves from the r th level of i th category to the s th level of j th category during the period $(t,t+1)$. $n_{A_{ir}}(t)$ is the initial number of employees in the r th level of i th category at time t.

(3) Based on the average probability, the employee flow table and employee transfer matrix P are established. In the table employee flow, taking into account the situation of employee turnover, there is $p_{A_{ir}A_{n+1}}$ in Table II.

$$P=\begin{pmatrix} p_{A_1A_1} & p_{A_1A_2} & \cdots & p_{A_1A_n} & \cdots & p_{A_1A_{n1}} & p_{A_1A_{n2}} & \cdots & p_{A_1A_m} & p_{A_1A_{n+1}} \\ p_{A_2A_1} & p_{A_2A_2} & \cdots & p_{A_2A_n} & \cdots & p_{A_2A_{n1}} & p_{A_2A_{n2}} & \cdots & p_{A_2A_m} & p_{A_2A_{n+1}} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ p_{A_nA_1} & p_{A_nA_2} & & p_{A_nA_n} & & p_{A_nA_{n1}} & p_{A_nA_{n2}} & & p_{A_nA_m} & p_{A_nA_{n+1}} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ p_{A_{n1}A_1} & p_{A_{n1}A_2} & \cdots & p_{A_{n1}A_n} & \cdots & p_{A_{n1}A_{n1}} & p_{A_{n1}A_{n2}} & \cdots & p_{A_{n1}A_m} & p_{A_{n1}A_{n+1}} \\ p_{A_{n2}A_1} & p_{A_{n2}A_2} & \cdots & p_{A_{n2}A_n} & \cdots & p_{A_{n2}A_{n1}} & p_{A_{n2}A_{n2}} & \cdots & p_{A_{n2}A_m} & p_{A_{n2}A_{n+1}} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ p_{A_mA_1} & p_{A_mA_2} & \cdots & p_{A_mA_n} & \cdots & p_{A_mA_{n1}} & p_{A_mA_{n2}} & \cdots & p_{A_mA_m} & p_{A_mA_{n+1}} \end{pmatrix}$$

The matrix is a one-step transition probability matrix. P_n is a n-step transition probability matrix, which can forecast the flow of employees from the initial year to the nth year.

(4) Establish the forecasting model. According to the number of employees in the end of the year and the transition probability matrix, the number of employees of internal supply can be predicted. Assuming that the nth distribution matrix of employees is $\left(p_{A_1}(n),\cdots,p_{A_n}(n),p_{A_{21}}(n),\cdots,p_{A_{2n}}(n),p_{A_{11}}(n),\cdots,p_{A_{1n}}(n),\cdots,p_{A_{n1}}(n),\cdots,p_{A_{nn}}(n)\right)$

The formula is shown in Eq.(2).

$$\begin{aligned}&\left(p_{A_{11}}(n),\cdots,p_{A_{1n}}(n),p_{A_{21}}(n),\cdots,p_{A_{2n}}(n),p_{A_{11}}(n),\cdots,p_{A_{1n}}(n),\cdots,p_{A_{n1}}(n),\cdots,p_{A_{nn}}(n)\right) \quad (2)\\ &=\left(p_{A_{11}},\cdots,p_{A_{1n}},p_{A_{21}},\cdots,p_{A_{2n}},p_{A_{11}},\cdots,p_{A_{1n}},\cdots,p_{A_{n1}},\cdots,p_{A_{nn}}\right)\bullet P_n\end{aligned}$$

IV CASE ANALYSIS

A. Total Amount of Human Resources

Although the growth rate of M enterprise has fluctuated, but it is greater than zero, which shows that the M enterprise were in the period of development and the total staff steadily increased in 2011-2016 (Figure 1). With the continuous expansion of the scale of production and operation, managers should pay more attention to the internal flow of employees, do a good job of internal supply of human resources, prevent the fault phenomena of supply, meanwhile attract outstanding talent to join, and the form a good flow of the talent.

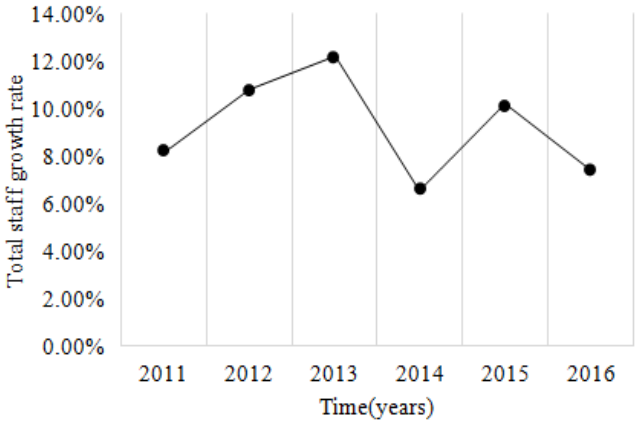

FIGURE I. TOTAL STAFF GROWTH RATE IN 2011-2016

According to the historical data in 2015 and the employee transition matrix, the number of human resource supply in 2016-2018 can be forecasted by the Eq. (2). The results are shown in Table I:

TABLE I. FORECASTING RESULTS IN 2016-2018

Category / Time(years)	M			T		G	Total amount
	M_1	M_2	M_3	T_1	T_2	G	
2016	1	3	7	5	7	25	48
2017	1	3	7	4	6	21	42
2018	1	3	7	4	5	17	37

V ANALYSIS OF RESULTS AND SUGGESTIONS

Comparing the actual quantity of the various categories of the M enterprise in 2016 with the amount the model predicted, it can be seen that the error of the forecasting results of managers and technicians is small and the accuracy of the model is high. It can also be seen from the overall prediction that the number of supply forecast of managers shows a steady trend, which is related to the stability of organizational structure of the M enterprise and the vertical promotion mechanism. Therefore, in the practical application of the M enterprise, we can only use this model to predict the key to managers. Therefore, in the practical application of the M enterprise, we can only use this model to emphatically predict the category of managers, and the managers are also an important part of the enterprise. Other categories can refer to the results of this model

and in combination with other forecasting methods to further improve the accuracy of the forecast.

The results of this paper show that it is feasible to apply the model to human resources planning in the enterprises. The flexibility of this model allows enterprises to predict only one category or level of positions, such as management category, etc. These categories are usually an important part of the enterprise and have stability and potential laws in terms of the flow of employees. The forecast of these categories is not only accurate, but also saves the forecasting cost of enterprises. At the same time, flexibility also means that this model can be combined with other forecasting methods to jointly forecast the human resources supply, which can provide reference and support for manpower planning. In addition, the model can also provide the structural distribution of the forecast quantity of the human resource internal supply, which can potentially sort out the internal positions, clarify the position level, and find gaps in talent. The prediction results of this model not only reflect the vertical promotion channel, but also reflect the possibility of horizontal flow of employees, which plays a good guiding role in the establishment of the development channels of employees and also play an important reference role in the construction of enterprise talent echelon.

VI CONCLUSIONS

The results of this paper show that it is feasible to apply this model to the human resources supply forecast. This model can provide information on the quantity and structure of human resources internal supply in enterprises, and provide support and reference for manpower planning. In addition, the model also can only forecast a certain category of positions in the enterprise, not only can forecast the different levels of positions within the category, but also can be used in conjunction with other methods to improve the accuracy of prediction, which reflects the flexibility of the model. The results of the model also reflect the number and channels of the horizontal and vertical flow of the staff in enterprises, which provides a reference and guidance for enterprises to develop the construction of staff echelon and establish a reserve talent pool. However, due to the limit of my knowledge level and the practice level, there are still shortcomings in the paper to be improved. Subject to time constraints, survey access to information is limited. At the same time, in the calculation of the transition probability is used on the average probability, which not according to the actual situation of enterprises to distinguish between different years and sets a different weight, resulting in a discrepancy between predicted results and actual data.

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