TWO FORECASTING METHODS TO ASSESS FUTURE LABOR DEMAND: A CASE STUDY

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Abstract

This study aims to predict the future labor demand with the proportional method and the trend extrapolation method. The proportional method was adopted to analyze the future demand for workforce based on the amount of future tasks. The study converted the amount of future tasks into the amount of future job tickets because the latter enjoys the following advantages: Utilizing job tickets can avoid the situations caused by variables such as employees' inertia and their familiarity with tasks. When different employees carry out the same task, they are required to complete the task on the same hourly basis. In contrast, the trend extrapolation method follows a different logic and uses last year's historical recruitment records as a reference to estimate the future labor demand. Under the premise of knowing the exact amount of future tasks, the empirical analysis results show that the proportional method can provide a more accurate prediction for future labor demand. However, the estimation ability of the trend extrapolation method is comparably limited. The study found the proportional method can obtain a more precise prediction on future labor demand when it is combined with job tickets. Consequently, it is concluded the proportional method is more suitable for long-term labor demand planning.

Keywords: proportional method, trend extrapolation method, job tickets

Introduction

This study takes Factory M as a research case and adopts two quantitative methods (i.e. the proportional method and the trend extrapolation method) to analyze the effectiveness of human resource planning. The proportional method uses the job tickets from Factory M as a reference basis. The job tickets are calculated based on working hours, which may be affected by several factors. Therefore, only 2 variables (i.e. employees' positivity and work experiences) are chosen for this study. In terms of positivity, an active employee can perform his job with higher efficiency. For example, if he was appointed with three tasks (including one equipment test and two equipment maintenance), he can check and maintain equipment while performing automatic detection for the other equipment.

But if the same tasks were carried out by a less active employee, he may tend to take a rest when the computer is running the self- detection program on equipment, and perform the other two equipment checks after the computer completes self-detection. Therefore, the working hours necessary for the two types of employees will be different. Gaps in working hours may also arise due to employees' work experiences. For illustration, senior staff with 20 years of experience will certainly spend less time on identifying and troubleshooting equipment issues than newcomers. Moreover, they can quickly determine the failure positions on the circuit board and repair it once they know the equipment problems. In contrast, new employees may need more time to troubleshoot and repair because they lack hands-on experience. When they encounter the same equipment issue, they need to follow the step- by-step instructions of maintenance guidelines until they identify the problems with the circuit board.

To summarize the aforementioned cases, the working hours required for the same task may vary greatly, depending on employees' positivity and work experiences. However, this variable is difficult to estimate accurately. For example, the working efficiency of a diligent employee on a specific date may be greatly affected if he is sick. From the viewpoint of troubleshooting equipment problems, if the variable values cannot be fixed, the easiest way is to define variables; which means, to assign the working hours required for each task. Factory M has considered the characteristics (positivity and work experiences) of each employee and developed standardized job tickets (or “job tickets”) for task assignments.

Each job ticket will provide detailed information such as project name, task item, task sequence, task types, and estimated working hours. In other words, job tickets can tell who will perform which task with certain workflows and goals and how much time it will take. This study has provided fixed values of team types and working hours to simplify the calculation.

Given that this study focuses on employing two quantitative methods, the proportional method and the trend extrapolation method, to predict future demand for the workforce, the job tickets are defined based on working hours, task sequence, and the task types to serve as the calculation basis for human resource prediction. With this calculation logic, employees' technical ability variables are quantified, and the factors of training costs are set as fixed values (assuming the abilities of employees remain at a fixed level). Meanwhile, the calculation equation only considers the employee retirement variables to avoid the equation from being too complicated. The preliminary discussion on defining the task sequence and working hours are similar to the Delphi method. However, it is found the opinions of participants are easily affected by other participants, so it is difficult to raise opinions "without any restrictions" (which is slightly different from the Delphi method). This study simplifies several variables of job tickets we discussed above and can be used as a reference for the proportional method. If the new tasks in the future can be converted into the number of job tickets, then the logic of "determining the future workforce based on the increase of job tickets" is just like the proportional method in quantitative methodology. If the historical trend of workforce in recent years is simply adopted to provide a reference for future workforce planning, this process is much like a quantitative trend extrapolation method. Consequently, this study intends to compare the calculation results of the two methods to understand which one is more suitable for the real situation and to provide companies with a more precise calculation method for workforce shortage.

Literature Review

For labor demand analysis, previous studies can generally be divided into quantitative research and qualitative research. Lu (2020) pointed out the quantitative study is mainly based on empirical analysis. In a quantitative study, a few hypotheses are firstly proposed, and then statistical analyses are conducted to explain the observed phenomena. In contrast, the qualitative study primarily explores existing activities such as interpersonal interactions and organizational operations, investigates the relationship between their implications and current phenomena, and focuses on describing the phenomena rather than providing empirical analysis. Tong (2020) and Chao (2017) further elaborated that qualitative study is more subjective and belongs to exploratory study. Similar to the Employers Opinion Method (or the Delphi Method), every expert can freely express his opinions without restrictions. If no conclusive prediction results are reached, the discussion should be continued, and a series of modifications and feedbacks should be carried out so the experts can gradually reach a more unanimous opinion. Nevertheless, these methods are time- consuming and difficult to quantify, and often cannot provide references for future study, and are more suitable for short-term research or when research data is insufficient. In comparison, quantitative methods (including linear regression model and time sequence model) are more objective because they apply the historical information to a mathematical model to provide the forecast of future labor demand.

An article entitled "The Basic Procedures and Demand Forecast of Human Resource Planning" in MBALib Database presents a more comprehensive description of qualitative methods and qualitative methods. The article demonstrates the qualitative methods used in predicting labor demand mainly consist of the empirical prediction method, descriptive method, and Delphi method. Empirical prediction methods are composed of bottom-up and top-down approaches. These methods utilize existing information or data to estimate companies' labor demand on account of employees' experiences and companies' characteristics. Human resource planners employ descriptive methods to describe "the companies' future changes caused by specific factors within a given period". After the processes of description, assumptions, and analysis, human resource planners can provide workforce prediction and establish corresponding human resource plans based on different situations or assumptions. However, the overall business environment may change over time. This method is difficult to describe various uncertain factors, so it is not suitable for long-term prediction. The Delphi method usually conducts a questionnaire survey and collects experts' opinions on estimating companies' future labor demand. A unanimous opinion will be reached after several rounds of discussions. The discussion is generally divided into four rounds: In the first round, the prediction goal and requirements will be proposed, and the selected experts will be counseled based on the collected information. In the second round, the prediction questions are listed in the tables for the experts to examine, aggregate, and provide predictions. In the third round, the prediction results will be modified by combining the opinions from experts. In the fourth round, the final prediction will include the feedback and references raised by experts. As illustrated by the grounded theory (Kuo, 2020), systematic data collection and analysis should be based on empirical results and research insights.

There are five quantitative methods, including (1) proportional method, (2) personnel ratio, (3) trend extrapolation method, (4) regression analysis, and (5) Markov analysis. The rationale and applicability of these methods are described below: The proportional method converts the company's business workload into the required number of employees. In other words, estimate the number of employees needed in the future based on the company's task amount and evaluate the number of supporting staff accordingly. The proportional method is applicable to short-term labor demand forecasting. However, this method has two disadvantages. First of all, the information of "the increase in future tasks", "the current status of tasks", and "the increase in work efficiency" must be accurate, so that evaluation and analysis can provide meaningful results. Second, this method only considers the total number of employees but does not explain the differences in the needs of different types of employees, and it is thus difficult to meet the actual needs. In the personnel ratio method, the ratio of key members of the company (such as technicians and management level) who work for critical missions will be calculated, and the number of employees required for each task will be predicted based on foreseeable changes. This method assumes "the number and allocation of employees in the past is optimized and reasonable, and the work efficiency is no different from the current situation", so its applicability is limited. The trend extrapolation method is employed to predict the possible trends and labor demand in the future and can be used to solve quantifiable human resource problems. The reliability of this prediction method is related to the length of time between the past and the present. The general regression model is $y = a + b*t$, where y is personnel demand, a and b are undetermined values, and t is a time variable. The specific value can be obtained by conducting regression analysis on the historical data of y and time t. Regression analysis is to predict future development trends based on the causal relationship. It can also be called the regression model prediction method or causal method. The general regression model is $y = a*xi + b*ni$, where y is the number of required personnel, xi is the i-th value, a, b, and ni are undetermined values, indicating the relationship between y and xi. After performing regression analysis on the existing data with SPSS (which is the most commonly used software), specific values can be obtained. When $ni = 1$, it is linear regression, and when $ni > 1$, it is non-linear regression. By observing the changes in the number of company employees over the years, Markov analysis can identify the organizational pattern of personnel changes and predict the trend and status of future personnel changes. The Markov model is a transition matrix that uses statistical data to forecast changes in future labor demand.

The complete workforce prediction theory mainly consists of the following six steps. Step 1 is to understand the company's current situation and the context that affects its future. Step 2 is to analyze the company's current situation of the workforce supply. Step 3 is to analyze the company's current situation of the labor demand. Step 4 is to predict the future workforce supply. Step 5 is to predict the future workforce shortage and demand. Step 6 is to analyze the supply and demand forecast. Wei (2013) pointed out that if you want to gain more precise insights into the future workforce shortage, you must understand the company's occupational type, quantity, technology, budget, training, and flow of people. The study further explained four key concepts, including "Understand the context and the current situation of the company that influences the future", "Analyze the company's current situation of the labor demand ", "Predict the future workforce shortage and demand", and "Analyze the supply and demand forecast". Feng (2007) took Taiwan Coast Guard Administration (CGA) as an example. CGA attempted to expand its staffing by calculating its future labor demand for hiring new cruisers to correspond to the increase of maritime services. The situation of CGA can be considered as the labor demand for new tasks. In this case, the new work firstly must be broken down into several detailed tasks based on the work breakdown structure (WBS). After knowing the working hours of each task, the company can calculate the total working hours required for the new tasks and recruit the required employees. Analyzing the company's current labor supply and predicting the future labor supply can be regarded as factors to be considered when calculating potential labor shortages. In other words, the

CGA should consider the factors of new recruitment and retirement and calculate the average interval to recruit newcomers.

Han (2020) stated that accumulated human capital is difficult to calculate and quantify. He pointed out the following two common situations: First, the number of education years alone cannot reflect the accumulation of human capital after employment. Second, even if two employees have the same educational background, their employment experiences (years of service) will also cause differences in human capital. Managers usually take employees' working experiences as a reference, but this indicator is not accurate enough. An example is given below to further illustrate. Two employees onboard at the same time with the same educational background, one of them is assigned to low-tech jobs, and the other is assigned to high-tech research and development work. Generally, the unevenness in work experiences for high-tech work should be greater than low-tech jobs. However, employees' years of service is not comprehensive enough (though the cumulative variance in human capital can be obtained from the length of working hours), and other methods are needed to complement this drawback. Ni (2014) demonstrated that middle-aged and elderly people usually don't choose the industry they used to work in when they change jobs, so the Gini coefficient of high-tech industries is more significant.

Study Case and Analysis

This study adopts two quantitative methods (the proportional method and the trend extrapolation method) to calculate the future labor demand in this case and compares the advantages and disadvantages of the two methods. The proportional method converts the number of future tasks into job tickets and estimates the type of tasks and working hours required in the future based on the job tickets. The trend extrapolation method proposes a hypothetical equation, collects historical records to obtain a future trend equation, and inputs the estimated year to gain the future labor demand. The study workflow is shown in Figure 1.

Proportional Method

a. Define task goals

This study adopts the proportional method to transform the company's business workload into labor demand. To be more specific, the future labor demand can be estimated based on the company's future tasks. After adopting this method when the future task goal is known (the task goal is pre-defined),

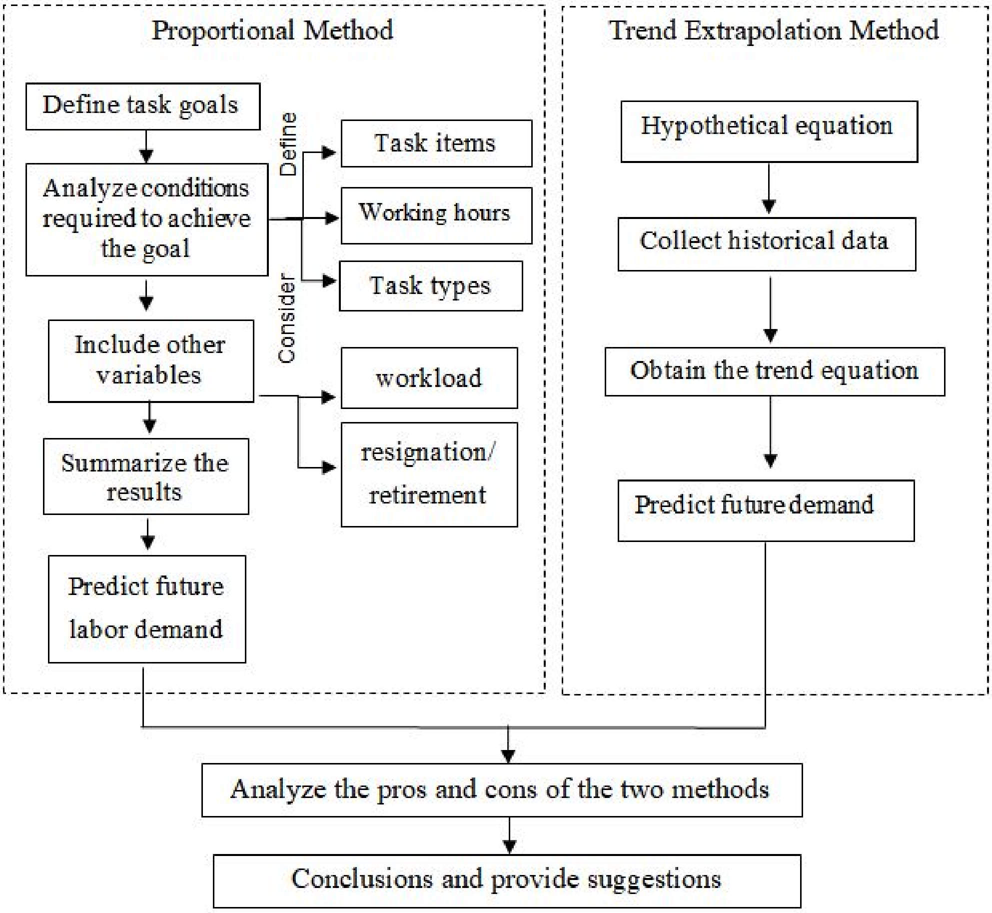

Fig.1 Research Flow

the task items required to complete task goals are analyzed, quantified, and broken down into job tickets to calculate the labor demand.

b. Analyze the conditions required to achieve the goal

Job tickets will include the information needed to perform tasks, including task items, working hours, and task types. However, the available working hours of each employee should be defined before the business workload is converted into labor demand. According to the annual calendar published by the Executive Yuan (R.O.C.), there is an average of 215 working days each year. Moreover, workers' daily working hours are 8 hours based on Labor Standards Act. Thus, if workers' overtime and vacations are not considered, the estimated working hours per person in a year (215 days x 8 hours) will be 1,720 hours.

c. Include other variables

If the task goal remains unchanged, the primary reason for the change in labor demand is either "change of employee workload" or "personnel resignation/retirement". Regarding employee workload, the equation of the known employee workload is $Pa = Wa / Wp * 100\%$ (Equation 1), where Pa stands for the employee workload (in percentage), Wa represents the actual working hours, and Wp is the estimated work hours. The best performance can be achieved when the employee workload is 125%. There are many reasons for the resignation and retirement of employees, so this study only uses "the maximum service life has been reached" as the calculation logic.

d. Summarize the results

In summary, the employee workload equation can be modified as $Pa \geqq Wa/1720\ Pall*100\%$, where Pa stands for the employee workload (in percentage), Wa represents the actual working hours, and $Pall$ is the total number of employees who perform the task. If the workload of employees is $\leqq 125\%$, the relationship between the total number of people engaged in work and their actual working hours is $Pall \geqq Wa/2150$ (Equation 2). When evaluating $Pall$ (i.e. the total number of employees), the employees who are about to retire and the new employees who are about to hire should be considered. For example, if two electronic workers retire in 2021 and another 10 electronic workers need to be recruited in the same year, the total number of electronic workers to be recruited in 2021 will be 12.

e. Calculate future labor demand

According to Equation 2, after converting the future task amount into job tickets, if the necessary working hours of future electronic workers is 21500, then $Pall \geqq 10$. In other words, the total number of task performers should be no less than 10. Moreover, the policy goal of "employee workload$\leqq$125%" can also be achieved. Table 1 shows the code list for this study:

Trend Extrapolation Method

The trend extrapolation method can be further divided into several evaluation methods, which can be used to predict the trend of future labor demand and solve quantifiable human resource problems. This study intends to choose a method suitable for evaluating the number of employees to be recruited in subsequent years, so the exponential smoothing method is

Table 1. Code list of this research

Item	Code	Meaning
1	*Pa*	Employee workload
2	*Pall*	Total number of employees
3	*Wa*	Actual work hours
4	*Wp*	Planned working hours

adopted because the time sequence is both stable and regular, and can be used to predict the trend in the upcoming years.

a. Hypothetical equation

The basic equation will be "exponential smoothing" $S_t = a * y_t + (1-a)S_{t-1}$, where S_t represents the smoothing value at time t, a is the smoothing coefficient value (ranging from 0 to 1), yt stands for the actual value of time t, and S_{t-1} is the smoothed value of time $t-1$. The value of a is "the sum of the squares of the difference between the actual value and the predicted value of each period divided by the total number of periods, and the minimum value is taken." In other words, when a equals to a specific value, the sum of the squares of the difference between the actual value and the predicted value of each period divided by the total period has a minimum value (which means, the error of the value is small), so this value is used as the coefficient a of the equation. Based on the collected historical data, the single exponential smoothing method is employed when there is no obvious change in the trend of the time sequence, and the double exponential smoothing method is adopted when the trend of the time sequence shows obvious linear changes.

b. Collect historical data

Collect historical data in recent years and calculate the electronic and mechanical workers needs to be hired.

c. Obtain the trend equation and predict the future demand

Organize the basic equation $S_t = a*y_t + (1-a)S_{t-1}$" into "$S_t = S_{t-1}+a (y_t -S_{t-1})$ (Equation 3). When $a = 0.7$, "the sum of the squares of the difference between the actual value and the predicted value of each period divided by the total number of periods" has the minimum value. If the historical information only provides data for y_1, then S_1 of the first period is $S_1 = y_1$. If the single exponential smoothing method applies to the actual cases, the prediction equation is $y'_{t+1} = a * y_t + (1-a)\, y'_t$ (Equation 4), where y'_{t+1} is the prediction value of period $t+1$, and y'_t is the prediction value of period t.

Case Analysis

Take Factory M as an example. The tasks of existing projects A, B, and C need to be completed by performing ship-related tasks such as delivery, service and planned maintenance, etc. Assuming that all projects can be carried out on time, the planned schedule includes launching in the first year, delivery in the second year, intermediate-level (I-level) maintenance in the third year, I-level maintenance in the fourth year, depot-level maintenance in the fifth year, and I-level maintenance in the sixth year. According to the aggregated data from 2021-2024, the number of electronic and mechanical workers to be recruited is shown in Table 2.

Table 2. The comparison table of two recruitment methods (2021-2024)

Year		2021	2022	2023	2024
Proportional method	Electronic workers to be recruited	22	22	15	19
	Mechanical workers to be recruited	13	11	7	14
Trend extrapolation method (single exponential smoothing method)	Electronic workers to be recruited	65	Based on the actual value of the previous year		
	Mechanical workers to be recruited	13	Based on the actual value of the previous year		

Both the proportional method and the trend extrapolation method have their own pros and cons. The proportional method predicts labor demands based on the number of future tasks, so it can display the annual workload and obtain a value that matches the real situation. But if the amount of future tasks cannot be determined, it is difficult to use this method to predict future labor demand due to the lack of reference points. In contrast, the trend extrapolation method takes the historical recruitment records of the last year as a reference to evaluate the future labor demand. Nonetheless, the amount of future tasks cannot be accurately measured based on historical records. In addition, the exponential smoothing method can only be used to estimate the trend of the next year (period). Without knowing the actual value of the next year, the predicted value of the following year cannot be calculated. After comparison, the advantages and disadvantages of the proportional method and the trend extrapolation method are illustrated in Table 3:.

Table 3. The Comparison Table Of Advantages And Disadvantages Between Proportional Method And Trend Extrapolation Method

Item	**Proportional method**	**Trend extrapolation method (single exponential smoothing method)**
Reference source	Future task requirements	Historical data
Calculation results	Obtain the actual future labor demand	Trend of future labor demand
Estimated range	Long	Short (Only applicable for the next period)
When new tasks are determined	Able to estimate new labor demand	Unable to estimate new labor demand

Conclusions and Suggestions

Conclusion

This study intends to employ two quantitative methods (proportional method and trend extrapolation method) to assess the future labor demand and to determine which method is more suitable for the study case. Given the amount of future tasks is known in the study case, the proportional method is utilized in order to convert the future tasks into equivalent job tickets, estimate the working hours needed for each task type, and obtain the future labor demand. The advantage of job tickets is that they can reduce the influences of variables including workers' inertia and familiarity with the task. If different employees perform the same task, they should complete the task within the same time. Thus, the labor demand of upcoming years predicted by the proportional method is more accurate and more in line with the actual situation and can display the task load. The trend extrapolation method utilizes last year's historical recruitment records as a reference to predict the future labor demand. The single exponential smoothing method can only be employed to estimate the predicted value of the next year (period). Without actual data for next year, this method cannot provide an accurate forecast for the following year and long-term labor demand. Moreover, by adopting this method, it is impossible to estimate the additional workers that need to be recruited in the future no matter how many new tasks are added due to insufficient historical data. The advantages and disadvantages of the proportional method and the trend extrapolation method were compared, and the analysis results demonstrate the proportional method is more suitable for the study case.

Suggestions for Future Research

Most literature indicated that the proportional method is more applicable for short-term forecasting. This study integrated the concept of job tickets with the proportional method because the task types, working hours, task order, and completed tasks have been defined within job tickets. It is discovered that the accuracy of the forecast provided based on job tickets can be enhanced. Therefore, job tickets can serve as effective references for similar tasks in the future. Most companies only use the proportional method for short-term purposes, even if breaking down tasks into several items is time-consuming. This is because companies cannot effectively incorporate job tickets with the proportional method. They either don't have time to define job tickets, or the economic benefits of defining job tickets are not high enough for them. If the amount of future tasks can be determined for a long period of time, the proportional method can provide more accurate prediction with more granular definitions are set for other task items. The drawback of combining the proportional method with job tickets is that it takes much time in the initial stage and it is thus difficult to show its effectiveness. After the definition of each task item has been given, the accuracy of this integrated method is rather high. By adopting other methods (such as fulfilling the job openings caused by retirement), the proportional method can also be used as an effective reference indicator for long-term forecasting.

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