International Journal of Knowledge, Innovation and Entrepreneurship
Volume 2 No. 2, 2014, pp. 39—49

Forecasting Internal Labour Supply with a Use of Markov Chain Analysis

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Received 16 May 2014; received in revised form 20 June 2014; approved 31 July 2014

ABSTRACT Manpower planning and forecasting can contribute to improving company's performance. Implementation of certain straightforward planning techniques can result in higher effectiveness of human resource policy and increased competitiveness of the organization. In this paper, a number of methods of forecasting internal labour supply has been described. Markov chain model has been characterized in more detail and a numerical example of manpower planning in a retail store, based on this approach has been presented. The main limitations of implementation of Markov model to internal labour supply forecasting have been discussed and conclusions drawn.

Keywords: human resources, internal labour supply, manpower planning, Markov chain model

Introduction

Business decision makers attempting to forecast company's internal labour supply tend to rely on judgement and intuition rather than rigorous statistical analyses (Taylor 2005, p. 97). They argue that rapidly changing company's environment and high level of uncertainty in contemporary economies make human resource planning increasingly difficult and the companies overly bureaucratic and rigid (Marchington and Wilkinson 2005, p. 158). Some specialists claim that competitive advantages of today's organizations come from the ability to generate swift and flexible responses to the fast changing economic and social environment and sophisticated forecasting methodology can stifle these qualities. Researchers in the field of management point out several reasons why decision makers can be reluctant to adopt a statistics-based approach to personnel planning (Taylor 2005, p. 98):

- hostility to the use of statistical techniques in place of intuitive judgement, and fear of mathematical methods,
- ignorance of decision makers, who are unaware of personnel planning methods,
- belief that human resource planning is not vital for achieving economic efficiency,
- short-termist approach,

- decentralization of contemporary organizations,
- practical problems resulting from the lack of reliable data for a formal analysis,
- controversy about the usefulness of past data for predicting future trends.

Despite some scepticism concerning the use of formal methods in management, systematic labour force forecasting based on quantitative methods can significantly contribute to organization's success. Human resource planning could have prevented, or at least eased, labour and human capital shortages suffered by companies in the past. The high turbulence and complexity of today's business environment – a point frequently raised by the opponents of the use of formal methods—can be seen more like an argument *for* application of sophisticated techniques of planning, rather than against it. Often, there is no need for pin-point accuracy—the use of forecasts can just contribute to the reduction of the level of uncertainty. Managers should view the planning process as flexible and adaptable anyway, so that unexpected changes in the environment could be catered for.

Methods of forecasting internal labour supply

A variety of methods designed for forecasting organization's internal labour supply are used. They can be divided into:

- qualitative methods: staffing charts, replacement charts, succession planning, skill inventories, and
- quantitative methods: analysis of wastage and stability indices, and Markov analysis.

Staffing charts are special tables including all job categories within an organization, the number of persons occupying those positions and the number of employees to be hired in a particular year. They do not show whether the planned new posts will be filled or not, they are merely used to show the total number of employees at the end of the budget period (Rothwell and Kazanas 2003, p. 223). Replacement charts present a list of current employees, their positions, promotion possibilities and potential replacements. They are prepared in order to secure the smooth transition of duties in case a sudden loss of certain key workers, especially the executives, occurs. Succession charts contain more detailed information and cover not only managers but other workers as well. They are used for long-term planning of employees development in the company. Succession planning programs usually include (Rothwell and Kazanas 2003, p. 225):

- data on candidates: performance appraisal results, career interests, etc.,
- job requirements and descriptions, connections between positions through career paths indicating what skills, education and experience is required to move from one place to another,
- formal procedure of systematic review of information on the candidates' qualifications in relation to the position requirements,
- development plans for employees, special assignments and testing methods for assessing their achievement,

- candidates' succession summaries which point out their strengths and weaknesses, as well as position succession summaries indicating what employees are ready for taking over particular position or what should be done to facilitate the promotion to the position.

Another type of tool of manpower planning are skill inventories. They are very detailed databases which can serve as a source information for succession planning programs. Specifically, they include: employee name, date of birth, date of hire, work location, present position title, previous position titles, educational background, training completed, fluency in foreign languages, career objectives, professional licenses, publications, salary history, medical record, hobbies, and any other information which company considers relevant.

Quantitative methods of forecasting internal labour supply are based on employee turnover (exit, wastage) rate (Marchington and Wilkinson 2005, p. 162) or Markov analysis. The turnover index indicates a number of leavers in a particular period of time as a share of the average number of employees[1]. Turnover rates depend on a variety of employees' demographic, social and economic characteristics, as well as on labour market conditions. Usually, exit rates are higher (Taylor 2005, p. 86):

- the lower the age of an employee,
- the shorter the span of work in a particular company,
- the lower the employee skills and responsibility,
- the lower the unemployment rate in the economy[2].

There are two types of labour turnover: involuntary and voluntary[3] (Secord 2003, p. 197). Involuntary leaves can be easily predicted by decision makers since they result from retirements, planned promotions and redundancies. Human resource managers are much more concerned with voluntary exits, as it is much more difficult to be prepared for them. It is never possible to calculate their future values accurately. To some extent, their levels are influenced by company's personnel policy, e.g., higher voluntary exit rates can be expected, when a company deliberately offers poor working conditions and salaries, or little development opportunities for employees.

Companies can benefit from predicting future exit rates. In some cases it is possible to use information from consulting agencies, however, the use of such data is limited as exit rates for a particular company will differ from the general, countrywide or sector-level values. Estimates of turnover are usually based on past experience of a specific organization and on an analysis of promotion patterns for specific homogenous employee cohorts. A company-wide turnover rate can be useful for comparisons with last year's or competitors' figures, but it is not suitable for forecasting internal labour supply as it averages out the differences between specific groups of employees. In order to obtain required accuracy of forecasts an analyst should break employees into cohorts and calculate separate figures for each group which will then serve as input data for calculating future values of labour supply.

Another quantitative method of labour supply forecasting, similar to exit rate analysis, is based on Markov chain model (Van Utterbeeck et al. 2009). This approach assumes that the company's current internal manpower supply in a particular class (group

of employees) depends on the stock of employees in that class in previous period (e.g. last year), and on percentage ratios representing shares of those members of the class who had been promoted, demoted, transferred, made redundant and those who had left the organization voluntarily.

Markov chain model as a tool of forecasting internal labour supply

Let us consider that company's employees are broken into N job categories (classes), and n=1, 2, 3,..., N. Let n=0 refer to the external environment of the organization, that is a source of new workers and a destination for leavers. Let us define $s_i(t)$ as the employee stock in job class *i* at time *t*; labour supply vector $s(t)$ $=[s_1(t), s_2(t), \ldots, s_N(t)]$ represents the number of employees in each class at observation point *t*. The total workforce at time *t* equals $\sum_{i=1}^{N} s_i(t)$.

We refer to period *t* as the time interval between observation points *t-1* and *t*. In order to account for changes in the system, a variable $f_{ij}(t)$ is introduced, which represents the flow of workers between class *i* and *j*, i.e. the number of employees that belong to the job category *i* at point *t-1* and to the class *j* at observation point *t*.

The stock of manpower in class *j* can be expressed as a sum of all inflows in period *t*:

$$s_j(t) = \sum_{i=0}^{N} f_{ij}(t) \quad . \qquad (1)$$

The sum expression includes not only the movements of employees, but also the number of individuals staying in class *j* during the whole period, which is represented by the flow $f_{ij}(t)$ for *i=j* (i.e., the "flow" from class *j* to class *j*[4]).

The formula (1) can be rewritten as follows:

$$s_j(t) = f_{0j}(t) + \sum_{i=1}^{N} f_{ij}(t) \quad , \qquad (2)$$

where $f_{0j}(t)$ is the inflow of employees from external source to class *j*.

The flow from job category *i* to *j* can be expressed as a fraction of the stock of employees in class *i* at previous observation point *t-1*:

$$f_{ij}(t) = q_{ji} s_i(t-1) \quad , \qquad (3)$$

for i = 1, 2, …, N, and j = 0, 1, …, N, where q_{ji} is the fraction of employees from class i that moved to class j in period t.

When combining (2) and (3) we can rewrite the formula for manpower stock in class j at the end of period t:

$$s_j(t) = f_{0j}(t) + \sum_{i=1}^{N} q_{ji} s_i(t-1) \quad . \qquad (4)$$

If we define $f_0(t)$ as a vector consisting of the inflows from external sources – $f_{0j}(t)$, and Q as a matrix containing the values of q_{ji}, we can write (4) in a matrix form:

$$s(t) = f_0(t) + Qs(t-1) \quad , \qquad (5)$$

where $s(t)$ is a vector of labour supply.

Formula (5) can be transformed into transition equations of a stochastic Markov chain (Van Utterbeeck et al. 2009, p. 3). We assume that the total number of employees remains the same in period t, i.e. all vacancies are filled, and we define:

- the recruitment Nx1 vector r $=[r_1, r_2, \ldots, r_N]^T$, consisting of r_j – fractions of the total recruitment of manpower that supplies job category j,
- the attrition 1xN vector a $=[a_1, a_2, \ldots, a_N]$, where $a_j = q_{0j}$, i.e. the fraction of employee stock in class j that leaves the organization.

Let us now assume that all vacancies created in the system are filled from external sources at each point in time. The number of vacancies in period t: $\sum_{i=1}^{N} a_i s_i(t-1)$ is equal to the sum of external recruitment flows into each class:

$$f_{0j}(t) = r_j \sum_{i=1}^{N} a_i s_i(t-1) \quad . \qquad (6)$$

After inserting formula (6) into (4) we can write:

$$s_j(t) = \sum_{i=1}^{N} (r_j a_i + q_{ji}) s_i(t-1) \quad , \qquad (7)$$

for j=1, 2, …,N.

The introduction of matrix $P = r \cdot a + Q$ gives:

$$s(t) = Ps(t-1) \quad (8)$$

Formula (8) is an equivalent of transition equations for a stochastic Markov chain, where $s(t)$ is a vector of labour supply and P is a stochastic matrix with non-negative elements $p_{ji} \geq 0$. It can be used for forecasting internal labour supply in an organization. Since $\sum_{j=1}^{N} r_j = 1$, and the fraction of employees leaving class *i* $a_i = q_{0i}$ (which is equal to $q_{0i} = 1 - \sum_{j=1}^{N} q_{ji}$), all columns of P sum to 1:

$$\sum_{j=1}^{N} p_{ji} = a_i \sum_{j=1}^{N} r_j + \sum_{j=1}^{N} q_{ji} = 1. \quad (9)$$

Wang (2005) indicates three potential limitations of Markov chain model applied to human resource systems. Firstly, Markov model is a descriptive, or explanatory, one. It is not an optimization model and it does not indicate the best solution in terms of the minimization of costs or maximization of productivity. Secondly, Markov model is linear[5]—it does not allow for feedback mechanism on the wastage rate (e.g. the impact of employees promotion prospects on turnover rate). Thirdly, a number of employees in each job category must be large enough so it is possible to estimate trustworthy probabilities for the transition matrix. It is best when job classes consist of more than 100 employees to fulfil the sample size requirement. This is why Markov model is frequently used in analyses of very large organizations or even whole sectors, such as defence (Van Utterbeeck at al. 2009), (Škulj, Vehovar and Štamfelj 2008), (Chin-Tsai, Su-Man and Chang-Tzu 2001), or health sector (Huan-Cheng et al. 2008) and (Trivedi et al. 1987). In small and medium sized companies it is difficult to build relatively homogenous groups of workers that would each contain large number of individuals. Nevertheless, Markov models are applied even in cases when sample size is smaller than 100.

Manpower planning on the example of a retail company

In this part of the article an internal labour supply analysis for a retail store based on Markov chain is implemented. The employees of the company are broken into five classes reflecting five job positions in the store's organizational hierarchy, from top to bottom: store managers, assistant store managers, section managers, department managers and sales associates. Table 1 presents the matrix containing probabilities of employee flows between job classes for the year *t*. In this example the values of probabilities have already been estimated on the base of past values and assumptions regarding

company's promotion policy. Figures in each column sum to 1. It follows from the matrix that, for example, 10 per cent of Section Managers are expected to get promoted to the post of Assistant Store Manager in period *t* and 5 per cent of them will be demoted, while 73 per cent of employees belonging to this job category will remain in the same position, and 12 per cent will leave the company, either voluntarily or involuntarily.

Job category	Store Managers	Assistant Store Managers	Section Managers	Department Managers	Sales Associates
Store Managers	0.90	0.08	-	-	-
Assistant Store Managers	-	0.85	0.10	-	-
Section Managers	-		0.73	0.11	-
Department Managers	-	-	0.05	0.69	0.07
Sales Associates	-	-	-	0.02	0.71
Exits	0.10	0.07	0.12	0.18	0.22

Table 1: Probabilities of employees' flows in a retail company
Source: based on retail store data.

Markov chain model uses transitional probabilities and stock of employees at the beginning of period *t* (observation point *t-1*) to determine forecasted internal labour supply at the end of the period (observation point *t*). A flow from job category *i* to *j* in period *t* is equal to a fraction of the stock of employees in class *i* at observation point *t-1*, i.e. $f_{ij}(t) = q_{ji}s_i(t-1)$. In table 2, the second and ninth columns contain input data from the store employment records. They show the number of workers in each job class at the beginning of period *t*, and the values of demand for labour in each category in period *t*, respectively. Values representing the flows of employees, rounded to natural numbers, are presented in bold in columns 3-7 (shaded areas).

Table 2 (next page) indicates flows of employees (rounded to whole numbers), stock of manpower and recruitment needs.
The forecasts of internal labour supply in each job class are shown in column 8. The external recruitment needed in a particular job category indicated in column 10. For example, a number of employees that need to be hired in the Sales Associates class equals $f_{05}(t) = 898$. The number of vacancies in the whole manpower system in period *t* equals $\sum_{i=1}^{N} a_i s_i(t-1) = 903$ (the sum of column 10 of table 2). Taylor (2005) proposes a simplified approach to forecasting manpower supply that does not

require estimating probabilities of workers' flows between job categories. Instead of using transition matrix, the number of posts that need to be filled in class *j* in year *t*, $f_{0j}(t)$, can be calculated with a turnover rate T_j and a ratio indicating a share of vacancies usually filled from internal sources I_j. The expected number of vacancies created in class *j* in period *t*, V_j, can be calculated with the following formula:

$$V_j = s_j(t)(1 + D_j)T_j \quad (10)$$

where:

$s_j(t)$ - labour supply in class *j* in period *t*,

T_j – turnover rate based on past trends,

D_j – expected rate of increase in labour demand during period *t*.

The number of posts which have to be filled from external sources is calculated as:

$$f_{0j}(t) = V_j\left(1 - I_j\right) \quad (11)$$

where I_j is a share of vacancies typically filled by internal promotion.

Turnover rates are estimated on the basis of past data and managerial judgement, while the fractions of vacancies that are filled by promotions follow from the company's personnel development and promotion policies. The approach proposed by Taylor requires less detailed input data to generate estimates of internal labour supply as compared to Markov chain analysis.

Job category	Number of employees at t-1: $s_j(t-1)$	Store Managers	Assistant Store Managers	Section Managers	Department Managers	Sales Associates	Forecasted internal supply at observation point t: $\sum_{i=1}^{n} e_{i,t-1}$	Manpower demand in period t: $s_j(t)$	Number of employees to be hired in period t: $f_{0j}(t)$
1	2	3	4	5	6	7	8	9	10
Store Managers	16	0.90*16? 14	0.08*58? 5	-	-	-	19	19	0
Assistant Store Managers	58	-	0.85*58? 49	0.10*170? 17	-	-	66	68	2
Section Managers	170	-		0.73*170? 124	0.11*512? 56	-	180	183	3
Department Managers	512	-	-	0.05*170? 9	0.69*512? 353	0.07*2387? 167	529	529	0
Sales Associates	2387	-	-	-	0.02*512? 10	0.71*2387? 1695	1705	2603	898
Exit	x	0.10*16? 2	0.07*58? 4	0.12*170? 20	0.18*512? 92	0.22*2387? 525	643	x	x

Table 2: Flows of employees (rounded to whole numbers), stock of manpower and recruitment needs Source: own calculations

Conclusions

Internal labour supply forecasting contributes to a more accurate human resource planning and, in result, through reduction of HR costs, to an improvement of company's performance. It supports the process of managing recruitment costs, but also facilitates the human capital management, due to enhanced timing and targeting of promotions and training. A number of sophisticated methods have been adopted in the field, such as succession planning programs or Markov chain analysis. Markov model has been applied in a number of studies concerning, especially, large organizations or even whole sectors of the economy, e.g. defence and health sectors. The model can be implemented to forecasting internal labour supply of a company, e.g. a retail store, in a form of simple, easy-to-use procedure. Its application is only possible when a company maintains a system of gathering and keeping human resource data, and when decision makers plan ahead employee promotions. The output of the analysis are forecasts of internal labour supply in each job category within an organization as well as the number of future vacancies which have to be filled from the labour market.

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NOTES

1. *The employee turnover can also be analyzed with a stability index, which indicates the percentage of workforce with n years' service at a given date in total number of employees n years ago.*
2. *Taylor reports that the general turnover rate in the United Kingdom at the bottom of the recession in 1992 was 10 per cent, while in 2004 when the economy was growing it reached the level of 20 per cent (Taylor 2005, p. 87).*
3. *Voluntary leaves can be further broken into those resulting from "pull" (external) factors – labour market opportunities, attractiveness of job offers from the competing employers, and "push" (internal) factors, such as a dissatisfaction with a job or a conflict with co-workers.*
4. *$j = 0$ when an employee leaves the company.*
5. *Some authors report that non-linear models outperform linear models. For overview of those studies see (Wang 2005).*

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