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18. OPTIMAL STRATEGIES FOR A KNOWLEDGE WORKERS ACQUISITION PROBLEM WITH EXPANDING AND VOLATILE DEMAND: TRAIN INTERNALLY OR RECRUIT EXTERNALLY?

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Abstract

The aim of this paper is to consider the process of supplying trained workers with knowledge and skills for upcoming business opportunities, and of training apprentices prepared to meet future demands in an IT service firm. As the demand for new workers has fluctuations, a firm should employ a buffer workforce such as apprentices or interns. However, as a result of rapid development of a business, the buffer's capacity may be exceeded, thus requiring the company to recruit skilled workers from outside the firm. It is thus important for a firm to map out a strategy for manpower planning so as to fulfill the demands of new business and minimize operation costs related to training apprentices and recruiting experienced workers. This paper first analyzes the demand and supply of workers for IT service in a knowledge-intensive field. It then presents optimal human resource planning via the familiar method of stochastic process - queueing analysis.

Keywords

Workforce Management, Knowledge Workers, Recruit Strategy, IT Service Firm, Stochastic Modeling, Queueing Theory.

1. Introduction

Suppose that you are an human resource (HR) manager at an IT service firm in the following situation: a new IT service is emerging of which the market is certain to be profitable and is

expected to continuously extend for the forthcoming years; however, since it is in the emerging stage, the future demand of the IT service will fluctuate considerably until the market matures. Moreover, as with other IT services, relevant knowledge and skills change so rapidly that knowledge of trained workers also has to be maintained in order to prevent the value of their knowledge from deteriorating. In addition, retaining skilled workers who specialize in a given service at the right time is a key success factor for winning a project opportunity. Hence, if your firm does not hold appropriately skilled and trained workers when a new project opportunity occurs, it is likely to lose the opportunity. Given this situation, what is an optimal strategy for capitalizing on new emerging opportunities, together with controlling the cost of training and maintaining human resources?

One possible strategy is to carry an excess of trained workers for the service, because expansion of the market of the service is strongly expected. However, the demand is so volatile that in the case of unforeseen circumstances, your firm might suffer from having overestimated the demand over a certain period due to the implicit cost of knowledge deterioration of trained workers as well as the explicit holding cost of unprofitable workers.

Another possible strategy is to acquire appropriate skilled workers from outside the firm when a new opportunity becomes tangible. This strategy could be the best choice because the demand is volatile and your firm does not need to carry an excess of workers. However, if the service is profitable, your firm will pay a heavy price for the urgent acquisition of necessary skilled workers, because the competitors of your firm also will have the same needs when an opportunity becomes tangible.

Obviously, a desirable strategy is a mixture between the former and latter strategies. The optimal decision on how many workers will be supplied from internal and external sources when demand rises mainly depends on the volatility of the demand and the characteristics of the labor market. If the increment of demand is expected to be rather steady, or if the rate of knowledge deterioration is low, or if the acquisition cost of skilled workers for the service is high, it will be preferable to hire new apprentices or transfer some workers from similar fields and internally train them for the service. On the other hand, if the increment of demand is expected to fluctuate, or if the rate of knowledge deterioration is high, or if skilled/trained workers can be acquired readily, it will be preferable to acquire skilled/trained workers in a timely manner. This would be reminiscent of a well-known managerial problem in supply chain management (SCM), “Make or Buy?”

This paper presents a quantitative model for the described managerial problem of determining an optimal mix of training unskilled workers internally in advance and acquiring skilled workers externally in a timely fashion under uncertain expanding demand. We utilize a queueing model for the analysis of the problem of “Train or Recruit” to capture the stochastic characteristics of the demand and supply of skilled workers for the service. Through the model, we derive optimal strategies under various demand characteristics and cost structures. These results provide theoretical insight into the problem and are expected to be helpful in making optimal decisions in real practical situations.

There have been few studies on the problem in terms of taking quantitative approaches. (See Cappelli (2008) and the references therein for the qualitative approaches.) Two approaches to optimize workforce planning problems have been presented. One is to maintain an organization as a desired steady-state structure of groups of individuals according to experience- or skill-levels. This approach is typified by the work of Bartholemew (1973, 1977, 1979) However, this class of studies does not consider the demand for the workforce that the structure of the workforce should meet. The other approach is to optimize the operation of the workforce under uncertain demand (Ebert 1976, Holt et. al. 1960, Anderson 2001a & 2001b). The related planning models specify an optimal workforce level (hiring and layoff from month to month) and workforce utilization (allowing idle time or by working overtime) given various demand characteristics and learning factors of employees. However, most of these studies assume that necessary skills and knowledge for the workforce are acquired only after hiring and do not consider the possibility that there exists a skilled workforce in the labor market that might be acquired in a timely manner. On the contrary, in the IT service field, recruiting skilled workers for a specific project opportunity takes place occasionally. Accordingly, our model and results reflect more realistic factors with respect to the acquisition strategy of skilled workers.

2. Problem description

2.1. Workforce demand

In an IT service firm, additional workers are needed when a new business opportunity arises or some workers retire. New contracts to support other customers necessitate hiring additional apprentices or skilled workers if there is no surplus labor who can deal with the existing task. Also, vacant positions should be filled within a certain period of time.

2.2. Workforce supply

Because IT technology evolves rapidly, it is critical for an IT service firm to train its workforce and retain the skilled/experienced workers. Generally, a company hires some apprentices regularly and cultivates their technical skills. However, a sudden request for skilled workers makes necessary the acquisition of experts outside the firm with a higher pay-off.

In short, there are two alternatives. One is to hire a sufficiently large workforce and train the workers for time when they will be needed. The other is to recruit skilled workers at the time of need. The former calls for directing considerable amount of the company's budget on employment while allowing it to respond to market expansion promptly. The latter could increase human resource management (HRM) costs, while it could decrease the risk for losing a new project due to a shortage of manpower.

2.3. Objective functions

In a situation where the IT service market is expanding and demand for skilled worker is increasing, the firm should retain a surplus workforce such as apprentices or interns. Also, a buffer workforce should be filled in order to be prepared for upcoming projects. This approach is

the same as safety stock in the area of inventory theory. However, if the buffer is about to be exhausted, the firm should recruit skilled workers.

The problem is to minimize the operation costs relating to hiring and training the workforce and lost cost. The cost factor is as follows:

- Lost cost: the cost that arises when new business opportunity is lost due to a shortage of man power;
- Holding cost: the cost of holding surplus manpower (buffer);
- Recruiting cost: the cost of hiring both apprentices and experienced workers. (Obviously, the cost of hiring the experienced workers is higher than the cost of hiring apprentices.)

Control variables that determine the total HR costs are the size of buffer, similar to a safety stock, and the point of transition from hiring apprentices to recruiting trained workers. The latter has an advantage of a short interval between hiring and assigning the worker to a new project. On the other hand, a time-consuming on-the-job training (OJT) course will be needed for the apprentice.

3. How to analyse

3.1. Modeling

Demand could be considered as work arrival and supply for the workforce as service. The queueing analysis deals with a stochastic process made up of the customer's arrival and departure after service completion. Hence, queueing theory is utilized in determining how to analyze the demand and supply of the workers and designing the optimal HR planning.

Workforce demand is a Poisson process. A random size of new workforce is involved. Also, it is assumed that the time interval between acquiring necessary manpower and assigning a task has an exponential distribution. If the firm hires an apprentice to cope with an additional project, a low service rate could be assumed, while recruiting an expert could bring a high service rate. The maximum buffer – the surplus labor – size is K . Thus, it could be considered as $M^X / M^H, M^L / 1 / K$ queueing system. The assumed cost factors are outlined in Table 1.

Cost factor	Assumptions
Holding cost	A fixed cost c_H is incurred on any surplus worker during a unit time
Lost cost	If a demand cannot be fulfilled with the amount of current surplus workers, all the units of demand are lost (not partially accepted). A fixed cost c_L is incurred for each unit of demand lost.
Recruiting cost	A fixed cost c_{RE} (c_{RA}) is incurred each time an experienced worker (apprentice) is recruited.

Table 1: Cost Factors

3.2. System size and performance measures

The notations in this paper are defined as follows:

K : Buffer size;

λ : Arrival (demand occurrence) rate;

G : Random variable of demand size, $\Pr(G = k) = g_k$;

μ_H : High service rate (hiring the experienced workers and assigning them to projects);

μ_L : Low service rate (hiring an apprentice and filling the buffer);

R : Buffer size at which service rate changes, $(1 \leq R \leq K)$;

P_n : The steady state probability where system size is n ;

L : Mean system size.

Since the Poisson arrival and exponential service times are assumed, the steady state probabilities $P_n; 0 \leq n \leq K$ can be obtained from the global balance equations and normalization condition as follows (see Wolff 1989):

$$n = 0 : \quad \lambda P_0 = \mu_L P_1 \quad (1.1)$$

$$1 \leq n \leq R-1 : \quad \lambda \sum_{k=1}^n P_{n-k} g_k + \mu_L P_{n+1} = \lambda + \mu_L P_n \quad (1.2)$$

$$n = R : \quad \lambda \sum_{k=1}^n P_{n-k} g_k + \mu_H P_{n+1} = \lambda + \mu_L P_n \quad (1.3)$$

$$R+1 \leq n \leq K-1 : \quad \lambda \sum_{k=1}^n P_{n-k} g_k + \mu_H P_{n+1} = \lambda + \mu_H P_n \quad (1.4)$$

$$n = K : \quad \lambda \sum_{k=1}^n P_{n-k} g_k + \mu_H P_{n+1} = \mu_H P_n \quad (1.5)$$

and

$$\sum_{n=1}^K P_n = 1 \quad (2)$$

Given $P_n; 0 \leq n \leq K$, the mean system size can be obtained as $L = \sum_{n=1}^K n P_n$. Since the service process corresponds to hiring surplus workers, state K represents the state with no surplus workers present while state 0 represents the state with the maximum K surplus workers present in the system. Thus, the expected number of surplus workers is $K - L$; hence, the expected holding cost during a unit time is given by $c_H \cdot K - L$.

A demand is lost when the demand size exceeds the number of surplus worker present in the system. Since the Poisson arrival process is assumed, the probability that there are n surplus workers in the system when a demand occurs is identical to the steady state probability P_n . Thus, the rate at which demands become lost is given by $\lambda \sum_{n=0}^K P_n \sum_{i=K-n+1}^{\infty} g_i$; hence, the expected lost cost is given by $\lambda \sum_{n=0}^K P_n \sum_{i=K-n+1}^{\infty} c_L i g_i$. Similarly, the rate at which experienced workers are recruited is given by $\mu_H \sum_{n=R}^K P_n$ while the rate at which apprentices are recruited is given by $\mu_L \sum_{n=0}^{R-1} P_n$. Therefore, the expected total cost per a unit time can be finally expressed as

$$TC = c_H \cdot K - L + c_L \cdot \lambda \sum_{n=0}^K P_n \sum_{i=K-n+1}^{\infty} i g_i + c_{RE} \cdot \mu_H \sum_{n=R}^K P_n + c_{RA} \cdot \mu_L \sum_{n=1}^{R-1} P_n \quad (3)$$

3.3. Discussion of optimal strategies

Given the arrival and service rates, and the cost factors, finding optimal strategies is merely to search for optimal combinations of parameters K and R such that the total cost TC is minimized. Obviously, the maximum size K of surplus workers affects both the holding cost and the lost cost, and, therefore, the total cost. However, we will assume that K is fixed and will see only the impact of the threshold R on the total cost, in order to focus our discussion on the comparison between two alternative strategies, “train or recruit”, and their optimal mixture. Moreover, the maximum size of surplus workers should be bounded by the financial and managerial capacities of the firm, which should be constant over a period of certain time.

If R is equal to K , it means that the firm takes the strategy that all necessary workers are supplied from the internal training of apprentices. On the other hand, if R is equal to 0, the strategy is that all workers are supplied from the external recruit of experience workers. Thus, as R decreases to 0, the average service rate increases and it implies a high level of the recruiting cost. It also implies a low level of the mean system size L and, therefore, a high level of the holding cost. In contrast, as R increases to K , the average service rate decreases and it implies a high level of the blocking probability of demands and, therefore, a high level of the lost cost. As a consequence, there is a tradeoff between the holding and recruiting cost, and the lost cost. In spite of depending highly on the demand and supply characteristics of knowledge workers, if the maximum size K of surplus workers is appropriately determined, the optimal values of R are likely to be between two extreme values 0 and K .

We now state our hypotheses explicitly in terms of parameter R :

- Under the same arrival and service rate and the same cost factors, as the volatility of demand size increases, the optimal value of R decreases;
- Under the same arrival and service rate and the same volatility of the demand size, as the difference of the recruiting costs of experienced workers and apprentice increases, the optimal value of R increases.

The first hypothesis means that if future demands are volatile, the urgent acquisition of experienced workers can be more desirable than the usual acquisition of apprentices in advance. In addition, the second hypothesis means that if the firm has to pay a heavier price for the urgent acquisition of experienced workers than the usual acquisition of apprentices, the usual

acquisition of apprentices is more desirable. We will show that our hypotheses are supported by numerical results in the next section.

4. Numerical Results

In this section, numerical results of the queueing model described in Section 3 are presented.

To examine the first hypothesis in Section 3.3, two distributions are used for the size of the batch with different coefficients of variation (CV). They are the geometric distribution (CV=0.89) and the negative binomial distribution (CV=0.37), and each has a mean of 5. It is assumed that the buffer size K is 19, μ_L equals 10 and μ_H equals 40. An arrival rate λ for demand is assumed to be 2.

Regarding to the second hypothesis of Section 3.3, two different cost structures were used. The first of these is that the cost of recruiting experienced workers is not so heavy and the second is the cost is much heavier than recruiting apprentice. To be more specific, the following cost structure is used: $c_L=4$, $c_H=0.1$, $c_{RA}=0.2$, and $c_{RE}=0.3$. In this cost structure, recruiting experienced workers is relatively easy. Henceforth, this set of the cost structure is termed as the ‘Easy’ set. The second is termed as the ‘Hard’ set, and the cost structure is as follows: $c_L=4$, $c_H=0.1$, $c_{RA}=0.2$, and $c_{RE}=0.6$. It was assumed that the holding cost was less significant relative to other costs. Henceforth, ‘the cost’ indicates the cost per unit time, and the total cost is defined as the sum of the three cost factors mentioned above.

4.1. Effect of volatility of demand size

Figures 1a and 1b verify the hypothesis in Section 3.3. They show the distribution with larger CV has a lower R value. These figures present when the demand has a relatively high volatility, it is reasonable to recruit workers than to train. Sharp increase in the latter part is due to the lost cost, the blocking probability grows very quickly.

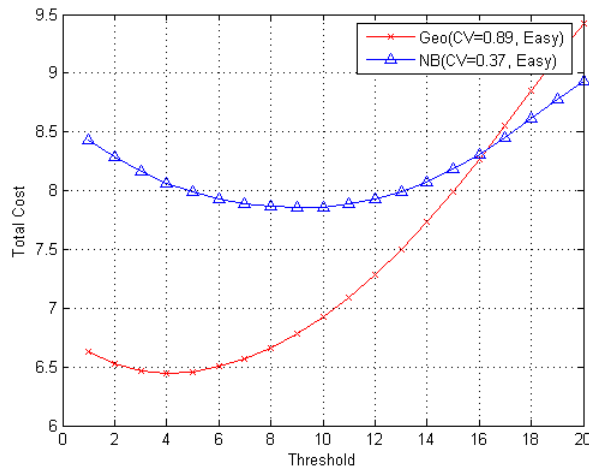


Figure 1a: Two distributions with the ‘Easy’ set

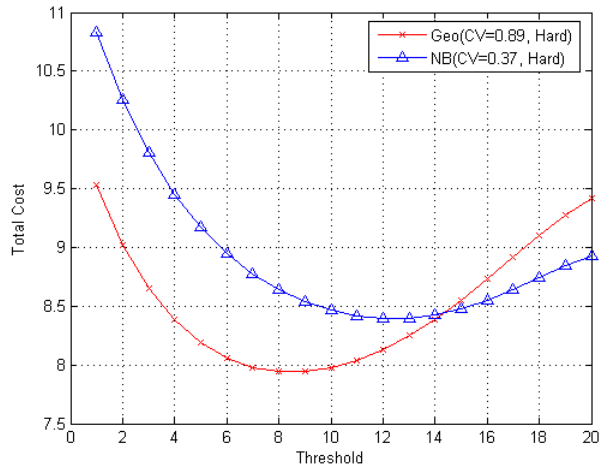


Figure 1b: Two distributions with the ‘Hard’ set

4.2. Effect of cost structure

Figures 2a and 2b are intuitively clear. It is hard to recruit experienced workers, the values of R are relatively high. Note that the difficulty of hiring experienced workers is expressed in terms of the cost. Also, the second hypothesis is supported by these figures. For both distributions, the value of R is higher when the cost structure is ‘Hard’.

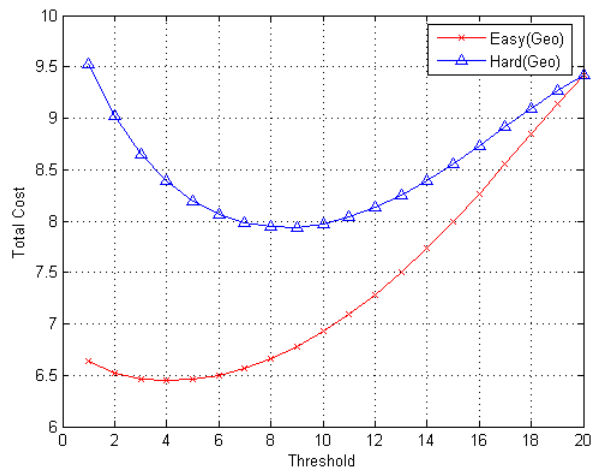


Figure 2a: Geometric distribution with the different cost structures

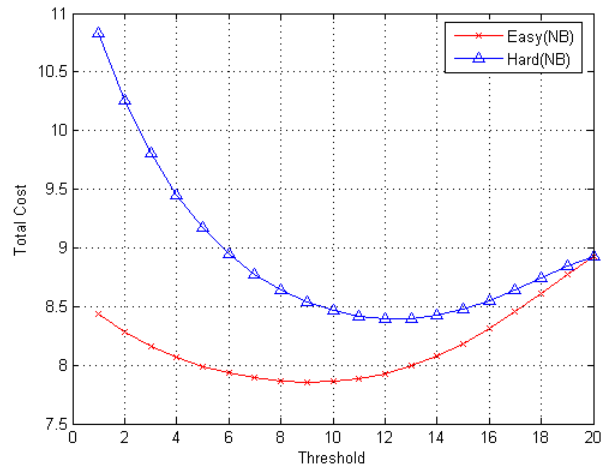


Figure 2b: Negative binomial distribution with the different cost structures

5. Conclusion

This paper presented a stochastic model for staffing strategies of knowledge workers in an IT service firm. Although many disciplines have studied the workforce planning for several decades, we believe this to be the first attempt at addressing the case of the uncertain demand for workforce quantitatively. Numerical results supported our two hypotheses. Thus we conclude that if future demands are volatile, managers would prefer recruiting experienced workers to apprentices, and if the firm has to pay a higher cost for hiring experienced workers, managers would prefer training apprentices to experienced workers.

We propose two major directions for future research. First, we can specify the uncertainty of workforce demand. Such factors as long-term business cycle and seasonality can specify the uncertainty of workforce demand. Second, qualitative characteristics of workforce, such as job types and levels, and knowledge types and levels can be considered.

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