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RESEARCH ARTICLE

RECRUITMENT MODEL WITH TANDEM PROCESS

Jeeva, M and Fernandes Jayashree Felix

Department of Mathematics, Ethiraj College for Women, Chennai – 600 008
Department of Mathematics, M.O.P. Vaishnav College for Women, Chennai -34

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ABSTRACT

Recruitment process plays a vital role in an organization. This paper proposes a recruitment model with tandem processes which involves a pool of permanent & additional personnel for the recruitment of applicants to the various grades. Applicants arrive for the walk-in interview in a Poisson process and they are served exponentially by the recruitment board. The steady state distribution of the recruitment process is derived. Other performance measures such as the expected number of applicants, probabilities of the system states are obtained. Some special cases are discussed.

INTRODUCTION

An organization calls for a walk-in-interview to recruit personnel to various grades. As the applicants arrive long waiting times causes discouragement to the applicants and a high level of service is recommended to avoid this. This can be done by providing additional personnel in the recruitment board to provide service. Abou-El-Aata and Shawky1992 have studied about queueing systems with balking, reneging and additional servers for a longer queue. Jain and Singh 1998 have discussed about a finite capacity priority queue with discouragement. Makkadis and Zaki 1983 have developed a single server queering model with additional servers. Varshney *et al.,* 1988, studied a multiserver queuing model with additional servers. Motivated by Jain *et al.,* 2001, we have developed a manpower recruitment model. Performance Analysis of a multiserver queue model with discouragement was discussed by Jain et *al.,* 2000. In this study we analyse a recruitment model with state dependent arrival and service rates. Additional personnel are incorporated in the recruitment board to reduce the waiting time of applicants and to complete the recruitment process without delay. Various system performance measures such as expected number of applicants in the process, probability that all additional personnel are busy are computed. Some special cases are discussed. In the conclusion section applicability of the model developed is discussed.

MODEL DESCRIPTION

A multinational organization is in the process of recruiting personnel in various grades. It calls for a walk-in interview to recruit people. The two components of the recruitment process which occurs in series are

I. Certificate verification process.
II. Interview process.

The recruitment board comprises of m_1 permanent personnel for the conduct of certificate verification process & m_2 permanent personnel for the interview process. Applicants arrive according to a Poisson process with mean rate of λ_1 for the certificate verification process. After completion of this process eligible candidates appear for the interview process at the rate of λ_2 & follow a Poisson distribution. Both the processes follow exponential service distribution with mean rate μ_1& μ_2 respectively.

The applicants who appear for the certificate verification are served by the personnel in the following ways.

- If the number of applicants present in the system is less than or equal to the threshold value K, then only m_1 permanent personnel will provide service.
- When the number of applicants is greater than K and less than or equal to 2K, one additional removable personnel is added to the process. In general if the number of applicants is greater than jK and less than or equal to (j+1) K, j additional personnel with provide service.
- When the number of applicants reaches a level or greater than rK then all r additional personnel will contribute service.
- When the number of applicants is less than jK-1 (j=1, 2….. r-1) the j th additional server is removed from the process.
- In the certificate verification process we consider the eliminating factor α. α is defined as the attribute that the system does not permit the applicant into the process after a stipulated time.(0< α<1).

* *Corresponding author:* Tel:
E-mail address: mjeeva58@gmail.com.

NOTATIONS

n_1: number of applicants who appear for the certificate verification process

n_2: number of applicants who appear for the interview.

m_1: number of personnel who are involved in the certificate verification process

m_2: number of personnel who are involved in the interview process.

λ_1: mean arrival rate of applicants for the certificate verification process.

λ_2: mean arrival rate of applicants for the interview process.

μ_1: mean service rate for the certificate verification process.

μ_2: mean service rate for the interview process.

N: system capacity

r: no. of removable personnel involved in the recruitment process

P_{n_1} : Steady state probability distribution for the certificate verification process

P_{n_2} : Steady state probability distribution for the certificate interview process

MATHEMATICAL ANALYSIS OF THE MODEL

The state dependent arrival and services rates for the certificate verification process are

$$\lambda_{n_1} = \begin{cases} \lambda_1 & n_1 < m_1 \\ \left(\dfrac{m_1}{n_1+1}\right)^{\alpha} \lambda_1 & m_1 \le n_1 < K \\ \left(\dfrac{m_1+j}{n_1+1}\right)^{\alpha} \lambda_1 & jK \le n_1 < (j+1)K \\ \left(\dfrac{m_1}{n_1+1}\right)^{\alpha} \lambda_1 & rK \le n_1 < N \end{cases}$$

The steady state probability distribution P_{n1} for certificate verification process is

$$Pn_1 = \begin{cases} P_0 \dfrac{\rho_1^{n_1}}{n_1!} & n_1 < m_1 \\ P_0 \dfrac{\rho_1^{n_1}}{(n_1!)^{\alpha}(m_1!)^{(1-\alpha)}} \dfrac{1}{m_1^{(n_1-m_1)(1-\alpha)}} & m_1 \le n_1 < K \\ P_0 \dfrac{\rho_1^{n_1}}{(n_1!)^{\alpha}} \times \left(\dfrac{m_1^{m_1-1}}{(m_1-1)!}\right)^{1-\alpha} \times \dfrac{1}{m_1^{(1-\alpha)K}} \times \dfrac{1}{\prod_{j=1}^{r-1} (m_1+j)^{(1-\alpha)(n_1-jK)}} & jK \le n_1 (j+1) < K \\ P_0 \dfrac{\rho_1^{n_1}}{(n_1!)^{\alpha}} \times \left(\dfrac{m_1^{m_1-1}}{(m_1-1)!}\right)^{1-\alpha} \times \dfrac{m_1^{\alpha(n_1-rK)}}{\prod_{j=1}^{r-1} (m_1+j)^{(1-\alpha)jK}} \times \dfrac{1}{m_1^{(1-\alpha)K}} \dfrac{1}{(m_1+r)^{(1-\alpha)(n_1-rK)}} & rK \le n_1 < N \end{cases}$$

where $\rho_1 = \lambda_1/\mu_1$

After the certificate verification process the applicants have to appear for the interview process Applicants who do not satisfy the eligibility requirement for the respective grades are not permitted to attend the interview. This attribute is called as scrutinizing factor β (0<β<1)

The state dependent arrival and services rates for the interview process is

$$\lambda_{n_2} = \lambda_2 \qquad 0 < n_2 \le N$$

$$\mu_{n_2} = \begin{cases} n_2 \mu_2 & n_2 < m_2 \\ \left(\dfrac{n_2}{m_2}\right)^{\beta} m_2 \mu_2 & m_2 \le n_2 < K \\ \left(\dfrac{n_2}{m_2+j}\right)^{\beta} (m_2+j)\mu_2 & jK \le n_2 < (j+1)K \\ \left(\dfrac{n_2}{m_2+r}\right)^{\beta} (m_2+r)\mu_2 & rK \le n_2 < N \end{cases}$$

The steady state probability distribution P_{n2} for the interview process is given by

$$P_{n_2} = \begin{cases} P_0 \times \dfrac{\rho_2^{n_2}}{n_2!} & n_2 < m_2 \\ \dfrac{P_0 \rho_2^{n_2}}{(n_2!)^{\beta}(m_2!)^{(1-\beta)} m_2^{(1-\beta)(n_2-m_2)}} \times \left(\dfrac{n_2}{m_2}\right)^{\beta} & m_2 \le n_2 < K \\ \dfrac{P_0 \rho_2^{n_2}}{(n_2!)^{\beta}(m_2!)^{(1-\beta)} m_2^{(1-\beta)(K-m_2)}} \times \left(\dfrac{n_2}{m_2}\right)^{\beta} \times \dfrac{1}{\prod_{j=1}^{r-1} (m_2+j)^{(1-\beta)(n_2-jK)}} & jK \le n_2 < (j+1)K \\ \dfrac{P_0 \rho_2^{n_2}}{(n_2!)^{\beta}(m_2!)^{(1-\beta)} m_2^{(1-\beta)(K-m_2)}} \times \left(\dfrac{n_2}{m_2}\right)^{\beta} \times \dfrac{1}{\prod_{j=1}^{r-1} (m_2+j)^{(1-\beta)jK} (m_2+r)^{(1-\beta)(n_2-rK)}} & rK \le n_2 < n \end{cases}$$

where $\rho 2 = \lambda_2/\mu_2$

The steady state probability distribution of the recruitment process is given by

$P(n_1,n_2) = P_{n_1} \times P_{n_2}$, $n_1=0,1,2\ldots. N$ $,n_2=0,1,2\ldots.N$

$$P(n_1,n_2) = \begin{cases} P_0 \left[\dfrac{\rho_1^{n_1}}{n_1!} \times \dfrac{\rho_2^{n_2}}{n_2!}\right] & 0 \le n_1 < m_1; 0 \le n_2 < m_2 \\ P_0 \left[\dfrac{\rho_1^{n_1} \rho_2^{n_2}}{(n_1!)^{\alpha}(m_1!)^{(1-\alpha)} m_1^{(n_1-m)(1-\alpha)} (n_2!)^{\beta} (m_2!)^{(1-\beta)} m_2^{(1-\beta)(n_2-m_2)}} \left(\dfrac{n_2}{m_2}\right)^{\beta}\right] & m_1 \le n_1 < K,\ m_2 \le n_2 < K \\ P_0 \left[\dfrac{\rho_1^{n_1} \rho_2^{n_2}}{(n_1!)^{\alpha}(n_2!)^{\beta} m_1^{(1-\alpha)K} m_2^{(1-\beta)(K-m_2)} (m_2!)^{(1-\beta)}} \left(\dfrac{m_1^{m_1-1}}{(m_1-1)!}\right)^{(1-\alpha)} \left(\dfrac{n_2}{m_2}\right)^{\beta} \times \dfrac{1}{\prod_{j=1}^{r-1} (m_1+j)^{(1-\alpha)(n_1-jK)} (m_2+j)^{(1-\beta)(n_1-jK)}}\right] & jK \le n_1, n_2 < (j+1)K \\ P_0 \left[\dfrac{\rho_1^{n_1} \rho_2^{n_2}}{(n_1!)^{\alpha}(n_2!)^{\beta}} \left(\dfrac{m_1^{(m_1-1)}}{(m_1-1)!}\right)^{(1-\alpha)} \dfrac{m_1^{\alpha(n_1-rK)}}{m_1^{(1-\alpha)K} (m_2!)^{(1-\beta)} m_2^{(1-\beta)(K-m_2)}} \left(\dfrac{n_2}{m_2}\right)^{\beta} \times \dfrac{1}{(m_1+r)^{(1-\alpha)(n_1-rK)} (m_2+r)^{(1-\beta)(n_2-rK)}} \times \dfrac{1}{\prod_{j=1}^{r-1} (m_1+j)^{(1-\alpha)jK} (m_2+j)^{(1-\beta)jK}}\right] & rK \le n_1, n_2 < N \end{cases}$$

The value of P_0 is determined from $\sum_{n_1=0}^{N} \sum_{n_2=0}^{N} P(n_1,n_2)=1$

PERFORMANCES MEASURES OF THE MODEL

(1) Expected number of applicants in the system with r additional personal in the recruitment board is

$$E(Q)=P_0\sum_{n_1=0}^{m_1-1}\sum_{n_2=0}^{m_2-1}\frac{\rho_1^{\,n_1}\rho_2^{\,n_2}}{(n_1-1)!\,(n_2-1)!}+\frac{1}{(m_1!)^{(1-\alpha)}(m_2!)^{(1-\beta)}}m_1 m_2\sum_{n_1=m_1}^{K-1}\sum_{n_2=m_2}^{K-1}\frac{\rho_1^{\,n_1}}{(n_1!)^{\alpha}}\frac{\rho_2^{\,n_2}}{(n_2!)^{\beta}}\times\left(\frac{n_2}{m_2}\right)^{\beta}$$

$$\frac{1}{m_1^{(n_1-m_1)(1-\alpha)-1}\times\dfrac{1}{m_2^{(n_2-m_2)(1-\alpha)-1}}}+\frac{1}{m_1^{(1-\alpha)K}\times(m_2!)^{(1-\beta)}\times m_2^{(1-\beta)(K-m_2)}}\times\left(\frac{m_1^{m-1}}{(m_1-1)!}\right)^{1-\alpha}$$

$$\times\frac{1}{(m_2!)^{(1-\beta)}m_2^{(1-\beta)(K-m_2)}}\sum_{j=1}^{r-1}\sum_{n_1=jK}^{(j+1)K}\sum_{n_2=jK}^{(j+1)K}(m_1+j)(m_2+j)\frac{\rho_1^{\,n_1}}{(n_1!)^{\alpha}}\times\frac{\rho_2^{\,n_2}}{(n_2!)^{\beta}}\times\left(\frac{n_2}{m_2}\right)^{\beta}$$

$$\times\frac{1}{\prod_{j=1}^{r-1}(m_1+j)^{(1-\alpha)(n_1-jK)}\times(m_2+j)^{(1-\beta)(n_2-jK)}}+\left(\frac{m_1^{m_1-1}}{(m_1-1)!}\right)^{1-\alpha}\times\frac{1}{m_1^{(1-\alpha)K}}$$

$$\times\frac{1}{(m_2!)^{(1-\beta)}m_2^{(1-\beta)(K-m_2)}}\sum_{n_1=rK}^{N}\sum_{n_2=rK}^{N}\frac{(m_1+r)(m_2+r)\rho_1^{\,n_1}m_1^{\alpha(n_1-rK)}}{(n_1!)^{\alpha}(m_1+r)^{(1-rK)(n_1-rK)}}\times\frac{\rho_2^{\,n_2}}{(n_2!)^{\beta}}$$

$$\times\left(\frac{n_2}{m_2}\right)^{\beta}\times\frac{1}{(m_2+r)^{(1-\beta)(n_2-rK)}}\times\frac{1}{\prod_{j=1}^{r-1}(m_1+j)^{(1-\alpha)K}(m_2+j)^{(1-\beta)jK}}$$

(2) The probability that the number of applicants is greater than or equal to jK+1 and less than (j+1)K is

$P[jK+1\le Q<(j+1)K]$

$$=P_0\left(\frac{m_1^{m_1-1}}{(m_1-1)!}\right)^{1-\alpha}\times\frac{1}{m_1^{(1-\alpha)K}(m_2!)^{(1-\beta)}m_2^{(1-\beta)(K-m_2)}m_2^{\beta}}$$

$$\sum_{j=1}^{r-1}\sum_{n_1=jK+1}^{(j+1)K}\sum_{n_2=jK+1}^{(j+1)K}\frac{(m_1+j)(m_2+j)\rho_1^{\,n_1}\rho_2^{\,n_2}}{(n_1!)^{\alpha}((n_2-1)!)^{\beta}\prod_{j=1}^{r-1}(m_1+j)^{(1-\alpha)(n_1-jK)}(m_2+j)^{(1-\beta)(n_2-jK)}}$$

(3) The probability that the number of applicants is greater than or equal to rK and less than N is

$P[rK\le Q<N]=$

$$=P_0\left(\frac{m_1^{m_1-1}}{(m_1-1)!}\right)^{1-\alpha}\times\frac{1}{m_1^{(1-\alpha)K}(m_2!)^{(1-\beta)}m_2^{(1-\beta)(K-m_2)}m_2^{\beta}}$$

$$\sum_{n_1=rK}^{N}\sum_{n_2=rK}^{N}\frac{\rho_1^{\,n_1}\rho_2^{\,n_2}m_1^{\alpha(n_1-rK)}}{(n_1!)^{\alpha}(n_2!)^{\beta}(m_1+r)^{(1-\alpha)(n_1-rK)}}\times\frac{1}{(m_2+r)^{(1-\beta)(n_2-rK)}}\frac{1}{((n_2-1)!)^{\beta}\times\prod_{j=1}^{r-1}(m_1+j)^{(1-\alpha)K}(m_2+j)^{(1-\beta)jK}}$$

SPECIAL CASES

Case 1: When the arrival and service rates for the certificate and Interview process are the same

$\lambda_1=\lambda_2,\ \mu_1=\mu_2,\ m_1=m_2=m$

$$P(n_1,n_2)=\begin{cases}P_0\left[\dfrac{\rho^{n_1+n_2}}{n_1!\,n_2!}\right] & 0\le n_1,n_2<m\\[2ex] P_0\left[\dfrac{\rho^{n_1+n_2}}{(n_1!)(n_2!)^{\beta}(m!)^{(2-(\alpha+\beta))}m^{(1+\alpha)(n_1-m)+(1-\beta)(n_2-m)}}\right] & m\le n_1,n_2\le K\\[2ex] P_0\left[\dfrac{\rho^{n_1+n_2}}{(n_1!)^{\alpha}(n_2!)^{\beta}m^{(2-(\alpha+\beta)K)}}\left(\dfrac{m^{m-1}}{(m-1)!}\right)^{(2-(\alpha+\beta))}\times\left(\dfrac{n_2}{m}\right)^{\beta}\times\dfrac{1}{\prod_{j=1}^{r-1}(m+j)^{(1-\alpha)(n_1-jK)+(1-\beta)(n_2-jK)}}\right] & jK\le n_1,n_2<(j+1)K\\[2ex] P_0\left[\dfrac{\rho^{n_1+n_2}}{(n_1!)^{\alpha}(n_2!)^{\beta}}\left(\dfrac{m^{m-1}}{(m-1)!}\right)^{1-\alpha}\dfrac{m^{\alpha(n_1-rK)}}{(m+r)^{(1-\alpha)j+(n_1-rK)+(1-\beta)(n_2-rK)}}\times\dfrac{1}{(m!)^{(1-\beta)}}\left(\dfrac{n_2}{m}\right)^{\beta}\times\dfrac{m^{\alpha(n_1-rK)}}{m^{(1-\alpha)K(1-\beta)(K-m_2)}}\ \dfrac{1}{\prod_{j=1}^{r-1}(m+j)^{(1-\alpha)jK+(1-\beta)jK}}\right] & rK\le n_1,n_2<N\end{cases}$$

Case 2: When the applicants who arrive for the certificate verification process are eligible to appear for the interview, that is $n_1=n_2=n$ in the above case

$$\therefore P(n)=\begin{cases}P_0\left[\dfrac{\rho^{2n}}{(n!)^2}\right] & 0\le n<m\\[2ex] P_0\left[\dfrac{\rho^{2n}}{(n!)^{\alpha+\beta}(m!)^{(2-(\alpha+\beta))}m^{(n-m)(2-(\alpha+\beta))}}\right] & m\le n<K\\[2ex] P_0\left[\dfrac{\rho^{2n}}{(n!)^{\alpha+\beta}m^{(2-(\alpha+\beta))K}}\left(\dfrac{m^{m-1}}{(m-1)!}\right)^{(2-(\alpha+\beta))}\times\left(\dfrac{n}{m}\right)^{\beta}\times\dfrac{1}{\prod_{j=1}^{r-1}(m+j)^{(n-jK)(2-(\alpha+\beta))}}\right] & jK\le n<(j+1)K\\[2ex] P_0\left[\dfrac{\rho^{2n}}{(n!)^{\alpha+\beta}}\left(\dfrac{m^{m-1}}{(m-1)!}\right)^{(1-\alpha)}\dfrac{m^{\alpha(n-rK)}}{m^{(1-\alpha)K+(1-\beta)(K-m_2)}}\times\dfrac{1}{(m!)^{(1-\beta)}}\left(\dfrac{n}{m}\right)^{\beta}\times\dfrac{1}{(m+r)^{((2-(\alpha+\beta))(n-rK))}}\times\dfrac{1}{\prod_{j=1}^{r-1}(m+j)^{((2-(\alpha+\beta))jK)}}\right] & rK\le n<N\end{cases}\qquad(2.21)$$

Case 3:

In the certificate verification process if there is no time constraint for the arrival of the applicants then the eliminating factor $\alpha=0$

$$\therefore P(n)=\begin{cases}P_0\left[\dfrac{\rho^{2n}}{(n!)^2}\right] & 0\le n<m\\[2ex] P_0\left[\dfrac{\rho^{2n}}{(n!)^{\beta}(m!)^{(2-\beta)}m^{(n-m)(2-\beta)}}\right] & m\le n<K\\[2ex] P_0\left[\dfrac{\rho^{2n}}{(n!)^{\beta}m^{(2-\beta)K}}\left(\dfrac{m^{m-1}}{(m-1)!}\right)^{(2-\beta)}\times\left(\dfrac{n}{m}\right)^{\beta}\times\dfrac{1}{\prod_{j=1}^{r-1}(m+j)^{(n-jK)(2-\beta)}}\right] & jK\le n<(j+1)K\\[2ex] P_0\left[\dfrac{\rho^{2n}}{(n!)^{\beta}}\left(\dfrac{m^{m-1}}{(m-1)!}\right)\dfrac{1}{m^{K+(1-\beta)(K-m_2)}}\times\dfrac{1}{(m!)^{(1-\beta)}}\left(\dfrac{n}{m}\right)^{\beta}\times\dfrac{1}{(m+r)^{(2-\beta)(n-rK))}}\times\dfrac{1}{\prod_{j=1}^{r-1}(m+j)^{(2-\beta)jK}}\right] & rK\le n<N\end{cases}\qquad(2.23)$$

Case 4:

The expected number of customers with r additional personnel is r in the recruitment board if all the applicants of certificate verification process are eligible to appear for the interview that is scrutinizing factor is 0.

$$E(Q)=P_0\left\{\begin{array}{l}\displaystyle\sum_{n=1}^{m-1}\frac{\rho^{2n}}{n!(n-1)!}+\sum_{n=m}^{K-1}\frac{m\rho^{2n}}{(n!)^{\beta}(n!)^{(2-\beta)}n!^{(n-m)(2-\beta)}}\\ \displaystyle+\sum_{j=1}^{r-1}\sum_{n=jk}^{(j+1)k}\frac{(m+r)\rho^{2n}}{((n-1)!)^{\beta}m^{(2-\beta)K+\beta}}\left(\frac{m^{m-1}}{(m-1)!}\right)^{(2-\beta)}\times\frac{1}{\prod_{j=1}^{r-1}(m+j)^{(n-j)}(2-\beta)}\\ \displaystyle+\sum_{n=rK+1}^{N}\frac{(m+r)\rho^{2n}}{[(n-1)!]^{\beta}}\frac{m^{m-1}}{(m-1)!m^{K+(1-\beta)(K-m)}}\times\frac{1}{(m!)^{(1-\beta)}\times m^{\beta}}\\ \displaystyle\times\frac{1}{(m+r)^{(2-\beta)(n-rK)}}\times\frac{1}{\prod_{j=1}^{r-1}(m+j)^{(2-\beta)jK}}\end{array}\right\}$$

CONCLUSION

In this paper the probability distribution of the recruitment process is obtained using product type solution of queueing theory. This model is a unique one as the concepts of tandem queues, balking and reneging of queueing theory have been adopted into manpower model of recruitment process. The model developed enables us to reduce the waiting times of the applicants in the system with the reasonable service cost by providing additional personnel in the recruitment model.

This model is of immense importance and has many potentially useful applications in computer, production, telecommunication systems to reduce the waiting time in case of heavy traffic. Some other areas of applications are air/railway reservation, collection counters at various places, particularly on last day, and priority health centres in rural area etc.

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