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Estimation of Mean Time to Recruitment for a Two Grade Manpower System with Inter - Exit Times as Geometric Process When Threshold has Two Components

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Abstract: *In this paper, for a two grade manpower system, three mathematical models are constructed and using univariate policy of recruitment based on the shock model approach, the expected time to recruitment is obtained when (i) the loss of manpower due to attrition form an ordinary renewal process (ii) inter – exit times form a geometric process and (iii) the threshold for each grade has two components. A different probabilistic analysis is used to derive the analytical result.*

Keywords: *Two grade manpower system, attrition, ordinary renewal process, exit times, geometric process, recruitment.*

AMS Mathematics Subject Classification (2010): 990B70, 91B40, 91D35, 60H30

1. Introduction

Exit of personnel, voluntary and involuntary, is a common phenomenon in any marketing organization. This leads to reduction in the total strength of marketing personnel and will adversely affect the sales turnover of the organization, if recruitment is not planned. In fact, frequent recruitments may also be expensive due to the cost of recruitments and training. As the loss of manpower is unpredictable, a suitable recruitment policy has to be designed to overcome this loss. Anunivariate recruitment policy, usually known as CUM policy of recruitment in the literature, is based on the replacement policy associated with the shock model approach in reliability theory and is stated as follows: *Recruitment is made whenever the cumulative loss of man hours exceeds a breakdown threshold.* Several researchers have studied the problem of time to recruitment for a two grade man power system using shock model approach. In this context, in [18], [11], [12], [3], [16], [14], [15], [19],[13] and [17] the authors have obtained the variance of the time to recruitment for a two grade man power system using several recruitment policies under different conditions on the loss of man power, breakdown thresholds when the inter – policy decision times form an ordinary renewal process. In [20], [2] and [4] the authors have estimated the mean time to recruitment using geometric process for inter – decision times. In [6], [5], [7] and [8] the authors have studied the problem of time to recruitment with two sources of depletion under different conditions on the inter-policy decisions, inter-transfer decisions when the breakdown threshold for each grade has only one component. In [1] the authors have determined the mean time to recruitment for a single manpower system with policy decisions forming the only one source of depletion when the threshold for the cumulative loss of manpower has three components. Recently, in [9] and [10] the authors have extended this work for a two grade man power system according as the inter-policy decision times and inter-transfer decision times form the same or different ordinary renewal processes respectively. The objective of this paper is to derive the mean time to recruitment for a two grade manpower system using univariate CUM policy of recruitment when (i) the inter-exit times (exit times can be either voluntary or involuntary) form a geometric process and (ii) the breakdown threshold for each grade has two components.

2. Model Description

Consider an organization consisting of two grades (grade A and grade B) in which exit of personnel takes place voluntarily (due to policy decisions, VRS etc.) or involuntarily (death, retirement etc.). Let

X_n be the loss of man power in the organization at the n^{th} exit point, n=1,2,3,… .It is assumed that$\{X_n\}_{n=1}^{\infty}$is a sequence of independent and identically distributed exponential random variables with tail distribution $\bar{G}(.)$ and mean$\frac{1}{\alpha}$ ($\alpha > 0$). Let $\chi_A(.)$ indicator function of the event A. Let S_n be the cumulative loss of man power in the organization corresponding to the first n exits. Let $U_n$be the time between $(n-1)^{th}$ and the n^{th} exit times, n=1,2,3,… and R_{i+1} be the waiting time upto $(i+1)^{th}$ exit. It is assumed that$\{U_n\}_{n=1}^{\infty}$is a geometric process with rate 'a' and $E(U_1)$ be the mean of U_1. Let T be the breakdown threshold for the cumulative loss of man power in the organization with probability density function h(.). For grade A, let T_{A1} be the normal exponential threshold of depletion of manpower with mean $\frac{1}{\theta_{A1}}$($\theta_{A1}> 0$) and T_{A2} be the exponential threshold of frequent breaks of existing workers with mean $\frac{1}{\theta_{A2}}$($\theta_{A2}> 0$). For grade B, let $T_{B1}$and T_{B2} be the normal exponential threshold of depletion of manpower, exponential threshold of frequent breaks of existing workers with means$\frac{1}{\theta_{B1}}$,$\frac{1}{\theta_{B2}}$(θ_{B1},$\theta_{B2}> 0$) respectively.Let$e_{S_i,T}(.,.)$ be the joint density function of S_i and T. The following recruitment policy, known as CUM policy of recruitment is employed in the present work. *Recruitment is done whenever the cumulative loss of man power in the organization exceeds the threshold level T.* Let W be the time to recruitment with mean E(W).

3. MAIN RESULTS

By the recruitment policy, recruitment is done whenever the cumulative loss of man power exceeds the threshold T. When the first exit takes place, recruitment would not have been done for U_1 units of time. If the loss of man power X_1 (=S_1) at the first exit point is greater than T, then recruitment is done and in this case W = U_1 = R_1. However, if $S_1 \leq T$ the non – recruitment period will continue till the next exit point. If the cumulative sum S_2 of the loss of man power upto the second exit point exceeds T, then recruitment is done and W = $U_1 + U_2 = R_2$. If $S_2 \leq T$, then the non – recruitment period will continue till the next exit point and depending on $S_3>T$ or $S_3 \leq T$, recruitment is done or the non – recruitment period continues and so on. This observation leads to the following expression for the time to recruitment.

$$W=\sum_{i=0}^{\infty} R_{i+1}\chi(S_i \leq T< S_{i+1}) \quad (1)$$

Since $E(R_{i+1}) =\sum_{j=0}^{i} E(U_{j+1})$, from (1) we get

$$E(W)=\sum_{i=0}^{\infty}\sum_{j=0}^{i} E(U_{j+1})\, P(S_i \leq T< S_{i+1}) \quad (2)$$

Using the law of total probability and the result $E(U_k)=\frac{E(U_1)}{a^{k-1}}$,k=1,2,… in (2), we get

$$E(W)=\sum_{i=0}^{\infty}\sum_{j=0}^{i}\frac{E(U_1)}{a^j}\int_0^{\infty}\int_0^{t}\bar{G}(t-x)\left(e_{S_i,T}(x,t)\right)dx\,dt \quad (3)$$

We now consider different forms for T and obtain the mean for time to recruitment.

CASE (I): T = max ($T_{A1}+T_{A2}$, $T_{B1}+T_{B2}$)

The present case for the breakdown threshold T is the best choice when we permit mobility of personnel from one grade to another in order to compensate loss of man power which is larger among the two grades. In this case it is found that

$$h(t) = \frac{\theta_{B1}\theta_{B2}e^{-(\theta_{B2})t}}{(\theta_{B1}-\theta_{B2})} - \frac{\theta_{B1}\theta_{B2}e^{-(\theta_{B1})t}}{(\theta_{B1}-\theta_{B2})} - \frac{\theta_{A1}\theta_{B1}\theta_{B2}e^{-(\theta_{A2}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} + \frac{\theta_{A1}\theta_{B1}\theta_{B2}e^{-(\theta_{A2}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} + \frac{\theta_{A2}\theta_{B1}\theta_{B2}e^{-(\theta_{A1}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} - \frac{\theta_{A2}\theta_{B1}\theta_{B2}e^{-(\theta_{A1}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} + \frac{\theta_{A1}\theta_{A2}e^{-(\theta_{A2})t}}{(\theta_{A1}-\theta_{A2})} - \frac{\theta_{A1}\theta_{A2}e^{-(\theta_{A1})t}}{(\theta_{A1}-\theta_{A2})} - \frac{\theta_{A1}\theta_{A2}\theta_{B1}e^{-(\theta_{A2}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} + \frac{\theta_{A1}\theta_{A2}\theta_{B1}e^{-(\theta_{A1}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} + \frac{\theta_{A1}\theta_{A2}\theta_{B2}e^{-(\theta_{A2}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} - \frac{\theta_{A1}\theta_{A2}\theta_{B2}e^{-(\theta_{A1}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})} \quad (4)$$

Since S_i and T are independent, using (4) in (3) and on simplification, we find the following expression for mean time to recruitment for the present case.

$$E(W) = E(U_1)a\left\{\begin{array}{c}\left(\frac{\theta_{B1}(\alpha+\theta_{B2})}{(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{B2})-\alpha)}\right)-\left(\frac{\theta_{B2}(\alpha+\theta_{B1})}{(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{B1})-\alpha)}\right)-\left(\frac{\theta_{A1}\theta_{B1}(\alpha+\theta_{A2}+\theta_{B2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A2}+\theta_{B2})-\alpha)}\right)+\\ \left(\frac{\theta_{A1}(\alpha+\theta_{A2})}{(\theta_{A1}-\theta_{A2})(a(\alpha+\theta_{A2})-\alpha)}\right)-\left(\frac{\theta_{A2}(\alpha+\theta_{A1})}{(\theta_{A1}-\theta_{A2})(a(\alpha+\theta_{A1})-\alpha)}\right)+\left(\frac{\theta_{A1}\theta_{B2}(\alpha+\theta_{A2}+\theta_{B1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A2}+\theta_{B1})-\alpha)}\right)+\\ \left(\frac{\theta_{A2}\theta_{B1}(\alpha+\theta_{A1}+\theta_{B2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A1}+\theta_{B2})-\alpha)}\right)-\left(\frac{\theta_{A2}\theta_{B2}(\alpha+\theta_{A1}+\theta_{B1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A1}+\theta_{B1})-\alpha)}\right)\end{array}\right\} \quad (5)$$

(5) gives the mean time to recruitment for the present case.

CASE (II): $T=\min(T_{A1}+T_{A2}, T_{B1}+T_{B2})$

The present case for the breakdown threshold T is the best choice when we assume that transfer of personnel between grades is not permitted. In this case it is found that

$$h(t)=\frac{\theta_{A2}\theta_{B1}\theta_{B2}e^{-(\theta_{A1}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})}-\frac{\theta_{A2}\theta_{B1}\theta_{B2}e^{-(\theta_{A1}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})}+\frac{\theta_{A1}\theta_{B1}\theta_{B2}e^{-(\theta_{A2}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})}-\frac{\theta_{A1}\theta_{B1}\theta_{B2}e^{-(\theta_{A2}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})}-\frac{\theta_{A1}\theta_{A2}\theta_{B2}e^{-(\theta_{A2}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})}+\frac{\theta_{A1}\theta_{A2}\theta_{B2}e^{-(\theta_{A1}+\theta_{B1})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})}+\frac{\theta_{A1}\theta_{A2}\theta_{B1}e^{-(\theta_{A2}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})}-\frac{\theta_{A1}\theta_{A2}\theta_{B1}e^{-(\theta_{A1}+\theta_{B2})t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})})$$

$$E(W)=E(U_1)a\left\{\begin{array}{c}\left(\frac{\theta_{A1}\theta_{B1}(\alpha+\theta_{A2}+\theta_{B2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A2}+\theta_{B2})-\alpha)}\right)-\left(\frac{\theta_{A1}\theta_{B2}(\alpha+\theta_{A2}+\theta_{B1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A2}+\theta_{B1})-\alpha)}\right)-\\ \left(\frac{\theta_{A2}\theta_{B1}(\alpha+\theta_{A1}+\theta_{B2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A1}+\theta_{B2})-\alpha)}\right)+\left(\frac{\theta_{A2}\theta_{B2}(\alpha+\theta_{A1}+\theta_{B1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(a(\alpha+\theta_{A1}+\theta_{B1})-\alpha)}\right)\end{array}\right\} \quad (7)$$

(7) gives the mean time to recruitment for the present case.

CASE (III): $T=((T_{A1}+T_{A2})+(T_{B1}+T_{B2}))$

The choice for T cited in case(iii) provides a better maximum allowable loss of man power in the entire organization compared to the choices mentioned in cases (i) and (ii).In this case it can be shown that

$$h(t)=\frac{\theta_{A1}\theta_{A2}^2\theta_{B2}e^{-\theta_{A2}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B1})}-\frac{\theta_{A1}\theta_{A2}\theta_{B1}\theta_{B2}e^{-\theta_{B1}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B1})}+\frac{\theta_{A1}\theta_{A2}\theta_{B1}\theta_{B2}e^{-\theta_{B1}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B1})}-\frac{\theta_{A1}^2\theta_{A2}\theta_{B2}e^{-\theta_{A1}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B1})}+\frac{\theta_{A1}\theta_{A2}\theta_{B1}\theta_{B2}e^{-\theta_{B2}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B2})}-\frac{\theta_{A1}\theta_{A2}^2\theta_{B1}e^{-\theta_{A2}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B2})}-\frac{\theta_{A1}\theta_{A2}\theta_{B1}\theta_{B2}e^{-\theta_{B2}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B2})}+\frac{\theta_{A1}^2\theta_{A2}\theta_{B1}e^{-\theta_{A1}t}}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B2})} \quad (8)$$

$$E(W)=E(U_1)a\left\{\begin{array}{c}\left(\frac{\theta_{A1}\theta_{A2}\theta_{B1}(\alpha+\theta_{B2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B2})(a(\alpha+\theta_{B2})-\alpha)}\right)-\\ \left(\frac{\theta_{A1}\theta_{A2}\theta_{B1}(\alpha+\theta_{A2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B2})(a(\alpha+\theta_{A2})-\alpha)}\right)-\\ \left(\frac{\theta_{A1}\theta_{A2}\theta_{B1}(\alpha+\theta_{B2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B2})(a(\alpha+\theta_{B2})-\alpha)}\right)+\\ \left(\frac{\theta_{A1}\theta_{A2}\theta_{B1}(\alpha+\theta_{A1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B2})(a(\alpha+\theta_{A1})-\alpha)}\right)-\\ \left(\frac{\theta_{A1}\theta_{A2}\theta_{B2}(\alpha+\theta_{B1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B1})(a(\alpha+\theta_{B1})-\alpha)}\right)+\\ \left(\frac{\theta_{A1}\theta_{A2}\theta_{B2}(\alpha+\theta_{A2})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A2}-\theta_{B1})(a(\alpha+\theta_{A2})-\alpha)}\right)+\left(\frac{\theta_{A1}\theta_{A2}\theta_{B2}(\alpha+\theta_{B1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B1})(a(\alpha+\theta_{B1})-\alpha)}\right)-\\ \left(\frac{\theta_{A1}\theta_{A2}\theta_{B2}(\alpha+\theta_{A1})}{(\theta_{A1}-\theta_{A2})(\theta_{B1}-\theta_{B2})(\theta_{A1}-\theta_{B1})(a(\alpha+\theta_{A1})-\alpha)}\right)\end{array}\right\} \quad (9)$$

(9) gives the mean time to recruitment for the present case.

NOTE:

The analytical results for the mean time to recruitment when the inter – exit times form an ordinary renewal process can be deduced from our results by taking a=1.

1. If the threshold for grade A(grade B) has a third component corresponding to backup or reservation sources, the analytical result for all the three cases can be obtained by convoluting the distribution of this component with that of the two components considered in this paper.

From the organization's point of view, case (iii) is more suitable than cases (i) and (ii) as the time to recruitment is elongated compared to cases (i) and (ii).

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