

Mean Time to Recruitment for a Two Graded Manpower System with Two Thresholds, Different Epochs for Exits and Two Types of Inter-Decisions

L.Saral¹, S.Sendhamizh Selvi², A. Srinivasan³

Ph.D Scholar, PG and Research Department of Mathematics, Government Arts College, Tiruchirappalli,
Tamil Nadu, India¹

Assistant Professor, PG and Research Department of Mathematics, Government Arts College, Tiruchirappalli,
Tamil Nadu, India²

Professor Emeritus, PG and Research Department of Mathematics, Bishop Heber College, Tiruchirappalli , Tamil
Nadu, India³

ABSTRACT: In this paper, the problem of time to recruitment is studied using a univariate policy of recruitment involving two thresholds for a two grade manpower system with attrition generated by its policy decisions. Assuming that the policy decisions and exits occur at different epochs, a stochastic model is constructed and the mean time to recruitment is obtained when the inter-policy decisions times forms (i) geometric process ,(ii) order statistics, and inter-exit times form an ordinary renewal process.

KEYWORDS: Two grade manpower system; decision and exit epochs; geometric process; order statistics;ordinary renewal process; univariate policy of recruitment with two thresholds, mean time to recruitment.

I. INTRODUCTION

Attrition is a common phenomenon in many organizations which leads to the depletion of manpower. Recruitment on every occasion of depletion of manpower is not advisable since every recruitment involves cost. Hence the cumulative depletion of manpower is permitted till it reaches a level, called the threshold. If the total loss of manpower exceeds this threshold, the activities in the organization will be affected and hence recruitment becomes necessary. In [1, 2, 6] the authors have discussed the manpower planning models by Markovian and renewal theoretic approach. In [8] the author has studied the problem of time to recruitment for a single grade manpower system and obtained the variance of the time to recruitment when the loss of manpower forms a sequence of independent and identically distributed random variables, the inter-decision times form a geometric process and the mandatory breakdown threshold for the cumulative loss of manpower is an exponential random variable by using the univariate cum policy of recruitment. In [5] the author has initiated the study of the problem of time to recruitment for a single grade manpower system by incorporating alertness in the event of cumulative loss of manpower due to attrition crossing the threshold, by considering optional and mandatory threshold for the cumulative loss of manpower in this manpower system. In [11] the author has studied the problem of time to recruitment for a two graded manpower system, by considering optional and mandatory thresholds. In [12] the author has studied the problem of time to recruitment for a two graded manpower system, by considering optional and mandatory thresholds using geometric process for inter-decision times.

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II. RELATED WORK

In all the above cited work, it is assumed that attrition takes place instantaneously at decision epochs. This assumption is not realistic as the actual attrition will take place only at exit points Which may or may not coincide with decision points. This aspect is taken into account for the first time in [3,4,7] and variance of time to recruitment is obtained when inter-decision times and exit times are independent and identically distributed exponential random variables using univariate policy for recruitment and Laplace transform in the analysis. Recently, in [9,10] the author has studied the work in [3,4,7] by considering optional and mandatory thresholds which considering non-instantaneous exits at decision epochs. In the present paper, for a two graded manpower system, a mathematical model is constructed in which attrition due to policy decision take place at exit points and there are optional and mandatory thresholds as control limits for the cumulative loss of manpower. A univariate policy of recruitment based on shock model approach is used to determine the expected time to recruitment when the system has different epochs for policy decisions and exits and the inter-policy decisions times forms (i) geometric process ,(ii) order statistics, and inter-exit times form an ordinary renewal process.

III. MODEL DESCRIPTION

Consider an organization taking decisions at random epochs in $(0, \infty)$ and at every decision making epoch, a random number of persons quit the organization. There is an associated loss of manpower if a person quits. It is assumed that the loss of manpower is linear and cumulative.

X_i -continuous random variable representing the amount of depletion of manpower (loss of manhours) at the i^{th} exit point

S_k - the total loss of manpower upto the first k exit points. X_i 's are independent and identically distributed random variable with density function $m(\cdot)$, distribution function $M(\cdot)$ & Mean $1/\alpha$; $\alpha > 0$.

U_j . Continuous random variable representing the time between the $(j-1)^{\text{th}}$ and j^{th} policy decisions $j = 1, 2, 3, \dots, \dots$. It is assumed that U_j 's are independent and identically distributed random variable with density function $f(\cdot)$, distribution function $F(\cdot)$ respectively.

W_i -continuous random variable representing the time between the $(i-1)^{\text{th}}$ and i^{th} exit times. It is assumed that W_i 's are independent and identically distributed random variables with probability density function $g(\cdot)$, probability distribution function $G(\cdot)$

$N_e(t)$ - number of exit points lying in $(0, t]$

Y_A, Y_B -exponential random variables denoting the optional thresholds for grade A and B with parameters λ_A, λ_B respectively

Z_A, Z_B -exponential random variables denoting the mandatory thresholds for grade A and B with parameters μ_A, μ_B respectively.

Assume that $Y_A < Z_A$ & $Y_B < Z_B$.

p -probability that the organization is not going for recruitment when optional threshold is exceeded by the cumulative loss of manpower.

q -probability that every policy decision has exit of personnel. As $q=0$ corresponds to the case where exits are impossible, it is assumed that $q \neq 0$.

T -random variable denoting the time to recruitment with distribution function $L(\cdot)$, density function $l(\cdot)$ and mean $E(T)$.

$\bar{a}(\cdot)$ - Laplace transform of $a(\cdot)$.

The univariate CUM policy of recruitment employed in is paper is stated as follows.

Recruitment is done whenever the cumulative loss of man hours in the organization exceeds the mandatory threshold. The organization may or may not go for recruitment if the cumulative loss of man hours exceeds the optional threshold.

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IV. MAIN RESULT

$P(T > t) = P\{ \text{Total loss of manpower at the exit points in } (0,t] \text{ does not exceed } Y \text{ or the total loss of manpower at the exit points in } (0,t] \text{ exceeds } Y \text{ but lies below } Z \text{ and the organization is not making recruitment} \}$

$$P(T > t) = P(S_{N_e(t)} \leq Y) + P(Y < S_{N_e(t)} \leq Z)p$$

$$P(T > t) = \sum_{k=0}^{\infty} P[N_e(t) = k]P(S_k < Y) + p \sum_{k=0}^{\infty} P[N_e(t) = k]P(S_k > Y)P(S_k \leq Z) \quad \text{-- (1)}$$

From Renewal theory,

$$P\{N_e(t) = k\} = G_k(t) - G_{k+1}(t) \text{ and } G_0(t) = 1 \text{---(2)}$$

From (1), we get

$$P(T > t) = \sum_{k=0}^{\infty} \{G_k(t) - G_{k+1}(t)\}P\{S_k \leq Y\} + p \sum_{k=0}^{\infty} \{G_k(t) - G_{k+1}(t)\}P\{S_k > Y\}P\{S_k \leq Z\} \quad \text{-- (3)} P(T > t) =$$

$$\sum_{k=0}^{\infty} \{G_k(t) - G_{k+1}(t)\} \{a_1^k + a_2^k - a_3^k\} + p \sum_{k=0}^{\infty} \{G_k(t) - G_{k+1}(t)\} \{1 - a_1^k - a_2^k + a_3^k\} \{b_1^k + b_2^k - b_3^k\} \quad \text{-- (4)}$$

$$\begin{aligned} l^*(s) &= \bar{a}_1 \sum_{k=1}^{\infty} [\bar{g}(s)]^k a_1^{k-1} + \bar{a}_2 \sum_{k=1}^{\infty} [\bar{g}(s)]^k a_2^{k-1} - \bar{a}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k a_3^{k-1} + p \{ \bar{b}_1 \sum_{k=1}^{\infty} [\bar{g}(s)]^k b_1^{k-1} \\ &+ \bar{b}_2 \sum_{k=1}^{\infty} [\bar{g}(s)]^k b_2^{k-1} - \bar{b}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k b_3^{k-1} + \bar{a}_1 \bar{b}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_1 b_3)^{k-1} - \bar{a}_1 \bar{b}_1 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_1 b_1)^{k-1} \\ &- \bar{a}_1 \bar{b}_2 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_1 b_2)^{k-1} + \bar{a}_2 \bar{b}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_2 b_3)^{k-1} - \bar{a}_2 \bar{b}_1 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_2 b_1)^{k-1} \\ &- \bar{a}_2 \bar{b}_2 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_2 b_2)^{k-1} + \bar{a}_3 \bar{b}_1 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_3 b_1)^{k-1} + \bar{a}_3 \bar{b}_2 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_3 b_2)^{k-1} \\ &- \bar{a}_3 \bar{b}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_3 b_3)^{k-1} \} \text{ where } \bar{a} = 1 - a, \bar{b} = 1 - b, \bar{ab} = 1 - ab \quad \text{--- (5)} \end{aligned}$$

It can be shown that distribution function $G(\cdot)$ of the inter exit times satisfy the relation

$$G(s) = \sum_{n=1}^{\infty} (1 - q_A)^{n-1} q_A F_n(x) + \sum_{n=1}^{\infty} (1 - q_B)^{n-1} q_B F_n(x) \quad \text{--(6)}$$

Note that $L(t) = 1 - P(T > t); E(T^r) = (-1)^r \left[\frac{d^r}{ds^r} \bar{l}(s) \right]_{s=0}, r = 1, 2, \dots \quad \text{-- (7)}$

Assuming $M(x) = 1 - e^{-\alpha x}, G(x) = 1 - e^{-\delta x}, H_A(y) = 1 - e^{-\lambda_A y}, H_B(y) = 1 - e^{-\lambda_B y}, H_A(z) = 1 - e^{-\mu_A z},$ and $H_B(z) = 1 - e^{-\mu_B z}$, we now determine the mean time to recruitment for two different models on inter-policy decision times.

Model-I: $\{U_k\}_{k=1}^{\infty}$ form a geometric process with rate $c, (c > 0).$ $\{U_k\}_{k=1}^{\infty}$ bethe time between the $(k-1)^{\text{th}}$ and k^{th} policy decisions. Let $F(\cdot), f(\cdot)$ be the distribution and probability density function of U_1 respectively.

Case(i): $Y = \max(Y_A, Y_B) \ \& \ Z = \max(Z_A, Z_B)$

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$$\bar{g}(s) = q_A \sum_{n=1}^{\infty} (1-q_A)^{n-1} \bar{f}_n(s) + q_B \sum_{n=1}^{\infty} (1-q_B)^{n-1} \bar{f}_n(s), \text{ where } \bar{f}_n(s) = \prod_{k=1}^n \bar{f}\left(\frac{s}{c^{k-1}}\right) \quad \text{---(8)}$$

$$\bar{g}(0) = 2 \text{ and } \bar{g}'(0) = \frac{-c\{1+2c(c-1)\}}{\lambda(c-q_A)(c-q_B)} \quad \text{--- (9)}$$

Using (9), (5) in (7), we get

$$E(T) = \frac{c[1+2c(c-1)]}{\lambda(c-q_A)(c-q_B)} \left\{ \frac{\bar{a}_1}{(1-2a_1)^2} + \frac{\bar{a}_2}{(1-2a_2)^2} - \frac{\bar{a}_3}{(1-2a_3)^2} + p \left\{ \frac{\bar{b}_1}{(1-2b_1)^2} + \frac{\bar{b}_2}{(1-2b_2)^2} - \frac{\bar{b}_3}{(1-2b_3)^2} - \frac{\bar{a}_1\bar{b}_1}{(1-2a_1b_1)^2} - \frac{\bar{a}_1\bar{b}_2}{(1-2a_1b_2)^2} + \frac{\bar{a}_1\bar{b}_3}{(1-2a_1b_3)^2} - \frac{\bar{a}_2\bar{b}_1}{(1-2a_2b_1)^2} - \frac{\bar{a}_2\bar{b}_2}{(1-2a_2b_2)^2} + \frac{\bar{a}_2\bar{b}_3}{(1-2a_2b_3)^2} + \frac{\bar{a}_3\bar{b}_1}{(1-2a_3b_1)^2} + \frac{\bar{a}_3\bar{b}_2}{(1-2a_3b_2)^2} - \frac{\bar{a}_3\bar{b}_3}{(1-2a_3b_3)^2} \right\} \right\} \quad \text{--- (10)}$$

Equation (10) gives the mean of the time to recruitment for Case(i) in Model-I

Case(ii): $Y = \min(Y_A, Y_B)$ & $Z = \min(Z_A, Z_B)$

$$l^*(s) = \bar{a}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k a_3^{k-1} + p \left\{ \bar{b}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k b_3^{k-1} - \bar{a}_3 \bar{b}_3 \sum_{k=1}^{\infty} [\bar{g}(s)]^k (a_3 b_3)^{k-1} \right\} \quad \text{--- (11)}$$

Using (9), (11) in (7), we get

$$E(T) = \frac{c[1+2c(c-1)]}{\lambda(c-q_A)(c-q_B)} \left\{ \frac{\bar{a}_3}{(1-2a_3)^2} + p \left\{ \frac{\bar{b}_3}{(1-2b_3)^2} - \frac{\bar{a}_3\bar{b}_3}{(1-2a_3b_3)^2} \right\} \right\} \quad \text{--- (12)}$$

Equation (12) gives the mean of the time to recruitment for Case(ii) in Model - I

Model-II: $\{U_k\}_{k=1}^{\infty}$ form an order statistics where the sample of size r associated with this order statistics is selected from an exponential population of independent and identically distributed inter-policy decisions times where the distribution function $F(t) = 1 - e^{-\lambda t}$.

Let $F_{u(j)}(\cdot)$ and $f_{u(j)}(\cdot)$ be the distribution and probability density function of the j^{th} orderstatistics selected from the sample of size r from the exponential population $\{U_k\}_{k=1}^{\infty}$. From the theory of order statistics, it is known that

$$f_{u(j)}(t) = j \binom{r}{j} [F(t)]^{j-1} f(t) [1-F(t)]^{r-j}, \quad j = 1, 2, \dots, r. \quad \text{---(13)}$$

Case(i): $Y = \max(Y_A, Y_B)$ & $Z = \max(Z_A, Z_B)$

$$\text{Suppose } f(t) = f_{u(1)}(t), \text{ where } \bar{f}_{a(1)}(s) = \frac{r\lambda}{r\lambda + s} \quad \text{---(14)}$$

$$\bar{g}(0) = 2 ; \bar{g}'(0) = \frac{-2}{r\lambda} \quad \text{---(15)}$$

Using (15), (5) in (7), we get

$$E(T) = \frac{2}{r\lambda} \left\{ \frac{\bar{a}_1}{(1-2a_1)^2} + \frac{\bar{a}_2}{(1-2a_2)^2} - \frac{\bar{a}_3}{(1-2a_3)^2} + p \left\{ \frac{\bar{b}_1}{(1-2b_1)^2} + \frac{\bar{b}_2}{(1-2b_2)^2} \right\} \right\}$$

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$$\begin{aligned}
 & -\frac{\bar{b}_3}{(1-2\bar{b}_3)^2} - \frac{\bar{a}_1\bar{b}_1}{(1-2\bar{a}_1\bar{b}_1)^2} - \frac{\bar{a}_1\bar{b}_2}{(1-2\bar{a}_1\bar{b}_2)^2} + \frac{\bar{a}_1\bar{b}_3}{(1-2\bar{a}_1\bar{b}_3)^2} - \frac{\bar{a}_2\bar{b}_1}{(1-2\bar{a}_2\bar{b}_1)^2} - \frac{\bar{a}_2\bar{b}_2}{(1-2\bar{a}_2\bar{b}_2)^2} + \frac{\bar{a}_2\bar{b}_3}{(1-2\bar{a}_2\bar{b}_3)^2} \\
 & + \frac{\bar{a}_3\bar{b}_1}{(1-2\bar{a}_3\bar{b}_1)^2} + \frac{\bar{a}_3\bar{b}_2}{(1-2\bar{a}_3\bar{b}_2)^2} - \frac{\bar{a}_3\bar{b}_3}{(1-2\bar{a}_3\bar{b}_3)^2} \} \dots (16)
 \end{aligned}$$

Suppose $f(t) = f_{u(r)}(t)$, where $f_{a(r)}(s) = \frac{r! \lambda^r}{(\lambda + s)(2\lambda + s) \dots (r\lambda + s)}$ ---

(17)

$$\bar{g}(0) = 2; \bar{g}'(0) = \frac{-2}{\lambda} \sum_{k=1}^r \frac{1}{k} \dots (18)$$

Using (18), (5) in (7), we get

$$\begin{aligned}
 E(T) = & \frac{2}{\lambda} \sum_{k=1}^r \frac{1}{k} \left\{ \frac{\bar{a}_1}{(1-2\bar{a}_1)^2} + \frac{\bar{a}_2}{(1-2\bar{a}_2)^2} - \frac{\bar{a}_3}{(1-2\bar{a}_3)^2} + p \left\{ \frac{\bar{b}_1}{(1-2\bar{b}_1)^2} + \frac{\bar{b}_2}{(1-2\bar{b}_2)^2} \right. \right. \\
 & - \frac{\bar{b}_3}{(1-2\bar{b}_3)^2} - \frac{\bar{a}_1\bar{b}_1}{(1-2\bar{a}_1\bar{b}_1)^2} - \frac{\bar{a}_1\bar{b}_2}{(1-2\bar{a}_1\bar{b}_2)^2} + \frac{\bar{a}_1\bar{b}_3}{(1-2\bar{a}_1\bar{b}_3)^2} - \frac{\bar{a}_2\bar{b}_1}{(1-2\bar{a}_2\bar{b}_1)^2} - \frac{\bar{a}_2\bar{b}_2}{(1-2\bar{a}_2\bar{b}_2)^2} + \frac{\bar{a}_2\bar{b}_3}{(1-2\bar{a}_2\bar{b}_3)^2} \\
 & \left. \left. + \frac{\bar{a}_3\bar{b}_1}{(1-2\bar{a}_3\bar{b}_1)^2} + \frac{\bar{a}_3\bar{b}_2}{(1-2\bar{a}_3\bar{b}_2)^2} - \frac{\bar{a}_3\bar{b}_3}{(1-2\bar{a}_3\bar{b}_3)^2} \right\} \dots (19)
 \end{aligned}$$

Equations (16), (19) gives the meantime to recruitment for case(i) in Model - II

Case(ii): $Y = \min(Y_A, Y_B)$ & $Z = \min(Z_A, Z_B)$

Using (13), (14) & (15) in (11)

$$E(T) = \frac{2}{r\lambda} \left\{ \frac{\bar{a}_3}{(1-2\bar{a}_3)^2} + p \left\{ \frac{\bar{b}_3}{(1-2\bar{b}_3)^2} - \frac{\bar{a}_3\bar{b}_3}{(1-2\bar{a}_3\bar{b}_3)^2} \right\} \right\} \dots (20)$$

Using (13), (17) & (18) in (11)

$$E(T) = \frac{2}{\lambda} \sum_{k=1}^r \frac{1}{k} \left\{ \frac{\bar{a}_3}{(1-2\bar{a}_3)^2} + p \left\{ \frac{\bar{b}_3}{(1-2\bar{b}_3)^2} - \frac{\bar{a}_3\bar{b}_3}{(1-2\bar{a}_3\bar{b}_3)^2} \right\} \right\} \dots (21)$$

Equations (20), (21) gives the mean time to recruitment for case(ii) in Model - II

Remark:

Computation of E(T) for extended exponential and SCBZ property possessing thresholds is similar for both the cases as their distributions will have just additional exponential terms.

Note:

When $c=1$, $p \neq 0$, $q \neq 1$ our results agree with the results for the manpower system having the inter-decision times as an ordinary renewal process.

V. FINDINGS

From the above results, the following observations are made which agree with the reality.

1. As λ increases, on the average, the inter-decision time decreases and consequently the mean of time to recruitment decreases when the other parameters are fixed.
2. The mean time to recruitment decreases or increases according as $c > 1$ or $c < 1$, since the geometric process of inter-policy decision times is stochastically decreasing when $c > 1$ and increasing when $c < 1$.

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VI.CONCLUSION

The models discussed in this paper are found to be more realistic and new in the context of considering (i) separate points (exit points) on the time axis for attrition, thereby removing a severe limitation on instantaneous attrition at decision epochs and (ii) associating a probability for any decision to have exit points. From the organization's point of view, our models are more suitable than the corresponding models with instantaneous attrition at decision epochs, as the provision of exit points at which attrition actually takes place, postpone the time to recruitment.

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BIOGRAPHY



Mrs. L. Saral, Ph.D., Scholar, PG & Research Department of Mathematics, Government Arts College (Autonomous), Trichy-22, was born on 25/04/1983 at Trichy district. She obtained her B.Sc degree in 2004, M.Sc degree in 2006 at Holy Cross College and M.Phil degree in 2011 in Alagapa University. She has 5 years of teaching experience in M. Kumarasamy college of Engineering and she has published a Research paper in Stochastic Processes in International Journal.

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Dr.S.Sendhamizhselvi , Assistant Professor, PG & Research Department of Mathematics, Government Arts College, Trichy-22, has obtained M.Sc degree in 1989 from Bharathidasan University M.Phil in 1999 from Madurai Kamaraj University and Ph.D in 2009 from Bharathidasan University. She worked in various designations in JJ college of Engineering & Technology for 10 years and as a Head of the Department for Humanities& Science for 5 years in Oxford Engineering College . At present she is working as an Assistant Professor of Mathematics in Government Arts College since 2011 .She has more than 25 years of experience in Teaching and 10 years of Research experience. She has presented more than 15 research papers in National and International Conferences. She has organized National level symposium and Seminar. She has produced 7 M.Phil students and she is guiding 2 M.Phil and 3 Ph.D candidates. She is a life member of AICTE



Dr. A. Srinivasan, Professor Emeritus PG & Research Department of Mathematics Bishop Heber College(Autonomous),Tiruchirappalli-17, has obtained M.Sc. Mathematics Degree in 1976 and Ph.D Degree in 1985 from Annamalai University. He joined Bishop Heber College in 1988 as Assistant Professor in Mathematics. He has 27 years of teaching and research experience and produced 10 Ph.D's and 32 M.Phil Degree students. At present he is guiding 8 students for Ph.D program. He has published 110 research papers in International Journals, 72 in National Journals, 23 papers in the Proceedings of the International conferences and 28 in that of National conferences. He has completed one UGC Minor Research Project. He has refereed research papers for International Journals. The thrust areas of his research are Stochastic manpower models, Queues, Retrial Queues, Fuzzy inventory models and First passage times. He is a life member in the Indian Mathematical Society, the Indian Society for Probability and Statistics and the forum for Inter disciplinary Research in Mathematics. He visited Manila in Philippines to present a research paper in an International conference in 2000. He presented a research paper at the International Congress for Mathematicians held in the University of Hyderabad during 19-27 August 2010. He is a resource person and Chairperson for several International and National level conferences / Seminars and Refresher courses for University and College teachers sponsored by UGC and DST. He is a member in several academic bodies and recruitment boards.