A MANPOWER MODEL FOR THE COST ANALYSIS IN A SINGLE GRADE SYSTEM WHEN THRESHOLD FOR THE LOSS OF MANPOWER HAS TWO COMPONENTS

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Abstract

In any organization the exit of personnel occurs, especially once the policy decisions relating to pay, perquisites and targets are proclaimed. In real time, once the exit of personnel happens, the recruitment cannot be introduced as a result of its time overwhelming and costly. Frequent recruitments are also not fascinating. Thus, the recruitment is made solely once the additive loss of manpower on sequent occasions cross the level referred to as threshold. Applying shock model approach, many stochastic models with bivariate policy of recruitment are constructed. In this paper, the explicit expression for the long - run average cost per unit time is derived when (i) survival time process is a geometric process and (ii) the threshold for the loss of manpower contains two components namely the level of wastage which can be allowed and the manpower due to extra time work. Numerical illustrations are additionally provided.

Key Words: *Single grade system, bivariate policy of recruitment, shock model.*

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1. INTRODUCTION

The best advantage of application of random processes is that any real world situation is often conceptualized as a mathematical model and therefore the optimal solution can be derived by using standard techniques. The formulation of appropriate policies which might be profitable for the organization is achieved by use of stochastic models in manpower planning. Wastage in the depletion of manpower from an organization is mainly due to the policy decisions regarding wages, perquisites and targets. Frequent recruitment is not potential because it involves cost. Hence the wastage on successive occasion is allowed to cumulate till the cumulative damage crosses a threshold level, at which the organization faces a breakdown due to yearning of manpower. In papers [2],[3],[4]and[5] researchers have considered the problem of time to recruitment in a marketing organization under different conditions. Using shock model and cumulative damage processes the mean time to recruitment and its variance are derived, by Elangovan et al [1]. Srinivasan and Saavithri [6] have considered a single grade system under univariate policy of recruitment with the assumption that survival time follows geometric process and the threshold level as a non-negative constant. An organization reaches an uneconomic status not only due to the loss of man-hour crossing a particular level but also due to number of decision making epochs in connection with recruitment. This motivated the researcher to consider manpower planning model following bivariate policy based on shock model approach. Srinivasan and Saavithri [7] have presented a manpower planning model for a single grade system with bivariate recruitment policy incorporating constant threshold. There are many real life situations where the constant threshold models may be inadequate due to random number of exits. To overcome this inefficiency two models in which threshold distributions following exponential and having SCBZ property have been proposed by Uma et al [8], [9]. Vijaysankar et al [10] have constructed a stochastic model by assuming the threshold with two components namely the level of wastage which can be allowed and the manpower which is available from what is known as backup resource. They have considered the threshold as the total of the maximum allowable attrition and the maximum available backup resource. The backup resource is similar to the manpower inventory on hand which can be utilized whenever it becomes necessary. Recently, Rojamary and Uma [11] derived the long run average cost per unit time for a single grade system under univariate policy of recruitment by assuming the threshold for the loss of manpower has two components. In this paper, using a bivariate policy of recruitment, the explicit expression for long- run average cost per unit time for a single grade system with two components for the threshold of the loss of manpower, is derived.

2. MODEL DESCRIPTION

Consider a single grade organization with bivariate policy of recruitment which takes decisions at random era**.** It is assumed that a random number of persons quit the organization whenever a decision occurs which in turn shows loss of man-hour to the organization. The loss of man-hour at any decision forms a sequence of independent and identically distributed random variables. The survival time process is a geometric process and it is independent process of loss of man-hour. There is a threshold level for the level of wastage and for available man-hour due to extra time work. If the total loss of man-hour crosses the sum of the threshold and available man-hour due to extra time work the break down occurs. The process that generates the loss of man-hour and the threshold put together is linearly independent. Recruitment takes place only at decision points and time of recruitment is negligible. . The recruitment takes place whenever the cumulative loss of man-hour exceeds the threshold or total number of decisions reaches a pre-assigned number whichever occurs earlier.

3. NOTATIONS

T_i : survival time after $(i-1)^{th}$ decision
Y_i : the loss of man-hour at the i^{th} decision
U_i : the cumulative loss of man-hour in the first i decisions
L(.) : distribution function of T_i with mean $\frac{\lambda}{a^{i-1}}$, a > 1
H (.) : distribution function of Y_i, i= 1, 2, 3, . .
H_i (.) : distribution function of U_i
U : The threshold of manpower depletion and $U = Z_1 + Z_2$.
(i) Z_1 = the maximum allowable attrition.
(ii) Z_2 = the maximum available man-hour due to extra time work.
f (.) : distribution function of U
X : time to recruitment under the given recruitment policy
M : a positive constant representing threshold for number of decisions
q : the fixed cost for each recruitment
A(Y) : cost incurred there is a loss of man-hour of magnitude Y
AC : the long-run average cost per unit time.

4. MAIN RESULT

In this section the expected time to recruitment and the expected total cost are derived. By assumption the recruitment is done either the cumulative loss of man-hour exceeds the threshold U or cumulative loss of decisions reaches M, a pre-assigned value whichever occurs earlier. Accordingly the time to recruitment $X = T_1$, if $U_1 > U$. If $U_1 \leq U$ then no recruitment is made till the next decision. If U_2 exceeds U then recruitment is made and $X= U_1 +U_2$, otherwise no recruitment. In general, if $U_l > U$ then recruitment is made and $X = U_1 + U_2 + . . . + U_l$ and if $U_l \leq U$ no recruitment is made till the next decision.

The expected time to recruitment E(X) is given by

$$E(X) = \sum_{k=1}^{M-1} E(T_k)\, P(U_{k-1} \leq U < U_M) + \sum_{k=1}^{l} E(T_k) P(U_M \leq U)$$

$$= \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} P(U_{k-1} \leq U < U_M) + \sum_{k=1}^{l} \frac{\lambda}{a^{k-1}} P(U_M \leq U)$$

$$= \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \int_0^{\infty}\int_0^{\infty}\int_t^{t+s} dF(u)\, dG_{M-K+1}(s)\, dG_{k-1}(t) + \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \int_0^{\infty}\int_v^{\infty} dF(u)\, dG_M(v) \qquad (1.1)$$

Assume that the loss of man-hours at the k^{th} decision X_k, follows exponential distribution with parameterθ_1. Then the cumulative loss of man-hours U_k follows gamma distribution with parameter θ_1 and k. Hence

$$dG_k(t) = {\theta_1}^k t^{k-1} \frac{e^{-\theta_1 t}}{(k-1)!} dt, \quad k = 1, 2, 3, \ldots$$

Let $Y_1 \sim \exp(\theta_2)$ and $Y_2 \sim \exp(\theta_3)$. Since $U = U_1 + U_2$ the p.d.f of U is the convolution of $U_1 + U_2$ and it is given by

$$f(u) = \frac{\theta_2\theta_3}{\theta_2-\theta_3}\left[e^{-\theta_3 u} - e^{-\theta_2 u}\right]$$

Now the time to recruitment in equation (1.1) becomes

$$E(X) = \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \int_0^{\infty}\int_0^{\infty}\int_t^{t+s} f(u) du\, dG_{M-k+1}(s)\, dG_{k-1}(t) + \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \int_0^{\infty}\int_v^{\infty} f(u) du\, dG_M(v)$$

$$E(X) = \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \int_0^{\infty}\int_0^{\infty}\int_t^{t+s} \frac{\theta_2\theta_3}{\theta_2-\theta_3}\left(e^{-\theta_3 u} - e^{-\theta_2 u}\right) du\, dG_{M-k+1}(s)\, dG_{k-1}(t)$$
$$+ \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \int_0^{\infty}\int_v^{\infty} \frac{\theta_2\theta_3}{\theta_2-\theta_3}\left(e^{-\theta_3 u} - e^{-\theta_2 u}\right) du\, dG_M(v))$$

$$= \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \int_0^{\infty}\int_0^{\infty} \frac{\theta_2\theta_3}{\theta_2-\theta_3}\left(\frac{e^{-\theta_3 u}}{-\theta_3} - \frac{e^{-\theta_2 u}}{-\theta_2}\right)_t^{t+s} dG_{M-k+1}(s)\, dG_{k-1}(t) + \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \int_0^{\infty} \frac{\theta_2\theta_3}{\theta_2-\theta_3}\left(\frac{e^{-\theta_3 u}}{-\theta_3} - \frac{e^{-\theta_2 u}}{-\theta_2}\right)_v^{\infty} dG_M(v)$$

$$= \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \frac{1}{\theta_2-\theta_3} \int_0^\infty \int_0^\infty (\theta_2 (e^{-\theta_3 t} - e^{-\theta_3(t+s)}) - \theta_3 (e^{-\theta_2 t} - e^{-\theta_2(t+s)})) dG_{M-k+1}(s)\, dG_{k-1}(t)$$
$$+ \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \int_0^\infty \frac{1}{\theta_2-\theta_3} (\theta_2 e^{-\theta_3 v} - \theta_3 e^{-\theta_2 v})\, dG_M(v)$$

$$= \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \left(\frac{\theta_2}{\theta_2-\theta_3}\right) \int_0^\infty \int_0^\infty (e^{-\theta_3 t} - e^{-\theta_3(t+s)})\, dG_{M-k+1}(s)\, dG_{k-1}(t)$$
$$- \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \left(\frac{\theta_3}{\theta_2-\theta_3}\right) \int_0^\infty \int_0^\infty (e^{-\theta_2 t} - e^{-\theta_2(t+s)})\, dG_{M-k+1}(s)\, dG_{k-1}(t) + \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \left(\frac{\theta_2}{\theta_2-\theta_3}\right) \int_0^\infty e^{-\theta_3 v}\, dG_M(v)$$
$$- \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \left(\frac{\theta_3}{\theta_2-\theta_3}\right) \int_0^\infty e^{-\theta_2 v}\, dG_M(v)$$
$$= \left(\frac{\theta_2}{\theta_2-\theta_3}\right) \left\{ \sum_{k=1}^{M-1} \frac{\lambda}{a^{k-1}} \int_0^\infty \int_0^\infty (e^{-\theta_3 t} - e^{-\theta_3(t+s)})\, dG_{M-k+1}(s)\, dG_{k-1}(t) + \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \int_0^\infty e^{-\theta_3 v}\, dG_M(v) \right\}$$
$$- \left(\frac{\theta_3}{\theta_2-\theta_3}\right) \left\{ \sum_{i=1}^{M-1} \frac{\lambda}{a^{k-1}} \int_0^\infty \int_0^\infty (e^{-\theta_2 t} - e^{-\theta_2(t+s)})\, dG_{M-k+1}(s)\, dG_{k-1}(t) + \sum_{k=1}^{M} \frac{\lambda}{a^{k-1}} \int_0^\infty e^{-\theta_2 v}\, dG_M(v) \right\}$$
$$E(X) = \lambda \left(\frac{\theta_2}{\theta_2-\theta_3}\right) \left\{ \frac{1}{a^{M-1}} \left(\frac{\theta_1}{\theta_1+\theta_3}\right)^M + \frac{\left({\theta_1}^{M-1} - (a(\theta_1+\theta_3))^{M-1}\right)}{\theta_1 - a(\theta_1+\theta_3)} (a(\theta_1+\theta_3))^{2-M} \right\}$$
$$- \lambda \left(\frac{\theta_3}{\theta_2-\theta_3}\right) \left\{ \frac{1}{a^{M-1}} \left(\frac{\theta_1}{\theta_1+\theta_2}\right)^M + \frac{\left({\theta_1}^{M-1} - (a(\theta_1+\theta_2))^{M-1}\right)}{\theta_1 - a(\theta_1+\theta_2)} (a(\theta_1+\theta_2))^{2-M} \right\} \qquad (1.2)$$

The total cost TC is

$$TC = q + \sum_{k=1}^{l} A(X_k)\psi(U_{k-1} \le U < U_M) + \sum_{k=1}^{M} A(X_K)\psi(U_M \le U)$$

$$E(TC) = q + E\left[\sum_{k=1}^{M-1} A(X_k)\psi(U_{k-1} \le U < U_M)\right] + E\left[\sum_{k=1}^{M} A(X_k)\psi(U_M \le U)\right]$$
$$E(TC) = q + \sum_{k=1}^{M-1} \int_0^\infty \int_0^\infty \int_0^\infty \int_t^{t+s+x} A(X)\, dF(u) dG(X)\, dG_{M-k}(s)\, dG_{k-1}(t) + \int_0^\infty \int_v^\infty A(v)\, dF(u) dG_M(v)$$
(1.3)

The cost associated with the loss of man-hour is assumed to be linear. Let$A(x)=B+Cx$ where B and C are real constants.

$$E(TC) = q + \sum_{k=1}^{M-1} \int_0^\infty \int_0^\infty \int_0^\infty \int_t^{t+s+x} (B+Cx)\, dF(u)\, dG(x) dG_{M-k}(s) d G_{k-1}(t) + \int_0^\infty \int_v^\infty (B+Cv)\, dF(u) dG_M(v)$$
$$= q + \sum_{k=1}^{M-1} \int_0^\infty \int_0^\infty \int_0^\infty \int_t^{t+s+x} (B+Cx) \frac{\theta_2\theta_3}{\theta_2-\theta_3} (e^{-\theta_3 u} - e^{-\theta_2 u}) du\, dG(x) dG_{M-k}(s) d G_{i-1}(t)$$
$$+ \int_0^\infty \int_v^\infty (B+Cv) \frac{\theta_2\theta_3}{\theta_2-\theta_3} (e^{-\theta_3 u} - e^{-\theta_2 u}) du\, dG_M(v)$$
$$= q + \sum_{k=1}^{M-1} \int_0^\infty \int_0^\infty \int_0^\infty (B+Cx) \frac{1}{\theta_2-\theta_3} \{\theta_2 (e^{-\theta_3 t} - e^{-\theta_3(t+s+x)}) - \theta_3 (e^{-\theta_2 t} - e^{-\theta_2(t+s+x)})\}\, dG(x)\, dG_{M-k}(s) dG_{k-1}(t)$$
$$+ \int_0^\infty (B+Cv) \frac{1}{\theta_2-\theta_3} (\theta_2 e^{-\theta_3 v} - \theta_3 e^{-\theta_2 v})\, dG_M(v)$$

$$= q + \sum_{k=1}^{M-1}\int_0^\infty\int_0^\infty\int_0^\infty (B+Cx)\left(\frac{\theta_2}{\theta_2-\theta_3}\right)\left(e^{-\theta_3 t} - e^{-\theta_3(t+s+x)}\right)\theta_1\, e^{-\theta_1 x}dx\, dG_{M-k}(s)\, dG_{k-1}(t)$$
$$- \sum_{k=1}^{M-1}\int_0^\infty\int_0^\infty\int_0^\infty (B+Cx)\left(\frac{\theta_3}{\theta_2-\theta_3}\right)\left(e^{-\theta_2 t} - e^{-\theta_2(t+s+x)}\right)\theta_1\, e^{-\theta_1 x}dG_{M-k}(s)\, dG_{k-1}(t)$$
$$+ \int_0^\infty (B+Cv)\left(\frac{\theta_2}{\theta_2-\theta_3}\right)e^{-\theta_3 v}\left(\frac{\theta_1{}^M v^{M-1}e^{-\theta_1 v}}{(M-1)!}\right)dv - \int_0^\infty (B+Cv)\left(\frac{\theta_3}{\theta_2-\theta_3}\right)e^{-\theta_2 v}\left(\frac{\theta_1{}^M v^{M-1}e^{-\theta_1 v}}{(M-1)!}\right)dv$$

$$\mathrm{E(TC)} = q + \left(\frac{\theta_2}{\theta_2-\theta_3}\right)\left\{\left(B+\frac{C}{\theta_1}\right)\left(\frac{\theta_1+\theta_3}{\theta_3}\right)\left[1-\left(\frac{\theta_1}{\theta_1+\theta_3}\right)^{M-1}\right]+\left(B(2-M)+\frac{C}{\theta_1+\theta_3}\right)\left(\frac{\theta_1}{\theta_1+\theta_3}\right)^{M}\right\}$$
$$-\left(\frac{\theta_3}{\theta_2-\theta_3}\right)\left\{\left(B+\frac{C}{\theta_1}\right)\left(\frac{\theta_1+\theta_2}{\theta_2}\right)\left[1-\left(\frac{\theta_1}{\theta_1+\theta_2}\right)^{M-1}\right]+\left(B(2-M)+\frac{C}{\theta_1+\theta_2}\right)\left(\frac{\theta_1}{\theta_1+\theta_2}\right)^{M}\right\}$$

The long-run average cost per unit time is given by

AC=E(TC) / E(X)

5. NUMERICAL ILLUSTRATION:

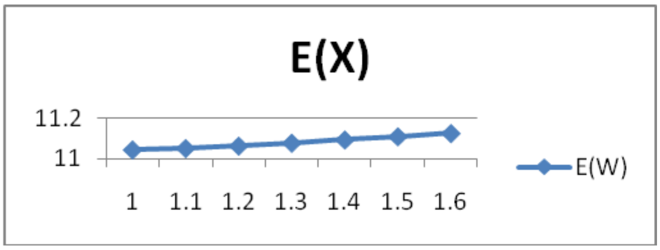
The values of the mean time to recruitment and long-run average cost per unit time can be determined numerically using the above expressions when the values of the various parameters are given.

Effect of loss of man-hours on performance measure

Table 1.1

$\lambda = 2, a = 2, B = 20, C = 15, q = 5000, M = 5, \theta_2 = 0.2, \theta_3 = 0.3$

θ_1	E(X)	AC
1	11.0427	461.5868
1.1	11.0502	461.1035
1.2	11.0624	460.3180
1.3	11.0772	459.3912
1.4	11.0932	458.4110
1.5	11.1096	457.4262
1.6	11.1259	456.4633



F igure 1.1(a) Graphical representation of θ_1 versus E(X)

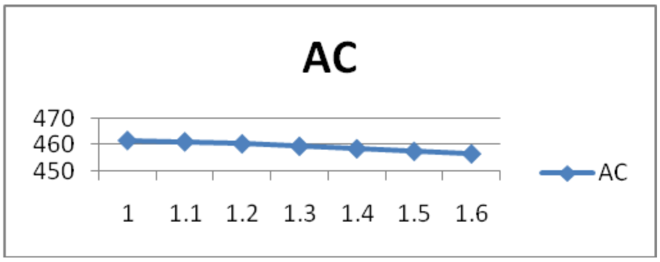


Figure 1.1(b) Graphical representation of θ_1 versus AC

Table 1.2:

$\lambda = 2, a = 2, B = 20, C = 15, q = 5000, M = 5, \theta_1 = 1, \theta_3 = 2$

θ_2	E(X)	AC
0.1	3.5367	1440.7
0.2	3.2708	1557.4
0.3	3.0599	1664
0.4	2.8952	1757.7
0.5	2.7732	1834
0.6	2.6940	1887.1
0.7	2.6608	1909.8

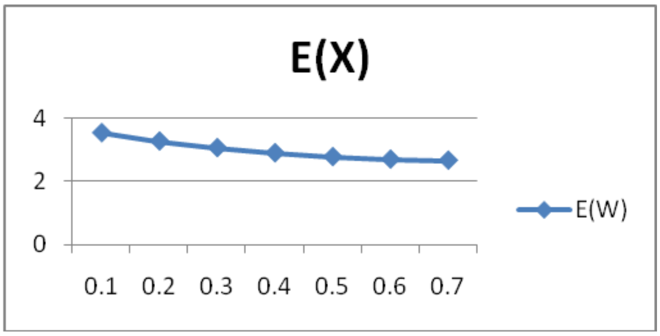


Figure 1.2(a) Graphical representation of θ_2 versus E(X)

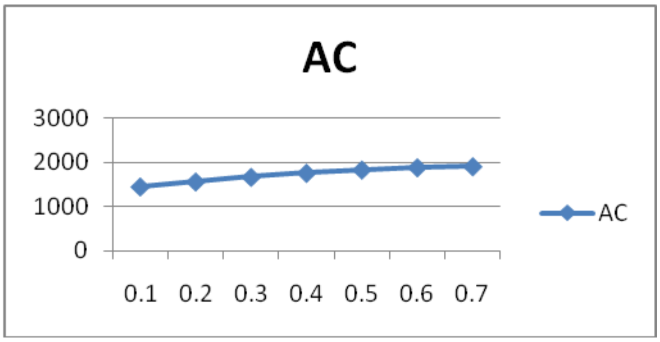


Figure1.2(b) Graphical representation of $\boldsymbol{\theta_2}$ versus AC

Table 1.3

$\lambda = 2, a = 2, B = 20, C = 15, q = 5000, M = 5, \theta_1 = 0.1, \theta_2 = 0.2$

$\boldsymbol{\theta_3}$	E(X)	AC
1	2.5327	2080
1.1	2.5143	2094.6
1.2	2.5002	2106
1.3	2.4891	2114.9
1.4	2.4801	2122.2
1.5	2.4728	2128.2
1.6	2.4666	2133.3

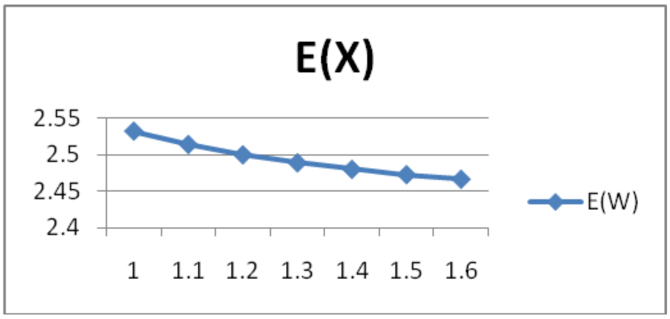


Figure 1.3(a) Graphical representation of $\boldsymbol{\theta_3}$ versus E(X)

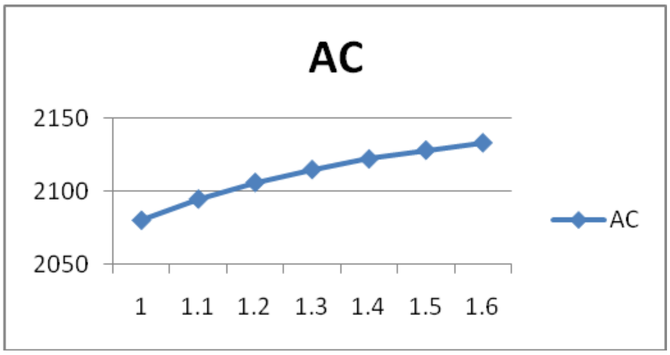


Figure 1.3(b) Graphical representation of $\boldsymbol{\theta_3}$ versus AC

Table 1.4

$\lambda = 2, B = 20, C = 15, \theta_1 = 0.1 \quad q = 5000, M = 5, \theta_2 = 0.2, \theta_3 = 0.3$

$\boldsymbol{a}$	E(X)	AC
1	6.2554	847.8967
1.1	5.9703	888.3823
1.2	5.7476	922.7986
1.3	5.5692	952.3578
1.4	5.4233	977.9856
1.5	5.3018	1000.4
1.6	5.1992	1020.1

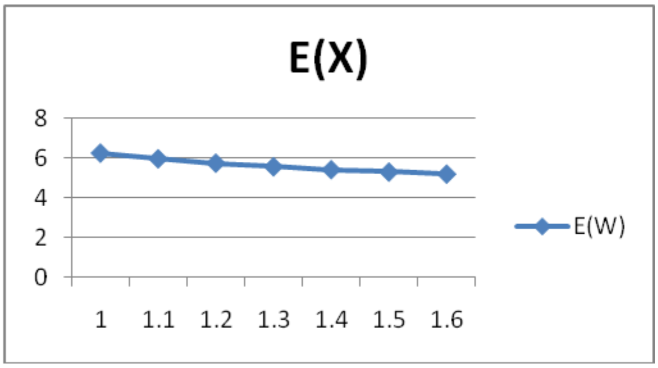


Figure 1.4(a) Graphical representation of 'a' versus E(X)

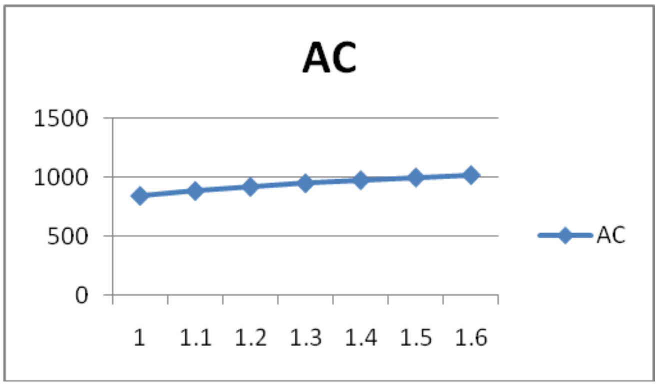


Figure 1.4(b) Graphical representation of 'a' versus AC

Table 1.5

$a = 2, B = 20, C = 15, \theta_1 = 0.1 , q = 5000, M = 5, \theta_2 = 0.2, \theta_3 = 0.$

λ	E(X)	AC
1	2.4554	2160.1
1.1	2.7009	1963.8
1.2	2.9464	1800.1
1.3	3.1920	1661.6
1.4	3.4375	1543
1.5	3.6830	1440.1
1.6	3.9286	1350.1

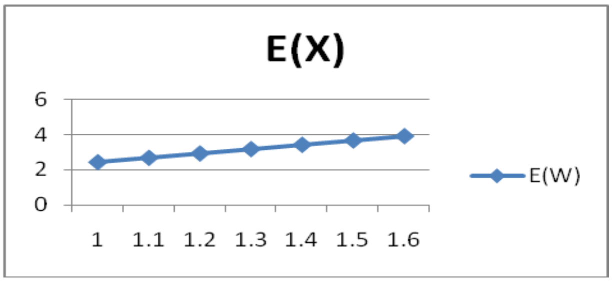


Figure 1.5(a) Graphical representation of λ versus E(X)

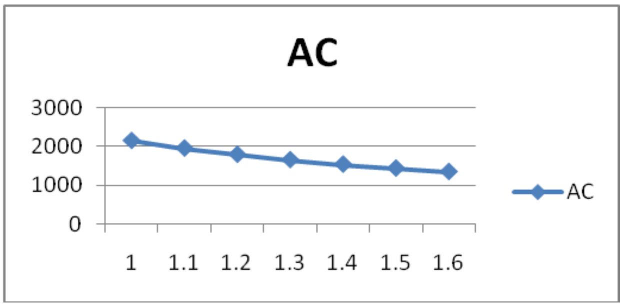


Figure 1.5(b) Graphical representation of λ versus AC

6. CONCLUSIONS

The influence of the parameters $\theta_1, \theta_2, \theta_3, a, \lambda$ on the performances measures are analyzed numerically.

From the above table(1.1) and figures(1.1(a)1&1.1(b)) it has been observed that the expected time to recruitment increases and the long run average cost per unit time decreases as the values of θ_1 the parameter of the random variables representing the total loss of manpower increases. As the random variable for the loss of manpower is exponentially distributed with parameter θ_1 ,its mean is 1/ θ_1 and hence the obtained result is realistic.

Also from tables (1.2), (1.3), (1.4) and figures (1.2(a)&1.2(b)) , (1.3(a)&1.3(b)) and (1.4(a)&1.4(b)) it have been observed the more realistic results that the values of the expected time to recruitment decreases and the average cost per unit time increases for the increases of a, θ_2, θ_3 .

From table (1.5) and the figures (1.5(a)&1.5(b)) observed that as λ increases the expected time to recruitment increases.

For real applications, the results of any research work should be viable. In the case of stochastic models this is very much essential since the results derived are based on real factors. In any industry or organization, the applications of stochastic model are of great need and it is also useful in every areas of human activity. It is important to identify those areas of human activity where the disequilibrium arises on the demand for manpower and the supply. For the development of human resource management the transformation of real life situations into mathematical model and identification of those areas are to be analyzed.

From the analysis and study of the influence of nodal parameters on the mean time to recruitment and long run average cost we observe that the constructed model yields profit for the organization and also to the society.

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