

# General Bulk Service Queueing System with Multiple Working Vacation

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**Abstract:** This paper analyses a single server with bulk service queue with general arrival pattern and multiple working vacation period. The model is analyzed by using Embedded Markov Chain technique. The steady state probability distribution at pre arrival epoch and arbitrary epoch are derived and measures like mean queue length are calculated. Finally, through some numerical examples, the parametric effect on the performance measures are discussed and presented graphically.

**Keywords:** Working vacation, Bulk service queue, and multiple vacations.

## 1. INTRODUCTION

Tian, Li and Zhang (2009) provided a survey of the results of working vacation queues and demonstrated that the matrix analytic methods developed by Neuts (1995) are powerful tools for analyzing the WVQ's. The survey also shows that neither bulk input nor bulk service WVQs are considered in the existing literature. Later Xu et al. (2009) and Julia Rose Mary and Afthab Begum (2010) studied the bulk input Markovian  $M^X / M / 1$  queue with working vacations and presented the PGF of the stationary queue length.

There are situations, particularly in transportation systems, where the service provided is such that a group (batch) of customers can be served simultaneously. The theory of batch service queues originated with the works of Bailey (1954). He considered a queue with Poisson arrival and fixed size service. Later many authors have investigated a variety of extensions of the basic model. The bulk service rule introduced by Neuts (1967) is the most general one and this has been further investigated by Medhi (1984), Borthakur et al. (1987). Julia Rose Mary and Afthab Begum (2009) have analyzed the Markovian  $M/M(a,b)/1$  queueing model under multiple working vacation and derived the steady-state probability distribution and the mean queue length for the model.

In some practical situations such as production systems and distribution systems, the input to the queueing system may not be a Poisson process so that a more general arrival process should be used. Baba (2005) have analyzed  $GI/M/1$  queue under multiple working vacation as an extension of  $M/1$  working vacation introduced by Servi and Finn (2002). In this paper,  $GI/M(a,b)/1$  multiple working vacation model analyzed by assuming that the inter arrivals form an independently identically distributed sequence of random variables having a general distribution function and the customers are served in batches following General Bulk Service Rule introduced by Neuts (1967). The results of  $GI/M/1$  multiple working vacation model and  $M/M(a,b)/1$  multiple working vacation are derived as special cases. It is also proved that when the arrival pattern is a Markov process, then the steady state probability distribution at pre arrival epoch and at arbitrary epoch coincide.

## 2. MATHEMATICAL ANALYSIS

We consider a batch service queueing system  $GI/M(a,b)/1$  under multiple working vacation. In this system, it is assumed that the inter arrival times ( $A$ ) form an independently identically distributed sequence of random variables having a general distribution function  $A(t) = \Pr(A \leq t)$ . The server processes the customers in batches according to the GBSR introduced by Neuts (1967). The service time of batches of size  $x$  ( $a \leq x \leq b$ ) ( $a$ : minimum number of units,  $b$ : maximum number of units) is assumed to be an independently identically distributed sequence of random variables with exponential distribution of parameter  $\mu_b$ .

Whenever the server completes a service and finds less than “a” customers in the queue then he begins a vacation which is an exponentially distributed random variable V with parameter  $\eta$ . After completing a vacation, if the system length is still less than “a”, then he takes another vacation and the vacations are repeated until the server finds at least “a” customers in the queue.

Suppose during vacation, if the queue size becomes at least “a” then the server starts a service under General Bulk Service Rule but with the service rate  $\mu_v$  which is strictly less than the regular service rate  $\mu_b$ . When the vacation ends, the server switches his service rate from  $\mu_v$  to  $\mu_b$ . It is assumed that, the size of service batch that being served remains unchanged when the server enters into the regular busy period. In either case (working vacation or regular busy period), the service rates are assumed to be independent of the size of the batch in service ( $a \leq x \leq b$ ).

The Queueing system is formulated as an embedded two dimensional Markov chain by choosing arrival epochs as embedded points. The steady state distribution for the number of customers in the queue at arrival epochs is derived by analyzing the embedded Markov chain defined. Using the theory of semi Markov process, the steady state distribution for the number of customers in the queue at arbitrary epochs is also derived.

**Case 1 : Pre-arrival Epoch**

Let  $t_n, n = 1, 2, \dots (t_0 = 0)$  be the arrival epoch at which the  $n^{th}$  customer arrives. The system is examined at time  $(t_n - 0)$ . The interarrival times  $\{T_n, n \geq 1\}$  are independent and identically distributed with a general distribution function denoted by  $A(t)$  with mean  $1/\lambda$ . The LST of  $A(t)$  is given by  $A^*(\theta) = \int_0^\infty e^{-\theta t} dA(t)$ . The working vacation times, the service times during regular service period and the service times during working vacation are all exponentially distributed with rates  $\eta, \mu_b$  and  $\mu_v$  respectively.

Let  $W(t)$  denote the number of customers in the queue at time  $t, W_n = W(t_n - 0)$  and

$$J_n = \begin{cases} 0, & \text{if the } n^{th} \text{ arrival occurs during idle vacation period} \\ 1, & \text{if the } n^{th} \text{ arrival occurs during working vacation period} \\ 2, & \text{if the } n^{th} \text{ arrival occurs during regular busy period} \end{cases}$$

Since, the working vacation times, the service times during regular and working vacation are all exponentially distributed, the process  $\{(W_n, J_n), n \geq 1\}$  is an embedded Markov chain with state space  $\Omega = \{(n, j); n \geq 0, j = 1, 2\} \cup \{(n, 0); 0 \leq n \leq a - 1\}$ .

The steady-state queue size probabilities are defined by  $R_n = \lim_{k \rightarrow \infty} \Pr\{W(t_k - 0) = n, J_k = 0\}, 0 \leq n \leq a - 1$

$Q_n = \lim_{k \rightarrow \infty} \Pr\{W(t_k - 0) = n, J_k = 1\}, n \geq 0$  and  $P_n = \lim_{k \rightarrow \infty} \Pr\{W(t_k - 0) = n, J_k = 2\}, n \geq 0$ .

Then  $R_n, Q_n$  and  $P_n$  respectively denote the probability that the queue contains  $n$  customers and the server is idle in vacation state, is busy in vacation state and regular busy state at pre arrival epochs. During idle vacation period, the number of customers in the system and queue are the same, whereas in working vacation period and in regular busy period  $n$  denotes the number of customers in the queue and the system will contain  $(n + k), (a \leq k \leq b)$  customers.

Let  $b_k$  denote the probability that  $k$  batches are served at regular service rate  $\mu_b$  during an interarrival time. Then

$$b_k = \int_0^\infty e^{-\mu_b t} \frac{(\mu_b t)^k}{k!} dA(t), k \geq 0 \tag{1}$$

and  $\sum_{k=0}^\infty b_k z^{kb} = B(z^b) = A^*(\mu_b(1 - z^b))$  (2)

Let  $c_k$  denote the probability that, the working vacation time is greater than an inter arrival time and  $k$  batches are served at rate  $\mu_v$  during an inter arrival time.

$$\text{Then } c_k = \int_0^{\infty} e^{-\eta t} e^{-\mu_v t} \frac{(\mu_v t)^k}{k!} dA(t), k \geq 0 \quad (3)$$

$$\text{and } \sum_{k=0}^{\infty} c_k z^{kb} = C(z^b) = A^*(\eta + \mu_v(1 - z^b)) \quad (4)$$

Let  $d_k$  denote the probability that, the server returns from vacation in an inter arrival time and  $k$  service completions occur in an inter arrival time. Then

$$d_k = \int_0^{\infty} \sum_{i=0}^k \left\{ \int_0^t \eta e^{-\eta x} \frac{(\mu_v x)^i}{i!} e^{-\mu_v x} \frac{(\mu_b(t-x))^{k-i}}{(k-i)!} e^{-\mu_b(t-x)} dx \right\} dA(t), k \geq 0 \quad (5)$$

i.e.,  $k$  services in an inter arrival time can occur in such a way that,  $i$  ( $0 \leq i \leq k$ ) service completions occur at rate  $\mu_v$  (till the server returns from vacation) and the remaining  $(k - i)$  service completions occur at rate  $\mu_b$

$$\text{and } \sum_{k=0}^{\infty} d_k z^{kb} = D(z^b) = \frac{\eta [A^*(\mu_b(1 - z^b)) - A^*(\eta + \mu_v(1 - z^b))]}{\eta + (\mu_v - \mu_b)(1 - z^b)} \quad (6)$$

The steady-state queue size equations at pre-arrival epochs, are obtained by noting the transitions between the states of the Markov chain and are given by :

$$Q_n = \sum_{k=0}^{\infty} Q_{kb+n-1} c_k, \quad n \geq 1 \quad (7)$$

$$Q_0 = \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} Q_{(k-1)b+j} c_k + R_{a-1} Q_0 \quad (8)$$

$$P_n = \sum_{k=0}^{\infty} P_{kb+n-1} b_k + \sum_{k=0}^{\infty} Q_{kb+n-1} d_k, \quad n \geq 1 \quad (9)$$

$$P_0 = \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} P_{(k-1)b+j} b_k + \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} Q_{(k-1)b+j} d_k + R_{a-1} d_0 \quad (10)$$

$$R_n = R_{n-1} + \sum_{k=0}^{\infty} Q_{kb+n-1} (1 - \sum_{i=0}^k (c_i + d_i)) + \sum_{k=0}^{\infty} P_{kb+n-1} (1 - \sum_{i=0}^k b_i), \quad 1 \leq n \leq a-1 \quad (11)$$

$$\begin{aligned} R_0 &= \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} Q_{(k-1)b+j} (1 - \sum_{i=0}^k (c_i + d_i)) \\ &+ \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} P_{(k-1)b+j} (1 - \sum_{i=0}^k b_i) + R_{a-1} (1 - (d_0 + c_0)) \end{aligned} \quad (12)$$

By operator technique, equation (7) and (9) becomes

$$\left( E - \sum_{k=0}^{\infty} c_k E^{kb} \right) Q_n = 0, \quad n \geq 0 \quad (13)$$

$$\text{and } \left( E - \sum_{k=0}^{\infty} b_k E^{kb} \right) P_n = \sum_{k=0}^{\infty} Q_{kb+n} d_k, \quad n \geq 0 \quad (14)$$

The characteristic equation  $z = C(z^b) = A^*(\eta + \mu_v(1 - z^b))$ ,  $\eta > 0$  of the homogeneous difference equation (13) has a unique root  $r_1$  inside  $(0, 1)$ .

$$\begin{aligned} \text{For } \psi(z) &= A^*(\eta + \mu_v(1 - z^b)), \text{ satisfies the inequality} \\ 0 < \psi(0) &= A^*(\eta + \mu_v) < \psi(1) = A^*(\eta) < 1, \text{ and for } 0 < z < 1, \\ \psi'(z) &= b \mu_b \int_0^\infty t e^{-(\eta + \mu_b(1 - z^b))t} dA(t) > 0 \\ \psi''(z) &= (b \mu_b)^2 \int_0^\infty t^2 e^{-(\eta + \mu_b(1 - z^b))t} dA(t) > 0 \end{aligned}$$

Therefore,  $r_1 = A^*(\eta + \mu_v(1 - r_1^b))$  with  $0 < r_1 < 1$  (Baba (2005)) (15)

Thus homogeneous difference equation (13) has solution

$$Q_n = r_1^n Q_0, \quad n \geq 0 \quad (16)$$

The characteristic equation of the non-homogeneous difference equation (14) is  $z = B(z^b) = A^*(\mu_b(1 - z^b))$  and  $B(z^b)$  is the pgf of  $b_k$ 's with  $B(1) = 1$ . Hence following the arguments of Gross and Harris (1998), the characteristic equation  $z = B(z^b)$  has a unique root in  $(0, 1)$ , if  $B'(1) > 1$ , i.e.,  $\rho_b = \frac{\lambda}{b \mu_b} < 1$ . Thus under the condition  $\rho_b < 1$ , the solution of the non-homogeneous equation (14) is

$$\begin{aligned} \text{given by } P_n &= (A_d r_1^n + B_d r_1^n) Q_0, \quad n \geq 0 \quad (17) \\ \text{where } B_d &= \frac{-\eta}{\eta + (\mu_v - \mu_b)(1 - r_1^b)} \end{aligned}$$

To find the remaining probabilities, the equations (11) and (12) are used.

$$R_n = \left[ A_d \frac{r_1^{a-1} - r_1^n}{(1 - r_1^b)} + (B_d + 1) \left( \frac{r_1^{a-1} - r_1^n}{1 - r_1^b} \right) + \frac{1}{r_1^b (1 - r_1)} \left( \frac{r_1^b - r_1^a}{c_0} + r_1^{a-1} - r_1^b \right) \right] Q_0$$

for  $0 \leq n \leq a-1$

After some algebraic manipulation, the steady-state queue size probabilities at arrival epochs are given by

$$\begin{aligned} Q_n &= r_1^n Q_0, \quad n \geq 0 \\ P_n &= (A_d r_1^n + B_d r_1^n) Q_0, \quad n \geq 0 \\ R_n &= \left[ A_d h_n(r) + (B_d + 1) h_n(r_1) + \frac{1}{(r_1^b (1 - r_1))} \left( \frac{r_1^b - r_1^a}{c_0} + r_1^{a-1} - r_1^b \right) \right] Q_0, \end{aligned}$$

for  $0 \leq n \leq a-1$  (18)

where  $h_n(x) = \frac{x^{a-1} - x^n}{1 - x^b}$ ,  $A_d f(r) + B_d f(r_1) = \frac{d_0}{c_0} \left( \frac{r_1^a - r_1^b}{r_1^b (1 - r_1)} \right)$  with

$$f(x) = \frac{x^a - x^b}{x^b (1 - x)} + b_0 \frac{(x^b - x^{a-1})}{x^b (1 - x)} \text{ and } B_d = \frac{-\eta}{\eta + (\mu_v - \mu_b)(1 - r_1^b)}$$

and by using the normalizing condition

$$Q_0^{-1} = A_d g(r) + (B_d + 1) g(r_1) + \frac{a}{r_1^b (1 - r_1)} \left( \frac{r_1^b - r_1^a}{c_0} + (r_1^{a-1} - r_1^b) \right) \quad (19)$$

where  $g(x) = \frac{1}{(1 - x^b)} \left( \frac{x^a - x^b}{1 - x} + a x^{a-1} \right)$

The mean queue length  $L_q$  is calculated as

$$L_q = \left[ A_d H(r) + (B_d + 1) H(r_1) + \frac{a(a-1)}{2r_1^b (1 - r_1)} \left( \frac{r_1^b - r_1^a}{c_0} + r_1^{a-1} - r_1^b \right) \right] Q_0$$

where  $H(x) = \frac{x}{(1-x)^2} + \frac{1}{(1-x^b)} \left[ \frac{a(a-1)}{2} x^{a-1} + \frac{ax^a(1-x) - x(1-x^a)}{(1-x)^2} \right]$

**Performance Measures at Pre-Arrival Epochs**

Let  $P_v$ ,  $P_I$  and  $P_{busy}$  denote that the server is busy in vacation, idle in vacation and in regular busy state respectively at pre-arrival epochs. Then,

(i)  $P_v = \sum_{n=0}^{\infty} r_1^n Q_0 = \frac{Q_0}{(1-r_1)}$

(ii)  $P_I = \left[ \left( \frac{A_d r^{a-1} a}{(1-r^b)} + \frac{(B_d+1)r_1^{a-1} a}{(1-r_1^b)} + \frac{a}{r_1^b(1-r_1)} \left( \frac{r_1^b - r_1^a}{c_0} + r_1^{a-1} - r_1^b \right) \right) - \frac{A_d(1-r^a)}{(1-r^b)(1-r)} - \frac{(B_d+1)(1-r_1^a)}{(1-r_1^b)(1-r_1)} \right] Q_0$

(iii)  $P_{busy} = \sum_{n=0}^{\infty} (A_d r^n + B_d r_1^n) Q_0 = \left( \frac{A}{(1-r)} + \frac{B_d}{(1-r_1)} \right) Q_0$

**Case 2 : Random Epoch**

To obtain the limiting probabilities of queue size at random epochs, the system is examined at some time  $t$ , preceding an arrival epoch. Then using the relation between the two sequences,  $(W(t), J(t))$ ,  $(t_n \leq t < t_{n+1})$  and  $(W_n, J_n)$ ,  $(n = 0, 1, 2, \dots)$ , the steady-state equations satisfied by the steady-state queue size probabilities

$(R_n^*, Q_n^*, P_n^*) = \lim_{t \rightarrow \infty} \Pr (W(t) = n, J(t) = (0,1,2))$  at arbitrary epochs are obtained :

$R_n^* = \sum_{k=0}^{\infty} Q_{kb+n-1} c_k^*, n \geq 1$  (20)

$Q_0^* = \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} Q_{(k-1)b+j} c_k^* + R_{a-1} c_0^*$  (21)

$P_n^* = \sum_{k=0}^{\infty} P_{kb+n-1} b_k^* + \sum_{k=0}^{\infty} Q_{kb+n-1} d_k^*, n \geq 1$  (22)

$P_0^* = \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} P_{(k-1)b+j} b_k^* + \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} Q_{(k-1)b+j} d_k^* + R_{a-1} d_0^*$  (23)

$R_n^* = R_{n-1} + \sum_{k=0}^{\infty} Q_{kb+n-1} \left( 1 - \sum_{i=0}^k (c_i^* + d_i^*) \right) + \sum_{k=0}^{\infty} P_{kb+n-1} \left( 1 - \sum_{i=0}^k b_i^* \right), 1 \leq n \leq a-1$  (24)

$R_0^* = \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} Q_{(k-1)b+j} \left( 1 - \sum_{i=0}^k (c_i^* + d_i^*) \right) + \sum_{k=1}^{\infty} \sum_{j=a-1}^{b-1} P_{(k-1)b+j} \left( 1 - \sum_{i=0}^k b_i^* \right) + R_{a-1} (1 - c_0^* - d_0^*)$  (25)

where  $b_k^*$ ,  $c_k^*$  and  $d_k^*$  are the corresponding quantities for  $b_k$ ,  $c_k$  and  $d_k$  respectively, where the interarrival time  $A$  is replaced by  $T$  – the period of time between a random epoch and the preceding arrival epoch. The distribution function  $F_T(t)$  and the density function  $f_T(t)$  of  $T$  are given by  $F_T(t) = \lambda \int_0^t (1-A(x))dx$ ,  $f_T(t) = \lambda (1-A(t)) dt$ . Thus we have,

$$b_k^* = \int_0^\infty \frac{(\mu_b t)^k}{k!} e^{-\mu_b t} \lambda (1-A(t)) dt, \quad c_k^* = \int_0^\infty e^{-\eta t} \frac{(\mu_v t)^k}{k!} e^{-\mu_v t} \lambda (1-A(t)) dt$$

$$d_k^* = \int_0^\infty \sum_{r=0}^k \left( \int_0^t \eta \frac{e^{-\eta x} (\mu_v x)^r}{r!} e^{-\mu_v x} \frac{(\mu_b (t-x))^{k-r}}{(k-r)!} e^{-\mu_b (t-x)} dx \right) \lambda (1-A(t)) dt$$

i.e.,  $b_k^*$  denotes the probability that  $k$  customers are served at regular service rate  $\mu_b$  in an interval of time  $T$  and similarly  $c_k^*$  and  $d_k^*$  can be interpreted.

Substituting for the steady-state probabilities at pre-arrival epochs, the limiting probability distribution at arbitrary epochs are

$$Q_0^* = \left[ \frac{r_1^{a-1} - r_1^b}{r_1^b (1-r_1)} \left( \frac{\lambda (1-r_1)}{\eta + \mu_v (1-r_1^b)} \right) + \frac{r_1^b - r_1^a}{r_1^b (1-r_1)} \frac{c_0^*}{c_0} \right] Q_0$$

$$P_0^* = \frac{Q_0 A_d (r_1^{a-1} - r_1^b)}{(1-r_1)r^b} \left[ \frac{\lambda (1-r)}{\mu_b (1-r^b)} - b_0^* \right]$$

$$+ \frac{B_d Q_0 (r_1^{a-1} - r_1^b)}{(1-r_1)r_1^b} \left[ \frac{\lambda (1-r_1)}{\eta + \mu_v (1-r_1^b)} - b_0^* \right] + \frac{d_0^*}{c_0} \left[ \frac{r_1^b - r_1^a}{r_1^b (1-r_1)} \right] Q_0$$

$$R_0^* = \left[ A_d h_0^*(r, \mu_b (1-r^b)) + (B_d + 1) h_0^*(r_1, \eta + \mu_v (1-r_1^b)) \right. \\ \left. + \frac{1}{r_1^b (1-r_1)} \left( \frac{(r_1^b - r_1^a)(1-c_0^* - d_0^*)}{c_0} + (r_1^{a-1} - r_1^b)(1-b_0^*) \right) \right] Q_0$$

where  $h_0^*(x, y) = \frac{x^{a-1} - x^b}{(1-x)x^b} \left[ \frac{x^b}{1-x^b} - \left( \frac{\lambda (1-x)}{(1-x^b)y} - b_0^* \right) \right]$

and the other queue size probabilities at arbitrary epochs are

$$Q_n^* = \frac{\lambda (1-r_1) r_1^{n-1} Q_0}{\eta + \mu_v (1-r_1^b)}, \quad n \geq 1$$

$$P_n^* = \left[ A_d r^{n-1} \frac{\lambda (1-r)}{\mu_b (1-r^b)} + B_d r_1^{n-1} \frac{\lambda (1-r_1)}{\eta + \mu_v (1-r_1^b)} \right] Q_0, \quad n \geq 1$$

$$R_n^* = \left[ A_d h_n^*(r, \mu_b (1-r^b)) + (B_d + 1) h_n^*(r_1, \eta + \mu_v (1-r_1^b)) \right. \\ \left. + \frac{1}{r_1^b (1-r_1)} \left( \frac{r_1^b - r_1^a}{c_0} + r_1^{a-1} - r_1^b \right) \right] Q_0, \quad 1 \leq n \leq a-1$$

The mean queue length  $L_q^*$  at arbitrary epoch is calculated as

$$L_q^* = \left[ A_d H(r, \mu_b(1-r^b)) + (B_d + 1) H(r_1, \eta + \mu_v(1-r_1^b)) + \left( \frac{r_1^b - r_1^a}{c_0} + (r_1^{a-1} - r_1^b) \right) \frac{a(a-1)}{2r_1^b(1-r_1)} \right] Q_0$$

where  $H(x, y) = \frac{\lambda}{(1-x)y} + \frac{1}{(1-x^b)} \left[ \frac{x^{a-1} a(a-1)}{2} + \frac{\lambda(a x^{a-1}(1-x) - (1-x^a))}{y(1-x)} \right]$

3. PARTICULAR CASES

I. **M / M(a, b) / 1 / MWV**: If the inter arrival time follows exponential distribution, then the limiting probabilities at arbitrary epochs and at pre-arrival epochs coincide and give the steady-state queue size probabilities of the Markovian M / M(a, b) / 1 / MWV. These results coincide with the corresponding results of Julia Rose Mary and Afthab Begum (2009) with the following identifications

$A(t) = (1 - e^{-\lambda t})$ ,  $A^*(\theta) = \frac{\lambda}{\lambda + \theta}$ , and  $r$  and  $r_1$  respectively satisfy the equations  $\frac{\lambda}{\mu_b(1-r^b)} = \frac{r}{1-r}$

and  $\frac{\lambda}{\eta + \mu_v(1-r_1^b)} = \frac{r_1}{1-r_1}$ . And also for every  $k$ ,  $b_k^* = b_k = \left( \frac{\lambda}{\lambda + \mu_b} \right) \left( \frac{\mu_b}{\mu_b + \lambda} \right)^k$ ,

$c_k^* = c_k = \left( \frac{\lambda}{\lambda + \mu_v + \eta} \right) \left( \frac{\mu_v}{\lambda + \mu_v + \eta} \right)^k$  and  $d_0^* = d_0 = \left( \frac{\lambda \eta}{(\lambda + \mu_b)(\lambda + \eta + \mu_v)} \right)$ .

II. **GI / M / 1 / MWV**: When  $a = b = 1$ , the steady-state queue size probabilities coincide with the corresponding results of Baba (2005) by using the following relations.

$$\frac{A}{r} = \frac{-B_d}{r_1}, \quad -B_d = \frac{\eta}{\eta - (\mu_b - \mu_v)(1-r_1)} = \alpha \text{ and } \frac{Q_0}{r_1} = (1-r)\beta$$

where  $\beta = \frac{\eta - (\mu_b - \mu_v)(1-r_1)}{\eta - (\mu_b - \mu_v)(1-r)}$

4. NUMERICAL ANALYSIS

To demonstrate the influence of the system parameters on (i) the waiting line ( $L_q$ ), (ii) steady state queue size probabilities and (iii) the average number of customers waiting in the queue, when the system is in different states, we consider different distributions for the interarrival time are considered.

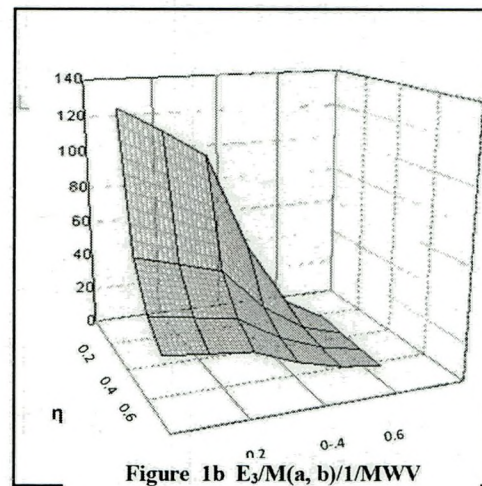
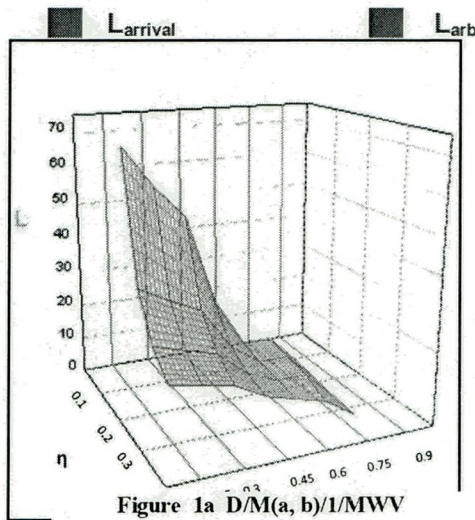
In Table 1, the mean queue size both at arbitrary epochs ( $L_{arb}$ ) and at pre-arrival epochs ( $L_{arrival}$ ) are presented for different values of the vacation parameter ( $\eta$ ) and vacation service rate ( $\mu_v$ ) corresponding to different interarrival time distributions (Erlang- $k = 1, 3, 5, 10$  and deterministic) to know how the expected queue length changes with the parameters. It is shown that

- (i) both  $L_{arb}$  and  $L_{arrival}$  decrease as  $\mu_v$  or  $\eta$  increases.
- (ii) The performance measures at arbitrary epoch and pre-arrival epochs coincide for Markovian interarrival time distribution.
- (iii) The smaller values of  $\eta$  significantly affect the queue size.
- (iv) When  $\mu_v = \mu_b$ , the queue length of working vacation model and classical non-vacation model coincide.

The graphical representation of the effect of  $\mu_v$  and  $\eta$  on the mean queue length ( $L_{arb}$ ) for Deterministic and Erlang-3 type inter arrival type can be seen in Figures 1a and 1b respectively.

Table 1 Expected queue size ( $L_{arrival}$  and  $L_{arb}$ ) with respect to  $\eta$  and  $\mu_v$   
 (a, b,  $\lambda$ ,  $\mu_b$ ,  $\rho_b$ ) = (5, 15, 7, 0.9, 0.5)

$\mu_v$	$\eta$	D/M(a, b)/1	M/M(a, b)/1	E <sub>3</sub> /M(a, b)/1	E <sub>5</sub> /M(a, b)/1	E <sub>10</sub> /M(a, b)/1
0.005	0.05	104.748	135.263	134.696	134.504	134.235
		71.232	135.264	134.942	134.832	134.678
	0.1	54.493	67.071	66.508	66.319	66.053
		38.583	67.071	66.750	66.642	66.488
	0.2	29.545	34.118	33.569	33.384	33.124
		22.219	34.118	33.804	33.699	33.549
0.050	0.05	94.139	122.801	122.225	122.031	121.759
		60.762	122.801	122.470	122.358	122.200
	0.1	49.584	61.328	60.761	60.570	60.301
		34.495	61.328	61.002	60.891	60.735
	0.2	27.449	31.665	31.124	30.939	30.679
		20.718	31.665	31.359	31.253	31.102
0.500	0.05	19.510	26.223	25.538	25.309	24.987
		15.834	26.223	25.770	25.618	25.405
	0.1	17.608	19.285	18.713	18.521	18.252
		14.387	19.285	18.938	18.821	18.658
	0.2	15.322	14.654	14.143	13.975	13.739
		12.742	14.654	14.362	14.267	14.134
0.900	0.05	7.130	9.382	9.000	8.872	8.694
		7.894	9.382	9.192	9.129	9.042
	0.1	7.130	9.382	9.000	8.872	8.694
		7.894	9.382	9.192	9.129	9.042
	0.2	7.130	9.382	9.000	8.872	8.694
		7.894	9.382	9.192	9.129	9.042



In Table 2, the values of the expected queue size at arbitrary and prearrival epochs are presented for different values of arrival rate  $\lambda$  and for different vacation service rates  $\mu_v$  for two

different values of regular service rate  $\mu_b$  for Erlang-3 interarrival distribution. The values show that mean queue size increases with the arrival rate  $\lambda$  and decreases as the service rate increases.

**Table 2 Mean queue size with respect to  $\lambda$  and  $\mu_v$  for  $\mu_b = 1$  and  $\mu_b = 1.5$**

$\lambda$	$\mu_v$	0.1	0.2	0.3	0.4	0.5
5	$\mu_b = 1$	34.508	24.641	17.238	12.381	9.390
		34.817	24.946	17.531	12.660	9.656
	$\mu_b = 1.5$	34.425	24.478	16.989	12.063	9.033
		34.729	24.779	17.276	12.336	9.290
6	$\mu_b = 1$	43.918	33.017	24.044	17.459	13.098
		44.233	33.332	24.348	17.754	13.382
	$\mu_b = 1.5$	43.663	32.697	23.638	16.967	12.541
		43.973	33.008	23.937	17.257	12.818
7	$\mu_b = 1$	53.727	42.085	31.916	23.758	17.862
		54.046	42.406	32.228	24.064	18.160
	$\mu_b = 1.5$	53.096	41.420	31.187	22.950	16.978
		53.411	41.737	31.495	23.250	17.270

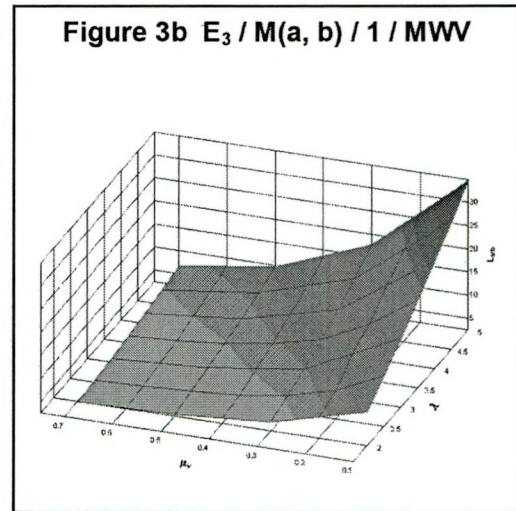
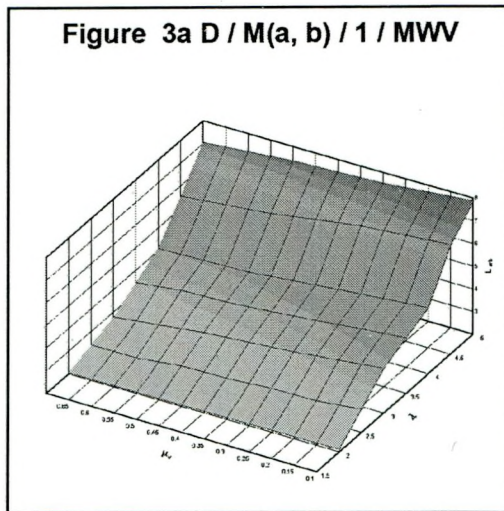
■ Prearrival epochs    ■ Arbitrary epochs

The influence of  $\lambda$  and  $\mu_v$  on the mean queue length at arbitrary epochs is graphically represented in Figures 3a and 3b for Deterministic and Erlang-3 inter arrival time distribution. Table 3 gives the data for the graphs.

**Table 3 Mean queue size with respect to  $\lambda$  and  $\mu_v$   
( $\mu_b, \eta, a, b$ ) = (0.9, 0.1, 5, 15)**

$\lambda$	$\rho_b$ \ $\mu_v$	0.1	0.3	0.5	0.7
2	0.15	2.106	2.088	2.062	2.047
		9.936	4.462	3.032	2.507
3	0.22	3.981	3.543	3.252	2.789
		17.411	7.654	4.661	3.485
4	0.29	4.916	4.573	4.211	4.101
		25.872	12.033	6.910	4.893
5	0.37	7.881	7.526	7.380	7.063
		34.950	17.713	9.873	6.736

■ D / M(a,b) / 1 / MWV    ■ E<sub>3</sub> / M(a, b) / 1 / MWV



### 5. CONCLUSION

In this paper, a Non Markovian bulk service queue GI/M(a,b)/1 is investigated using Embedded Markov chain technique and the steady state queue size probabilities at pre arrival epochs as well as arbitrary epochs are obtained and few existing models are proved as particular cases. The expected queue length is calculated numerically and presented graphically.

### ACKNOWLEDGEMENT

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**IMPACT OF EXCESSIVE TELEVISION VIEWING BY CHILDREN  
– AN ANALYSIS USING INTUITIONISTIC FUZZY SOFT MATRICES**

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**Abstract – Television being an effective medium of entertainment and communication attracts people of all ages. Television viewing has become the more important affair than any other in the daily routine. The influence of television on children causes great concern to the parents as excessive viewing by children results in physical, mental, behavioral, social and academic setbacks to younger generation. The concept of Intuitionistic fuzzy soft matrices is applied to identify the group of children (based on age) worst affected.**

**Keywords – Soft set, Fuzzy soft set, Intuitionistic Fuzzy soft Set, Intuitionistic fuzzy soft matrix.**

**Introduction**

Television, an effective medium of mass communication, plays a predominant role in the daily routine of the public. It is the first one to switch -on and the last one to switch - off in many houses. Though the taste differs based on the age of the viewer, all in the family are in the habit of viewing the programs of their taste. Monthly tariff, payable to the service provider for viewing TV programs, gains prime significance in the monthly budgets, irrespective of the level of income of the family. This indoor medium has multidimensional values. In addition to entertainment, matters relating to science and technology, social and cultural aspects, sports and games, economics and business, wild life and adventure and many more are telecasted. Viewing of such programs undoubtedly enrich wisdom of the people, especially the children. They are privileged to view and learn everything around the world. Many programs motivate and develop creativity among such younger generation.

It is quite natural that every coin has two sides. Though better exposure is the prime advantage, long time viewing is common in case of children. Such long time viewing of television programs by children not only causes health hazards to the children but also affects their overall performance in their academic activities. Many researchers observed that viewing programs that shows terror, horror, super power heroism, barbaric fights and so on has short term negative impact on their behavior. The researchers insisted that the parents should effectively supervise their children viewing television in terms of time of viewing and the programs to be viewed. Many research studies in India and abroad bring to light the prevalence of excessive viewing of television by children and its ill – effects on children. So the authors intended to identify the various problems encountered by the children, based on the opinion of the parents

regarding the ill - effects of excessive viewing of television and analyze the same using intuitionistic fuzzy soft matrices.

**Basic Definitions**

**Definition 1[2]** : Let  $U$  be a nonempty finite set of objects called universe and let  $E$  be a nonempty set of parameters. An ordered pair  $(F,E)$  is said to be a **soft set** over  $U$ , if  $F$  is a mapping from  $E$  to the set of all subsets of  $U$ .

**Definition 2[4]** : Let  $U$  be a universe. A fuzzy set  $X$  over  $U$  is a set defined by a function  $\mu_x$  representing a mapping  $\mu_x:U \rightarrow [0,1]$ . Here,  $\mu_x$  called membership function of  $X$ , and the value  $\mu_x(u)$  is called the grade of membership of  $u \in U$ . The value represents the degree of  $u$  belonging to the fuzzy set  $X$ . Thus, a **fuzzy set**  $X$  over  $U$  can be represented as follows,

$$X = \{(u/(\mu_x(u)):u \in U, \mu_x(u) \in [0,1]\}$$

**Definition 3[1]** : Let  $U$  be a universal set,  $E$  a set of parameters and  $A \subseteq E$ . Then a pair  $(F,A)$  is called **fuzzy soft set** over  $U$ , where  $F$  is a mapping from  $A$  to the set of all fuzzy subsets of  $U$ .

**Definition 4[3]** : An **intuitionistic fuzzy set**  $A$  in a non empty set  $U$  (a universe of discourse) is an object having the form  $A = \{x, \mu_A(x), \nu_A(x) : U \rightarrow [0,1]\}$ , where the functions  $\mu_A(x) : U \rightarrow [0,1]$ ,  $\nu_A(x) : U \rightarrow [0,1]$ , denotes the degree of membership and degree of non-membership of each element  $x \in U$  to the set  $A$ , respectively, and  $0 \leq \mu_A(x) + \nu_A(x) \leq 1$  for all  $x \in U$ .

Given an universal set  $U$  and a set of parameters  $E$ , for  $A \subseteq E$ , the pair  $(F, A)$  is called an **intuitionistic fuzzy soft set** over  $U$  if  $F$  is a mapping from  $A$  to the set of all Intuitionistic Fuzzy subsets of  $U$ .

**Definition 5[5]** : Let  $U = \{c_1, c_2, c_3 \dots c_m\}$  be the universal set and  $E = \{e_1, e_2, e_3 \dots e_n\}$  be the set of parameters. Let  $A \subseteq E$  and  $(F, A)$  be a intuitionistic fuzzy soft set in the fuzzy soft class  $(U, E)$ . Then intuitionistic fuzzy soft set  $(F,A)$  can be represented in matrix form as  $S_{m \times n} = [a_{ij}]_{m \times n}$  or  $S = [a_{ij}]$   $i = 1, 2, 3, \dots, m, j = 1, 2, 3, \dots, n$  where

$$a_{ij} = \begin{cases} (\mu_j(c_i), \nu_j(c_i)) & \text{if } e_j \in A \\ (0,1) & \text{if } e_j \notin A \end{cases}$$

Here  $\mu_j(c_i)$  represents the membership of  $c_i$  in the intuitionistic fuzzy set  $F(e_j)$  and  $\nu_j(c_i)$  represents the non-membership of  $c_i$  in the intuitionistic fuzzy set  $F(e_j)$ . The matrix  $S_{m \times n}$  is called **intuitionistic fuzzy soft matrix**. This matrix  $S$  can also be written as  $S = (\mu_A, \nu_A)$  or  $S = [(\mu_{ij}, \nu_{ij})]$ .

**Definition 6[5]** : Let  $A = [a_{ij}]_{m \times n}$  be an intuitionistic fuzzy soft matrix, where  $a_{ij} = (\mu_j(c_i), \nu_j(c_i))$ . Then we define the **value matrix** of intuitionistic fuzzy soft matrix  $A$  is  $V(A) = [a_{ij}] = [\mu_{ij} - \nu_{ij}]$   $i = 1, 2, \dots, m, j = 1, 2, \dots, n$ .

**Definition 7[5]** : If  $A = [a_{ij}]_{m \times n}, B = [b_{ij}]_{m \times n}$  be two intuitionistic fuzzy soft matrices, then we define **score matrix** of  $A$  and  $B$  as  $S_{(A,B)} = [d_{ij}]_{m \times n}$  where  $[d_{ij}] = V(A) - V(B)$ .

**Definition 8[5]** : Let  $A = [a_{ij}]_{m \times n}, B = [b_{ij}]_{m \times n}$  be two intuitionistic fuzzy soft matrices. Let the corresponding value matrices be  $V(A), V(B)$  and their score matrix is  $S_{(A,B)} = [d_{ij}]_{m \times n}$  then we define **total**

**score** for each  $c_i$  in  $U$  is  $S_i = \sum_{j=1}^n d_{ij}$ .

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### Algorithm for decision making method by using Intuitionistic Fuzzy soft matrices

Step 1 : Input the intuitionistic fuzzy soft set (F,C) and obtain the intuitionistic fuzzy soft matrix A corresponding to (F,C) respectively .

Step 2 : Write the intuitionistic fuzzy soft complement matrix  $A^c$  .

Step 3 : Compute  $V(A)$ ,  $V(A^c)$  and  $S_{((A), (A^c))}$  .

Step 4 : Compute the total score  $S_i$  for each  $u_i$  in U.

Step 5 : Find  $u_i$  for which  $\max (S_i)$ .

Incase  $\max S_i$  occurs for more than one value, then repeat the process by reassessing the parameters.

### Application of Intuitionistic fuzzy soft matrices

To ascertain the ill-effects of television viewing by the children, an interview schedule was administered to the parents and response was elicited regarding the behavioral changes of their children. Based on the pilot study the authors grouped the problems into 5 categories as follows:

1. Physical – Obesity , Eye problems and Food intake
2. Mental – Lack of Concentration , Depression and Feeling fear
3. Behavioral – Aggressive Behavior, Experiencing harmful practices and Avoiding outdoor games
4. Social – Not mingling with friends and relatives, Avoiding functions and festivals, Preferring to be lonely at home
5. Academic – Poor performance in tests and exams , Late to school and Frequent failure in completing home works .

The respondents were grouped into 5 categories based on the age of their children which forms the alternative set or universal set  $U = \{ u_1, u_2, u_3, u_4, u_5 \}$  and the categories of problems were used to form the criteria set  $C = \{ c_1, c_2, c_3, c_4, c_5 \}$ .

### Group of Respondents ( Universal set U )

( Based on age of children)

$u_1$  – 6 to 8 years

$u_2$  – 9 to 10 years

$u_3$  – 11 to 12 years

$u_4$  – 13 to 14 years

$u_5$  – 15 to 16 years

### Criteria Set C

$c_1$  - Physical

$c_2$  - Mental

$c_3$  - Behavioural

$c_4$  - Social

$c_5$  - Academic

In order to collect data an interview schedule was developed, pre-tested and administered to the respondents. A sample of 200 respondents (40 in each group) was selected adopting convenient sampling technique. Care was taken to include the parents of children of age group ranging between 6 years and 16 years and pursuing education in government, government aided and private schools in Coimbatore. Five point scaling technique ( Strongly Agree, Agree, Neither agree nor disagree, Disagree and Strongly disagree) was used and they were asked to respond based on the prevalence and intensity of each of the 5 categories of problems of their children.

The membership function and non – membership function was ascertained based on the response. The number of respondents who marked either “Strongly agree” or “Agree” was counted and its proportion to the total respondents of a particular group was used for framing membership function. In the same manner, the response under “ Disagree” or “Strongly disagree” was used for framing non-membership function.

Therefore the corresponding intuitionistic fuzzy soft set is

$$\begin{aligned}
 (F,C) &= \{F(c_1) = \{(u_1,0.5,0.4) (u_2,0.7,0.2) (u_3,0.8,0.1) (u_4,0.7,0.3) (u_5,0.6,0.3)\} \\
 &F(c_2) = \{(u_1,0.5,0.4) (u_2,0.6,0.4) (u_3,0.9,0.1) (u_4,0.8,0.2) (u_5,0.7,0.3)\} \\
 &F(c_3) = \{(u_1,0.6,0.4) (u_2,0.7,0.3) (u_3,0.9,0.1) (u_4,0.8,0.2) (u_5,0.8,0.2)\} \\
 &F(c_4) = \{(u_1,0.7,0.3) (u_2,0.8,0.2) (u_3,0.6,0.4) (u_4,0.5,0.4) (u_5,0.6,0.4)\} \\
 &F(c_5) = \{(u_1,0.8,0.2) (u_2,0.9,0.1) (u_3,0.7,0.3) (u_4,0.6,0.4) (u_5,0.6,0.3)\} \}
 \end{aligned}$$

Therefore the intuitionistic fuzzy soft matrix is

$$A = \begin{matrix} & \begin{matrix} c_1 & c_2 & c_3 & c_4 & c_5 \end{matrix} \\ \begin{matrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \end{matrix} & \left[ \begin{matrix} (0.5,0.4) & (0.5,0.4) & (0.8,0.2) & (0.7,0.3) & (0.6,0.4) \\ (0.7,0.2) & (0.6,0.4) & (0.9,0.1) & (0.8,0.2) & (0.7,0.3) \\ (0.6,0.3) & (0.7,0.3) & (0.6,0.3) & (0.6,0.4) & (0.8,0.2) \\ (0.7,0.3) & (0.8,0.2) & (0.6,0.4) & (0.5,0.4) & (0.8,0.2) \\ (0.8,0.1) & (0.9,0.1) & (0.7,0.3) & (0.6,0.4) & (0.9,0.1) \end{matrix} \right] \end{matrix}$$

Then the intuitionistic fuzzy soft complement matrix is

$$A^c = \begin{matrix} & \begin{matrix} c_1 & c_2 & c_3 & c_4 & c_5 \end{matrix} \\ \begin{matrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \end{matrix} & \left[ \begin{matrix} (0.4,0.5) & (0.4,0.5) & (0.2,0.8) & (0.3,0.7) & (0.4,0.6) \\ (0.2,0.7) & (0.4,0.6) & (0.1,0.9) & (0.2,0.8) & (0.3,0.7) \\ (0.3,0.6) & (0.3,0.7) & (0.3,0.6) & (0.4,0.6) & (0.2,0.8) \\ (0.3,0.7) & (0.2,0.8) & (0.4,0.6) & (0.4,0.5) & (0.2,0.8) \\ (0.1,0.8) & (0.1,0.9) & (0.3,0.7) & (0.4,0.6) & (0.1,0.9) \end{matrix} \right] \end{matrix}$$

c1 c2 c3 c4 c5

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$$V(A) = \begin{matrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \end{matrix} \begin{bmatrix} 0.1 & 0.2 & 0.6 & 0.4 & 0.2 \\ 0.5 & 0.2 & 0.8 & 0.6 & 0.4 \\ 0.3 & 0.4 & 0.3 & 0.2 & 0.6 \\ 0.4 & 0.6 & 0.2 & 0.1 & 0.6 \\ 0.7 & 0.8 & 0.4 & 0.2 & 0.8 \end{bmatrix}$$

$$V(A^c) = \begin{matrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \end{matrix} \begin{matrix} c_1 & c_2 & c_3 & c_4 & c_5 \\ \begin{bmatrix} -0.1 & -0.2 & -0.6 & -0.4 & -0.2 \\ -0.5 & -0.2 & -0.8 & -0.6 & -0.4 \\ -0.3 & -0.4 & -0.3 & -0.2 & -0.6 \\ -0.4 & -0.6 & -0.2 & -0.1 & -0.6 \\ -0.7 & -0.8 & 0.4 & -0.2 & -0.8 \end{bmatrix} \end{matrix}$$

$$S_{((A), (A^c))} = \begin{matrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \end{matrix} \begin{matrix} c_1 & c_2 & c_3 & c_4 & c_5 \\ \begin{bmatrix} 0.1 & 0.2 & 0.6 & 0.4 & 0.2 \\ 0.5 & 0.2 & 0.8 & 0.6 & 0.4 \\ 0.3 & 0.4 & 0.3 & 0.2 & 0.6 \\ 0.4 & 0.6 & 0.2 & 0.1 & 0.6 \\ 0.7 & 0.8 & 0.4 & 0.2 & 0.8 \end{bmatrix} \end{matrix} \quad \text{Total Score} = \begin{matrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \end{matrix} \begin{bmatrix} 2.8 \\ 4.0 \\ 3.6 \\ 3.8 \\ 5.8 \end{bmatrix}$$

It is seen that the last group  $u_5$  has the maximum score and it is concluded that the children in the age group of 15 to 16 years are worst affected.

### Conclusion

Excessive television viewing by children causes many problems to them. As total deprivation of children viewing television is also not advisable, parents need to supervise their children in terms of timing and channels. Such efforts will facilitate the children to watch and enjoy programs of their interest without possible ill effects. Application of intuitionistic fuzzy soft matrices to develop mathematical models, which helps to identify the most vulnerable group, is much helpful to parents and it is possible for them to take extra care while dealing with the children of that particular age group.

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