

Cost Analysis of Power Supply Queuing Model in Fuzzy Environment

Karm Jeet, Aabhas Kumar and S.S. Mishra*

Department of Mathematics and Statistics,

Dr. Rammanohar Lohia Avadh University Ayodhya, (U.P.), India

Corresponding Email: smssmishra5@gmail.com

(Received May 15, 2024, Accepted June 02, 2024)

Abstract: In this paper, we compute the total cost optimization for power supply queuing model with infinite servers in fuzzy environment. The objective of this research paper is to compute the optimal total-cost by establishing the total optimal cost function for the model system in fuzzy environment so as to present more realistic results of the queuing model to yield explicit result. Finally, sensitivity analysis of the model is provided by the mathematical demonstration of the model of queuing system. The model has wide applications in different areas including industry and manufacturing etc.

Keywords: Power Supply Queuing Model, Fuzzified Total Cost Function, Fuzzified Cost, Sensitivity Analysis.

MSC 2020: 90B22, 90C70

1. Introduction

Almaniotis and Alexiou¹ have developed a connection of fuzzy porous kettle and virtual barrier for big-scale socially powered solar energy in times of crisis in bright city zones. Aravind and Maddikunta² have studied solar energy well planned geographic facts that depend on optimum fuzzy linkage for internet of items. Chaleshigar et al.³ have examined the analysis of form lines systems and cost models governed unreliability. Chen et al.⁴ have studied a fuzzy command-satisfaction model for the justifiable evolution of voltaic automobiles in China terminated a three uniform facility chain.

Datta and Kumar⁵ have analyzed the fuzzy directory model for depletion of accumulation position and degenerating items. Fei and Liu⁶ have given actual time non-linear electric model prophetic control about actual power strainers with the advice based on my self response recurrent fuzzy nervous network calculator. Gaiffe et al.⁷ have established a fuzzy searching allocated

index as the very good about funneled water supply service facility inside a minimum income town surrounding by a complex. Grigorieva et al.⁸ have studied solar power supply patterns during performance adequacy analysis.

Guo et al.⁹ have developed an optimal path calculating method for solar vehicles taking through journal power supply. Homaei et al.¹⁰ have investigated an excellent distributed excess control pattern during the traditional 6LOPAN rules applying a fuzzy choice pattern. Hussain et al.¹¹ have studied adequacy improvement to electric instrument charging shell based on gracious fuzzy positive integer linear and bilinear programming. Jain and Sanga¹² have analyzed fuzzy price optimization by admission resistance for machine power supply reverse problem and re-examination crisis. Jiang et al.¹³ analyzed queuing on solar power methods of dual uncertainties by the efforts based on depository issues. Kumar¹⁵ studied optimum strategy as inventory models by demand costs within small move trapezoidal fuzzy surroundings. Kumar and Datta¹⁶ developed full excess limitations a decline inventory model, and alike spread random command.

Liu et al.¹⁷ have investigated the value of inventory construction system within a several ecological provide chain utilize fuzzy order predict and game theory. Mishra et al.¹⁸ have analyzed queuing modeling related to the banking. Mishra et al.¹⁹ have studied the optimization based on fuzzy solvent order capacity models of full inventory and allowing humiliation. Mittal and Sharma²⁰ have investigated the customising and queuing theory based on communication webs belonging fuzzy environments. Mohammed et al.²¹ have developed a stochastic power control framework of fuzzy PDMM for sharp grid cognition power storage methods and blest park. Muoz and Ruspini²² have conducted a study using fuzzy queuing theory towards examined the effect based on electric cars on electricity webs.

Narayanan and Tamil Selvan²³ have presented triangle- shap fuzzified assist vector return based on manyviate circle robust improve categorising as traffic and blocking conscious of data carriage in WSNs. Pourmohammadi et al.²⁴ have explained the solar energy systematic bright home warm up methods away answer the hub situation implanted problem besides a queuing system amenable social authority through a fuzzy suggests- searching algorithm. Ramesh and Seenivasan²⁵ have established the practicability of fuzzy queuing model by an fickle electric transformer. Singh et al.²⁶ have conducted an logical analysis based on fuzzified queuing method and irritated customers. Shavarani et al.²⁷ have studied a blockage potential several scale fuzzy space location difficulty aside an efficient couch delivery technique. Simon and Santa²⁸ have explained energy well planned bright

home heating technique using continuous electric source by fuzzy blockage design.

Shelke et al.²⁹ have analyzed crisis vehicles and fuzzy order based sharp traffic blockage restrictions based on congestion- receptive routing technique. Thakur et al.³⁰ have explained value optimization for order vehicle utilize leave and Markovian chain. Wang et al.³¹ have developed a series based on best technique and web process through association to perfect solution application and conducted a combined fuzzy inspection being solid misuse through energy plant place selection within Vietnam. Wang et al.³² have provided a atypical Stackelberg game conceptual optimization system for the interactivity between two exclusive loop transfer queues by a queuing proposal. Zhao et al.³³ have studied adequacy planning as an solar vehicle charging point appreciation several charging options by unclear quality based on service. Zhou et al.³⁴ have investigated a modern fuzzy many criteria conclusion making application as the production analysis and assessment based on a set scale unified energy technique.

In this paper, an attempt is made to discuss the power supply model. The queue model in its real state with one or more parameters known uncertainly is subjected to optimization which leads to designing and controlling the queue model in fuzzy environment as these are its functions. Here, we discuss the cost of power supply queue model with infinite servers in fuzzy environment by fuzzification of parameters by suitable fuzzy sets, evaluation of some fuzzy operations and defuzzification by signed distance method and then optimization and computing. Our aim is to construct the total cost function in fuzzy environment and subject it to optimization. These mathematical calculations form the non-linear equation, which is solved to get the optimal total cost of the proposed queue system with the help of its optimal performance measurement R-software. Finally, sensitivity analysis is presented with the help of numerical demonstration of the model.

2. Preliminaries

Definition 2.1: $\tilde{B} = (c, d, e, f)$ is representing fuzzy trapezoidal number with membership function $\mu_{\tilde{B}}$ as:

$$\mu_{\tilde{B}}(y) = \begin{cases} R(y) = \frac{y-c}{d-c}, & \text{if } c \leq y \leq d \\ L(y) = \frac{f-y}{f-e}, & \text{if } e \leq y \leq f \\ 1 & , \text{if } d \leq y \leq e \\ 0 & , \text{otherwise} \end{cases}$$

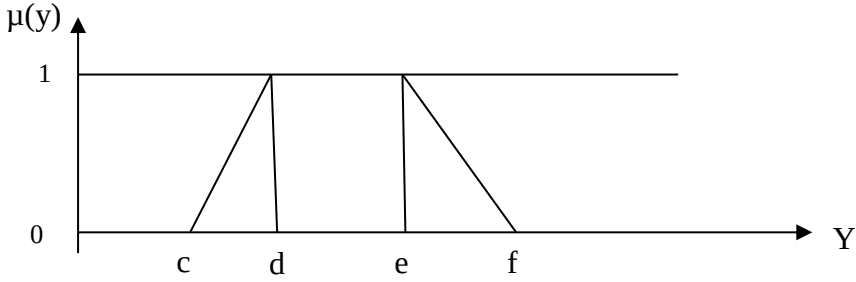


Fig 1: Graph b/w membership function $\mu_{\tilde{B}}(y)$ and the trapezoidal fuzzy number's

Definition 2.2: If the constants $p > 0$ & $q > 0$ together membership-function with respect to functions R for right as well as L for left. Fig. 1 plot the Graph between $\tilde{B}$ and $\mu_{\tilde{B}}(y)$, then $\tilde{B}$ is noted in RL system

$$\mu_{\tilde{B}}(y) = \begin{cases} R\left(\frac{y-\delta}{q}\right) & \text{if } y \geq \delta \\ L\left(\frac{\gamma-y}{p}\right) & \text{if } y \leq \gamma \\ 1, & \text{if } \gamma \leq y \leq \delta \\ 0 & , \text{otherwise} \end{cases}$$

The "Right" expansion represents p and "left" expansion represents q respectively. In this condition γ is a real number, this represents the mean cost of $\tilde{B}$. The R & L is a mapping $R^+ \rightarrow [0, 1]$, this is decreasing in RL pattern fuzzy number is expressed in the form $\tilde{B} = (\gamma, \delta, p, q)_{RL}$.

Definition 2.3: Let $\tilde{B}$ is fuzzy set is defined on R . Then the signed-distance of $\tilde{B}$ is explained in the form $d(\tilde{B}, 0) = \frac{1}{2} \int_0^1 [B_L(\beta) + B_R(\beta)] d\beta$, where $B_\beta = [B_L(\beta), B_R(\beta)] = [G + (H - G)\beta, J - (J - I)\beta]$, $\beta \in [0, 1]$, is a fuzzy set $\tilde{B}$, it is close interval.

3. Notations & Assumptions

The following notations & assumptions are used in this paper.

3.1 Notations:

k = number of customers for the system.

m = Cost of service rate per unit.

b = No of customers supply the electric circuit.

n = Cost of waiting customers rate per unit time.

$E(k)$ = Average no's of customers for the system.

λ = Arrival rate.

μ = Service rate .

μ^* = Optimal service rate for customers.

$\tilde{\lambda}$ = Fuzzified arrival rate of customers.

$\tilde{\mu}$ = Fuzzified cost of waiting rate per unit time.

P_0 = Steady state probability for the system being empty.

TC = Total Cost.

$\widetilde{TC}$ = Fuzzified total optimal cost

$[\widetilde{TC}]_{ds}$ = Defuzzified price for Fuzzified price of fuzzy no Tc (By S.D. rule)

3.2 Assumptions:

The power supply model has assumptions:

- (i) Arriving customers that follow Poisson distribution & service time that follows an exponential distribution.
- (ii) The evaluation along with the methods of model building and working considers a queuing system in which a single power plant supplies electricity to a number of machinery.
- (iii) The model helps in understanding issues such as the scheduled capacity of the resources that operate the system, downtime, maintenance of machines and lead times.
- (iv) Based on these approaches, repairs are added to the queue when machines break down.
- (v) The queuing model includes many useful factors of performance - such as order of time, service utility factor, the estimated number of customers waiting in queue, the need number of clients with the waiting time required by the system in the line busy time or technique and service discharge factors.
- (vi) Most studies describe operational characteristics, yet there is a dearth of studies on this topic.

4. Cost Analysis

Total cost is defined as $TC = m k \mu + n E(k)$

$$TC = m\mu + n \left[b \frac{\lambda}{\mu} + \frac{(b^2 - b)}{2!} \frac{\lambda^2}{\mu^2} + \frac{b(b-1)(b-2)}{6} \left(\frac{\lambda}{\mu} \right)^3 + \dots \right] P_0 ,$$

where $E(k)$ = average no of customers for the system

m = price of service rate in per section

n = price of queue rate in per section.

4.1. Computational formula in crisp environment:

The power supply model contains infinite service point of the model with infinite storage. Therefore TC is given below

$$TC = m k \mu + n \left[b \frac{\lambda}{\mu} + \frac{(b^2 - b)}{2!} \frac{\lambda^2}{\mu^2} + \dots \right] P_0$$

Taking sum of first term $TC = m k \mu + n b \frac{\lambda}{\mu} P_0$

Putting particular value's of $P_0 = 1$, TC is given by $TC = m k \mu + n b \frac{\lambda}{\mu}$.

For minimum cost, we have

$$\frac{d(TC)}{d\mu} = mk - nb \frac{\lambda}{\mu^2} \text{ with } \frac{d^2(TC)}{d\mu^2} = 2b \frac{\lambda}{\mu^3} \text{ it implies that } \frac{d^2(TC)}{d\mu^2} \geq 0.$$

4.2. Computational formula in fuzzy environment:

Again, we subject the model system in fuzzy environments. We find the fuzzified cost with arrival rate m , n , λ with the help of trapezoidal fuzzy numbers as $\tilde{m}$, $\tilde{n}$, $\tilde{\lambda}$ respectively.

We have $\tilde{k} = (k_1, k_2, k_3, k_4)$, $\tilde{m} = (m_1, m_2, m_3, m_4)$, $\tilde{n} = (n_1, n_2, n_3, n_4)$, $\tilde{\lambda} = (\lambda_1, \lambda_2, \lambda_3, \lambda_4)$, $\tilde{b} = (b_1, b_2, b_3, b_4)$.

$$\begin{aligned} \widetilde{TC} &= \tilde{m} \tilde{k} \mu + \tilde{n} \tilde{b} \frac{\tilde{\lambda}}{\mu} \\ \widetilde{TC} &= [(m_1, m_2, m_3, m_4)(k_1, k_2, k_3, k_4) \mu \\ &\quad + (b_1, b_2, b_3, b_4)(n_1, n_2, n_3, n_4) \left(\frac{(\lambda_1, \lambda_2, \lambda_3, \lambda_4)}{\mu} \right)] \end{aligned}$$

After solving, we get

$$\begin{aligned} \widetilde{TC} &= \left(m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu}, m_2 k_2 \mu + b_2 \frac{n_2 \lambda_2}{\mu}, m_3 k_3 \mu + b_3 \frac{n_3 \lambda_3}{\mu}, m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu} \right) \\ \widetilde{TC} &= (G, H, I, J), \end{aligned}$$

where $G = m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu}$, $H = m_2 k_2 \mu + b_2 \frac{n_2 \lambda_2}{\mu}$, $I = m_3 k_3 \mu + b_3 \frac{n_3 \lambda_3}{\mu}$, $J = m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu}$.

Again, we find defuzzified value of the fuzzy number $\widetilde{TC}$ by applying the signed-distance technique.

$$(1) \quad [\widetilde{TC}]_{ds} = \frac{1}{2} \int_0^1 [B_L(\beta) + B_R(\beta)] d\beta.$$

Again, the β -cuts, $B_L(\beta)$ & $B_R(\beta)$ the trapezoidal fuzzy number TC are given by $B_L(\beta) = G + (H - G)\beta$

$$B_L(\beta) = (m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu}) + [(m_2 k_2 \mu + b_2 \frac{n_2 \lambda_2}{\mu}) - (m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu})] \beta$$

It implies that

$$B_L(\beta) = (m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu}) + \left[(m_2 k_2 - m_1 k_1) \mu + (n_2 \lambda_2 b_2 - n_1 \lambda_1 b_1) \frac{1}{\mu} \right] \beta$$

Similarly for $B_R(\beta) = J - (J - I)\beta$

$$B_R(\beta) = (m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu}) - [(m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu}) - (m_3 k_3 \mu + b_3 \frac{n_3 \lambda_3}{\mu})] \beta$$

$$B_R(\beta) = (m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu}) - \left[(m_4 k_4 - m_3 k_3) \mu + (n_4 \lambda_4 b_4 - n_3 \lambda_3 b_3) \frac{1}{\mu} \right] \beta$$

Putting the value of $B_L(\beta)$ & $B_R(\beta)$ in equation (1), we have

$$\begin{aligned} [\widetilde{TC}]_{ds} &= \frac{1}{2} \int_0^1 \left[\left(m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu} \right) + \left[(m_2 k_2 - m_1 k_1) \mu + (n_2 \lambda_2 b_2 - n_1 \lambda_1 b_1) \frac{1}{\mu} \right] \beta + \left(m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu} \right) \right. \\ &\quad \left. - \left[(m_4 k_4 - m_3 k_3) \mu + (n_4 \lambda_4 b_4 - n_3 \lambda_3 b_3) \frac{1}{\mu} \right] \beta \right] d\beta \\ [\widetilde{TC}]_{ds} &= \frac{1}{2} \left[\left(m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu} \right) + [(m_2 k_2 - m_1 k_1) \mu + (n_2 \lambda_2 b_2 - n_1 \lambda_1 b_1) \frac{1}{\mu}] + \left(m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu} \right) \right. \\ &\quad \left. - \left[(m_4 k_4 - m_3 k_3) \mu + (n_4 \lambda_4 b_4 - n_3 \lambda_3 b_3) \frac{1}{\mu} \right] \left(\frac{\beta^2}{2} \right)_0^1 \right] \\ [\widetilde{TC}]_{ds} &= \frac{1}{2} \left[\left(m_1 k_1 \mu + b_1 \frac{n_1 \lambda_1}{\mu} \right) + \frac{1}{2} [(m_2 k_2 - m_1 k_1) \mu + (n_2 \lambda_2 b_2 - n_1 \lambda_1 b_1) \frac{1}{\mu}] + \left(m_4 k_4 \mu + b_4 \frac{n_4 \lambda_4}{\mu} \right) \right. \\ &\quad \left. - \frac{1}{2} \left[(m_4 k_4 - m_3 k_3) \mu + (n_4 \lambda_4 b_4 - n_3 \lambda_3 b_3) \frac{1}{\mu} \right] \right] \\ [\widetilde{TC}]_{ds} &= \frac{1}{4} [m_1 k_1 + m_2 k_2 + m_3 k_3 + m_4 k_4] \mu \\ &\quad + \frac{1}{4\mu} [n_1 \lambda_1 b_1 + n_2 \lambda_2 b_2 + n_3 \lambda_3 b_3 + n_4 \lambda_4 b_4] \end{aligned}$$

Again, differentiating w.r.t. μ , we get

$$\begin{aligned} \frac{d[\widetilde{TC}]_{ds}}{d\mu} &= \frac{1}{4} \left[(m_1 k_1 + m_2 k_2 + m_3 k_3 + m_4 k_4) - \frac{(n_1 \lambda_1 b_1 + n_2 \lambda_2 b_2 + n_3 \lambda_3 b_3 + n_4 \lambda_4 b_4)}{\mu^2} \right] \end{aligned}$$

For minimum defuzzified total cost $\frac{d[\widetilde{TC}]_{ds}}{d\mu} = 0$ with $\frac{d^2[\widetilde{TC}]_{ds}}{d\mu^2} \geq 0$, we get

$$\frac{1}{4} (m_1 k_1 + m_2 k_2 + m_3 k_3 + m_4 k_4) - \frac{1}{4} \frac{(n_1 \lambda_1 b_1 + n_2 \lambda_2 b_2 + n_3 \lambda_3 b_3 + n_4 \lambda_4 b_4)}{\mu^2} = 0$$

with

$$\frac{d^2}{d\mu^2} [\widetilde{TC}]_{ds} = \frac{1}{4} \frac{(n_1 \lambda_1 b_1 + n_2 \lambda_2 b_2 + n_3 \lambda_3 b_3 + n_4 \lambda_4 b_4)}{\mu^3} \geq 0$$

$$\text{and } \frac{1}{4} (m_1 k_1 + m_2 + m_3 + m_4) - \frac{1}{4} \frac{(n_1 \lambda_1 b_1 + n_2 \lambda_2 b_2 + n_3 \lambda_3 b_3 + n_4 \lambda_4 b_4)}{\mu^2} = 0.$$

It implies that

$$(m_1 + m_2 + m_3 + m_4)\mu^2 - (n_1 \lambda_1 b_1 + n_2 \lambda_2 b_2 + n_3 \lambda_3 b_3 + n_4 \lambda_4 b_4) = 0.$$

This is general defuzzified non-linear equation for the power supply queuing model.

5. Non-linear equations

Upon observing numerical values of k , b , λ , m and n , we get some non-linear equations in μ for some different cases.

For case I, we get

$$750\mu^2 - 16800 = 0, 810\mu^2 - 16800 = 0, 870\mu^2 - 16800 = 0, 930\mu^2 - 16800 = 0.$$

For case II, we get

$$3584\mu^2 - 60960 = 0, 3584\mu^2 - 63760 = 0, 3584\mu^2 - 66560 = 0, 3560\mu^2 - 69360 = 0.$$

For case III, we get

$$3584\mu^2 - 60960 = 0, 3548\mu^2 - 60960 = 0, 4112\mu^2 - 60960 = 0, 4376\mu^2 - 60960 = 0.$$

For case IV, we get

$$3584\mu^2 - 60960 = 0, 3584\mu^2 - 68912 = 0, 3584\mu^2 - 76864 = 0, 3584\mu^2 - 84816 = 0.$$

6. Computational flow chart

We develop the computational flow chart in fuzzy environment as in fig 2.

Table 1: Calculation table for λ & TC

Case -I	b	k	m	n	λ	μ	TC
	40	30	25	20	21	4.73	7099
	40	30	27	20	21	4.55	7377
	40	30	29	20	21	4.39	7646
	40	30	31	20	21	4.25	7905

Table 2: Computation table for $\tilde{b}$ & $\tilde{TC}$

Case -II	$\tilde{b}$	$\tilde{k}$	$\tilde{m}$	$\tilde{n}$	$\tilde{\lambda}$	μ^*	$\tilde{TC}$
	(40,42,44,46)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(12,14,16,18)	4.13	7390
	(42,44,46,48)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(12,14,16,18)	4.22	7558
	(44,46,48,50)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(12,14,16,18)	4.31	7722
	(46,48,50,52)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(12,14,16,18)	4.40	7883

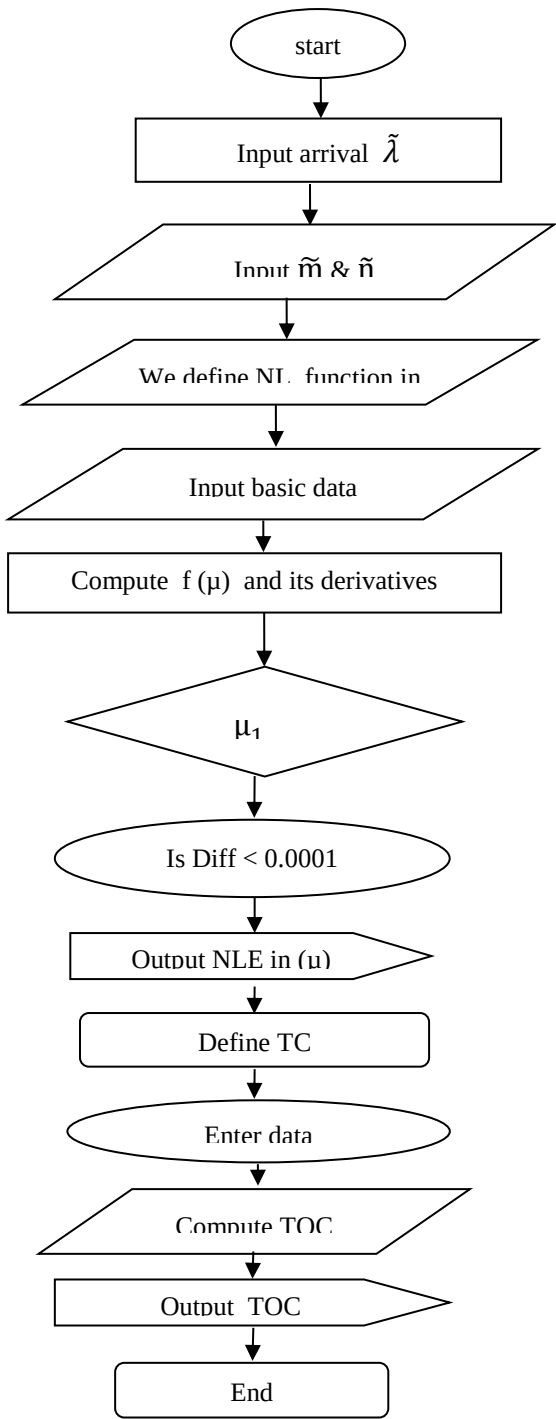


Fig 2: Computational flow chart

Table 3: Computation table for $\tilde{m}$ & $\tilde{TC}$

Case	$\tilde{b}$	$\tilde{k}$	$\tilde{m}$	$\tilde{n}$	$\tilde{\lambda}$	μ^*	$\tilde{TC}$
-III	(40,42,44,46)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(12,14,16,18)	4.13	7390
	(40,42,44,46)	(30,32,34,36)	(26,28,30,32)	(20,22,24,26)	(12,14,16,18)	3.98	7658
	(40,42,44,46)	(30,32,34,36)	(28,30,32,34)	(20,22,24,26)	(12,14,16,18)	3.85	7916
	(40,42,44,50)	(30,32,34,36)	(30,32,34,36)	(20,22,24,26)	(12,14,16,18)	3.73	8166

Table 4: Computation table for $\tilde{\lambda}$ & $\tilde{TC}$

Case	$\tilde{b}$	$\tilde{k}$	$\tilde{m}$	$\tilde{n}$	$\tilde{\lambda}$	μ^*	$\tilde{TC}$
-IV	(40,42,44,46)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(12,14,16,18)	4.13	7390
	(40,42,44,46)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(14,16,18,20)	4.39	7558
	(40,42,44,46)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(16,18,20,22)	4.63	7722
	(40,42,44,46)	(30,32,34,36)	(24,26,28,30)	(20,22,24,26)	(18,20,22,24)	4.87	7883

Table 5: Service cost vs total optimum fuzzified cost

Case-V	Service cost	Total optimal fuzzified cost
	25	7390
	27	7658
	29	7916
	31	8166

7. Sensitivity Analysis

Table 1 represents that if the arrival rate increases, the total cost increases. Total cost increases if number of customers supply in the model increases in fuzzy environment, it is evident from table 2. The total optimal cost of the power supply queuing model increases in table 3 if per section service rate increases. Table 4 shows total fuzzified cost increases, if arrival rate per unit increases. Finally if service cost increases in crisp and fuzzy both environment, it is clear that total cost is near about same in both environment. Total cost increases in fuzzy environment if service cost/unit increases in crisp environment, it represents in table 5.

8. Conclusion

During the analysis of the present paper, we have proposed a model of queue for providing services to customers in fuzzy environment which is valid even when the observation is beyond our capability. To compute the total optimal cost while customers are queued in fuzzy environment. The results of the model have been exhibited in table 1 to 6. If we extend our model to fuzzy environment, then we can get a lot more applications along with the

uncertainty aspects. By building the power supply model for fuzzy environment, all the researchers are likely to establish a more valuable resource for alternative information collection and reliable conclusions. This power supply model is more helpful for building more efficient system for arrival management, pricing, staffing requirements and diagnosis, quality of facilities, customer waiting time and serving maximum number of customers, among other things. This model can further be used in manufacturing operations to implement operations management systems for inventory management and scheduling at locations where queue are clearly formed to serve customers.

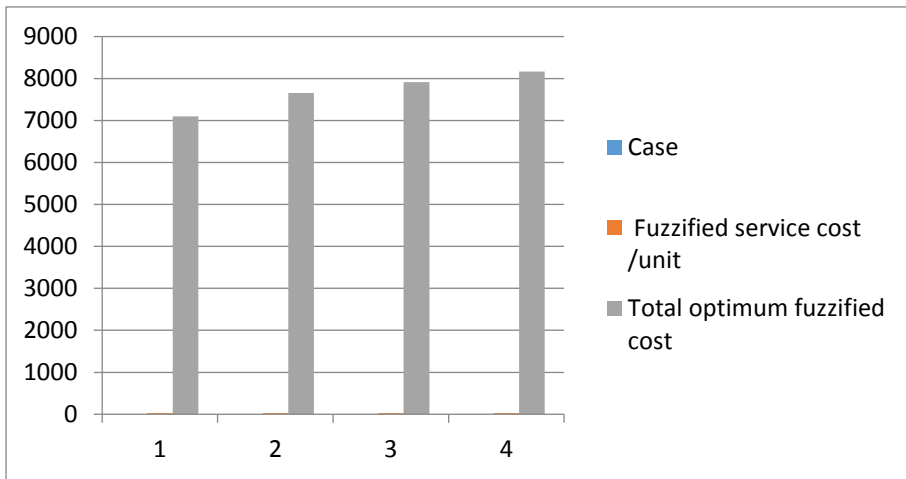


Fig 3: Service cost per unit time v/s fuzzified total cost

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