

Cost Computation of Machine Repairman Queueing Model in Fuzzy Environment

Aabhas Kumar, Karm Jeet 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: Machine repairman queueing model is a mathematical structure used to analyse system where machine occasionally fail and require repair. This paper focuses on cost analysis of machine repairman queueing model in fuzzy environment to provide more realistic results as compared to crisp environment. Optimal service and optimal total cost as important operating characteristics of the model have been obtained in the paper. Sensitivity analysis and graphical representation of the model have been presented to gain better insight of the model.

Keywords: Queueing model, Machine repairman, Fuzzy environment, Cost function, Sensitivity Analysis.

MSC 2020: 90B22, 90C70

1. Introduction

The fuzzified cost analysis of the model of M/M/R/N is a comprehensive approach which combines fuzzy logic and using queueing-theory to assess a queueing system with numerous servers and a finite buffer size's cost-effectiveness. This analysis considers the uncertain and imprecise nature of real-world queueing system by introducing fuzzy sets and membership function. It provides a more accurate representation of system performance and cost by incorporating linguistic variables and subjective judgments. This approach enables decision-makers to optimize resource allocation, improve service quality and enhance overall operational efficiency in complex queueing environments. Now, machines are a major component of our routine activities as we need them to produce, manufacture and improve the things. It is understood that machines are never completely reliable anything can cause a breakdown. Because of its potential use the 'machine repair problem' (MRP) in the real world attracted much attention and we take the broken

machinery to the maintenance facility for repair. The first concept introduced by Zadeh¹ is fuzzy set and the traditional concept of set permits components to have varying degrees of membership is developed by Zadeh². The researcher was very interested in fuzzy set theory. A vague decision-making model surrounded by ambiguous elements suggested by Jain³. Dubois *et al.*⁴ described several activities thereafter in 1978 with fuzzy numbers. The use of fuzzy sets in operational-research was explored by Zimmerman⁵. A few scholars started using fuzzy set theory to management-related inventory problems. Ecker *et al.*⁶ have been developed an introduction to operations research. Swarup *et al.*⁷ have been discussed operation research. Park⁸ proposed the economic quantity of orders inventory problem, a fuzzy set theory-based model is applied. Dutta *et al.*⁹ created an item-specific fuzzy inventory framework that deteriorate with limitations in completely circumstances with backlogs in 2013. Some pertinent articles have also been examined; vide Mishra *et al.*¹⁰⁻¹⁴, Meena *et al.*¹⁵ created a harmony search and fuzzy-simulation optimization for a grinding system requiring regular maintenance, hack up assistance and holiday. Also Singh *et al.*¹⁶, discussed optimization of Markovian arrival and service queuing model under fuzziness. Refaie *et al.*¹⁷ developed an optimum fuzzy repairs planning and failure type sequencing across numerous periods. Sanga *et al.*¹⁸⁻¹⁹ created the machine repair issue involving retrial under admission F-policy control may be modeled fuzzy and its cost optimized as well as employing balking. A chronological review of the literature reveals that our earlier researchers only partially attempted the Fuzzified cost analysis of the machine repairman model.

In the present paper, we propose the cost analysis of M/M/R/N queueing model of machine repairman in fuzzy environment. Fuzzified cost analysis of such model provides more realistic measures of performance of queueing models as compared to crisp queueing models, leading to advancement of results of the queueing model under consideration. In fuzzy environment, optimal total cost of queueing model of machine repairman has been obtained by applying computational approach to non-linear equation developed through the mathematical process of defuzzification by using singed distance method and subjecting it to the optimization. Sensitivity analysis and graphical representation of the model have been presented to receive substantial gain and insight about the model.

2. Fuzzy Definitions

Definition 2.1: A trapezoidal fuzzy number $\tilde{A} = (p, q, r, s)$ is representing with membership function $\mu_{\tilde{A}}$ as:

$$\mu_{\tilde{A}}(x) = \begin{cases} L(x) = \frac{x-p}{q-p}, & p \leq x \leq q \\ 1, & q \leq x \leq r \\ R(x) = \frac{s-x}{s-r}, & r \leq x \leq s \\ 0, & \text{otherwise} \end{cases}$$

Definition 2.2: If there are scalars $m>0$ and $n>0$ with membership function, as well as reference functions L for left and R for right, then a fuzzy set is

termed in LR-Form $\mu_{\tilde{A}}(x) = \begin{cases} L\left(\frac{\sigma-x}{m}\right), & \text{for } x \leq \sigma \\ 1, & \text{for } \sigma \leq x \leq \gamma \\ R\left(\frac{x-\gamma}{n}\right), & \text{for } x \geq \gamma \end{cases}$

The terms "left" and "right spread" refers to m and n , respectively, in the case when σ is a real number that represents the mean value of $\tilde{A}$. The function L and R map $R^+ \rightarrow [0,1]$, and are decreasing a LR-Type fuzzy number can be represented as $\tilde{A}=(\sigma, \gamma, m, n)_{LR}$

Definition 2.3: Let $\tilde{A}$ be a fuzzy set defined on R . Then the signed distance of $\tilde{A}$ is defined as $d(\tilde{A}, 0) = \frac{1}{2} \int_0^1 [A_L(\alpha) + A_R(\alpha)] d\alpha$, where $A_\alpha = [A_L(\alpha), A_R(\alpha)] = [A + (B - A)\alpha, D - (D - C)\alpha]$, $\alpha \in [0,1]$, is a fuzzy set $\tilde{A}$, which is close interval.

3. Notations

Following Notations and Assumptions are given as under:

TC = Optimal total cost.

η = Cost of service rate per unit.

ω = Cost of waiting rate per unit time.

$E(n)$ = Average number of customer in the system.

λ = Arrival rate of customer

μ = Service rate

μ^* = Optimal service rate

$\tilde{\eta}$ = Fuzzified Cost of service rate per unit.

$\tilde{\omega}$ = Fuzzified Cost of waiting rate per unit time.

$\tilde{\lambda}$ = Fuzzified Arrival rate of customer

$\tilde{TC}$ = Fuzzified Optimal total cost.

$[\tilde{TC}]_{dc}$ = The defuzzified value of Fuzzified value of fuzzy number (signed distance methods)

4. Assumptions

Following assumptions are given as:

- (i) The queuing model makes assumptions about the Poisson distribution of client arrival and the exponential distribution of service times.
- (ii) Model creation and evaluation consider the queueing system, in which a single repairman serves many machines. It aids in comprehending issues such as system downtime, maintenance timeframes and resource allocation efficiency.
- (iii) In these approaches, the machine causes failures and joins a repair queue. The queueing model has numerous operational features or measures of performance, including the anticipated number of customers waiting in line and the systems expected number of customers in line and the system expected waiting time in queue, as well as the busy time or system and service use factor. The bulk of studies describe operation features, yet there is a paucity of study on the subject.

5. Mathematical Model

Cost function is defined by $TC = K_1\mu + K_2E(n)$ for the repairman model M/M/R/N Let

$$\lambda_n = \begin{cases} (k-n)\lambda & \text{if } 0 \leq n \leq N \\ 0 & \text{if } n \geq N \end{cases} \quad \text{And } \mu_n = \begin{cases} n\mu & \text{if } 0 \leq n \leq N \\ R\mu & \text{if } n \geq N \\ 0 & \text{if } n > N \end{cases}$$

This model describes a queueing system in which there are R service channels and the maximum limits on incoming customer say N fixed .

Now, we obtain the total cost in different cases of service rates.

6. Crisp Mathematical Formulation

In this section, we define total cost function is denoted by TC and is defined by $TC = \eta n\mu + \omega E(n)$ the repairman model M/M/R/N contains R servers and the model's maximum capacity is constrained by N. Now TC is given by

$$TC = \eta n\mu + \omega \left[P_0 \sum_{n=0}^{R-1} n \binom{N}{n} \left(\frac{\lambda}{\mu}\right)^n + P_0 \frac{1}{R!} \sum_{n=R}^N n \binom{N}{n} \frac{n!}{R^{(n-R)}} \left(\frac{\lambda}{\mu}\right)^n \right],$$

this case is valid for $0 \leq n \leq N$

Taking first term,

$$TC = \eta n\mu + \omega \left[P_0 \frac{1}{R!} R \binom{N}{R} \frac{R!}{R^{(R-R)}} \left(\frac{\lambda}{\mu}\right)^R \right], \text{ and finally gives us}$$

$$TC = \eta n \mu + P_0 \omega \left[R \binom{N}{R} \left(\frac{\lambda}{\mu} \right)^R \right]$$

For putting particular values of $R=1$, $n=5$, $N=15$, $P_0 = 0.105$, TC is given by

$$TC = 5\eta\mu + 0.105\omega \left[15 \left(\frac{\lambda}{\mu} \right) \right]$$

For minimum cost, we must have

$$\frac{d}{d\mu} TC = 5\eta - 1.575\omega \frac{\lambda}{\mu^2} = 0 \quad \text{with} \quad \frac{d^2}{d\mu^2} TC = \frac{1.575\omega\lambda}{\mu^3} > 0.$$

7. Fuzzy Mathematical Model

Now, we consider the model in fuzzy environments we wish to fuzzify cost coefficients and arrival rate η , ω , λ with the help of trapezoidal fuzzy number as $\tilde{\eta}$, $\tilde{\omega}$, $\tilde{\lambda}$ respectively. We have

$$\tilde{\eta} = (\eta_1, \eta_2, \eta_3, \eta_4), \quad \tilde{\lambda} = (\lambda_1, \lambda_2, \lambda_3, \lambda_4), \quad \tilde{\omega} = (\omega_1, \omega_2, \omega_3, \omega_4),$$

$$\widetilde{TC} = 5\tilde{\eta}\mu + 1.575\tilde{\omega} \left(\frac{\tilde{\lambda}}{\mu} \right)$$

$$\widetilde{TC} = 5(\eta_1, \eta_2, \eta_3, \eta_4)\mu + 1.575(\omega_1, \omega_2, \omega_3, \omega_4) \left(\frac{(\lambda_1, \lambda_2, \lambda_3, \lambda_4)}{\mu} \right).$$

This implies that

$$\widetilde{TC} = 5(\eta_1\mu, \eta_2\mu, \eta_3\mu, \eta_4\mu) + 1.575 \left(\frac{\omega_1\lambda_1}{\mu}, \frac{\omega_2\lambda_2}{\mu}, \frac{\omega_3\lambda_3}{\mu}, \frac{\omega_4\lambda_4}{\mu} \right),$$

which simplified as

$$\widetilde{TC} = \left(5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu}, 5\eta_2\mu + \frac{1.575\omega_2\lambda_2}{\mu}, 5\eta_3\mu + \frac{1.575\omega_3\lambda_3}{\mu}, 5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu} \right)$$

$$\widetilde{TC} = (A, B, C, D),$$

$$\text{where } A = 5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu}, B = 5\eta_2\mu + \frac{1.575\omega_2\lambda_2}{\mu}, C = 5\eta_3\mu + \frac{1.575\omega_3\lambda_3}{\mu},$$

$$D = 5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu}.$$

The defuzzified value of the fuzzy number $\widetilde{TC}$, obtained by applying the signed distance technique.

$$[\widetilde{TC}]_{ds} = \frac{1}{2} \int_0^1 [A_L(\alpha) + A_R(\alpha)] d\alpha$$

Now the α -cuts of the trapezoidal fuzzy number TC , $A_L(\alpha)$ and $A_R(\alpha)$ are provided by $A_L(\alpha) = A + (B - A)\alpha$

$$= \left(5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu} \right) + \left[\left(5\eta_2\mu + \frac{1.575\omega_2\lambda_2}{\mu} \right) - \left(5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu} \right) \right] \alpha$$

$$= \left(5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu} \right) + \left[5(\eta_2 - \eta_1)\mu + 1.575(\omega_2\lambda_2 - \omega_1\lambda_1) \right] \frac{1}{\mu} \alpha$$

$$A_R(\alpha) = D - (D - C) \alpha$$

$$= \left(5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu} \right) - \left[\left(5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu} \right) - \left(5\eta_3\mu + \frac{1.575\omega_3\lambda_3}{\mu} \right) \right] \alpha$$

$$= \left(5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu} \right) - \left[5(\eta_4 - \eta_3)\mu + 1.575(\omega_4\lambda_4 - \omega_3\lambda_3) \frac{1}{\mu} \right] \alpha$$

Putting these value in equation (1)

$$[\widetilde{TC}]_{ds} = \frac{1}{2} \int_0^1 \left[\left(5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu} \right) + \left(5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu} \right) \right. \\ \left. + \left[5(\eta_2 - \eta_1)\mu + 1.575(\omega_2\lambda_2 - \omega_1\lambda_1) \frac{1}{\mu} \right] \alpha \right. \\ \left. - \left[5(\eta_4 - \eta_3)\mu + 1.575(\omega_4\lambda_4 - \omega_3\lambda_3) \frac{1}{\mu} \right] \alpha \right] d\alpha$$

$$[\widetilde{TC}]_{ds} = \frac{1}{2} \left[\left(5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu} \right) + \left(5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu} \right) \right. \\ \left. + \left[5(\eta_2 - \eta_1)\mu + 1.575(\omega_2\lambda_2 - \omega_1\lambda_1) \frac{1}{\mu} \right] \left[\frac{\alpha^2}{2} \right]_0^1 \right. \\ \left. - \left[5(\eta_4 - \eta_3)\mu + 1.575(\omega_4\lambda_4 - \omega_3\lambda_3) \frac{1}{\mu} \right] \left[\frac{\alpha^2}{2} \right]_0^1 \right]$$

$$[\widetilde{TC}]_{ds} = \frac{1}{2} \left[\left(5\eta_1\mu + 1.575 \frac{\omega_1\lambda_1}{\mu} \right) + \left(5\eta_4\mu + \frac{1.575\omega_4\lambda_4}{\mu} \right) \right. \\ \left. + \frac{1}{2} \left[5(\eta_2 - \eta_1)\mu + 1.575(\omega_2\lambda_2 - \omega_1\lambda_1) \frac{1}{\mu} \right] \right. \\ \left. - \frac{1}{2} \left[5(\eta_4 - \eta_3)\mu + 1.575(\omega_4\lambda_4 - \omega_3\lambda_3) \frac{1}{\mu} \right] \right]$$

$$[\widetilde{TC}]_{ds} = \frac{1}{2} \left(5\eta_1\mu + \frac{1.575\omega_1\lambda_1}{\mu} \right) + \frac{1}{2} \left(5\eta_4\mu + 1.575 \frac{\omega_4\lambda_4}{\mu} \right) \\ + \frac{1}{4} \left[5(\eta_2 - \eta_1)\mu + 1.575(\omega_2\lambda_2 - \omega_1\lambda_1) \frac{1}{\mu} \right] \\ - \frac{1}{4} \left[5(\eta_4 - \eta_3)\mu + 1.575(\omega_4\lambda_4 - \omega_3\lambda_3) \frac{1}{\mu} \right]$$

$$[\widetilde{TC}]_{ds} = \frac{5}{2} (\eta_1\mu + \eta_4\mu) + \frac{1.575}{2} \left(\frac{\omega_1\lambda_1}{\mu} + \frac{\omega_4\lambda_4}{\mu} \right) + \frac{5}{4} (\eta_2\mu - \eta_1\mu) \\ - \frac{5}{4} (\eta_4\mu - \eta_3\mu) + \frac{1.575}{4} (\omega_2\lambda_2 - \omega_1\lambda_1) \frac{1}{\mu} \\ - \frac{1.575}{4} (\omega_4\lambda_4 - \omega_3\lambda_3) \frac{1}{\mu}$$

$$[\widetilde{TC}]_{ds} = \frac{5}{4}(\eta_1 + \eta_2 + \eta_3 + \eta_4)\mu + \frac{1.575}{4\mu}(\omega_1\lambda_1 + \omega_2\lambda_2 + \omega_3\lambda_3 + \omega_4\lambda_4)$$

Now differentiate w.r.to μ , we have

$$\frac{d}{d\mu}[\widetilde{TC}]_{ds} = \frac{5}{4}\left[(\eta_1 + \eta_2 + \eta_3 + \eta_4) - 1.575\left(\frac{\omega_1\lambda_1 + \omega_2\lambda_2 + \omega_3\lambda_3 + \omega_4\lambda_4}{\mu^2}\right)\right]$$

For optimization, $\frac{d}{d\mu}[\widetilde{TC}]_{ds} = 0$ and consequently this implies that

$$\frac{5}{4}\left[(\eta_1 + \eta_2 + \eta_3 + \eta_4) - 1.575\left(\frac{\omega_1\lambda_1 + \omega_2\lambda_2 + \omega_3\lambda_3 + \omega_4\lambda_4}{\mu^2}\right)\right] = 0,$$

with sufficient condition

$$\frac{d^2}{d\mu^2}[\widetilde{TC}]_{ds} = \frac{1.575}{4}\left(\frac{\omega_1\lambda_1 + \omega_2\lambda_2 + \omega_3\lambda_3 + \omega_4\lambda_4}{\mu^3}\right) \geq 0$$

This gives

$$\frac{5}{4}(\eta_1 + \eta_2 + \eta_3 + \eta_4)\mu^2 - 1.575(\omega_1\lambda_1 + \omega_2\lambda_2 + \omega_3\lambda_3 + \omega_4\lambda_4) = 0.$$

This nonlinear equation is solved by Newton-Raphson method with the help of R-software using the following computational flowchart for optimum service rate μ^* .

8. Computing Flowchart

To determine the overall ideal cost and optimal service rate of the model, the flowchart is given in figure 1. Upon using following computing flow chart with the help of R-software, we get the following tables. Here, three important cases will be considered for the computation. Case 1 will vary η while ω , λ are fixed; case 2 will vary ω while η and λ are fixed; case 3 will vary λ while η and ω are fixed. Further, cases are Fuzzified which, in turn, gives us case 4, 5 and case 6 which are given later.

Now, we give computational table in crisp environment as below.

Table 1: computation table for η & T_c

	η	ω	λ	μ	TC
Case 1	4	97	4	4.51	223.32
	5	97	4	4.93	246.68
	6	97	4	4.50	270.42
	7	97	4	4.123	292.49

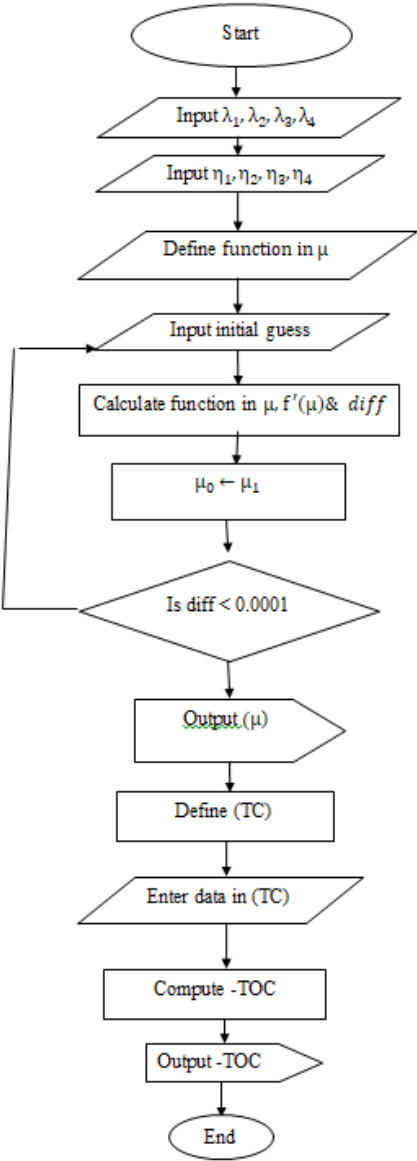


Fig 1

Table 2: computation table for ω & Tc

Case 2	η	ω	λ	μ	TC
	5	97	4	4.93	247.14
	5	98	4	4.96	248.46
	5	99	4	4.98	249.3
	5	100	4	5.01	251.02

Table 3: computation table for λ & T_c

Case 3	η	ω	λ	μ	TC
	5	97	3	4.27	213.69
	5	97	4	4.93	247.71
	5	97	5	5.51	287.46
	5	97	6	6.04	302.70

Table 5: computation table for $\tilde{\eta}$ & $\tilde{TC}$

Case 4	$\tilde{\eta}$	$\tilde{\omega}$	$\tilde{\lambda}$	$\tilde{\mu}$	TC
	$(\eta_1, \eta_2, \eta_3, \eta_4)$	$(\omega_1, \omega_2, \omega_3, \omega_4)$	$(\lambda_1, \lambda_2, \lambda_3, \lambda_4)$		
	(1,3,5,7)	(94,96,98,100)	(1,3,5,7)	11.12	277.42
	(2,4,6,8)	(94,96,98,100)	(1,3,5,7)	9.93	303.27
	(3,5,7,9)	(94,96,98,100)	(1,3,5,7)	9.06	326.82
	(4,6,8,10)	(94,96,98,100)	(1,3,5,7)	8.39	348.67

Table 6: computation table for $\tilde{\eta}$ & $\tilde{TC}$

Case 5	$\tilde{\eta}$	$\tilde{\omega}$	$\tilde{\lambda}$	μ^*	$\tilde{TC}$
	$(\eta_1, \eta_2, \eta_3, \eta_4)$	$(\omega_1, \omega_2, \omega_3, \omega_4)$	$(\lambda_1, \lambda_2, \lambda_3, \lambda_4)$		
	(2,4,6,8)	(94,96,98,100)	(1,3,5,7)	9.90	311.06
	(2,4,6,8)	(95,97,99,101)	(1,3,5,7)	9.98	312.67
	(2,4,6,8)	(96,98,100,102)	(1,3,5,7)	10.03	314.4
	(2,4,6,8)	(97,99,101,103)	(1,3,5,7)	10.86	330.5

Table 7: computation table for $\tilde{\omega}$ & $\tilde{TC}$

Case 6	$\tilde{\eta}$	$\tilde{\omega}$	$\tilde{\lambda}$	μ^*	$\tilde{TC}$
	$(\eta_1, \eta_2, \eta_3, \eta_4)$	$(\omega_1, \omega_2, \omega_3, \omega_4)$	$(\lambda_1, \lambda_2, \lambda_3, \lambda_4)$		
	(2,4,6,8)	(94,96,98,100)	(0,2,4,6)	8.62	254.54
	(2,4,6,8)	(94,96,98,100)	(1,3,5,7)	9.93	309.55
	(2,4,6,8)	(94,96,98,100)	(2,4,6,8)	11.09	366.68
	(2,4,6,8)	(94,96,98,100)	(3,5,7,9)	12.14	380.27

9. Discussion of Results and Sensitivity Analysis

Tables 1-3 provide the results regarding the crisp model and the outcomes of the fuzzy-model are shown in tables 4-6 in this section. Here, we take the repairman queueing model, which has a finite server with a first-come, first-served policy and finite fixed capacity and whose arrival and service both follow the Poisson probability rule. The queueing model has a variety of operational features or performance indicators including estimated customer

numbers in the queue and framework anticipated ‘waiting times’ in the line and system and utilization of services index or occupied phase. The majority of studies focus on discussing these operational aspects but there is little research on the queuing system's optimal total cost particularly in fuzzy-environment. The evaluation among a model's variation-propensity is the overall focus of a sensitivity analysis. As the service cost per unit rises, table-1 demonstrates that the model's overall optimal cost also rises. table-2 demonstrates that the model's total optimum cost rises whenever the waiting per unit cost and the waiting duration per unit increase. Similarly, the overall optimum cost of the model rises as the client rate of arrival to the service outlet does, as shown by table-3 and fig. 1 respectively. According to table-4, the overall optimal fuzzy cost of the fuzzy model under consideration grows as the cost of fuzzy services per unit increases. The fuzzy waiting cost per unit is shown in table-5 if increases, the model’s overall optimal fuzzy cost also rise. Finally, table-6 shows that as the fuzzy arrival rate of customers to the channel of services rises, the total optimal fuzzy cost of the model also rises. A key factor in determining if a model is appropriate for use is correlation. As a result, there are favourable relationships between the service, waiting, and arrival rate as one variable and the total optimal cost of the model as another in both the crisp and fuzzy scenarios. The correlation in the earlier scenario is less positive than it is in the later situation, which is the single fundamental difference between the two contexts.

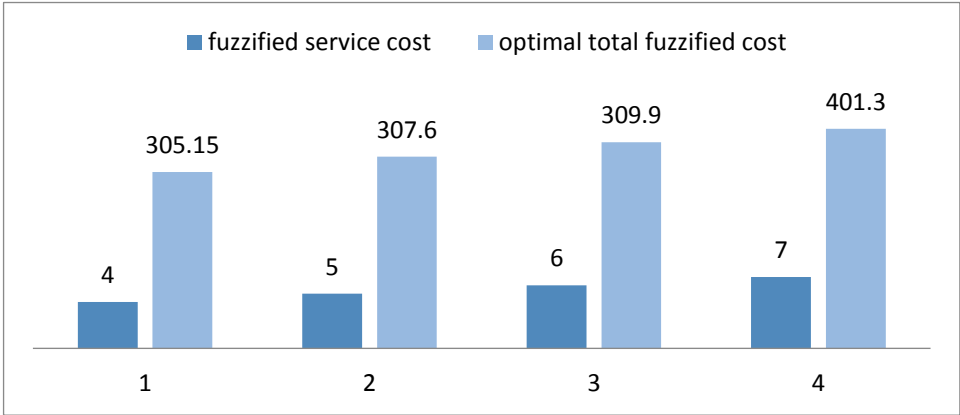


Fig. 1: Variation of Fuzzified service cost and optimal total Fuzzified cost /unit

10. Conclusion and Future Research

In the current study, we developed a model of queuing in a environment of fuzzy that is additionally accurate when assessments are outside of our limit. Calculating the queuing model's overall optimum cost the fuzzy

environment with a repairman server is improved alternative to the current queueing system. We can have more applications with aspects of uncertainty if we extend our queueing model to the fuzzy environment. In order to construct repairman queueing models for fuzzy environments, researchers are likely to find this study to be a valuable resource for additional details and reliable results. These repairman models are highly helpful for creating more effective queue line systems to handle, among other things, pricing, arrival management, personnel needs and settlement, service quality, reducing customer wait times, and serving a higher number of customers. These models can also be used to create operational management techniques for scheduling and inventory control in businesses where lines are obviously formed. This will improve customer service. Six sigma practitioners can utilize this repairman queueing model technique to enhance customer service in their organizations. Fuzzy neural and intuitionistic fuzzy techniques will be more practical in the future to analyse these queueing models.

References

1. L.A. Zadeh; Fuzzy sets, *Information Control*, 8 (1965), 338-353.
2. L.A. Zadeh and R.E. Bellman; Decision making in a fuzzy environment, *Management Science*, 17 (1970), 140-164.
3. R. Jain; Decision making in the presence of fuzzy variables, *IIIE Transactions on systems, Man and Cybernetics*, 17 (1976), 698-703.
4. D. Dubois and H. Prade; Operations on fuzzy numbers, *International Journal of Systems Science*, 9(6) (1978), 613-626.
5. H.J. Zimmerman; Using fuzzy sets in operational research, *European journal of operational research*, 13(3) (1983), 201-216.
6. J.G. Ecker and M. Kupferschmid; *Introduction to operations research*, New York: Wiley, 1988.
7. K. Swarup and P. Gupta; *Manamohan-Operation Research*, S Chand and Sons Educational Publishers.
8. K.S. Park; Fuzzy set theoretical interpretation of economic order quantity, *IEEE Trans. Systems Man. Cybernet SMC*, 17 (1987), 1082-1084.
9. D. Dutta and P. Kumar; Fuzzy inventory model for deteriorating items with shortages under fully backlogged condition, *International Journal of Soft Computing and Engineering (IJSCE)*, 3(2) (2013), 2231-2307.
10. S S Mishra, D K Sharma, S K Yadav and S Rawat; Computational approach to Fuzzified profit optimization of inventory flow in supply chain with deteriorating items, *International Journal of Operations Research*, 30-1 (2017), 83-97.

11. S S Mishra; Developing intelligent index for fuzzified inventory of supply chain by using neural computing, *International Journal of Operations Research*, 29-4 (2017), 460-477.
12. S S Mishra, S Gupta, S K Yadav and S Rawat; Optimization of Fuzzified Economic Order Quantity Model Allowing Shortage and Deterioration with Full Backlogging, *American Journal of Operational Research*, 5(5) (2015), 103-110.
13. S S Mishra and P P Mishra; A (Q, R) model for fuzzified deterioration under cobweb phenomenon and permissible delay in payment, *Computers and Mathematics with Applications*, 61-4 (2011), 921-932.
14. S S Mishra, H Pandey and R S Singh; A Fuzzified deteriorating inventory model with breakdown of machine and shortage cost, *International Journal of Mathematical Sciences*, 3-1 (2004), 241-255.
15. R K Meena, M Jain, S S Sanga and A Assad; Fuzzy modeling and harmony search optimization for machining system with general repair, standby support and vacation, *Applied Mathematics and Computation*, 361 (2019), 858-873.
16. B.B. Singh, S. Rawat, S.K. Yadav, S.S. Mishra; Optimization of Markovian Arrival and Service Queuing Model under Fuzziness, *International Journal of Agricultural & Statistical Sciences*, 16(2) (2020).
17. A. Refaie Al. and A Al-Hawadi; Optimal fuzzy repairs' scheduling and sequencing of failure types over multiple periods, *Journal of Ambient Intelligence and Humanized Computing*, 13(1) (2022), 201-217.
18. S.S. Sanga and G.S. Charan; Fuzzy modeling and cost optimization for machine repair problem with retrial under admission control F-policy and feedback, *Mathematics and Computers in Simulation*, 211 (2023), 214-240.
19. S.S. Sanga and K. Antala; Fuzzy Cost Optimization for Single Server Queue under Admission Control F-policy and Balking, *Research Square preprint* (2023).