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Comparison of Single Transmit Queuing System Including Proportions of Execution Using Fuzzy Queuing Model and Intuitionistic Fuzzy Queuing Model with Two Classes

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Abstract: This research provides a two-class single transmit queuing model. We also calculate the model's execution proportions under a vague environment. The main purpose of this inquiry is to compare the results of a single transmit queuing model based on fuzzy queuing theory and intuitionistic fuzzy queuing theory. Triangular fuzzy numbers and triangular intuitionistic fuzzy numbers are used to describe the entry (arrival) and administration (service) rates. The fuzzy queuing theory model's evaluation metrics are supplied as a range of values, but the intuitionistic fuzzy queuing theory model offers a wide range of values. An analysis is offered to discover quality measures utilizing a proposed methodology in which the fuzzy values are retained as is without being altered into crisp values, hence we can use the proposed method to draw scientific conclusions in an uncertain environment. Two numerical problems are solved to demonstrate the sustainability of the suggested method. Subsequently, prototype components were exposed to sensitivity analyses. Sensitivity testing is used to find discrepancies between the two groups when calculating their execution proportions. We employed the triangular fuzzy number in an intuitionistic fuzzy environment in this study, accounting for the degree of comfort and refusal so that the sum of both values is always less than 1. For this type of fuzzy integer, we gave various non-normal arithmetic procedures. The proposed formulations are simple and direct, having been devised using classical algebraic mathematics. This strategy is simple and straightforward to use in actual situations. The nearest interval number is then used to round a TIFN. The key benefit of this approach is that using a multi-section algorithm, we can quickly solve a bound unbridled optimization problem with coefficients as TIFN. The present methodologies and strategies are intended to be applicable to a variety of contemporary decision-making challenges in areas of economic share, finance, administration, and ecology, which are the focus of our future study.

Keywords: Single transmit queue, Triangular fuzzy number, Intuitionistic triangular fuzzy number, Execution proportions, Sensitivity analysis.

1. Introduction

As evidenced by the large number of resources identified, the fuzzy set hypothesis is a well-established and growing scientific discipline. Its application as a method for displaying and deconstructing decision patterns is critical to researchers' ongoing management. The rationale for this is its ability to model difficulties like ambiguity and imprecision statistically and aesthetically. Queuing models are frequently used in government entities. Legitimate situations are one of these application zones, with a technique of two class administrative streams. Numerous lining models have been examined, ranging from those with consistent freshness characteristics to those with fuzzy properties. In this sense, the Zadeh [1, 2] standard depicted certain models as having articulations as a possibility. As a result, queuing systems in fuzzy environments are more practical than classical queuing systems in a variety of real-world scenarios.

Because fuzzy numbers do not frame a conventional linear approach like genuine numbers, how to look at fuzzy numbers is a major challenge in operationalizing the fuzzy set hypotheses. For placing fuzzy numbers, various approaches have been developed. Thus, we have projected a method for solving the single transmission fuzzy queuing model in both fuzzy and intuitionistic fuzzy environments without compromising their essence in this paper. In comparison to earlier ways, this approach is advantageous in that it is concise, customizable, and relevant. According to the results of the analysis, the fuzzy queuing model's performance measurements are within the range of the intuitionistic fuzzy queuing model's estimated performance measures.

Kao et al. [3] provided a universal approach for estimating the participation components of the representation approximations FM/FM/1/, F/F/1/, F/M/1/, and M/F/1/ lines, where F represents fuzziness and FM represents exponential time. Similarly, Jau Chuan Ke et al. [4] calculated the framework's enrolment capacity using the retrial line model's features as well as the representation of a fuzzy component of the admission and management rate. Even though Kao et al. [3] exploited fuzzy line models in their formulation. Nevertheless, a nonlinear parametric programming approach was used to process the exhibition proportions of the line. We have offered a fresh technique for solve difficulties that are quick, beneficial, and flexible to use. Nevertheless, earlier research has not taken into account twin classes [5, 11] of entry and two exponentially administrations rates under the inaugural began items out provider arriving configuration. Later Usha Prameela et al [6] dealt with the left and right placement strategy, which is a mechanism for transforming fuzzy to crisp features in one of the queuing models. As a result, this study will focus on one of the queuing models that use the strategy of not transitioning fuzzy to crisp attributes and implementing it to two types of participatory capabilities: triangular fuzzy and triangular intuitionistic fuzzy membership potentials.

Fuzzy queuing models have been explained by several researchers, namely K. Atanavssov [13], that publication has been the first approach to providing a broader and comprehensive account of intuitionistic fuzzy set theory and its more adapted in a range of domains. S.S. Sanga et al [25] used the probability generating function to produce the steady flow mathematical formulation for the probabilistic distributions and systems evaluation methods. K. Atanavssov [12] incorporated the intuitionistic fuzzy set, and he also departed from the temporal intuitionistic fuzzy sets. B. R. Kumar et al [29] employed estimation theory and defuzzification to analyze the performance of a system. R. Sethi et al [26] applied a recursive approach to extract the stable distributions of queues and created the multiple performance indices and carried out numerical experiments to characterize the behavior of the system indices as different system parameters are changed. F. Ferdowsi [28] proposed an intuitionistic fuzzy measure to handle the uncertainty where he used credibility measure to convert fuzzy to crisp model. In fuzzy linear programming problems, Arpita Kabiraj et al [21] used intuitionistic concepts in a linear programming problem. S. Hanumantha Rao et al. [23] proposed a solitary semi-markov queuing system with finite capacity, encouraging or discouraging arrivals, and a tweaked customer reneging policy in their paper. A. Tamilarasi [27] used trapezoidal intuitionistic fuzzy numbers to investigate the intuitionistic fuzzy and queuing model. The membership function of the fuzzy cost function is proposed by S. Hanumantha Rao et al [24] to get confident predictions for certain key metrics of a configurable 2 different service dedicated server markovian gating queues with server starts and breakdown over N-policy. G. Chen et al [22] investigated the optimum and equilibria techniques in fuzzy M/M/1 queues with all fuzzy numbers as control variables in this study. S. Narayana Moorthy et al [20] used intuitionistic fuzzy numbers for input parameters and the basic approach is based on Atanassov's extension principle and (α, β) - cut method. Noor Hidayah Mohd Zaki et al [16] compared both queuing model and fuzzy queuing model using the DSW algorithm. Mueen Zeina et al [11] proposed a ranking technique to find different performance indicators in consideration of crisp value for new single fuzzy queues with 2 different classes of arrival. G. Choudhury et al [9] derived the reliability function and related reliability indices for the $M^X/G/1$ unreliable queuing model. N. Subashini et al [8] proposed a DSW algorithm based on the alpha cut method to find the different performance measures for fuzzy queues with two classes in terms of crisp values. Sama Hanumantha Rao et al [7] analysed the effectiveness of the 2-phase $MX/M/1$ queuing model and used probabilistic generation functions to solve the equations. K. Usha Prameela et al [6] used the ranking technique for conversion of fuzzy to a crisp to find out the performance indicators of the single transmit fuzzy queuing model with two classes.

This prompted the acquisition of several execution measures for the fuzzy queuing model, including 2 classes of landing rates and a combination of exponentially administrations rates in terms of crisp characteristics. This paper's main idea is to keep the fuzziness till the end and then use the fuzzy values in the queuing performance calculations.

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Successfully obtaining the desired outcome.

This paper's structure is as follows: Fragment 1 provides an overview, fragment 2 explains some basic definitions, fragment 3 explains the model description, fragment 4 depicts the mathematical model, fragment 5 explains the fuzzy queuing performance measures, fragment 6 provides numerical examples, fragment 7 provides complimentary and implications, fragment 8 examines sensitivity analysis, fragment 9 shows the restrictions and fragment 10 concludes the article.

2. Preliminaries

The motive of this division is to give some basic definitions, annotations, and outcomes that are used in our subsequent calculations.

Definition 2.1: [14] A fuzzy set $\tilde{A}$ is defined on R, the set of real numbers is called a fuzzy number if its membership function $\mu_{\tilde{A}}: R \to [0,1]$ has the following conditions:

(a) $\tilde{A}$ is convex, which means that there exists $x_1, x_2 \in R$ and $\lambda \in [0,1]$, such that $\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min\{\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\}$
(b) $\tilde{A}$ is normal, which means that there exists an $x \in R$ such that $\mu_{\tilde{A}}(x) = 1$
(c) $\tilde{A}$ is piecewise continuous."

Definition 2.2: [14] A fuzzy number $\tilde{A}$ is defined on R, the set of real numbers is said to be a triangular fuzzy number (TFN) if its membership function $\mu_{\tilde{A}}: R \to [0,1]$ which satisfy the following conditions:"

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-\tilde{a}_1}{\tilde{a}_2-\tilde{a}_1} \text{for } \tilde{a}_1 \leq x \leq \tilde{a}_2 \\ 1 \text{ for } x = \tilde{a}_2 \\ \frac{\tilde{a}_3-x}{\tilde{a}_3-\tilde{a}_2} \text{ for } \tilde{a}_2 \leq x \leq \tilde{a}_3 \\ 0 \text{ otherwise} \end{cases}$$

The triangular fuzzy number is illustrated in Fig. 1.

Definition 2.3:[14] "Let the two triangular fuzzy numbers be $\tilde{P} \approx (\tilde{a}_1, \tilde{a}_2, \tilde{a}_3) = (\tilde{m}_1, \tilde{\alpha}_1, \tilde{\beta}_1)$ and $\tilde{Q} \approx (\tilde{b}_1, \tilde{b}_2, \tilde{b}_3) = (\tilde{m}_2, \tilde{\alpha}_2, \tilde{\beta}_2)$ and then the arithmetic operations on TFN be given as follows:

(A)Addition

$$\tilde{P} + \tilde{Q} \approx (\tilde{m}_1 + \tilde{m}_2, \max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, \max\{\tilde{\beta}_1, \tilde{\beta}_2\}) \quad (1)$$

(B)Subtraction

$$\tilde{P} - \tilde{Q} \approx (\tilde{m}_1 - \tilde{m}_2, max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, max\{\tilde{\beta}_1, \tilde{\beta}_2\}) \quad (2)$$

(C) Multiplication

$$\tilde{P}.\tilde{Q} \approx (\tilde{m}_1.\tilde{m}_2, max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, max\{\tilde{\beta}_1, \tilde{\beta}_2\}) \quad (3)$$

(D) Division

$$\frac{\tilde{P}}{\tilde{Q}} \approx \left(\frac{\tilde{m}_1}{\tilde{m}_2}, \max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, \max\{\tilde{\beta}_1, \tilde{\beta}_2\}\right)\text{"} \quad (4)$$

Definition 2.4: "For every triangular fuzzy number $\tilde{P} \approx (\tilde{a}_1, \tilde{a}_2, \tilde{a}_3) \in F(R)$ ranking function $\Re: F(R) \to R$ is defined by graded mean as

$$\Re(\tilde{P}) = \frac{(\tilde{a}_1 + 4\tilde{a}_2 + \tilde{a}_3)}{6}$$

For any two TFN $\tilde{P} \approx (\tilde{a}_1, \tilde{a}_2, \tilde{a}_3)$ and $\tilde{Q} \approx (\tilde{b}_1, \tilde{b}_2, \tilde{b}_3)$ We have the following comparisons,

$$(a)\tilde{P} \succ \tilde{Q} \Leftrightarrow \Re(\tilde{P}) > \Re(\tilde{Q})$$
$$(b)\tilde{P} \prec \tilde{Q} \Leftrightarrow \Re(\tilde{P}) < \Re(\tilde{Q})$$
$$(c)\tilde{P} \approx \tilde{Q} \Leftrightarrow \Re(\tilde{P}) = \Re(\tilde{Q})$$
$$(d)\tilde{P} - \tilde{Q} \approx 0 \Leftrightarrow \Re(\tilde{P}) - \Re(\tilde{Q}) = 0$$

A triangular fuzzy number $\tilde{P} \approx (\tilde{a}_1, \tilde{a}_2, \tilde{a}_3) \in F(R)$ is known to be positive if $\Re(\tilde{P}) > 0$ and defined by $\tilde{P} \succ 0$."

Definition 2.5: [15] "Let a non–empty set be X. An intuitionistic fuzzy set (IFS) $\tilde{A}'$ is defined as $\tilde{A}' = \{(x, \mu_{\tilde{A}'}(x), \gamma_{\tilde{A}'}(x)/x \in X)\}$, where $\mu_{\tilde{A}'}: X \to [0,1]$ and $\gamma_{\tilde{A}'}: X \to [0,1]$ denotes the degree of membership and degree of non– membership functions respectively where $x \in X$, for every $x \in X, 0 \leq \mu_{\tilde{A}'}(x) + \gamma_{\tilde{A}'}(x) \leq 1$"

Definition 2.6: [15] "An intuitionistic fuzzy set $\tilde{A}'$ described on R, the real numbers are said to be an intuitionistic fuzzy number (IFN) if its membership function $\mu_{\tilde{A}'}: R \to [0,1]$ and its non – membership function $\gamma_{\tilde{A}'}: R \to [0,1]$ should agreeable to the following conditions:

i) $\tilde{A}'$ is normal, which means that there exists an $x \in R$, such that $\mu_{\tilde{A}'}(x) = 1, \gamma_{\widetilde{A'}}(x) = 0$
ii) $\tilde{A}'$ is convex for the membership functions $\mu_{\widetilde{A'}}$, which means that there exists $x_1, x_2 \in R$ and $\lambda \in [0,1]$ such that

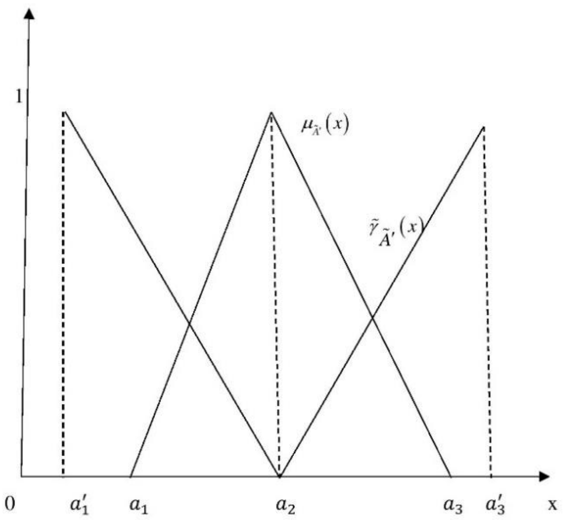

Figure. 2 Intuitionistic triangular fuzzy number

$$\mu_{\tilde{A}'}(\lambda x_1 + (1-\lambda)x_2) \geq \min\{\mu_{\tilde{A}'}(x_1), \mu_{\tilde{A}'}(x_2)\}$$

iii) $\tilde{A}'$ is concave for the non – membership function $\gamma_{\tilde{A}'}$, which means that there exists $x_1, x_2 \in R$ and $\lambda \in [0,1]$ such that" $\gamma_{\tilde{A}'}(\lambda x_1 + (1-\lambda)x_2) \leq max\{\gamma_{\tilde{A}'}(x_1), \gamma_{\tilde{A}'}(x_2)\}$

Definition 2.7: [15] "A fuzzy number $\tilde{A}'$ on R is said to be a triangular intuitionistic fuzzy number (TIFN) if its membership function $\mu_{\tilde{A}'}: R \to [0,1]$ and non – membership function.

$\gamma_{\tilde{A}'}: R \to [0,1]$ has the following conditions:

$$\mu_{\tilde{A}'}(x) = \begin{cases} \frac{x-\tilde{\alpha}_1}{\tilde{\alpha}_2-\tilde{\alpha}_1} \text{ for } \tilde{\alpha}_1 \leq x \leq \tilde{\alpha}_2 \\ 1 \text{ for } x = \tilde{\alpha}_2 \\ \frac{\tilde{\alpha}_3-x}{\tilde{\alpha}_3-\tilde{\alpha}_2} \text{ for } \tilde{\alpha}_2 \leq x \leq \tilde{\alpha}_3 \\ 0 \text{ otherwise} \end{cases} \quad \text{and}$$

$$\gamma_{\tilde{A}'}(x) = \begin{cases} 1 \text{ for } x < \tilde{\alpha}_1', x > \tilde{\alpha}_3' \\ \frac{\tilde{\alpha}_2-x}{\tilde{\alpha}_2-\tilde{\alpha}_1'} \text{ for } \tilde{\alpha}_1' \leq x \leq \tilde{\alpha}_2 \\ 0 \text{ for } x = \tilde{\alpha}_2 \\ \frac{x-\tilde{\alpha}_2}{\tilde{\alpha}_3-\tilde{\alpha}_2} \text{ for } \tilde{\alpha}_2 \leq x \leq \tilde{\alpha}_3' \end{cases}$$

and is given by $\widetilde{A'} = (\tilde{\alpha}_1, \tilde{\alpha}_2, \tilde{\alpha}_3; \tilde{\alpha}'_1, \tilde{\alpha}_2, \tilde{\alpha}'_3)$ where $\tilde{\alpha}'_1 \leq \tilde{\alpha}_1 \leq \tilde{\alpha}_2 \leq \tilde{\alpha}_3 \leq \tilde{\alpha}'_3$."

The intuitionistic triangular fuzzy number is illustrated in Fig 2.

Cases: Let $\widetilde{A'} = (\tilde{\alpha}_1, \tilde{\alpha}_2, \tilde{\alpha}_3; \tilde{\alpha}'_1, \tilde{\alpha}_2, \tilde{\alpha}'_3)$ be a TIFN then the following cases arise.

Case:1 If $\tilde{\alpha}'_1 = \tilde{\alpha}_1, \tilde{\alpha}'_3 = \tilde{\alpha}_3$ then $\widetilde{A'}$ represent a triangular fuzzy number.

Case:2 If $\tilde{\alpha}'_1 = \tilde{\alpha}_1 = \tilde{\alpha}_2 = \tilde{\alpha}'_3 = \tilde{\alpha}_3 = \widetilde{m}$ then $\widetilde{A'}$ represent a real number $\widetilde{m}$. The parametric form of TIFN $\widetilde{A'}$ is represented as $\widetilde{A'} = (\tilde{\alpha}, \widetilde{m}, \tilde{\beta}; \tilde{\alpha}', \widetilde{m}, \tilde{\beta}')$ where $\tilde{\alpha}, \tilde{\alpha}' \& \tilde{\beta}, \tilde{\beta}'$ represents the left spread and right spread of membership functions and non – membership functions respectively."

Definition 2.8: [15]"TIFN $\widetilde{A'} \in F(R)$, (where $F(R)$ is the set of all TIFN) can also be represented as a pair $\tilde{A}' = (\tilde{a}, \tilde{\bar{a}}; \tilde{a}', \tilde{\bar{a}}')$ of functions $\tilde{a}(\tilde{r}'), \tilde{\bar{a}}(\tilde{r}'), \tilde{a}'(\tilde{r}') \& \tilde{\bar{a}}'(\tilde{r}')$ for $0 \leq \tilde{r}' \leq 1$ which satisfies the following requirements:

i) $\tilde{a}(\tilde{r}') \& \tilde{\bar{a}}'(\tilde{r}')$ is a bounded monotonic increasing left continuous function for membership and non – membership functions respectively.

ii) $\tilde{\bar{a}}(\tilde{r}') \& \tilde{a}'(\tilde{r}')$ is a bounded monotonic decreasing left continuous function for membership and non – membership functions respectively.

iii) $\tilde{a}(\tilde{r}') \leq \tilde{\bar{a}}(\tilde{r}'), 0 \leq \tilde{r}' \leq 1$.

iv) $\tilde{a}'(\tilde{r}') \leq \tilde{\bar{a}}'(\tilde{r}'), 0 \leq \tilde{r}' \leq 1$."

Definition 2.9: "The extension of fuzzy arithmetic operations of Ming Ma et al [14] to the set of TIFN based upon both location indices and functions of fuzziness indices. The location indices number is taken in the regular arithmetic while the functions of fuzziness indices are assumed to follow the lattice rule which is the least upper bound in the lattice $\tilde{I}'$. For any two arbitrary TIFN $\tilde{P}' \approx (\widetilde{m}_1, \tilde{\alpha}_1, \tilde{\beta}_1; \widetilde{m}_1, \tilde{\alpha}'_1, \tilde{\beta}'_1)$ and $\tilde{Q}' \approx (\widetilde{m}_2, \tilde{\alpha}_2, \tilde{\beta}_2; \widetilde{m}_2, \tilde{\alpha}'_2, \tilde{\beta}'_2)$ and $* \in \{+, -, \times, \div\}$, then the arithmetic operations on TIFN are defined by $\tilde{P}' * \tilde{Q}' = (\widetilde{m}_1 * \widetilde{m}_2, \tilde{\alpha}_1 \vee \tilde{\alpha}_2, \tilde{\beta}_1 \vee \tilde{\beta}_2; \widetilde{m}_1 * \widetilde{m}_2, \tilde{\alpha}'_1 \vee \tilde{\alpha}'_2, \tilde{\beta}'_1 \vee \tilde{\beta}'_2)$

In particular for any two TIFNs $\tilde{P}' \approx (\widetilde{m}_1, \tilde{\alpha}_1, \tilde{\beta}_1; \widetilde{m}_1, \tilde{\alpha}'_1, \tilde{\beta}'_1)$ and $\tilde{Q}' \approx (\widetilde{m}_2, \tilde{\alpha}_2, \tilde{\beta}_2; \widetilde{m}_2, \tilde{\alpha}'_2, \tilde{\beta}'_2)$ the arithmetic operations are defined as

$$\tilde{P}' * \tilde{Q}' = (\widetilde{m}_1, \tilde{\alpha}_1, \tilde{\beta}_1; \widetilde{m}_1, \tilde{\alpha}'_1, \tilde{\beta}'_1) * (\widetilde{m}_2, \tilde{\alpha}_2, \tilde{\beta}_2; \widetilde{m}_2, \tilde{\alpha}'_2, \tilde{\beta}'_2)$$

$$\tilde{P}' * \tilde{Q}' = \begin{pmatrix} \widetilde{m}_1 * \widetilde{m}_2, max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, max\{\tilde{\beta}_1, \tilde{\beta}_2\}; \\ \widetilde{m}_1 * \widetilde{m}_2, max\{\tilde{\alpha}'_1, \tilde{\alpha}'_2\}, max\{\tilde{\beta}'_1, \tilde{\beta}'_2\} \end{pmatrix}$$

$$\tilde{P}' * \tilde{Q}' = \left(\tilde{m}_1 * \tilde{m}_2, \tilde{\alpha}_1 \vee \tilde{\alpha}_2, \tilde{\beta}_1 \vee \tilde{\beta}_2 ; \widetilde{m}_1 * \tilde{m}_2, \tilde{\alpha}'_1 \vee \tilde{\alpha}'_2, \tilde{\beta}'_1 \vee \tilde{\beta}'_2\right)$$

In particular, for any two TIFN $\tilde{P}' \approx \left(\tilde{a}_1, \tilde{a}_2, \tilde{a}_3; \tilde{a}'_1, \tilde{a}'_2, \tilde{a}'_3\right) \approx \left(\tilde{m}_1, \tilde{\alpha}_1, \tilde{\beta}_1; \tilde{m}_1, \tilde{\alpha}'_1, \tilde{\beta}'_1\right)$, $\tilde{Q}' \approx \left(\tilde{b}_1, \tilde{b}_2, \tilde{b}_3 ; \widetilde{b}'_1, \tilde{b}'_2, \tilde{b}'_3\right) \approx \left(\tilde{m}_2, \tilde{\alpha}_2, \tilde{\beta}_2 ; \widetilde{m}_2, \tilde{\alpha}'_2, \tilde{\beta}'_2\right)$we define:"

Addition

$$\tilde{P}' + \tilde{Q}' = \begin{pmatrix} \tilde{m}_1 + \tilde{m}_2, max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, max\{\tilde{\beta}_1, \tilde{\beta}_2\}; \\ \tilde{m}_1 + \tilde{m}_2, max\{\tilde{\alpha}'_1, \tilde{\alpha}'_2\}, max\{\tilde{\beta}'_1, \tilde{\beta}'_2\} \end{pmatrix} \quad (5)$$

Subtraction

$$\tilde{P}' - \tilde{Q}' = \begin{pmatrix} \tilde{m}_1 - \tilde{m}_2, max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, max\{\tilde{\beta}_1, \tilde{\beta}_2\}; \\ \tilde{m}_1 - \tilde{m}_2, max\{\tilde{\alpha}'_1, \tilde{\alpha}'_2\}, max\{\tilde{\beta}'_1, \tilde{\beta}'_2\} \end{pmatrix} \quad (6)$$

Multiplication

$$\tilde{P}' \times \tilde{Q}' = \begin{pmatrix} \tilde{m}_1 \times \tilde{m}_2, max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, max\{\tilde{\beta}_1, \tilde{\beta}_2\}; \\ \tilde{m}_1 \times \tilde{m}_2, max\{\tilde{\alpha}'_1, \tilde{\alpha}'_2\}, max\{\tilde{\beta}'_1, \tilde{\beta}'_2\} \end{pmatrix} \quad (7)$$

Division

$$\tilde{P}' \div \tilde{Q}' = \begin{pmatrix} \tilde{m}_1 \div \tilde{m}_2, max\{\tilde{\alpha}_1, \tilde{\alpha}_2\}, max\{\tilde{\beta}_1, \tilde{\beta}_2\}; \\ \tilde{m}_1 \div \tilde{m}_2, max\{\tilde{\alpha}'_1, \tilde{\alpha}'_2\}, max\{\tilde{\beta}'_1, \tilde{\beta}'_2\} \end{pmatrix}\text{"} \quad (8)$$

Definition 2.10: "Consider an arbitrary TIFN $\widetilde{A'} = \left(\tilde{a}_1, \tilde{a}_2, \tilde{a}_3; \widetilde{a'}_1, \tilde{a}_2, \widetilde{a'}_3\right) = \left(\tilde{m}, \tilde{\alpha}, \tilde{\beta}; \tilde{m}, \widetilde{\alpha'}, \tilde{\beta}'\right)$ and the magnitude of TIFN $\widetilde{A'}$ is given by

$$mag\left(\tilde{A}'\right) = \frac{1}{2}\int \left(\tilde{a} + \tilde{\tilde{a}} + 2\tilde{m} + \widetilde{a'} + \tilde{\tilde{a}}'\right)\tilde{f}(\tilde{r}')d\tilde{r}'$$

$$mag\left(\tilde{A}'\right) = \frac{1}{2}\int \left(\tilde{\beta} + \tilde{\beta}' + 6\tilde{m} - \tilde{\alpha} - \widetilde{\alpha'}\right)\tilde{f}(r')d\tilde{r}'$$

In real life scenario, decision-makers select the value of $\tilde{f}(\tilde{r}')$ based on their circumstances. Here for our ease, we choose $\tilde{f}(\tilde{r}') = \tilde{r}'^2$

$$mag\left(\tilde{A}'\right) = \frac{\left(\tilde{\beta} + \tilde{\beta}' + 6\tilde{m} - \tilde{\alpha} - \tilde{\alpha}'\right)}{6}$$

$$mag\left(\tilde{A}'\right) = \frac{\left(\tilde{a} + \tilde{\tilde{a}} + 2\tilde{m} + \tilde{a}' + \tilde{\tilde{a}}'\right)}{6}$$

For any two TIFN $\tilde{P}' \approx \left(\tilde{m}_1, \tilde{\alpha}_1, \tilde{\beta}_1; \tilde{m}_1, \widetilde{\alpha'}_1, \tilde{\beta}'_1\right)$, $\tilde{Q}' \approx \left(\tilde{m}_2, \tilde{\alpha}_2, \tilde{\beta}_2; \tilde{m}_2, \widetilde{\alpha'}_2, \tilde{\beta}'_2\right)$ in $F(R)$, we define

$$(a)\tilde{P}' \geq \tilde{Q}' \Leftrightarrow mag\left(\tilde{P}'\right) \geq mag\left(\tilde{Q}'\right)$$

$$(b)\tilde{P}' \leq \tilde{Q}' \Leftrightarrow mag\left(\tilde{P}'\right) \leq mag\left(\tilde{Q}'\right)$$

$$(c)\tilde{P}' \approx \tilde{Q}' \Leftrightarrow mag\left(\tilde{P}'\right) = mag\left(\tilde{Q}'\right)$$

3. Model description

Imagine $FM/F(h_1, h_2)/1$ fuzzy queuing model with two classes and a solitary channel but no entering prioritization, where FM indicates the landing rates in fuzzy as a poisson process, while $F(h_1, h_2)$ indicates the hyper exponentially administrations time rates under the fuzzy environment with two different classes. However, inside the same class, the customers are provided service according to the FIFO order with infinite framework limit and population size.

The rate of arrival and service is determined in the form of both TFN and TIFN. The major goal is to figure out the performance measures using both triangular fuzzy numbers and intuitionistic fuzzy numbers and models are compared based on the results of the mean no. of customers in the queue and system as well as their sojourn(waiting) time in the line and system. Here we retain the fuzziness values till the end i.e., without changing it into crisp, the problems are solved. Hence it has more able to apply in a real-life situation.

4. Hypotheses and syntaxes

4.1 Hypotheses

i) Consider the infinite capacity single transmit fuzzy queuing model with 2 classes with an unlimited size of the population.
ii) The System is served by a single server.
iii) Interarrival rates are tweaked appropriately.
iv) In addition, service rates are disseminated concurrently.
v) The rate of arrivals and services are taken as TFN and TIFN.
vi) Service discipline followed as FIFO.

4.2 Syntaxes

Here we are using the following notations:

$FM \rightarrow$ Fuzzy landing rate per second
$F(h_1, h_2) \rightarrow$ Administration rate under the fuzzy environment with two classes per second

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$\tilde{\lambda}_1 \& \tilde{\lambda}_2$ →The mean no. of customers who arrive in a predetermined period.
$\tilde{\mu}_1 \& \tilde{\mu}_2$ →The mean no. of customers being serviced per unit of time.
$\tilde{\rho}$ →Steady-state stability
$\tilde{N}^1{}_q \& \tilde{N}^2{}_q$ → The mean no. of customers of the first and second class in the queue respectively.
$\tilde{N}^1{}_s \& \tilde{N}^2{}_s$ →The mean no. of customers of the first and second class in the system respectively.
$\tilde{T}^1{}_q \& \tilde{T}^2{}_q$ →The mean sojourn(awaiting) time of the customers of the first and second class in the queue respectively.
$\tilde{T}^1{}_s \& \tilde{T}^2{}_s$ →The mean sojourn(awaiting) time of the customers of the first and second class in the system respectively.
$\tilde{P}'$ →Interarrival rate.
$\tilde{Q}'$ →Service rate.

5. Unified transmits fuzzy queuing model with two different classes

Let $\tilde{\lambda}_1, \tilde{\lambda}_2$ and $\tilde{\lambda}'_1, \tilde{\lambda}'_2$ be the fuzzy and intuitionistic fuzzy arrival rates respectively. Let $\tilde{\mu}_1, \tilde{\mu}_2$ and $\tilde{\mu}'_1, \tilde{\mu}'_2$ be the fuzzy and intuitionistic fuzzy service rates respectively. At the steady-state, the FIFO discipline is upheld, without any priorities in entry rates.

i) The no. of customers in the queue is given as

$$\tilde{N}_q^1 = \frac{\tilde{\lambda}_1\left(\frac{\tilde{\rho}_1}{\tilde{\mu}_1}+\frac{\tilde{\rho}_2}{\tilde{\mu}_2}\right)}{(1-\rho)} \tag{9}$$

$$\tilde{N}_q^2 = \frac{\tilde{\lambda}_2\left(\frac{\tilde{\rho}_1}{\tilde{\mu}_1}+\frac{\tilde{\rho}_2}{\tilde{\mu}_2}\right)}{(1-\rho)} \tag{10}$$

ii) The sojourn(waiting) time of the customers in the queue is given as

$$\tilde{T}_q^i = \frac{\tilde{N}_q^i}{\tilde{\lambda}_i}; i = 1,2 \tag{11}$$

iii) The sojourn(waiting) time of customers in the system is given as

$$\tilde{T}_s^i = \tilde{T}_q^i + \frac{1}{\tilde{\mu}_i}; i = 1,2 \tag{12}$$

iv) The no. of customers in the system is given as

$$\tilde{N}_s^i = \tilde{\lambda}_i \tilde{T}_s^i; i = 1,2 \tag{13}$$

Where,

$$\tilde{\rho} = \tilde{\rho}_1 + \tilde{\rho}_2 < 1, 0 < \rho < 1$$

$$\tilde{\rho}_1 = \frac{\tilde{\lambda}_1}{\tilde{\mu}_1}; \tilde{\rho}_2 = \frac{\tilde{\lambda}_2}{\tilde{\mu}_2}; \tilde{\rho} = \frac{\tilde{\lambda}}{\tilde{\mu}}$$

6. Mathematical description

Assuming an apparatus with a progressive formwork system that gets two types of entries customers $\tilde{\lambda}_1$ and $\tilde{\lambda}_2$ then the administrative time is viewed as a form of the exponential transit $\tilde{\mu}_1$ and $\tilde{\mu}_2$ independently. All of the criteria are ambiguous. The overall line and system length, as well as the overall line and system waiting time, must be recorded by the authority for each of the classes.

6.1 Single transmit fuzzy queuing model with two classes

Acknowledge that both the two-class touchdown rate and the administration's rate are TFN in a first in first out (FIFO) manner, with unlimited bandwidth and population density, as follows:

Let $\tilde{\lambda}_1 = (2,4,6), \tilde{\lambda}_2 = (3,5,7)$ are the arrival rates and $\tilde{\mu}_1 = (16,19,22)$ and $\tilde{\mu}_2 = (18,21,24)$ are the service rates respectively.

Determine the TFN in the form of $(\tilde{m}, \tilde{\alpha}, \tilde{\beta})$ as $\tilde{\lambda}_1 = (4,2,2), \tilde{\lambda}_2 = (5,2,2)$ and $\tilde{\mu}_1 = (19,3,3)$ and $\tilde{\mu}_2 = (21,3,3)$.

To determine the values of a no. of customers and their sojourn time in the queue as well as a system of first and second class respectively using suitable formulas among (9), (10), (11), (12), & (13). It is necessary to use the appropriate arithmetic operations described in (1), (2), (3), and (4) for add, sub, multiply, and divide, respectively.

The metrics of performance are calculated and tabulated in Table 1.

6.2 Single transmit intuitionistic fuzzy queuing model with two classes

Acknowledge that both the two-class touchdown rate and the administration's rate are TIFN in a first in first out (FIFO) manner, with unlimited bandwidth and population density, as follows:

Let $\tilde{\lambda}'_1 = (3,4,5; 2,4,6)$ and $\tilde{\lambda}'_2 = (4,5,6; 3,5,7)$ are the arrival rates and $\tilde{\mu}'_1 = (17,19,21; 16,19,22)$ and $\tilde{\mu}_2 = (19,21,23; 18,21,24)$ are the two different service rates respectively.

Table 1. Performance measures using triangular fuzzy numbers

	Number of Classes	
	Class 1	Class 2
$\tilde{N}_q$	$(-2.8376,0.1624,3.1624)$	$(-2.797,0.2030,3.2030)$
$\tilde{T}_q$	$(-2.9594,0.0406,3.0406)$	$(-2.9594,0.0406,3.0406)$
$\tilde{N}_s$	$(-2.6272,0.3728,3.3728)$	$(-2.559,0.441,3.441)$
$\tilde{T}_s$	$(-2.9068,0.0932,3.0932)$	$(-2.9118,0.0882,3.0882)$

Table 2. Performance measures using intuitionistic triangular fuzzy numbers

	Number of Classes	
	Class 1	Class 2
$\tilde{N}'_q$	$(-1.8383,0.1617,2.1617;-2.8383,0.1617,3.1617)$	$(-1.7979,0.2021,2.2021;-2.7979,0.2021,3.2021)$
$\tilde{T}'_q$	$(-1.9596,0.0404,2.0404;-2.9596,0.0404,3.0404)$	$(-1.9596,0.0404,2.0404;-2.9596,0.0404,3.0404)$
$\tilde{N}'_s$	$(-1.628,0.372,2.372;-2.628,0.372,3.372)$	$(-1.56,0.44,2.44;-2.56,0.44,3.44)$
$\tilde{T}'_s$	$(-1.907,0.093,2.093;-2.907,0.093,3.093)$	$(-1.912,0.088,2.088;-2.912,0.088,3.088)$

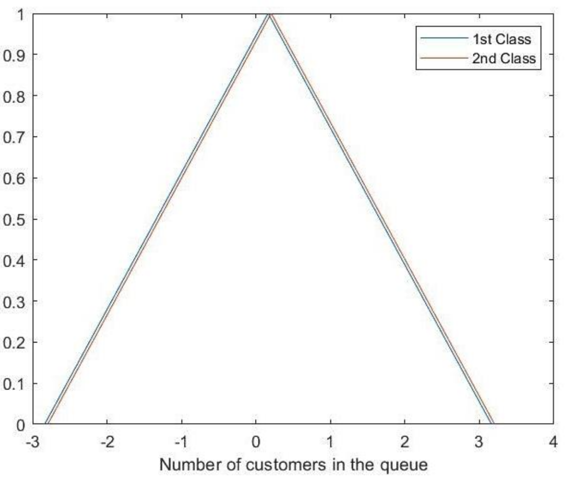

Figure. 3 The number of customers of classes 1 & 2 in the queue

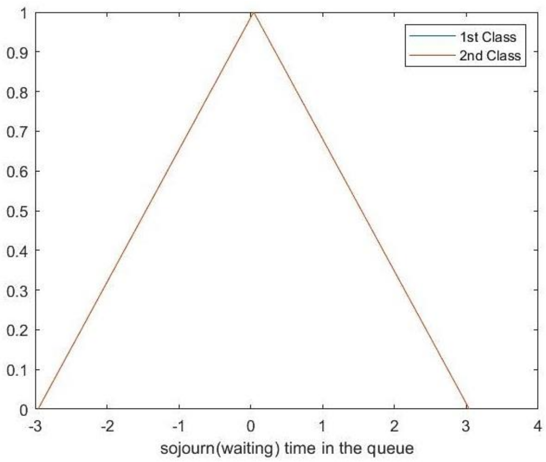

Figure. 4 The sojourn time of customers of classes 1 & 2 in the queue

Determine the TIFN in the form of $(\tilde{m},\tilde{\alpha},\tilde{\beta};\tilde{m},\widetilde{\alpha'},\tilde{\beta'})$ as $\tilde{\lambda}'_1 = (4,1,1;4,2,2)$ and $\tilde{\lambda}'_2 = (5,1,1;5,2,2)$, $\tilde{\mu}'_1 = (19,2,2;19,3,3)$ and $\tilde{\mu}'_2 = (21,2,2;21,3,3)$.

To determine the values of a no. of customers and their sojourn time in the queue as well as a system of first and second class respectively using suitable formulas among (9), (10), (11), (12), & (13). It is necessary to use the appropriate arithmetic operations described in (5), (6), (7), and (8) for addition, subtraction, multiplication, and division, respectively.

The metrics of performance are calculated and tabulated in Table 2.

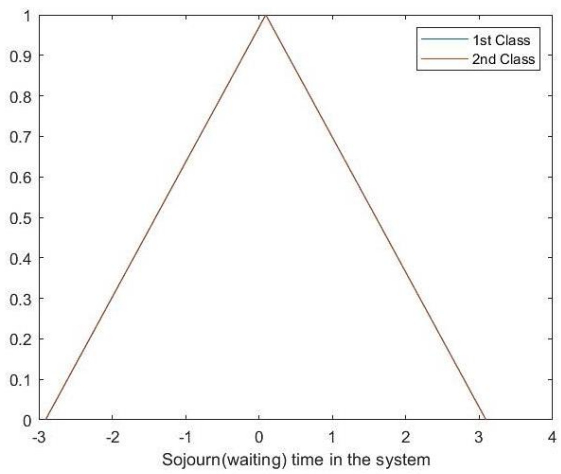

Figure. 5 The sojourn time of customers of classes 1 & 2 in the system

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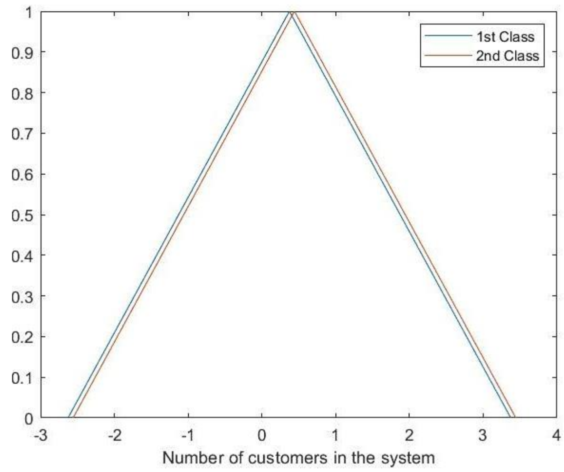

Figure. 6 The number of customers of classes 1 & 2 in the system

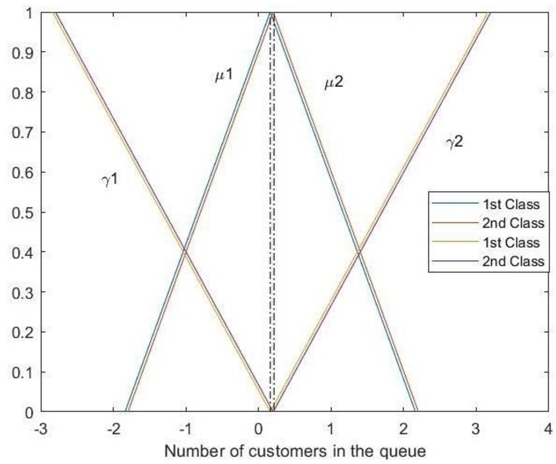

Figure. 7 The membership (μ_1&μ_2) and the non-membership (γ_1&γ_2) functions of classes 1 & 2 number of customers in the queue

7. Commentary and implications

Tables 1 and 2 provide the findings, which show multiple evaluations of every class for a diverse range of membership functions (TFN, and TIFN).

The following figures depict the visualizations of Tables 1 and 2.

The repositioning methodology generates new configurations of real variables, such as touchdown and administrations rates, for each class, as illustrated in Tables 1 and 2 and its visual presentation in Figures. 1 to 8. Consequently, various operation parameters are estimated and appear to converge across two classes in the entire framework. Tables also show that in the framework, all executing proportion of class 1 has been less than otherwise comparable to executing proportion of class 2 for both types of fuzzy numbers (i.e., triangular, triangular intuitionistic).

8. Sensitivity investigation

A sensitivity investigation is applied with distinct fuzzy numbers (triangular, triangular intuitionistic fuzzy numbers) based on predictions of each class in this part to assess the model's responsivity. The goal of sensitivity analysis is to find differences between the two groups while estimating their implementation probabilities. Table 3 shows the results that were generated.

This queuing model's sensitivity is investigated by altering, i.e., declining or raising the values of any parameter $(\tilde{\lambda}_1 \& \tilde{\lambda}'_1; \tilde{\mu}_1 \& \tilde{\mu}'_1; \tilde{\lambda}_2 \& \tilde{\lambda}'_2; \tilde{\mu}_2 \& \tilde{\mu}'_2)$ while maintaining the values of all other components constant. For instance, in the case of TFN when the value of the component $\tilde{\lambda}_1$ is reduced by 0.5, then the value of $\tilde{\lambda}_1$ becomes $\tilde{\lambda}_1 = (1.5,3.5,5.5) \approx (3.5,2,2)$ retaining $\tilde{\lambda}_2, \tilde{\mu}_1, \tilde{\mu}_2$ as it is, then the quantifiable metrics $\tilde{N}_q, \tilde{N}_s, \tilde{T}_q \& \tilde{T}_s$ of class 1 are less than or comparable to the quantifiable metrics of class 2. Likewise, when $\tilde{\lambda}_1$ is raised by 0.5, then the value of $\tilde{\lambda}_1$ becomes $\tilde{\lambda}_1 = (2.5,4.5,6.5) \approx (4.5,2,2)$ a similar occurrence can be seen. In the case of triangular intuitionistic fuzzy numbers when $\tilde{\lambda}'_1$ is declined by 0.5 and raised by 0.5 we got the same consequence. We also noticed that using predetermined variables of fuzzy numbers stimulates us to ensure precise data and make more versatile recommendations in the process.

Furthermore, the use of various types of fuzzy numbers (triangular and triangular intuitionistic) encourages us to obtain more accurate data, allowing the management to select the most appropriate values and act rationally.

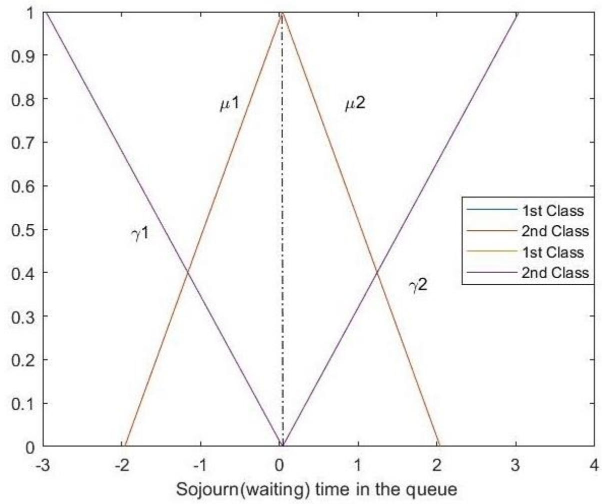

Figure. 8 The membership (μ_1&μ_2) and the non-membership (γ_1&γ_2) functions of classes 1 & 2 sojourn time of customers in the queue

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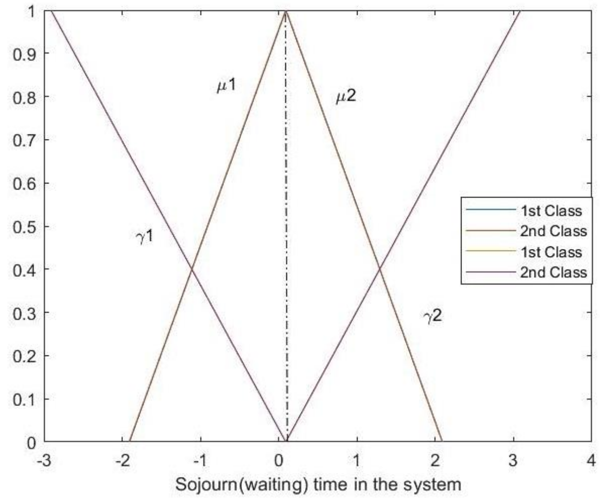

Figure. 9 The membership (μ_1&μ_2) and the non-membership (γ_1&γ_2) functions of classes 1 & 2 sojourn time of customers in the system

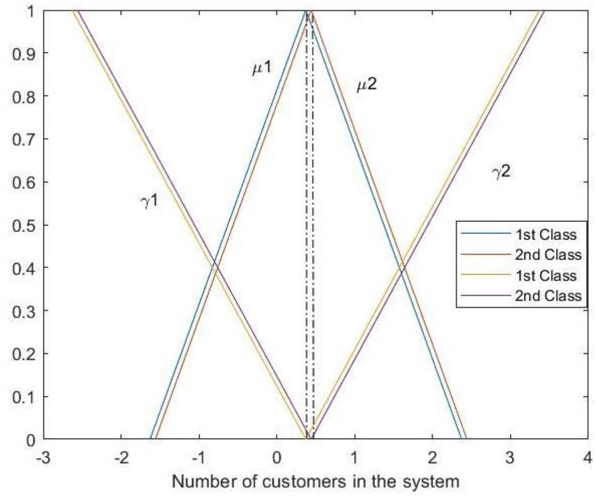

Figure. 10 The membership (μ_1&μ_2) and the non-membership (γ_1&γ_2) functions of class 1 & 2 number of customers in the system

Table 3. Sensitivity investigation of executing proportion

		Decrease $(\tilde{\lambda}_1 or \tilde{\lambda}'_1)$ value by 0.5	**Increase $(\tilde{\lambda}_1 or \tilde{\lambda}'_1)$ value by 0.5**
TFN	$\tilde{N}_q^{(1)}$	$(-2.8734, 0.1266, 3.1266)$	$(-2.7971, 0.2029, 3.2029)$
	$\tilde{N}_q^{(2)}$	$(-2.8192, 0.1808, 3.1808)$	$(-2.7744, 0.2256, 3.2256)$
	$\tilde{T}_q^{(1)}$	$(-2.9639, 0.0361, 3.0361)$	$(-2.955, 0.045, 3.045)$
	$\tilde{T}_q^{(2)}$	$(-2.9639, 0.0361, 3.0361)$	$(-2.9549, 0.0451, 3.0451)$
	$\tilde{N}_s^{(1)}$	$(-2.6896, 0.3104, 3.3104)$	$(-2.5608, 0.4392, 3.4392)$
	$\tilde{N}_s^{(2)}$	$(-2.5815, 0.4185, 3.4185)$	$(-2.5365, 0.4635, 3.4635)$
	$\tilde{T}_s^{(1)}$	$(-2.9113, 0.0887, 3.0887)$	$(-2.9024, 0.0976, 3.0976)$
	$\tilde{T}_s^{(2)}$	$(-2.9163, 0.0837, 3.0837)$	$(-2.9073, 0.0927, 3.0927)$
TIFN	$\widetilde{N'}_q^{(1)}$	$\begin{pmatrix}-1.8735, 0.1265, 2.1265; \\ -2.8735, 0.1265, 3.1265\end{pmatrix}$	$\begin{pmatrix}-1.7971, 0.2029, 2.2029; \\ -2.7971, 0.2029, 3.2029\end{pmatrix}$
	$\widetilde{N'}_q^{(2)}$	$\begin{pmatrix}-1.8192, 0.1808, 2.1808; \\ -2.8192, 0.1808, 3.1808\end{pmatrix}$	$\begin{pmatrix}-1.7744, 0.2256, 2.2256; \\ -2.7744, 0.2256, 3.2256\end{pmatrix}$
	$\widetilde{T'}_q^{(1)}$	$\begin{pmatrix}-1.9639, 0.0361, 2.0361; \\ -2.9639, 0.0361, 3.0361\end{pmatrix}$	$\begin{pmatrix}-1.955, 0.0450, 2.0450; \\ -2.955, 0.0450, 3.0450\end{pmatrix}$
	$\widetilde{T'}_q^{(2)}$	$\begin{pmatrix}-1.9639, 0.0361, 2.0361; \\ -2.9639, 0.0361, 3.0361\end{pmatrix}$	$\begin{pmatrix}-1.9549, 0.0451, 2.0451; \\ -2.9549, 0.0451, 3.0451\end{pmatrix}$
	$\widetilde{N'}_s^{(1)}$	$\begin{pmatrix}-1.6896, 0.3104, 2.3104; \\ -2.6896, 0.3104, 3.3104\end{pmatrix}$	$\begin{pmatrix}-1.5608, 0.4392, 2.4392; \\ -2.5608, 0.4392, 3.4392\end{pmatrix}$
	$\widetilde{N'}_s^{(2)}$	$\begin{pmatrix}-1.5815, 0.4185, 2.4185; \\ -2.5815, 0.4185, 3.4185\end{pmatrix}$	$\begin{pmatrix}-1.5365, 0.4635, 2.4635; \\ -2.5365, 0.4635, 3.4635\end{pmatrix}$
	$\widetilde{T'}_s^{(1)}$	$\begin{pmatrix}-1.9113, 0.0887, 2.0887; \\ -2.9113, 0.0887, 3.0887\end{pmatrix}$	$\begin{pmatrix}-1.9024, 0.0976, 2.0976; \\ -2.9024, 0.0976, 3.0976\end{pmatrix}$
	$\tilde{T'}_s^{(2)}$	$\begin{pmatrix}-1.9163, 0.0837, 2.0837; \\ -2.9163, 0.0837, 3.0837\end{pmatrix}$	$\begin{pmatrix}-1.9073, 0.0927, 2.0927; \\ -2.9073, 0.0927, 3.0927\end{pmatrix}$

IFS appears to provide some potential in strategic planning challenges. Decision-makers may be unable to appropriately articulate their perspectives on the circumstance in some contexts due to a lack of comprehensive, persistent, or substantial insight into the problem, or because they are unable to differentiate the extent to which one alternative is preferable to another. The decision-maker may exhibit significant inclinations for possibilities in some circumstances, but it's conceivable that they aren't completely convinced. To address the necessity of combinatorial optimization with inconsistency and ambivalence, several academics have emphasized IFS theory.

9. Constrictions

The arrival rate is not consistent, which is a glaring restriction. It is contingent on the state. The steady-state solution will be implemented by the queuing model. Unlike the conventional model, which posits that arrivals track a poisson process with exponential random service times, in many real-world circumstances, the arrival rate is more empirical than deterministic. There is only one channel model accessible. The average rate of arrival is lower than the average rate of service, that is, this model can only be used for two classes; it cannot be used for more than two classes.

10. Conclusion

In this paper, IFS is proven to be a stronger tool than fuzzy set theory when grappling with prospective implementation in queuing models with 2 classes, including the commercial production process. Despite switching queues from fuzzy to crisp nature, we evaluated the system using typical evaluation criteria such as the projected length of the queue of customers in lines and system for both categories of arrivals. Furthermore, the predicted sojourn time of customers in the line and across the system is computed using fuzzy values and intuitionistic fuzzy values. Sensitivity analysis is used in this work to evaluate the difference between the two categories while assessing their performance proportions. In every scenario, the implementation proportions of class one in the framework are less than or comparable to the executing proportions of class two. Another reason for adopting the proposed technique index is that it provides more than a single remedy of morals in the queuing system with different kinds of membership functions while also achieving accurate value inside the closed crisp interval.

When the available information is insufficient for the decision - makers, the researcher will choose to reach conclusions in a fuzzy environment. Only the degree of acceptance is addressed in fuzzy sets, while an intuitive fuzzy set is defined by a membership function and a non-membership function, the sum of which is less than 1. IFN appear to fit the vagueness and lack of precision of data in one way. As a result, IFS could be used to help humans make choices and do other tasks that require cognitive experience and expertise but are intrinsically imprecise or unreliable.

The fuzzy and intuitionistic fuzzy queue with two classes is more precisely explained, and the proposed method is used to reach scientific conclusions. TFN and TIFN arithmetical representations are used to assess the correctness of the proposed queuing system. The intuitionistic fuzzy queuing model is substantially more productive and convenient in appraising measurements of the queuing models since this intuitionistic fuzzy theory is more flexible and scalable. As a result, intuitionistic fuzzy queuing is one of the better ways of computing assessment criteria because the evidence gathered from the application is simpler to pick up and decipher, according to this investigation.

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Conflicts of interest

The authors state that they have no conflicting interests in the publication of this paper.

Author contributions

Conceptualization, S. Aarthi and M. Shanmugasundari; methodology, S. Aarthi and M. Shanmugasundari; software, S. Aarthi; validation, M. Shanmugasundari and S. Aarthi; formal analysis, M. Shanmugasundari; investigation, S. Aarthi and M. Shanmugasundari; resources, S. Aarthi and M. Shanmugasundari; data-curation, S. Aarthi and M. Shanmugasundari; writing—original draft preparation, S. Aarthi; writing—review and editing, S. Aarthi; visualization, S. Aarthi and M. Shanmugasundari; supervision, M. Shanmugasundari.

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