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A Decision-Making Framework for Sustainable Highway Restaurant Site Selection: AHP-TOPSIS Approach based on the Fuzzy Numbers

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ABSTRACT

This research work indicates the site selection problem for a restaurant beside the highway. It is really challenging as well as demanding work. It mainly depends on the cost of the selected location, transportation, parking facilities, hygienic atmosphere, distance from the city, etc. In this paper, the proposed site selection problem is constructed and solved by using a fuzzy Multi-Criteria Decision Making (MCDM) process. The two methods of MCDM that we use here, namely the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), are used to calculate criteria weights and rank the proposed restaurant locations, respectively. Multiple decision makers' (DMs) opinions are considered for data collection, and Trapezoidal Fuzzy Numbers (TrFNs) are taken as uncertainty tools to deal with uncertainty. Finally, we perform sensitivity and comparative analyses to verify the system's vagueness and flexibility.

1. Introduction

In the present life, on hectic days when every minute counts, food delivery in fast could be a great option of people when especially they travel by road. Fast food is also a fantastic choice when you don't have time to prepare a meal. Actually, quick-service restaurants (QSR) or fast-food cuisine are popular day by day all over the world besides first-world countries. So, the site selection of a restaurant beside the highway is very demanding and asserting work. It becomes more difficult to construct when more criteria or features are added. Choosing the best location can play a vital role in this business. From

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this motivation, this article are constructed. For this work, the fuzzy set and number are regarded as a mathematical tool. Specifically, Trapezoidal Fuzzy Numbers (TrFNs) [1] are used here to solve this site selection problem. As the selection of the perfect site is influenced by multiple aspects, it can be chosen as an application of multi criteria decision making (MCDM). The decision making tools like the Analytic Hierarchy Process (AHP) [2] and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [3] are applied here to process the site selection problem. To compute the criteria weight and ranking of sites, we process the AHP and TOPSIS methods, respectively.

1.1 Novelties of the research

This portion describes the novelties of this paper. The site selection for a restaurant beside the highway is a very difficult and asserting matter. The following points are the novelties in the work:

1. Various challenges are adopted and analysed for the site selection problem of a restaurant beside the highway.
2. Different things like cost of land and transportation, parking facility, healthy atmosphere and distance from big cities are mainly considered and elaborately discussed as criteria.
3. Two MCDM techniques are applied to evaluate the proposed model, namely the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods.
4. Two DMs are considered for required data collection.
5. To find the uncertainty of the work consider Trapezoidal Fuzzy Numbers (TrFNs).
6. To verify the stability and vagueness of the result sensitivity and comparative analyses are conducted.

1.2 Structure of this paper

The structure of this study is discussed in detail in this section. Section 1 introduced the introduction, motivation and novelties of this work. A brief literature review on mathematical tools like fuzzy sets and MCDM methodologies is discussed in Section 2. Section 3 describes the preliminary of fuzzy sets and numbers. Two MCDM techniques are covered in Section 4. The criteria selection and alternatives of restaurant site selection beside the highway of this research problem are fully discussed in Section 5. Section 6 mentions the model formulation, data collection and numerical illustration. Then sensitivity analysis and comparative analysis are performed in Section 7. Lastly, the conclusion and future research scope are perfectly described in Section 8.

2. Literature survey of this study

This section describes on literature survey of this study. First discussed the fuzzy set theory [4] and then the MCDM methods [5] very briefly.

2.1 Fuzzy Set theory

Uncertainty concepts are very popular nowadays for statistical and mathematical modelling. Fuzzy set theory is one of the uncertainty measures ideologies which has great applicability in the scientific community. Fuzzy set theory was introduced by Lotfi A. Zadeh in 1965 [6], which is a mathematical framework for dealing with uncertainty and imprecision. In the classical set theory, the concept is that an element either belongs or does not belong to a set whereas fuzzy sets allow for degrees of membership, characterized by a membership function that assigns each element a value between 0 and 1. This type of flexibility makes fuzzy sets particularly very useful in fields such as decision-making, control systems and machine learning in real-world situations modelling. Here are some important key sources on fuzzy set theory that can give the basic concepts, theories and structures [7–12].

Here are some fuzzy sets applications oriented papers in recent times in the field of social science [13], differential equation [4], site selection [5], Bio mathematical modelling [14], Manufacturing design [15], inventory planning problem [16], discrete system modelling [17], arms race modelling [18], edge computing model [19].

2.2 Multi Criterion Decision Making method

Multi-Criterion Decision Making (MCDM) is a topic that belongs to the field of operations research that deals with decision-making problems involving multiple criterion and also with conflicting criteria. It has various methods, techniques and approaches for finding the criterion weight and evaluating, comparing, and prioritizing different alternatives for making the best possible decision. There exist several methods for solving MCDM namely AHP [20], Entropy [13], CRITIC [21], TOPSIS [20], COPRAS [22], WASPAS [19], CoCoSo [19], VIKOR [13], DEMATEL [23], MOORA [24], MULTIMOORA [25], ELECTRE [26], etc.

Thus these MCDM approaches help decision-makers in complex situations where it is essential to expressly take choices between criteria to be considered, preferences of alternatives as well as improving the process's flexibility and transparency. Here are some areas where MCDM are already applied: Selection of an ideal MQL [27], Service quality evaluation [28], Shopping mall site selection [29], Car selection [30], risk factor for COVID-19 [31], diseases detection [21], measuring pollution attribute [32], etc.

3. Fuzzy Sets and Number

In this section, we reminisce some vital and primary concepts of fuzzy sets, fuzzy numbers, Trapezoidal Fuzzy Numbers (TrFNs), pursuing their definitions, properties and connate examples.

3.1 Fuzzy Set and Fuzzy Number

Fuzzy notion may vary or significantly depending on the situation or context, whose bounds are not always defined. This concept is restricted to a certain interval value. To extend the classical concept of a set, Lotfi A. Zadeh [6] represented a set, named 'Fuzzy' in 1965. Fuzzy techniques are generally used for solving complex problems and bioinformatics fields.

Definition 1. ***Fuzzy Set:****[33, 34]*

Consider, $\mathscr{Y}$ be a universal set and y be an arbitrary element of $\tilde{\mathscr{P}}$. So, the fuzzy set $\tilde{\mathscr{P}}$ on $\mathscr{Y}$ is defined as,

$$\tilde{\mathscr{P}} = \{(y, \mu_{\tilde{\mathscr{P}}}(y)) : y \in \mathscr{Y}\} \tag{1}$$

where $\mu_{\tilde{\mathscr{P}}}(y) : \mathscr{Y} \to [0, 1]$ be the membership value of element y in $\tilde{\mathscr{P}}$.

Example 1. *In the real world, the words 'good', 'bad', 'tall' and 'high' are fuzzy terms. Because, just as a 5'6" person is tall, a 6' person is also tall and there is no fixed cleaning range for being 'tall'* *which is fuzzy concept. For more clear concept, let, the set of heights of a group of boys in a college is $\mathscr{Y} = \{y_1, y_2, y_3, y_4, y_5\}$. And, $\tilde{\mathscr{P}}$ be the set of these 'tall' boys. Here, the term 'tall' is used as fuzzy term. Finally, the required fuzzy set is, $\tilde{\mathscr{P}} = \{(y_1, 0.3), (y_2, 0.4), (y_3, 1), (y_4, 0.8), (y_5, 0.7)\}$.*

Here, the y_2 boy is 'tall' of the 0.4 range and so on.

Definition 2. ***Fuzzy Number:*** *[4, 34]*

Let, a fuzzy set $\tilde{\mathscr{P}}$ on the set of real numbers $\mathbb{R}$. It must maintain the following five criteria to be a fuzzy number. These are:

(a) $\tilde{\mathscr{P}}$ needs to be the normal fuzzy set. i.e., $\mu_{\tilde{\mathscr{P}}}(z) = 1$ where $z \in \tilde{\mathscr{P}}$.

(b) $\tilde{\mathscr{P}}$ must be a convex fuzzy set. i.e., for all $\alpha-$cuts $\tilde{A}_\alpha$, $\alpha \in [0, 1]$.

(c) The membership function of $\tilde{\mathscr{P}}$, i.e., $\mu_{\tilde{\mathscr{P}}}(z)$ exhibits piecewise continuity.

(d) ${}^0\tilde{\mathscr{P}}$, the support of $\tilde{\mathscr{P}}$, must be limited or bounded within a particular range.

Example 2. *If we consider that, Ratul is a 'young' office colleague. But only the word 'young' cannot indicate his actual age. It can mean different age to different people. So, from 0 ('Not young' in fuzzy idea) to 1 ('young' in fuzzy idea) is the membership function of above mentioned object.*

Remark 1. *The fuzzy number is a special type of fuzzy set which is defined on the set of real number $(\mathbb{R})$ and satisfies the above four criteria. In further evaluation and numerical illustration, we consider fuzzy numbers as an uncertainty tool.*

3.2 Trapezoidal Fuzzy Numbers (TrFNs)

Definition 3. ***Trapezoidal Fuzzy Numbers (TrFNs):*** *[1]*

Let, $\rho_1, \rho_2, \rho_3, \rho_4$ be the real numbers and $\tilde{\mathscr{P}} = \{\langle r, (\rho_1, \rho_2, \rho_3, \rho_4); \mu_{\tilde{\mathscr{P}}}(r)\rangle : r \in \mathbb{R}\}$ be a Trapezoidal Fuzzy Number (TrFN) whose membership function $\mu_{\tilde{\mathscr{P}}}(r)$ define as

$$\mu_{\tilde{\mathscr{P}}}(r) = \begin{cases} 0 & ;\text{ when } r < \rho_1 \\ \frac{r-\rho_1}{\rho_2-\rho_1} & ;\text{ when } \rho_1 \leq t < \rho_2 \\ 1 & ;\text{ when } \rho_2 \leq r \leq \rho_3 \\ \frac{\rho_4-r}{\rho_4-\rho_3} & ;\text{ when } \rho_3 < r \leq \rho_4 \\ 0 & ;\text{ when } \rho_4 < r \end{cases} \tag{2}$$

where $0 \leq \rho_1 \leq \rho_2 \leq \rho_3 \leq \rho_4$.

Example 3. *Let us consider, $\tilde{\mathscr{P}} = \{\langle r, (0.6, 0.7, 0.8, 0.9); \mu_{\tilde{\mathscr{P}}}(r)\rangle : r \in \mathbb{R}\}$ be a Trapezoidal Fuzzy Numbers (TrFN). Here, $0 < 0.6 < 0.7 < 0.8 < 0.9$. So, the membership function $\mu_{\tilde{\mathscr{P}}}(r)$ is denoted as,*

$$\mu_{\tilde{\mathscr{P}}}(r) = \begin{cases} 0 & ;\text{ when } r < 0.6 \\ \frac{r-0.6}{0.7-0.8} & ;\text{ when } 0.6 \leq t < 0.7 \\ 1 & ;\text{ when } 0.7 \leq r \leq 0.8 \\ \frac{0.9-r}{0.9-0.8} & ;\text{ when } 0.8 < r \leq 0.9 \\ 0 & ;\text{ when } 0.9 < r \end{cases}$$

This example really satisfies the Definition 3.

3.3 Arithmetic Operations of Trapezoidal Fuzzy Numbers (TrFNs)

The arithmetic operations of Trapezoidal Fuzzy Numbers (TrFN) are discussed in this section. Some basic arithmetic operations such as addition, subtraction, multiplication and division on TrFN are defined as follows:

Here we consider, $\tilde{\mathscr{P}} = \{\langle r, (\rho_1, \rho_2, \rho_3, \rho_4); \mu_{\tilde{\mathscr{P}}}(r)\rangle : r \in \mathbb{R}\}$ and $\tilde{\mathscr{H}} = \{\langle r', (\rho_5, \rho_6, \rho_7, \rho_8); \mu_{\tilde{\mathscr{H}}}(r')\rangle : r' \in \mathbb{R}\}$ are two TrFNs define on $\mathbb{R}$ [35]. These are some fundamental arithmetic operations with their descriptions:

(a) **Addition of two TrFNs:**
The addition of these two TrFNs $\tilde{\mathscr{P}}$ and $\tilde{\mathscr{H}}$ is define as

$$\begin{aligned} \tilde{\mathscr{P}} \oplus \tilde{\mathscr{H}} =&(\rho_1, \rho_2, \rho_3, \rho_4) + (\rho_5, \rho_6, \rho_7, \rho_8) \\ =&(\rho_1 + \rho_5, \rho_2 + \rho_6, \rho_3 + \rho_7, \rho_4 + \rho_8) \end{aligned} \tag{3}$$

(b) **Subtraction of TrFNs:**
The subtraction of these two TrFNs $\tilde{\mathscr{P}}$ and $\tilde{\mathscr{H}}$ is define as

$$\begin{aligned} \tilde{\mathscr{P}} \ominus \tilde{\mathscr{H}} =&(\rho_1, \rho_2, \rho_3, \rho_4) - (\rho_5, \rho_6, \rho_7, \rho_8) \\ =&(\rho_1 - \rho_8, \rho_2 - \rho_7, \rho_3 - \rho_6, \rho_4 - \rho_5) \end{aligned} \tag{4}$$

(c) **Multiplication of two TrFNs:**
The multiplication of two TrFNs $\tilde{\mathscr{P}}$ and $\tilde{\mathscr{H}}$ is define as

$$\begin{aligned} \tilde{\mathscr{P}} \otimes \tilde{\mathscr{H}} =&(\rho_1, \rho_2, \rho_3, \rho_4) \times (\rho_5, \rho_6, \rho_7, \rho_8) \\ =&(\rho_1\rho_5, \rho_2\rho_6, \rho_3\rho_7, \rho_4\rho_8) \end{aligned} \tag{5}$$

(d) **Scalar Multiplication of TrFN:**
Let, M be any real number, then the Scalar Multiplication with the given TrFN $\tilde{\mathscr{P}}$ is,

$$\begin{aligned} M \otimes \tilde{\mathscr{P}} =&M \times (\rho_1, \rho_2, \rho_3, \rho_4) \\ =&(M\rho_1, M\rho_2, M\rho_3, M\rho_4) \end{aligned} \tag{6}$$

Example 4. *Let us consider,* $\tilde{\mathscr{P}} = \{\langle r, (2,3,4,5); \mu_{\tilde{\mathscr{P}}}(r)\rangle : r \in \mathbb{H}\}$ *and* $\tilde{\mathscr{H}} = \{\langle r', (6,7,8,9); \mu_{\tilde{\mathscr{H}}}(r')\rangle : r' \in \mathbb{R}\}$ *are two TrFNs define on* $\mathbb{R}$ *where* 10 *is scalar.So, the arithmetic Operations of Trapezoidal Fuzzy Numbers (TrFNs) is denoted as,*

(a) ***Addition of two TrFNs:***
Addition of two TrFNs $\tilde{\mathscr{P}}$ *and* $\tilde{\mathscr{H}}$ *is,*

$$\begin{aligned} \tilde{\mathscr{P}} \oplus \tilde{\mathscr{H}} =&(2,3,4,5) + (6,7,8,9) \\ =&(8,10,12,14) \end{aligned}$$

(b) ***Subtraction of TrFNs:***
Subtraction of two TrFNs $\tilde{\mathscr{P}}$ *and* $\tilde{\mathscr{H}}$ *is,*

$$\begin{aligned} \tilde{\mathscr{P}} \ominus \tilde{\mathscr{H}} =&(2,3,4,5) - (6,7,8,9) \\ =&(2-9, 3-8, 4-7, 5-6) \\ =&(-7,-5,-3,-1) \end{aligned}$$

(c) ***Multiplication of two TrFNs:***
Multiplication of two TrFNs $\tilde{\mathscr{P}}$ *and* $\tilde{\mathscr{H}}$ *is,*

$$\begin{aligned} \tilde{\mathscr{P}} \otimes \tilde{\mathscr{H}} =&(2,3,4,5) \times (6,7,8,9) \\ =&(12,21,32,45) \end{aligned}$$

(d) ***Scalar Multiplication of TrFN:***
Scalar Multiplication with the TrFN $\tilde{\mathscr{P}}$ is,

$$\begin{aligned}10 \otimes \tilde{\mathscr{P}} =& 10 \times (2, 3, 4, 5)\\ =& (20, 30, 40, 50)\end{aligned}$$

3.4 *Defuzzification of Trapezoidal Fuzzy Numbers (TrFNs)*

This section discoursed the de-fuzzification methods of Trapezoidal Fuzzy Numbers (TrFNs). Since there is no order relation of the fuzzy set and the fuzzy number, therefore de-fuzzification method [5, 13] gives a crisp number for every fuzzy number. There are several de-fuzzification techniques on TrFNs in various studies. The de-fuzzification technique utilized in this study is presented as follows:

Definition 4. *Let, $\tilde{\mathscr{P}} = \{\langle r, (\rho_1, \rho_2, \rho_3, \rho_4); \mu_{\tilde{\mathscr{P}}}(r)\rangle : r \in \mathbb{R}\}$ be a Trapezoidal Fuzzy Number(TrFN). Then, the defuzzification value of $\tilde{\mathscr{P}}$, denoted as $\mathscr{D}(\tilde{\mathscr{P}})$ [36] is,*

$$\mathscr{D}(\tilde{\mathscr{P}}) = \frac{\rho_1 + 2\rho_2 + 2\rho_3 + \rho_4}{6} \tag{7}$$

Example 5. *Let, $\tilde{\mathscr{P}} = \{\langle r, (2, 3, 4, 5); \mu_{\tilde{\mathscr{P}}}(r)\rangle : r \in \mathbb{R}\}$ and $\tilde{\mathscr{H}} = \{\langle r', (6, 7, 8, 9); \mu_{\tilde{\mathscr{R}}}(r')\rangle : r' \in \mathbb{R}\}$ are two Trapezoidal Fuzzy Numbers (TrFNs). Then, the defuzzification values of $\tilde{\mathscr{P}}$ and $\tilde{\mathscr{H}}$, denoted as $\mathscr{D}(\tilde{\mathscr{P}})$ and $\mathscr{D}(\tilde{\mathscr{H}})$ respectively as,*

$$\begin{aligned}\mathscr{D}(\tilde{\mathscr{P}}) =& \frac{2 + (2 \times 3) + (2 \times 4) + 5}{6}\\ =& \frac{21}{6} = 3.5\end{aligned}$$

and

$$\begin{aligned}\mathscr{D}(\tilde{\mathscr{H}}) =& \frac{6 + (2 \times 7) + (2 \times 8) + 9}{6}\\ =& \frac{45}{6} = 7.5\end{aligned}$$

4. MCDM Methodologies in Fuzzy Environment

This section discussed the mathematical process through multi-criteria decision making (MCDM) [19] methodologies used in this study. It is a popular process for calculating the factor's weight and ranking the alternatives for making decisions in considering multiple conflicting factors. There are two MCDM methods applied here to evaluate results, namely the Analytic Hierarchy Process (AHP) [20] and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [37] methods. The methodologies of the above mentioned methods are described as follows:

4.1 *Analytic Hierarchy Process (AHP): a weight method*

When assessing multi criteria to aid in decision-making, the analytical hierarchy process (AHP) [20] is an effective tool. This is a technique for making and analysing difficult decisions based on real-life mathematical problems and psychology in the branch of multi criteria decision making (MCDM).

Decision-makers must evaluate the criteria, that are named the comparison matrix in this process, in order to reach a decision. This approach also can be used to fix the relative value in pairs of the criterion for each sub-criteria. The AHP method was invented and structured by Thomas L. Saaty [2]. This comparison matrix is used to design by linguistic terms, further transfer into Trapezoidal Fuzzy Numbers (TrFNs) and help to take clear final decision from decision makers (DMs). Structural flowchart of the AHP method is depicted in Figure 1. Now, let the numerical procedure of this method as follows:

(a) The number of Decision Makers (DMs) is d,

(b) The number of criteria is β.

So, the procedure of AHP is discussed as follows:

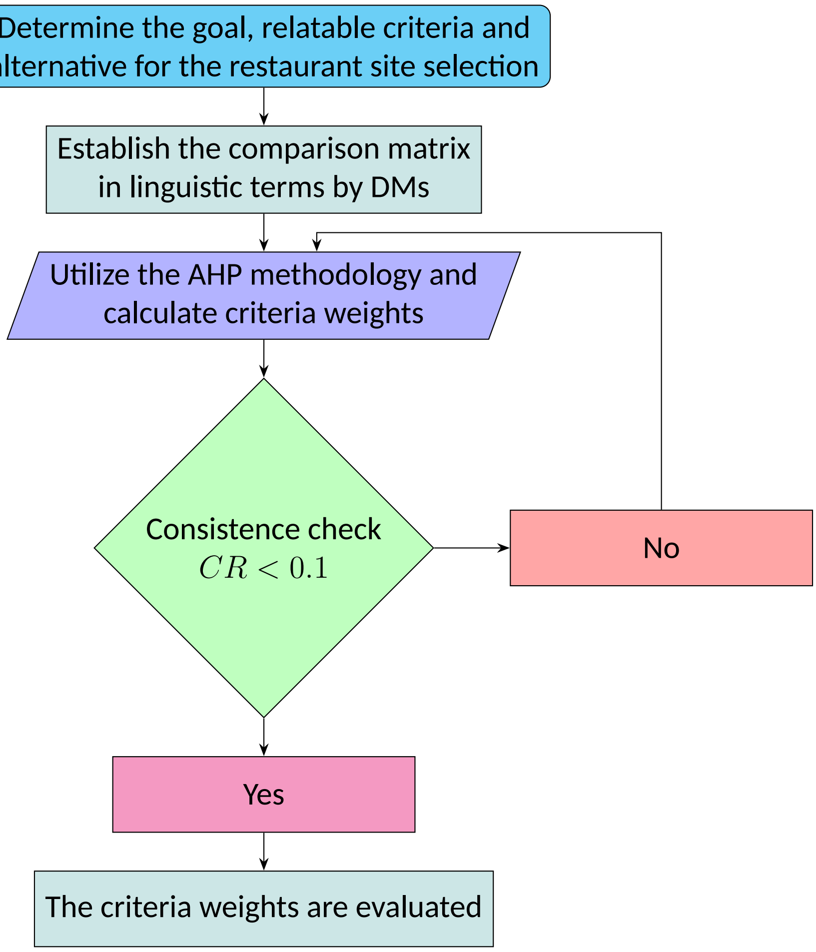

Fig. 1. Flowchart of the AHP method and determine the weights of the criteria

I. Design the hierarchical form:
The first step in solving the problem by this method is to identify the factors and choose the DMs.

II. Structured the comparison matrix with the help of DMs:
In this work, the comparison matrix is formed with trapezoidal Fuzzy Numbers (TrFNs) on the

conception of ρth DMs as follows:

$$\tilde{\mathscr{A}}_\rho = \begin{bmatrix} (\tilde{E}_{11})_\rho & (\tilde{E}_{12})_\rho & \cdots & (\tilde{E}_{1\beta})_\rho \\ (\tilde{E}_{21})_\rho & (\tilde{E}_{22})_\rho & \cdots & (\tilde{E}_{2\beta})_\rho \\ \vdots & \vdots & \ddots & \vdots \\ (\tilde{E}_{\beta 1})_\rho & (\tilde{E}_{\beta 2})_\rho & \cdots & (\tilde{E}_{\beta\beta})_\rho \end{bmatrix}_{\beta\times\beta} \tag{8}$$

Here, each entry is a TrFNs element that appears in comparison matrices $\tilde{\mathscr{A}}_\rho$.

Now, the Equation (8) can also be described as follows,

$$\tilde{\mathscr{A}}_\rho = \left[\left(\tilde{E}_{\eta\zeta}\right)_\rho\right]_{\beta\times\beta} = \left[\left((\tilde{\delta}_1, \tilde{\delta}_2, \tilde{\delta}_3, \tilde{\delta}_4)_{\eta\zeta}\right)_\rho\right] \tag{9}$$

Each entry of these is described by ρth DMs with ratting on criteria ζ to η, so,

$$\left(\tilde{E}_{\eta\zeta}\right)_\rho = \left((\tilde{\delta}_1, \tilde{\delta}_2, \tilde{\delta}_3, \tilde{\delta}_4)_{\eta\zeta}\right)_\rho = \left((\tilde{\delta}_1)^\rho_{\eta\zeta}, (\tilde{\delta}_2)^\rho_{\eta\zeta}, (\tilde{\delta}_3)^\rho_{\eta\zeta}, (\tilde{\delta}_4)^\rho_{\eta\zeta}\right) \tag{10}$$

where, $\eta, \zeta = 1, 2, \ldots, \beta$ and $\rho = 1, 2, \ldots, d$.

III. Aggregation to all the comparison matrices:

In this step, we aggregate the comparison Matrices (8) and get a single comparison matrix $\tilde{\mathscr{A}}$ in Equation (11).

The single comparison matrix is,

$$\tilde{\mathscr{A}} = \left[\tilde{E}_{\eta\zeta}\right]_{\beta\times\beta} = \left[\left(\tilde{\delta}_1, \tilde{\delta}_2, \tilde{\delta}_3, \tilde{\delta}_4, \tilde{\delta}_5\right)_{\eta\zeta}\right]_{\beta\times\beta} = \left[\left((\tilde{\delta}_1)_{\eta\zeta}, (\tilde{\delta}_2)_{\eta\zeta}, (\tilde{\delta}_3)_{\eta\zeta}, (\tilde{\delta}_4)_{\eta\zeta}\right)\right]_{\beta\times\beta} \tag{11}$$

when $\eta, \zeta = 1, 2, \ldots, \beta$ and each entry of Equation (11) can simplify by the following way, i.e.,

$$\begin{cases} (\tilde{\delta}_1)_{\eta\zeta} = & \min\limits_{\rho=1,2,\ldots,d} (\tilde{\delta}_1)^\rho_{\eta\zeta} \\ (\tilde{\delta}_2)_{\eta\zeta} = & \min\limits_{\rho=1,2,\ldots,d} (\tilde{\delta}_2)^\rho_{\eta\zeta} \\ (\tilde{\delta}_3)_{\eta\zeta} = & \max\limits_{\rho=1,2,\ldots,d} (\tilde{\delta}_3)^\rho_{\eta\zeta} \\ (\tilde{\delta}_4)_{\eta\zeta} = & \max\limits_{\rho=1,2,\ldots,d} (\tilde{\delta}_4)^\rho_{\eta\zeta} \end{cases} \tag{12}$$

IV. De-fuzzify the aggregated comparison matrix

Calculate the de-fuzzified aggregated comparison matrix $(\mathscr{A})$ from aggregated comparison matrix $(\tilde{\mathscr{A}})$. The de-fuzzified aggregated comparison matrix $\mathscr{A}$ displayed as follows:

$$\mathscr{A} = [E_{\eta\zeta}]_{\beta\times\beta} \tag{13}$$

where $E_{\eta\zeta}$ be de-fuzzified value of TrFN $\tilde{E}_{\eta\zeta}$ evaluated by de-fuzzified formula mentioned in Equation (7) and $\eta, \zeta = 1, 2, \ldots, \beta$.

V. Normalized the above comparison matrix:

Equation (13) yielded the de-fuzzified aggregated comparison matrix $(\mathscr{A})$, which was normalised $(\mathscr{B})$ to Equation (14) as follows:

$$\mathscr{B} = [\mathscr{H}_{\eta\zeta}]_{\beta\times\beta} = \left[\frac{E_{\eta\zeta}}{\sum_{\zeta=1}^{\beta} E_{\eta\zeta}}\right]_{\beta\times\beta} \tag{14}$$

where $\eta, \zeta = 1, 2, \ldots, \beta$.

VI. Evaluate the weight of criteria:
The weight of the criteria η is denoted by $\mathscr{W}_\eta$ and evaluated by Equation (15), as follows:

$$\mathscr{W}_\eta = \frac{\left(\sum_{\zeta=1}^{\beta} \mathscr{H}_{\eta\zeta}\right)^{\frac{1}{\beta}}}{\sum_{\eta=1}^{\beta}\left\{\left(\sum_{\zeta=1}^{\beta} \mathscr{H}_{\eta\zeta}\right)^{\frac{1}{\beta}}\right\}} \tag{15}$$

where $\eta = 1, 2, \ldots, \beta$.

VII. Calculate the weighted comparison Matrix:
We can calculate the weighted comparison Matrix $(\mathscr{W}\mathscr{C})$ from normalized comparison matrix $(\mathscr{B})$ in Equation (14) and criteria weight $(\mathscr{W}_\eta)$ by using Equation (16), as follows:

$$\mathscr{W}\mathscr{C} = [\mathscr{W}\mathscr{C}_{\eta\zeta}]_{\beta\times\beta} = \mathscr{W}_\eta \times \mathscr{B} = [\mathscr{W}_\eta \times \mathscr{H}_{\eta\zeta}]_{\beta\times\beta} \tag{16}$$

where $\eta = 1, 2, \ldots, \beta$.

VIII. Weighted sum of each factor of the comparison matrix:
The weighted sum $(\mathscr{W}\mathscr{S}_\eta)$ of each factor of the comparison matrix is,

$$\mathscr{W}\mathscr{S}_\eta = \frac{\left(\sum_{\zeta=1}^{\beta} \mathscr{W}\mathscr{C}_{\eta\zeta}\right)}{\mathscr{W}_\eta} \tag{17}$$

where, $\eta = 1, 2, \ldots, \beta$ and β be the number of criteria.

IX. Find the maximum eigenvalue $(\alpha_{\max})$:
The maximum eigenvalue $(\alpha_{\max})$ of the above comparison matrix is,

$$\alpha_{\max} = \frac{\sum_{\eta=1}^{\beta} \mathscr{W}\mathscr{S}_\eta}{\beta} \tag{18}$$

where $\eta = 1, 2, \ldots, \beta$.

X. Evaluate the Consistency Index (CI):
Now, the consistency index (CI) of the comparison matrix is as follows,

$$CI = \frac{\alpha_{\max} - \beta}{\beta - 1} \tag{19}$$

XI. Find the final the Consistency Ratio (CR):
Finally, the CR value is determined as,

$$CR = \frac{CI}{RI} \tag{20}$$

The Random Index (R.I.) is proposed by Thomas L. Saaty [2] shown in Table 1 for various sizes of comparison matrix.

The calculated value of the Consistency Ratio (CR) must be ≤ 0.1; otherwise, the comparison matrix will be inconsistent and it has to be rectified and reconstructed again.

Table 1
Random Index (R.I.) values [2] among the different number of factors

Λ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54	1.56	1.57	1.59

4.2 *Technique for Order Preference by Similarity to Ideal Solution (TOPSIS): a ranking method*

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [20, 37] method is one of the popular MCDM methods for ranking alternatives. In this method, ratio analysis of the minimum distance from the positive ideal solution and the maximum distance from the negative ideal solution and based on the evaluated results rank the alternatives. Hwang *et al.*, [3] in 1981 first proposed the TOPSIS method and further modified it. This method is mainly used for different business purposes of different industries [38]. The structural procedure of the TOPSIS methodology is presented in Figure 2.

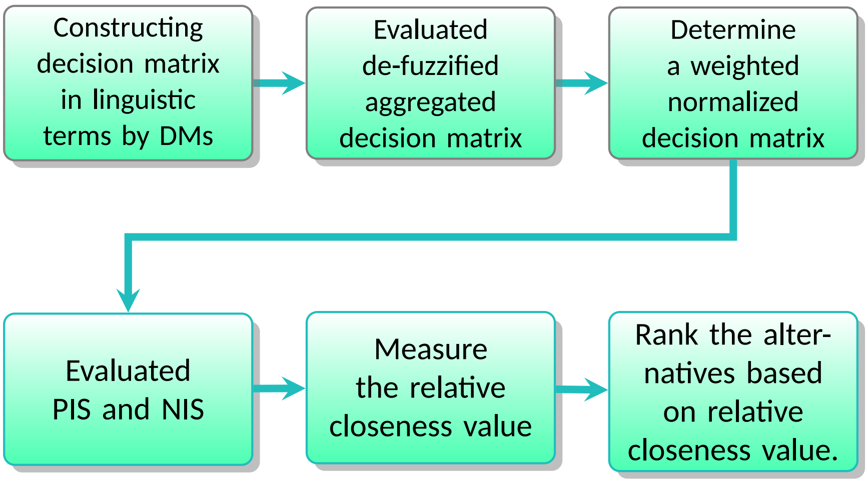

Fig. 2. Constructional framework of the TOPSIS methodology

Let us choose, an MCDM site selection problem with β number of criteria associated with γ number of alternatives exist, respectively. This process is described with the TrFNs environment with d number of DMs. The numerical computation steps of the fuzzy TOPSIS method are as follows:

A. Figure out a fuzzy decision matrix:
In this paper, the initial decision matrix is designed with linguistic terms which are transformed into Trapezoidal Fuzzy Numbers (TrFNs). Let us choose, a decision matrix with β criteria and γ alternatives considered as structured in Equation (21) shown.

$$\tilde{\mathscr{D}}_\rho = \begin{bmatrix} (\tilde{F}_{11})_\rho & (\tilde{F}_{12})_\rho & \cdots & (\tilde{F}_{1\beta})_\rho \\ (\tilde{F}_{21})_\rho & (\tilde{F}_{22})_\rho & \cdots & (\tilde{F}_{2\beta})_\rho \\ \vdots & \vdots & \ddots & \vdots \\ (\tilde{F}_{\gamma 1})_\rho & (\tilde{F}_{\gamma 2})_\rho & \cdots & (\tilde{F}_{\gamma\beta})_\rho \end{bmatrix}_{\gamma\times\beta} \tag{21}$$

here $\tilde{\mathscr{D}}_\rho = [(\tilde{F}_{\iota\eta})_\rho]_{\gamma\times\beta}$ represented the Equation (21), where $\iota = 1, 2, \ldots, \gamma$ and $\eta = 1, 2, \ldots, \beta$.

B. Aggregated the decision matrix:
The decision matrices given by d numbers of DMs are aggregated and produce one decision

matrix $(\tilde{\mathscr{D}})$, as follows:

$$\tilde{\mathscr{D}} = \begin{bmatrix} \tilde{F}_{11} & \tilde{F}_{12} & \cdots & \tilde{F}_{1\beta} \\ \tilde{F}_{21} & \tilde{F}_{22} & \cdots & \tilde{F}_{2\beta} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{F}_{\gamma 1} & \tilde{F}_{\gamma 2} & \cdots & \tilde{F}_{\gamma\beta} \end{bmatrix}_{\gamma\times\beta} \tag{22}$$

where $\tilde{F}_{\iota\eta}$ be the aggregated TrFN of DMs opinions on TrFNs $\{(\tilde{F}_{\iota\eta})_\rho : \rho = 1, 2, \ldots, d\}$ and aggregated by Equation (12) with $\iota = 1, 2, \ldots, \gamma$ and $\eta = 1, 2, \ldots, \beta$.

C. De-fuzzified the aggregated decision matrix:
De-fuzzified the TrFN in an aggregated decision matrix $(\tilde{\mathscr{D}})$ by the de-fuzzified method in Equation (7). The de-fuzzified aggregated matrix $(\mathscr{D})$ structured as

$$\mathscr{D} = [F_{\iota\eta}]_{\gamma\times\beta} \tag{23}$$

where $F_{\iota\eta}$ be the de-fuzzified value of $\tilde{F}_{\iota\eta}$ with $\iota = 1, 2, \ldots, \gamma$ and $\eta = 1, 2, \ldots, \beta$.

D. Determine weighted decision matrix:
The weighted decision matrix $(\mathscr{D}^w)$ calculated from the de-fuzzified aggregated decision matrix $(\mathscr{D})$ and weight of the criteria $(\mathscr{W}_\eta)$ evaluated in the previous section by Equation (15), as follows:

$$\begin{aligned} \mathscr{D}^w &= \left[F^w_{\iota\eta}\right]_{\gamma\times\beta} = \mathscr{W}_\eta \times [F_{\iota\eta}]_{\gamma\times\beta} \\ &= \left[\mathscr{W}_\eta \times F^w_{\iota\eta}\right]_{\gamma\times\beta} \end{aligned} \tag{24}$$

where $\iota = 1, 2, \ldots, \gamma$ and $\eta = 1, 2, \ldots, \beta$.

E. Identification and normalization of fuzzy decision matrix:
In this step, we find a new normalized decision Matrix (25) with Beneficial criteria and Non-beneficial criteria, which is denoted as B.C. (more is better) and N.B.C. (less is better), respectively. So, we get that,

$$\mathscr{D}^n = \begin{bmatrix} F^n_{11} & F^n_{12} & \cdots & F^n_{1\beta} \\ F^n_{21} & F^n_{22} & \cdots & F^n_{2\beta} \\ \vdots & \vdots & \ddots & \vdots \\ F^n_{\gamma 1} & F^n_{\gamma 2} & \cdots & F^n_{\gamma\beta} \end{bmatrix}_{\gamma\times\beta} \tag{25}$$

Equation (25) is represented as, $\mathscr{D}^n = [F^n_{\iota\eta}]_{\gamma\times\beta}$, where $\iota = 1, 2, \ldots, \gamma$ and $\eta = 1, 2, \ldots, \beta$. The normalized value $(F^n_{\iota\eta})$ are calculated in Equation (26), as follows:

$$F^n_{\iota\eta} = \frac{F_{\iota\eta}}{\sum_{\iota=1}^{\gamma} F_{\iota\eta}} \tag{26}$$

where $\eta = 1, 2, \ldots, \beta$.

F. Find the Positive Ideal Solutions (PIS) and Negative Ideal Solutions (NIS):
The PIS and NIS are denoted by $\mathscr{I}^+$ and $\mathscr{I}^-_\eta$, respectively. So, we use the following formula,

$$\mathscr{I}^+_\eta = \left\{F^+_1, F^+_2, \ldots, F^+_\eta, \ldots, F^+_\beta\right\} = \left\{\max\left\{F_{\iota\eta} : \eta \in B.C.(I^+)\right\}, \min\left\{F_{\iota\eta} : \eta \in N.B.C.(I^-)\right\}\right\} \tag{27}$$

and

$$\mathscr{I}^-_\eta = \left\{F^-_1, F^-_2, \ldots, F^-_\eta, \ldots, F^-_\beta\right\} = \left\{\min\left\{F_{\iota\eta} : \eta \in B.C.(I^+)\right\}, \max\left\{F_{\iota\eta} : \eta \in N.B.C.(I^-)\right\}\right\} \tag{28}$$

where $B.C.(I^+)$ and $N.B.C.(I^-)$ are the sets of beneficial and non-beneficial criteria, respectively.

G. Caltulate the separation measure for each alternative far from the PIS and NIS::
The standard separation measures are defined in the following way,

$$\tilde{\Upsilon}_{\iota}^{+} = \sqrt{\sum_{\eta=1}^{\beta} \left(F_{\iota\eta}^{n} - \mathscr{I}_{\eta}^{+}\right)^{2}} \tag{29}$$

and

$$\tilde{\Upsilon}_{\iota}^{-} = \sqrt{\sum_{\eta=1}^{\beta} \left(F_{\iota\eta}^{n} - \mathscr{I}_{\eta}^{-}\right)^{2}} \tag{30}$$

where $\iota = 1, 2, \ldots, \gamma$.

H. Determine the Relative Closeness Coefficient (RCC):
The Relative Closeness Coefficient (RCC) $(\tilde{\Upsilon}_{\iota})$ to the ideal alternatives is denoted as,

$$\tilde{\Upsilon}_{\iota} = \frac{\tilde{\Upsilon}_{\iota}^{-}}{\tilde{\Upsilon}_{\iota}^{+} + \tilde{\Upsilon}_{\iota}^{-}} \tag{31}$$

where $\iota = 1, 2, \ldots, \gamma$.

I. Required result:
This is the last and final step in this procedure. Here, the options that are ranked as ideal alternatives are those that are based on RCC $(\tilde{\Upsilon}_{\iota})$. The closest coefficient is with the highest value of the first alternatives and so on.

5. Criterion selection for restaurant site selection beside the highway

This section discusses on application of the proposed model. There are two parts of this section, first the selection process of the criteria for restaurants beside highways and second the different sites (locations) for restaurants. The criteria and alternatives of the proposed model are briefly discussed as follows:

5.1 *Criterion for site selection problem regarding restaurant beside the highway*

The site selection for highway side restaurant involves various essential criteria to ensure that the proposed locations are viable for business and profitable for owners. Selection of an accessible, profitable and visible location for a restaurant [39, 40] is very challenging task. Figure 3 represents the flowcharts of the site selection criteria, which are described below:

5.1.1 *Cost of restaurant land* (C_1)*:*

For a highway side restaurant, the cost of land is important since it affects the initial investment, impacts operating cost and overall profitability. Elevated land prices may lead to increased registration charges, higher property taxes, more spending on insurance and extra capital expenditure, necessitating higher menu pricing to pay costs thus impacting competitiveness. Expensive locations can provide better access and exposure, drawing in more clients. To ensure a positive return on investment, it is crucial to balance the cost of the land with the potential for foot traffic and revenue creation.

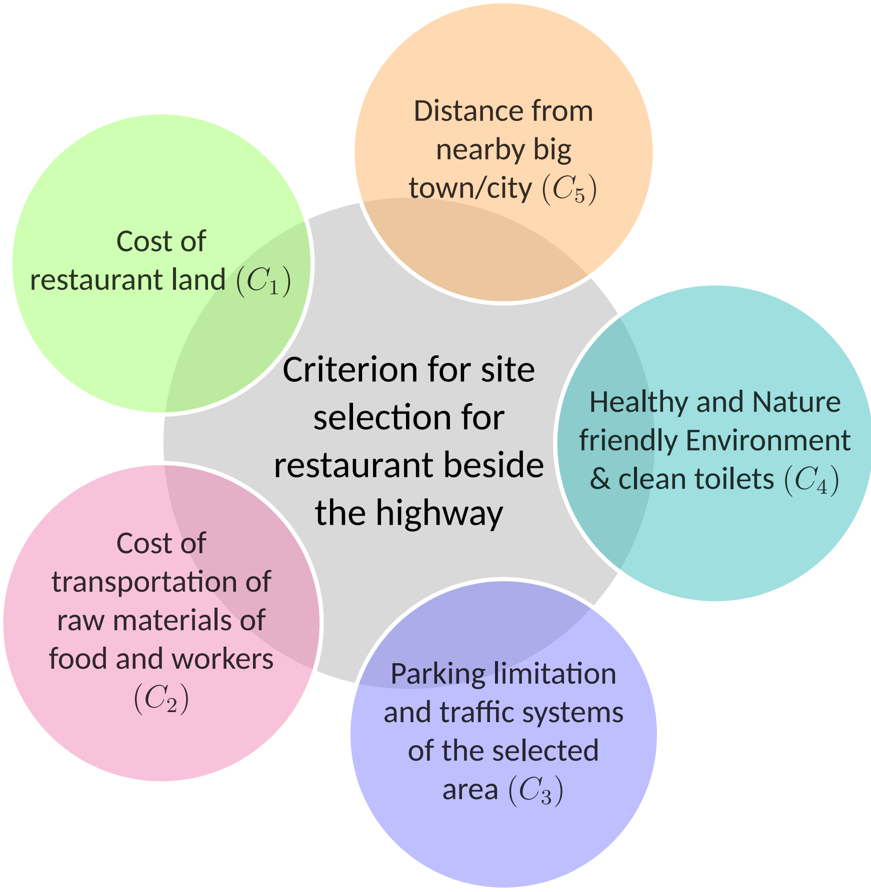

Fig. 3. Criteria for choosing locations for restaurant beside highway

5.1.2 *Cost of transportation of raw materials of food and workers* (C_2)*:*

A restaurant's operational costs are strongly impacted by the cost of labour and raw material transportation, making it an important consideration while choosing a location. Proximity to suppliers and a dependable transportation system reduces expenses and ensures fresh ingredients arrival on time, which is essential for maintaining the quality of food and upholding the standard of service. Additionally, labour costs and employee happiness is impacted by staff accessibility to transportation. Since effective logistics save operating costs, boost profitability, and ensure constant product quality and customer service, transportation costs are a crucial factor to take into account when selecting a location.

5.1.3 *Parking limitation and traffic systems of the selected area* (C_3)*:*

When picking a location for a restaurant next to a highway, parking restrictions and the local traffic pattern are important considerations because they have an immediate effect on customer convenience, safety and accessibility. Sufficient parking is necessary to serve drive-thru and dine-in patrons, guaranteeing a seamless and effective experience. A well-thought-out traffic plan that allows for simple entry and exit reduces traffic, augments safety, and draws more patrons. On the other hand, insufficient parking and complex traffic pattern discourages prospective visitor, lower employee retention, and eventually impact the restaurant's earnings and standing. Consequently, choosing the best site requires a careful assessment of these factors.

5.1.4 *Healthy and Nature friendly Environment, clean toilets* (C_4)*:*

A healthy and nature-friendly environment, along with clean toilets, is vital when choosing a site for a restaurant near a highway, as it significantly influences customer satisfaction and the restaurant's reputation. A pleasant, well-maintained environment attracts travellers looking for a comfortable and hygienic place to rest and eat, enhancing their overall experience. Clean facilities, especially toilets, are a basic expectation for travellers and can be a decisive factor in choosing a dining spot. Additionally, promoting an eco-friendly image through sustainable practices can appeal to environmentally conscious customers, differentiating the restaurant in a competitive market. These factors collectively help build customer loyalty and encourage repeat visits.

5.1.5 *Distance from nearby big town/city* (C_5)*:*

A restaurant business along a highway should consider its distance from a local town or city because this affects foot traffic volume and consumer accessibility. Being nearer to cities can increase prospective sales by drawing in both locals and tourists. Additionally, it streamlines supply chain operations, which lowers costs and simplifies the process of getting frequent deliveries of fresh ingredients. On the other hand, a restaurant that is too far from a town or city may find it harder to attract locals and may have to pay more for personnel and supplies transportation. Thus, it is essential to strike a balance between highway visibility and closeness to population centres in order to maximise customer engagement and operational efficiency.

5.2 *Alternative selection as different sites*

Selection for sites as alternatives for the restaurant beside the highway is discussed in this section. Five locations are chosen for this study besides the National Highway 12 (NH-12) in the state of West Bengal, India. The NH-12 highway connects South Bengal with North Bengal, especially two big cities Kolkata and Siliguri in West Bengal and we proposed five small cities beside this highway. The proposed sites and their geographical specifications are described in Table 2. Furthermore, we show the satellite view of the NH-12 from Kolkata to Siliguri and mention all five locations in Figure 4 from Google Maps.

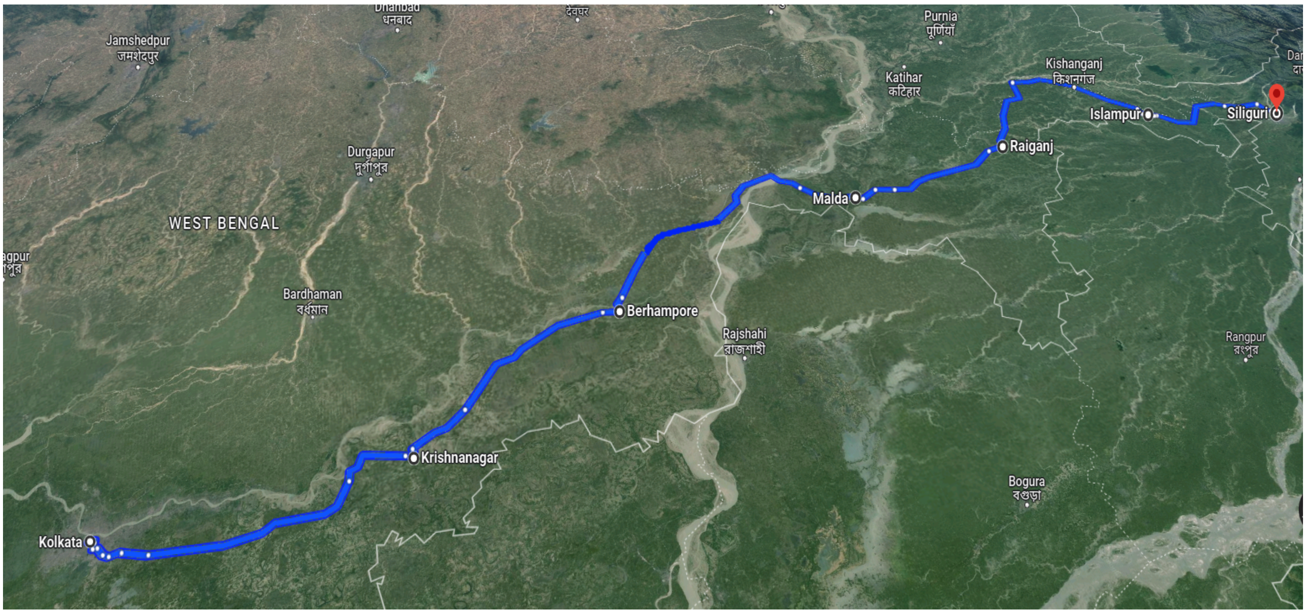

Fig. 4. Proposed restaurant locations beside NH-12 in West Bengal from Google map, 2024

Table 2
Alternatives (locations) and their details for site selection of restaurant

Location	Latitude	Longitude	Locations details
Krisnanagar (Nadia) (L_1)	23.4013° N	88.5021° E	It is the headquarters of the Nadia district and the distance from Kolkata is 119 km via NH-12.
Baharampur (Murshidabad) (L_2)	24.0983° N	88.2684° E	The administrative headquarters of the Murshidabad district is Berhampore and the distance from Kolkata is 199 km via NH-12.
Malda (Malda) (L_3)	25.0108° N	88.1411° E	Malda, also known as English Bazar is the sixth largest city of West Bengal and the government headquarters of the Malda district. Its distance from Kolkata is 328 km via NH-12.
Raiganj (Uttar Dinajpur) (L_4)	25.6329° N	88.1319° E	An administrative unit and Sadar city of Uttar Dinajpur district of state West Bengal. Also, 403 km far from Kolkata via NH-12.
Islampur (Uttar Dinajpur) (L_5)	26.2554° N	88.2009° E	This city is a municipality in Uttar Dinajpur district and distance from Kolkata is 509 km via NH-12.

The distance between different proposed cities with beginning and destination cities is presented in Table 3 in kilometres (km). The distance between Kolkata and Siliguri is near about 579 km and further any combinations among cities are easily calculated from the below table.

Table 3
Distance between different cities in West Bengal shown in kilometres (km) via NH-12

City							
1	**Kolkata**						
2	119	**Krisnanagar**					
3	199	80	**Baharampur**				
4	328	209	129	**Malda**			
5	403	284	204	75	**Raiganj**		
6	509	390	310	181	106	**Islampur**	
7	579	460	380	251	176	69	**Siliguri**

6. Model structure, data sets and solution

This section presented the application of the proposed fuzzy framework more elaborately. First, formulate the model and collect data for the numerical study, followed by numerical results by two MCDM methods.

6.1 Model formulation and Data collection

The model formulation for this study, together with data collection and formulation are covered in this section.

6.1.1 Model structure

There are five criteria considered for this site selection study of a restaurant beside the highway, which are mentioned in Section 5. This portion mainly describes the structure of this work. Here, five different locations are also taken as alternatives which is discussed in Section 6. Therefore, the decision matrix and comparison matrix have ordered 5×5 and 5×5, respectively. The flowchart of this proposed site selection work of a restaurant is structured in Figure 5. Required data are gathered by two decision makers (DMs). All these DMs are experts and professionals in this field. The two DMs are:

DM1: A successful businessman in restaurant section;

DM2: Persons having knowledge in economics and travelling.

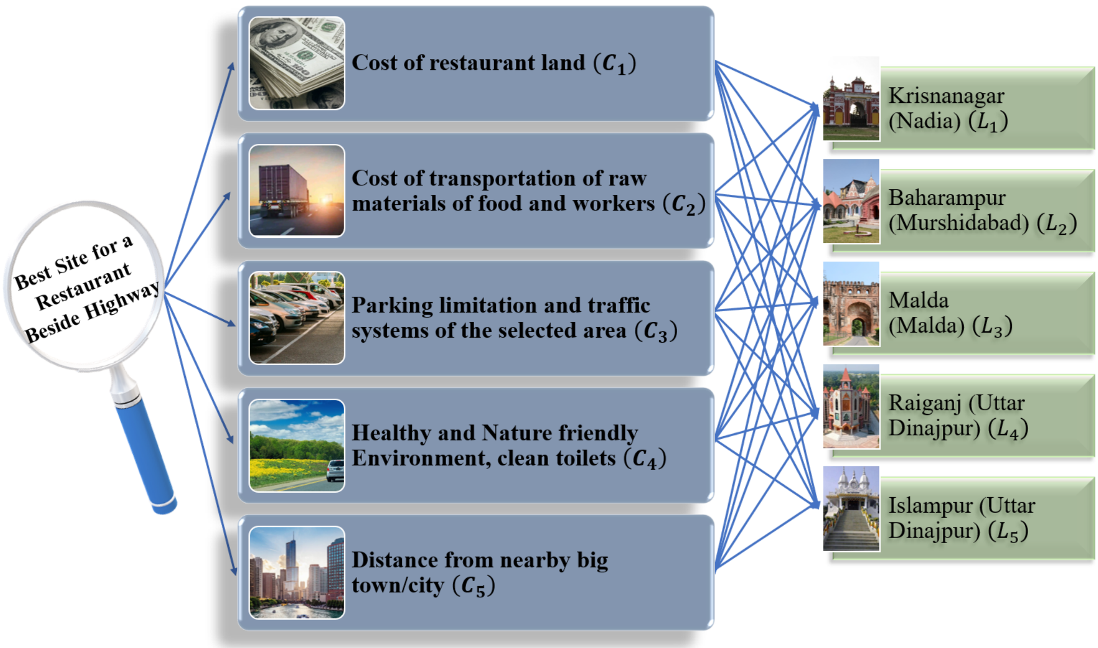

Fig. 5. Structural flowchart of the proposed model

6.1.2 Data collection

This section covers the data sources of this study. All the data was collected from two DMs in linguistic terms form and after that, it was converted into TrFN by Table 4 and Table 6. The comparison matrix among criteria is presented in Table 5 in linguistic terms using Table 4. For the AHP method, the comparison matrix was utilised as the data source.

After that, the decision matrix between criteria and alternative is shown in Table 7 in linguistic terms by using Table 6. The decision matrix helps to rank alternatives using the TOPSIS method.

Table 4
Conversion table between linguistic term and TrFNs for comparison matrix

Linguistic Terms	Trapezoidal Fuzzy Number (TrFN)	Defuzzified Value
Absolutely Important (AI)	$(5, 6, 8, 9)$	7
Strongly Important (SI)	$(3, 4, 6, 7)$	5
Very Important (VI)	$(1, 2, 4, 5)$	3
Equally Important (EI)	$(0.2, 0.25, 1, 3)$	0.95
Weakly Important (WI)	$(0.2, 0.25, 0.5, 1)$	0.33
Low Important (LI)	$(0.14, 0.17, 0.25, 0.33)$	0.2
Poorly Important (PI)	$(0.11, 0.13, 0.17, 0.2)$	0.14

Table 5
Comparison matrix in linguistic terms given by two DMs

	Criteria vs Criteria	Cost of restaurant land (C_1)	Cost of transportation of raw materials of food and workers (C_2)	Parking limitation and traffic systems of the selected area (C_3)	Healthy and Nature friendly Environment, clean toilets (C_4)	Distance from nearby big town/city (C_5)
DM 1	Cost of restaurant land (C_1)	EI	SI	VI	VI	AI
	Cost of T. of raw materials of food and workers (C_2)	LI	EI	WI	WI	SI
	Parking L. and traffic systems of the selected area (C_3)	WI	VI	EI	VI	AI
	Healthy and Nature friendly E., clean toilets (C_4)	WI	VI	WI	EI	LI
	Distance from nearby big town/city (C_5)	PI	LI	PI	SI	EI
	Criteria vs Criteria	Cost of restaurant land (C_1)	Cost of transportation of raw materials of food and workers (C_2)	Parking limitation and traffic systems of the selected area (C_3)	Healthy and Nature friendly Environment, clean toilets (C_4)	Distance from nearby big town/city (C_5)
DM 2	Cost of restaurant land (C_1)	EI	AI	SI	VI	SI
	Cost of T. of raw materials of food and workers (C_2)	PI	EI	LI	LI	VI
	Parking L. and traffic systems of the selected area (C_3)	LI	SI	EI	SI	SI
	Healthy and Nature friendly E., clean toilets (C_4)	WI	SI	LI	EI	WI
	Distance from nearby big town/city (C_5)	LI	WI	LI	VI	EI

Table 6
Linguistic term with corresponding Trapezoidal Fuzzy Number (TrFN) for decision matrix

Linguistic Term	Trapezoidal Fuzzy Number (TrFN)	Defuzzified Value
Definitely Priority (DP)	$(7, 8, 10, 11)$	9
Highly Priority (HP)	$(6, 7, 9, 10)$	8
Very Priority (VP)	$(5, 6, 8, 9)$	7
Average Priority (AP)	$(4, 5, 7, 8)$	6
Below Priority (BP)	$(3, 4, 6, 7)$	5
Low Priority (LP)	$(2, 3, 5, 6)$	4
Negligible Priority (NP)	$(1, 2, 4, 5)$	3

Table 7
Decision matrix in linguistic terms given by two DMs

	Criteria vs Alternative	Cost of restaurant land (C_1)	Cost of transportation of raw materials of food and workers (C_2)	Parking limitation and traffic systems of the selected area (C_3)	Healthy and Nature friendly Environment, clean toilets (C_4)	Distance from nearby big town/city (C_5)
DM 1	Krisnanagar (Nadia) (L_1)	DP	DP	HP	HP	DP
	Baharampur (Murshidabad) (L_2)	HP	VP	DP	VP	HP
	Malda (Malda) (L_3)	HP	DP	HP	HP	DP
	Raiganj (Uttar Dinajpur) (L_4)	VP	VP	AP	BP	AP
	Islampur (Uttar Dinajpur) (L_5)	BP	LP	LP	NP	AP
	Criteria vs Alternative	Cost of restaurant land (C_1)	Cost of transportation of raw materials of food and workers (C_2)	Parking limitation and traffic systems of the selected area (C_3)	Healthy and Nature friendly Environment, clean toilets (C_4)	Distance from nearby big town/city (C_5)
DM 2	Krisnanagar (Nadia) (L_1)	DP	HP	DP	HP	DP
	Baharampur (Murshidabad) (L_2)	VP	HP	HP	HP	VP
	Malda (Malda) (L_3)	HP	DP	DP	HP	DP
	Raiganj (Uttar Dinajpur) (L_4)	AP	BP	AP	BP	AP
	Islampur (Uttar Dinajpur) (L_5)	LP	NP	LP	NP	BP

6.2 *Numerical illustration*

In this section, we can show the site selection problem for a restaurant beside the highway and how it varies with locations by numerical way. Here, we have taken the MCDM methodology with the help of TrFN. In the decision making process, to find criteria weights and the rank of alternatives, we apply AHP and TOPSIS techniques, respectively.

First of all, we collect the perfect decision from two DMs to make the comparison matrix Table 5 and the decision matrix Table 7. Then, we compute the factor weights using the AHP method in the fuzzy environment discussed in Section 4.1. The weight of the criteria is shown in Table 8 by the AHP method.

Table 8
Criteria weight evaluated by AHP methodology

Criteria	**Weight**
Cost of restaurant land (C_1)	0.4640
Cost of transportation of raw materials of food and workers (C_2)	0.0926
Parking limitation and traffic systems of the selected area (C_3)	0.2544
Healthy and Nature friendly Environment, clean toilets (C_4)	0.1089
Distance from nearby big town/city (C_5)	0.0801

Table 8 narrates the criteria weight of this site selection problem. Therefore, Figure 6 shows it more clearly using the Pi diagram.

Remark 2. *It is clear from the above Table 8 and Figure 6 show that, the Cost of restaurant land* (C_1) *get the maximum and the Distance from nearby big town/city* (C_5) *gets the minimum weight. Then, Parking limitation and traffic systems of the selected area*(C_3)*, Healthy and Nature friendly Environment, clean toilets* (C_4) *and Cost of transportation of raw materials of food and workers* (C_2) *are the*

Images/Screenshot (114).png

Fig. 6. Pi diagram of the criteria weight (AHP method)

second, third and forth weight, respectively.

In ranking various locations as alternatives for confirming and determining that which location would be best for the site selection for a restaurant. Here, we use the TOPSIS method of MCDM methodology, that already discussed in Section 4.2 under a fuzzy sphere. We represent the ranking of alternatives in Table 9 with the TOPSIS method to understand the difference between best and worst location for the restaurant which depends on the weighting of several criteria in Table 8.

The relative distance between the alternatives was shown in Table 9 with their criteria weight and Figure 7 presents the bar diagram of the location ranking.

Remark 3. *According to the two decision makers perspective, it can be said that Baharampur (Murshidabad) (L_2) is the most preferable (best) and Islampur (Uttar Dinajpur) (L_5) is less preferable (worst) location for this site selection problem. Furthermore, Malda (Malda) (L_3), Krisnanagar (Nadia) (L_1) and Raiganj (Uttar Dinajpur) (L_4) occupied the 2nd, 3rd and 4th rank, respectively.*

Table 9
Ranking of the restaurant sides using the TOPSIS method

Alternative	$\tilde{\Upsilon}_\iota^+$	$\tilde{\Upsilon}_\iota^-$	$\tilde{\Upsilon}_\iota$	Ranking
Krisnanagar (Nadia) (L_1)	0.2760	0.4002	0.5918	3
Baharampur (Murshidabad) (L_2)	0.2608	0.4154	0.6143	1
Malda (Malda) (L_3)	0.2628	0.4135	0.6114	2
Raiganj (Uttar Dinajpur) (L_4)	0.3838	0.2925	0.4325	4
Islampur (Uttar Dinajpur) (L_5)	0.3853	0.2909	0.4302	5

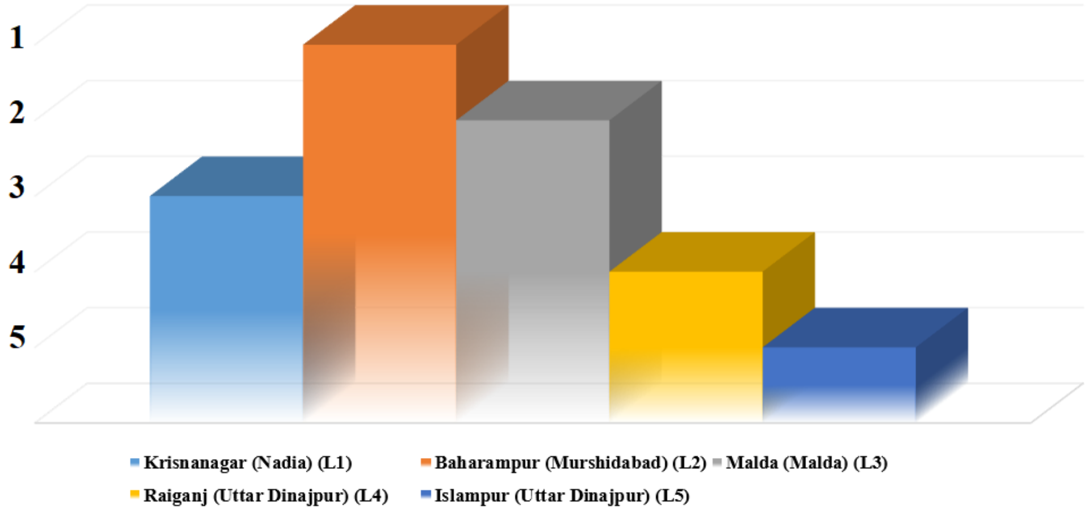

Fig. 7. Rank of proposed sites for a restaurant beside highway by TOPSIS method

7. Sensitivity Analysis and Comparative Analysis

This section describes the sensitivity analysis and comparative analysis of this study. Two cases are conducted on sensitivity analysis and comparative analysis performed based on the VIKOR based MCDM method [5, 41]. The sensitivity analysis and comparative analysis are conducted as follows:

7.1 *Sensitive analysis*

Sensitivity analysis is used to analysis and compute the system's resilience and stability. It is carried out by weighting the criteria differently or extruding some of them, then ranking the options according to the modified methods. Then, we discuss the problem of site selection for a restaurant beside highway according to the various locations. Now, we talk about two instances and each is listed below.

7.1.1 *Case 1 [Removing the criteria C_2 (Cost of transportation of raw materials of food and workers)]:*

In this case, to examine the sensitivity analysis of this problem, we remove the criteria cost of transportation of raw materials of food and workers C_2. So, taking the valuable decision of 2Dms and analysing the rest categories, we find that, Malda (Malda) L_3 is the best location for a restaurant beside the highway and so on.

Remark 4. *We observe that L_1 grabs Rank 1 and L_5 grabs Rank 5, that is shown in Table 10. Meanwhile, Figure 8 describes this case more clearly.*

7.1.2 Case 2 [Removing the criteria C_5 (Distance from nearby big town/city)]:

We analysis this case without the C_5 category, i.e., Distance from nearby big town/city. And, we get the result (Case 2) in the following Table 10. From here, we notice that it is not very different from the original method results.

Remark 5. *Here, Table 10 describes that the alternative L_2 (Baharampur (Murshidabad) and L_4 (Raiganj (Uttar Dinajpur) are ranked at 1 and rank 5, respectively. Others are L_3, L_1 and L_5 which hold the rank 3, 2 and 4, respectively. Figure 8 describes this in a pictorial representation.*

The following Table 10 presents the ranking of two special cases with the TOPSIS method of MCDM methodology and compares it with the main model. Figure 8 is the graphical representation of it.

Table 10
Alternatives ranking by removing factors in two cases by TOPSIS Method

Alternative	Case 1	Case 2	Main Method
Krisnanagar (Nadia) (L_1)	2	3	3
Baharampur (Murshidabad) (L_2)	3	1	1
Malda (Malda) (L_3)	1	2	2
Raiganj (Uttar Dinajpur) (L_4)	4	5	4
Islampur (Uttar Dinajpur) (L_5)	5	4	5

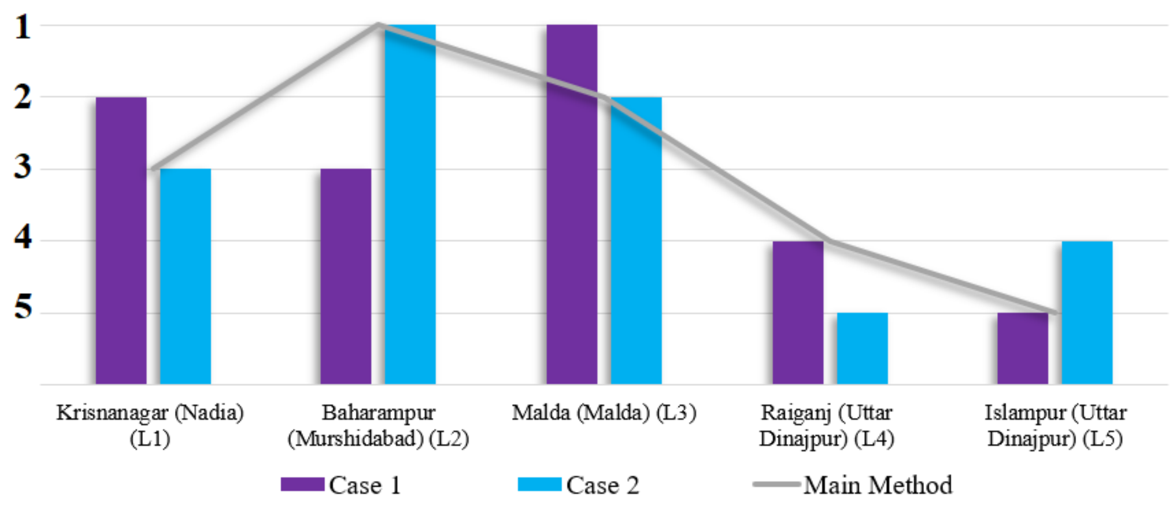

Fig. 8. Sensitivity analysis with two different cases by TOPSIS technique

7.2 Comparative analysis

This section conducted a comparative analysis of this proposed system to check the system's stability and vagueness using different MCDM techniques. Here, rank the alternatives by the VIKOR based MCDM method considering the weight evaluated by the AHP method described in the previous section. The rank of the alternatives is presented in Table 11 and comparative analysis with the main TOPSIS method ranking.

Table 11
Ranking of suggested locations based on VIKOR and TOPSIS methods

Alternative	VIKOR	TOPSIS
Krisnanagar (Nadia) (L_1)	1	3
Baharampur (Murshidabad) (L_2)	4	1
Malda (Malda) (L_3)	2	2
Raiganj (Uttar Dinajpur) (L_4)	3	4
Islampur (Uttar Dinajpur) (L_5)	5	5

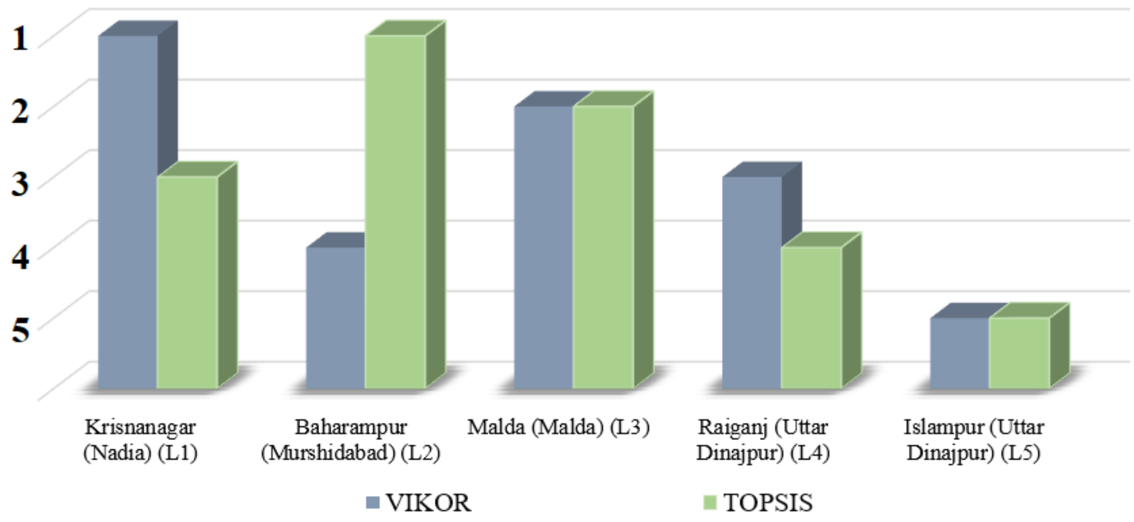

Fig. 9. Comparative analysis using two MCDM techniques

Remark 6. *From Table 11 and Figure 9, we conclude that the most stable alternatives are Malda (Malda) (L_3) and Islampur (Uttar Dinajpur) (L_5). On the other hand, alternatives Krisnanagar (Nadia) (L_1), Baharampur (Murshidabad) (L_2) and Raiganj (Uttar Dinajpur) (L_4) are interchange their position from 1st, 4th and 3rd rank, respectively.*

8. Conclusions and future research scope

This section discusses the conclusion and future research outlines in more detail. The main aim of this study is to evaluate the best restaurant locations beside the highway (NH-12 in West Bengal). To choose the most efficient sites for restaurants the criterion's play a significant role and it is a very challenging work. There are five important criteria selected according to decision makers (DMs) opinions and five proposed cities beside highways are chosen as alternatives. There are two MCDM based optimization techniques are applied to select the optimized sites. All the data was collected by two DMs in linguistic terms and then converted into TrFNs. First, the criteria weight is calculated using the AHP method and then the ranking of the locations is determined using the TOPSIS method. Here rank the proposed locations based on their priorities and suggest businessmen or anyone who wants to open a restaurant to open a restaurant in a scientifically.

From the numerical illustration section, the Cost of restaurant land (C_1) criteria obtained maximum weight and other weights of the criteria are shown in Table 8. Furthermore, Baharampur (Murshidabad) (L_2) becomes the best location for restaurants beside the highway. The full ranking of the alternatives is presented in Table 9. Lastly, the sensitivity analysis and comparative analysis were conducted to check the system's stability and robustness.

Selecting the most suitable restaurant sites is the purpose of this study. This study may be beneficial for business owners looking to invest in restaurants, food trucks, food vans, food trailers, module canteen, module kitchens, cloud kitchens as well as companies looking to open a restaurant and location specific utilities. This study is also profitable for a food lover to select his destination.

This study has limitations and it's extended in future research as follows:

1. Only the five most important criteria are considered for this study which may extended with more criteria in future. Also, a sub-criteria based MCDM model may be formulated.

2. In future studies, more sites as alternatives were taken for evaluation and different highway sites shall be considered in future evaluation. We may extend our data set for the accuracy of the results.

3. Different MCDM methodologies are taken to calculate the criteria weight and rank the alternatives.

4. To capture the uncertainty of the data collection, various fuzzy numbers may be considered like intuitionistic fuzzy numbers, neutrosophic fuzzy numbers, grey numbers, probability linguistic term sets, etc. Further, different de-fuzzified methods can be considered for de-fuzzifying the fuzzy numbers.

5. More cases can be considered for sensitivity and comparative analysis of the proposed model. Additionally, a comparative analysis may be performed using different uncertain numbers on the proposed model.

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Conflicts of Interest

The authors declare no conflicts of interest.

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