**Fuzzy Reasoning of Perceived Value in Customer Satisfaction**

Fuzzy Logic is a leading method for analysis of sentiment from linguistic terms. The development of Fuzzy logic tools the field of study of Fuzzy has been widespread. In the field of recommendation system for food industry, restaurant, university subject ranking or university ranking it can be used to reach the delicate balance between human reasoning and predicting output. In this proposal we are concerned about the growing industry of restaurant. As with the proliferation of different formats of online expressions such as reviews and ratings, the recommendation process in the competitive world of business becoming more complicated. It is difficult to determine the true intent of the customer because of large number of false reviews available on the internet that hinders the way of actual ratings of a service. To solve this issue and analyse the actual feedback of the customers to provide a good review soft computing can be best suited. In this regard, the aim of this study is to analysis the factors that may have impact on the perceived value and customer satisfaction in the fine dining system. A fuzzy based model has been proposed in this study to build a recommendation system. To see a comparative stand and to choose the best one, different membership functions and defuzzification methods are employed and a comparative analysis has been provided based on the result obtained from the study. A comprehensive example is provided to illustrate the decision procedure.

Keywords: Fuzzy Logic; Recommendation System; Linguistics; Membership Function

# 1. Introduction

We live in the age of YouTube, Amazon, Netflix, and a plethora of other web services. We cannot imagine those online services without the use of recommendation systems(Yera & Martínez, 2017). In a nutshell, recommendation systems are algorithms designed to suggest relevant items to users. The recommendation system is beneficial to both users and service providers because it reduces the transaction costs associated with selecting and finding items from any web service. It aids in increasing sales, making sound decisions in online transactions, and rearranging the user's experience with web services(Al-Dossari & Alyahya, 2020).

There are various techniques for making recommendations, such as content-based filtering, collaborative filtering (Rezaimehr & Dadkhah, 2021; Zhang et al., 2021), hybrid filtering, and so on. Collaborative filtering is the most commonly used technique because it recommends items by identifying other users who have similar tastes. In content-based filtering (Niyazov et al., 2021; Okada et al., n.d.), a user profile is created based on his or her browsing history or data provided by the user, and then likable contents are suggested to the user. Content-based filtering, collaborative filtering, and other approaches are combined in hybrid filtering (2021; Rajendran & Sundarraj, 2021). However, most recommendation systems work with a binary value of 0 or 1(Nilashi et al., 2019). That is, after filtering the contents and performing calculations If the value becomes 1, the item will be suggested; otherwise, it will not. However, there may be values ranging from 0 to 1 that define how close the content is to being suggested. Then came fuzzy logic to define the values ranging from 0 to 1. It has been widely used in the design of a recommender system to more accurately suggest items and to deal with uncertainty, impreciseness in item features, and user behavior. Design of complex system has been simplified by leveraging the explicability of the FL system and additionally the exploration of different rule-based methods have been also simplified and being applied in different research fields. In the sector of prediction or recommendation there are many ways like, ANN (Sood & Saini, 2021), FIS (Forouzandeh et al., 2021), ANFIS (Solichin & Saputri, 2021) and so on. Among them FIS is the simplest way to do human reasoning that resembles human thinking (Rojas et al., 2021).

For the evaluation of the customer's performance expectancy, a fuzzy based system has been proposed. This section presents the details of the proposed fuzzy logic-based model. Figure 1 describes the framework of a fuzzy logic-based model. Here the input data enters a block that denotes fuzzification, resulting in a fuzzy set that can be used for subsequent processing. We designed the rule base using the Mamdani inference system. The output of this inference system is the fuzzy output which needs to be defuzzfied using defuzzification process that converts the fuzzy set to crisp set. In this study we have applied several defuzzication method; COA, BOA, MOM, LOM, SOM.

To summarize, the contributions of this paper are as follows:

* This article provides a FLS based model for the analysis the impact of customer satisfaction and the perceived value on the intention of customer to recommend a place as show in Figure 1. The impact of the factors such as; food quality, facility comfort, cleanliness and timelines on perceived value and customer satisfaction also analyzed here
* Formulated 27 rules for both cases to compute the sentiment of a user in the review system.
* Comparative analysis with the aid of different defuzzification methods.

**Organization:**

The rest of the paper has been formed as follows: We discuss the related work in section II. Section III presents the system design and modelling with a broad discussion. Again, Result and Discussion section IV. Finally, this paper concludes by section V.

# 2. Related Work

The authors in (Chen, 2020) worked to improve ubiquitous hotel recommendations for online applications. They created the FUTCHR system, which is a fuzzy widespread traveler clustering and recommendation system for hotels. This system grouped travelers based on their decisions and past data. They then solved it using a fuzzy mixed binary-nonlinear programming model.

In another work (Alghamdi et al., 2019)the authors worked to create a Fuzzy-Based Recommendation System using a fuzzy inference engine, which is a decision support system that assists students in choosing their major subject at university. They used a clustering-based technique to determine the students' preferred majors.

The authors of (Shrimal et al., n.d.) worked to recommend a framework that helps users monitor their calories based on their BMI and also provides food suggestions based on their history and preferences. This recommender framework is built using personal preferences, Collaborative Filtering, and Fuzzy logic. Users can also use the Android application or Pedometer to track their steps or workouts.

The authors in (Yera & Martínez, 2017)worked on developing recommendation systems that use fuzzy tools to detect common research topics as well as research gaps. They attempt to suggest future research directions and to improve the current recommendation systems. It is designed to analyze papers in terms of key features, evaluation strategies, datasets used, and application areas.

# 3. System Design & Modelling

To recommend the perceived value and customer satisfaction more effectively, the authors present a fuzzy logic-based architecture as depicted in Figure 1. The first task required for the framework is the conversion of crisp input into a fuzzy input set. The authors chose two scenarios for this work., the first steps is to determine the perceived value based on the quality of food served, the comfort facilities available, and the time it takes to serve food, which is measured from the time the order is placed to the time the food is served on the table. The second step is to determine customer satisfaction based on the following factors: food quality, facility comfort, and cleanliness. The inputs are linguistic forms that are represented as a set of fuzzy with membership degrees. The triangular membership function was used in this work to compute MF. Then the logic needs to be set up that resembles human reasoning and comparatively the IF-THEN form of rules considered to be the simplest way of expressing human thinking. In the Fuzzy logic-based system, the antecedents, as well as the consequents, are the linguistic variables and this characteristic makes the FIS system most useful for building a complex system. For simplicity, this work considered the Mamdani FIS method, which uses the IF-THEN format to build the rules, among the three methods of inference system Mamdani, Sugeno (Murnawan & Lestari, 2021)(Tian & Wang, 2021), and Tsukamoto(Murnawan & Lestari, 2021). Table 1 presents the overall scenario of the proposed fuzzy logic-based system.



Figure Proposed Methodology

Table Properties of the proposed FLS(Sakz et al., 2021)

|  |  |
| --- | --- |
| **Properties** | **Description** |
| **Method** | Mamdani Rule Base system |
| Fuzzy AND operation | Minimum between two variables |
| Fuzzy **OR** operation | Maximum between two variables |
| **Implication** | MIN |
| **Aggregation** | MAX |
| **Defuzzification** | Centroid, Bisector, Mean of Maximum, Smallest of Maximum, Largest of Maximum |

The schematic diagram of Mamdani FIS is shown in Figure \ref{sf} that follows the following structure:

IF a is X and b is Y THEN output membership function

After designing the rule base, the defuzzification method applied to obtain the output crisp value. This process is simply the opposite of fuzzification procedure.

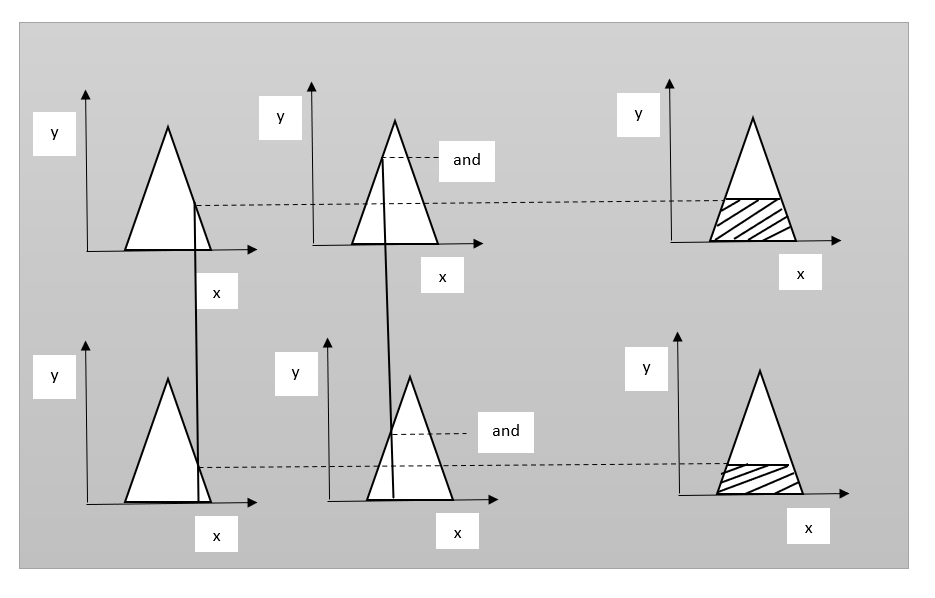


Figure Mamdani FIS-Block Representation

## 3.1 Development of Fuzzy system

For the formulation of Fuzzy Rule Base system, we have used the popular fuzzy inference method which is known as Mamdani Model. In order to develop a fuzzy system, it includes some steps as follows.

* Recognizing the input and output linguistic terms, as well as their associated values (as depicted in Table 2 and Table 3.)
* Identification of fuzzy sets and membership functions

For evaluating the performance expectancy, we have subdivided our task into two parts as follows:

* Case:1 The Impact of service quality on consumer perception.
* Case:2 The effect of service quality and perceived value on customer satisfaction

### Data set for Case-1:

According to the analysis of (Tuncer et al., 2021) the selected factors to analyse the perceived values are:

* Food Quality that has three linguistic variables “High” with range of 6-10, “Medium” 2-8 and “Low”
* Facility Comfort with linguistic variable “Amazing” (6-10), “Acceptable” (2-8) and “Poor (0-4)”
* Timeliness with linguistic variable “Fast” (6-10), “Medium” (2-8) and “Poor” (0-4).
* Another variable “Perceived Value” is used for the measurement of customer’s behavioral intention based on the input variables that have the range of 0-10 with five linguistic terms; “Very low”, “Low”, “Medium”, “High”, “Very High”.

Table Input and output variable for Case-1

|  |  |  |
| --- | --- | --- |
| Input/output | Linguistic Variable | Linguistic Values |
| Input | Food Quality | High, Low or Medium |
| Facility Comfort | Poor, Acceptable or Amazing |
| Timeliness | Poor, Medium, Fast |
| Output | Perceived Value | Very low, Low, Medium, High, Very high |

### Data set for Case-2:

Furtherthe factors in the selected factors to analyse the Customer satisfaction values are:

* Food Quality that have three linguistic variable “High” with range of 6-10, “Medium” 2-8 and “Low”
* Facility Comfort with linguistic variable “Amazing” (6-10), “Acceptable” (2-8) and “Poor (0-4)”
* Cleanlinesswith linguistic variable “Amazing” (6-10), “Acceptable” (2-8) and “Poor (0-4)”
* Another variable “Customer Satisfaction” is used for the measurement of customers behavioral intention based on the input variables that have the range of 0-10 with three linguistic terms; “Satisfied”, “Neutral”, “Dissatisfied”.

Table Input and output variable for Case-2

|  |  |  |
| --- | --- | --- |
| Input/output | Linguistic Variable | Linguistic Values |
| Input | Food Quality | High, Low or Medium |
| Facility Comfort | Poor, Acceptable or Amazing |
| Cleanliness | Poor, Acceptable or Amazing |
| Output | Customer Satisfaction | Satisfied, Neutral, Dissatisfied |

### Data set for Recommendation Procedure:

According to the study in (Tuncer et al., 2021)customer satisfaction and perceived value both have positive impact on the intention of a customer to recommend a place or not recommend. Sometimes there might be some cases where the food quality and price of the food does not match rather may unreasonable. In that case the perceived value of a customer changes that impact the recommendation procedure. They might be satisfied with the food or the place but the perceived value may restrict them to recommend the place with good score. In this scenario this section presents the input and output variable as shown in Table 4.and values for the analysis of behavioural intention of a person based on two factors perceived value and customer satisfaction.

Table Input and output variable for Behavioural Intention

|  |  |  |
| --- | --- | --- |
| Input/output | Linguistic Variable | Linguistic Values |
| Input | Perceived Value | Very low, Low, Medium, High, Very high |
| Customer Satisfaction | Satisfied, Neutral, Dissatisfied |
| Output | Possibility to Recommend | Will not recommend, less possibility of Recommendation and Will Recommend |

## 3.2 Defining Fuzzy MF

Facility Comfort, Food Quality, Cleanliness has impact on the perceived value. Customer's perceived value changes when the place is not clean or the arrival of food is not on time. On the other customer satisfaction rely Facility Comfort, Food Quality, Cleanliness in this sector timeliness does not have that high impact because in fine dining system the service and the quality matter the most (Tuncer et al., 2021)In Figure 1 the triangular membership function of the input variable is shown.

## 3.3 Formulation of Fuzzy Rule Base

In this work, we have formulated fuzzy rules separately for the two cases.

Case-1; as there are three membership variable each having three values, we have formed a rule base with 3 \* 3 \* 3 forming twenty-seven rules.

For example:

If Food Quality is “High” and Facility Comfort is “Amazing” and Timeliness is “Fast” then Perceived Value is “Very High”

The total rule base is shown in Table 5.

Table Fuzzy Rules for Case-1

|  |  |  |  |
| --- | --- | --- | --- |
| **Food Quality** | **Facility Comfort** | | |
| Poor | Acceptable | Amazing |
|  | 1. **Timeliness: Poor** | | |
| Low | Very Low | Very Low | Low |
| Medium | Low | Low | Medium |
| High | Medium | Medium | High |
|  | 1. **Timeliness: Medium** | | |
| Low | Low | Medium | Medium |
| Medium | Low | High | High |
| High | Medium | High | Very High |
|  | 1. **Timeliness: Fast** | | |
| Low | Low | Medium | Medium |
| Medium | Medium | High | Very High |
| High | Medium | Very High | Very High |

Case-2; as there are three membership variable each having three values, we have formed a rule base with 3 \* 3 \* 3 forming twenty-seven rules.

For example:

If Food Quality is “High” and Facility Comfort is “Amazing” and Cleanliness is “Amazing” then Customer is “Satisfied”

The total rule base is shown in Table 6

Table Fuzzy Rules for Case-2

|  |  |  |  |
| --- | --- | --- | --- |
| **Food Quality** | **Facility Comfort** | | |
| Poor | Acceptable | Amazing |
|  | 1. **Cleanliness: Poor** | | |
| Low | Dissatisfied | Dissatisfied | Dissatisfied |
| Medium | Dissatisfied | Dissatisfied | Neutral |
| High | Neutral | Neutral | Satisfied |
|  | 1. **Cleanliness: Acceptable** | | |
| Low | Dissatisfied | Neutral | Neutral |
| Medium | Dissatisfied | Satisfied | Satisfied |
| High | Neutral | Satisfied | Satisfied |
|  | 1. **Cleanliness: Amazing** | | |
| Low | Dissatisfied | Neutral | Neutral |
| Medium | Neutral | Satisfied | Satisfied |
| High | Neutral | Satisfied | Satisfied |

Case-3; As discussed in the previous section in this case there are two input variables having five and three input values so the total rules will be of 3\* 5 that means fifteen rules will be formed in this scenario as depicted in Table 7.

For example:

If Customer Satisfaction is “Neutral” and Perceived Value is “Medium” then Customer intention is “Less possibility to recommend”

Table Fuzzy Rules for Case-3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Customer Satisfaction** | **Perceived Value** | | | | |
| Very\_Low | Low | Medium | High | Very\_High |
| Dissatisfied | Will not Recommend | Will not Recommend | Will not Recommend | Less possibility to Recommend | Less Possibility to Recommend |
| Neutral | Will not Recommend | Will not Recommend | Less possibility to Recommend | Will Recommend | Will Recommend |
| Satisfied | Less possibility to Recommend | Less possibility to Recommend | Will Recommend | Will Recommend | Will Recommend |

## 3.4 Rule Aggregation & Defuzzification

Rule aggregation is the step of obtaining the output membership function. After the aggregation procedure then comes the defuzzification step. It is basically the opposite of fuzzification process and produces crisp output that a user can understand. In this process of producing crisp output fuzzy sets along with corresponding membership degrees are provided and based on these the crisp output is produced. For the sake of achieving goal in this work the authors proposed five type of defuzzification method.

### COA Method

This is the most widely used defuzzification method, also known as the "Centroid" method. The COA is calculated using the following equation 1 after taking into account the range of output linguistic variables under the membership function (Shamshiden & others, 2021).

…………………………..(1)

### BOA Method

In this method the actual task is done by dividing the total fuzzy sets into 2 equal regions as shown in equation 2 (Nayak et al., 2020).

……………………….. (2)

### Mean of Maximum Method

In this method the defuzzified output is the element with the largest MF value but in case of more than one having maximum it calculates the mean value for finding the output(Putri & Saputro, 2021).

……………… (3)

### Largest of Maximum Method:

From the output membership function domain it selects the maximum value(Shamshiden & others, 2021).

### Smallest of Maximum Method:

From the maximum output MF domain, it selects the smallest one (Vahabzadeh et al., 2020).

# 4. Results analysis & Discussion

To obtain the final result this model is divided into three parts. First, the perceived value is calculated then the customer satisfaction is evaluated based on the factors of facility comfort, timeliness, cleanliness, and food quality. After defuzzification of both cases, the defuzzified output enters into the final stage, and then the further processing is continued where based on the perceived value and customer satisfaction level the intention of a person to recommend a place is observed.

For the analysis of customer satisfaction first this method generated the membership values and presented graphically for better visualization.

**Case-1:**

In this scenario the input and output membership function generated for the analysis of the impact of the factors on Perceived Value. As depicted in Figure 3 , Input Membership Function: Facility Comfort, the membership function of the input variable facility comfort is shown in terms of “Poor”, “Acceptable” and, “Amazing”. In the same way Figure 4 & Figure 5, are the graph showing the input membership function for food quality and Timeliness that is used for the evaluation of Perceived Value. Again, Figure 6 represents the output membership function having the linguistic value “Very Low”, “Low”, “Medium”, “High” and “Very High”. Finally, the output membership activity of the customer satisfaction based on the “Facility Comfort” =5, “Food quality” =6 and “Timeliness” =7 input terms with the five defuzzification methods COA, BOA, MOM, LOM, and SOM applied and graphically represented inFigure 7.

The impact of different defuzzifaction methods on output with the change of input is shown in Figure 7. First 10 input and their corresponding defuzzified output is presented in Table 8.

Table Defuzzified Values Derived Through Different Defuzzification Methods (Case-1)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Food Quality | Facility Comfort | Timeliness | Op. Centroid | Op. Bisector | Op.  LOM | Op.  MOM | Op.  SOM |
| 1 | 2 | 1 | .77 | .75 | 1 | 0 | 0 |
| 2 | 2 | 4 | .77 | .75 | 1 | 0 | 0 |
| 4 | 4 | 4 | 7 | 7 | 7 | 7 | 7 |
| 2.5 | 3 | 1 | 2.39 | 2.437 | 4 | 3 | 2 |
| 6 | .5 | .5 | 2.99 | 3 | 3 | 3 | 3 |
| 10 | 10 | 10 | 9.33 | 9.41 | 10 | 10 | 10 |
| 7.5 | 10 | .5 | 6.4 | 5.75 | 7 | 6.8 | 4 |
| .5 | 6 | .5 | 2.99 | 3 | 3 | 3 | 3 |
| .5 | .5 | .5 | .68 | .61 | 0 | 0 | 0 |
| 5.88 | 9.44 | .5 | 5 | 5 | 5 | 5 | 5 |

|  |  |
| --- | --- |
| Figure Input Membership Function: Facility Comfort | Figure Input Membership Function: Food Quality |
| Figure Input Membership Function: Timeliness | Figure Output Membership Function: Perceived Value |
| Figure Output Membership Activity | |

**Case-2**: Similarly, for case-2 the input and output membership function generated for the analysis of the impact of the factors on Customer Satisfaction. As depicted in Figure 8 , Input Membership Function: Facility Comfort, the membership function of the input variable facility comfort is shown in terms of “Poor”, “Acceptable” and, “Amazing”. In the same way Figure 9 &Figure 10, are the graph showing the input membership function for food quality and Cleanliness that is used for the evaluation of Customer satisfaction. Again, Figure 11 represents the output membership function having the linguistic value “Dissatisfied”, “Satisfied” and “Neutral”. Finally, the output membership activity of the customer satisfaction based on the “Facility Comfort” =5, “Food quality” =6, and “Cleanliness” =7 input terms with the five defuzzification methods COA, BOA, MOM, LOM, and SOM applied as depicted in, Figure 12 Output Membership Activity.

The impact of different defuzzifaction methods on output with the change of input is shown in Table 2. First 10 input is presented in Table 9.

Table Defuzzified Values Derived Through Different Defuzzification Methods (Case-2)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Food Quality | Facility Comfort | Cleanliness | Op. Centroid | Op. Bisector | Op.  LOM | Op.  MOM | Op.  SOM |
| 1 | 2 | 1 | 1.5 | 1.5 | 2 | 1 | 0 |
| 2 | 2 | 4 | 1.5 | 1.5 | 2 | 1 | 0 |
| 4 | 4 | 4 | 8.55 | 8.67 | 10 | 9.5 | 7 |
| 2.5 | 3 | 1 | 1.67 | 1.62 | 2 | 1 | 0 |
| 6 | .5 | .5 | 1.44 | 1.325 | 1 | .5 | 0 |
| 10 | 10 | 10 | 8.8667 | 8.828 | 10 | 10 | 10 |
| 7.5 | 10 | .5 | 6.28 | 6.25 | 10 | 7 | 4 |
| .5 | 6 | .5 | 1.44 | 1.32 | 1 | .5 | 0 |
| .5 | .5 | .5 | 1.36 | 1.21 | 0 | 0 | 0 |
| 5.88 | 9.44 | .5 | 4.99 | 5 | 5 | 5 | 5 |

|  |  |
| --- | --- |
| Figure Input Membership Function: Facility Comfort | Figure Input Membership Function: Food Quality |
| Figure Input Membership Function: Cleanliness | Figure Output Membership Function: Customer Satisfaction |
| Figure Output Membership Activity | |

**Case-3:** Again, for the final stage the input and output membership function defined same as the previous cases. In this case as input the output from the above two cases are considered those are, customer satisfaction and the perceived value and the output is the possibility of recommendation based on the input terms. Figure 13 is the input membership function that defines the Customer Satisfaction, Figure 14 depicts the input membership function of perceived value, Figure 15 shows the output membership function. In Figure 16 the defuzzified output membership activity is shown for the input values “Perceived Value”=6.66 and “Customer Satisfaction” =8.37 that mean with high perceived value and with being satisfied the possibility to recommend a place becomes high.

|  |  |
| --- | --- |
| Figure Input Membership Function: Customer Satisfaction | Figure Input Membership Function: Perceived Value |
| Figure Output Membership Activity Behavioural Intention | Figure Output Membership Activity |

Finally, the 3D plot of the input perceived value and customer satisfaction and output customer intention is shown in Figure 17.

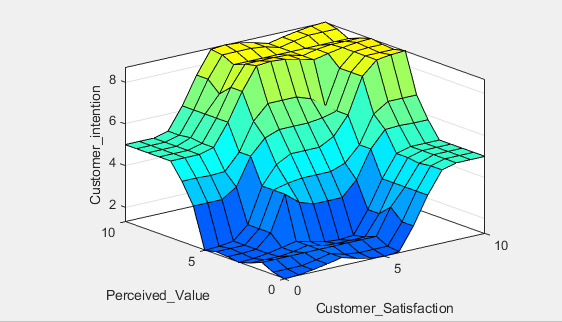


Figure 3D plot

# 5. Conclusion & Future Work

Finding a better place to have food has been considered as a source of entertainment. Many people consider the review of other person who have been in one place and shared their opinion. Finding from huge amount of review it is difficult to judge a place. For this reason, this work presented a fuzzy based model that can analyse the customer sentiment to recommend a place for food. This system will reduce the load of reading a huge number of posts mentioning the ratings of a place. Again, this work analysed the recommendation system in two perspective based on the worthiness of a place with consistence price and quality as well as the customer satisfaction after been in that place with better service. Five defuzzification methods have been applied.

From the final result it is clear that the customer satisfaction and the perceived value both have positive impact on the overall intention of a customer to give good review. Though a through a service a person gets fully satisfied but if there is any mismatch between the service provided and the perceived value then the possibility to recommend a place may deteriorate

However, this work presented a possible solution of recommendation system with assuming some possible values that may have impact on the factors. For computational simplicity considered only the parameters that may have the highest impact on the fine dining system. For future work will consider other factors like aesthetic, price and other to see the change in the result also some other defuzzification method and their comparison to check the system performance works. Based on this analysis future work will include some other area of recommendation such as, online food delivery system, fast food business etc. AFNIS model involvement will increase the efficiency of the system with more deep analysis (Habibi et al., 2020).

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