A

DISSERTATION REPORT

ON

A Hybrid Fuzzy Multi Attribute Decision Making Approach for Prioritizing Catering Service Companies

Submitted in partial fulfilment of the requirements for the award of degree of

MASTER OF TECHNOLOGY

IN

INDUSTRIAL ENGINEERING

Submitted By

Sanjeev Kumar

(2014PIE5413)

Supervised by

Dr. M L Mittal

Associate. Professor

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

JUNE 2016

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY

Jaipur-302017 (Rajasthan)

CERTIFICATE

This is to certify that the dissertation work entitled "A Hybrid Fuzzy Multi attribute decision making approach for prioritizing catering service companies" by Mr Sanjeev Kumar is a bonafide work completed under my supervision and guidance, and hence approved for submission to the Department of Mechanical Engineering, Malaviya National Institute of Technology in partial fulfilment of the requirements for the award of the degree of Master of Technology with specialization in Industrial Engineering. The matter embodied in this Seminar Report has not been submitted for the award of any other degree, or diploma.

(Dr. M L Mittal)
Department of Mechanical Engineering,
Malaviya National Institute of Technology
Jaipur.

Place: Jaipur
Date: 27 June, 2016

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY

Jaipur-302017 (Rajasthan)

Candidate's Declaration

I hereby certify that the work which is being presented in the dissertation entitled "A Hybrid Fuzzy Multi attribute decision making approach for prioritizing catering service companies", in partial fulfilment of the requirements for the award of the Degree of Master of Technology in Industrial Engineering, submitted in the Department of Mechanical Engineering, MNIT, Jaipur is an authentic record of my own work carried out for a period of one year under the supervision of Dr. M L Mittal of Mechanical Engineering Department, MNIT, Jaipur.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

(Sanjeev Kumar)
M. Tech (IE)
ID: 2014PIE5413

Place: Jaipur
Date: 27 June, 2016

ACKNOWLEDGEMENT

Inspiration and guidance are invaluable in all aspects of life. I'm indebted, firstly to god for providing me the wonderful world and my stay in MNIT Jaipur and to my thesis guide **Dr. M L Mittal** for providing me good facilities and his expert guidance. I am in debt to him for all his suggestions and critics. These one year interactions with him have a great influence for growing me as an individual person and stimulate my intellectual for research work.

I am sincerely thankful to **Mr Mukesh Kumar Sharma, Mr Pankaj Kumar Barman** who helped me beyond their work at time of need.

Home is where one starts from; I express my deepest gratitude to my parents and my younger brothers for sharing their love. The motivation I could not find within was rendered to me by them.

Sanjeev Kumar

Jaipur

27 June, 2016

ABSTRACT

Catering is the business of delivering food and services or it can also be defined as preparing and providing food for someone else to consume; or to prepare, deliver and serving food at the place or location of another person or event. The main objective is the selection of best catering firm to provide customer satisfaction and to find out the important factor that need to be consider for the improvement of service quality.

I have considered three hostel messes of Malaviya national institute of technology for my dissertation work. The institute is considering no such parameters to analyse the best catering mess and on what quality criteria they are working. But I have applied an analytic tool to select the best catering firm (mess) using five criteria which are Hygiene, Quality of Meal, Quality of service, Facility and Flexibility.

In this dissertation work, first of all the key factors involved in the selection of catering firm have been identified. A survey has been conducted for data collection from student in the college. After that the criteria weights for the selection of catering firm are calculated using Fuzzy AHP method and using fuzzy TOPSIS method the ranking of the catering firm are determined. The rating has been represented by linguistic variables and then parameterized by triangular fuzzy number. The contribution of this study is to define the important factor for improvement of service quality and to prioritize the catering firm. The fuzzy analytic hierarchy and TOPSIS process was used to compare these catering firms.

CONTENTS

LIST OF FIGURE

LIST OF TABLE

LIST OF ABBREVIATIONS

Where,

C1 Hygiene

C2 Quality of meal

C3 Quality of service

C4 Facility

C5 Flexibility

C11- Hygiene of meal

C12 Hygiene of service personnel

C13 Hygiene of serving dishes

C21 Variety of meal

C22 Complementary meal in a day

C23 Taste of meal

C31 Service time

C32 Problem solving ability

C33 Behaviour of service personnel

C41 Cleanliness of mess

C42 Seating arrangement

C43 Conditioning of Air in mess

C51 Flexibility in volume of meal

C52 Flexibility in adjusting the extra no. of students

C53 Flexibility of seating arrangement

M1 Hostel No. 8 mess

M2 Hostel No. 6 mess

M3 Aurobindo Mess

AHP Analytical Hierarchy Process

TOPSIS Technique for order preferences by similarity to ideal solution

CHAPTER 1: INTRODUCTION

1.1 Background

Catering is primarily concerned with the provision of meals, food and refreshments fully prepared away from people's homes. Catering is defined as the business of providing food and drink, typically at social events and in a professional capacity either on-site or at a remote location. The term was originally coined by the Merchant marines, who were among the first to employ catering officers for their vessels. These catering officers were responsible for purchasing goods, preparing food and serving the meals and beverages to the other people on board the vessels. They also had to perform other ship-related tasks.
However the trade goes back much further than that. Catering dates back in the 4^{th} millennium BC in china. The culture of grand eating and drinking was also present in old Egypt at that time. Most of the service provide by the slaves. The ancient Greeks are credited with making catering a trade by offering free services at their inns and hostels which continued into the Roman Empire. At this time the intent was primarily to serve soldiers. In the Middle Ages catering cantered on monasteries and the Christian pilgrimages in Europe. The trade spreads during the reign of Charlemagne. By the middle ages the new bourgeoises and a monetary economy helped the popularity of catering to flourish. When the industry drew the attention of German legislators in the 14^{th} and 15^{th} century, food and beer regulations began to take form. But much of the industry was still primarily seen in feasts and celebrations for kings and other nobleman. After the French revolution in the 18^{th} century and the lack of an aristocracy, catering guilds were forced to find new ways to sell their talents and the first French restaurants were started.

The aim of catering systems which have been developed over recent years is to overcome problems of the shortage of skilled labour and reducing operational costs by industrializing the catering operation. The main basis for developing these systems has been the industrialization of the catering operation through adopting new methods of food

processing technology such as centralized production, large-scale equipment, consistent heat treatments and sophisticated packaging.

The big distinction in the catering industry is between on-premises caterers and off-premises caterers.

In on-premises catering, the food preparation and serving of the food is done in a facility that is owned, leased, or rented by the caterer. This type of catering is often known as "banquet" or "hall" catering. On-premises caterers are typically attached to the venue. Their home kitchen is located in the building and they will do all the preparation and cooking on the site. Off-premises caterers cook the food and bring it to the site, meaning they serve many different venues. In on-premises catering, Caterers have a lot of advantages. They work in the same space every day and they are able to walk directly from their kitchen to the venue floor where your event is being held. This means it is easy to make last minute changes or corrections if needed. But the main thing setting apart on-premises caterers is that they typically offer a lot more than food. Since they are attached to the venue, they have access to its supply of tables, tablecloths, stemware, dishes, and décor which allows them to manage many aspects of the event presentation.

In off-premises catering, the food is prepared in a licensed commissary, transported to a location selected by the client, and served often without the support of an available kitchen. Caterers are essentially food delivery and service personnel. Since their kitchen is removed from the venue, they will arrive at the set time with everything you ordered, but making last minute changes may be harder. Many off-premises caterers offer full waiter service, and once they bring the food to your event site as they can set up to begin table service. In general, your guests will never know the difference as all they see is that hot, delicious food arrives at their table.

Although scientists and engineers may look to new technologies to produce many new types of prepared foods and enjoy conquering the consequent problems of practical application, consumer may not have the same enthusiasm. They will be influenced by attitudes formed over many years through their own experience and cultural background, from the all-pervading power of marketing and advertising on their expectation of the qualities of the prepared foods and also effects from the social situation and the surroundings.

1.2 Catering service firm selection criteria

A criterion can be thought of as any measure of performance for a particular choice. An attribute is also sometimes used to refer to a measurable criterion. Criterion is a general term and includes both the concepts of attributes and objectives. An attribute is measurable quantity whose value reflects the degree to which a particular objective is achieved. An objective is a statement about the desired state of the system under consideration. It indicates the directions of improvements of one or more attributes. Objectives are functionally to, derived from a set of attributes. There might a formal relation shift between objective and attributes, but usually the relationship is informal. To assign an attributes to a given objectives, two properties which are comprehensive and measurability should be satisfied. An attributes is comprehensive if its value sufficiently indicates the degree to which the objective is met. It is measurable if it is reasonable practical to assign a value in a relevant measurable scale. In this study the word criterion rather than attribute will be used.

1.3 Catering service firm selection method

There are many method present for solving and prioritising catering service firm. Here are some methods like Multi criteria decision making, artificial intelligence, statistical analysis, Delphi technique, SERQUAL model for customer satisfaction and many more decision tools. Now here in this dissertation work I will going to use multi criteria decision making tool in which I will find out the weight using fuzzy analytical hierarchy process and then using fuzzy TOPSIS (top order preference by similarity to ideal solution) i will prioritize among the three catering service firm.

1.4 Objective of the Research

The major objectives of the current study are

- To prioritize/rank the three messes for their catering services.
- To find out and suggest the important factors on the basis of global importance which need to be consider to increase overall performance of the catering service providers in MNIT Jaipur.

1.5 Thesis Structure

The dissertation report contains five chapters.

CHAPTER 1: The current chapter gives an introduction to catering service firm selection criteria and its selection methods. This chapter also gives the objective of the research.

CHAPTER 2: Literature review which describes catering service companies and their selection criteria and attributes and its selection methods.

CHAPTER 3: Explains the FAHP and fuzzy TOPSIS method used in catering service company selection procedure.

CHAPTER 4: Case study of catering service firms selection in Malaviya national institute of technology Jaipur.

CHAPTER 5: Conclusion

CHAPTER 2: LITERATURE REVIEW

Catering is mainly bothered with the provision of meals, food and refreshments fully processed away from people's homes. Contract caterers are third-party companies contracted to supply food management services to organizations whose main business is not providing catering. The aim of catering systems developed over recent years is to overcome the problems of lack of skilled labour and to decrease the operational costs by industrializing the catering operation to the depth. The basic behind the development of these systems has been the industrialization of the catering operation by adopting methods of food processing technology like centralized production, consistent heat treatments, large-scale equipment and sophisticated packaging.

2.1 Catering serving firm/mess criteria

There are various criteria and sub criteria to determine the best catering service provider, some of them from the literature review are.

- FUNCTION
  - Effectiveness
  - Efficiency
- INTRACTION
  - Access
  - Problem solving ability
  - Advice
- SERVICES
  - Productivity
  - Maintenance
  - Leisure
- DIVERSION
  - Ambience
  - Décor
- SERVING PERSONNEL
  - Attitude

- Behaviour
- Expertise

❖ FACILITY
- Air conditioning
- Seating arrangement

❖ Hygiene
- Hygiene of meal
- Hygiene of serving dishes
- Hygiene of serving personnel

❖ QUALITY
- Quality of meal
- Quality of service

❖ FLEXIBILITY

These are some factors which could be used. In my research work I have studies some of the factors from literature and after studying I discussed with the experts in catering service industry and students who are using catering service from many years.

Catering service firm selection, which includes multi criteria, sub criteria and multiple objectives, can be defined as the process of finding the right service provider with the right quality. Catering firm selection has a major impact on proper functioning of catering industry as well as on overall quality. Selection of right provider improves the efficiency and significantly increases corporate competitiveness.

There is no specific method for every problem because each problem is unique. To work reasonably in the catering service firm selection, a large number of methods would be needed.

Here the literature review on catering service industry given below:

Splaver, B., Reynolds, W.N., Roman (1991) provides a detailed definition on the types of catering, according to them there are two type of catering (a) On premises catering (b) Off premises catering. In case of on-premises catering, all the food preparation & serving is done in a facility that is owned, leased or rented by the caterer. This type of catering is

often referred to as ‘banquet’ or ‘hall’ catering. On premises catering is influenced by the hotel and motel industry along with the thousands of free standing privately retained banquet halls. In off premises catering, the food is prepared in a licensed party, transported to a location selected by the consumer, and prepared often without the support of an available kitchen.

Although engineers and scientists may look up to new technologies to produce many new types of prepared foods and enjoy dominating the consequent problems of practical utilization, consumers may not have the same eagerness. They will be attracted by attitudes formed over many years through their own experience and cultural background, from the all-infused power of marketing and advertising on their confidence of the qualities of the prepared foods and also effects from the social condition and the surroundings.

Cebeci and Kahraman (2002) compare some catering firms in turkey using four attributes and fuzzy AHP.

Creed (2001) confer the results of a survey on how consumers recognize the acceptability of the prepared meals considering social class, age group, gender and frequency of eating out, and the potential for extending and widening the use of prepared meals to those who could benefit from it.

Jansen et al. (2001) develop a simulation model to evaluate a multi-compartment distribution system which should placate customer demands for shorter lead times, increases delivery frequency and improving quality of process and products. The simulation model compute logistic and financial performances in various alternative logistic scenarios for multi-compartment distribution in the catering supply chain. This stochastic simulation model is constructed on the basis of a value chain analysis having activities and performance indicators.

Martınez-Tome et al. (2000) check food production in four school kitchens in order to upgrade food safety by endowing a self-regulated control system relied on good manufacturing practices and as an introduction to risk analysis and critical control points. A form, which assigned to different aspects such as the personnel hygiene, cleanliness of

the installations and the prevention of cross-contamination is used to obtain the necessary data.

Murthy and Kumar (2000) developed a general game-theoretical model for the study of total Product quality. Total product quality involves three strongly inter-related notations of quality

(i) Quality of performance (QOP).
(ii) Quality of conformance (QOC).
(iii) Quality of service (QOS).

They derive and obtain the optimal manufacturer and retailer actions and discuss various economic and structural implications of the model such as the inverse relationships between

(i) QOS and QOP and
(ii) QOS and retail price.

Badri (2001) classify five sets of quality measures by using the results of above studies of service quality attributes. These indicators or quality measures, through the analytic hierarchy process (AHP) are accurately and consistently weighted using this technique. This study presents two important issues: how to blend quality control & how to decide upon quality control measures in a service industry.

Susannah Read Denise Worsfold, (1998),"Catering service for older people in residential care homes" Here in this paper a nutritional analysis of the weekly menus from 24 residential homes was conducted and the information gathered by questionnaire on the planning, preparation and services of meals are collected. And they find that nutritional standard of menus provided by the homes was generally satisfactory.

Riadh Ladhari (2010) proposed a literature survey on electronic service quality which emphasises methodological issues in developing measurement scale. They also find issues

related to the dimensionality of electronic service quality construct. They find out several conceptual and methodological limitations comes under development of electronic service quality measurement like lack of rigorous validation process, the sample size and composition.

2.2 Solution techniques

There are various methods present to solve the catering service firm selection. Some of them are:
Multiple criteria decision making (MCDM)
Artificial intelligence
SERQUAL model

Multiple criteria decision making (MCDM)
In today's highly competitive environment, enterprises need to take decision for selection of best out of the rest. Multiple criteria decision making approach is one of the best technique use to prioritize the best alternative from the list of alternatives. There are various methods in multiple criteria decision making such as AHP method, TOPSIS method, PROMETHEE, grey AHP, DEA, DEAHP, multi attribute utility theory, Fuzzy sets, judgmental modelling , linear weighted point, interpretive etc.

TOPSIS
According to TOPSIS, a closeness coefficient is defined which use to determine the ranking order of all alternatives and linguistic values are used to assess the ratings and weights of the factors. The concept behind this technique is that the optimal alternative should have minimum strech from the positive ideal solution and the longest strech from the negative ideal solution. If we embed fuzzy with TOPSIS then, linguistic values are used to assess the ratings and weights for various factors. Linguistic ratings can be expressed in trapezoidal or triangular fuzzy numbers. Since human judgments including preferences are

often vague and cannot estimate his preference with an exact numerical value. The ratings and weights of the criteria described in the problem are assessed by means of linguistic variables. One can convert the decision matrix into a fuzzy decision matrix and construct a weighted-normalized fuzzy decision matrix once the decision-makers' fuzzy ratings have been pooled. Finally a closeness coefficient of each alternative is defined to determine the ranking order of all alternatives.

Artificial intelligence

Artificial Intelligence (AI) models are computer-based systems competent by the decision maker using historical or related data and experience practice. These systems usually handle very well with the complication and unpredictability involved in the selection process. Some of the AI models are:

Artificial Neural Network

The Artificial neural network model saves money and time. The vulnerability of this model is that it demands particular purposeful software and requires qualified personnel who are expert in their field.

Case-Based-Reasoning (CBR) Systems

Case base reasoning systems comes under the category of so-called artificial intelligence (AI) approach. Basically, a Case base reasoning system is a software-driven database which provide a decision-maker with helpful information and experiences from similar, comparable previous decision situations. It is still very new and only few systems have been developed for this technique.

SERQUAL model

Zeithaml (1990) suggest key factors that affect the consumer expectation and they can be described as word of mouth communication, personal needs, past experiences & communication by the service providers to the consumers. These are general criteria or dimension to assess the customer satisfaction. SERVQUAL refers to service quality and service quality dimensions are

- Reliability

- Responsiveness
- Assurance
- Empathy
- Tangible

2.3 Hybrid approaches

Hybrid refers to combination of two or more approach rather than to apply simple single approach. Here the output of one becomes the input for the other approach. It is widely use to get better result. Many applied integrated approaches to evaluate the performance of various firms are used in this literature review.

2.3.1 Hybridization of fuzzy and AHP

Many decision-making & problem-solving tasks are too difficult and hectic to be understood quantitatively; however, people succeed by using knowledge that is imprecise knowledge rather than precise knowledge.

Fuzzy set theory simulate human reasoning in its use of relative information and uncertainty to generate decisions. It was designed to mathematically represent uncertainty and vagueness and provide formalized tools for dealing with the imprecision peculiar to many problems. As knowledge can be expressed in efficient natural way by using fuzzy sets, many engineering and decision problems can be greatly abridged. Fuzzy set theory have classes or groupings of data with boundaries that are not sharply defined (i.e., fuzzy) or we can say that which are not having clear boundaries. Any methodology or theory actualize 'crisp' definitions such as classical set theory, arithmetic, and programming, may be 'fuzzified' by using the concept of a crisp set to a fuzzy set with vague boundaries. The benefit of using crisp theory and analysis method to fuzzy technique is the courage to solve the real world problem.

Accordingly, linguistic variables are analytical aspect of some fuzzy logic applications, where we uses general terms such as 'large', 'medium', and 'small'. Which are used to

capture a range of numerical values. Fuzzy set theory contains fuzzy logic, fuzzy mathematical programming, fuzzy arithmetic, fuzzy topology, fuzzy data analysis, and fuzzy graph theory, though the term fuzzy logic is used to describe all of these. The AHP is one of the broadly used multi-criteria decision-making methods. One of the main advantages of this method is the relative easiness with which it handles multiple criteria. Apart from this, AHP is easier to understand and can effectively handle both qualitative and quantitative data. The use of AHP doesn't involve heavy mathematics.

AHP involves the principles of decomposition, pairwise comparisons, and priority vector generation and synthesis. Though the essential purpose of AHP is to capture the expert's knowledge, the conventional method of AHP cannot reflect the human style of thinking. That's why, fuzzy AHP and its extension was developed to solve the hierarchical fuzzy problem in real world.

2.3.2 Hybridization of fuzzy set theory and fuzzy TOPSIS

Taho Yang, Chin-Ching Hung (2006) explores the use of multi criteria decision making approaches in layout design problem. They had taken a practical application from an integrated circuit IC packaging company. They use two different technique general TOPSIS and fuzzy TOPSIS and compare their result. General method is used for precise value performance rating and if the performance rating are imprecise and vague then fuzzy TOPSIS method is preferred solution.

2.3.3 Hybridization of fuzzy AHP and fuzzy TOPSIS

Although there are several studies that combine these two methods in fuzzy environment, service quality evaluation studies are limited in literature.

Tsaur, Chang, and Yen (2003) used fuzzy set theory, AHP and TOPSIS together for evaluation of airline service quality. A fuzzy approach to service Quality diagnosis, here in this the purpose is to define service quality dimension that could enhance the level of service provided by various air carrier and to rank them. Here in above paper they have taken three alternatives which are emirates airline, Mahan air and Iran air, and attributes are tangible, reliability, Responsiveness, assurance and empathy.

Gulcin Buyukokan and Gizem Cifci examine the electronic service quality concept and determine the key components of electronic service quality. They uses SERVQUAL methodology as their theoretical instrument. They implemented their model in health care sector in turkey by using MCDM methodology consisting of hybridization of fuzzy AHP and fuzzy TOPSIS. Finally they also explains the complexity in various aspect observed in implementing of health care services through internet.

Metin Dag deviren Serkan Yavuz , Nevzat Kılınç (2008) uses hybridization of AHP and fuzzy TOPSIS in weapon selection problem. Weapon selection is a typical issue and it has an important impact on efficiency of defence system. They uses AHP to analyse and determine the weight while later they uses TOPSIS to find the best weapon among five alternatives. One is the factors or criteria that are important and should be considered and the other is the process or methodology applied to rank the suppliers.

2.3.4 Hybridization of fuzzy AHP and fuzzy PROMETHEE

R. ufuk, Gulcin Buyukozkan and Da Ruan (2006) present a quality model for measuring the performances of hospital websites. Basically model is projected on conceptual framework basis. It consist of seven electronic service quality attributes, including Tangible, reliability, responsiveness, empathy, confidence, integration of communication issues in websites and quality of information. In their work firstly they attributes weight are evaluated using AHP method and later they are ranked using PROMETHEE (preference Ranking Organization Method for Enrichment Evaluation ranking method). The proposed model is defined as a framework for website performance evaluation which can be utilized in various sectors with little modification in criteria weight.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter deals with the steps of research process that were taken in order to obtain the data on the matter researched. It includes a statement of the problem and the objectives of the research. If then explains how the data was obtained; the formulation of the questionnaire and analysis, problem experienced during the study and the reliability and contribution of the study.

The questionnaire survey was taken in May 2016 in mnit through email to the students who have went to the all three mess that I have taken into consideration. Altogether there were 15 questions and received83 respondents to fill up the questionnaires form. In this chapter how the survey was planned and conducted is discussed. And then hybridization of fuzzy AHP and fuzzy TOPSIS was used to analyse the data and to prioritize the best mess amongst the three.

3.2 Planning and conducting the survey

The idea behind the survey was to examine students‟ opinions on the mess in mnit Jaipur. The goal was to be able to create ideas regarding mess services and food quality. The main purpose of the survey is to give students an opportunity to express their opinions so that the food quality and excellent services could be improved. The survey was effective and the objectives were met. And also the question is referring back to the objectives. Here actually, the question is related to closed-ended questions meaning that the respondents would have been provided with response alternatives for grading of certain question on a scale from 1 to 5. In these questions the student were not able to choose more than one alternative and the student were asked to mark the choices from 1 to 5 according to their preference. Here 1 stands for worst and 5 stands for best. In our model, we have taken five criteria for catering service firms which contains fifteen sub criteria.

Now before going through the sequence of method applied in my research we will briefly describe the theory of tools and technique used to get the results.

3.3 Fuzzy Set- theory

Fuzzy set theory is a mathematical theory pioneered by Zadeh (1965), which is designed to model the vagueness or imprecision of human cognitive processes. It has the capability to represent manipulate data and information possessing based on non-statistical uncertainties. Fuzzy set theory has been designed to mathematically represent uncertainty and vagueness and to provide formalized tools for dealing with the imprecision inherent to decision making problems. The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set (Negoita, 1985; Zimmermann, 1985). A fuzzy set is defined by a membership function that maps elements to degrees of membership within a certain interval, which is usually [0, 1]. If the value assigned is zero, the element does not belong to the set (it has no membership). If the value assigned is one, the element belongs completely to the set (it has total membership). Finally , if the value lies within the interval , the element has a certain degree of membership (it belongs partially to the fuzzy set) Some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from Zadeh (1975), Buckley (1985), Negi (1989), Kaufmann and Gupta (1991). The basic definitions and notations which are given below will be used throughout this thesis.

Fuzzy logic is a form of many-valued logic that deals with approximate, rather than fixed and exact reasoning. Compared to traditional binary logic (where variables may take on true or false values), fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false.

3.4 Definitions of Fuzzy Sets

Definition1. A fuzzy set A in a universe of discourse X is characterized by a membership function $\mu A(x)$ which associated with each element x in X a real number in the interval (0,1), the function value is the term of grade of membership of x in A (Kaufmann and Gupta, 1991).

Definition2**.** A fuzzy set A in a universe of discourse X is convex if and only if

$\mu A (\lambda + (1-\lambda) \min (\mu A(x1), A(x2))$

For all in X and all λ [0, 1], where min denotes the minimum operator (Klir and Yuan, 1995).

Definition3**.** The height of a fuzzy set is the largest membership grade attained by any element in that set. A fuzzy set A in the universe of discourse X is called normalized when the height of A is equal to 1(Klir and Yuan, 1995).

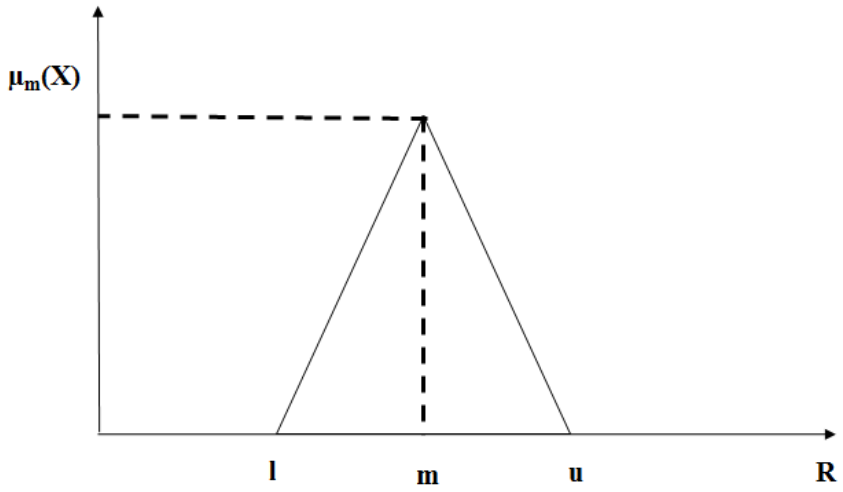


Figure 1Membership function of a TFN

3.5 Definitions of fuzzy numbers

Definition: A fuzzy number is a special fuzzy set A = {(x, μA(x)), x € R}, where x takes values on the real line R: -∞ < x < + ∞ and μA(x) is a continuous mapping from R to the closed interval [0, 1]. A triangular fuzzy number denoted as $\tilde{A}$ = (l, m, u), where l≤m≤u, has the following triangular type membership function:

$$\mu_{\tilde{A}}(x)=\begin{cases} 0, & x < l \text{ or } m > u \\ \frac{x-l}{m-l} & l \le x \le m \\ \frac{u-x}{u-m} & m \le x \le u \end{cases}$$

Alternatively, by defining the interval of confidence level α, the triangular fuzzy number can be described as

$$\forall \alpha \in [0,1] \tilde{A}_{\alpha} = [l^{\alpha}, u^{\alpha}] = [(m-l)\alpha + l, -(u-m)\alpha + u]$$

Flow Chart of Methodology

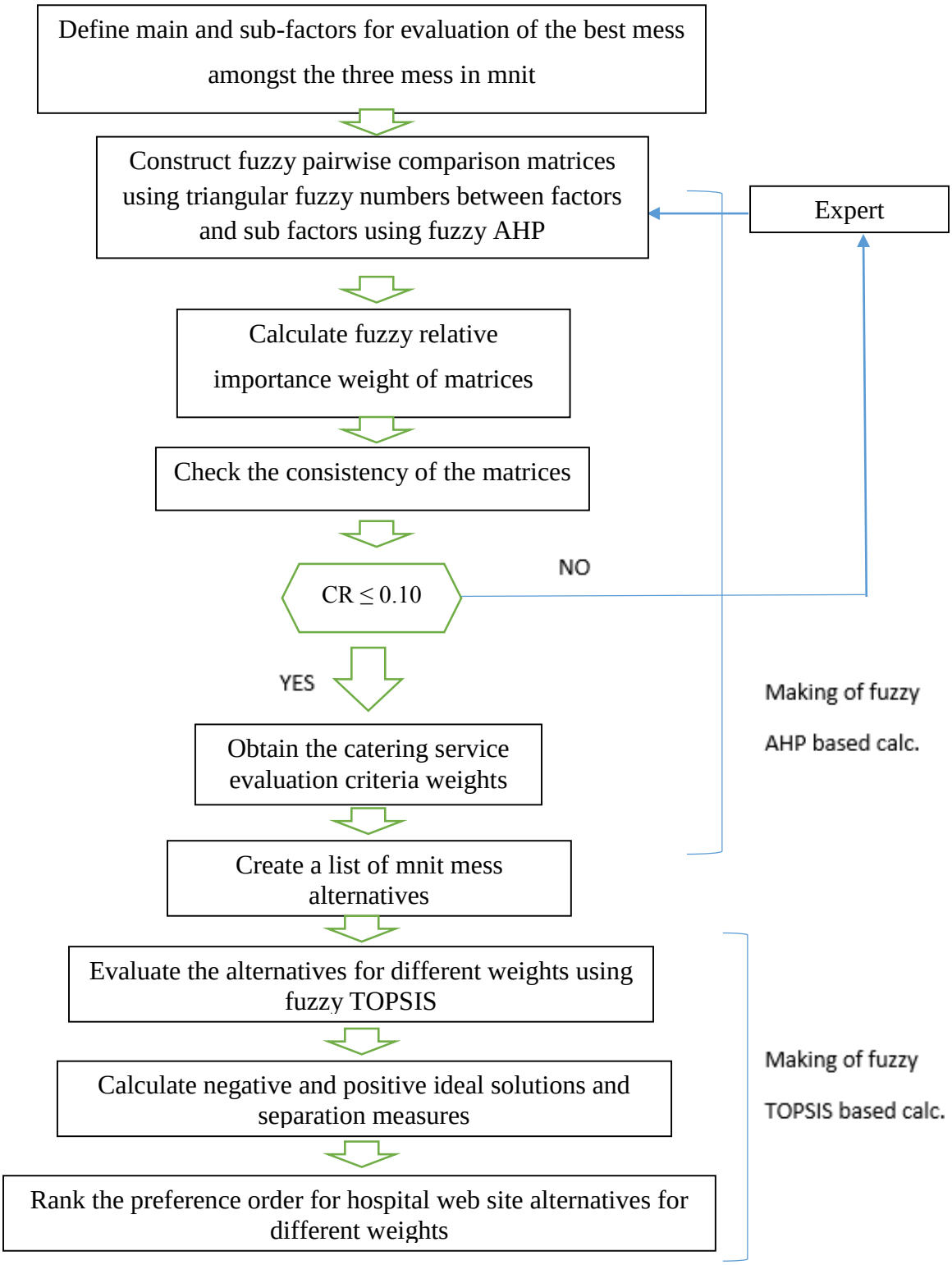


Figure 2 Flow chart of methodology

3.6 Fuzzy AHP

Fuzzy Analytic hierarchy process (FAHP) The AHP (Saaty, 1980) is a quantitative technique that structures a multi-attribute, multi-person and multi-period problem hierarchically so that solutions are facilitated. One of the main advantages of this method is the relative effectiveness with which it handles multiple criteria. It can effectively handle both qualitative and quantitative data (Kahraman, Cebeci, & Ruan, 2004). Even though the aim of AHP is to capture the expert's knowledge, the conventional AHP still cannot reflect the ambiguity in human thinking style. Therefore, fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems and many fuzzy AHP methods by various authors are proposed (Chamodrakas, Batis, & Martakos, 2010; Dura´n & Aguilo, 2008).

There are many fuzzy AHP methods proposed by various authors. These methods are systematic approaches to the alternative selection and justification problem by using the concepts of Fuzzy set theory and hierarchical structure analysis. Decision makers usually find that it is more confident to give interval judgments than fixed value judgments. This is because usually he/she is unable to explicit about his/her preferences due to the fuzzy nature of the comparison process.In this method it takes pair wise comparison of different alternatives with respective to various criteria and provides a decision support tool for multi criteria decision problems.. In a general AHP model, the objective is in the first level, the criteria and sub criteria are in the second and third levels respectively. Finally the alternatives are found in the fourth level.

3.6.1 The procedure for determining the criteria weights by fuzzy AHP can be described in the following steps.

Step-1 The hierarchy is constructed in such a way that the overall goal is at the top, criteria and sub criteria are in the middle and various alternatives at the bottom.

Step-2 The relative importance of each criteria with respect to the goal of the problem is determined by using a typical pair-wise comparison matrix in which all the attributes are

compared with each other, and scores are given using a nine-point scale. For N criteria the size of the comparison matrix (C) will be N×N and the entry c_{ij} donates the relative importance of criterion i with respect to criterion j. if more than one decision maker, than average are taken.

$$c^k = \begin{bmatrix} {c_{11}}^k & \cdots & {c_{1n}}^k \\ \vdots & \ddots & \vdots \\ {c_{n1}}^k & \cdots & {c_{nn}}^k \end{bmatrix},$$

$\tilde{c}_{ij} = \frac{\sum_{k=1}^{k} {c_{ij}}^k}{k}$ Where k is the number of decision maker

Step-3pairwise comparisons matrix updated according to average of decision matrix

$$\widetilde{C} = \begin{bmatrix} \widetilde{c_{11}} & \cdots & \widetilde{c_{1N}} \\ \vdots & \ddots & \vdots \\ \widetilde{c_{N1}} & \cdots & \widetilde{c_{NN}} \end{bmatrix}, \widetilde{c_{ij}} = 1, \widetilde{c_{ij}} = \frac{1}{\widetilde{c_{ij}}}, \widetilde{c_{ij}} \neq 1$$

Step-4 The geometric mean method is used for fuzzy weights evaluation. The fuzzy geometric mean;

$\widetilde{r_1} = [\widetilde{c_{i1}} \times \widetilde{c_{i2}} \times \ldots\ldots \times \widetilde{c_{iN}}]^{1/N}$, i=1, 2, 3……n

Step-5 fuzzy weights of each criterion is calculated by using Eq. 5

Step-5a find the vector addition of each $\widetilde{r_1}$.

Step-5b calculate the inverse of addition vector. Replace the fuzzy triangular number, to make it in ascending order

Step-5c the fuzzy weight of the i^{th}criteria, indicated by a triangular fuzzy number

$$\widetilde{W_i} = \widetilde{r_1} \text{ x } [\widetilde{r_1} + \widetilde{r_2} \ldots\ldots\ldots\ldots\ldots \widetilde{r_N}]^{-1}$$

$$= (lw_i, mw_i, nw_i)$$

Step-6 Since $\widetilde{W}_i$ are still fuzzy triangular numbers, they need to de-fuzzified by Centre of area

Method proposed by Chou and Chang

$$M_i = \frac{lw_i + mw_i + nw_i}{3}$$

Step-7 M_i is is a non-fuzzy number. But it needs to be normalized

$$N_i = \frac{M_i}{\sum_{i=1}^{N} M_i}$$

These 7 steps are performed to find the normalized weights of both criteria and the alternatives. Then by multiplying each alternative weight with related criteria, the scores for each alternative is calculated. According to these results, the alternative with the highest score is suggested to the decision maker.

3.7 Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

TOPSIS method was introduced for the first time by Yoon and Hwang and was appraised by surveyors and different operators. TOPSIS is a decision making technique. It is a goal based approach for finding the alternative that is closest to the ideal solution. In this method, options are graded based on ideal solution similarity. If an option is more similar to an ideal solution, it has a higher grade. Ideal solution is a solution that is the best from any aspect that does not exist practically and we try to approximate it. Basically, for measuring similarity of a design (or option) to ideal level and non-ideal, we consider distance of that design from ideal and non-ideal solution. The optimal solution should have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution.

Similarly for the same reason that human judgments are usually rely on imprecision, subjectivity and vagueness, subsequently fuzzy extension of TOPSIS method is needed.

Fuzzy technique for order preference by similarity to Ideal solution (F-TOPSIS) embeds the fuzzy theory to basic TOPSIS method. For fuzzy TOPSIS method, the entry in the decision matrix is represented by triangular fuzzy number. This kind of representation may be a better way to characterize the practical issue under fuzzy environment.

3.7.1 Fuzzy TOPSIS specific steps can be described in the following steps:

Step-1 Calculate the aggregate fuzzy linguistic ratings for criteria performance of alternatives.

Table 1 Transformation rules of linguistic variables of decision maker for criteria performance of alternatives.

Linguistic terms	**Membership Function**
Equal strong	(1,1,1)
Weakly strong	(2,3,4)
Fairly strong	(4,5,6)
Very strong	(6,7,8)
Absolute strong	(9,9,9)

We use the above table for formation of fuzzy decision matrix

Step-2 Build initial fuzzy decision matrix:

Suppose that there are m alternatives to be ranked. The performances of n criteria are defined in linguistic terms.

$$A = (\tilde{a}_{ik})_{m\times n} = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix}$$

$$= \begin{bmatrix} (a_{11}^L, a_{11}^M, a_{11}^R) & \cdots & (a_{1n}^L, a_{1n}^M, a_{1n}^R) \\ \vdots & \ddots & \vdots \\ (a_{m1}^L, a_{m1}^M, a_{m1}^R) & \cdots & (a_{mn}^L, a_{mn}^M, a_{mn}^R) \end{bmatrix}$$

Step-3 Normalize the initial fuzzy decision matrix A

Generally, different criteria may hold different attributes. Some criteria hold the benefit-type attribute, namely the larger the better, while some criteria show the cost-type attribute, namely the smaller the better.Therefore, the normalization processing on all criteria need to be firstly performed.

For **benefit-type criteria**, the normalization processing is expressed as

$\tilde{b}_{ik} = (a_{ik}^{L}/t_k, a_{ik}^{M}/t_k, a_{ik}^{R}/t_k)$

Where

$t_k = max_i\{a_{ik}^{R}\}$

For **cost-type criteria,** the normalization processing is expressed as

$\tilde{b}_{ik} = (t_k/a_{ik}^{R}, t_k/a_{ik}^{M}, t_k/a_{ik}^{L})$

Where

$t_k = min_i\{a_{ik}^{L}\}$

Then, the normalized fuzzy decision matrix B can be obtained as:

$$B = (\tilde{b}_{ik})_{m\times n} = \begin{bmatrix} \tilde{b}_{11} & \cdots & \tilde{b}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{b}_{m1} & \cdots & \tilde{b}_{mn} \end{bmatrix}$$

$$= \begin{bmatrix} (b_{11}^{L}, b_{11}^{M}, b_{11}^{R}) & \cdots & (b_{1n}^{L}, b_{1n}^{M}, b_{1n}^{R}) \\ \vdots & \ddots & \vdots \\ (b_{m1}^{L}, b_{m1}^{M}, b_{m1}^{R}) & \cdots & (b_{mn}^{L}, b_{mn}^{M}, b_{mn}^{R}) \end{bmatrix}$$

Step-4: Construct the weighted normalized fuzzy decision matrix.

$$C = (\tilde{c}_{ik})_{m\times n} = \begin{bmatrix} \tilde{b}_{11} \times s_1 & \cdots & \tilde{b}_{1n} \times s_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{b}_{m1} \times s_{m1} & \cdots & \tilde{b}_{mn} \times s_{mn} \end{bmatrix}$$

Step-5: Determine the fuzzy positive and negative ideal solution Let $C^{+}$and C^{-}represent the fuzzy positive ideal solution and fuzzy negative ideal solution, respectively, which can be computed by

$$C^+ = \tilde{c}_k{}^+ = \{(max\ c_{ik}|j\epsilon j_1), (min\ c_{ik}|j\epsilon j_2)\}$$
$$C^- = \tilde{c}_k{}^- = \{(minc_{ik}|j\epsilon j_1), (max\ c_{ik}|j\epsilon j_2)\}$$

Where

$$max\ c_{ik} = (\max s_k b_{ik}^L \max s_k b_{ik}^M, \max s_k b_{ik}^R);$$
$$min\ c_{ik} = (\min s_k b_{ik}^L \min s_k b_{ik}^M, \min s_k b_{ik}^R);$$

$$\tilde{c}_k{}^+ = (\tilde{c}_k{}^{+L}, \tilde{c}_k{}^{+M}, \tilde{c}_k{}^{+R});$$
$$\tilde{c}_k{}^- = (\tilde{c}_k{}^{-L}, \tilde{c}_k{}^{-M}, \tilde{c}_k{}^{-R});$$

Where J_1 and J_2 respectively represent the benefit type criteria set and cost type criteria set.

Step-6: Calculate the distance of each alternative from fuzzy positive and negative ideal solution.

There are various methods for calculating the distance between two fuzzy numbers.

Let $\tilde{a} = (a_1, a_{2,} a_3)$ and $\tilde{b} = (b_1, b_{2,} b_3)$ be two triangular fuzzy number, then the vertex method is defined to calculate the distance between them

$$d(\tilde{A}, \tilde{B}) = \sqrt{\{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]\ \}}$$

Step-7: Compute the closeness coefficient (CC_i) of each alternative.

Where

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad 0 \leq CC_i \leq 1$$

Step-8 Rank the alternatives.

According to the calculation result, the alternative with the maximum(CC_i) value has the highest ranking score, which should be selected as the optimal alternative.

CHAPTER 4: CASE STUDY

4.1 Introduction of catering service providers in Mnit Institute.

- Malaviya national institute of technology Jaipur has hostel facilities for more than five thousand students and they also provide dining service to all those students who are using their hostel facilities.
- In order to serve that much quantity of students they has provided mess facilities in many hostel and some hostel share the dining service with other hostel. In mnit, for boys they have 9 hostels named from one to eight and last is aurobindo hostel.
- Hostel number 1 and 2 share the same dining area, similarly hostel number 3 and 8, hostel 4 and 6 and hostel 5 and 7 share the same dining area. Only aurobindo hostel has their separate mess with its premises.
- All hostels messes have three time dining service in a day as Breakfast then lunch and dinner at the end of the day.
- All the hostel messes run by the institute employees (working as a mess staff member) except hostel aurobindo is run by a private company.
- But in holidays like in summer vacation and winter vacation many messes called off as aurobindo hostel mess facility can be used by rest of the students.
- Aurobindo hostel catering service is providing by Ben Temps Pvt Ltd.
- My research objective is concerned with only three messes that are mess number 6, mess number 8, and aurobindo mess. For data collection on all three messes I have conducted an online survey through electronic mail from all the students and got responses from them regarding the facilities, quality provided to them.

4.2 Catering service firms selection criteria

In this thesis, I have taken five criteria named as Hygiene, quality of meal quality of service provided by the messes, facility and the last is flexibility.

Further in each criteria I have taken three sub- criteria from the literature review and the workers who are working in hostel mess from the last many years. I also took help from those students who are using mess facilities in their life from so many years in

order to determine the best criteria and sub criteria which can be effectively use to determine prioritization and those factors which if would consider may improve the overall quality of service provided.

The criteria and sub criteria used are:-

Table 2 Criteria and sub criteria used

CRITERIA	SUB CRITERIA
Hygiene	Hygiene of meal
	Hygiene of service personnel
	Hygiene of serving dishes
Quality of meal	Variety of meal
	Complementary meal in day
	Taste of meal
Quality of service	Service time
	Problem solving ability
	Behavior of service personnel
Facility	Cleanliness of mess
	Seating arrangement
	A/C in dining hall
Flexibility	Flexibility in volume of meal
	Flex. in adjusting extra number of students
	Flexibility in seating arrangement

4.3 Catering service firms selection criteria description

There are number of criteria to select catering service firms. In my research work I considered five main criteria and fifteen sub criteria, three to each criteria. All the criteria and sub criteria are defined in the above table 2 above displayed and they are defined below.

4.3.1 Hygiene

Hygiene is a set of practices performed for the preservation of health. According to the World Health Organization (WHO), "Hygiene refers to conditions and practices that help to maintain health and prevent the spread of diseases. Hygiene in its fullest and original meaning goes much beyond that to include all circumstances and practices, lifestyle issues, premises and commodities that engender a safe and healthy environment.

Hygiene is a very important factor in catering service firm selection criteria. Hygiene includes following sub factors:

Hygiene of meal

Food hygiene or hygiene of meal is concerned with the hygiene practices that prevent food poisoning. The five key principles of food hygiene

1. Prevent contaminating food with mixing chemicals, spreading from people, and animals
2. Separate raw and cooked foods to prevent contaminating the cooked foods.
3. Cook foods for the appropriate length of time and at the appropriate temperature to kill pathogens.
4. Store food at the proper temperature.
5. Use safe water and raw materials.

Hygiene of service personnel

Personal hygiene involves those practices performed by an individual to care for one's bodily health and wellbeing, through cleanliness. Motivations for personal hygiene practice include reduction of personal illness, healing from personal illness, optimal health and sense of wellbeing, social acceptance and prevention of spread of illness to others.

Other practices that are generally considered proper hygiene include bathing regularly, washing hands regularly and especially before handling food, washing scalp hair, keeping hair short or removing hair, wearing clean clothing, brushing one's teeth, cutting finger nails, besides other practices.

Hygiene of serving dishes

Hygiene of serving dishes involves cleanliness of dishes. It is an important factor which need to be considered to improve the overall quality of messes. It follows the following steps like firstly to organize the dishes (plate with plates, utensils with utensils), scrap any leftover food into the compost, pre-soak your dishes in hot water, wash the dishes using dish soap and a clean dish cloth, Rinse the dishes with hot water, Place dishes in the dish rack and lastly allow dishes to air dry in the dish rack.

4.3.2 Quality of meal

Quality of meal is the quality characteristics of food that is acceptable to consumers. This includes external factors as appearance (size, shape, colour, gloss, and consistency), texture, and flavour; factors such as federal grade standards (e.g. of eggs) and internal (chemical, physical, microbial).

Variety of meal

Variety of meal refers to variation in meal provided to the consumers. Variety does not mean to eat more food than you need or would normally eat in order to get a variety of foods every day. It simply means to eat different foods on different days. Many of us eat the same foods day in and day out because it is easy, fast, and what we know and like. However, this can cause some nutritional concern. Different foods contain different vitamins and minerals. No single food can give us all the nutrients that we need in the amounts needed.

Complementary meal in a day

It means that there must be a schedule decided to give a complimentary serve in a day or in a regular period. The reason to have it that due to this a consumer does not get bored and can added enjoyment to his meal.

Taste of meal

Taste of meal means that food, especially savoury food, is tasty and it has a pleasant and fairly strong flavour which makes it good to eat.

4.3.3 Quality of service

The quality of service in catering industry is an important factor of successful business. Service quality is a way to manage business processes in order to ensure total satisfaction to the customer on all levels (internal and external). It is an approach that leads to an increase of competitiveness, effectiveness and flexibility of the entire company. It includes various factors like service time, problem solving ability and the most important is behaviour of service personnel.

4.3.4 Facility

An installation, contrivance, or other things which facilitates something; a place for doing something. Facility includes the overall things that the consumer receive during a facility. It includes many factors but some of the important factors are cleanliness of mess as it defines the how hygiene the dining area is. Seating arrangement defines seating in the dining area as it is ergonomically design and comfortable for seating. Air conditioning in dining hall means the environment or atmosphere in the dining hall is comfortable, pleasant and good.

4.3.5 Flexibility

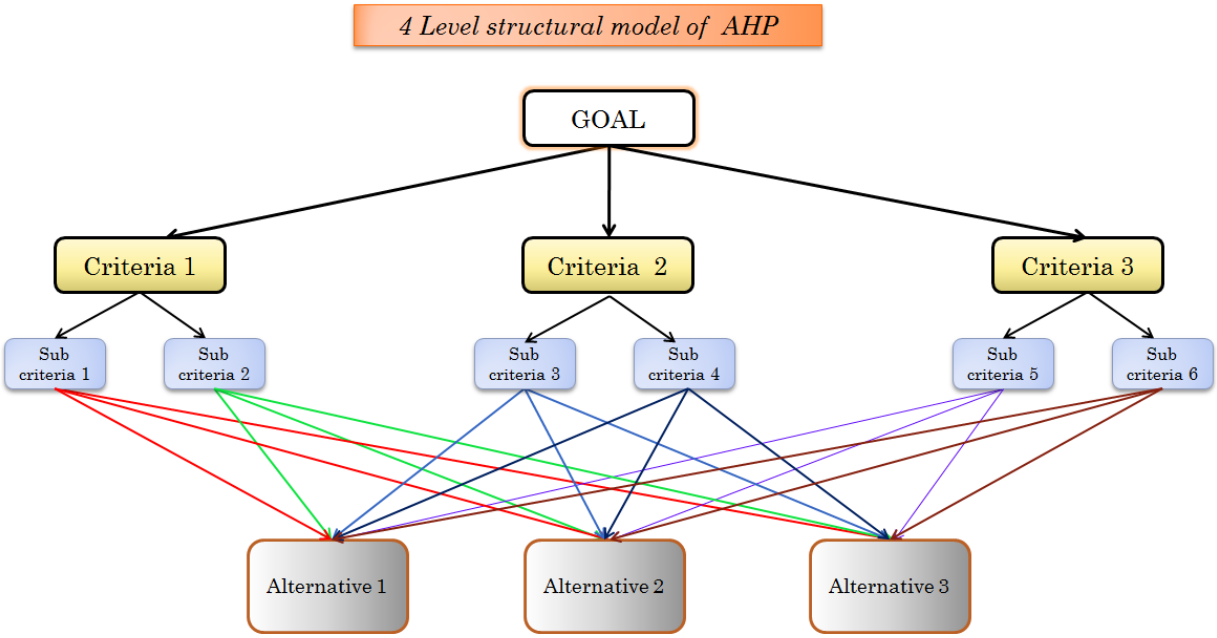
Flexibility is defined as the ability of a system to adapt to changes due to the external condition, while maintaining satisfactory performance in the system. System performance can be characterized by many parameters such as capacity of system, level of service provided by the system, maintainability and profitability in the system. External changes comes under uncontrolled conditions which affect the system, including changes in level of demand or use, shifts in spatial traffic patterns, infrastructure loss and degradation, and changes in the price and availability of important resources such as fuel, etc. Flexibility measures are broadly divided under the three headings in respect of catering service industry:

(1) Flexibility in volume of meal: the ability to respond to change in demand.
(2) Flexibility in adjusting extra number of students
(3) Flexibility in seating arrangement.

4.4 Solution of Catering service firm Selection Problem Using FUZZY AHP and Fuzzy TOPSIS Method

In this section we will solve the case study problem using multi criteria decision making with fuzzy AHP and TOPSIS tools. The solution of the problem will be follow through the methodology described below in Figure 4. Here we select five criteria and fifteen sub criteria, 3 sub criteria to each criteria. The catering service selection criteria is defined in the Table 2.

Figure 3 Four level structural model of AHP



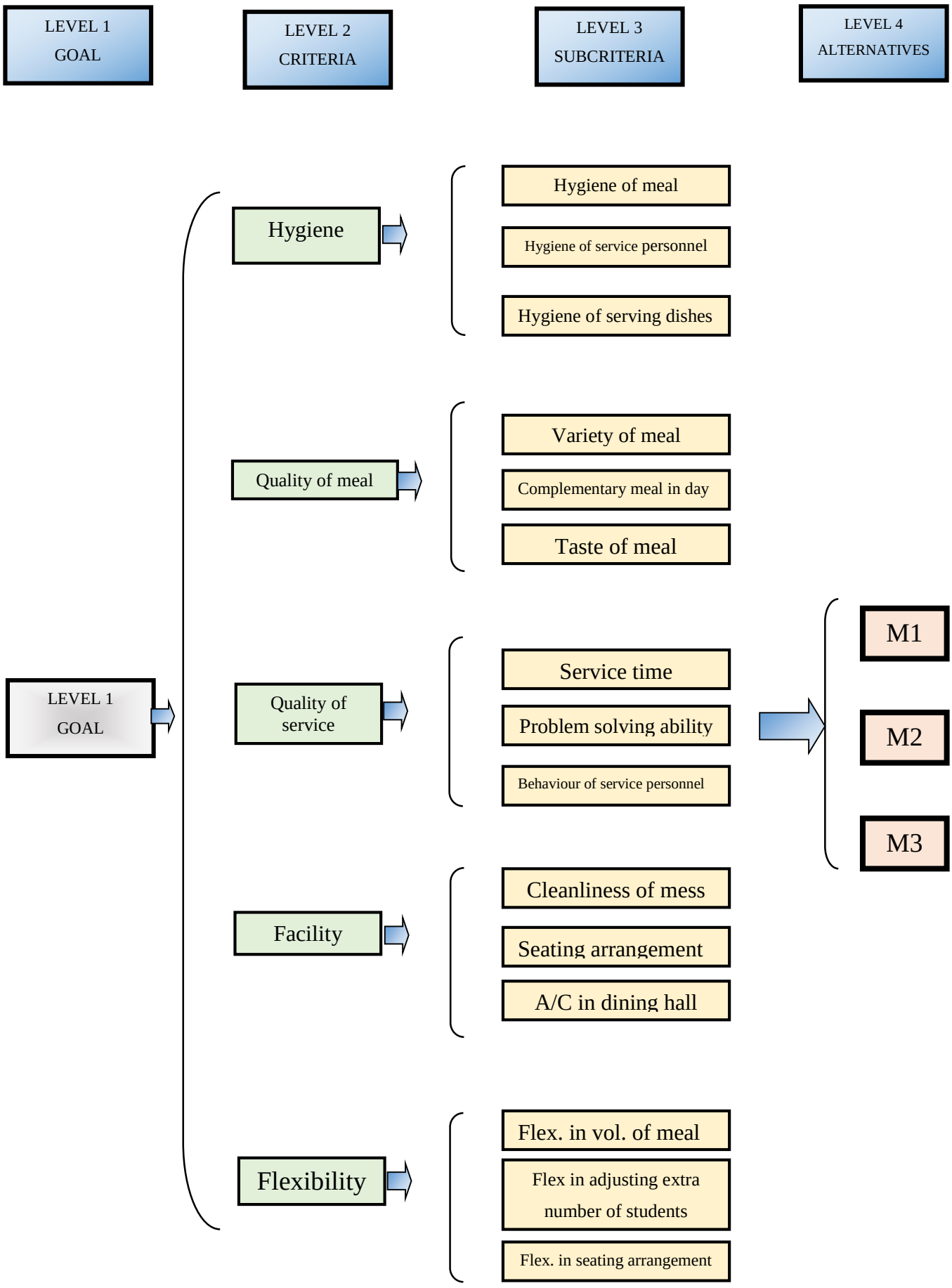


Figure 4 Hierarchy of the selection of best mess

4.4.1 Evaluation of criteria and sub criteria weight using fuzzy AHP

We adopt the fundamental relational scale for pair-wise comparisons in which intensity of importance on an absolute scale in between 1 to 9 scales. If absolute scale is 1 then its meaning equal importance which means two activities contributes equally to the objective. If absolute scale is 2 then its meaning weak importance which means experience and judgment slightly favour one activity over another and it represented in the scale of fuzzy number as (1,2,3). The fundamental relational scale which is follow in this work is shown in Table 3.

Table 3 Fundamental relational scale for pair-wise comparisons

Intensity of importance on absolute scale	Definition	Explanation	Scale of Fuzzy numbers
1	Equal strong	Two activities contribute equally to the objective	(1,1,1)
3	Weak strong	Experience and judgment moderately favor one activity over another	(2,3,4)
5	Fairly strong	Experience and judgment strongly favor one activity over another	(4,5,6)
7	Very strong	An activity is very strongly favored and its dominance is demonstrated in practice	(6,7,8)
9	Absolutely strong	The evidence favoring one activity over another is of the highest possible order of affirmation	(9,9,9)

We use the above Table 3 in the pair wise comparison. From the online survey and discussion from students who are using mess service from many years and some personnel

from the mess of hostel number 8 and aurobindo. After that we made the comparison matrix of criteria to criteria described in Table 4.

Consistency Index

In the pair-wise comparison matrix decision makers decided the importance of one criterion to other criteria. After the making of pair-wise matrix we find the consistency index (CI) value by the use of AHP calculator.

Where consistency index value is measure the consistency of the pair wise comparison. The CI value is defined as

$$CI=\frac{\lambda_{max}-n}{n-1}$$

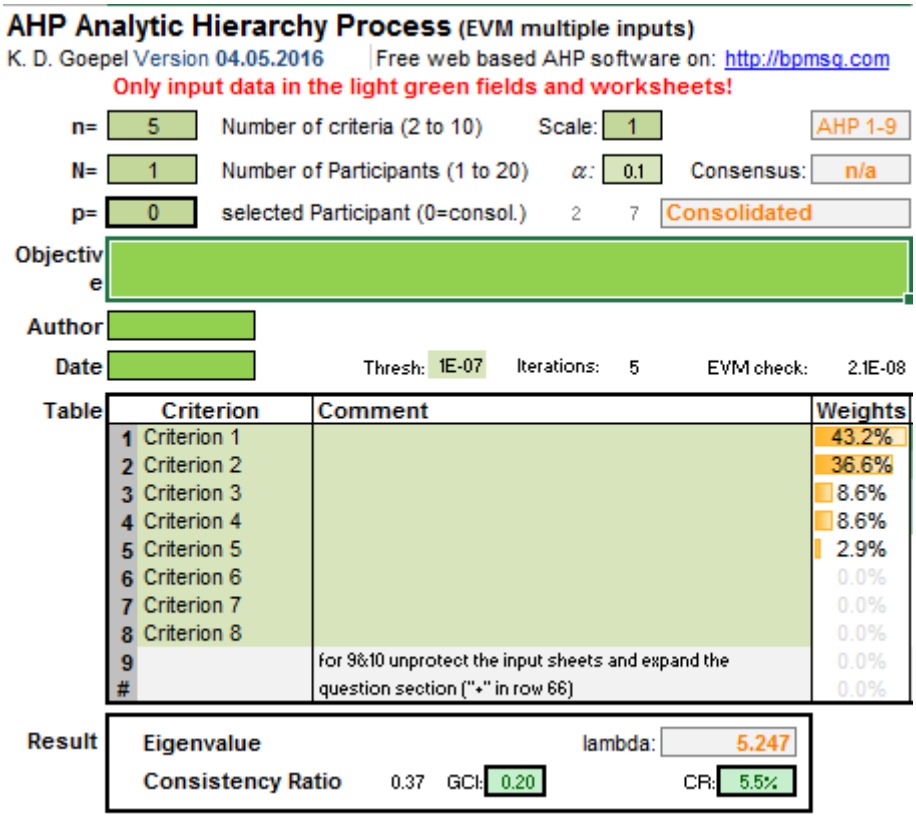


Figure 5 AHP calculator

Where n is the size of matrix and λ_{max} is principle Eigen value of the matrix. It is well known that $\lambda_{max} \geq n$ holds for a pairwise comparison matrix and that λ_{max} = n if and only if the corresponding comparison matrix is completely consistent.

Hence, in general the more CI value is, the less consistent a pair wise comparison matrix is, and Saaty indicates that a comparison matrix can be thought to be consistent if its CI value is less than 0.10.

AHP calculator gives the following results:

$\lambda_{max} = 5.247$

N = 5

So,

CI = $\frac{5.247-5}{5-1} = 0.06175$

Now using equation for $CR = \frac{CI}{RI}$

Taking value of Random consistency Index from the figure

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Figure 6 Random consistency Index

Now RI = 1.12 for N = 5

$$CR = \frac{CI}{RI} = \frac{0.6175}{1.12} = 0.0551$$

So finally the value of CR is 0.0551 which is less than 0.1, hence the matrix is consistent and we can proceed for the further calculation.

Table 4 Comparison matrix

Criteria	Hygiene	Quality of meal	Quality of service	Facility	Flexibility
Hygiene	ES	ES	VS	VS	AS
Quality of meal	ES	ES	FS	FS	AS
Quality of service			ES	ES	FS
Facility				ES	FS
Flexibility					ES

Table 5 Comparison matrix of criteria to criteria in triangular membership function

Criteria	Hygiene	Quality of meal	Quality of service	Facility	Flexibility
Hygiene	(1,1,1)	(1,1,1)	(6,7,8)	(6,7,8)	(9,9,9)
Quality of meal	(1,1,1)	(1,1,1)	(4,5,6)	(4,5,6)	(9,9,9)
Quality of service	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)	(4,5,6)
Facility	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)	(4,5,6)
Flexibility	(1/9,1/9,1/9)	(1/9,1/9,1/9)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)

Table 6 Geometric means of fuzzy comparison values for criteria

Criteria	$\bar{r}_i$		
Hygiene	4.547	3.379	3.565
Quality of meal	2.701	2.954	3.177
Quality of service	.608	.677	.757
Facility	.608	.677	.757
Flexibility	.202	.218	.238
Total	8.666	7.905	8.494
Reverse(power of-1)	0.1153	0.1265	0.1177
Increasing order	0.1153	0.1177	0.1265

Table 7 Relative fuzzy weight of each criteria

Criteria	$\widetilde{w_i}$		
Hygiene	0.5252	0.3977	0.4509
Quality of meal	0.3114	0.3476	0.4018
Quality of service	0.0701	0.0796	0.0957
Facility	0.0701	0.0796	0.0957
Flexibility	0.0232	0.02586	0.0301

Table 8 Averaged and normalized relative weights of each criteria

Criteria	M_i	N_i
Hygiene	0.4576	0.4570
Quality of meal	0.3536	0.3532
Quality of service	0.0818	0.0817
Facility	0.0818	0.0817
Flexibility	0.0263	0.0262

Table 9 Evaluation of sub dimension with respect to hygiene

	C11	C12	C13
C11	(1,1,1)	(4,5,6)	(1/8,1/7,1/6)
C12	(1/6,1/5,1/4)	(1,1,1)	(1/8,1/7,1/6)
C13	(6,7,8)	(6,7,8)	(1,1,1)

Table 10 Geometric means of fuzzy comparison values for sub criteria

Sub Criteria	$\bar{r}_i$		
C11	0.793	0.894	1
C12	0.275	0.305	0.346
C13	3.301	3.659	4
Total	4.369	4.858	5.346
Reverse(power of-1)	0.228	0.205	0.187
Increasing order	0.187	0.205	0.228

Table 11 Relative fuzzy weight of each sub criteria

Sub Criteria	$\widetilde{w_i}$		
C11	0.148	0.183	0.228
C12	0.051	0.062	0.078
C13	0.617	0.750	0.912

Table 12 Averaged and normalized relative weights of each sub criteria

Criteria	M_i	N_i
C11	0.186	0.184
C12	0.063	0.0625
C13	0.759	0.752

Table 13 Evaluation of sub dimension with respect to Quality of meal

	C21	C22	C23
C21	(1,1,1)	(6,7,8)	(1,1,1)
C22	(1/8,1/7,1/6)	(1,1,1)	(1/8,1/7,1/6)
C23	(1,1,1)	(6,7,8)	(1,1,1)

Table 14 Geometric means of fuzzy comparison values for sub criteria

Sub Criteria	$\bar{r}_i$		
C21	1.817	1.912	2
C22	0.25	0.273	0.302
C23	1.817	1.912	2
Total	3.884	4.097	4.302
Reverse(power of-1)	0.257	0.244	0.232
Increasing order	0.232	0.244	0.257

Table 15 Relative fuzzy weight of each sub criteria

Sub Criteria	$\widetilde{w_i}$		
C21	0.421	0.466	0.514
C22	0.058	0.066	0.077
C23	0.421	0.466	0.514

Table 16 Averaged and normalized relative weights of each sub criteria

Criteria	M_i	N_i
C21	0.467	0.466
C22	0.067	0.066
C23	0.467	0.466

Table 17 Evaluation of sub dimension with respect to Quality of service

	C31	C32	C33
C31	(1,1,1)	(4,5,6)	(6,7,8)
C32	(1/6,1/5,1/4)	(1,1,1)	(2,3,4)
C33	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1,1,1)

Table 18 Geometric means of fuzzy comparison values for sub criteria

Sub Criteria	$\bar{r}_i$		
C31	2.884	3.271	3.634
C32	0.693	0.8434	1
C33	0.314	0.362	0.436
Total	3.891	4.4764	5.07
Reverse(power of-1)	0.257	0.223	0.1972
Increasing order	0.1972	0.223	0.257

Table 19 Relative fuzzy weight of each sub criteria

Sub Criteria	$\widetilde{w_i}$		
C31	0.568	0.729	0.933
C32	0.136	0.188	0.257
C33	0.0619	0.080	0.112

Table 20 Averaged and normalized relative weights of each sub criteria

Criteria	M_i	N_i
C31	0.743	0.728
C32	0.193	0.189
C33	0.0846	0.0828

Table 21 Evaluation of sub dimension with respect to Facility

	C41	C42	C43
C41	(1,1,1)	(4,5,6)	(1,1,1)
C42	(1/6,1/5,1/4)	(1,1,1)	(1/6,1/5,1/4)
C43	(1,1,1)	(4,5,6)	(1,1,1)

Table 22 Geometric means of fuzzy comparison values for sub criteria

Sub Criteria	$\bar{r}_i$		
C41	1.587	1.709	1.817
C42	0.302	0.341	0.396
C43	1.587	1.709	1.817
Total	3.476	3.759	4.03
Reverse(power of-1)	0.287	0.266	0.248
Increasing order	0.248	0.266	0.287

Table 23 Relative fuzzy weight of each sub criteria

Sub Criteria	$\widetilde{w_i}$		
C41	0.393	0.454	0.521
C42	0.074	0.090	0.113
C43	0.393	0.454	0.521

Table 24 Averaged and normalized relative weights of each sub criteria

Criteria	M_i	N_i
C41	0.456	0.454
C42	0.092	0.091
C43	0.456	0.454

Table 25 Evaluation of sub dimension with respect to Flexibility

	C51	C52	C53
C51	(1,1,1)	(4,5,6)	(4,5,6)
C52	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)
C53	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)

Table 26 Geometric means of fuzzy comparison values for sub criteria

Sub Criteria	$\bar{r}_i$		
C51	2.519	2.924	3.301
C52	0.550	0.584	0.629
C53	0.550	0.584	0.629
Total	3.619	4.092	4.559
Reverse(power of-1)	0.276	0.244	0.219
Increasing order	0.219	0.244	0.276

Table 27 Relative fuzzy weight of each sub criteria

Sub Criteria	$\widetilde{w_i}$		
C51	0.551	0.713	0.911
C52	0.120	0.142	0.173
C53	0.120	0.142	0.173

Table 28 Averaged and normalized relative weights of each sub criteria

Criteria	M_i	N_i
C51	0.725	0.714
C52	0.145	0.142
C53	0.145	0.142

Table 29 Summary of criteria weight

Criteria	Local importance	Sub criteria	Local importance	Global importance
C1	0.4570	C11	0.184	0.084
		C12	0.062	0.028
		C13	0.752	**0.343**
C2	0.3532	C21	0.466	**0.164**
		C22	0.066	0.023
		C23	0.466	**0.164**
C3	0.0817	C31	0.728	0.059
		C32	0.189	0.015
		C33	0.082	0.006
C4	0.0817	C41	0.454	0.037
		C42	0.091	0.007
		C43	0.454	0.037
C5	0.0262	C51	0.714	0.018
		C52	0.142	0.003
		C53	0.142	0.003

According to the case study, results showed that caterers should focus more on C13, C21 and C23 to satisfy the needs and the expectations of consumers.

4.4.2 Prioritization of catering service firms using fuzzy TOPSIS.

Table 30 Initial fuzzy decision matrix in linguistic term

	C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52	C53
M1	VS	VS	VS	AS	FS	VS	VS	ES	VS	VS	WS	VS	VS	FS	FS
M2	FS	WS	FS	FS	FS	VS	VS	FS	FS	FS	VS	WS	FS	FS	WS
M3	FS	VS	FS	FS	WS	FS	ES	WS	WS	FS	VS	WS	ES	VS	VS

Table 31 Initial fuzzy decision matrix in triangular membership function term

	C11	C12	C13	C21	C22	C23	C31	C32
M1	(6,7,8)	(6,7,8)	(6,7,8)	(9,9,9)	(4,5,6)	(6,7,8)	(6,7,8)	(1,1,1)
M2	(4,5,6)	(2,3,4)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)	(6,7,8)	(4,5,6)
M3	(4,5,6)	(6,7,8)	(4,5,6)	(4,5,6)	(2,3,4)	(4,5,6)	(1,1,1)	(2,3,4)

	C33	C41	C42	C43	C51	C52	C53
M1	(6,7,8)	(6,7,8)	(2,3,4)	(6,7,8)	(6,7,8)	(4,5,6)	(4,5,6)
M2	(4,5,6)	(4,5,6)	(6,7,8)	(2,3,4)	(4,5,6)	(4,5,6)	(2,3,4)
M3	(2,3,4)	(4,5,6)	(6,7,8)	(2,3,4)	(1,1,1)	(6,7,8)	(6,7,8)

Table 32 Normalized fuzzy decision matrix

	C11	C12	C13	C21	C22	C23	C31
M1	(.75,.875,1)	(.75,.875,1)	(.75,.875,1)	(1,1,1)	(.66,.83,1)	(.75,.875,1)	(.75,.875,1)
M2	(.5,.625,.75)	(.25,.375,.5)	(.5,.625,.75)	(.44,.55,.66)	(.66,.83,1)	(.75,.875,1)	(.75,.875,1)
M3	(.5,.625,.75)	(.75,.875,1)	(.5,.625,.75)	(.44,.55,.66)	(.33,.5,.66)	(.5,.625,.75)	(.125,.125,.125)
W	0.084	0.028	0.343	0.164	0.023	0.164	0.059

	C32	C33	C41	C42	C43	C51	C52	C53
M1	(.166,.166,.166)	(.75,.875,1)	(.75,.875,1)	(.25,.375,.5)	(.75,.875,1)	(.75,.875,1)	(.5,.625,.75)	(.5,.625,.75)
M2	(.66,.83,1)	(.5,.625,.75)	(.5,.625,.75)	(.75,.875,1)	(.25,.375,.5)	(.5,.625,.75)	(.5,.625,.75)	(.25,.375,.5)
M3	(.33,.5,.66)	(.25,.375,.5)	(.5,.625,.75)	(.75,.875,1)	(.25,.375,.5)	(.125,.125,.125)	(.75,.875,1)	(.75,.875,1)
W	0.015	0.006	0.037	0.007	0.037	0.018	0.003	0.003

Table 33 Weighted normalized fuzzy decision matrix

	C11	C12	C13	C21	C22	C23	C31
M1	(.063,.073,.084)	(.021,.0245,.028)	(.257,.300,.343)	(.164,.164,.164)	(.015,.019,.023)	(.123,.143,.164)	(.044,.051,.059)
M2	(.042,.052,.063)	(.007,.01,.014)	(.171,.214,.257)	(.072,.090,.108)	(.015,.019,.023)	(.123,.143,.164)	(.044,.051,.059)
M3	(.042,.052,.063)	(.021,.0245,.028)	(.171,.214,.257)	(.072,.090,.108)	(.007,.011,.015)	(.082,.102,.123)	(.007,.007,.007)

	C32	C33	C41	C42	C43	C51	C52	C53
M1	(.002,.002,.002)	(.004,.005,.006)	(.027,.032,.037)	(.001,.002,.003)	(.027,.032,.037)	(.013,.015,.018)	(.001,.001,.002)	(.001,.001,.002)
M2	(.009,.012,.015)	(.003,.003,.004)	(.018,.023,.027)	(.005,.006,.007)	(.009,.013,.018)	(.009,.011,.013)	(.001,.001,.002)	(.000,.001,.001)
M3	(.004,.007,.009)	(.001,.002,.003)	(.018,.023,.027)	(.005,.006,.007)	(.009,.013,.018)	(.002,.002,.002)	(.002,.002,.003)	(.002,.002,.003)

Table 34 Fuzzy positive and negative ideal solution

	C11	C12	C13	C21	C22	C23	C31
C^+	(.063,.073,.084)	(.021,.024,.028)	(.257,.300,.343)	(.164,.164,.164)	(.015,.019,.023)	(.123,.143,.164)	(.044,.051,.059)
C^-	(.042.052,.063)	(.007,.01,.014)	(.171,.214,.257)	(.072,.090,.108)	(.007,.011,.015)	(.082,.102,.123)	(.007,.007,.007)

	C32	C33	C41	C42	C43	C51	C52	C53
C^+	(.009,.012,.015)	(.004,.005,.006)	(.027,.032,.037)	(.005,.006,.007)	(.027,.032,.037)	(.013,.015,.018)	(.002,.002,.003)	(.002,.002,.003)
C^-	(.002,.002,.002)	(.001,.002,.003)	(.018,.023,.027)	(.001,.002,.003)	(.009,.013,.018)	(.002,.002,.002)	(.001,.001,.002)	(.000,.001,.001)

Table 35 Distance of alternative from fuzzy positive and negative ideal solution and closeness coefficient

	d_i^+	d_i^-	CC_i	Ranking
M1	.011135527	0.134556343	0.923567959	1
M2	0.119129102	0.062766763	0.345069762	2
M3	0.133912878	0.015708199	0.104986021	3

CHAPTER 5: CONCLUSION

Decisions are made today in increasingly complex environments. In more and more cases the use of experts in various fields is necessary, different value systems are to be taken into account, etc. In many of such decision-making settings the theory of fuzzy decision making can be of use. Fuzzy group decision making can overcome this difficulty. In general, many concepts, tool and techniques of artificial intelligence, in particular in the field of knowledge representation and reasoning, can be used to improve human consistency and implement ability of numerous models and tools in broadly perceived decision making and operations research. In this thesis, catering firms were compared using Hybrid of fuzzy AHP and fuzzy TOPSIS. Humans are often uncertain in assigning the evaluation scores in crisp AHP. Fuzzy AHP can capture this difficulty. There are many other methods to use in comparing catering firms. These are multi-attribute evaluation methods such as ELECTRE, DEA. These methods have been recently developed to use in a fuzzy environment. Further research work could be of the application of these methods to the catering selection problem and the comparison of the results.

In my research, I have done a hybridization of FAHP and FTOPSIS to evaluate the best alternatives which satisfies the needs and the expectations of consumers. In three hostel messes of MNIT, hostel 8 is the highest scoring alternative followed by hostel 6 and aurobindo hostel. According to the case study, results showed that caterers should focus more on C13, C21 and C23 to satisfy the needs and the expectations of consumers. Where C13, C21 and C23 are Hygiene of serving dishes, variety of meal and taste of meal respectively. Other than three there are many factors if, which would consider can change the overall all scenario of the catering service providing industry and some of them are Hygiene of meal, service time, cleanliness of mess, air conditioning in mess and hygiene of service personnel. The model also could be applied to several studies to investigate how consumer's perception and evaluation of catering service quality change over time.

REFERENCES

Badri, M. A. (2001). A combined AHP–GP model for quality control systems. *International Journal of Production Economics*, *72*(1), 27-40.

Beikkhakhian, Y., Javanmardi, M., Karbasian, M., & Khayambashi, B. (2015). The application of ISM model in evaluating agile supplier's selection criteria and ranking suppliers using fuzzy TOPSIS-AHP methods. *Expert Systems with Applications*, *42*(15), 6224-6236.

Bilsel, R. U., Büyüközkan, G., & Ruan, D. (2006). A fuzzy preference-ranking model for a quality evaluation of hospital web sites. *International Journal of Intelligent Systems*, *21*(11), 1181-1197.

Büyüközkan, G., & Çifçi, G. (2012). A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry. *Expert Systems with Applications*, *39*(3), 2341-2354.

Byun, D. H. (2001). The AHP approach for selecting an automobile purchase model. *Information & Management*, *38*(5), 289-297.

Cheng, C. H. (1997). Evaluating naval tactical missile systems by fuzzy AHP based on the grade value of membership function. *European Journal of Operational Research*, *96*(2), 343-350.

Creed, P. G. (2001). The potential of foodservice systems for satisfying consumer needs. *Innovative Food Science & Emerging Technologies*, *2*(3), 219-227.

Dağdeviren, M., Yavuz, S., & Kılınç, N. (2009). Weapon selection using the AHP and TOPSIS methods under fuzzy environment. *Expert Systems with Applications*, *36*(4), 8143-8151.

Deng, H. (1999, August). Multi criteria analysis with fuzzy pairwise comparison. In *Fuzzy Systems Conference Proceedings, 1999. FUZZ-IEEE'99. 1999 IEEE International* (Vol. 2, pp. 726-731). IEEE.

Fodness, D., & Murray, B. (2007). Passengers' expectations of airport service quality. *Journal of Services Marketing*, *21*(7), 492-506.

Gangurde, S. R., & Akarte, M. M. (2013). Customer preference oriented product design using AHP-modified TOPSIS approach. *Benchmarking: An International Journal*, *20*(4), 549-564.

Guo, S., & Zhao, H. (2015). Optimal site selection of electric vehicle charging station by using fuzzy TOPSIS based on sustainability perspective. *Applied Energy*, *158*, 390-402.

Ho, W. (2008). Integrated analytic hierarchy process and its applications–A literature review. *European Journal of operational research*, *186*(1), 211-228.

Jansen, D. R., Van Weert, A., Beulens, A. J., & Huirne, R. B. (2001). Simulation model of multi-compartment distribution in the catering supply chain. *European Journal of Operational Research*, *133*(1), 210-224.

Jones, P. (1995). Developing new products and services inflight catering. *International Journal of Contemporary Hospitality Management*, *7*(2/3), 24-28.

Kahraman, C., Cebeci, U., & Ruan, D. (2004). Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey. *International Journal of Production Economics*, *87*(2), 171-184.

Kahraman, C., Yasin Ates, N., Çevik, S., Gülbay, M., & Ayça Erdogan, S. (2007). Hierarchical fuzzy TOPSIS model for selection among logistics information technologies. *Journal of Enterprise Information Management*, *20*(2), 143-168.

Kang, D., Jang, W., & Park, Y. (2016). Evaluation of e-commerce websites using fuzzy hierarchical TOPSIS based on ES-QUAL. *Applied Soft Computing*, *42*, 53-65.

Keramati, M. A., Zorriassatine, F., & RezaFeylizadeh, M. (2012). An order acceptance using FAHP and TOPSIS methods: A case study of Iranian vehicle belt production industry. *International Journal of Industrial Engineering Computations*, *3*(2), 211-224.

Ladhari, R. (2010). Developing e-service quality scales: A literature review. *Journal of Retailing and Consumer Services*, *17*(6), 464-477.

Li, M. (2013). A multi-criteria group decision making model for knowledge management system selection based on TOPSIS with multiple distances in fuzzy environment. *Kybernetes*, *42*(8), 1218-1234.

Martínez-Tomé, M., Vera, A. M., & Murcia, M. A. (2000). Improving the control of food production in catering establishments with particular reference to the safety of salads. *Food Control*, *11*(6), 437-445.

Maudsley, C. (1989). Catering for health. *Nutrition & Food Science*, *89*(3), 2-3.

Murthy, D. N. P., & Kumar, K. R. (2000). Total product quality. *International Journal of Production Economics*, *67*(3), 253-267.

Prascevic, Z., & Prascevic, N. (2013). One modification of fuzzy TOPSIS method. *Journal of Modelling in Management*, *8*(1), 81-102.

Read, S., & Worsfold, D. (1998). Catering for older people in residential care homes. *Nutrition & Food Science, 98*(1), 30-37.

Rolls, B. J., Rowe, E. A., Rolls, E. T., Kingston, B., Megson, A., & Gunary, R. (1981). Variety in a meal enhances food intake in man. *Physiology & Behavior, 26*(2), 215-221.

Rostamzadeh, R., & Sofian, S. (2011). Prioritizing effective 7Ms to improve production systems performance using fuzzy AHP and fuzzy TOPSIS (case study). *Expert Systems with Applications, 38*(5), 5166-5177.

Saeida Ardakani, S., Nejatian, M., Farhangnejad, M. A., & Nejati, M. (2015). A fuzzy approach to service quality diagnosis. *Marketing Intelligence & Planning, 33*(1), 103-119.

Tikkanen, I., & Silvan, A. (2012). Developing the service process of municipal home care catering. *Nutrition & Food Science, 42*(5), 315-323.

Tikkanen, I., & Varkoi, T. (2011). Consumption of Fairtrade products in a municipal catering organisation. *Nutrition & Food Science, 41*(3), 183-190.

Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of operational research, 169*(1), 1-29.

Wang, Y. M., Luo, Y., & Hua, Z. (2008). On the extent analysis method for fuzzy AHP and its applications. *European Journal of Operational Research, 186*(2), 735-747.

Wu, C., & Barnes, D. (2011). A literature review of decision-making models and approaches for partner selection in agile supply chains. *Journal of Purchasing and Supply Management, 17*(4), 256-274.

Yang, Z. L., Bonsall, S., & Wang, J. (2011). Approximate TOPSIS for vessel selection under uncertain environment. *Expert Systems with Applications, 38*(12), 14523-14534.

Zeynali, M., Aghdaie, M. H., Rezaeiniya, N., & Zolfani, S. H. (2012). A hybrid fuzzy multiple criteria decision making (MCDM) approach to combination of materials selection. *African Journal of Business Management*, *6*(45), 11171.

APPENDIX

Online survey for data collection

https://docs.google.com/forms/d/13mSUe9WUsBne68--kat1Xxy-HYzOSVBf99c6Joj5bHA/viewform?c=0&w=1&usp=mail_form_link