A

Dissertation Report

On

Suppliers Selection using Fuzzy AHP and Fuzzy TOPSIS Method

Dissertation submitted in fulfillment of the requirements for the Degree of

MASTER OF TECHNOLOGY

by

RAMESH KARWAL

(2013PIE5049)

Supervisor

Dr. M.L.MITTAL

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY, JAIPUR

June, 2015

CERTIFICATE

This is to certify that the dissertation entitled **"Suppliers Selection using Fuzzy AHP and Fuzzy TOPSIS method"** being submitted by **Ramesh Karwal (2013PIE5049)** is a bonafide work carried out by him under my supervision and guidance, and hence approved for submission to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** in partial fulfillment of the requirements for the award of the degree of **Master of Technology (M.Tech) in Industrial Engineering**. The matter embodied in this dissertation report has not been submitted anywhere else for award of any other degree or diploma.

Place: Jaipur

Dated: 14/June/2015

Dr. M.L. Mittal
Associate Professor,
Department of Mechanical Engineering,
MNIT Jaipur

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
JAIPUR – 302017 (RAJASTHAN), INDIA

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled **"Suppliers Selection using Fuzzy AHP and Fuzzy TOPSIS method"** in partial fulfillment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial Engineering**, and submitted to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** is an authentic record of my own work carried out by me during a period of one year from July 2014 to June 2015 under the guidance and supervision of **Dr. M. L. Mittal** of the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur.

The matter presented in this dissertation embodies the results of my own work and has not been submitted anywhere else for award of any other degree or diploma.

Ramesh karwal

(2013PIE5049)

ACKNOWLEDGEMENT

With great delight, I acknowledge my indebted thanks to my guide and mentor **Dr. M. L. Mittal** who has always been a source of inspiration and encouragement for me. His stimulated guidance and unwavering support always motivated me to reach out for, and achieve higher levels of excellence. This dissertation could not have attained its present form, both in content and presentation without his active interest, direction and help. I am grateful to him for keeping trust in me in all circumstances. I thank him for being big-hearted with any amateurish mistakes of mine.

I express my sincere gratitude to **Prof. Rakesh Jain, Prof. Awadhesh Bhardwaj, Prof. A.P.S. Rathore and Dr. Gunjan Soni** for their support and guidance throughout the course of study at MNIT Jaipur.

I highly acknowledge and duly appreciate the support extended by my seniors, colleagues-friends and juniors for their help & support in accomplishment of this work during my stay at MNIT Jaipur.

Ramesh karwal

ABSTRACT

An effective supplier selection process is very important to the success of any manufacturing organization. The main objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser and develop closeness and long-term relationships between buyers and suppliers in today's competitive industrial scenario. The aim of this research work is to determine the key factors of supplier selection and ranking of potential suppliers.

In jaipur a bearing manufacturing company has been considered for my dissertation work. The company was considering two criteria of suppliers selection i.e. quality rating and service rating. But I have considered six criteria instead of two for improving the supplier's selection process which are product quality, product cost, location, delivery time, information system and service rating.

In this dissertation work, first of all the key factors involved in supplier selection have been identified. A survey has been conducted for data collection from purchase department in the company. After that the criteria weights for the suppliers' selection are calculated using Fuzzy AHP method and using fuzzy TOPSIS method the ranking of the suppliers are determined. The rating has been represented by linguistic variables and then parameterized by triangular fuzzy number. The contribution of this study is to give improved suppliers' selection process to the company.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

TOPSIS	Technique for Order Preference by Similarity to Ideal Solution method
AHP	Analytic hierarchy process
TQM	Total quality management
JIT	Just in time
MCDM	Multiple criteria decision making
FAHP	Fuzzy Analytic hierarchy process
FTOPSIS	Fuzzy Technique for Order Preference by Similarity to Ideal Solution method
MADA	Multi-Attribute Decision Analysis
SR	Service rating
NN	Neural networks
CBR	Case-base reasoning
MAUT	Multiple Attribute Utility Theory
DEA	Data envelopment analysis
TCO	Total Cost of Ownership
TFN	Triangular fuzzy number
FPIS	Fuzzy positive ideal solution
FNIS	Fuzzy negative ideal solution
CI	Consistency index

CHAPTER 1: INTRODUCTION

1.1 Background

In most industries, the cost of raw materials and component parts represents the largest percentage of the total product cost. For instance, in high technology firms, purchased materials and services account for up to 80% of the total product cost. Therefore, selecting the right suppliers is the key to procurement process and represents a major opportunity for companies to reduce costs across its entire supply chain. Choosing the right method for supplier selection effectively leads to a reduction in purchase risk and increases the number of just in time (JIT) suppliers and total quality management (TQM) production. Supplier selection problem has become one of the most important issues for establishing an effective supply chain system.

Supplier selection, the process of determining the suitable suppliers who are able to provide the Buyer with the right quality products and/or services at the right price, at the right time and in the right quantities, is one of the most critical activities for establishing an effective supply chain. In other words, supplier selection is a multi-criteria decision making problem which includes both qualitative and quantitative factors. In order to choose the best suppliers, it is essential to make a trade-off between these tangible and intangible factors, some of which may conflict. The aim of this study is to develop a methodology to evaluate suppliers in supply chain cycle based on Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS).

Supplier selection, which includes multi criteria and multiple conflicting objectives, can be defined as the process of finding the right suppliers with the right quality at the right price, at the right time, and in the right quantities. It is noted that, manufacturers spend more than 60% of its total sales on purchased items. In addition, their purchases of goods and services constitute up to 70% of product cost. Therefore, selecting the right supplier significantly reduces purchasing costs, improves competitiveness in the market and enhances end user satisfaction. Since this selection process mainly involves the evaluation of different criteria and various supplier attributes, it can be considered as a multiple criteria decision making (MCDM) problem. Based on several criteria and alternatives to be considered, various decision making methods have been proposed to provide a solution to this problem. Basically there are two types of supplier selection problems. In single sourcing type, one supplier can satisfy all the buyer's needs. In the multiple sourcing types, no supplier can satisfy all the buyer's requirements. Hence the management wants to split order quantities among different suppliers (William, 2010).

Today manufacturer on average spends approximately half of its revenue to purchase goods and services, thus making a company's success reliant on their interaction with suppliers. The role of purchase Managers with in company has become particularly important. Supplier selection involves the congregation of decisions made by different organizational levels in the company. Each level or each department may have their own priorities based on their ease of manufacturing. Taking all these into study, one cannot have an optimal solution. So, in selecting an appropriate supplier, one has to consider all these requirements and should take a compromising decision. With much of company's money being spent and increasing dependency on the outsourcing of many critical and complex parts ,the role of buyer is not only critical but also challenging .Buyers must define and calculate what will be the best value means for the buying organization ,and undertake purchase action accordingly. To identify the best value, the purchase manager must have a common meeting with technical, operations and legal experts within the company, and should be a professional negotiator and director across many internal and external parties.

Supplier selection is the process by which the buyer identifies, estimates, and deals with suppliers. The challenges mentioned make supplier selection a rich topic for industrial operations and management disciplines.

To cope with the growing competition, it isn't enough only to select from the existing or known suppliers but the management should be able to identify new suppliers. New supplier advantage or low labour cost which ultimately impact the cost of the product and may be able to supply it for cheaper than any other or may be able to deliver with lesser lead time that might allow maintaining minimum inventory which reduces expenses for maintenance as well as money will be put to best use.

Therefore, supplier selection, evaluation and monitoring are crucial for an industry to survive in long term. Ranking of suppliers become complex when suppliers must be evaluated across multiple dimensions evaluation indices. For example , if the buyer wishes to evaluate supplier's bids on the extents of price and lead-time, the buyer must build a trade-off between these two dimensions to determine whether it favours, say, a bid with a high price and less lead time to a bid with a low price and higher lead time. The real challenge of supplier evaluation lies in constructing this trade-off in a way that perfectly reflects the buyer's preferences (Bello.M, 2003).

Traditionally, suppliers were considered to be adversaries and cost of goods was the only factor considered for supplier selection. But, now it is realized both by academics and practicing managers that the supplier is not adversaries but the partners in the supply chain. It is also realized that the supplier selection should not be solely based on cost but on the factors such as quality, delivery, historical supplier performance, capacity, communication systems, service and geographic location, among others which can be qualitative and quantitative. The organizations attach different importance/preference to these factors.

Probable suppliers for single items, in practice, are many having their positives and negatives related to these factors. Under these circumstances the ranking of the suppliers giving due consideration to the above factors and their importance, requires some formal method. Several methods have been used for this purpose differing in their suitability to qualitative/ quantitative factors, the methodology used for ranking and complexity.

Decision or selection making is a vital part of daily life; of which the major concern is that almost all issues requiring decisions have multiple, often conflicting, criteria. In reality, there is no avoidance of the co existing of qualitative and quantitative data, and the data are often full of fuzziness and uncertain .In order to mediate the conflicts and contradictions in the process and act in response to the lack of flexibility while adopting traditional multi-criteria method to solve fuzzy problem.

1.2 Supplier criteria

A criterion can be thought of as any measure of performance for a particular supplier 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 Supplier selection methods

There are many methods of supplier selection which are as mathematical programming, multiple criteria decision making (MCDM), multivariant statistical analysis, artificial intelligence & expert systems and decision making tools. In this work we use the multiple criteria decision making method. In the MCDM we use fuzzy AHP method for weighting of criteria and fuzzy TOPSIS method use for ranking of supplier alternatives.

1.4 Objective of the Research

The major objectives of the current study are

- To identify the supplier evaluation criteria.
- The second objective is to identify and the ranking the potential supplier alternatives.
- The third objective is to develop a supplier selections procedure for a manufacturing company.

1.5 Thesis Outline

The dissertation report contains five chapters.

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

CHAPTER 2: Literature review which describes types of supplier and supplier selection criteria and attributes and supplier selection methods.

CHAPTER 3: Explains the FAHP and FTPOSIS method used in supplier selection procedure.

CHAPTER 4: Case study of supplier selection in NBC company jaipur.

CHAPTER 5: Conclusion

CHAPTER 2: LITERATURE REVIEW

Supplier selection, which includes multi criteria and multiple conflicting objectives, can be defined as the process of finding the right suppliers with the right quality at the right price, at the right time, and in the right quantities.

Supplier selection or evaluation is common problem for acquiring the necessary material so support the outputs of organizations. The problem is to find and evaluate periodically the best or most suitable vendor's capabilities. This usually happens when the purchase is complex, high rupee value, and perhaps critical. There are two areas of research in supplier selection. 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. Supplier selection is an important decision –making process in the supply chain management. Different suppliers have varied 'pros and cons' associated with them. Therefore, selecting an appropriate is always difficult task. Supplier selection has a major impact on proper functioning of supply chain as well as product quality. Selection of right supplier improves the efficiency of supply chain and significantly increases corporate competitiveness. Organizations must be very cautions not only about price and quality of raw material but also about the structure of the organization , production capabilities , reliability, company policies etc. for some cases, it is not only enough to look at supplier conditions but also supplier reliability and capacity. For the case of just in time (JIT) manufacturing, supplier selection is the most importance. There has been an evolution in the role and structure of the purchasing function through the nineties. The purchasing function has gained great importance in the supply chain management due to factors such as globalization, increase value added in supply and accelerated technological change. Purchasing involves buying the raw materials, supplies and components for the organization. The activities associated with it include selecting and qualifying suppliers, rating supplier performance, negotiating contracts, comparing price, quality and service, sourcing goods and service, timing purchases, selling terms of sale, evaluating the value received, predicting price, service and sometimes demand changes, specifying the form in which goods are to be received etc. A key and perhaps the most important process of the purchasing function is the efficient selection of suppliers because it brings significant saving for organization. The objective of the supplier selection process is to reduce risk and maximize the total value for the buyer and it involves considering a series of strategic variables. Among these variables is the frame of the relationship with the suppliers, the choice between domestic and international suppliers and the number of suppliers that is choosing between single or multiple sourcing and the type of the product. (Bhutta, 2003)

2.1 Types of suppliers

Suppliers are essential to any business and the process of identifying and selecting a supplier is both relevant and important .Sometimes supplier contacts with purchasing organization through their sales representatives, but more often, the buyer need to locate them either at trade shows, wholesale showrooms and conventions, or through buyer's directories, industry contacts and trade. Supplier can be divided into three general categories manufacturers, distributors and independent crafts people.

The first category of supplier is manufacturers, these are the companies that research, develop and actually produce the finish product ready for purchase. Manufacturers and vendors are the source of supply chain.

The second types of suppliers are the distributors who are also known as whole sellers, brokers or jobbers, distributors buy in quantity from several manufacturers and warehouse the goods for sale to retailers. Although their prices are higher than manufacturers, they can supply retailers with small orders from a variety of manufacturers. A lower freight bill and quick delivery time from a nearby distributor often compensates for the higher per –item cost. The third kind is the independent craftspeople that are exclusive distributers of unique creations frequently offered by this independent crafts people, those are representatives or at trade shows.

2.2 Supplier selection criteria

Supplier selection is complicated by the fact that various criteria must be considered in the decision making process. The analysis of criteria for selecting and measuring the performance of the suppliers has been the focus of many research papers. Some papers reviewed and examined the decision criteria used for supplier selection. Most papers attempted to identify and determine the relative importance of criteria for supplier selection in various industries. The decision criteria used for supplier selection and the weights assigned to them can be different due to a number of factors (Sonmez, 2006).

- The demographic characteristics of the purchasing managers.

- The size of the buyer organization.
- The existence of purchasing strategy.
- The type of products and /or services purchased.

On the basis of the literature reviewed it has been observed that the basic criteria typically utilized for selecting the suppliers are pricing structure, delivery, product quality, and service etc. While most buyers still consider cost to be their primary concern, few more interactive and interdependent selection criteria are increasingly being used by the manufacturers. 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.

The various important criteria for the supplier selection as observed from the literature reviewed are:

- Price
- Quality
- Delivery
- Performance History
- Business overall performance
- Warranties & Claims Policies
- Production Facilities and Capacity
- Technical Capability
- Financial Position
- Procedural Compliance
- Reputation and Position in Industry
- Desire for Business
- Repair Service
- Attitude
- Packaging Ability
- Labour Relations Record

- Geographical Location
- Amount of Past Business
-
- Reciprocal Arrangement

2.3 Supplier selection methods

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

The large number of methods available also presents a weakness, as it is not clear which method should be used for which situation. A number of studies have been devoted to examining vendor selection methods. The common conclusion of these studies is that the supplier selection is a multi criteria decisions making problem (Nydick and hill, 1992; De Boer et. Al, 2001). Sonmez (2006) reviewed the decision making methods for supplier selection and clustered them into several broad categories.

There are many methods of supplier selection which is given in the Table 1.

Table 1: Supplier selection methods (Bhutta, 2003)

S.No	Category	Method
1	Mathematical programming	Total cost based approaches Non-linear programming Mixed integer programming Linear programming Integer programming Goal programming Data envelopment analysis (DEA)
2	MCDM	AHP methods Outranking methods Multi-attribute utility theory (MAUT) Linear weighted point Judgmental modeling Interpretive structural modeling Categorical methods Fuzzy sets

3	Artificial intelligence & expert systems	Neural networks (NN) Case-base reasoning (CBR)
4	Multivariate statistical analysis	Structural equation modeling Principal component analysis Factor analysis Cluster analysis
5	Other decision making tools	Group decision making Multiple

2.3.1 Mathematical programming

Mathematical programming models make it possible to formulate a decision-making problem in terms of a mathematical objective function. An advantage of mathematical programming models
is that they are more objective than rating and linear weighting models, because the decision-maker (DM) explicitly has to state objective functions.

Total Cost Approach

Companies wanting to implement a total cost-based supplier selection process often stumble over how to include non-monetary issues such as delivery and quality performance, lead time, services, and social policies (Jafar Rezaei, 2014). Unit Total Cost is the total cost to the purchaser per unit after inclusion of all relevant factors. Harding (1998) provides a detailed application of this approach. - Total Cost of Ownership (TCO) is a methodology, which looks beyond the price of a purchase to include many other purchase-related costs. This approach has become increasingly important as organizations look for ways to better understand and manage their costs. (Ellram, 1995). Too may include, in addition to the price paid, elements such as order placement costs, research costs, transportation costs, receiving, inspecting, and holding or disposal costs and so on. In their book (Handfield et ah, 1999), explore the understanding of TCO using the product life-cycle approach. They note that the costs related to a product are directly related to where the product is in its life cycle. Though there are other selection and evaluation approaches closely aligned with TCO such as life cycle costing (Ellram, 1995), Zero base pricing (Monckza, 1988), and cost-based supplier performance evaluation (Handheld et al.1999) among others. None of these approaches has received significant, widespread support in literature or in practice for a variety of reasons.

Data Envelopment Analysis

DEA is a mathematical programming method for assessing the comparative efficiencies of decision-making units (DMUs) where the presence of multiple inputs and outputs makes comparison difficult. Recent work by authors such as Weber (1996) has shown the efficacy of using Data Envelopment Analysis (DEA) in Supplier selection problems especially when multiple conflicting criteria have to be considered. DEA identifies an 'efficient frontier' from the inputs and outputs to be evaluated creating Decision Making Units (DMU's) and then the efficiency of each of these DMUs are compared to the ‘efficient frontier’.

Optimization Techniques- Several optimization techniques have been applied to SS. Among the more commonly applied techniques are Dynamic programming (Masella, 2000), Linear programming (Ghodsypour et al., 2006) and Multi-Objective programming (Weber et al., 1993).

Goal Programming

Another important tool is Goal Programming (GP). Unlike most mathematical programming models, goal programming provides the decision maker (DM) with enough flexibility to set target levels on the different criteria and obtain the best compromise solution that comes as close as possible to each one of the defined targets.

Integer linear programming

Talluri (2002) developed a binary integer linear programming model to evaluate alternative supplier bids based on ideal targets for bid attributes set by the buyer, and to select an optimal set of bids by matching demand and capacity constraints. Based on four variations of model, effective negotiation strategies were proposed for unselected bids.

Hong et al. (2005) presented a mixed-integer linear programming model for the supplier selection problem. The model was to determine the optimal number of suppliers, and the optimal order quantity so that the revenue could be maximized. The change in suppliers’ supply capabilities and customer needs over a period of time were considered.

Integer non-linear programming

Ghodsypour and O’Brien (2001) formulated a mixed integer non-linear programming model to solve the multi-criteria sourcing problem. The model was to determine the optimal allocation of products to suppliers so that the total annual purchasing cost could be minimized. Three constraints were considered in the model.

2.3.2 Multiple criteria decision making (MCDM)

There are various methods in multiple criteria decision making such as AHP method, TOPSIS method, multi attribute utility theory, Fuzzy sets, judgmental modeling, linear weighted point, interpretive etc. The general methods are describes bellow as.

Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) provides a framework to cope with multiple criteria situations involving intuitive, rational, qualitative and quantitative aspects (Bhutta et al., 2003). The primary objectives affecting supplier selection criteria are grouped under three main categories: performance assessment, business structure capability assessment and quality system assessment. The AHF is used as a framework to formalize the evaluation of tradeoffs between the conflicting selections criteria associated with the various supplier offers. This is the main reason for selecting the AHF as the decision support model for solving the supplier selection problem, which involves many intangible factors, but still requires a logical and rational control of decisions (Nydick et al., 1992). Generally the hierarchy has three levels: the goal, the criteria and the alternatives. For the supplier selection problem, the goal is the best supplier, the criteria could be quality, on-time delivery, price, etc and the alternatives are the suppliers or proposals of the suppliers.

Analytical Hierarchical Process (AHP) is a decision-making method developed for prioritizing alternatives when multiple criteria must be considered and allows the decision maker to structure complex problems in the form of a hierarchy, or a set of integrated levels. This method incorporates qualitative and quantitative criteria. The hierarchy usually consists of three different levels, which include goals, criteria, and alternatives. Because AHP utilizes a ratio scale for human judgments, the alternatives weights reflect the relative importance of the criteria in achieving the goal of the hierarchy.

Multiple Attribute Utility Theory

Multiple Attribute Utility Theory (MAUT) is especially appropriate in situations where there are a variety of uncontrollable and unpredictable factors affecting the decision as it is capable of handling multiple conflicting attributes inherent in international supplier selection,. It also enables the purchasing manager to evaluate 'what if scenarios associated with changes in company policy (Weber, 1991).

Multi-objective Programming

This approach is especially suitable to just-in-time scenarios (Weber, 1993). The analysis occurs in a decision support system environment. A multi objective programming decision support system allows for judgment in decision making while simultaneously trading off key supplier selection criteria. An additional flexibility of this model is that it allows a varying number of suppliers into the solution and provides suggested volume allocation by supplier.

Technique for the Order Performance by Similarity to Ideal Solution (TOPSIS)

According to the concept of the TOPSIS, a closeness coefficient is defined to determine the ranking order of all suppliers and linguistic values are used to assess the ratings and weights of the factors. TOPSIS is based on the concept that the optimal alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS).

Outranking Method

Outranking methods are useful decision tool to solve multicriteria problems. These methods are only partially compensatory and are capable of dealing with situations in which imprecision is present. Lot of attention has been paid to outranking models, primarily in Europe. However, so far, in the purchasing literature there is no evidence of applications of outranking models in purchasing decisions.

2.3.3 Artificial intelligence & expert systems

Artificial Intelligence (AI) models are computer-based systems trained by the decision maker using historical data and experience. These systems usually cope very well with the complexity and uncertainty involved in the supplier selection process. Some of the AI models are:

Artificial Neural Network

The ANN model saves money and time. The weakness of this model is that it demands specialized software and requires qualified personnel who are expert.

Case-Based-Reasoning (CBR) Systems

CBR systems fall in the category of the so-called artificial intelligence (AI) approach. Basically, a CBR system is a software-driven database which provides a decision-maker with useful information and experiences from similar, previous decision situations. CBR is still very new and only few systems have been developed for purchasing decisionmaking.

2.3.4 Multivariate statistical analysis

There are various methods which are considered under these categories such as structural equation modeling, factor analysis, cluster analysis etc.

Cluster analysis (CA)

CA is a basic method from statistics which uses a classification algorithm to group a number of items which are described by a set of numerical attribute scores into a number of clusters such that the differences between items within a cluster are minimal and the differences between items from different clusters are maximal. Obviously, CA can also be applied to a group of suppliers that are described by scores on some criteria. The result is a classification of suppliers in clusters of comparable suppliers (Bhutta, 2003).

Fuzzy logic approach

In this method, linguistic values are used to assess the ratings and weights for various factors. These 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 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.

Table 2: Technique and its proponents (Bhutta, 2003)

Technique	**Proponents**	**Methodology**	**Applications**
Analytic hierarchy process(AHP)	Saaty, Belton, Dyer, Bard, Bhutta, Nydick, Hill	AHP provides a framework to cope with multiple criteria situations involving intuitive, rational, qualitative and quantitative aspects.	Prioritizing Alternatives
Unit Total Cost	Harding, Porter, Monckza.	Unit Total Cost is the total cost to the purchaser per unit after inclusion of all relevant factors	Cost of product is less significant than other costs
Total Cost of Ownership (TCO)	Ellram, Cart, Cavinto, Porter,	TCO is a methodology and philosophy, which looks beyond the price of a	Cost of product is less

	Bhutta	purchase to include many other purchase-related costs. This approach has become increasingly important as organizations look for ways to better understand and manage their costs	significant than other costs
ABC costing Approach	Tyndall, Morris, Kaplan	Categorizing costs into ABC categories and then making a selection based on the criteria selected	When cost categories of parts is critical
Life Cycle Costing Approach	Jackson, Ostrom, Handfield, Pannesi	Looks at the cost of the product over its whole life	When periodic maintenance or replacement is needed and costs are high
Multi-Objective Programming	Weber, Ellram	The use of a multi-objective programming approach is generally used in the just-in-time scenarios. The analysis occurs in a decision support system environment	Where multiple conflicting criteria have to be considered in a JIT environment.
Multi-Attribute Utility Theory (MAUT)	Weber, Nitszch	Use of MAUT, can help purchasing professionals to formulate viable sourcing strategies, as it is capable of handling multiple conflicting attributes inherent in international supplier selection	In situations of International supplier selection, where the environment is more complicated and risky.
Dynamic Programming	Masella, Rangone	By setting Input Variables as Control & Environmental variables, State Variables as the internal workings of the organization, and the Output variables as the performance achieved by the organization based on the selection of suppliers made.	Where output is a measured quantity And discretization of variables can be achieved
Data Envelopment Analysis (DEA)	Weber, Kleinsouza, Clarke, Kent	DEA is an optimization method of mathematical programming used to generalize single-input/ single-output technical efficiency measure to the multiple-input/ multiple-output case by constructing a relative efficiency score	Where there are multiple inputs and outputs that make comparisons difficult

		as the ratio of a single virtual output to a single virtual input.	

CHAPTER 3: FUZZY SET THEORY AND FUZZY AHP AND FUZZY TOPSIS METHOD

3.1 Fuzzy Set- theory

To deal with vagueness in human thought, Lotfi A. Zadeh(1965) first introduced the fuzzy set theory, which 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. 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.

3.2 Definitions of Fuzzy Sets

Definition1. A fuzzy set A in a universe of discourse X is characterized by a membership function μA(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

$$\mu A\ (\lambda x_1 + (1-\lambda)x_2) \geq \min\ (\mu A(x1), \mu A(x2))$$

For all x_1, x_2 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).

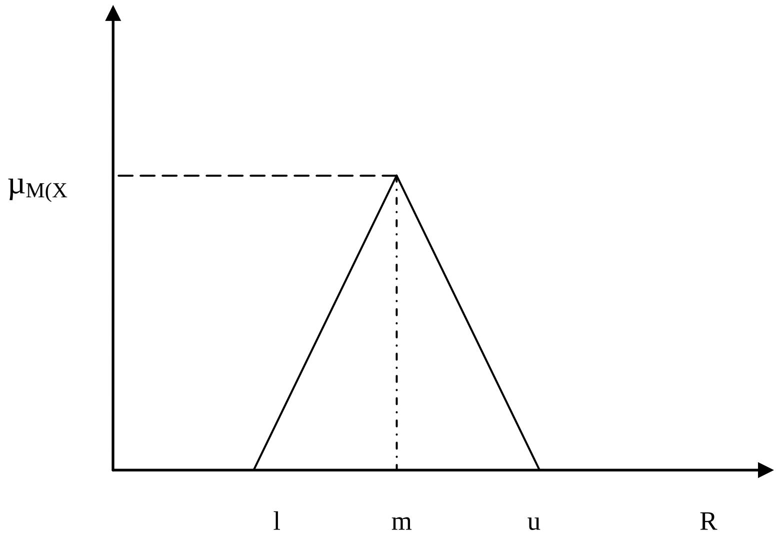

Figure 1: Membership function of a TFN (Zadeh, Lotfi A, 1965)

3.3 Definitions of fuzzy numbers

Definition1. A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal. Fig. shows a fuzzy number ñ in the universe of discourse X that conforms to this definition (Kaufmann and Gupta, 1991).

Fuzzy set theory is a mathematical theory given by Zadeh. The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set, ranging between 0 and 1. A triangular fuzzy number (TFN) is defined by a triplet (l, m, n). The membership function of this fuzzy number $\mu_{\tilde{A}}$ (X): R → [0, 1] given in equation 1.

$$\mu\tilde{A}(X) = \begin{cases} 0 & x < 1 \\ \frac{x-1}{m-1} & 1 \leq x \leq m \\ \frac{x-n}{m-n} & m \leq x \leq n \\ 0 & x > n \end{cases} \quad (1)$$

Let Ã= $(l_1, m_{1,} n_1)$ and $\tilde{B}$ = (l_2, m_2, n_2) are two TFNs then the operational laws of these TFNs are shown in table. Assuming that Ã= $(l_1, m_{1,} n_1)$ and $\tilde{B}$ = (l_2, m_2, n_2) are real numbers then the distance between Ã and $\tilde{B}$ is equal to the Euclidean distance given by the vertex method as in Eq. 2.

$$D(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(l1 - l2)2 + (m1 - m2)2 + (n1 - n2)2]} \quad (2)$$

Table 3: Fuzzy operational laws

Operational laws	Description
Addition	$\tilde{A}+\tilde{B}$ = (l_1,m_1,n_1) +(l_2,m_2,n_2) = $(l_1+l_2 ,m_1+m , n_1+n_2)$
Subtraction	$\tilde{A}-\tilde{B}$ = (l_1,m_1,n_1) - (l_2,m_2,n_2) = $(l_1-n_2 , m_1-m_2 , n_1-l_2)$
Multiplication	$\tilde{A}\times \tilde{B}$ = $(l_1,m_1,n_1)\times (l_2,m_2,n_2)$ = $(l_1\times l_2 ,m_1\times m_2, n_1\times n_2)$
Division	$\tilde{A} / \tilde{B}$ =$(l_1,m_1,n_1) /(l_2,m_2,n_2)$ = $(l_1/n_2, m_1/ m_2,n_1/ l_2)$
Inverse	$(\tilde{A})^{-1}$ = $(l_1,m_1,n_1)^{-1}$ = $(1/l_1, 1/m_1, 1/n_1)$

3.4 Fuzzy AHP

Fuzzy Analytic Hierarchy Process (F-AHP) embeds the fuzzy theory to basic Analytic Hierarchy Process (AHP), which was developed by Saaty. AHP is a widely used decision making tool in various multi-criteria decision making problems. It takes the pair-wise comparisons 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.

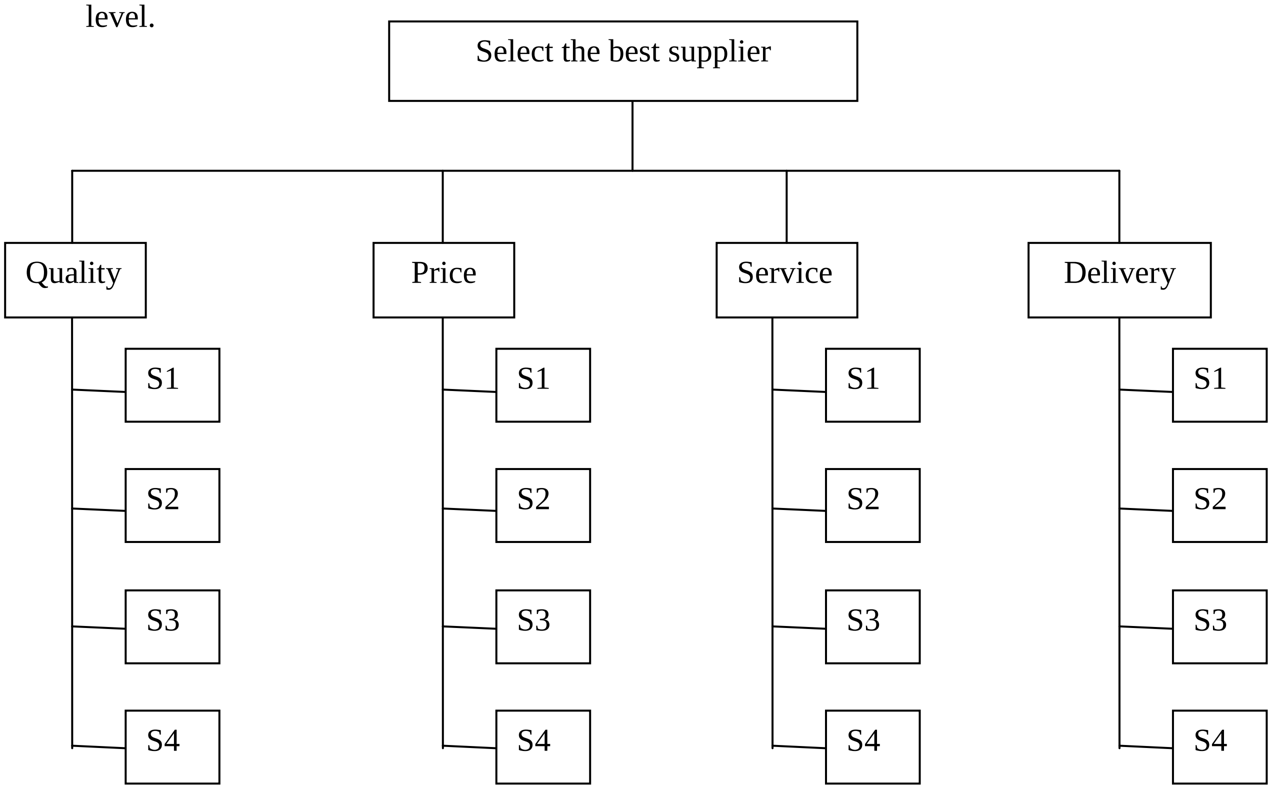

Figure 2: Hierarchy of AHP example

Benefiting from fuzzy logic approach. in F-AHP, the pair wise comparisons of both criteria and the alternatives are performed through the linguistic variables, which are represented by triangular numbers. One of the first fuzzy AHP applications was performed by van Laarhoven and Pedrycz. They defined the triangular membership functions for the pair wise comparisons. Afterwards, Buckley has contributed to the subject by determining the fuzzy priorities of comparison ratios having triangular membership functions. Chang also introduced a new method related with the usage of triangular numbers in pair-wise comparisons. Although there are some more techniques embedded in F-AHP, within the scope of this study, Buckleys methods is implemented to determine the relative importance weights for both the criteria and the alternatives.

3.4.1 The procedure for determining the evaluation criteria weights by FAHP can be summarized in the following steps

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

Step-II 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.

$$C = \begin{bmatrix} c_{11} & \cdots & c_{1N} \\ \vdots & \ddots & \vdots \\ c_{N1} & \cdots & c_{NN} \end{bmatrix}, \; c_{ii} = 1, c_{ij} = \frac{1}{c_{ij}}, \; c_{ij} \neq 0 \qquad (3)$$

Linguistic terms are applied to the pair wise comparisons

$$\tilde{c} = \begin{bmatrix} \widetilde{c_{11}} & \cdots & \widetilde{c_{1N}} \\ \vdots & \ddots & \vdots \\ \widetilde{c_{N1}} & \cdots & \widetilde{c_{NN}} \end{bmatrix}, \; \tilde{c}_{ii} = 1, \; \tilde{c}_{ji} = \frac{1}{\tilde{c}_{ji}}, \; \tilde{c}_{ji} \neq 0 \qquad (4)$$

Step-III The geometric mean method is used for fuzzy weights evaluation. The fuzzy geometric mean and fuzzy weights of each criterion is calculated by using Eq. 5; the fuzzy weight of the i^{th} attribute, indicated by a triangular fuzzy number, is given by Eq. 6.

$$\tilde{r}_1 = [\tilde{c}_{i1} \times \tilde{c}_{i2} \times \ldots\ldots\ldots \times \tilde{c}_{iN}]^{1/N} \qquad (5)$$

$$\widetilde{W}_i = \tilde{r}_1 \times [\tilde{r}_1 + \tilde{r}_1 + \ldots\ldots\ldots + \tilde{r}_N]^{-1} \qquad (6)$$

3.5 The FTOPSIS method for ranking of alternatives

The TOPSIS (technique for order preference by similarity to ideal solution) has wide applicability and is used for tackling ranking problems due to its simplicity. TOPSIS was developed by Hwang and Yoon. Due to the presence of ambiguous and vague issues in the performance evaluation of friction composite materials, FTOPSIS is employed for performance evaluation which use linguistic values rather than numerical values, which means that the rankings in the performance evaluation are evaluated by linguistic variables. Linguistic value can deal with ambiguities, uncertainties and vagueness.

The FTOPSIS consist of the following steps:

Step I: A decision matrix is created after identifying the performance defining criterion and alternatives of the problem. If the number of alternatives is M and the number of performance defining criterion are N then the decision matrix having an order of M × N is represented according to Eq. 7.

$$D_M \times_N = \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \vdots & \ddots & \vdots \\ a_{M1} & \cdots & a_{MN} \end{bmatrix} \qquad (7)$$

where an element a_{ij} of the decision matrix DM×N represents the actual value of the i^{th} alternative in term of j^{th} attribute.

Step II: In order to transform the performance values to fuzzy linguistic variables, the decision matrix is converted to a normalized decision matrix (a_{ij}) by converting the performance values of the decision matrix into a range of [0, 1]. The normalized values of each element in the normalized decision matrix can be calculated by using Eq. 8.

$$r_{ij} = \frac{a_{ij-\min\{a_{ij}\}}}{\max\{a_{ij}\} - \min\{a_{ij}\}}, \text{ for benefit criteria, and}$$

$$r_{ij} = \frac{\max\{a_{ij}\} - a_{ij}}{\max\{a_{ij}\} - \min\{a_{ij}\}}, \text{ for the cost criteria} \qquad (8)$$

Step III: The linguistic values ($\widetilde{a_{ij}}$, i= 1, 2... M, j = 1, 2... N) are chosen for M alternatives with respect to N criteria. These fuzzy linguistic values preserve the properties that the range of fuzzy numbers belongs to [0, 1].

Step IV: A weighted normalized fuzzy decision matrix is calculated by using Eq. 9.

$$\tilde{V}_{ij} = \tilde{a}_{ij} \times \tilde{W}_i \tag{9}$$

Step V: A determination of fuzzy positive ideal solution (FPIS, $\tilde{A}^+$)
and a fuzzy negative ideal solution(FNIS, $\tilde{A}^-$) are made by using Eq. 10 and 11.

$$\tilde{A}^+ = (\tilde{V}_1^{\ +}, \tilde{V}_2^{\ +}, \ldots\ldots\ldots\ldots..\tilde{V}_N^{\ +}),$$

$$\text{and } \tilde{A}^- = (\tilde{V}_1^{\ -}, \tilde{V}_2^{\ -}, \ldots\ldots\ldots\ldots..\tilde{V}_N^{\ -}) \tag{10}$$

where

$$\tilde{V}_j^{\ +} = \begin{Bmatrix} (max\ i\ \tilde{V}_{ij})\text{if j is benefits criteria} \\ (min\ i\ \tilde{V}_{ij})\text{if j is cost criteria} \end{Bmatrix}, \text{ and}$$

$$\tilde{V}_j^{\ -} = \begin{Bmatrix} (min\ i\ \tilde{V}_{ij})\text{if j is benefits criteria} \\ (max\ i\ \tilde{V}_{ij})\text{if j is cost criteria} \end{Bmatrix}, \text{ for j =1,2……N} \tag{11}$$

Step VI: The Euclidian distances between each of the alternatives and the fuzzy positive ideal solution and the fuzzy negative ideal solution are calculated by using Eq. 12.

$$\tilde{D}_i^{\ +} = \sqrt{\textstyle\sum_{j=1}^{N} D(\tilde{V}_i^{\ +} - \tilde{V}_{ij})^2} \text{ ,and}$$

$$\tilde{D}_i^{\ -} = \sqrt{\textstyle\sum_{j=1}^{N} D(\tilde{V}_i^{\ +} - \tilde{V}_{ij})^2} \text{ , for i=1,2,3…………..M} \tag{12}$$

Step VII: Finally, the overall preference or fuzzy closeness index ($\check{C}, \check{I}_i$) of the alternatives is calculated with the help of Eq. 13.

$$\tilde{C}\tilde{I}_i = \frac{\tilde{D}_i^{\ +}}{\tilde{D}_i^{\ +} + \tilde{D}_i^{\ -}} \text{ , for i=1,2,3………..M} \tag{13}$$

CHAPTER 4: CASE STUDY

4.1 Introduction of the Company

- NBC Bearings is the premier brand of India’s leading bearings manufacturer and Exporter Company, founded in 1946 by the great industrialist late "“Shri B.M.Birla”.
- With increasing activities and grant of industrial licenses for other vital industries and manufacturing, the name of the company was changed in1958 to “National Engineering Industries Ltd” retaining its original trade mark NBC.
- NBC produces over 100 million bearings each year in more than 1000sizes to serve a host of varied customers across India and 21 other countries in 5 continents.
- It has the capacity to develop bearings from 10 mm bore to 2000 mm outer diameter. The product range includes ball bearings, tapered roller bearings and double row angular contact (DRAC) bearings, cylindrical and spherical roller bearings.
- The present procedure is applicable to the following category of supplier
  - Raw material (tubes , bars, wires ,forged rings)
  - Semi finish product
  - Product packing material

4.2 Current supplier selection method

The present procedure of the supplier selection in NBC Company is based on the quality rating and service rating factor but there are more than two factors important like product price, information system, location etc. Therefore in this thesis we consider the six factors such as product price, service rating, information system, location, products quality and delivery time. In this thesis, six criteria and eight potential suppliers are determined as a result of negotiations held with decision markers.

4.3 Supplier selection criteria description

There are a number of supplier selection criteria. In this thesis work six criteria are considered which are cost, product quality, location, price, information system and service rating. These six criteria are explained below.

4.3.1 Cost / price

Cost / price are an obvious consideration for any purchase, many researchers and mentioned cost as an important factor in selecting suppliers. In ordinary usage, price is the quantity of payment for something. In business, the cost may be one of acquisition, in which case the amount of money expended to acquire it is counted as cost. In this case, money is the input that is gone in order to acquire (Wikipedia, 2007). The cost/ price factor has been measured on the basis of the importance of the following cost/ price dimensions in the buying organizations supplier selection :total cost (evaluating a supplier is cost structure involves providing detailed cost data by the supplier), payment procedures understanding, offering the supplier to competitive pricing, quantity , discount (suitability of discount scheme implemented on payment of invoices within time frame) and payment terms (suitability of terms and conditions regarding payment of invoices, open accounts, sight drafts, credit letter and payment schedule) (HS Keska, 2004).

4.3.2 Quality

The supplier's quality systems and processes that maintain and improve quality and delivery performance are key factors. Selection criteria may consider the supplier's quality assurance and control procedures, complaint handling procedures, quality manuals, ISO 9000 standard registration status, and internal rating and reporting systems. Just as the role of price has reduced as a criterion in supplier selection in many sectors, so quality has become a more important factor. The supplier's capability to reduce his price in the future and to further optimize his quality potential comes into play as well. In addition, the understanding of the concept quality has been transformed. Quality no longer simply applies to the product itself but also applies to the service and other received aspects of the supplier-manufacturer relationship (HS Keskar, 2004).A good relationship is a prerequisite to good problem solving and co-operation in product modification. Supplier quality has been established as a primary concern in the supplier selection process for decades (De Boer et al., 1998). The quality factor was measured in terms of suppliers ability to provide inputs that are reliable and durable (measure of useful life of the product), possessing the supplier to quality system, adherence to quality tools, percent rejection and supplier reputation and position.

4.3.3 Service rating

Service rating is the flexibility in the implementing changes in delivery, design etc. Service rating is a very important factor in supplier selection criteria. Service rating includes following parameters:

- Cooperativeness and readiness to help in emergencies.
- Response on quality complaints including replacement of rejected materials.
- Flexibility in implementing changes in delivery, design etc.
- Promptness in reply.
- Compatibility to bill payment terms.

Service rating (SR) on overall basis is to be assigned by a committee consisting of representatives from purchase department and planning department. The final service rating for a given vendor will be the average of rating assigned by all members of the committee.

The service rating shall be once a year for a given vendor and shall be completed well before the tendering action for the next year's requirement, based on the experiment from the supplier for the previous year.

4.3.4 Delivery time

In general, time when actual delivery takes place. If a supplier submits the lowest price, it doesn't mean much to the firm if the vendor is also late two or three weeks on all contracts (De Boer and Der Wegan, 2003). The delivery factor has been measured on the basis of the importance of the following delivery dimensions in the buying firm is supplier selection process: ability and willingness to expedite an order, how quickly a supplier can deliver, the amount of time that it takes a supplier to deliver the supplies, upcoming delivery commitments, safety and security components during the transportation and modes of transportation facility.

4.3.5 Location of supplier

Location is also important criteria for supplier selection. If supplier locate near the organization then it is better for organization. Supplier location is also impact on supplier selection.

4.3.6 Information system

Supplier should be fully integrated with information and communication technology. Information is essential to making good supply chain decisions because it provides the broad view needed to make optimal decisions. Information is the factual component on which decisions about each of the other drivers are based. In essence, information is the glue that holds the entire supply chain together and allows it to function, making information the most important supply chain driver. Management must consider the depth to which an IT system deals with the firm's key success factors. There is a trade-off between the ease of implementing a system and the system's level of complexity. Therefore, it is important to consider just how much sophistication a company needs to achieve its goals and then ensure that the system chosen matches that level.

4.4 Solution of Supplier Selection Problem Using FUZZY AHP and FUZZY TOPSIS Method

In this section we follow the evaluation methodology which is describes in previous section. We select the eight supplier alternatives and six criteria which is shown in Table 4.

Table 4: Supplier Selection Criteria

S.No.	Criteria
1	Product Quality
2	Service Quality
3	Delivery Time
4	Price
5	Location
6	Information System

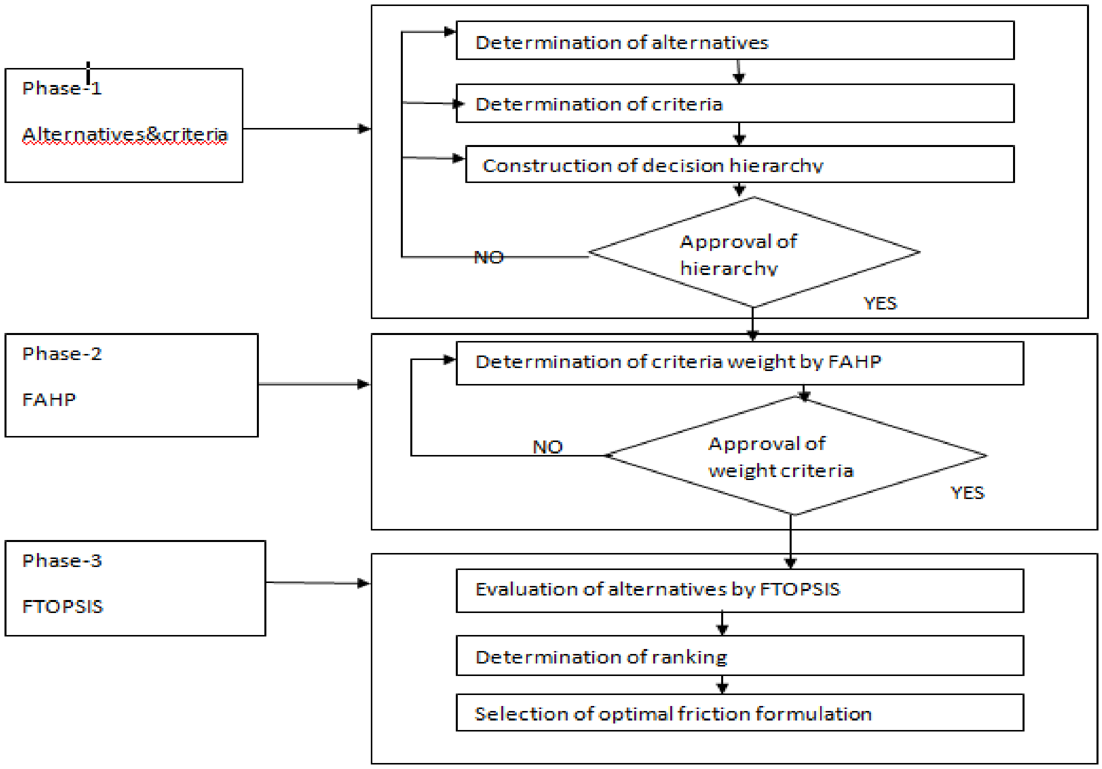

Figure 3: Evaluation methodology of supplier selection

We give the supplier alternative rating according to the supplier criteria in terms of linguistic values. The selection criteria of supplier and alternatives of supplier are transformed into linguistic variables which are given in following table 5. This table 5 gives the linguistic values in terms of fuzzy number.

Table 5: Linguistic values and fuzzy numbers (Kilincci, 2011)

Linguistic values	**Fuzzy numbers**
Very low (VL)	(0, 0.10, 0.25)
Low (L)	(0.15, 0.30, 0.45)
Medium (M)	(0.35,0.50,0.65)
High (H)	(0.55, 0.70, 0.85)
Very high (VH)	(0.75, 0.90, 1)

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 6.

Table 6: The fundamental relational scale for pair-wise comparisons (Singh, Tej, 2013)

Intensity of importance on an absolute scale	Definition	Explanation	Scale of FUZZY numbers
1	Equal importance	Two activities contribute equally to the objective	(1,1,1)
2	Weak importance	Experience and judgment slightly favour one activity over another	(1,2,3)
3	Moderate importance	Experience and judgment moderately favour one activity over another	(2,3,4)
4	Preferable	Experience and judgment strongly favour one activity over another	(3,4,5)
5	Essential or strong importance	Experience and judgment strongly favour one activity over another	(4,5,6)
6	Fairly good importance	Experience and judgment strongly favour one activity over another	(5,6,7)
7	Very strong importance	An activity is very strongly favored and its dominance is demonstrated in practice	(6,7,8)
8	Absolute	An activity is absolutely favored and its dominance is demonstrated in practice	(7,8,9)
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation	(8,9,10)

We use the above Table 6 in the pair wise comparison. From the survey in purchase department and brainstorming we made the comparison matrix. In the product quality row and service rating column value is 2 which means product quality is two times weighting than service rating. Similarly, in product quality row and delivery time column value is 3 means product quality is 3 time important than delivery time. All the criteria value corresponding other criteria is shown in Table 7.

Table 7: Pair-wise comparison matrix

	Product quality	Service rating	Delivery time	Price	location	Information system
Product quality	1	2	3	2	2	2
Service rating	0.5	1	2	1	3	3

Delivery time	0.333	0.5	1	3	2	2
Price	0.5	1	0.333	1	2	2
Location	0.5	0.333	0.5	0.5	1	0.5
Information system	0.5	0.333	0.5	0.5	2	1

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 software CGI .CGI software gives the following results:

Max. Eigen value =6.46843

C.I. = 0.0936856

Weights (Eigen vector)

Product quality = 0.291707

Service rating = 0.213817

Delivery time = 0.178594

Product Price = 0.140721

Supplier Location = 0.0778034

Information system = 0.0973571

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

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

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.

After making the pair wise comparison matrix we convert this matrix in terms of fuzzy number by the use of Table no. 6. The every element of the pair wise matrix is convert in fuzzy number which is shown in Table 8.

Table 8: Pair-wise comparison matrix in terms of fuzzy numbers

	Product quality	**Service rating**	**Delivery time**	**Price**	**location**	**Information system**
Product quality	(1,1,1)	(1,2,3)	(2,3,4)	(1,2,3)	(1,2,3)	(1,2,3)
Service rating	(0.333,0.5,1)	(1,1,1)	(1,2,3)	(1,1,1)	(2,3,4)	(2,3,4)
Delivery time	(0.25,0.333,0.5)	(0.333,0.5,1)	(1,1,1)	(2,3,4)	(1,2,3)	(1,2,3)
Price	(0.333,0.5,1)	(1,1,1)	(0.25,0.333,0.5)	(1,1,1)	(1,2,3)	(1,2,3)
Location	(0.333,0.5,1)	(0.25,0.333,0.5)	(0.333,0.5,1)	(0.333,0.5,1)	(1,1,1)	(0.333,0.5,1)
Information system	(0.333,0.5,1)	(0.25,0.333,0.5)	(0.333,0.5,1)	(0.333,0.5,1)	(1,2,3)	(1,1,1)

After the converting the pair wise comparison matrix in fuzzy number terms we calculate the individual weight of each criteria or attribute. The fuzzy weight criteria are given in Table 9. In this result we multiply the first fuzzy number in each row and then give the power 1/6. Further use this process for second fuzzy numbers in first row and similarly for third numbers ($l_{1,}$ $m_{1,}$ n_1). We use similar calculation for every row. Then sum the all rows first fuzzy numbers, second fuzzy numbers and third fuzzy numbers ($l_{2,}$ $m_{2,}$ n_2). Then we use the formula for individual row as [($l_{1/}$ n_2),($m_{1/}$ m_2),($n_{1/}$ l_2)].finally we get the individual criteria weight in fuzzy terms which is shown in below Table 9.

Table 9: Result of comparison matrix by using FAHP

Attribute	Fuzzy weight criteria
Product quality	(0.11948,0.289230,0.59374)
Service quality	(0.1116968,0.218819,0.43200)
Delivery time	(0.07899,0.17032,0.3668)
Price	(0.07035,0.1417927,0.29115)
Location	(0.04060,0.07957,0.20187)
Information system	(0.048772,0.100273,0.24245)

After weighting the criteria we collect the linguistic scale value for supplier alternatives from purchase department of NBC Company for each criterion. The linguistic values are consists of five values such as very low (VL), low (V), medium (M), high (H), very high (VH). The Table 10 shows the linguistic fuzzy evaluation matrix for the supplier alternatives.

Table 10: The linguistic fuzzy evaluation matrix for the ranking of alternatives

	Product quality	Service rating	Delivery time	Price	Location	Information system
VINAYAK	VH	VH	H	H	H	M
CHANDRA	M	VH	M	VH	VH	H

WIRE RINGS	M	VH	VH	M	M	VH
ADITYA	VH	H	M	VL	H	H
TASHI	M	M	L	M	M	VH
HARSHA	VH	VH	M	M	H	H
MANU	VH	M	L	L	M	M
AGARSEN	VL	M	H	M	H	M

The linguistic fuzzy evaluation matrix is create by decision maker and purchase department. According to the scale we convert this linguistic value into the fuzzy number by the use of scale Table 5. This Table 5 is follows by most of the journals which is related to linguistic values and fuzzy number. So we also follow this fundamental Table 5. We convert the linguistic values as VL = (0,0.10,0.25), L = (0.15,0.30,0.45), M = (0.35,0.50,0.65), H = (0.55,0.70,0.85) and VH = (0.75,0.90,1).

Table 11: The linguistic fuzzy evaluation matrix for the ranking of alternatives in terms of fuzzy number

	Product quality	**Service rating**	**Delivery time**	**Price**	**Location**	**Information system**
VINAYAK	(0.75,0.90,1)	(0.75,0.90,1)	(0.55,0.70,0.85)	(0.55,0.70,0.85)	(0.55,0.70,0.85)	(0.35,0.50,0.65)
CHANDRA	(0.35,0.50,0.65)	(0.75,0.90,1)	(0.35,0.50,0.65)	(0.75,0.90,1)	(0.75,0.90,1)	(0.55,0.70,0.85)

WIRE RINGS	(0.35,0.50,0.65)	(0.75,0.90,1)	(0.75,0.90,1)	(0.35,0.50,0.65)	(0.35,0.50,0.65)	(0.75,0.90,1)
ADITYA	(0.75,0.90,1)	(0.55,0.70,0.85)	(0.35,0.50,0.65)	(0,0.10,0.25)	(0.55,0.70,0.85)	(0.55,0.70,0.85)
TASHI	(0.35,0.50,0.65)	(0.35,0.50,0.65)	(0.15,0.30,0.45)	(0.35,0.50,0.65)	(0.35,0.50,0.65)	(0.75,0.90,1)
HARSHA	(0.75,0.90,1)	(0.75,0.90,1)	(0.35,0.50,0.65)	(0.35,0.50,0.65)	(0.55,0.70,0.85)	(0.55,0.70,0.85)
MAV	(0.75,0.90,1)	(0.35,0.50,0.65)	(0.15,0.30,0.45)	(0.15,0.30,0.45)	(0.35,0.50,0.65)	(0.35,0.50,0.65)
AGARSEN	(0,0.10,0.25)	(0.35,0.50,0.65)	(0.55,0.70,0.85)	(0.35,0.50,0.65)	(0.55,0.70,0.85)	(0.35,0.50,0.65)
Weight criteria	(0.1194,0.2892,0.5937)	(0.1116,0.2188,0.4320)	(0.0789,0.1703,0.3668)	(0.0703,0.1417,0.29115)	(0.0406,0.0795,0.20187)	(0.0487,0.1002,0.2424)

Table 12: The fuzzy weighted evaluation matrix

	Product quality	**Service rating**	**Delivery time**	**Price**	**Location**	**Information system**
VINAYAK	(0.089,0.260,0.593)	(0.083,0.196,0.432)	(0.043,0.119,0.311)	(0.038,0.099,0.247)	(0.022,0.055,0.171)	(0.017,0.050,0.157)

CHANDRA	(0.418,0.144,0.385)	(0.083,0.196,0.432)	(0.027,0.085,0.238)	(0.052,0.127,0.291)	(0.030,0.071,0.210)	(0.026,0.070,0.206)
WIRE RINGS	(0.418,0.144,0.385)	(0.083,0.196,0.432)	(0.059,0.153,0.366)	(0.024,0.070,0.189)	(0.014,0.039,0.131)	(0.036,0.090,0.242)
ADITYA	(0.089,0.260,0.593)	(0.061,0.153,0.367)	(0.027,0.085,0.238)	(0,0.014,0.072)	(0.022,0.055,0.171)	(0.026,0.070,0.206)
TASHI	(0.418,0.144,0.385)	(0.039,0.109,0.280)	(0.011,0.051,0.165)	(0.024,0.070,0.189)	(0.014,0.039,0.131)	(0.036,0.090,0.242)
HARSHA	(0.089,0.260,0.593)	(0.083,0.196,0.432)	(0.027,0.085,0.238)	(0.024,0.070,0.189)	(0.022,0.055,0.171)	(0.026,0.070,0.206)
MANU	(0.089,0.260,0.593)	(0.039,0.109,0.280)	(0.011,0.051,0.165)	(0.010,0.0425,0.131)	(0.014,0.039,0.131)	(0.017,0.050,0.157)
AGARSEN	(0,0.028,0.148)	(0.039,0.109,0.280)	(0.043,0.119,0.311)	(0.024,0.070,0.189)	(0.022,0.055,0.171)	(0.017,0.050,0.157)

In the Table 12 we get fuzzy weighted evaluation matrix. From the help of Table 9, we multiplying weighted criteria in each row corresponding to criteria. For example supplier alternative VINAYAK the product quality weighting criteria is (0.1194, 0.2892, 0.5937) and vinayak product quality value in terms of fuzzy is (0.75, 0.90, 1) then the value of fuzzy weighted evaluation matrix for vinayak is calculated as [(0.75× 0.1194), (0.90×0.2892), (1×.05937)]. The value for vinayak is [0.089, 0.260, 0.593]. Similar calculation is done for other supplier alternatives and we get the above fuzzy weighted evaluation matrix Table 12.

The fuzzy positive ideal and fuzzy negative ideal solution for given criteria is shown in following Table 13.

Table 13: Fuzzy positive ideal solution and fuzzy negative ideal solution

	Product quality	**Service rating**	**Delivery time**	**Price**	**Location**	**Information system**
$\tilde{A}^{+}$	$\tilde{V}_1^{+}$=(1,1,1)	$\tilde{V}_2^{+}$=(1,1,1)	$\tilde{V}_3^{+}$=(0,0,0)	$\tilde{V}_4^{+}$=(0,0,0)	$\tilde{V}_5^{+}$=(0,0,0)	$\tilde{V}_6^{+}$=(1,1,1)
$\tilde{A}^{-}$	$\tilde{V}_1^{-}$=(0,0,0)	$\tilde{V}_2^{-}$=(0,0,0)	$\tilde{V}_3^{-}$=(1,1,1)	$\tilde{V}_4^{-}$=(1,1,1)	$\tilde{V}_5^{-}$=(1,1,1)	$\tilde{V}_6^{-}$=(0,0,0)

In the Table 12 the given element is normalized to TFN and their ranges are close to interval [0,1]. We consider fuzzy positive ideal solution as $\tilde{V}_j^{+}$=(1,1,1) and $\tilde{V}_j^{-}$=(0,0,0) for benefit criteria and fuzzy negative ideal solution as $\tilde{V}_j^{+}$=(1,1,1) and $\tilde{V}_j^{-}$=(0,0,0) for cost criteria according to eq. 10 and 11. The fuzzy positive ideal solution and fuzzy negative ideal solution is calculated from equation 10 and 11. Then the distance between each alternative from $\widetilde{D}_i^{+}$ *and* $\widetilde{D}_i^{-}$ is calculated from equation 12 given in chapter 3. $\widetilde{C}\widetilde{I}_i$ is the closeness index which is calculated from equation 13. The value of closeness index is given in following Table 14.

Table 14: Fuzzy closeness index and ranking of supplier alternatives

Supplier	$\widetilde{D}_i^{+}$	$\widetilde{D}_i^{-}$	$\widetilde{C}\widetilde{I}_i$	Ranking
VINAYAK	5.065	1.202	0.808	2

CHANDRA	5.005	1.203	0.806	3
WIRE RINGS	4.856	1.372	0.779	6
ADITYA	5.024	1.028	0.830	1
TASHI	5.024	1.261	0.799	4
HARSHA	5.110	1.418	0.782	5
MANU	5.313	1.905	0.736	8
AGARSEN	5.212	1.770	0.746	7

The fuzzy closeness index of the supplier alternatives is calculated which is shown in the above Table14. According to the closeness index the ranking of supplier alternatives in descending order is ADITYA, VINAYAK, CHANDRA, TASHI, HARSHA, WIRE RINGS, AGARSEN and MANU.

The final result of supplier selection alternatives are shown in Table 14 which shows the final ranking for suppliers alternatives, which is based on closeness index. The supplier ADITYA is selected as the best one for the NBC Company.

CHAPTER 5: CONCLUSION

Supplier selection is an important task in the whole purchasing process. It has a great impact over the expenditure and organization objective. Generally, there are many suppliers for single items with varying capabilities. Organization generally faces a problem of selection of a supplier for an item fulfilling the organizational objectives. This requires a systematic approach. The literature related to this is reviewed in this dissertation which falls into two categories: the criteria to be used and the methodology for the ranking of the suppliers based on the company requirements and the supplier capabilities. The most important criteria include price, quality, service rating, delivery time, location and information system. A large variety of MADM techniques have been used for the supplier selection problem such as AHP, TCO, DEA, TOPSIS etc.

A case study is presented in this dissertation in which a private sector company, NBC, is considered as the case company. Existing supplier selection process in the company is first reviewed and the weaknesses are identified. In order to overcome these weaknesses a supplier selection process is proposed. Four factors which have not been used by the company earlier are suggested for use. In this research work we have used fuzzy AHP for the weighting the selection criteria and fuzzy TOPSIS method for the ranking of supplier alternatives. Supplier selection is a broad comparison of suppliers using a common set of criteria and measures to identify suppliers with the highest potential for meeting a firm's needs consistently and at an acceptable cost. Selecting the right suppliers significantly reduces the purchasing costs and improves corporate competitiveness therefore supplier selection one of the most important decision making problems.

The initial response of the company executives is very good for the new process and it is hoped that company will be benefited to a great extent by the new supplier selection process.

REFERENCES

Bello, M. J. S. (2003). A case study approach to the supplier selection process (Doctoral dissertation, UNIVERSITY OF PUERTO RICO MAYAGÜEZ CAMPUS).

Dodgson, J., Spackman, M., Pearman, A., & Phillips, L. (2001). DTLR multi-criteria analysis manual. UK: National Economic Research Associates.

Winn, M. I., & Keller, L. R. (2001). A modeling methodology for multiobjective multistakeholder decisions. Journal of Management Enquiry, 10(2), 166-181.

Malczewski, J. (2000). Book Selection-GIS and Multicriteria Decision Analysis.Journal of the Operational Research Society, 51(2), 247-247.

Sonmez, M. (2006). Review and critique of supplier selection process and practices. © Loughborough University.

Keskar, H. S. (2004). Supplier Selection Metrics and Methodology (Doctoral dissertation, University of Cincinnati).

De Boer, L., van der Wegen, L., & Telgen, J. (1998). Outranking methods in support of supplier selection. European Journal of Purchasing & Supply Management, 4(2), 109-118.

De Boer, L., & Van der Wegen, L. L. M. (2003). Practice and promise of formal supplier selection: a study of four empirical cases. Journal of Purchasing and Supply Management, 9(3), 109-118.

Nydick, R. L., & Hill, R. P. (1992). TJsing the Analytic Hierarchy Process to Structure the Supplier Selection Procedure.

Rezaei, J., Fahim, P. B., & Tavasszy, L. (2014). Supplier selection in the airline retail industry using a funnel methodology: conjunctive screening method and fuzzy AHP. Expert Systems with Applications, 41(18), 8165-8179.

Weber, C. A., Current, J. R., & Benton, W. C. (1991). Vendor selection criteria and methods. European journal of operational research, 50(1), 2-18.

Ellram, L. M. (1995). Total cost of ownership: an analysis approach for purchasing. *International Journal of Physical Distribution & Logistics Management*, *25*(8), 4-23.

Bhutta, M. K. S. (2003). Supplier selection problem: methodology literature review. *Journal of International Information Management*, *12*(2), 5.

Amid, A., Ghodsypour, S. H., & O'Brien, C. (2006). Fuzzy multiobjective linear model for supplier selection in a supply chain. *International Journal of Production Economics*, *104*(2), 394-407.

Zadeh, L. A. (1965). Fuzzy sets. *Information and control, 8*(3), 338-353.

Zadeh, Lotfi A. "The concept of a linguistic variable and its application to approximate reasoning—I." *Information sciences* 8.3 (1975): 199-249.

Buckley, R. C. (1985). Distinguishing the effects of area and habitat type on island plant species richness by separating floristic elements and substrate types and controlling for island isolation. *Journal of Biogeography*, 527-535.

Kaufmann, A., & Gupta, M. M. (1991). *Introduction to fuzzy arithmetic: theory and applications*. Arden Shakespeare.

SINGH, T., PATNAIK, A., SATAPATHY, B., & TOMAR, B. (2013). Development and optimization of hybrid friction materials consisting of nanoclay and carbon nanotubes by using analytical hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) under fuzzy atmosphere. *Walailak Journal of Science and Technology (WJST),10*(4), 343-362.

Yuan, Y., & Shaw, M. J. (1995). Induction of fuzzy decision trees. *Fuzzy Sets and systems*, *69*(2), 125-139.

Kilincci, O., & Onal, S. A. (2011). Fuzzy AHP approach for supplier selection in a washing machine company. *Expert systems with Applications*, *38*(8), 9656-9664.

Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. European Journal of Operational Research, 202(1), 16-24.

Taji, K., & Matsumoto, K. (2006). Inverse Sensitive Analysis of Pairwise Comparison Matrices. Journal of the Operations Research Society of Japan,49(4), 332.

Kahraman, C., Cebeci, U., & Ulukan, Z. (2003). Multi-criteria supplier selection using fuzzy AHP. Logistics Information Management, 16(6), 382-394.

Aissaoui, N., Haouari, M., & Hassini, E. (2007). Supplier selection and order lot sizing modeling: A review. Computers & operations research, 34(12), 3516-3540.

Chai, J., Liu, J. N., & Ngai, E. W. (2013). Application of decision-making techniques in supplier selection: A systematic review of literature. Expert Systems with Applications, 40(10), 3872-3885.

PLAGIARISM DETECTION CHART

Originality report details:	
Generation Time and Date:	6/24/2015 9:39:07 AM
Document Name:	Thesis_ Ramesh-2013PIE5049.doc
Document Location:	C:\Users\ Ramesh_K\Desktop\Thesis_Ramesh-2013PIE5049.doc
Document Words Count:	18011
Check time [hs:ms:ss]:	00:07:40