Prediction of future demand and selection of supplier considering multiple criteria for a raw material-A Case Study.

by

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CERTIFICATE OF APPROVAL

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I hereby certify that the research work presented in this thesis has been completely performed by me and this work or any part of it has not been submitted elsewhere for any other purposes except for publication.

31st March 2018

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DEDICATION

This thesis is dedicated to my parents and my honorable teachers. Their uninterrupted inspiration, support, guidance made this effort possible.

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ABSTRACT

RMG sector is the single most important manufacturing industry in Bangladesh. Most of the raw materials in this sector are being imported from abroad. Hence, incoming material management is of paramount importance for effective and efficient management of the supply chain in this sector. Demand forecasting and supplier selection are two major components of incoming material management.Efficient demand forecasting plays a vital role to make the supply chain effective and successful and an analytical way to reach the best decision is more preferable in many business platforms.This work focuses on to develop a forecasting model based on Artificial Neural Networking (ANN) to predict the future demand of a raw material in RMG factory. A particular raw material, which is widely used, is taken into consideration to implement this technique. Fuzzy Analytic Hierarchy Process (FAHP) technique will be implemented to find out suitable supplier of this raw material considering multiple criteria like quality, cost, lead-time, reputation, capacity etc. This will help the RMG sector to improve their supply chain efficiency.

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LIST OF ABBREVIATIONS

ANN	: Artificial Neural Networking
FAHP	: Fuzzy Analytical Hierarchy Process
TFN	: Triangular Fuzzy Numbers
RMG	: Ready-made Garments
PE	: Processing Elements
NNs	: Neural Networks
SS	: Spring-Summer
AW	: Autumn-Winter
MSE	: Mean Square Error
MAD	: Mean Absolute Deviation
MAPE	: Mean Absolute Percentage Error
AHP	: Analytical Hierarchy Process
KG	: Kilogram
SU	: Supplier
PT	: Payment Term
TT	: Telegraphic Transfer
LC	: Letter of Credit
FOB	: Free on Board
GSM	: Gram Per Square Metter
A	: Supplier A
B	: Supplier B
C	: Supplier C
∆	: Selection symbol

CHAPTER 1

INTRODUCTION

1.1 Background and Present Status of The Problem

Ready-made Garments (RMG) industry is the major export-base for Bangladesh. It has considerable impact on national economy, as well as high of degree of social implications, as a large number of female workers are employed in this labor-intensive industry. In the current post MFA era, international competition in this sector has been increased a lot. Therefore, garments companies in Bangladesh need to become more competitive and efficient to survive, to retain market position and increase market base. The foreign competitors have upper-hand basically in three areas: stronger backward linkage, more skilled manpower, and better methodology of manufacturing. Among these three, backward linkage is the most important factor as almost most of the raw materials needed in this sector are being imported from different countries. Proper management of supply chain is of outmost importance for smooth operations of the manufacturing processes in this sector that can help in maintaining the delivery schedule [1].Efficient demand forecasting is very important to make the supply chain effective and successful. Jaouadi et, al, showed that the artificial neural network (ANN) model has the best results for predicting the demand of sewing thread consumption with a reliability of 95 percent and average Root mean square error (RMSE) [2]. Anandi et, al, used ANN to forecast the demand of pulp wood which is most common raw material for paper making [3].Fradinata et, al, presented ANN as one of the methods to obtain more accurate prediction of demand of cement in Indonesia Region.They concluded that this method had a high accuracy based on their MSE and the predicted data. After demand prediction, the next step is to select one or more supplier to minimize cost and to fulfill the demand. The supplier selection exercise is a critical factor towards the success of a company [4]. Khan et, al, considered the Fuzzy AHP method to maximize the manufacturer's profit by determining the most suitable suppliers based on the selection criteria like cost, delivery reliability, quality, supplier's profile, and service level [5]. Jain et, al, used Fuzzy-AHP approach to prioritize the criteria for supplier selection in the context of Indian[6].Nazeri et, al, proposed a systematic model to evaluate suppliers and used Triangular Fuzzy Number (TFN) to express linguistic values that consider the subjective judgments of evaluators and then applied fuzzy multiple criteria decision-making approach to synthesize the decision making [7].

This work focuses on to develop a forecasting model based on ANN to predict the future demand of a raw material in RMG factory. A particular raw material, which is widely used, is taken into consideration to implement this technique. Fuzzy AHP technique will be implemented to find out suitable supplier of this raw material considering multiple criteria like quality, cost, lead-time, reputation, capacity etc.

1.2 Objectives with Specific Aims and Possible Outcomes

The specific objectives of this study are:

- To predict the future demand of a raw material used in garment industry.
- To compare the result of ANN model & Holt's-Winter method.
- To select supplier by using Fuzzy AHP to optimize multiple criteria.

The possible outcomes of this study will be a model to predict future demand of a raw material in RMG industry and a supplier selection model that will optimize multiple criteria like quality, cost, lead-time, reputation, Capacity etc. This will help the RMG sector to improve their supply chain efficiency.

1.3 Scope of The Study

The general area has been included in the thesis encompasses the RMG sector. Particular emphasis has been on the specific garment supplier where particular raw material, which is widely used "Yarn" is taken into consideration for the study.

There is a potential scope to predict the future demand of Yarn, which is major raw material and also select best supplier which will help decision maker to optimize multiplecriteria.

1.4 Organization of The Thesis

The contents of the thesis are arranged into six chapters. These are summarized as follows:

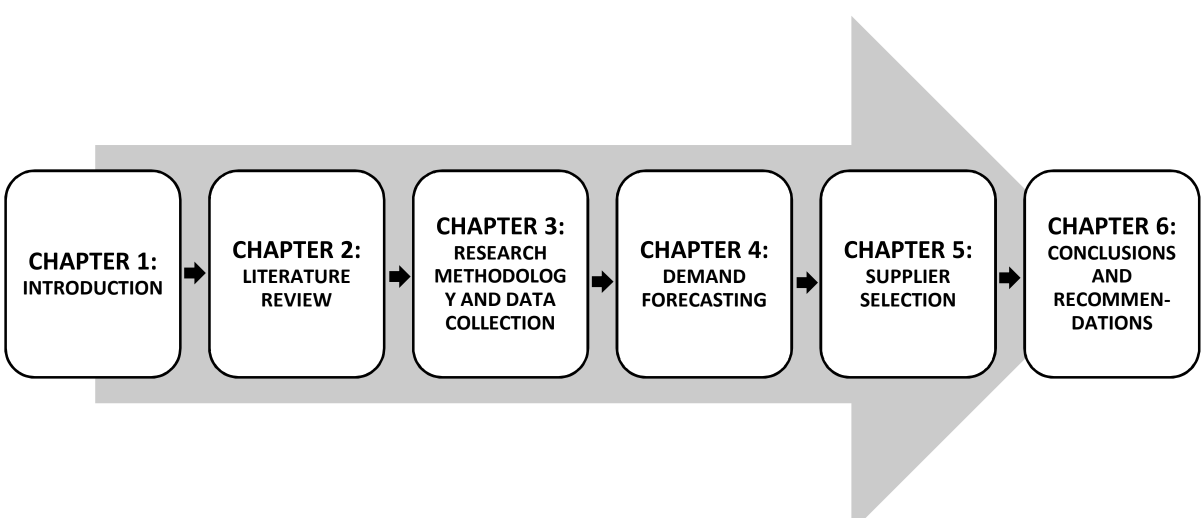


Figure 1.1: Structure of the Thesis

Chapter 1: Introduction: This chapter contains the general background and present status of the problem, scope of the study, objectives of the study and the thesis organization.

Chapter 2: Literature Review: The relevant literatures on demand forecasting, artificial neural networking (ANN), fuzzy AHP theory for alternative selection considering multiple criteria.

Chapter 3: Research Methodology and Data Collection: In this chapter, outlines the overall design of the study and research methodology that were followed for this thesis is presented here. The tasks include the process of data collection, sources and sectors of data and data analysis procedure are also described in this chapter.

Chapter 4: Demand Forecasting: In this chapter contains the prediction of Yarn demand by using ANN model & also comparing with the Holt's-Winter model.

Chapter 5:Supplier Selection: In this chapter contains the selection of best supplier by using Fuzzy Analytic Hierarchy Process (FAHP) considering multiple criteria.

Chapter 6: Conclusions and Recommendations: This chapter summarized the outcomes of thestudy and some recommendations for further study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Highly competitive market is currently forcing every factory to think globally. Survival becomes increasingly difficult and critical to find new ways to grow. Looking back at North American and European business trends, it seems that strategies have been changing and updating frequently. "How to do more" was emphasized in 60s; "How to do it cheaper" became important in 70s; "How to do better quality" was in the 80s and "How to do quicker" was the key in the 90s. All of those are still important in our business, however meeting the increasing time demands of customers will become important. Shorter lead time and will be the strategic focus for at least the next decade. Time – the number of seconds, minutes, hours, days, months or years – is the yardstick by which we increasingly judge around us –particularly organizations providing manufacturing services [1].

Demand forecasting is an integral part of any kind of supply chain management and very important to sustain profitability. Improving demand forecasting performance has long been a concern of people involved in any kind of Industry [9].There is a number of works contributed in performance assessment of ANN method. Bansal, Vadhavkar and Gupta has identified the inventory patterns of a large medical distribution organization and elaborated a method to construct and choose an appropriate Neural Network for optimizing theinventory. The implementation led to the reduction of the total inventory by 50% in the organization while the customer satisfaction level was still high [10].

Decision-making is a phenomenon encountered constantly in every areas of human activities. Decisionmaking process is about selecting the most suitable alternatives according to certain criteria in occasions that one faces with existing alternatives. This process is considered to be a tough one for decision makers because of its uncertainty and subjectivity [11].In 2011, Fuzzy AHP approach is used for supplier selection in a washing machine company. Ffirst they determine the criteria providing the most customer satisfaction and design the hierarchy structure including the main attributes and sub-attributes for supplier selection. The weights of attributes and alternatives are calculated using pair wise comparison matrices [12].

2.2 Artificial Neural Networking (ANN)

An artificial neural network (ANN) is a data processing system based on the structure of the biological neural simulation by learning from the data generated experimentally or using validated models. An ANN, usually called 'neural network' (NN), is a mathematical model or computational model that is inspired by the structure and/or functional aspects of biological NNs. An NN consists of an interconnected group of artificial neurons, and itprocesses information using a connectionist approach to computation. In most cases anANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern NNs arenon-linear statistical data modelling tools. They are usually used to model complex relationships between inputs and outputs or to find patterns in data[13].

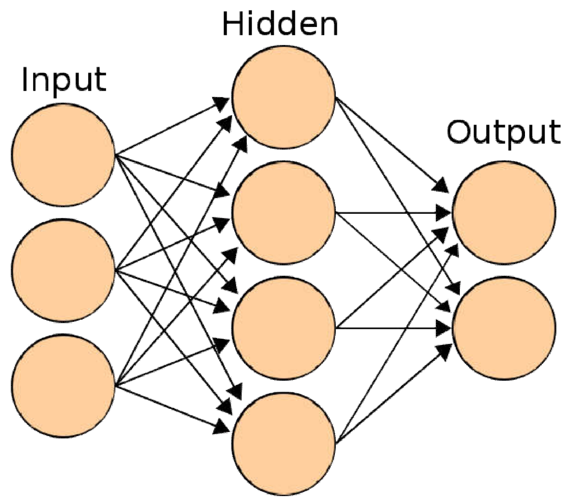


Figure 2.1: Artificial Neural Networking (ANN)

Some terms required to be defined for ANN users are:

ANN: A neural network is a processing device, either an algorithm, or actual hardware, whose inspired by the design in and functioning of animal brains and components thereof. It is computer program designed to simulate the brain neurons.

Processing element: In an ANN, the unit analogous to the biological neuron is processing elements (PE). Each PE has many inputs and outputs. The network consists of many units or neurons, each possibly having a small amount of local memory. The unit by undirectional communication channels “connections” which carry numeric data. The units operate only on their local data and on the inputs they receive connection.

Connection weight: The output path of a processing element is connected to input pathsof other PEs through connection weights, analogous to the synaptic strength of neural connections.

Input, output and hidden layers: A network consists of sequence of layers with connections between successive layers. Data to the network is presented at input layer and the response of the network to the given data is produced in the output layer. There may be several layers between these two principal layers, which are called hidden layers.

Training: Most neural networks have some sort of “training“ rule whereby the weights of connection are adjusted on the basis of presented patterns. In other words, neural network patterns “learn from example”.

Error: It is defined as the total sum of the difference between desired output and output produced by the network for the set of inputs.

Learning rate: A learning rule, which changes the connection weights of the network inresponse to the example inputs and desired output to those inputs. The training of neural network model is similar to the way humans or animals are trained by reinforcement technique, where certain synapses that connect the neurons selectively get strengthened leading to increase in the gain.

Recall: Recall refer to how the network processes a data set presented at its input layerand produces a response at the output layer. The weights are not changed during the recall process.

Neural Networks (NNs) are flexible non-linear data driven models that have attractive properties for forecasting. Statistical methods are only efficient for data having seasonal or trend patterns, while artificial neural techniques can accommodate the data influenced by the special case, like promotion or extreme crisis demand fluctuation.Artificial intelligence forecasting techniques have been receiving much attention lately in order to solve problems that are hardly solved by the use of traditional methods. ANNs have the ability to learn like humans, by accumulating knowledge through repetitive learning activities. Animal brain’s cognitive learning process is simulated in ANNs [14].ANN is a technology that has been mainly used for prediction, clustering, classification, and alerting of abnormal patterns [15].

2.3 Application of Artificial Neural Network

Artificial Neural Networks (ANN) have been applied in different industry like food industry, sales forecasting, wood industry, machine industry, paper industry and also garment industry but not that much using in Bangladesh garment industry for their raw material management. So in this study use of ANN would be an effective model for yarn forecasting. Anandi et, al, used ANN to forecast the demand of pulp wood which is most common raw material for paper making [3].

2.4 Fuzzy Analytical Hierarchy Process (FAHP)

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 [16]. In addition, their purchases of goods and services constitute up to 70% of product cost [17]. Therefore, selecting the right supplier significantly reduces purchasing costs, improves competitiveness in the market and enhances end user satisfaction [18].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. As a brief of all criteria that have appeared in literature since 1966, quality, price, and delivery performances are suggested as the most important selection criteria [19].
The uncertainty and vagueness of the experts‟ opinion is the prominent characteristic of the problem, this impreciseness of human‟s judgments can be handled through the fuzzy sets theory developed by Zadeh [20].Fuzzy AHP method systematically solves the selection problem that uses the concepts of fuzzy set theory and hierarchical structure analysis. Basically, Fuzzy AHP method represents the elaboration of a standard AHP method into fuzzy domain by using fuzzy numbers for calculating instead of real numbers [21]. There are many applications of F-AHP in various fields including; personnel selection [22], weapon selection [23], energy alternatives selection [24], job selection [25] and performance evaluation systems [26].

In 2010, a Fuzzy AHP method is used for supplier selection in electronic market places. According to their two phase methodology, at the first phase, initial screening of the suppliers through the enforcement of hard constraints on the selection criteria is performed. In the second phase, final supplier evaluation is performed through the application of a modified variant of Fuzzy AHP. This methodology facilitates an easier elicitation of user preferences through the reduction of necessary user input (i.e. pair wise comparisons) and reduces computational complexity [27].

In 2011, Fuzzy AHP approach is used for supplier selection in a washing machine company. First they determine the criteria providing the most customer satisfaction and design the hierarchy structure including the main attributes and sub-attributes for supplier selection. The weights of the attributes and alternatives are calculated using pair wise comparison matrices [28].

Based on comprehensive literature review, considering multi criteria structure of the supplier selection problem and the vagueness in real environment, fuzzy AHP is thought to be a suitable and simple enough for selecting the best supplier.

2.5 Fuzzy Set Theory and Triangular Fuzzy Numbers

In daily life, it is impossible to make a certain definition of many occasions. The reason for this is the high degree of uncertainty in real life. In order to define effectively subjective judgment or ambiguous problems via linguistic variables, fuzzy set theory was proposed by Zadeh on the uncertainty of human thought, for the first time. Sometimes it may happen that some data or numbers cannot be specified precisely or accurately due to the error of the measuring technique or instruments etc. Suppose the height of a person is recorded as 160 cm. However, it is impossible in practice to measure the height accurately; actually this height is about 160 cm; it may be a bit more or a bit less than 160 cm. Thus the height of that person can be written more precisely as triangular fuzzy number ($160 \quad \alpha, 160, 160 + \beta$), where α and β are the left and right spreads. In general, a TFN "a" can written as ($a \quad \alpha, a, a + \beta$), where α and β are the left and right spreads of a respectively. These type of numbers are alternately represented as (a, α, β). The mathematical definition (2.1) of a TFN is given below.

A triangular fuzzy number denoted by M = (m, α, β) has the membership function

$$\mu M(x) = \begin{cases} 0 & for\ x \leq m - \alpha \\ 1 - \dfrac{m - x}{\alpha} & for\ m - \alpha < x < m \\ 1 & for\ x = m \\ 1 - \dfrac{x - m}{\beta} & for\ m < x < m + \beta \\ 0 & for\ x \geq m + \beta \end{cases} \qquad 2.1$$

The point m, with membership grade of 1, is called the mean value and α, β are the left hand and right hand spreads of M respectively. Below is the Fuzzy Triangular Scale:

Fuzzy Numbers	Definition	Fuzzy Triangular Scale	Reciprocal Fuzzy Scale
1	Equally important (Eq. Imp.)	(1, 1, 1)	(1, 1, 1)
3	Weakly important (W. Imp.)	(2, 3, 4)	(1/4, 1/3, 1/2)
5	Fairly important (F. Imp.)	(4, 5, 6)	(1/6, 1/5, 1/4)
7	Strongly important (S. Imp.)	(6, 7, 8)	(1/8, 1/7, 1/6)
9	Absolutely important (A. Imp.)	(9, 9, 9)	(1/9, 1/9, 1/9)
2	The intermittent values between two adjacent scales	(1, 2, 3)	(1/3, ½, 1/1)
4		(3, 4, 5)	(1/5, 1/4, 1/3)
6		(5, 6, 7)	(1/7, 1/6, 1/5)
8		(7, 8, 9)	(1/9, 1/8, 1/7)

Table 2.1: TFN Scale.

Below figure shows two triangular fuzzy numbers A & B, to illustrate the operations of fuzzy numbers. The fuzzy number of A can be represented as (1, 2, 3) and the fuzzy number of B can be expressed as (2, 3, 4).

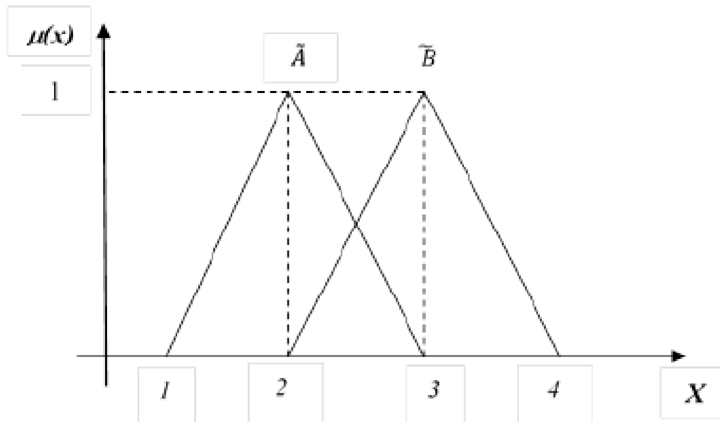


Figure 2.2: Triangular Fuzzy Numbers

CHAPTER 3

RESEARCH METHODOLOGY AND DATA COLLECTION

3.1 Introduction

Methodology outlines here the techniques for the collection of data and the procedures applied for the execution of the study. It expresses a systematic way through which any study can be done in a fruitful way. This chapter outlines the overall design of the study and research methodologies that have been followed to achieve the objectives setout in Chapter 1. It also describes data collection procedures at different stage of the research work. Data analysis procedures and techniques are also presented here.

3.2 Outline of The Research Methodology

- A particular raw material has been selected.
- Actual consumption data of that raw material has been collected.
- Trend and seasonality factors have beenidentified and analyzed.
- Future demand has been predicted by using an ANN model.
- Result from ANN model has been compared with Holt-Winter's model.
- The potential suppliers have been listed.
- The evaluation criteria have been defined.
- Decision hierarchy has been developed.
- Priority matrix of different criteria has been analyzed.
- Priority matrix of different supplier has been analyzed.
- Overall priorities of suppliers have been calculated.
- The highest priority supplier has been selected.

3.3 Relevant Sectors and Field Selection

To predict the future demand and selection of the best supplier the following sectors or field have been selected:

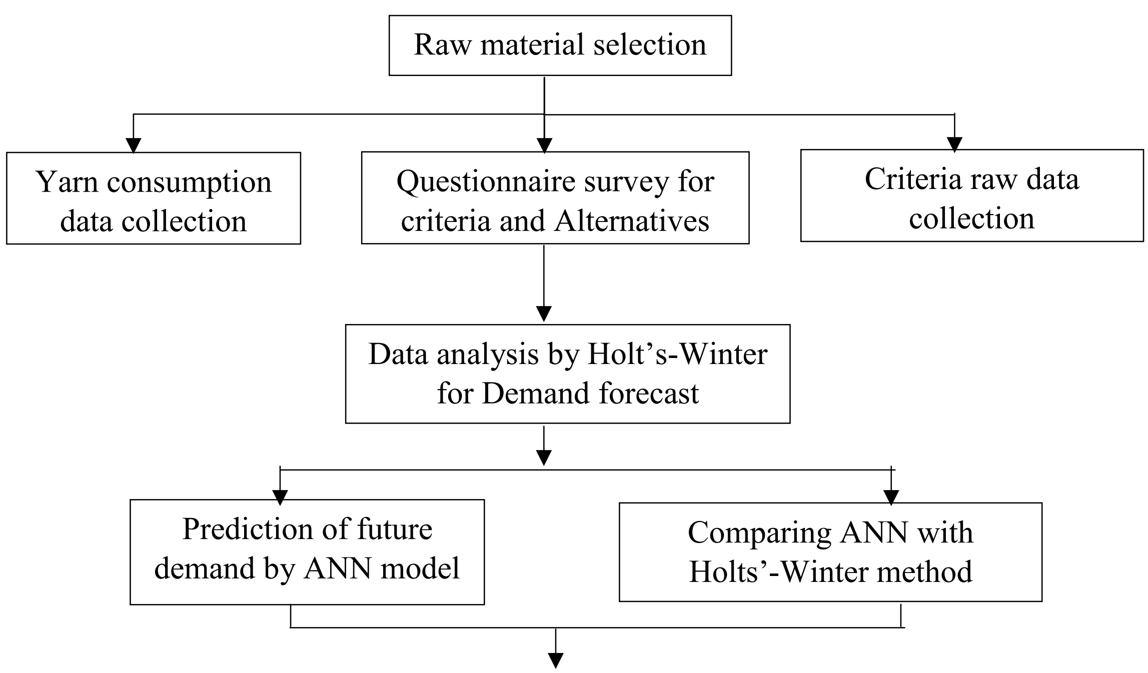
- A vertical garment factory ("Name: A") has been selected.
- A particular major raw material which is "Yarn" has been considered.
- 3 main yarn supplier A, B and C have been considered for alternatives.

3.4 Data Collection

Major types of data are provided in below:

- 3 years yarn consumption data has been collected from textile unit.
- Questionnaire survey for criteria and alternative selection.
- All criteria raw data has been collected from respective department.
- Overall observation and discussion with the professionals or policy makers.

Flow chart of the main steps of the researchmethodology is provided below:



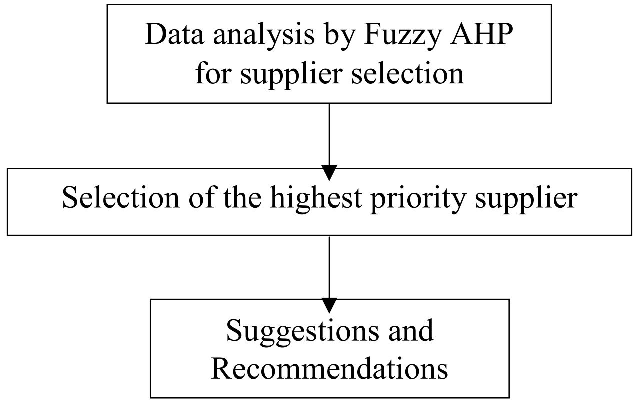


Figure 3.1: Research Methodology flow chart.

CHAPTER 4

DEMAND FORECASTING

4.1 Introduction

One of the first steps to make any decisions for the planning of a company are the specific forecast data to provide adequate information for decision making. Appropriate forecasting models create a higher quality result, allowing better decisions. This study takes into account the importance of understanding the current demand data in an effort to make future demand by Artificial Neural Networking (ANN) model.

4.2 Time Series Patterns

A time series is a sequence of observations on a variable measured at successive points in time or over successive periods of time. The measurements may be taken every hour, day, week, month, or year, or at any other regular interval. The pattern of the data is an important factor in understanding how the time series has behaved in the past. If such behavior can be expected to continue in the future, we can use the past pattern to guide us in selecting an appropriate forecasting method. To identify the pattern in the data, a useful first step is to construct a time series plot. A time series plot is a graphical presentation of the relationship between timeand the time series variable.

4.3 Actual Demand

The actual yarn consumption information is provided in below:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Actual Consumption	540	542	547	545	543	558	546	545	548	547	545	560

Month	13	14	15	16	17	18	19	20	21	22	23	24
Actual Consumption	549	548	553	551	550	562	552	550	558	556	554	566

Month	25	26	27	28	29	30	31	32	33	34	35	36
Actual Consumption	555	553	563	561	562	569	560	559	567	564	567	572

Table 4.1: Actual Yarn Consumption.

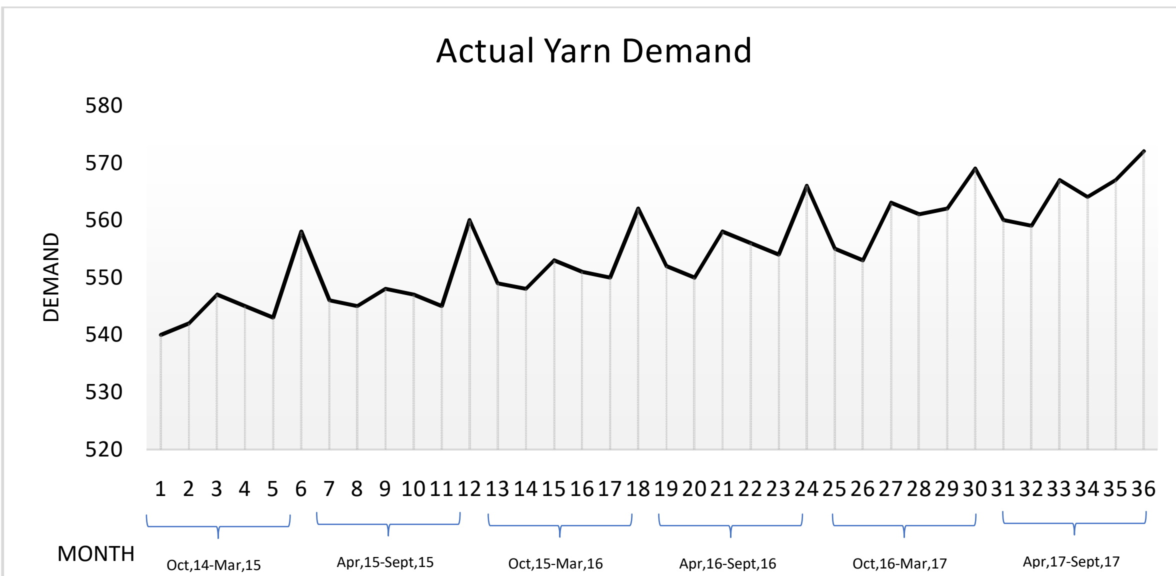


Figure 4.1: Actual Yarn Demand.

4.4 Time Series Component

- **Level:** Data fluctuates around a constant mean. (Without considering the trend & seasonality).
- **Trend:** There is a trend exists which is upward trend as demand is increasing every year. As this supplier is the partner supplier of the buyer.
- **Seasonality:** There is regular fluctuation during every year. There are two seasons which are AW (Autumn-Winter)& SS (Spring-Summer). And demand is comparatively higher at end of every season. So as per seasonality pattern that regularly repeats itself & is of a constant length.
- **Cyclical:** There is no up & down movement over time.
- **Irregular:** There is no irregularity & unexpected or random fluctuation.

4.5 Holt's-Winter Method with Trend & Seasonality

Holt and Winters extended Holt's method to capture seasonality. The Holt-Winters seasonal method comprises the forecast equation and three smoothing equations- one for the level (4.2), one for trend (4.3), and one for seasonal (4.4) component, with smoothing parameters α, β and γ.

Forecast $$F_{t+m} = (L_t + mT_t) \quad S_{t+m-s} \tag{4.1}$$

Level $$L_t = \alpha\left(\frac{D_t}{S_{t-s}}\right) + (1 \quad \alpha)(L_{t-1} + T_{t-1}) \tag{4.2}$$

Trend $$T_t = \beta(L_t \quad L_{t-1}) + (1 \quad \beta)T_{t-1} \tag{4.3}$$

Seasonality $$S_t = \gamma\left(\frac{D_t}{L_t}\right) + (1 \quad \gamma)S_{t-s} \tag{4.4}$$

Month	Actual	Level	Trend	Seasonal	Forecast	Error	Sq Error	MAD	MAPE
1	540			0.9893					
2	542			0.9930					
3	547			1.0021					
4	545			0.9985					
5	543			0.9948					
6	558	545.83	0.00	1.0223					
7	546	546.15	0.32	0.9997	540	6	36	6	1.10%
8	545	546.59	0.44	0.9971	542.6273165	2.372683	5.629627	2.372683	0.44%
9	548	547.02	0.43	1.0018	548.1990906	-0.19909	0.039637	0.199091	0.04%
10	547	547.47	0.45	0.9991	546.6136996	0.3863	0.149228	0.3863	0.07%
11	545	547.92	0.45	0.9947	545.0756189	-0.07562	0.005718	0.075619	0.01%
12	560	548.33	0.42	1.0213	560.585027	-0.58503	0.342257	0.585027	0.10%
13	549	548.77	0.44	1.0004	548.598637	0.401363	0.161092	0.401363	0.07%
14	548	549.23	0.46	0.9978	547.6095947	0.390405	0.152416	0.390405	0.07%
15	553	549.81	0.58	1.0058	550.6700649	2.329935	5.428598	2.329935	0.42%
16	551	550.44	0.64	1.0010	549.912593	1.087407	1.182454	1.087407	0.20%
17	550	551.17	0.73	0.9979	548.1442718	1.855728	3.443727	1.855728	0.34%
18	562	551.82	0.65	1.0184	563.6506175	-1.65062	2.724538	1.650617	0.29%
19	552	552.43	0.61	0.9992	552.7031345	-0.70313	0.494398	0.703135	0.13%
20	550	552.95	0.52	0.9947	551.8106435	-1.81064	3.27843	1.810643	0.33%
21	558	553.54	0.59	1.0081	556.6844957	1.315504	1.730551	1.315504	0.24%
22	556	554.19	0.65	1.0033	554.6850599	1.31494	1.729067	1.31494	0.24%
23	554	554.86	0.67	0.9984	553.6631584	0.336842	0.113462	0.336842	0.06%
24	566	555.55	0.68	1.0188	565.7800097	0.21999	0.048396	0.21999	0.04%
25	555	556.19	0.64	0.9979	555.7906767	-0.79068	0.62517	0.790677	0.14%
26	553	556.78	0.60	0.9932	553.8559078	-0.85591	0.732578	0.855908	0.15%
27	563	557.44	0.65	1.0100	561.8739846	1.126015	1.267911	1.126015	0.20%
28	561	558.15	0.71	1.0051	559.9148936	1.085106	1.177456	1.085106	0.19%
29	562	559.07	0.92	1.0052	557.9920024	4.007998	16.06404	4.007998	0.71%
30	569	559.91	0.84	1.0162	570.5284941	-1.52849	2.336294	1.528494	0.27%

31	560	560.78	0.87	0.9986	559.5575913	0.442409	0.195725	0.442409	0.08%
32	559	561.70	0.93	0.9952	557.8259488	1.174051	1.378396	1.174051	0.21%
33	567	562.57	0.86	1.0079	568.244267	-1.24427	1.5482	1.244267	0.22%
34	564	563.31	0.74	1.0012	566.3066884	-2.30669	5.320811	2.306688	0.41%
35	567	564.05	0.74	1.0052	567.009136	-0.00914	8.35E-05	0.009136	0.00%
36	572	564.69	0.64	1.0129	573.962293	-1.96229	3.850594	1.962293	0.34%
37					564.5529735				
38					563.2539755				
39					571.0859268				
40					567.9577788				
41					570.872496				
42					575.9022031				

MSE	3.24
MAD	1.32
MAPE	0.2%

Alpha	0.052
Beta	1.000
Gamma	1.000

Table 4.2: Holts'-Winter Method.

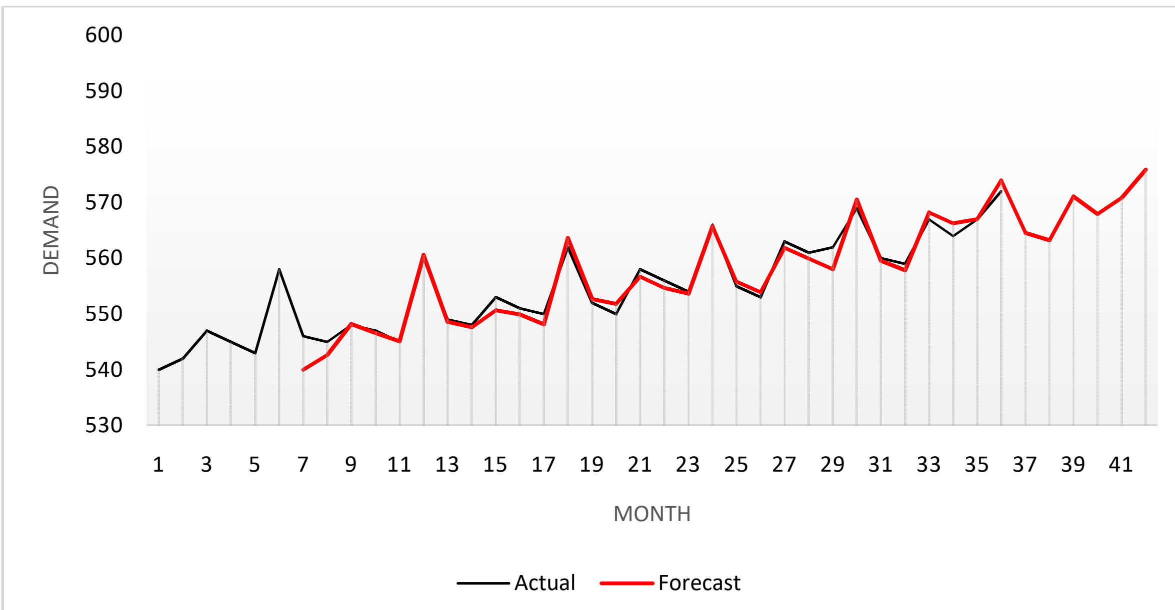


Figure 4.2: Holts-Winter Forecast.

From the Holts'-Winter analysis the trend plot is given in below:

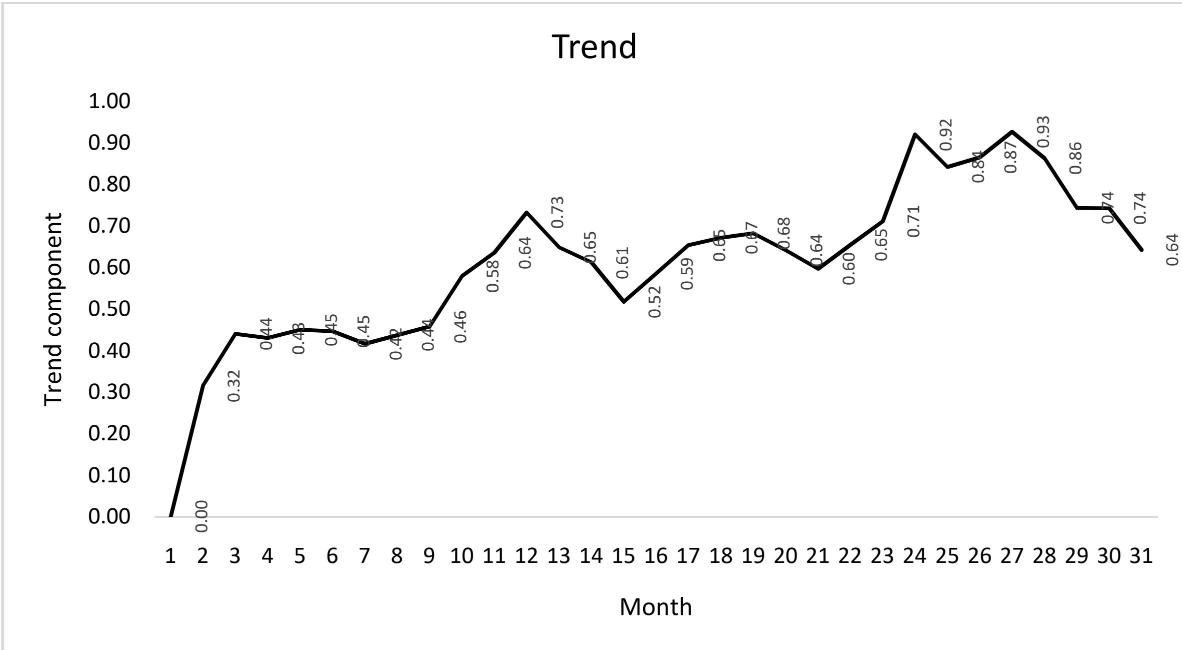


Figure 4.3: Trend Plot.

To analysis the error of forecasting below error formulas have been used:

1. A Mean Absolute Deviation:

$$MAD = \frac{\sum|Forecast\ errors|}{n} \qquad 4.5$$

2. Mean Squared Error:

$$MSE = \frac{\sum(Forecast\ error)^2}{n} \qquad 4.6$$

3. Mean absolute percent error:

The mean absolute percentage error (MAPE) is a measure of prediction accuracy of a forecasting method in statistics, for example in trend estimation. It usually expresses accuracy as a percentage:

$$MAPE = \frac{100}{n} \quad \frac{\sum|A_t \quad F_t|}{A_t} \qquad 4.7$$

4.6 Artificial Neural Networking Model (ANN)

Neural networks approximate a mapping function from input variables to output variables. Neural networking is able to forecast data patterns that are too complex for the traditional statistical models. A strong advantage of neural networks is that, when properly trained, they can consider experts with regard to the particular output project for which they were designed to examine.

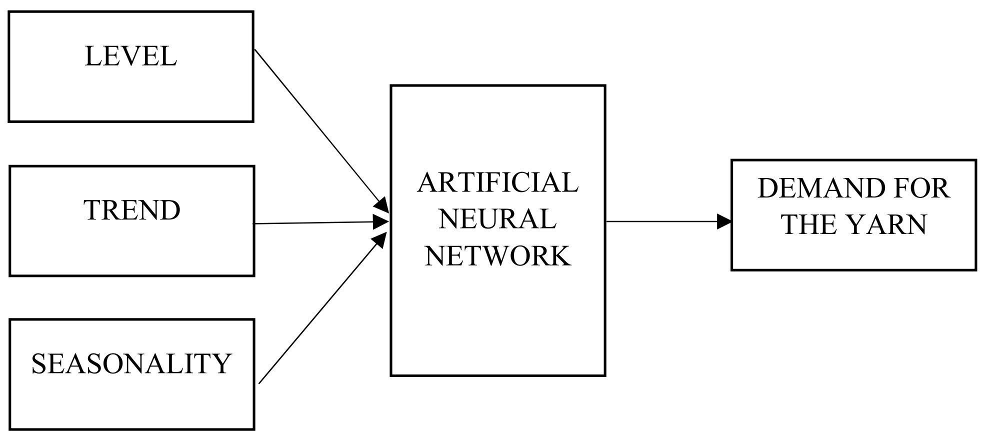


Figure 4.4: Architecture of ANN.

4.6.1 Types of ANN tools

There are different types of ANN commercial and excel software like below:

- MATLAB Neural Toolbox.
- Alyuda Forecaster XL
- NeuroXL.
- Membrain.
- Palisade Neural Tools.
- Statistica Neural Network.
- NeuroSolutions. Etc.

In this study “Alyuda Forecaster XL” Neural Networking application has been used to predict the future demand of the raw material.

4.6.2 Alyuda Forecasting XL

Alyuda Forecaster XL is a forecasting excel add-in, based on neural networks. It is reliable and easy to use for non-technical people. Alyuda Forecaster is specifically designed to solve major problems encountered while using a neural network for forecasting purposes. In addition to the feature benefits are:

- Time saving - no need to spend too much time on learning the neural network theory.
- Automatically data can be prepared - data will be analyzed and converted to make it suitable for a neural network;
- Automatically accomplish the best neural network.

4.6.3 ANN influencing factors

After analyzing the Holts'-Winter method below components are considered as an influencing factors for ANN model.

- Level
- Trend
- Seasonality

4.6.4 ANN analysis

By using Alyuda Forecaster XL the ANN analysis has been done & performance report is given in below:

Actual vs. Forecasted Table								
	Input			Target	Output			
	C16	D16	E16	B16	Forecast	Abs. Error	Rel. Error	Estimate
	546.14921	0.3158766	0.9997268	546	546.90593	0.905931	0.17%	Good
	546.58954	0.4403283	0.9970919	545	546.34154	1.3415361	0.25%	Good
	547.01952	0.429981	1.0017924	548	548.26854	0.2685409	0.05%	Good
	547.46965	0.4501317	0.9991421	547	547.56497	0.5649665	0.10%	Good
	547.91582	0.4461726	0.9946783	545	546.33329	1.3332947	0.24%	Good
	548.33219	0.4163668	1.0212787	560	560.48748	0.4874773	0.09%	Good
	548.76947	0.4372769	1.0004201	549	549.01056	0.0105575	0.00%	Good
	549.22714	0.4576698	0.9977657	548	548.25143	0.251435	0.05%	Good
	549.80594	0.5788038	1.0058094	553	552.67412	-0.325875	0.06%	Good
	550.44143	0.6354884	1.0010148	551	550.75418	-0.245825	0.04%	Good
	551.17409	0.7326583	0.9978698	550	549.89685	-0.10315	0.02%	Good
	551.82257	0.6484796	1.0184433	562	562.6837	0.6836959	0.12%	Good
	552.43444	0.6118733	0.9992136	552	551.66446	-0.335543	0.06%	Good
	552.9518	0.5173575	0.9946617	550	549.82489	-0.175107	0.03%	Good
	553.53728	0.5854778	1.0080622	558	558.11269	0.1126864	0.02%	Good
	554.19117	0.653895	1.0032639	556	555.86238	-0.13762	0.02%	Good
	554.86265	0.6714763	0.9984453	554	553.69167	-0.308329	0.06%	Good
	555.54537	0.6827267	1.0188187	566	566.55783	0.5578253	0.10%	Good
	556.18689	0.6415131	0.997866	555	554.74869	-0.251314	0.05%	Good
	556.78358	0.5966952	0.9932046	553	552.64201	-0.357988	0.06%	Good
	557.43846	0.654873	1.009977	563	563.63741	0.6374104	0.11%	Good
	558.14966	0.7112052	1.0051068	561	561.51556	0.5155606	0.09%	Good
	559.06994	0.9202807	1.005241	562	562.68006	0.6800602	0.12%	Good

	559.91208	0.8421419	1.016231	569	568.92483	-0.075173	0.01%	Good
	560.77732	0.8652334	0.9986139	560	560.4775	0.4774991	0.09%	Good
	561.70412	0.9268004	0.9951859	559	559.39201	0.3920071	0.07%	Good
	562.56675	0.8626348	1.0078804	567	567.40759	0.4075872	0.07%	Good
	563.30986	0.7431049	1.0012252	564	564.68116	0.6811644	0.12%	Good
	564.05249	0.7426315	1.0052256	567	567.37861	0.3786053	0.07%	Good
	564.69455	0.6420609	1.012937	572	570.71598	-1.284018	0.22%	Good

Table 4.3: ANN analysis.

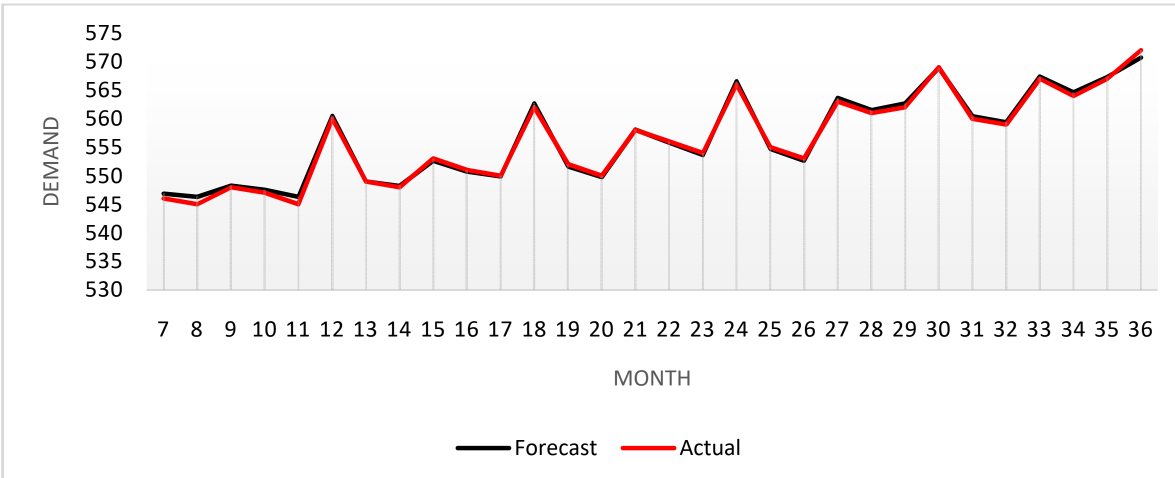


Figure 4.5: ANN forecast.

4.7 Error Comparison

Error comparison between ANN & Holts'-Winter model is provided in below:

Model	**MSE**	**MAD**	**MAPE**
Holt's-Winter Method with Trend & Seasonality	3.24	1.32	0.20%
ANN (Artificial Neural Networking) Model	0.35	0.48	0.10%

Table 4.4: Error comparison.

4.8 Future Yarn Prediction by ANN

Next Months	Level	Trend	Seasonality	ANN Forecast
37	564.48	0.87	0.9880	557.9942
38	565.13	0.88	0.9874	558.3585
39	565.78	0.90	0.9994	566.1376
40	566.43	0.91	0.9958	564.8614
41	567.08	0.93	0.9946	564.8467
42	567.73	0.94	1.0151	572.6107
43	568.37	0.96	0.9964	566.9683
44	569.02	0.97	0.9940	566.3712
45	569.67	0.99	1.0055	571.2026
46	570.32	1.00	1.0019	570.4865
47	570.97	1.02	1.0013	570.6644
48	571.62	1.04	1.0205	574.2356

Table 4.5: Future ANN prediction.

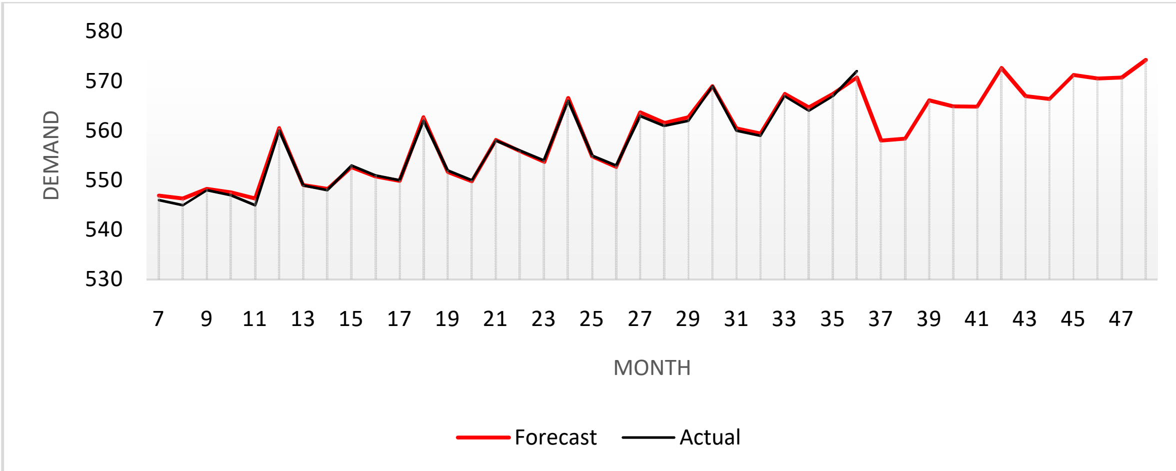


Figure 4.6: ANN future prediction plot.

So as actual demand is trendy & seasonality pattern then after comparing with the Holt's-Winter model the Artificial Neural Networking model shows the less error compare to Holt's-Winter Method. So yarn purchasing department can forecast the future demand by using ANN model considering influencing factors.

CHAPTER 5

SUPPLIER SELECTION

5.1 Introduction

Supplier selection is one of the most important functions of a purchasing department. Since by deciding the best supplier, companies can save material costs and increase competitive advantage. However this decision becomes complicated in case of multiple suppliers, multiple conflicting criteria, and imprecise parameters. Therefore an extensively used multi criteria decision making tool Fuzzy AHP can be utilized as an approach for supplier selection problem. This paper reveals the application of Fuzzy AHP in a Textile industry determining the best supplier with respect to selected criteria.

5.2Fuzzy Analytical Hierarchy Process (F-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.

Since basic AHP does not include vagueness for personal judgments, it has been improved by benefiting from fuzzy logic approach. One such criticisms of the AHP is its inability to accommodate uncertainty in the decision making process. The analytic hierarchy process (AHP) is usually used for multi-attribute decision-making problems like supplier selection. The drawback with this approach is its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-makers perception to exact numbers. However, in many practical cases the human preference model is uncertain and decision makers might be reluctant or unable to assign an exact number. Since some of the evaluation criteria are subjective and qualitative in nature, it isvery difficult for the decision maker to express the preferences using exact numerical values and to provideexact pair wise comparison judgments. To improve this and to facilitate supplier selection process, the paperdiscusses a fuzzy - AHP approach using triangular fuzzy numbers to represent decision makers' comparisonjudgments. 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, Buckley's methods is implemented to determine the relative importance weights for both the criteria and the alternatives.

5.3 The steps of the FAHP procedure

Step 1: Decision Maker compares the criteria or alternatives via linguistic terms.

Fuzzy Numbers	Definition	Fuzzy Triangular Scale	Reciprocal Fuzzy Scale
1	Equally important (Eq. Imp.)	(1, 1, 1)	(1, 1, 1)
3	Weakly important (W. Imp.)	(2, 3, 4)	(1/4, 1/3, 1/2)
5	Fairly important (F. Imp.)	(4, 5, 6)	(1/6, 1/5, 1/4)
7	Strongly important (S. Imp.)	(6, 7, 8)	(1/8, 1/7, 1/6)
9	Absolutely important (A. Imp.)	(9, 9, 9)	(1/9, 1/9, 1/9)
2	The intermittent values between two adjacent scales	(1, 2, 3)	(1/3, ½, 1/1)
4		(3, 4, 5)	(1/5, 1/4, 1/3)
6		(5, 6, 7)	(1/7, 1/6, 1/5)
8		(7, 8, 9)	(1/9, 1/8, 1/7)

Table 5.1: Linguistic terms and the corresponding triangular fuzzy numbers

According to the corresponding triangular fuzzy numbers of these linguistic terms, for example ifthe decision maker states “Criterion 1 is Weakly Important than Criterion 2, then it takes the fuzzy triangular scale as (2, 3, 4). On the contrary, in the pair wise contribution matrices of the criteria, comparison will take the reciprocal fuzzy triangular scale as (1/4, 1/3, 1/2).

$$A^k = \begin{matrix} d_{11}^k & d_{12}^k & \dots & d_{1n}^k \\ d_{21}^k & \dots & \dots & d_{2n}^k \\ \dots & \dots & \dots & \dots \\ d_{n1}^k & d_{n2}^k & \dots & d_{nn}^k \end{matrix} \qquad 5.1$$

Step 2: According to Buckley, the geometric mean of fuzzy comparison values of each criterion is calculated as shown in below. Here, it’s represents triangular values.

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}} \right)^{1/n}, i = 1,2,3, \qquad 5.2$$

Step 3: The fuzzy weights of each criterion can be found by incorporating next 3 sub steps.

Step 3a: Find the vector summation of each r.

Step 3b: Find the (-1) power of summation vector. Replace the fuzzy triangular number, to make it in an increasing order.

Step 3c: To find the fuzzy weight of criterion, multiply each “r”with this reverse vector.

$$\widetilde{w_i} = (lw_i, mw_i, uw_i) \qquad 5.3$$

Step 4: Since“w” are still fuzzy triangular numbers, they need to de-fuzzified by Centre of areamethod proposed by Chou and Chang, via applying the equation below:

5.4

$$\widetilde{M_i} = \frac{(lw_i, mw_i, uw_i)}{3}$$

Step 5: Mi is a non-fuzzy number. But it needs to be normalized by following Eq.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \qquad 5.5$$

Step 6: Multiply each alternative weight with related criteria, scores for each alternative is calculated.

5.3.1The hierarchy of the criteria and the alternatives

By using questionnaire survey below criteria & alternatives are selected for analysis. Detail of questionnaire survey and each criterion raw data are provided in the appendix page.

Criteria	Alternatives		
	Supplier A	Supplier B	Supplier C
Quality	Medium	Good	Relatively poor
Lead Time	13 Days	15 Days	7 Days
Cost	FOB 3.50 USD/KG	FOB 3.20 USD/KG	FOB 3.70 USD/KG
Reputation	Medium	Good	Relatively poor
Capacity	950 Tons	650 Tons	720 tons

Table 5.2: Summary of each criteria data.

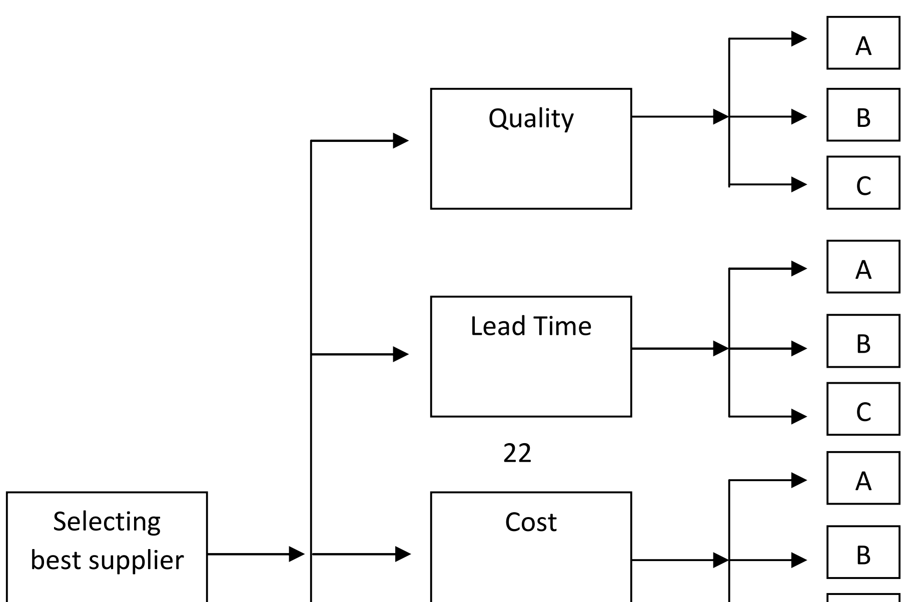


Figure 5.1: Hierarchy of the criteria and the alternatives.

5.3.2 Step-1: Determining Weights of Criteria

By using each criterion raw data below comparative decision has been taken.

(9, 9, 9)	(7,8,9)	(6, 7, 8)	(5,6,7)	(4, 5, 6)	(3,4,5)	(2, 3, 4)	(1,2,3)	CRITERION	(1, 1, 1)	CRITERION	(1,2,3)	(2, 3, 4)	(3,4,5)	(4, 5, 6)	(5,6,7)	(6, 7, 8)	(7,8,9)	(9, 9, 9)
				Δ				Quality		Lead Time								
								Quality		Cost				Δ				
		Δ						Quality		Reputation								
				Δ				Quality		Capacity								
								Lead Time		Cost				Δ				
				Δ				Lead Time		Reputation								
						Δ		Lead Time		Capacity								
		Δ						Cost		Reputation								
		Δ						Cost		Capacity								
								Reputati		Capacity		Δ						

								on										

Table 5.3: Weights of criteria.

5.3.3 Pair wise Comparison matric for Criteria

Criteria	Quality			Lead Time			Cost			Reputation			Capacity		
Quality	1	1	1	4	5	6	0.167	0.2	0.25	6	7	8	4	5	6
Lead Time	0.167	0.2	0.25	1	1	1	0.167	0.2	0.25	4	5	6	2	3	4
Cost	4	5	6	4	5	6	1	1	1	6	7	8	6	7	8
Reputation	0.125	0.142	0.167	0.167	0.2	0.25	0.125	0.142	0.167	1	1	1	0.25	0.33	0.5
Capacity	0.167	0.2	0.25	0.25	0.33	0.5	0.125	0.142	0.167	2	3	4	1	1	1

Table 5.4: Comparison matric.

5.5.4Step-2:Geometric means of Fuzzy Comparison values

After completing the 1st step of the methodology now the geometric mean, according to step-2:

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}} \right)^{1/n} , i = 1,2,3, \qquad 5.2$$

Quality = [$(1*4*1/6*6*4)^{1/5}$; $(1*5*1/5*7*5)^{1/5}$; $(1*6*1/4*8*6)^{1/5}$)]
= [1.74 ; 2.04 ; 2.35]

Similarly for other criteria is given in below:

Criteria	ri		
Quality	1.74	2.04	2.35
Lead Time	0.74	0.90	1.08
Cost	3.57	4.15	4.70
Reputation	0.23	0.27	0.32
Capacity	0.40	0.49	0.61
Total	6.68	7.84	9.07

Reverse	0.15	0.13	0.11
Increasing order	0.11	0.13	0.15

Table 5.5: Geometric means.

5.5.5Step-3:Relative Fuzzy weight

Now the relative fuzzy weight according to step-3:

Quality, W_i = [(1.74*0.11) ; (2.04*0.13) ; (2.35*0.15)] = [0.19 ; 0.26 ; 0.35]

Similarly for other criteria is given in below:

Criteria	Wi		
Quality	0.19	0.26	0.35
Lead Time	0.08	0.12	0.16
Cost	0.39	0.53	0.70
Reputation	0.03	0.03	0.05
Capacity	0.04	0.06	0.09

Table 5.6: Relative fuzzy weight.

5.5.6 Step-4 and Step-5: Averaged and normalized relative weights

Now according to step-4 and step-5:

Criteria	Mi	Ni
Quality	0.27	0.26
Lead Time	0.12	0.12
Cost	0.54	0.53
Reputation	0.04	0.03
Capacity	0.07	0.06

Table 5.7: Averaged and normalized relative weights of criteria

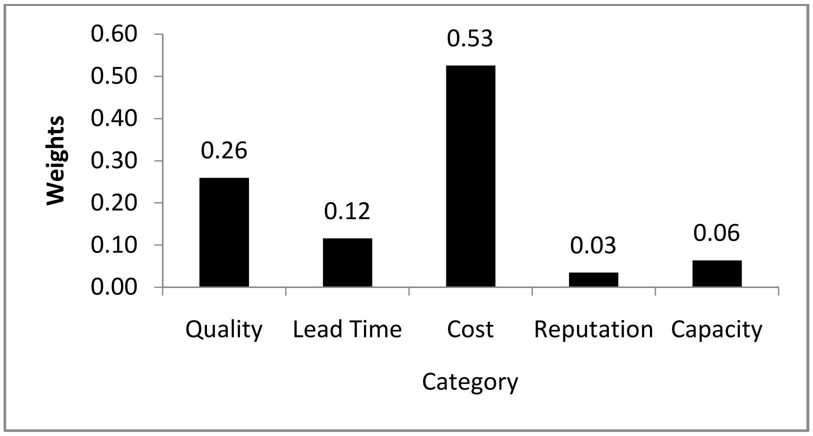


Figure 5.2: Relative weight of each criteria.

Now the same methodology is applied to find the respective values for alternatives. But now, the alternatives should be pair wise compared with respect to each criterion particularly. That means, this analysis should be repeated for 5 more times for each criterion. Details are in the appendix page.

(9, 9, 9)	(7, 8, 9)	(6, 7, 8)	(5, 6, 7)	(4, 5, 6)	(3, 4, 5)	(2, 3, 4)	(1, 2, 3)	Criteria	(1, 1, 1)	Criteria	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	(5, 6, 7)	(6, 7, 8)	(7, 8, 9)	(9, 9, 9)
								A		B				Δ				
						Δ		A		C								
		Δ						B		C								

Table 5.8: Pair Wise Comparisons of Alternatives with respect to "Quality" Criteria

Alternatives	A			B			C		
A	1	1	1	0.17	0.2	0.25	2	3	4
B	4	5	6	1	1	1	6	7	8
C	0.25	0.33	0.5	0.13	0.14	0.17	1	1	1

Table 5.9: Comparison matric of alternatives with respect to "Quality" criterion

Now Geometric means and fuzzy weights of alternatives with respective to "Quality" Criterion.

Alternatives	ri		
A	0.70	0.84	1.00

B	2.85	3.23	3.59
C	0.32	0.37	0.44
Total	3.87	4.44	5.03
Reverse	0.26	0.23	0.20
Increasing order	0.20	0.23	0.26

Table 5.10: Geometric means.

Alternatives	Wi		
A	0.14	0.19	0.26
B	0.57	0.73	0.93
C	0.06	0.08	0.11

Table 5.11: Relative Fuzzy weight.

Alternatives	Mi	Ni
A	0.20	0.19
B	0.74	0.72
C	0.09	0.08

Table 5.12: Averaged and normalized relative weights.

Similarly, the normalized weights of each alternative for each criterion are found and tabulated in Table below:

Alternatives	Quality	Lead Time	Cost	Reputation	Capacity
A	0.19	0.19	0.26	0.29	0.63
B	0.72	0.08	0.63	0.57	0.11
C	0.08	0.72	0.11	0.14	0.26

Table 5.13: The Aggregated results for each alternative according to each criterion.

5.5.7 Step-6: Aggregated results for each alternative according to each criterion

Multiply each alternative weight with related criteria, scores for each alternative is calculated.

Criteria	Weight	A	B	C

Quality	0.26	0.19	0.72	0.08
Lead Time	0.12	0.19	0.08	0.72
Cost	0.53	0.26	0.63	0.11
Reputation	0.03	0.29	0.57	0.14
Capacity	0.06	0.63	0.11	0.26
Total		26%	55%	19%

Table 5.14: Aggregated final results.

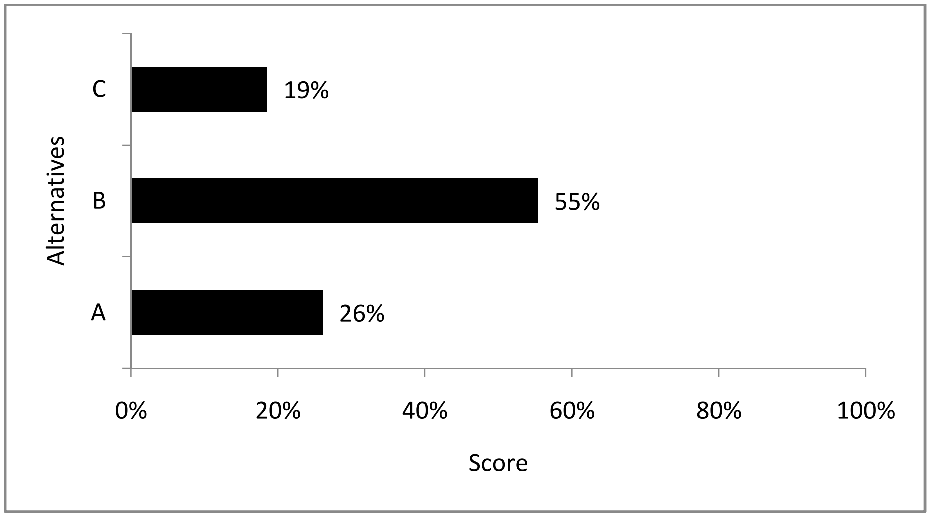


Figure 5.3: Final Score of Alternatives.

Depending on this result, Alternative B has the largest total score. Therefore, it is suggested as thebest supplier among 3 of them, with respect to 5 criteria and the fuzzy preferences of decisionmakers.

Similarly, by changing the priority of the criteria in the pair wise comparison below different final scores have been analyzed.

Changing Category Priority	Relative weights	Supplier selection	Final Score
Cost	0.53	SU-B	55%
Lead Time	0.45	SU-C	39%
Quality	0.5	SU-B	58%
Capacity	0.45	SU-A	41%
Reputation	0.48	SU-B	55%
Capacity & Reputation	0.35 & 0.11	SU-B	41%
Lead Time & Capacity	0.29 & 0.38	SU-A	37%
Quality & Lead Time	0.25 & 0.50	SU-C	42%

Table 5.15: Different scores by changing category priority.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The present study focused on predicting the future demand of raw material-yarn by using Artificial Neural Networking (ANN) model and also comparing with the Holts'-Winter method. Then for best supplier selection the Fuzzy Analytical Hierarchy Process (FAHP) has been used by considering multiple criteria like Quality, Cost, Lead time, Reputation and Capacity. In order to achieve this, actual data and questionnaire interviews were undertaken in different areas of garment industry.

6.1 Conclusion

Based on the results of the present study the following conclusion can be drawn:

- To predict the future yarn demand ANN model has given the less error (MSE: 0.35) compared to Holts'-Winter method (MSE: 3.24).
- Next 1 year (37-48 months) future yarn demand has been established by using ANN model.
- The most priority yarn supplier which is "B" (score is 55%) has been selected by using Fuzzy AHP.

6.2Recommendations for further study

Based on the findings and experiences of the research work presented in this thesis the following recommendations can be forwarded for future study.

- This study is targeted the major raw material which Yarn for demand forecasting, So it can be further carried out for the other important raw materials.
- This study is considered 5 criteria, so it can be further researched on more than 5 criteria.
- This study is considered 3 suppliers as alternatives, so it can be further researched on more than 3 suppliers.

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APPENDIX-A

Multi Criteria & Alternative selection questionnaire Survey

Name: Date:
Designation:

1. Do you consider any key factors to purchase the Yarn?

Yes	

No	

2. Rate below affecting factors from 1 (less) to 5 (most) for Yarn selection?

Rating (1-5)	1	2	3	4	5
Quality					
Lead Time					
Cost					
Responsiveness					
Capacity					
Reputation					
Payment Flexibility					
Trust					
Technical Capability					

3. Do you purchase the Yarn from different suppliers?

Yes	
No	

4. To purchase the Yarn do you cross verify with the different suppliers?

Yes	
No	

5. Rate below (1-worst to 5 best) potential suppliers for Yarn sourcing?

Rating (1-5)	1	2	3	4	5
Supplier A					
Supplier B					
Supplier C					
Supplier D					
Supplier E					

6. If you consider any other criteria then please write in below box:

7. If you consider any other supplier then please write in below box:

8. Actually, which criteria you are always giving most priority for yarn purchasing?

APPENDIX-B

QUALITY DETAIL INFORMATION

Lot-wise 5 kg knitting physical quality checking procedure. Considered 20 lots for sampling.

Lot No.	SU A	Reason	SU B	Reason	SU C	Reason
Lot-1	Pass		Pass		Pass	
Lot-2	Pass		Pass		Pass	
Lot-3	Pass		Pass		Pass	
Lot-4	Fail	hairiness	Pass		Pass	
Lot-5	Fail	hole	Pass		Pass	
Lot-6	Pass		Fail	hairiness	fail	GSM discrepancy
Lot-7	Pass		Pass		fail	hairiness
Lot-8	Pass		Pass		fail	hole
Lot-9	Pass		Pass		Pass	
Lot-10	Pass		Pass		Pass	
Lot-11	Pass		Pass		Pass	
Lot-12	Fail	hairiness	Pass		fail	hairiness
Lot-13	Pass		Fail	hairiness	fail	hairiness
Lot-14	Pass		Pass		Pass	
Lot-15	Pass		Pass		Pass	
Lot-16	Pass		Pass		fail	GSM discrepancy
Lot-17	Pass		Pass		Pass	
Lot-18	Pass		Pass		fail	Hand feel
Lot-19	Fail	Hand feel	Pass		Pass	
Lot-20	Pass		Pass		Pass	

APPENDIX-C

LEAD TIME DETAIL INFORMATION

Considered 20 lots for Lead time calculation.

Lot No.	SU A (Days)	SU B (Days)	SU C (Days)
Lot-1	13	16	6
Lot-2	14	17	7

Lot-3	13	15	6
Lot-4	12	15	8
Lot-5	15	16	7
Lot-6	13	17	7
Lot-7	13	14	6
Lot-8	15	15	6
Lot-9	16	14	6
Lot-10	12	15	7
Lot-11	13	16	8
Lot-12	12	14	7
Lot-13	12	15	6
Lot-14	12	16	8
Lot-15	14	16	7
Lot-16	13	14	6
Lot-17	13	17	8
Lot-18	15	15	6
Lot-19	15	16	6
Lot-20	12	14	8

APPENDIX-D

COST DETAIL INFORMATION

Considered latest yarn price:

Years	SU A FOB Price (USD/KG)	SU B FOB Price (USD/KG)	SU C FOB Price (USD/KG)
2017	3.50	3.20	3.70

APPENDIX-E

REPUTATION FOR EACH SUPPLIER

Considered below points for supplier reputation evaluation:

SU A	SU B	SU C
PT: TT 30 days	PT: TT Advance	PT: Sales contract
Company profile	Company profile	Company profile
History	History	History
Pro-activeness	Pro-activeness	Pro-activeness
Communication	Communication	Communication

APPENDIX-F

CAPACITY DETAIL INFORMATION

Considered supplier current capacity strength.

Capacity (KG/Month)		
SU A (Monthly)	SU B (Monthly)	SU C (Monthly)
950 Tons	650 Tons	720 tons

APPENDIX-G

PAIR WISE COMPARISONS OF ALTERNATIVES WITH RESPECT TO "LEAD TIME" CRITERIA

(9, 9, 9)	(7, 8, 9)	(6, 7, 8)	(5, 6, 7)	(4, 5, 6)	(3, 4, 5)	(2, 3, 4)	(1, 2, 3)	Criteria	(1, 1, 1)	Criteria	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	(5, 6, 7)	(6, 7, 8)	(7, 8, 9)	(9, 9, 9)
						Δ		A		B								
								A		C				Δ				
								B		C						Δ		

Alternatives	A			B			C		
A	1	1	1	2	3	4	0.166667	0.2	0.25
B	0.25	0.3333333	0.5	1	1	1	0.125	0.142857	0.166667
C	4	5.00	6	6.00	7.00	8.00	1	1	1

Alternatives	ri		
A	0.70	0.84	1.00
B	0.32	0.37	0.44
C	2.85	3.23	3.59
Total	3.87	4.44	5.03
Reverse	0.26	0.23	0.20
Increasing order	0.20	0.23	0.26

Alternatives	Wi		
A	0.14	0.19	0.26
B	0.06	0.08	0.11
C	0.57	0.73	0.93

Alternatives	Mi	Ni
A	0.20	0.19
B	0.09	0.08
C	0.74	0.72

APPENDIX-H

PAIR WISE COMPARISONS OF ALTERNATIVES WITH RESPECT TO "COST" CRITERIA

(9, 9, 9)	(7, 8, 9)	(6, 7, 8)	(5, 6, 7)	(4, 5, 6)	(3, 4, 5)	(2, 3, 4)	(1, 2, 3)	Criteria	(1, 1, 1)	Criteria	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	(5, 6, 7)	(6, 7, 8)	(7, 8, 9)	(9, 9, 9)
								A		B		Δ						
						Δ		A		C								
				Δ				B		C								

Alternatives	A			B			C		
A	1	1	1	0.25	0.33	0.5	2.00	3.00	4
B	2	3	4	1	1	1	4	5	6
C	0.25	0.3333333	0.5	0.17	0.20	0.25	1	1	1

Alternatives	ri		
A	0.80	1.00	1.26
B	1.99	2.44	2.85
C	0.35	0.41	0.50
Total	3.13	3.85	4.61
Reverse	0.32	0.26	0.22
Increasing order	0.22	0.26	0.32

Alternatives	Wi		
A	0.17	0.26	0.40
B	0.43	0.63	0.91
C	0.08	0.11	0.16

Alternatives	Mi	Ni
A	0.28	0.26
B	0.66	0.63
C	0.11	0.11

APPENDIX-I

PAIR WISE COMPARISONS OF ALTERNATIVES WITH RESPECT TO “REPUTATION” CRITERIA

(9, 9, 9)	(7, 8, 9)	(6, 7, 8)	(5, 6, 7)	(4, 5, 6)	(3, 4, 5)	(2, 3, 4)	(1, 2, 3)	Criteria	(1, 1, 1)	Criteria	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	(5, 6, 7)	(6, 7, 8)	(7, 8, 9)	(9, 9, 9)
								A		B		Δ						
						Δ		A		C								
						Δ		B		C								

Alternatives	A			B			C		
A	1	1	1	0.25	0.33	0.5	2	3	4
B	2	3	4	1	1	1	2	3	4
C	0.25	0.33	0.5	0.25	0.33	0.5	1	1	1

Alternatives	ri		
A	0.80	1.00	1.26
B	1.58	2.06	2.50
C	0.40	0.48	0.63
Total	2.78	3.55	4.39
Reverse	0.36	0.28	0.23
Increasing order	0.23	0.28	0.36

Alternatives	Wi		
A	0.18	0.28	0.45
B	0.36	0.58	0.90
C	0.09	0.14	0.23

Alternatives	Mi	Ni
A	0.31	0.29
B	0.61	0.57
C	0.15	0.14

APPENDIX-J

PAIR WISE COMPARISONS OF ALTERNATIVES WITH RESPECT TO “CAPACITY” CRITERIA

(9, 9, 9)	(7, 8, 9)	(6, 7, 8)	(5, 6, 7)	(4, 5, 6)	(3, 4, 5)	(2, 3, 4)	(1, 2, 3)	Criteria	(1, 1, 1)	Criteria	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	(5, 6, 7)	(6, 7, 8)	(7, 8, 9)	(9, 9, 9)
				Δ				A		B								
						Δ		A		C								
								B		C		Δ						

Alternatives	A			B			C		
A	1	1	1	4.00	5.00	6	2	3	4
B	0.166667	0.2	0.25	1	1	1	0.25	0.333333	0.5
C	0.25	0.33	0.5	2	3.00	4	1	1	1

Alternatives	ri		
A	1.99	2.44	2.85
B	0.35	0.41	0.50
C	0.80	1.00	1.26
Total	3.13	3.85	4.61
Reverse	0.32	0.26	0.22
Increasing order	0.22	0.26	0.32

Alternatives	Wi		
A	0.43	0.63	0.91
B	0.08	0.11	0.16
C	0.17	0.26	0.40

Alternatives	Mi	Ni
A	0.66	0.63
B	0.11	0.11
C	0.28	0.26