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-SHORT COMMUNICATION-

Jute Yarn Consumption Prediction by Artificial Neural Network and Multilinear Regression

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Abstract

In today's increasing competitive market conditions, the companies operating in the production and service sectors should meet the demand of the customers in a timely and completely manner. Therefore, all resources (raw materials, semi-finished products, energy sources, etc.) should be planned and supplied at the right time, at the right place and at sufficient quantity based on an accurate forecast of the demand. In the literature, there have been few studies about forecasting of raw material consumption in a production sector. In this study, ANN method was employed to predict the raw material consumption of a carpet production company. The relevant variables of the actual data belonging to 2015-2016 and 2017 were used. In addition, a multiple linear regression (MLR) model was also established to compare the performance of ANN method. The results show that ANN method produces more accurate forecasts when compared to MLR method.

Keywords: Artificial Neural Network (ANN), Multiple Linear Regression (MLR), Raw Material Consumption

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Introduction

ANN method is one of the most widely used methods in recent years. Actually, in the literature, there are so many studies about ANN method from different science areas and also for distinct application studies. ANN method was used to solve MRP (Material Requirement Planning) problem of lot-sizing (Gaafar&Choueiki, 2000). Hwarng (2001) studied about ANN to understand better the modelling and forecasting ability of back propagation neural networks (BPNNs) on a special class of time series to improve performance. As a result of this study, when compared Box-Jenkins model BPNNs generally performed well (Hwarng, 2001). Zhang et. al. presented an article about a simulation study of artificial neural networks for nonlinear time series forecasting. In this study, they examined the effects of three factors which are input nodes, hidden nodes, and sample size. As a result of this study, the number of input nodes is much more important than the number of hidden nodes (Zhang, Patuwo, & Hu, 2001). In another study ANN method was used for ABC classification of stock keeping units (SKUs) in a pharmaceutical company and compared with the multiple discriminate analysis (MDA) technique. The results indicated that ANN models had higher predictive accuracy than MDA (Partovi&Anandarajan, 2002). In 2002, Daniel J. Fonseca and Daniel Navaresse studied about ANN method for job shop simulation. As a result of this study, ANN-based simulations were able to fairly capture the underlying relationship between jobs' machine sequences and their resulting average flowtimes (Fonseca &Navaresse, 2002). G. Peter Zhang studied about a hybrid methodology that combines both ARIMA and ANN models in linear and nonlinear modeling. The results of this study showed that the proposed combined model can be an effective way to improve forecasting accuracy (Zhang, 2003). In another study, G. Peter Zhang and Min Qui studied about ANN method forecasting for seasonal and trend time series. They investigated the effectiveness of data preprocessing , that includes deseasonalization and detrending (Zhang & Qi, 2005). Another combined method of ANN was studied by Azadeh et. al. In this study, integrated genetic algorithm (GA) and ANN methods were used to estimate and predict electricity demand using stochactis procedures (Azadeh, Ghaderi, Tarverdian, &Saberi, 2007). Henry C. Co and RujirekBoosarawongse studied about forecasting Thailand's rice export by using ANN with exponential smoothing and ARIMA models. The results showed that ANN performed relatively well (Co &Boosarawongse, 2007). In another study, ANN prediction method was used to optimize work-in-process inventory level for wafer fabrication. This study about finding an optimal work-in-process (WIP) value of wafer fabrication processes, which can be properly used to trigger the decision of when to release wafer lots, by integrating ANN and the sequential quadratic programming (SQP) method. The result of this study show that the offered integrated method is greatly improved finding the optimal WIP level (Lin, Shie, & Tsai, 2009).

The focus of this study is the accurate estimation of the consumption amount of the jute, which is one of the most basic raw materials in carpet production. The raw material of jute grows in India. This means carpet production companies supply jute from India by sea shipment. The fact that jute is provided in about 6 months by sea trade makes it important to estimate the amount of jute that will be needed. Accurate estimation of the amount of raw material consumption ensures that customer demands are met in a timely and complete manner, thus leading to competitive market conditions.

The most basic methods used in the estimation are statistical estimation methods. However, these statistical methods may be inadequate in view of increasing uncertainties and dynamic economic conditions. At this point, the method of ANN which have been successful and widespread in recent years, steps in.

In this study, two methods are used in order to forecast raw material consumption. One of the methods is ANN, which is the most popular and wide-ranging methods in recent years. The method of ANN has many advantages. The main advantage is that the ANN method can be used for nonlinear problems and most of the real world problems are nonlinear. Also, ANN method is applicable to different problems from distinct areas for both service and production sectors. In addition to this, a neural network has more fault tolerance when compared to traditional methods because of its parallel connections of neurons. The other method is one of the statistical methods of MLR. For ANN method, the Neural Network Toolbox of MATLAB software was used while, the Minitab program software was executed for MLR approach.

The required data have been taken from one of the carpet production company located in Gaziantep. Data belongs to the years 2015- 2016 and 2017.

Graphs and figures have been used to illustrate the results of two employed approaches. In order to compare the performance of two methods, MSE, R^2 and adjusted R^2 performance indicators have been used. And the results show that ANN values for performance indicators are better than MLR method.

Data Used in The Study

In this study, the amount of the jute yarn used, which is one of the most basic raw materials used by a carpet production company, has been estimated for the future. For this purpose, 246 data points (actual values) were used for 11 different types of jute on a monthly basis.

For analysis of the raw material consumption of the future, 6 input variables were selected. These 6 input variables were selected because of their relation with the total jute consumption and decided with supply chain director of the company. These variables and their statements are as given in Table 1.

Table 1. Variables definition table

Variable Symbol	**Variable Name**	**Statement**
X_1	Jute Type	There are 11 types of jute to be used in different carpet models. The main differences between different types of jutes are the thickness and the number of yarn layers.

X_2	Purchasing Price	The purchase price of jute of different quality (different thickness and number of floors) is different. In addition, a jute type of the same quality can be obtained from different companies. In this case, the weighted average of purchase prices based on order quantity was used.
X_3	Exchange Rate	As the buying prices are in $ terms, the exchange rate input is used. This data is taken from the official web address of the Central Bank of the Republic of Turkey.
X_4	Amount of Stock	The monthly stock of each type of jute varies.
X_5	Production %	Different types of jute are used in the production of different carpet models. The production m^2 of these carpets are kept separately in the ERP system used by the company. The 'production %' shows percentage of the stated jute in the total amount.
X_6	Average Consumption in 1 m^2	In different carpet models, even if the same type of jute is used, the amount of consumption can be different. While the average consumption is taken in this data type, weighted usage is calculated on the basis of m^2 produced.
Y	Amount of Consumption on the Basis of Jute Type	Dependent variable calculated according to 6 independent input variables

An example of data that has been used is given in Table 2.

Table 2. Sample of the raw data used in application

Jute Type	Purchasing Price ($)	Exchange Rate	Amount of Stock (tons)	Production %	Average consumption in 1 m^2	Purchasing Amount (tons)
1	1.38	2.46	15.639	4.228	0.52313	26
2	1.18	2.46	32.225	15.123	0.80209	78
3	1.15	2.46	89.413	20.474	0.77556	104
4	0	2.46	41.217	0.529	0.75833	0
5	1.125	2.46	5.414	8.556	0.73667	52

Since the types of data used ($, ton, kg) are different, they must be subjected to normalization before being used in the software. In addition, normalization of the data, makes ANN method much more meaningful to be used in the solution of nonlinear problems. ***Min_Max normalization method*** was used to normalize the data. In this method, Min is the smallest value in a data type; Max represents the highest value in this data type. With the Min_Max method, the data is reduced to a range of 0 to 1. The formula used for normalization is shown in Eq.1:

$$X' = \frac{Xi - Xmin}{Xmax - Xmin} \quad (1)$$

The data shown in Table 2 after the normalization process is as in Table 3.

Table 3. Normalized values of the data shown in Table 2

Jute Type	Purchasing Price	Exchange Rate	Amount of Stock	Production %	Average Consumption in 1 m^2	Purchasing Amount
0	0.951724	0	0.05145	0.11142	0.52313	0.1
0.1	0.813793	0	0.11588	0.39856	0.80209	0.3
0.2	0.793103	0	0.29416	0.53958	0.77556	0.4
0.3	0	0	0.13560	0.01394	0.75833	0
0.4	0.775862	0	0.01781	0.22549	0.73667	0.2

Forecasting with Artificial Neural Network Method

In this study, ANN method was used for the estimation of the amount of raw material for jute feed. Feed forward and back propagation multilayer ANN model is preferred for the solution of this problem. In a feed forward neural network, the direction is towards from input layer to output layer. Most widely used ANNs in forecasting problems are multilayer

perceptron (MLPs) (Hamzacebi, 2008). MATLAB software was used for the training and testing of the networks created for this purpose.

As the first stage of the problem solving, data were divided as training, validation, and testing as in the following percentages. These percentages are default values of Neural Network Toolbox of MATLAB software:

- Training = 70 %
- Validation = 15 %
- Testing = 15 %

The number of neurons, activation function and training algorithm parameters in the hidden layer constituting the structure of the ANN affect the performance of the resulting network. For this reason, models with different network structures and learning parameters were established and experiments were made and the obtained results were compared. The most suitable network for the problem has been found by trial and error. As a result, the properties of most appropriate network are given in Table 4.

Table 4. Properties of network structure

Network Type	Feed forward – back propagation
Training Function	TRAINLM
Adap. Learning Function	LEARNGDM
Number of Hidden Layers	1
Number of Neurons	10
Transfer Function	LOGSIG
Epoch	500

MSE and regression graphs that have been obtained with the most appropriate ANN are shown in Figure 1 and Figure 2, respectively:

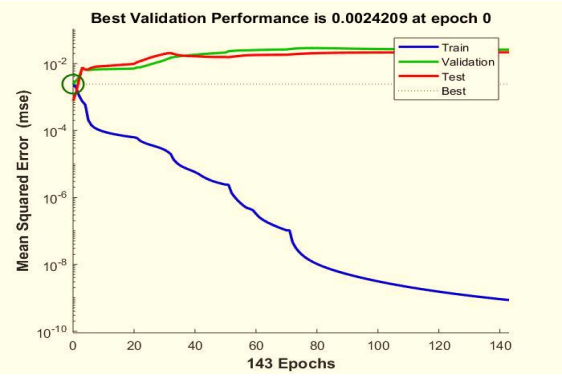

Figure 1. MSE graph of neural net

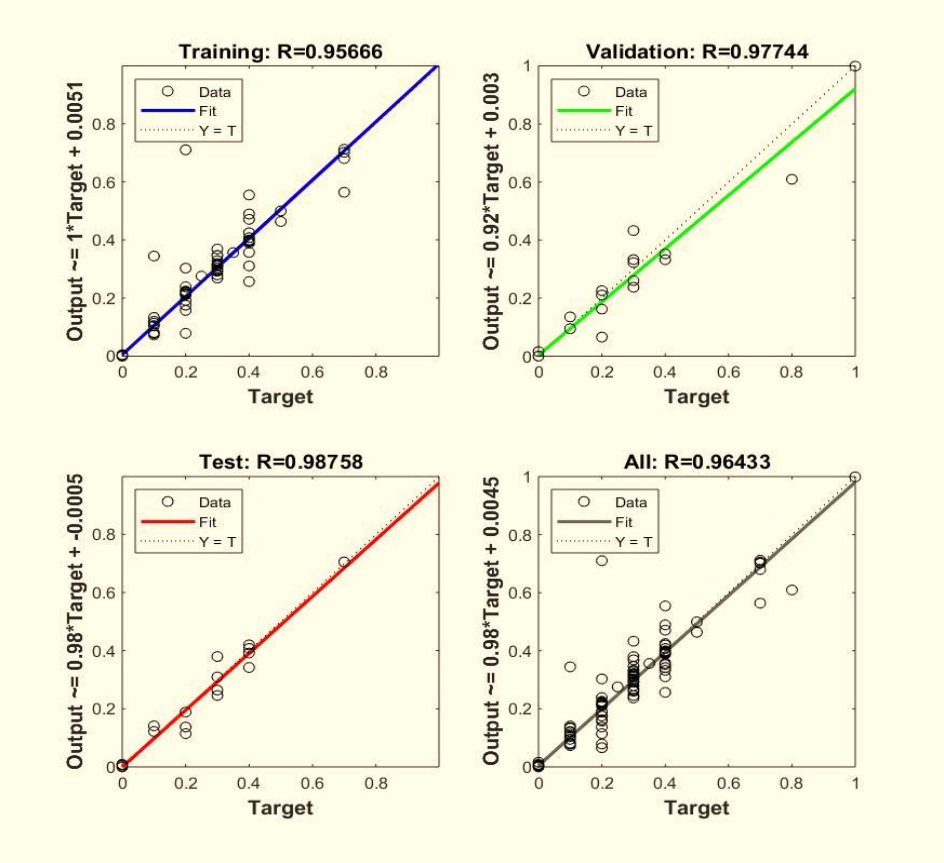

Figure 2. Regression graphs of neural net

MLR method was used in order to compare performance of the ANN method. The performance indicators to compare two methods are MSE, R^2, and adjusted R^2.

Adjusted R^2 formulation is given in Equation 2.

$$R - sq(adj) = 1 - (1 - R^2)(\frac{n-1}{n-k-1}) \quad (2)$$

where;
n = sample size
k = number of independent variables
R^2 = coefficient of determination
All three performance indicators of ANN method is given in Table 5.

Table 5. Performance indicators of the neural net

Performance indicator	
MSE	0,00265
R^2	0,9604
Adjusted R^2	0,9845

Forecasting with Multiple Linear Regression Method

In forecasting with MLR approach, Minitab software is used. The same 246 data points were used for MLP study and performance indicators that are MSE, R2 and adjusted R2 were calculated in order to compare with ANN method.

In order to apply MLR method for any problem, the independent variables in the model should satisfy multicollinearity constraint. One of the methods to measure multicollinearity is known as the variance inflation factor (VIF). When multicollinearity increases, the VIF value increases.

In this study, 246 data points were executed in the Minitab software and obtained VIF results are given in Table 6.

Table 6.VIF values of independent variables

Variable Name	VIF Value	Variable Name	VIF Value
Purchasing price	1,26	Jute type 4	2,15
Rate	1,01	Jute type 5	2,22
Amount of stock	1,2	Jute type 6	2,51
Production %	3,43	Jute type 7	2,23
Avg. consumption in 1 m^2 carpet	1,47	Jute type 8	2,17
Jute type 1	1,3	Jute type 9	2,29
Jute type 2	2,44	Jute type 10	3,33
Jute type 3	2,62	Jute type 11	2,41

As it can be seen from Table 6, all of the VIF values for independent variables are less than 5. Therefore, it is concluded that there is no multicollinearity among all x variables and ensure necessary condition.

In addition to multicollinearity condition, significance of overall regression model should be checked to ensure whether the overall model is significant. The F-test is a method for testing whether the regression model explains a certain proportion of the variation in the y, dependent variable. The formulation of F-test is given in Equation 3:

$$F = \frac{\frac{SSR}{k}}{\frac{SSE}{n-k-1}} \quad (3)$$

where;
SSR = sum of squares regression

SSE = sum of squares error
n = sample size
k = number of independent variables
degrees of freedom = $D^1 = k$, and $D^2 = (n-k-1)$

The result of analysis of variance is given in Table 7.

Table 7. Analysis of variance result for MLR

Source	DF	Adj SS	Adj MS	F-value	P-value
Regression	15	6,16582	0,41105	53,89	0,000
Error	230	1,75451	0,00763		
Total	245	7,92033			

The null and alternative hypotheses are given below:

$H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$
H_A = At least one $\beta i \neq 0$

If the null hypothesis is true and all the slope coefficients of independent variables are equal to zero, the overall regression model is not appropriate for predictive applications.

Other necessary parameters to perform F-test are given as follows:

Criticial $\alpha = 0.05$
$k = 6$
$n - k - 1 = 239$ degrees of freedom

F-table value is equal to approximately 2,14.

$F = 53,89 > 2,14$

Therefore, H_0 is rejected and it can be concluded that the overall regression model explains a significant proportion of the variation.

As a result; MSE, R^2 and adjusted R^2 values for multiple linear regression method is as given in Table 8.

Table 8. Performance indicators of MLR

Performance	Regression results
MSE	0,00713
R^2	0,7785
Adjusted R^2	0,7640

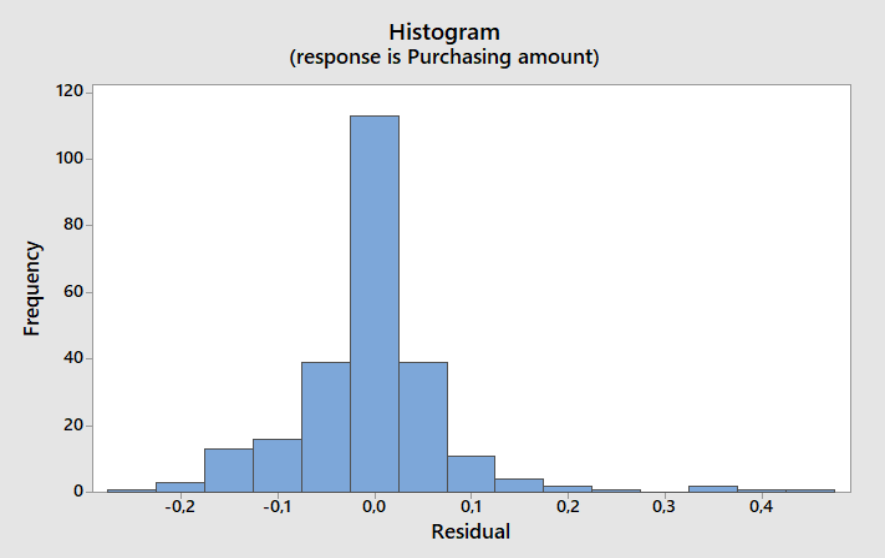

Figure 3. Histogram plot of residuals

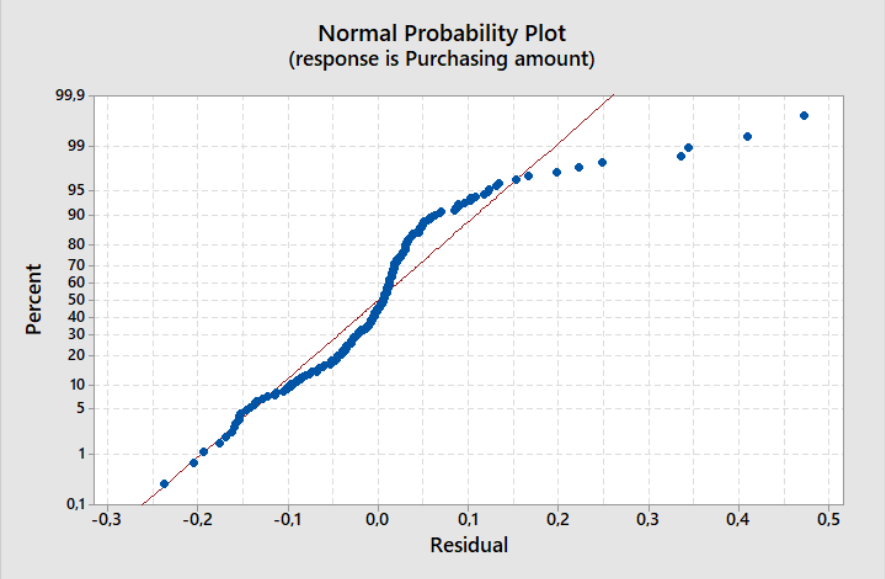

Figure 4. Normal probability plot of residuals

Relative results of ANN and MLR models according to MSE, R^2 and adjusted R^2 is given in Table 9. As it can be seen from the table, the ANN model more successful than MLR method according to performance indicators' values.

Table 9. Relative results of ANN and MLR methods

Performance indicator	**Results of ANN model**	**Results of MLR model**
MSE	0,00265	0,00713
R^2	0,9604	0,7785
Adjusted R^2	0,9845	0,7640

Conclusion

In this study, a real world business problem has been solved by using two methods, ANN and MLR. As a result, it is concluded that the results of ANN method are much closer to actual values when compared MLR and therefore ANN seems to be more appropriate for dynamic real world conditions. In this study, the ANN method has been shown to be a reliable method in estimating jute consumption. In addition, by using this method customer demands can be estimated roughly and thereby they can be met in timely manner. In this respect customer satisfaction can be increased. As a future work, this method can be extended to include several macro level parameters like the interest rate. The proposed approach can be applied to other manufacturing sectors for forecasting the possible raw material consumption.

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