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PREDICTING ANNUAL ELECTRICITY CONSUMPTION IN IRAN USING ARTIFICIAL NEURAL NETWORKS (NARX)

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ABSTRACT

In this study, a method for predicting annual electricity consumption in Iran based on economic criteria using Artificial Neural Networks has been proposed. So as, narx neural network receives variables of population, GNP, import and export as the input and its output is annual electricity consumption in Iran. To test and evaluate designed network, data from 1983 to 2010 have been collected which data due to 4 last years have been used to test network performance. To investigate the accuracy of designed network prediction, 2 models, Time Series ARIMA model and Perceptron Neural Network have been designed. Comparing results shows that Narx neural network has more ability to predict Iran electricity consumption. Another objective of this research is to study the effect of new factors such as performing Subsidy Reform and sanctions plan in the Iran annual electricity consumption in 2011. Therefore, with using obtained model, the Iran annual electricity consumption in 2011, if these factors are not performed, has been predicted. Also, it is shown that these factors cause to decrease Iran annual electricity consumption.

KEYWORDS: Predicting Electricity Consumption, Narx Neural Network, Time Series ARIMA Model, Perceptron Neural Network, Subsidy Reform and Sanctions Plan

Electricity power is accounted one of the most important powers in the today modern life and it is effective on welfare level and also the quality and efficiency of job and production. Due to the importance of electricity power, governments and organizations related to it in the developed and developing countries have greatly paid attention to the prediction of electricity consumption. Mistake in predicting electricity consumption can cause making added capacities or shortage of electricity and this issue leads to a great deal of costs. Demand and electricity consumption in Iran is rapidly increasing. Increase in population, economic growth and increase in urban life are imperative factors in electricity consumption in Iran. Statistics show that electricity consumption in Iran between 1981 and 2005 has been 9 times increased. During these years, electricity production, productive capacity, transfer capacity and the length of electricity lines are 9.4, 5.3, 6.9 and 7.8, respectively. Also, in this period, the number of electricity customers has 5 times increased and Iran population has 2.1 times increased. Due to presented statistics, number of electricity customers in 2005 has been 19.5 persons. In this year, electricity consumption percapita has been 143 kilowatt/ hour, while percapita electricity production is 122 kilowatt/hour [1]. Therefore, statistics indicate that electricity consumption in Iran is rapidly increasing. That's why, electricity power industry has to have accurate statistic from predicting electricity consumption in order to be able to provide required electricity power. To achieve an accurate model to predict annual electricity consumption, it is needed to consider two important points in its designs procedures. The first point is to identify effective factors on electricity consumption. In this study, factors such as time, population, GNP and import and export have been used as the input variables to predict electricity consumption. The relationship between electricity consumption and the population is transparent, because increase in population definitely cause increase in electricity consumption. The rate of import and export in any country indicates the industrial activities. Increase in import and export causes increase in the industrial activities. Subsequently, increase in the industrial activities requires increase in electricity consumption. Finally, GNP which is the criterion to measure all activities of a country and its growth indicates the improvement in the welfare level which is certainly led to the increase in energy consumption.

The second point is to choose an appropriate tool in order to resolve the problems in the context of electricity consumption prediction. One of the current problems in this context is this issue that the relationship between input and output variables is nonlinear and this relationship is not clear. So, defining a relation with mathematic structure between input and output variables which its parameters can be estimated by a series of calculations such as regression is not simple. In this type

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of issues, tools like Artificial Neural Networks which can determine such nonlinear relations with any desirable accuracy, are used. To predict, different methods like Artificial Neural Networks [2, 3 and 4], time series [3], fuzzy logic [5, 6], genetic algorithm [7], regression [8] and other methods have been used. Artificial Neural Networks has various applications in modeling and nonlinear systems simulation. One of the most useful and considerable aspects of Artificial Neural Networks is to apply them to predict. Due to complicated and nonlinear mapping between a series of inputs and outputs, many researches in the context of short-term prediction of consumption like hourly and daily prediction [9, 11], the middle-term prediction of power consumption [3, 7, 10 and 12] and also long-term power consumption prediction [4, 13, 14] have been done using them. In the most of conducted researches in this context, Multilayer Perceptron Neural Network has been sued. One of the innovations of this study is to use Narx Neural Network. Narx is the new neural network which is applied in prediction of time series. Also, in the studies which have been done in the context of middle-term and long-term electricity consumption prediction, parameters such as population, GNP and import and export have been less used. In the [15] paper, it has been shown that using these parameters improve the results of electricity consumption prediction in the middle-term and long-term domain. In the following and the second part of the conducted studies, the predicting annual electricity consumption in Iran using neural networks will be reviewed. Proposed algorithm in this study to predict annual electricity consumption in Iran and sued methods will be described in the third pert. Then, in the fourth part, implementation of proposed method to predict electricity consumption will be expressed. Evaluating and comparing proposed method with Time Series ARIMA model and Perceptron Neural Network will be presented in the fifth part. In following, the annual electricity consumption in Iran in 2011 will be predicted and it is compared with the real values. Ultimately, research's conclusions have been brought in the seventh part.

LITERATURE REVIEW OF PREDICTING ANNUAL ELECTRICITY CONSUMPTION IN IRAN USING ARTIFICIAL NEURAL NETWORKS

Paper [7] has proposed a basis based on genetic algorithm and neural networks to predict electricity consumption. In this study, the proposed method to predict Iran annual electricity consumption has been implemented in the agriculture part. Data between 1981 and 2005 for training data and data between 2005 and 2008 have been used to test proposed model. Presented results in this study indicate that compared with regression methods, neural network has shown the better performance. Paper [3] has proposed a mode for predicting annual electricity consumption in Iran based on Neural Networks. In this study, monthly data of electricity consumption from 1994 to 2001 have been used and the last 12 data have been used for testing data. Perceptron Neural Network with 1-6-16-12 architecture has been selected as the best network and data relevant to the recent 12 months have been determined as the input data for the network. Ultimately, regression analysis method has been used to compare proposed method with the real data and data obtained from regression and presented results in this study show that prediction with neural network is more accurate.

Paper [4] has proposed a method based on neural networks to predict Iran annual electricity consumption in the industry sector. In this paper, to predict, criteria such as electricity cost, consumer numbers, weighted average price of fossil fuels, added value and the severity of electricity cost. Also, data relevant to the 1979 to 2003 have been used. Data from the 4 last years have been considered as the testing data. Comparing results obtained from proposed model with the real data and regression methods indicate better performance of neural networks.

In paper [12], prediction of annual electricity consumption in Iran has been done using neural networks. To compare it, neural network methods with simulated data and ARIMA method have been used. To implement the proposed method, monthly electricity consumption data in Iran from 1994 to 2005 have been used. In this paper, Perceptron Neural Network with 1-2-3 architecture has been used. Input data to the network includes data relevant to the previous 2 months and electricity consumption in the similar month of the last year. To comparison between proposed method with the real data and other methods indicates the superiority of neural networks.

Paper [6] has used a neural network with fuzzy inference engine to predict Iran monthly electricity consumption. Proposed method is able to identify the uncertainty and complexities of data, because the proposed method has exploited a combination of fuzzy logic and neural network. Data relevant to the Iran monthly electricity consumption from 1995 to 2005 have been used to implement the proposed model. To validate the model, the best ARIMA model, genetic algorithm and Perceptron Neural Network have been obtained. Comparing the proposed method with these methods indicate the better performance of neural network with fuzzy inference engine to predict Iran monthly electricity consumption.

Paper [16] has presented the combination method based on artificial neural networks, Principal Component Analysis (PCA), Data Envelopment Analysis(DEA) and variance analysis to predict monthly electricity consumption. In the proposed method in this paper, for the different methods of pre-processing and post-processing of data, different Perceptron Neural Networks have been designed. Then, performance of each network has been investigated using DEA method. Also in this paper, Principal Component Analysis (PCA) has been sued to choose the best input data. To implement the proposed method, the monthly electricity consumption data from 1992 to 2004 were used. The comparison between the proposed method and genetic algorithm methods, fuzzy regression, neural networks and neural networks with fuzzy interference engine has shown that the proposed method has presented the better results.

GENERAL TREND OF PROPOSED ALGORITHM

According to the aforementioned factors, in the current study, we intend to propose a model for predicting middle-term electricity consumption in order to perform required programming for providing electricity power based on that model. Also, one of the objectives we are following in this study is to investigate the effect of issues in 2011 such as the effect of Subsidy Reform project on the increase or decrease in electricity consumption. So as to investigate it, the real electricity consumption in 2011 has compared with estimated value by the proposed model in order to determine the increase and decrease in electricity consumption due to issues in 2011 such as Subsidy Reform project.

In this study, to predict electricity consumption, 3 methods of Narx Neural Network, Time Series ARIMA Model and Perceptron Neural Network have been used. So as, for 2 models of neural networks, data from population, GNP, import and export are considered as the effective factors on the electricity consumption. These data were collected from 1983 to 2010. For time series, also data relevant to the electricity consumption between 1985 and 2010 were used. Then, optima parameters for each model are estimated using current data in order to obtain the best prediction for each model. To determine this issue that the prediction of which method is closer to the real data, variance analysis is used to test the equity of means of values predicted by models and real data. If the null hypothesis was rejected in variance analysis test, we would take an advantage of Duncan’s multiple range test to determine this point that results obtained from which method is closer to the real data. Otherwise, a model that has the least Mean Absolute Percentage Error (MAPE) is chosen as the best model.

Narx neural system

Simple Recursive Neural Networks are the kind of Recursive Neural Networks which are similar to the leading networks, but they have the low number of Local / Global backward loops in their architecture. Leading networks like Perceptron Neural Network can be applied in solving problems related to the time series prediction with inserting delayed inputs. This set of networks is called neural networks with time delay which can be easily become Simple Recursive Neural Networks with returning the output neurons of hidden layers and output to the input layer which are known element and Jordan neural networks, respectively. It is important to mention that while the leading neural networks with time delay are applied for the long-term predictions, these networks ultimately will act like Recursive Neural Networks which need a loop to insert output values of network in each step into the next input of network [17].These kinds of networks are usually educated by the back-propagation algorithm based on the gradient, but educating these networks is so hard when there is the long-term time dependency between inputs and outputs [18]. Some of the researchers announced that educating networks by gradient decrease algorithms for such time dependency is more effective in the set of Recursive Neural Networks which is called nonlinear networks with external input (Narx) compared with leading Recursive Neural Networks. Because the input axis of these networks has two time delay lines: A: time delay for all inputs B- time delay for the network outputs [19].

Narxneural network is a kind of nonlinear time discontinuous systems which is mathematically shown as the (1) relation [20]:

y(n+1)=f[y(n),…,y(n-d_y+1) ;u(n),u(n-1),…,u(n-d_u+1)] (1)

u(n)∈R and y(n)∈R indicate the inputs and outputs of network in discontinuous time, respectively. . $d_u \geq$ and و $d_y \geq 1$، $d_u \leq d_y$ indicates the time delay in inputs and outputs, respectively. Squeezed form of above relation would be as following:

y(n+1)=f[y(n);u(n)] (2)

y(n) and u(n)vectors indicate input and output vectors.

In the general sense, there are 2 underlying forms of Narx network:

A- Series – parallel: we use this sense when we intend to do one-stage prediction. In this network, the next time stage prediction is done by real values of before time stages. in another words, the real output values ofbefore time stages are inserted into the network as the input vector which its mathematic form is as the following relation (3):

y □(n+1)=f □[y_sp (n);u(n)]=f □(y(n),…,y(n-d_y+1;u(n),u(n-1),…,u(n-d_u+1) (3)

This network architecture is also brought in the figure 1.

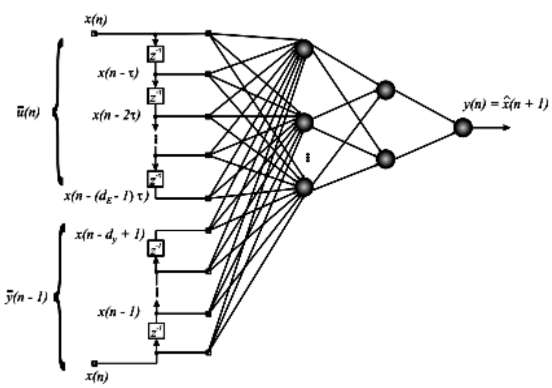

Figure 1: Narx network architecture (parallel-series)

B- Parallel: when we intend to do multistage prediction, this mode of network is being used which its architecture has been brought in the fig 2. In this case, prediction in each stage is being done based on outputs estimated by network in the previous stage. It means that to predict in any stage, network outputs in the previous stage is given to the network as the input data which its mathematic form is like the relation (4):

y □(n+1)=f □[y_p (n);u(n)]= f □[y □(n),…,y □(n-d_y+1);u(n),u(n-1),…,u(n-d_u+1)] (4)

Narx neural network has two senses: parallel-series and series which are respectively used for one and multi stage prediction. So as in the series-parallel, the real output values in each stage is given to the network as the input to predict the next time stage, but in the parallel stage, network has the close loop which the output values estimated by the network in each stage is given to the network as the input to predict the next time stage. So in this research, first Narx neural network in series-parallel sense is taught using current data.

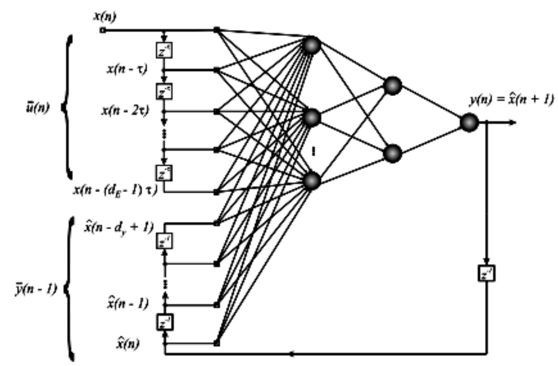

Figure 2: Narx network architecture (parallel)

Then, to test network performance, we change it to the parallel sense and then prediction is done by it and network error is calculated.

Perceptron Neural Network

Multi-layer feed forward neural networks and especially Multi-layer Perceptron Neural Networks are the most common artificial neural network. These networks with having the sufficient number of layers and number of neurons in their layers are capable to estimate each non linear mapping with disable estimation. Many networks have been recommended to be used in the prediction, but this network is the most successful and public network in the prediction [4]. General form of Perceptron Networks has 3 layers: input layer, latent layer and output layer. Input and output layers indicate the input and output variables of the model, respectively. Between these 2 layers, there are one or more latent layers which network ability in learning nonlinear relations between inputs and outputs is dependent on them. Data process in this network is in leading form and toward the output layer. General structure of this network has been brought in the fig 3. This network architecture is in this form: the input of each neuron is only form neurons of previous layers each neuron is connected to the next layer's neurons and has the complete connection. Each neuron can have the in dependent bias. Mathematic form of Perceptron network is as following:

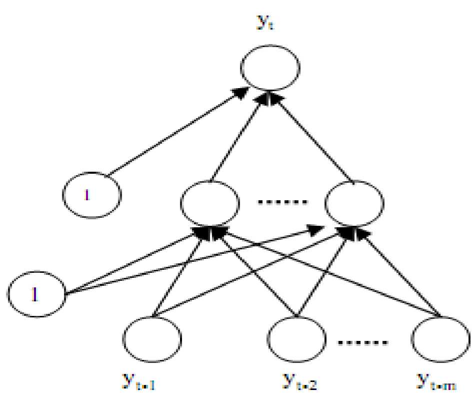

Figure 3: Perceptron neural network architecture

$$y\_t = \alpha\_0 + \sum_{j=1}^{n} \alpha_j f\left(\sum_{i=1}^{m} \beta_{ij} y_{t-i} + \beta\_0j\right) + \varepsilon_t \quad (5)$$

M is number of neurons of input layer, n is number of neurons of latent layer and f is Conversion function of neurons of latent layer.$\{\alpha_j, j = 0,1, \dots, n\}$ is the scale vector of neurons of latent and output layerand {β_ij,i=1,2,…,m;j=0,1,…,n} is the scale vector of neurons between input and latent layers. Also,$\alpha_0$and$\beta_{0j}$are the bias values which are constant and equal to 1. The most useful and desirable learning principle of perceptron networks is the Error back propagation algorithm which is considered as one of the learning methods with observation. In this method, primary values of all network scales are accidentally done. Then, the set of training data are given to the network and network outputs is compared with the real data. Now, if there is any difference between network outputs and the real data, network error is calculated and network scales are corrected using obtained error in order to minimize the Sum Squared Error (SSE) between network outputs and the real data [12].

Neural networks architecture is one of the underlying issues in different studies and is dependent on various factors which are:

A) Number of latent layers and their neurons.
B) Activation functions of latent and output layers.
C) Network learning algorithm.

Fundamentally, to design the network architecture, aforementioned factors are explained using trial and error method and the network with the least SSE is chosen as the best network.

ARIMA model

Box and Jenkins [22] have developed a method which its principals are based on a broad area of prediction models for the time series. This method chooses his model among a set of models which are called ARIMA and with the systematic method. The future values of a linear function variable are from the various past observations and random errors. ARIMA mathematic model is as (6) relation:

$$\not{c} \quad (6)$$

$$\not{c}$$

$$\theta$$

L is the operator which is defined as$L^k y_t = y_{t-k}$andε_t is the prediction error which has the zero mean and constant variance. This relation is popularized as ARIMA(p,q) which p and q indicatereturn parameters and moving average, respectively. These models and tools used in are merely applied in static time series. So, before analyzing a non-static time series by this model, it has to become a static series using differentiation methods.

ARIMA model is being made through 3 stages: At the first step, some of models among the generic group of ARIMA models based on the relevant criteria, without specific rules and based on the judgment and experience of the analyst are identified which generally to identify the kind and the rank of model, charts of Autocorrelation function and Partial autocorrelation function are being used. To measure stagnation and eliminating trend, generalized Dickey - Fuller test is being used. At the second step, parameters of identified models are estimated and tested which in this study; linear least squares method has been used. To choose the best model, Akaike information criteria and Schwarz Information Criterion are taken advantage. The third step is the reviewing recognition phase model (residuals test). In this step, efficiency (check the studied random model errors) is measured. In this study, Ljung-Box test is being used. If the estimated model is not efficient, another model is chosen. Ultimately, after recognition the best model, we use it to predict the future values of time series.

Data preprocessing

In some cases, if it was the appropriate process over the data inputted in network and the values of goals according to it, an appropriate conversion (preprocessing) would be happen. Network shows the better performance. So that, after conversion on the data and network training with converted data, each time it is needed to insert new data into the network like testing data, performed conversion have to be done over these data again or data are re-scaled. Different conversions in different researches have been proposed, but since the input data in this study have different scales, it is needed to use a method to re-scale the input data. So following conversions are being used:

Linear normalization of data in[L,H] distance

In this method, a conversion will happen over input data which are located in[L, H] distance. This action is done using relation (7):

$$X\_n = (X\_i - X\_min)/(X\_max - X\_min\ ) * (H - L) + L, i = 1,2, \dots, N \qquad (7)$$

In this relation, X_i is the real value of network input andX_n is the normalized form corresponding to it.$X_{min}$and$X_{max}$are the minimum and the maximum values of X_is,respectively.

Standard normalization of data to the zero mean and 1 standard deviance

This normalization method has many usages in the statistic which is obtained using data difference from mean and dividing it into standard deviance:

$$X \qquad (8)$$

In this method, values less than mean have negative value; equals to mean have the zero value and more than mean have the positive value. This method will map the data in (-4, 4) distance with zero mean.

Logarithmically data conversion

Logarithmically data conversion relation is as (9) relation:

$$X_n = log(X_t) - log(X_{t-1}) \qquad (9)$$

PREDICTING ANNUAL ELECTRICITY CONSUMPTION IN IRAN

This study aims to predict annual electricity consumption in Iran using population, GNP, import and export variables .so, the relation between these factors with electricity consumption has to be estimated. Fig 4 shows the general state of studied problem in this study. Since, the relationship between these factors with electricity consumption is nonlinear and vague and also to find the time dependency in electricity consumption and the effective factors on it to predict the electricity consumption in t time$\hat{y}_t$, data related to the last year) $x_{1,t-1}, x_{2,t-1}, x_{3,t-1}, x_{4,t-1}, y_{t-1}$ and two years ago) $x_{1,t-2}, x_{2,t-2}, x_{3,t-2}, x_{4,t-2}, y_{t-2}$ (were used.

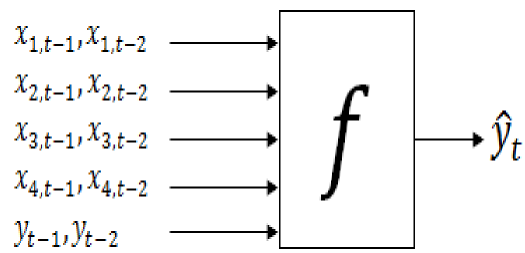

Figure 4: The general state of electricity consumption prediction issue

Annual electricity consumption in Iran between 1982 and 2010 has been collected. Also, effective factors including population, GNP, import and export in Iran in this duration have been accumulated which have been used as the network input in order to predict electricity consumptions. To investigate the network performance, data are categorized into two categories of testing and training data. Training data are used for teaching network and testing data are used to study the network performance. Fundamentally, when the data size is high, a set of testing and training data are being randomly chosen among the current data. When the data size is low, testing and training data are conveniently chosen. Also, it is needed to balance between the size of training and testing set. In this study, due to studying annual electricity consumption, the data size is not vast. Testing and training data were chosen so as data related to the 1983 to 2006 (24 years) were considered as the training data and data related to the 2007 to 1010 were considered testing data. In following, we trend to design two neural networks to predict the Iran annual electricity consumption. As it was previously expressed, 3 following factors in designing neural networks have to be determined:

Number of neurons and network latent layers

Activation functions of latent and output layers of network.

Training network algorithm

So that, different Narx neural networks according to number of layers and different neurons and conversion functions were produced and error of each imprecating testing data were calculated. Also, the effect of data preprocessing on the network performance was calculated. Results obtained from the best networks have been given in table 1.To compare networks performance, 2 criteria of coefficient of determination which are shown by and Mean Absolute Percentage Error were used. Increase in coefficient of determination and decrease in Mean Absolute Percentage Error shows the improvement in network performance.

With using different conversion functions for input and latent layers when hyperbolic tangent function is used for the latent layers and linear function for the output layer, the better results will be obtained. Also in different repetitions, this conclusion is reached that using more than 2 latent layers for networks causes a problem called "overall adaptation" and network is not able to predict testing data. Plus, to teach the network, Levenberg - Marquardt algorithm has been used. As the results show, Narx neural network with one or two neurons in the first and the second latent layer, respectively that has the hyperbolic tangent conversion function in its latent layer and linear function in its output layer is educated by Levenberg - Marquardt algorithm. Also, we came to this conclusion that logarithmical preprocessing over the input data has the least error.

Table 1: Results obtained from Narx neural network

Preprocessing								**Number of neurons**	
Logarithmical conversion		**Standard conversion**		**Linear conversion**		**Standard**		**Second latent layer**	**First latent layer**
MAPE		MAPE		MAPE		MAPE			

Figure 5 shows the predicting annual electricity consumption in Iran using chosen network.

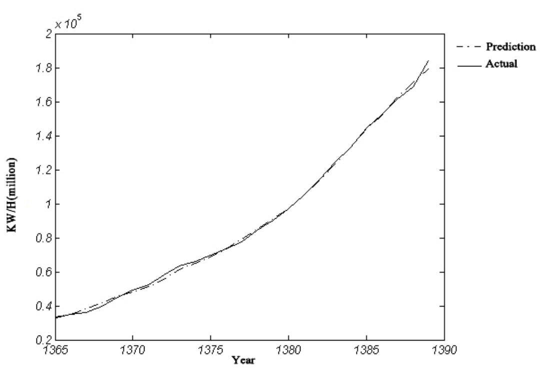

Figure 5: Predicting annual electricity consumption in Iran using Narx neural network

At the first step, a base Perceptron Neural Network is designed and then the best parameters of network are obtained using trial and error and Repeated Measures. So, the base network includes 4 neurons in input layer (effective factors on electricity consumption: population, GNP, import and export) and one neuron in the output layer. Levenberg - Marquardt algorithm is used to educate network. Number of latent layers is the maximum two and number of neurons for these layers is chosen the maximum 3, because more increase in neurons causes to happen overall adaptation. To design Perceptron Neural Network using trial and error, it was determined that using more than 2 latent layers for networks causes overall adaptation problem and using hyperbolic tangent conversion function for latent layers and linear functions for output layers will bring the best results. For Perceptron Network also, the effect of data preprocessing on network performance and number of neurons of each latent layer was calculated. Results show that the architecture of the best Perceptron Network is as following: Two latent layers with hyperbolic tangent conversion function which each one has one neuron and its output layer has the linear conversion function, While standard normalization is applied over the input data. Also, standard normalization is applied over the input data. Also, Levenberg - Marquardt algorithm has been used to educate network. The coefficient of determination and error absolute average for this network is 94.62 and 0.0153, respectively. Fig 6 shows the predicting annual electricity consumption in Iran using Perceptron Network.

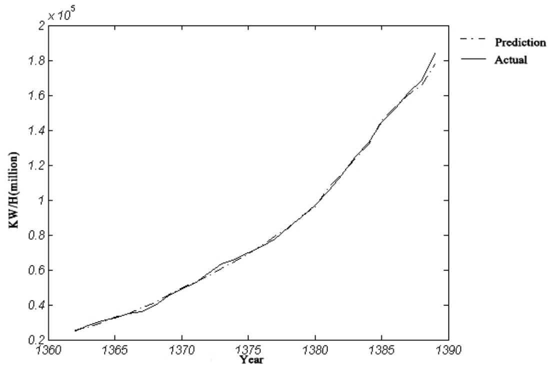

Figure 6: Predicting annual electricity consumption in Iran using Perceptron Network

To build ARIMA model, data from Iran annual electricity consumption from 1957 to 2010 (in total 44 years) have been used. Data related to the last 9 years (2002 to 2010) are allocated as the testing data and the rest of data are allocated to the modeling. Figure 7 shows the data chart related to the Iran electricity consumption. As it is clear in the fig 7, data are not clear static and has the increase trend. So, it is needed to use conversion over it. For this purpose, two differencing and logarithmic conversions are done over data. Following charts shows the data autocorrelation function with twenty intervals.

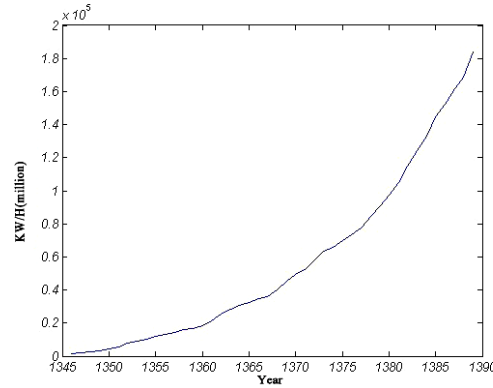

Figure 7: Data related to Iran annual electricity consumption from 1957 to 2010

As fig 8 (A) shows, autocorrelation function for data with logarithmical conversion is exponentially decreased. Therefore, it seems that data are static. To be more certain, Dickey-Fuller test is being used. P-value obtained from this test is equals to 0.0312. Since this value is less than 0.05, null hypothesis can't be rejected. It means that data don't have unique root and are static. Autocorrelation function for data with the firs differentiation conversion indicates this issue that data are not static. Also P-value obtained from Dickey - Fuller test is equal to 0.6392. This value indicates that null hypothesis can't be rejected and data are not static.

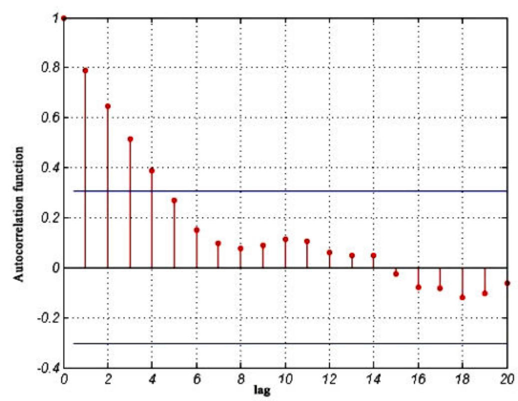

Figure 8: Autocorrelation function for data with logarithmical conversion (A)

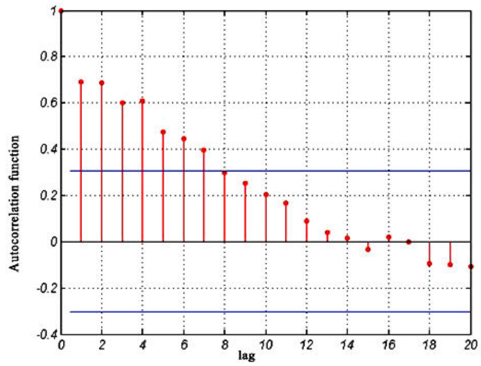

Figure 8: Autocorrelation function for data with the first conversion (B)

Now, it is the time to identify the model kind and rank. To do this, ACF and PACF charts are being used which are given in fig (A) and fig 9, respectively.

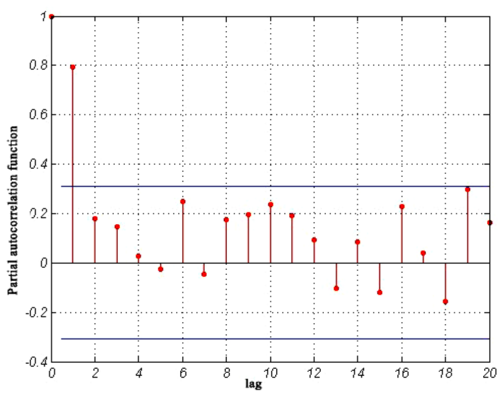

Figure 9: Partial Autocorrelation function for data with logarithmical conversion

Due to charts of Autocorrelation and partial Autocorrelation function, for auto-return rank p= 1, 2 and for the moving average rank q= 1, 2, 3, 4, 5, have been considered to estimate and determine the parameters of primary model. Therefore, 18 primary models are chosen to be studied. In the next step, parameters of primary models are estimated. Those categories of models which their coefficients are not in [-1, 1] domain, are eliminated. After determination of acceptable models, among them, the best model based on AIC and SBC criteria are chosen that results show that ARIMA (1, 5) model has to be chosen.

At the end, to check the chosen random model‘s residuals, Ljung-Box test is being used which has been shown in table 2 in 3 legs, 12, 18, 24.

Table 2: Ljung-Box test to check the chosen random model‘s residuals

p-value	Critical value	Freedom degree	Statistic Q	Leg

As it is shown in table 2, in all 3 cases, testing statistic value is less than critical value (P-value> 0.05). So, null hypothesis is not rejected and shows the random residuals. Therefore, the final model is ARIMA (1, 5) model. In fig 10, prediction of annual electricity consumption in Iran has been shown.

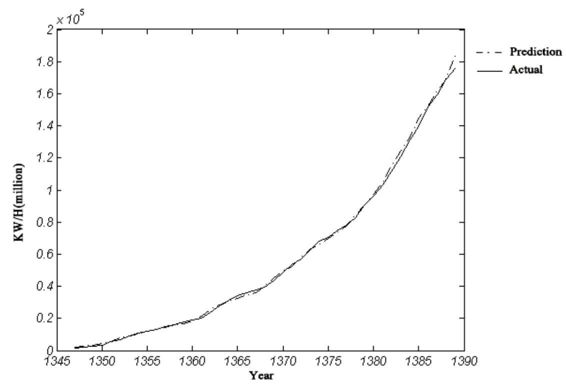

Figure 10: Prediction of annual electricity consumption in Iran

COMPARISON AND EVALUATION OF PREDICTION MODELS

So far, 3 models for predicting annual electricity consumption in Iran have been proposed using Narx Neural Network, Time Series ARIMA Model and Perceptron Neural Network. In these models, parameters are determined so that the best sense for predicting electricity consumption is obtained. Predicting obtained from each of models has been brought in table 3.

Table3: Predicting electricity consumption by obtained models

MAPE	Year				Model
	2010	2009	2008	2007	
					Real data
					Narx Neural Network
					Perceptron Neural Network
					ARIMA Model

To compare the mean of values obtained from prediction of 3 designed models, variance analysis test is being used which investigates 2 following hypotheses:

indicate the average of valuesestimated by real data,Narx Neural Network, Time Series ARIMA Model and Perceptron Neural Network and confidence level of %5 is chosen for the test. If null hypothesis was not rejected, the model which has the least MAPE error would be chosen as the best model. Otherwise, with rejecting null hypothesis, Duncan's multiple range tests is used to determine the best model. Results obtained from variance analysis test have been brought in table 4:

Table 4: Results obtained from variance analysis test

p-value	F Value	Square of mean	Freedom degree	Square of sum	Changes resource
0.9053	0.18	2.438e+7	3	7.315e+7	Intergroup
		1.326e+8	12	1.591e+9	Block
			15	1.664e+9	Sum

As it is shown in table 4, null hypothesis is not rejected (the average of real data and 3 prediction models are equal). So, Narx neural model which has the least MAPE error is chosen as the best model.

Prediction of 2011 and Comparison with the Real Statistic

As it was previously mentioned, in this study, we intend to study the effect of issues and factors of 2011 such as Subsidy Reform project and sanction on the annual electricity consumption in Iran. So, in this part, we estimate the electricity consumption using designed Narx neural network. Fig 11 shows this prediction.

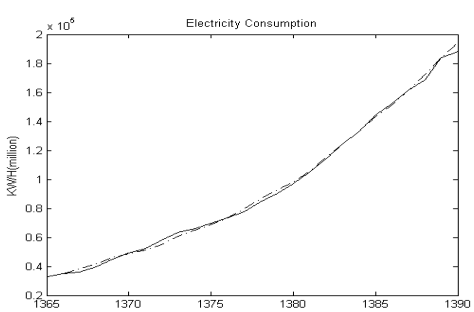

Figure 11: prediction of electricity consumption in 2011

Also, the numerical value of annual electricity consumption in Iran has been given in table 5.

Table 5: Real and prediction value of electricity consumption in 2011(KW/H)

Prediction value of electricity consumption in KW/H 2011	Real value of electricity consumption in 2011 KW/H

As results in table 5 shows, prediction shows that electricity consumption in 2011 has to be around 194845MKW/ H, but with performing Subsidy Reform project; this value decreased about 3.5% due to 1.2% error of network and reached to the 1988165MKW/ H. So this result can be concluded that that issues and factors of 2011 such as Subsidy Reform project and beginning of sanction cause to decrease the electricity consumption in Iran in 2011.

CONCLUSION

In this study, we have tried to propose a model to predict Iran annual electricity consumption using neural networks. To do this purpose, Narx neural network has been used and data of population, GNP, import and export with 2 stage time delay are inserted into the network as the input vector. Also in this study, logarithmical preprocessing over the input data causes improvement in performance. To compare the results obtained from this network, 2 methods of ARIMA regression Model and Perceptron Neural Network were used and results obtained from these 3 networks were compared using variance analysis test. Results showed that Narx neural network has had the closer prediction to the real data. So, Iran electricity consumption in 2011 has been estimated using Narx neural network. Also, results showed that issues and factors of 2011 such as Subsidy Reform project and beginning of sanction could decrease the electricity consumption in Iran about 3.5%.

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