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Artificial Neural Networks Modeling of the Electricity Demands in the Jordanian Industrial Sector

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Abstract

Since the beginning of the 21st century, it has been noted that the rate of energy consumption has increased globally due to the technological progress that has taken place. The industrial sector occupies one of the first sectors in the consumption of electrical energy. Therefore, this paper aims to use the method of artificial neural networks (ANN) to model, analyze, and forecast electricity consumption in Jordan's industrial sector. In the present analysis, several factors affecting energy consumption in this sector are studied and verified, namely: the number of the industrial establishments (ES), the number of employees (EM), the electricity price ($E\$$), the price of fuel ($F\$$), gross output (G), structural effect (GI/GN) and the capacity utilization (CU). Several networks are executed and tested in terms of the root mean square error (RMSE), mean absolute percentage error (MAPE), and coefficient of determination (R^2). The results of this study implicated that the electricity consumption levels in the Jordanian industrial segment are highly driven by the number of industrial establishments and employees followed by the gross output, among others. Additionally, the present ANN-predicted electricity consumption results are compared with literature and showed superior accuracy. Finally, this ANN model is combined with the time series analysis approach to forecast the electricity needs of the Jordanian industrial sector for the next decade.

Keywords: Energy, Electricity, Sustainability Analysis, Artificial Neural Networks (ANN), Time Series Analysis, Industrial sector.

1. Introduction

Electricity is an important form of energy. It is a fundamental indicator for many aspects like economic development, uses of technology tools, employment, and economic competitiveness [1-3]. According to the central statistics agency, with the rapid increase in a short period of electricity use, there might be a global scarcity of electrical energy [4]. Jordan's government facing challenges from rising electricity demand because of the high reliance on expensive fuel imports [5,6]. Moreover, the industrial segment has the second-largest electrical use in Jordan through the year 2019 [7].

Many literature studies on analyzing and forecasting energy usage in the industrial sector have been conducted to ensure that countries throughout the world energy demands are met. Ngutsav et al. [8] found that real income, population, industrial segment, production, and electricity price are the parameters affecting electricity consumption for industrial, commercial, and residential sectors in Nigeria. In Canada, Latif [9] used two independent parameters, per capita real (GDP) and electricity price to study per capita electricity usage. Thus, they found that electricity prices have a negligible impact on per capita electricity usage. Additionally, two models implemented in Al-Ghandoor et al. [10] research using different methods, gross output, and capacity utilization were the most significant factors that affect electricity use in Jordan. Moreover, the role of the two variables in electricity consumption was emphasized in a previous research paper [11].

Nevertheless, all previous studies about analyzing and modeling electricity consumption for Jordan's industrial sector are quite old and limited to the period between 1985 and 2009. Therefore, this study aims to analyze electricity demand using artificial neural network (ANN) using updated and recent data. Also, this study provides a forecasted demand of the electricity consumption in the Jordanian industrial sector for the next decade.

The structure of this paper begins with an overview of the industrial sector of Jordan electricity structure and the affecting factors. The data collection procedure and government sources are presented in detail subsequently. Followed by the details of the artificial neural networks used to analyze and model the electricity consumption levels. Consequently, the results of the artificial intelligence-based model results are discussed and validated with government data as well as with literature-based models. Finally, the newly-developed ANN model is trustfully used to forecast and predict the electricity needs of the Jordanian industrial sector in the next decade. This paper also provided some recommendations to the decision makers in the country to consider in the future.

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2. Jordan's Industrial Sector Electricity Consumption

2.1. Overview

The industrial sector contributes significantly to Jordan's economy, employing around 18 % of the country's workforce [12]. The electrical use in this segment is influenced by several elements. To illustrate, each year there is a number of facilities that open to increase production in the industrial sector, these facilities required the amount of energy that is essential to make the production wheel turn, thus the number of facilities refers to establishments. Moreover, the Gross output indicates the monetary value of the commodities that were produced, and this factor affects energy consumption. Additionally, capacity utilization indicates the relationship between production (gross output) and the number of available factories. The greater the number of factories, the greater the production, and the greater the production, the more electrical energy is needed to make the factory work. In general, prices have been affected around the world for many reasons, and one of these reasons is the geopolitical situation, as we know that our Arab region is one of the regions affected greatly by the political situation. Due to frequent geopolitical issues, oil supplies from neighboring countries are interrupted, and the price of Jordan oil became higher, in addition to the increase in electricity prices. This affects the total consumption of energy in Jordan, especially in the industrial sector. In summary, the following are the variables that affect energy consumption in Jordan's industrial, and the references from which these variables were collected. In fact, such parameters were previously identified as the main affecting factors in the energy demands of the industrial sector of Jordan [13-15]. By considering these crucial factors, the present study aims to model and analyze the energy consumption in Jordan's industrial sector, providing valuable insights for understanding and predicting future energy needs in this domain.

2.2. Influencing Factors

2.2.1. Structural Effect (GI/GN)

When demand shifts toward industries that use more electricity, electricity demand will increase correspondingly for a given level of output. A shift away from businesses that use a lot of electricity, however, would have the opposite result: a net decrease in overall electricity consumption. The manufacturing industry is divided into two industrial clusters: electricity-intensive (GI) and non-electricity-intensive (GN) clusters, the ratio between the gross outputs of these two clusters is called Structural Effect (GI/GN). The electricity-intensive industries include mining and quarrying, textiles, papers, basic metals, plastics, and chemical industries, and the non-electricity-intensive industries include all other industries in the industrial sector. Data for each component in each cluster were collected from literature source [10], as well as from the annual statistical reports for the Department of Statistics (DOS) [16] through the years 1985 to 2020 (1985-2004, literature,2005-2020, DOS). As illustrated in Figure 1, structural effect fluctuates over the years and provides an indication of how much it will affect electrical consumption since structural effect decreases and increases depending on electricity use. As a result, this impact should be investigated.

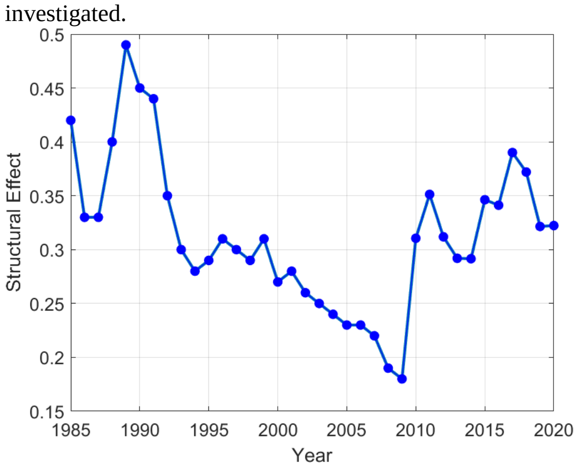

Figure 1. Structural Effect in Jordan for the period 1985 to 2020.

2.2.2. Electricity Prices ($E\$$)

As mentioned previously, electricity prices are affected by several aspects, and this will lead to changes in electrical use. The industry is anticipated to respond by utilizing electricity more effectively, i.e., by implementing energy management and conservation techniques, when the unit price of electricity is increased. Values for electricity prices every year were gathered from literature source [10] between the years 1985 to 2004 and from the annual report of the National Electricity Power Company (NEPCO) [17] between the years 2005 to 2020. Figure 2 shows that electricity prices increased year after year until 2015 due to the increased number of the Syrian refugees.

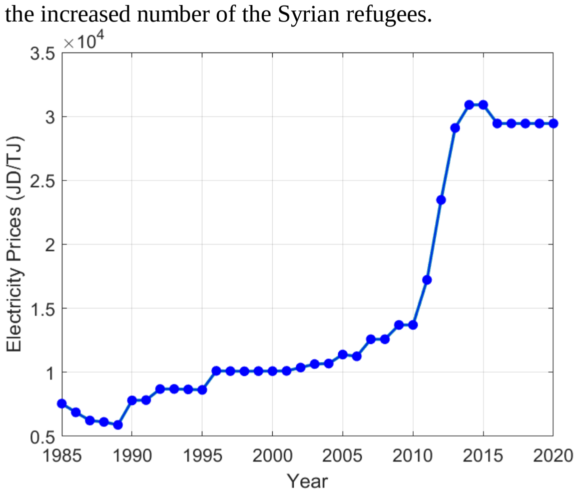

Figure 2. Electricity Prices in Jordan for the period 1985 to 2020.

2.2.3. Fuel Prices ($F\$$)

In Jordan, heavy fuel oil (HFO) and diesel are now the most popular electricity replacements, particularly for manufacturing activities like heating and drying applications. It is important to note that Jordan is a non-oil country and almost all oil is imported from neighboring countries, so as mentioned previously the prices of fuel are affected immediately if Jordan has an import shortage of oil. It is anticipated that most industries would convert to electricity in response to rising prices for diesel and HFO, and vice versa. The present paper takes into account the weighted average of diesel and HFO prices. Moreover, literature source [10] and the annual report for the Ministry of Energy and Mineral Resources (MEMR) [18] were used to collect data for yearly diesel and HFO prices between the years 1985 to 2020 (1985-2004, literature,2005-2020, MEMR). Figure 3 demonstrates that because the Jordanian government supported fuel prices from 1980 to 2000, price of fuel did not vary. Following that, government assistance was withdrawn, and the country was put to a free pricing policy. The price shift from 2005 to 2020 is determined by worldwide fuel prices, which are heavily influenced by global politics and conflicts.

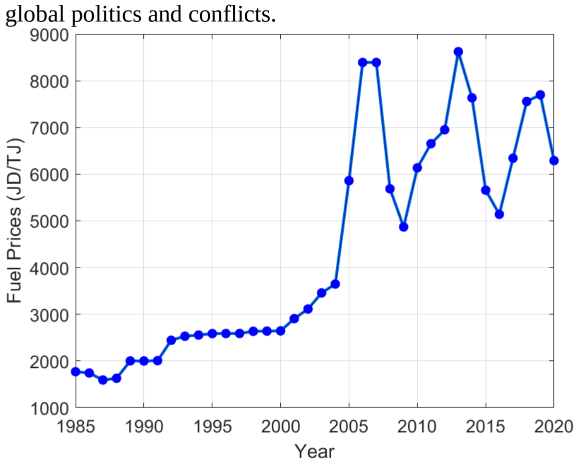

Figure 3. Fuel Prices in Jordan for the period 1985 to 2020.

2.2.4. Establishments (ES)

As mentioned before every new industrial facility that is established requires a quantity of electrical energy to ensure the functioning of this facility. The greater the number of facilities, the greater the need for electrical energy consumption. The number of establishments (ES) was taken from literature source [10] between the years 1985 to 2004 and from the Jordan Chamber of Industry [19] between the years 2005 to 2020. Figure 4 shows that the number of establishments increased from 1990 to 1992 because of the gulf war and also from 2000 to 2020 increased rapidly because of the second Palestinian uprising, and Iraqi and Syrian refugees.

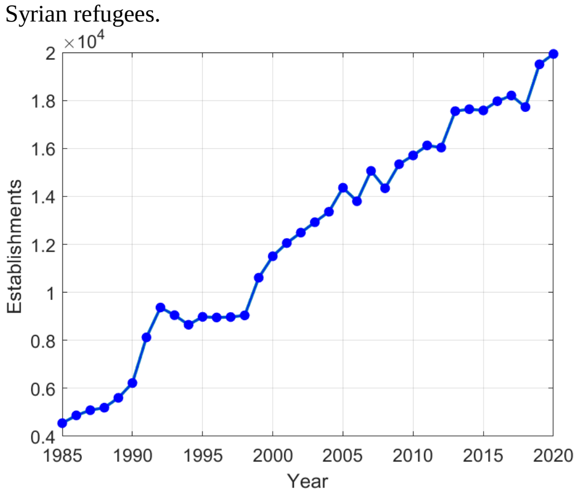

Figure 4. Establishments in Jordan for the period 1985 to 2020.

2.2.5. Capacity Utilization (CU)

This parameter describes how effectively established production capacity will be used by industrial facilities. Simply said, this variable is included in the research since it shows how well the available resources, such as electricity, is used as the capacity utilization factor rises. Moreover, the relationship between production (gross output) and establishments is called Capacity Utilization (CU). Capacity utilization grows year after year, as seen in Figure 5, however there was an enormous jump between 2009 and 2010.

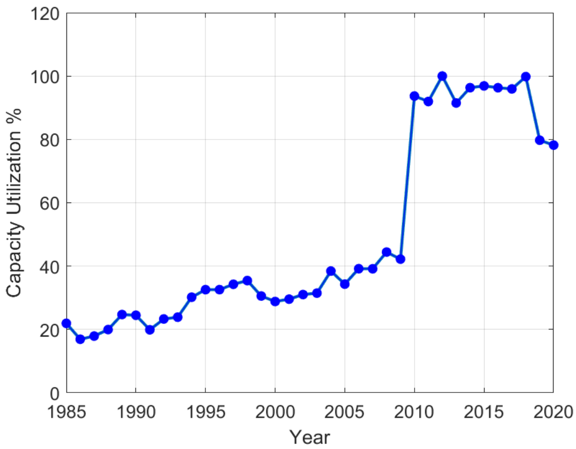

Figure 5. Capacity Utilization in Jordan for the period 1985 to 2020.

2.2.6. Number of Employees (EM)

There are two possible perspectives for this variable. Technology has partially replaced the bulk of industries that use human labor because of the growing demand for electricity on automated systems and industrial lines. On the other hand, however, each employee needs more electricity in the form of heated water, conditioned air, lights, etc., and so electricity use would decline as more old-fashioned manually operated ones are replaced by advanced machines. The number of employees was gathered from literature source [10] and from the statistical tables of employment and unemployment by the Department of Statistics (DOS) [20] through the years 1985 to 2020 (1985-2004, literature,2005-2020, DOS). Figure 6 presents the increase of the number of employees year by year. Furthermore, the number of employees decrease from 2009 to 2010 due to the global financial crisis of 2008 and the start increase again because of the Syrian refugees.

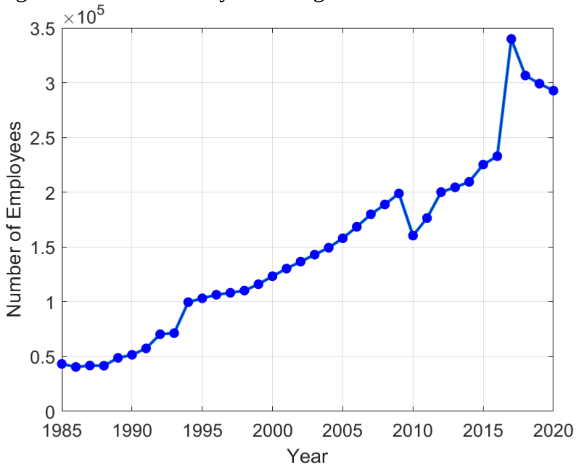

Figure 6. Number of Employees in Jordan for the period 1985 to 2020.

2.2.7. Gross Output (G)

In Jordan, a variety of items are produced, including everything from food to chemicals and mining industries.

Consequently, it is quite challenging to rely on the actual goods to show the degree of manufacturing. As a result, the monetary worth of the commodities is utilized in place of the quantity of things under inquiry. So, when productivity increases electrical usage increases. Data for this variable was collected from literature source [10] and from the annual statistical reports for the Department of Statistics (DOS) [16] between the years 1985 to 2020 (1985-2004, literature,2005-2020, DOS). Gross output increases year after year, as seen in Figure 7, however there was a huge increase between 2009 and 2010.

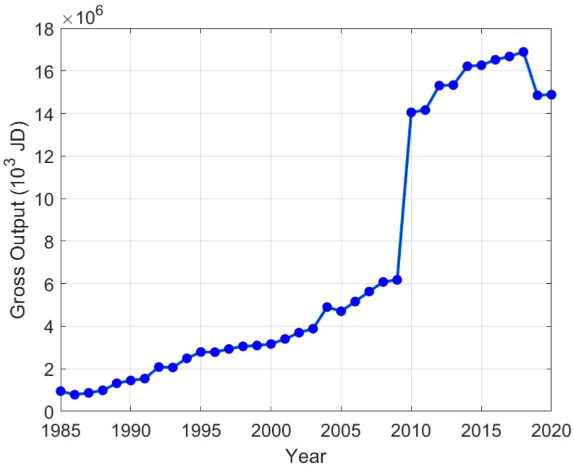

Figure 7. Gross Output in Jordan for the period 1985 to 2020.

2.2.8. Electricity Consumption (Ec)

The electricity consumption (Ec) data, in Tera Joule (TJ), over the years are collected from annual publications of the ministry of energy and mineral resources [18]. As shown in Figure 8, electricity consumption climbed gradually and steadily from 1985 to 2003. Despite this, there has been a significant increase since 2003 as a result of Iraqi and Syrian refugees. Appendix 1 shows the full data set including all affecting variables and electricity consumption from 1985 to 2020.

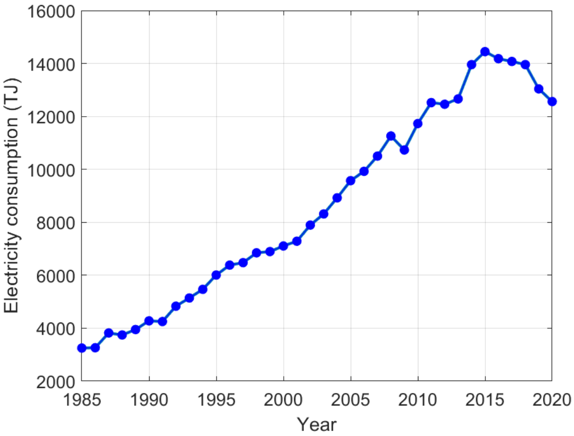

Figure 8. Electricity Consumption in Jordan for the period 1985 to 2020.

3. Analysis using Artificial Neural Network (ANN)

Artificial neural networks are widely employed in a wide range of applications. Prediction, which is defined as the process of anticipating future patterns or events, is one of the most popular. Furthermore, projections in a range of fields, such as weather, asset prices, and economic downturn forecasts, are rather popular. Therefore, the present research employs a powerful artificial intelligence tool, the artificial neural network (ANN), to assess and forecast Jordan's industrial sector's electricity requirements. ANN, unlike many statistical and probabilistic approaches, does not require prior knowledge of the correlations between the inputs and outputs of a given issue since its structure is similar to that of the human brain. As a result, ANNs can handle nonlinear regression problems with high efficiency and accuracy [21,22]. Each ANN is made up of an input layer, an output layer, and a number of hidden layers. As illustrated in Figure 9, each hidden layer is made up of a number of processing components known as neurons. To develop an ANN, the network must first be trained by analyzing a variety of input patterns and matching them to their corresponding outputs. Following that, the neural network models the results and switches them into the hidden layer, where the neurons define the weight. The weight is then sent from neurons into the input layer using the transfer function. As a result, the output layer receives the needed output predictions. A common ANN method is often written as:

$$Y_j = f(\theta_j + \sum_{i=1}^{n} w_{ji} X_i) \quad (1)$$

where: θ_j is the bias at the hidden layer; n is the number of neurons in the hidden layer; w_{ji} the connection weight between the input variable and the hidden layer; X_i is the input variable; Y_j is the output variable; f is the transfer function [23].

The ANN approach was utilized in this study to estimate the electricity consumption of Jordan's industrial sector while considering all of the previously indicated influencing elements ($GI/GN, E\$, F\$, ES, CU, EM$, and G). Before beginning the ANN modeling process, all components, including the electricity consumption E_c, are normalized to have data between 0 and 1, as recommended by the ANN, using the following equation:

$$normalized\ value = \frac{input\ value - minimum\ value}{maximum\ value - minimum\ value} \quad (2)$$

Appendix 1 data set is also separated into training, validation, and testing sets, 70%, 15%, and 15%, respectively, chosen at random by the ANN. To find the optimum ANN design, 100 networks with varying numbers of hidden layers and neurons are analyzed. The root means square error (RMSE) between predicted values ($Ec_{predict,i}$) and true values (($Ec_{actual,i}$) of electricity consumption was computed for each network using the following formula:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Ec_{actual,i} - Ec_{predict,i})^2} \quad (3)$$

Thus, in the current work, the ANN with the lowest root mean square error (RMSE) is used to conduct the electricity consumption analysis and forecasts.

It is important to mention that the results of this paper were based on executing data from 1985 to 2020 resulting in only 36 data points to correlate the energy consumption demands with the affecting factors. Afterwards, the 36 data points were used to train the ANNs to establish the relationship between the energy consumption levels and the influencing parameters, accordingly. In fact, the limited number of data points could possibly affect the results. To overcome this, the present paper created 100 ANNs to make sure that highest accuracy is achieved by selecting the network with lowest error. In other words, instead of using more data points, the present paper trained more neural networks to maximize accuracy and ensure solution convergence. In fact, this approach has been previously successfully adopted in recent research studies of the authors [24-27].

4. Results and Discussion

4.1. ANN Model Results

As previously stated, multiple ANNs were evaluated in order to find the most accurate artificial intelligence network. Figure 10 depicts the RMSE values of each network, revealing that network number one has the lowest RMSE value of 152.1. This network is made up of one hidden layer and one neuron. Appendices 2, 3, and 4 show the whole set of training, validation, and testing data, 70%, 15%, and 15%, respectively, picked at random by the ANN. Appendix 5 show the network weights and biases. Furthermore, the amount of the weights implies relevance; a negative weight suggests that increasing the input would diminish the outcome.

Figure 11 depicts the ANN-predicted versus real values of electricity consumption in Jordan's industrial sector for the training, validation, testing, and full data sets. This figure shows that nearly all data points cluster along the normal line for all data sets, indicating that the ANN is highly well-trained. To acquire more trust in the established network the values of the mean absolute percentage error (MAPE) and the coefficients of determination (R^2) are computed and analyzed. The MAPE is provided by:

$$MAPE = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|E_{c_{predict,i}}-E_{c_{actual,i}}\right|}{E_{c_{actual,i}}} * 100\% \quad (4)$$

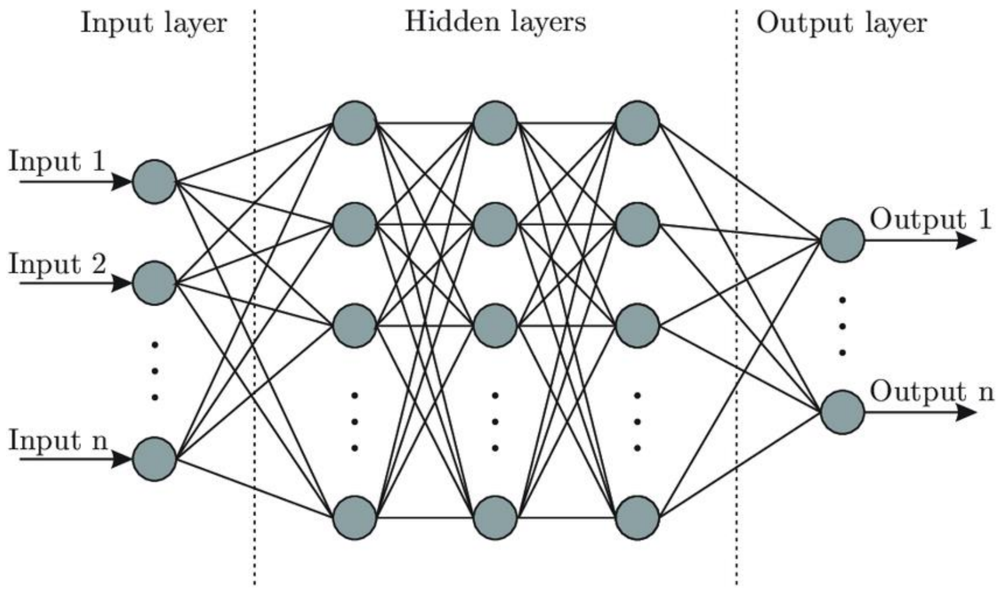

Figure 9. Typical ANN architecture

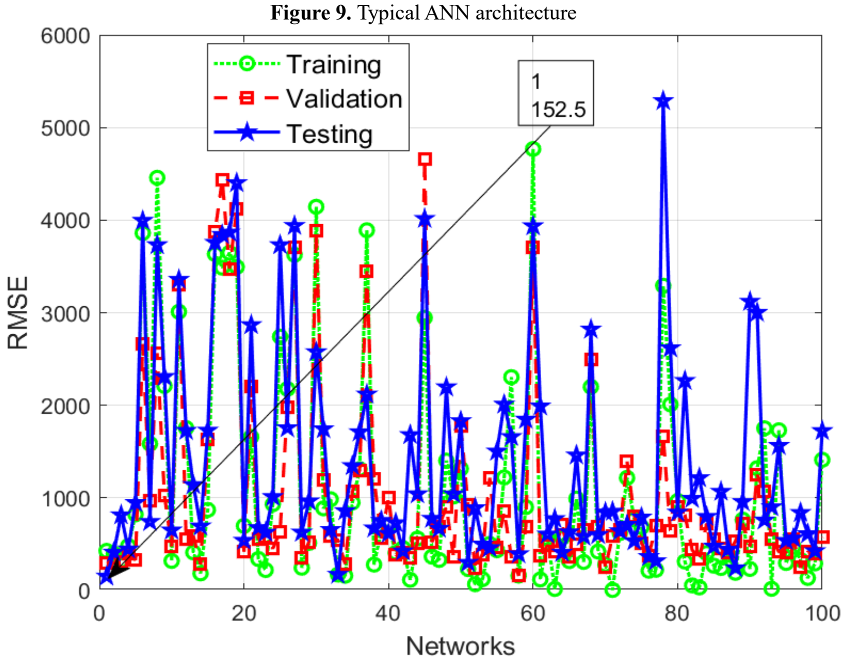

Figure 10. RMSE for training, validation, and testing sets vs networks.

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It was discovered that the MAPE is equal to 3.34 %, a very low error value reflecting the present ANN model's excellent accuracy, and the R^2 is equal to 0.98, suggesting a very great quality match.

4.2. Comparison with Literature

The current ANN model's predictions are compared to the literature model accessible in [10]. Appendix 6 summarizes the outcomes of this comparison.

After comparing the two models (ANN and literature), the results shown in Appendix 6 show that the present ANN model's electricity consumption calculations are in strong agreement with the actual electricity consumption data. To demonstrate, the electricity consumption value for the ANN model in 2010 was 11984 TJ, which is quite close to the actual value of 11729 TJ with a 2.17 % error. Furthermore, the literature model projected an electricity consumption value of 15623 TJ for 2009, while the actual value was 10732 TJ, with a 45.5% error, suggesting low performance and accuracy. As seen in Figure 12, our ANN beats the literature model with substantially lower % error values.

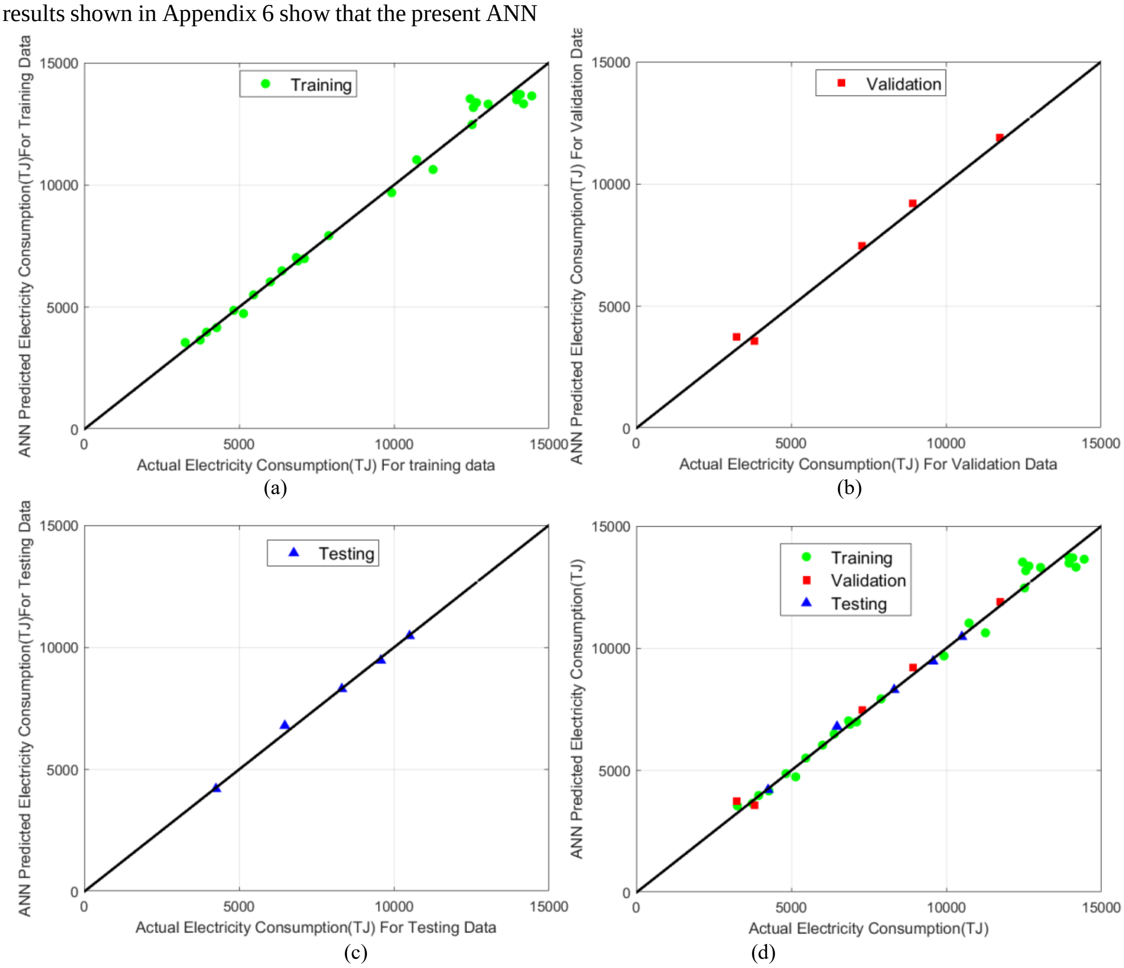

Figure 11. Actual electricity consumption (TJ) vs ANN predicted energy consumption (TJ) (a) Training Data (b) Validation Data (c) Testing Data (d) All Data.

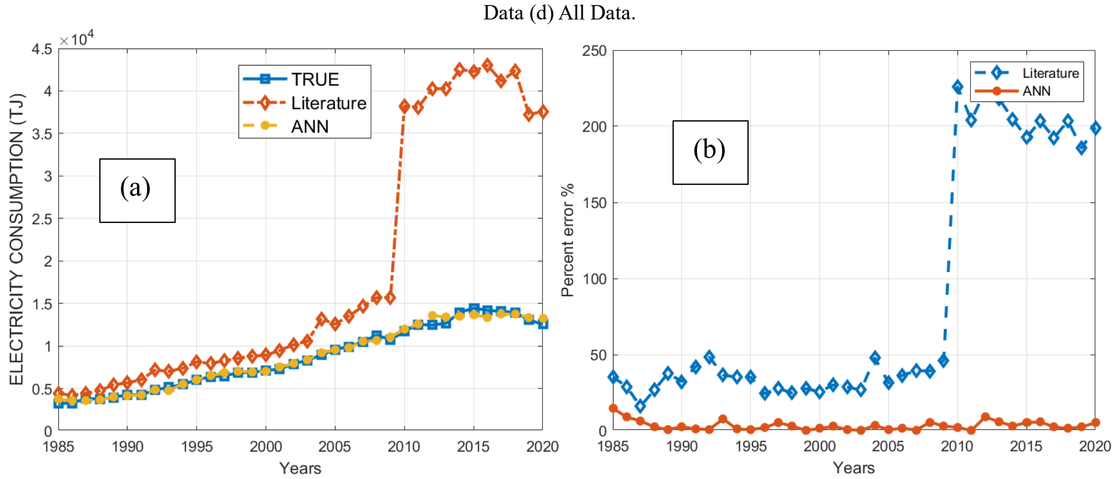

Figure 12. Comparison between the ANN model and previous literature model of reference [10]. (a) True value with literature and ANN values (b) Percentage error for true value with literature and ANN errors.

It is worth noting that the reference model [10] was based on out-of-date data (1985-2004), and its quality was not confirmed at the time. As a consequence, it is reasonable to say that the currently developed ANN can reliably compute the electricity consumption levels of Jordan's industrial sector and should be confidently utilized to estimate Jordan's future demands in this critical sector.

4.3. Forecasting of Electricity Demands and Time Series Analysis

After validating the present ANN-based electricity consumption model, it is now viable to apply this model to anticipate Jordan's industrial sector's projected electricity demands over the next decade (2021-2030). It is necessary to determine the predicted value of the seven independent variables ($GI/GN, E\$, F\$, ES, CU, EM$, and G) in the years 2021 to 2030 in order to utilize this AI model. This was accomplished through the use of time series analysis [28-30]. In such cases, the double exponential smoothing forecasting time series technique is often suggested [31-35].

The double exponential forecasting is mathematically expressed as:

$$Z_{t+m} = a_t + b_t m \quad (5)$$

where Z_{t+m} is the forecast after m the number of periods ahead to be forecast, a_t the forecasted intercept, and b_t the forecasted slope.

The intercept a_t and the slope b_t are estimated as follows:

$$a_t = 2S'_t - S''_t \quad (6)$$

$$0 \leq \alpha < 1 \quad (7)$$

where α is the smoothing constant used to weight recent and historical observations, and S'_t and S''_t the single and double exponential smoothing values respectively for time t. These S'_t and S''_t values are calculated as follows:

$$S'_t = \alpha Y_t + (1-\alpha) S'_{t-1} \quad (8)$$

$$S''_t = \alpha S'_t + (1-\alpha) S''_{t-1} \quad (9)$$

The more α is greater, the more importance is placed on the most recent observations. α should be chosen before starting the analysis. The projections are produced using many α's, and the α that produces a low mean square error and indicates anticipated future growth is selected.

Note. The values of ($S'_1 = S''_1 = Y_1$) in period ($t = 1$) [31].

Table 1 lists the resulting smoothing factors (α) for each independent variable, and Table 2 summarizes the anticipated values for such factors.

The values in Table 2 were normalized using the previously stated approach and utilized in the ANN model to anticipate electricity consumption levels in the years 2021-2030. Table 2 displays the results, while Figure 13 depicts the values of electricity usage from 1985 to 2030.

Table 1. Smoothing constants (α's) for the influencing variables.

	GI/GN	$E\$$ (JD/TJ)	$F\$$ (JD/TJ)	EM	G (10^3JD)	CU	ES
Smoothing constant	0.25	0.32	0.12	0.46	0.25	0.20	0.64

To investigate the influence of each independent variable on the electricity consumption demands, Figure 14 is plotted. The influence of the structural effect and number of employees on electricity consumption is depicted in Figure 14(a). It has been demonstrated that as the number of employees rises, so does the amount of electricity consumed. Furthermore, this effect outweighs the effect of the structural effect. Figure 14(b) illustrates the effects of the number of employees and establishments on electricity consumption. Moreover, this figure confirms the importance of the number of employees in electricity use. Furthermore, the number of employees had more effect than the effect of establishments on consuming electricity. In terms of affecting electricity consumption, Figure 14(c) confirmed the affecting of establishments. Also, establishments are the dominating factor on electricity consumption when comparing it with capacity utilization which has a small role on electricity. On the other hand, when putting capacity utilization and gross output as influencing variables on electricity use in the same plot gross output shows an effect on electricity consumption whereas the capacity utilization has no discernible effect as Figure 14(d) depicts. Figure 14(e) illustrates the effects of prices for both electricity and fuel on electricity consumption. Moreover, this figure presents that electricity prices and fuel prices had a huge effect on consuming electricity. However, electricity prices are dominating one. Figure 14(f) depicts the impact of gross output and electricity prices on electricity usage. It has been established that when gross output grows, so does electricity consumption. Furthermore, the influence of the electricity prices is negligible. Additionally, in Figure 14(g) both gross output and number of employees had a huge effect on electricity consumption, but the gross output had the most significant effect on electricity usage. Eventually, the electricity consumption of Jordan's industrial sector is mostly influenced by the country's gross output and number of employees, with the gross output having a greater impact.

Table 2. Projected values for the influencing variables and electricity consumption.

year	GI/GN	$E\$$ (JD/TJ)	$F\$$ (JD/TJ)	EM	G (10^3JD)	CU %	ES	Ec (TJ)
2021	0.35	31148	7647	309175	16703501	94	20593	14191
2022	0.35	31838	7758	316371	17075274	96	21251	14289
2023	0.36	32529	7868	323568	17447047	98	21910	14358
2024	0.36	33219	7979	330764	17818820	100	22568	14407
2025	0.37	33909	8089	337960	18190592	101	23227	14441
2026	0.37	34599	8200	345157	18562365	103	23885	14465
2027	0.38	35290	8310	352353	18934138	105	24543	14482
2028	0.38	35980	8421	359549	19305911	107	25202	14494
2029	0.39	36671	8531	366746	19677684	109	25860	14502
2030	0.39	37361	8642	373942	20049457	111	26519	14507

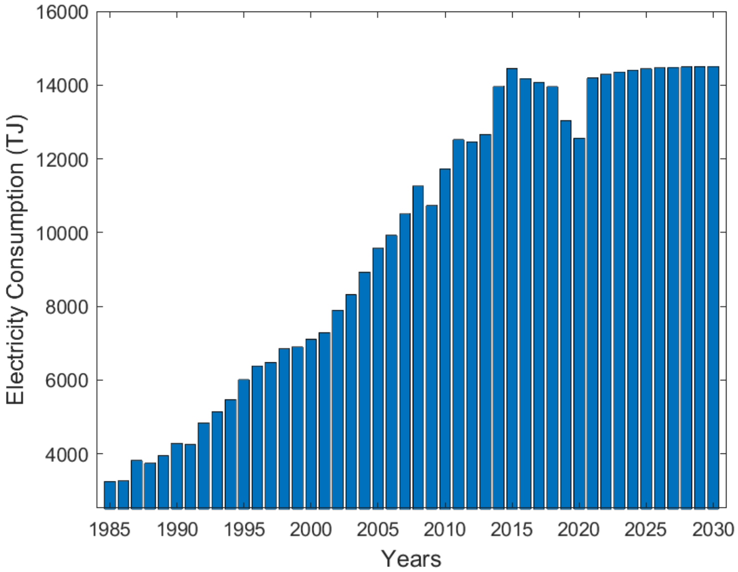

Figure 13. Bar plot for the electricity consumption (TJ) values in Jordan's industrial sector from 1985-2030.

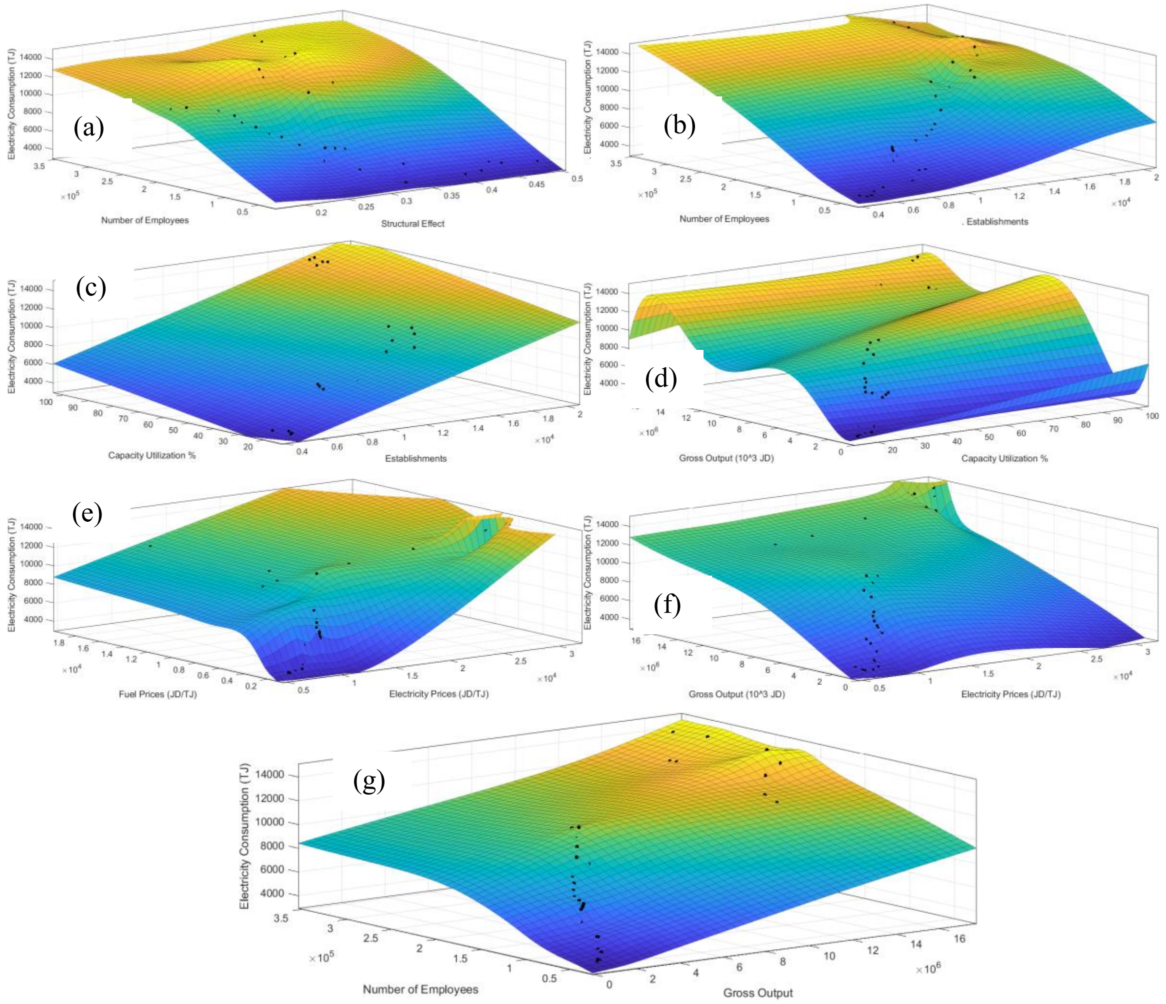

Figure 14. Surface chart for electricity consumption (TJ) in z-axis with two factors in x-axis and y-axis affecting it. (a) $GI/GN, EM$ (b) EM, ES (c) CU, ES (d) CU, G (e) $E\$, F\$$ (f) $E\$, G$ (g) G, EM.

5. Conclusions

The artificial neural network approach was used in this article to model, assess, and anticipate Jordan's industrial sector's electricity consumption. The number of establishments (ES), number of employees (EM), electricity price ($E\$$), fuel price ($F\$$), gross output (G), structural effect (GI/GN), and capacity utilization (CU) data were collected from various literature works and Jordan's government reports and incorporated to model the electricity consumption levels in this study. Furthermore, the proposed neural network model has 5 hidden layers with 2 neurons each. Thus, the ANN-based model demonstrated remarkable efficiency and accuracy, with RMSE, MAPE, and R^2 values of 152.1, 3.34 %, and 0.98, respectively. Additionally, the correctness of the resulting neural network model was confirmed by comparing its results to actual electricity consumption data and a literature-based model. Also, this artificial intelligence model was utilized to forecast Jordan's industrial sector's electricity demands for the next decade. Finally, this study discovered that the gross output and the number of employees as well as the number of the industrial establishments are the most influencing variables influencing electricity usage, hence Jordan's government should enact regulations to manage such important variables. In summary, electricity consumption is expected to expand over the next decade, and Jordan's government should boost the number of industrial facilities that rely on machines with a high-efficiency rate for utilizing electricity in the manufacturing process. Furthermore, it is important to create laws to enforce the industrial establishments to rely on renewable energy resources like solar and wind energy.

Data Availability

Data used in this research will be made available upon reasonable request.

Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

List of abbreviations

ANN	Artificial Neural Network
GDP	Gross Domestic Product
PSD	Public Security Department
DOS	Department of Statistics
MEMR	Ministry of Energy and Mineral Resources
NEPCO	National Electricity Power Company
TJ	Tera Joule
HFO	Heavy Fuel Oil

Nomenclature:

E_c	Electricity Consumption
$Ec_{actual,i}$	True Values of Electricity Consumption
$Ec_{predict,i}$	Predicted Values of Electricity Consumption
GI/GN	Structural Effect
ES	Establishments
CU	Capacity Utilization
$E\$$	Electricity Prices
$F\$$	Fuel Prices
EM	Number of Employees
G	Gross Output
RMSE	Root Mean Square Error
MAPE	Mean Absolute Percentage Error
R^2	Coefficients of Determination
Y_j	The Output Variable
θ_j	The Bias at The Hidden Layer
w_{ji}	The Connection Weight between The Input Variable and The Hidden Layer
X_i	The Input Variable
f	The Transfer Function
Z_{t+m}	The Forecast After m
m	The Number of Periods Ahead to be Forecast
a_t	The Forecasted Intercept
b_t	The Forecasted Slope
α	The Smoothing Constant
S'_t , S''_t	he Single and Double Exponential Smoothing Values Respectively for Time t

Subscripts:

i	Counter for Hidden Layers
j	Counter for Neurons Inside Hidden Layers
n	Number of Neurons Inside Hidden Layers

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Appendix 1. Data set for the electricity consumption and the influencing factor in the industrial sector of Jordan.

Year	GI/GN	$E\$$ (JD/TJ)	$F\$$ (JD/TJ)	EM	G (10^3 JD)	CU %	ES	Ec (TJ)
1985	0.42	7553	1771	43313	952231	22	4546	3251
1986	0.33	6874	1744	40529	786734	17	4871	3262
1987	0.33	6234	1593	41824	870660	18	5088	3820
1988	0.40	6121	1630	41647	990026	20	5192	3744
1989	0.49	5889	2002	48791	1322170	25	5603	3949
1990	0.45	7804	2001	51617	1454955	24	6221	4277
1991	0.44	7828	2008	57434	1543584	20	8123	4252
1992	0.35	8692	2445	70393	2084846	23	9367	4831
1993	0.30	8700	2531	71413	2063737	24	9049	5141
1994	0.28	8665	2556	99660	2493167	30	8649	5468
1995	0.29	8628	2587	103176	2792184	33	8979	6008
1996	0.31	10112	2589	106437	2784456	33	8951	6383
1997	0.30	10095	2590	108219	2935171	34	8970	6476
1998	0.29	10079	2636	110229	3058377	35	9039	6847
1999	0.31	10094	2641	116061	3096897	31	10610	6894
2000	0.27	10094	2645	123348	3167108	29	11504	7106
2001	0.28	10111	2908	130296	3404568	30	12055	7286
2002	0.26	10372	3114	136653	3699853	31	12489	7895
2003	0.25	10644	3458	143010	3884816	31	12923	8316
2004	0.24	10687	3648	149367	4902862	38	13357	8924
2005	0.23	11389	5861	157980	4705625	34	14360	9572
2006	0.23	11250	8392	168456	5162862	39	13797	9925
2007	0.22	12583	8392	179861	5632008	39	15062	10501
2008	0.19	12583	5687	188820	6084007	44	14337	11261
2009	0.18	13703	4870	198876	6181981	42	15340	10732
2010	0.31	13703	6136	160400	14051785	94	15706	11729
2011	0.35	17222	6653	176450	14160230	92	16122	12521
2012	0.31	23472	6950	200117	15311435	100	16033	12460
2013	0.29	29097	8623	204468	15335503	91	17551	12661
2014	0.29	30903	7634	209444	16219993	96	17633	13957
2015	0.35	30903	5658	225212	16267705	97	17581	14447
2016	0.34	29444	5141	232867	16525016	96	17966	14180
2017	0.39	29444	6343	339881	16677901	96	18204	14076
2018	0.37	29444	7557	306522	16892729	99	17723	13957
2019	0.32	29444	7699	299079	14853216	80	19504	13039
2020	0.32	29444	6291	292697	14885417	78	19935	12560

Appendix 2. ANN training set.

Year	Ec(TJ), training	GI/GN	$E\$$ (JD/TJ)	$F\$$ (JD/TJ)	EM	G (10^3 JD)	CU %	ES
1986	3262	0.33	6874	1744	40529	786734	17	4871
1988	3744	0.4	6121	1630	41647	990026	20	5192
1989	3949	0.49	5889	2002	48791	1322170	25	5603
1990	4277	0.45	7804	2001	51617	1454955	24	6221
1992	4831	0.35	8692	2445	70393	2084846	23	9367
1993	5141	0.3	8700	2531	71413	2063737	24	9049
1994	5468	0.28	8665	2556	99660	2493167	30	8649
1995	6008	0.29	8628	2587	103176	2792184	33	8979
1996	6383	0.31	10112	2589	106437	2784456	33	8951
1998	6847	0.29	10079	2636	110229	3058377	35	9039
1999	6894	0.31	10094	2641	116061	3096897	31	10610
2000	7106	0.27	10094	2645	123348	3167108	29	11504
2002	7895	0.26	10372	3114	136653	3699853	31	12489
2006	9925	0.23	11250	8392	168456	5162862	39	13797
2008	11261	0.19	12583	5687	188820	6084007	44	14337
2009	10732	0.18	13703	4870	198876	6181981	42	15340
2011	12521	0.35	17222	6653	176450	14160230	92	16122
2012	12460	0.31	23472	6950	200117	15311435	100	16033
2013	12661	0.29	29097	8623	204468	15335503	91	17551
2014	13957	0.29	30903	7634	209444	16219993	96	17633
2015	14447	0.35	30903	5658	225212	16267705	97	17581
2016	14180	0.34	29444	5141	232867	16525016	96	17966
2017	14076	0.39	29444	6343	339881	16677901	96	18204
2018	13957	0.37	29444	7557	306522	16892729	99	17723
2019	13039	0.32	29444	7699	299079	14853216	80	19504
2020	12560	0.32	29444	6291	292697	14885417	78	19935

Appendix 3. ANN validation set.

Year	Ec (TJ), validation	GI/GN	$E\$$ (JD/TJ)	$F\$$ (JD/TJ)	EM	G (10^3 JD)	CU %	ES
1985	3251	0.42	7553	1771	43313	952231	22	4546
1987	3820	0.33	6234	1593	41824	870660	18	5088
2001	7286	0.28	10111	2908	130296	3404568	30	12055
2004	8924	0.24	10687	3648	149367	4902862	38	13357
2010	11729	0.31	13703	6136	160400	14051785	94	15706

Appendix 4. ANN testing set.

Year	Ec (TJ), testing	GI/GN	$E\$$ (JD/TJ)	$F\$$ (JD/TJ)	EM	G (10^3 JD)	CU %	ES
1991	4252	0.44	7828	2008	57434	1543584	20	8123
1997	6476	0.3	10095	2590	108219	2935171	34	8970
2003	8316	0.25	10644	3458	143010	3884816	31	12923
2005	9572	0.23	11389	5861	157980	4705625	34	14360
2007	10501	0.22	12583	8392	179861	5632008	39	15062

Appendix 5. Weights and biases for the ANN model.

Weights					Biases	
Neurons	GI/GN	$E\$$ (JD/TJ)	$F\$$ (JD/TJ)	EM	Neurons	Input bias
K=1	0.11	0.71	-0.007	0.33	k=1	-0.130
Neurons	G (10^3)	CU	ES	E_C(TJ) (output)	Neurons	Output bias
K=1	-4.76	3.82	2.02	0.99	k=1	0.019

Appendix 6. Comparison between ANN model and previous literature model of reference [10].

Year	E_C ,true (TJ)	E_C , ANN (TJ)	error %	E_C , Literature (TJ)	error %
1985	3251	3732	14.7	4401	35.3
1986	3262	3552	8.89	4205	28.8
1987	3820	3573	6.46	4428	15.9
1988	3744	3654	2.40	4742	26.6
1989	3949	3976	0.68	5439	37.7
1990	4277	4164	2.64	5655	32.2
1991	4252	4210	0.98	6038	41.9
1992	4831	4875	0.91	7164	48.2
1993	5141	4743	7.74	7021	36.5
1994	5468	5520	0.95	7387	35
1995	6008	6054	0.76	8122	35.1
1996	6383	6507	1.94	7935	24.3
1997	6476	6818	5.28	8272	27.7
1998	6847	7054	3.02	8546	24.8
1999	6894	6910	0.23	8797	27.6
2000	7106	7004	1.43	8926	25.6
2001	7286	7493	2.84	9476	30
2002	7895	7954	0.74	10150	28.5
2003	8316	8330	0.16	10540	26.7
2004	8924	9237	3.50	13183	47.7
2005	9572	9514	0.60	12572	31.3
2006	9925	9758	1.68	13535	36.3
2007	10501	10539	0.36	14643	39.4
2008	11261	10629	5.61	15516	37.7
2009	10732	11054	3.00	15623	45.5
2010	11729	11984	2.17	38213	225.7
2011	12521	12543	0.17	38064	204
2012	12460	13571	8.91	40242	222.9
2013	12661	13415	5.95	40285	218.1
2014	13957	13529	3.06	42521	204.6
2015	14447	13679	5.31	42287	192.7
2016	14180	13364	5.75	43025	203.4
2017	14076	13736	2.41	41147	192.3
2018	13957	13757	1.43	42368	203.5
2019	13039	13351	2.39	37253	185.6
2020	12560	13216	5.22	37559	199