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A Study on the Effectiveness of Artificial Intelligence Approach on Sustainable and Intelligent Supply Chain Management in Food Industry

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ABSTRACT

The current research aims to study the effectiveness of artificial intelligence (AI) on sustainable and intelligent supply chain management in the food industry of East Azarbaijan province. The use of intelligent technologies and sustainability components based on organizational knowledge in the product supply chain not only improves the information level of the supply chain but also reduces the risk of product security problems, especially perishable products, by controlling the supply chain. Also, when a product security problem occurs, companies can help solve this problem through intelligentization and knowledge management. In this research, by comparing the regression rate, which is closer to the desired number of one, and the MSE rate of the obtained error value, which is very close to zero, in the best case, the results related to one hidden layer and two neurons were selected. Then, by calculating the sum of the weights of each layer and normalizing the weights, the importance of each input layer was determined. The research results showed that the order of importance of the independent variables in the neural network structure model is cultural factors, economic factors, environmental factors, and social factors. measures to be taken by businesses to realize digital transformation. **©authors**

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1. Introduction

Various advancements in IT capabilities have changed the industry at a faster pace than in the last decade (Kian, 2022).

A single supply chain consists of multiple processes and efficient planning is necessary to complete a supply cycle. In this regard, an effective logistics knowledge management system needs detailed planning (Nagajan et al., 2022). Motivating employees to change and adopt a new approach is challenging. Since people's understanding of the system is of great importance; Using a precise and measured method ensures its successful deployment (Hrouga et al., 2022). This solution provides the possibility to evaluate the level of user absorption and makes the necessary improvements to increase the use of knowledge management tools (Guo et al., 2022). The adoption and implementation of information technology are among the methods that apply a distinctive competitive personality in companies and supply chains (Aliahmadi et al., 2022). The supply chain is a set of steps that includes the preparation, planning, logistics planning, production, and distribution of a product (Qarakhani et al., 2022). The main goal of a supply chain network is to meet customers' needs, so the customer is a significant part of the supply chain network. The technological revolution based on applied knowledge in the field of supply chain intelligence experiences a transformative wave of innovations and new challenges (Abdul Zahra et al., 2022).

Despite the current fast digital technologies, customers expect that the process of ordering and delivering goods is done faster, and as a result, this has caused organizations that seek to implement new technologies and create databases and generate knowledge to provide services faster and more efficiently. Sayadi et al., 2022). A change in one link affects the other links because the processes are interconnected. Processes are constantly exchanging information and data, and links are constantly changing. Supply chain configuration must be customized based on the specific characteristics of each company and industry, so there is no universal intelligent supply chain model (Daya et al., 2022).

The application of information technology and the creation of a smart supply chain in the field of procurement and implementation can bring huge benefits by simultaneously reducing costs and increasing customer satisfaction (Al-Fuqaha et al., 2015). Usually, investing only in information technology and knowledge extraction is not enough, but fundamental changes in the physical aspects of management may be necessary so that the potential benefits of the intelligent supply chain can be fully realized (Xu, 2020).

Therefore, the competitive improvements resulting from the intelligent supply chain in the direction of sustainable development based on organizational knowledge can create threats for other competitors who are willing or unable to achieve such improvements. As a result, changes in the supply chain (facilitated by the dimensions of sustainable development and practical knowledge) can be ignored in some companies or, on the contrary, in some other companies, cause fundamental and costly changes in the production method (Strozzi et al., 2017).

Due to the reasons mentioned above, the sustainable supply chain can no longer be a partial function and issue, but it needs to be considered and managed as a central factor to achieve the success of the entire company. In this way, internal and external changes in smart supply chain activities based on sustainability components may be a sufficient reason for some companies to fundamentally revise their overall strategy (Yu et al., 2022). The benefits of smart implementation are evident throughout a sustainable supply chain: cost optimization, process flexibility, improved forecasting accuracy, improved customer satisfaction, and more. However, to use the intelligence opportunities based on the organization's knowledge capabilities, the required investment should be considered (Pal, 2022).

To face the challenges of technological developments, a significant investment of capital and resources is required. To determine whether an organization is mature enough to integrate advanced technology into its smart and connected supply chain, it is necessary to conduct comprehensive prior studies on each of the integrated elements of the smart and connected supply chain and examine them in turn. How the company operates as a whole requires that procedures and processes change, that the right people are hired to make the changes and that the organization is built in such a way that continuous improvement occurs. However, the driving force behind the digitization of the supply chain and its evolution into a system of intelligent and connected links is a continuous development (Zhu et al., 2018).

As the population increases, the problems related to food distribution among people become more complicated.

Hence, yesterday's food supply chains can no longer effectively meet demand, so they need to be restructured. Therefore, this chain should be a set of interdependent companies that work together to manage the flow of goods and services along the added value chain of food products. They can also realize customer value at the lowest possible cost. Due to the globalization of food, supply chains are growing and cross-border links are essential.

Therefore, it is necessary to identify the effective factors of intelligent sustainable supply chain management. Considering the food industry, this research is looking for an answer to the question, what is the effectiveness of the intelligent management of the sustainable supply chain with the approach of artificial intelligence?

2. Literature Review

Intelligentization, based on the Internet of Things (IoT) and blockchain, is one of the expected innovations that transforms the complex supply chain into an integrated process. Intelligence innovations, such as sensor data and RFID, provide information to equip the supply chain with features such as real-time tracking and alerting to improve decision-making. Such data can be turned into critical information to help improve operations. Smartization based on the IoT and Blockchain is driving supply chain logistics forward (Barreto et al., 2017). Intelligence based on the IoT and Block chain is a set of interconnected (physical) devices that can monitor, report, and send and exchange data. The information collected through the IoT and Block chain provides a wealth of information to manufacturers and other stakeholders for updated business visibility.

There are many devices in the field of IoT in the supply chain, such as autonomous and self-driving vehicles, and sensors for warning and informing customers, but the most interesting application of smartness based on the IoT and Block chain is the embedding of smart sensors in the production of a product to allow customers to track themselves throughout the smart supply chain to the final delivery stage (Wójcicki et al., 2022).

The novelty associated with IoT-based and blockchain-based intelligence comes from its potential for widespread application, as the technical barriers associated with automated monitoring are gradually removed and the associated costs are drastically reduced. The IoT envisions an ecosystem where intelligent, interconnected objects can sense changes in their surroundings, communicate with each other, process information, and play active roles in decision-making. Optimizing supply chain performance is one of the main concerns of production and logistics organizations (Szmelter et al., 2021).

Studies show the effect of information technology on improving responsiveness, distribution, and transmission of information, chain efficiency, and increasing cooperation in both internal and external dimensions, preventing the Bullwhip Effect and developing sales channels. The applications of information technology in supply chain management with two approaches of technology and information systems are also very important.

Studies have shown that factors such as organization size, success rate, uncertainty, and pressure from other chain partners play an important role in the adoption of information technology (Campos & Villa, 2018).

A comprehensive analysis of creating intelligence based on organizational knowledge should include all processes or components involved (Mohammadi et al., 2015).

Information and knowledge are important factors for success (Nahr et al., 2021). In order to align all integrated parties, all information must be generated and processed.

In recent years, all supply chain processes due to technological development and innovation, mainly in manufacturing under the umbrella of the IoT and Blockchain (Atzori et al., 2010), which include other innovations such as the cloud, digital assimilation, smart factories, and artificial intelligence. have been subjected to unprecedented changes (Kazancoglu et al., 2022).

Blockchain and the IoT have affected the current world from health monitoring, smart services, and integrated logistics to autonomous drones (Rani et al., 2021).

The IoT can optimize sustainable supply chain management, use knowledge and physical resources effectively, make the entire supply chain visible to improve the transparency of supply chain information, manage an intelligent supply chain in real time, and finally achieve agility. to improve

It brought great and complete integration to the smart supply chain based on sustainability components (Zadtootaghaj et al., 2019).

Compared to the electronic supply chain, the supply chain based on the IoT uses an information-sharing mechanism (Filina et al., 2021).

Product information in the supply chain is sent to the management database through information readers in different parts of the network, and this database sends the necessary feedback through information analysis. This allows for both repairs and price corrections to be made in a timely and accurate manner.

The information-sharing mechanism can enable manufacturers, distributors, and retailers to respond to market supply and demand information in a timely manner, ultimately balancing supply and demand and preventing product price fluctuations.

As a result, the IoT plays an important role in the supply chain and processes of intelligence and knowledge extraction.

3. Method

In this research, artificial intelligence technology has been used to determine the effectiveness of intelligent sustainable supply chain management. The artificial neural network is widely used to solve complex and non-linear problems. If these networks are not used to solve complex problems, computer codes and analytical algorithms are necessary (Jani et al., 2017).

To execute these codes and algorithms, in addition to taking a long time, computers with high speed and performance are needed; For this reason, the use of neural network algorithms helps to reduce simulation problems. The main components of a standard neural network are the input unit, the processing unit (neurons, nodes, and connections), and the output unit (Shahin, 2019).

This research uses data from food and beverage factories of East Azarbaijan province. Based on the fact that artificial neural networks need training data to perform calculations, the use of Shannon's entropy method for weighting was adopted. For the weighting of the training layers, the weights obtained from the training of the networks were used. Based on the training layers, the neural network analyzed the data using the Levenberg-Marquardt backpropagation method. MATLAB software was used for analysis.

LevenbergMarquardt is similar to lsqnonlin while levenberg-marquardt algorithm has three main advantages:

1- the jacobian can be updated using the Broyden method which minimizes function evaluations

2- the variables are transformed to implement box-constraints, and

3- function arguments can be passed on.

This toolbox requires the Jacobian toolbox of the same author (Alexander, 2023)

4. Findings

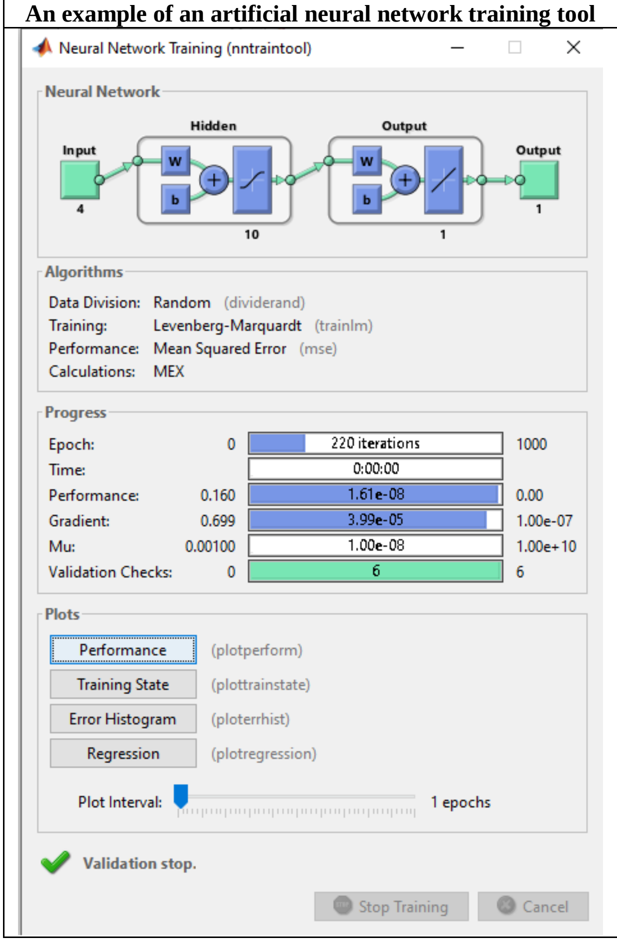
The suitability of the neural network model for developing a sustainable supply chain model is proposed as follows: The resulting neural network architecture includes 4 input layers, 1 middle layer with 2 units and 1 output layer. The performance function used in the middle layer is hyperbolic tangent function and the error function used is entropy. It should be noted that 70% of the data were used as training samples and 15% of the data were used as testing samples.

***Table 1.** Summary of the neural network model*

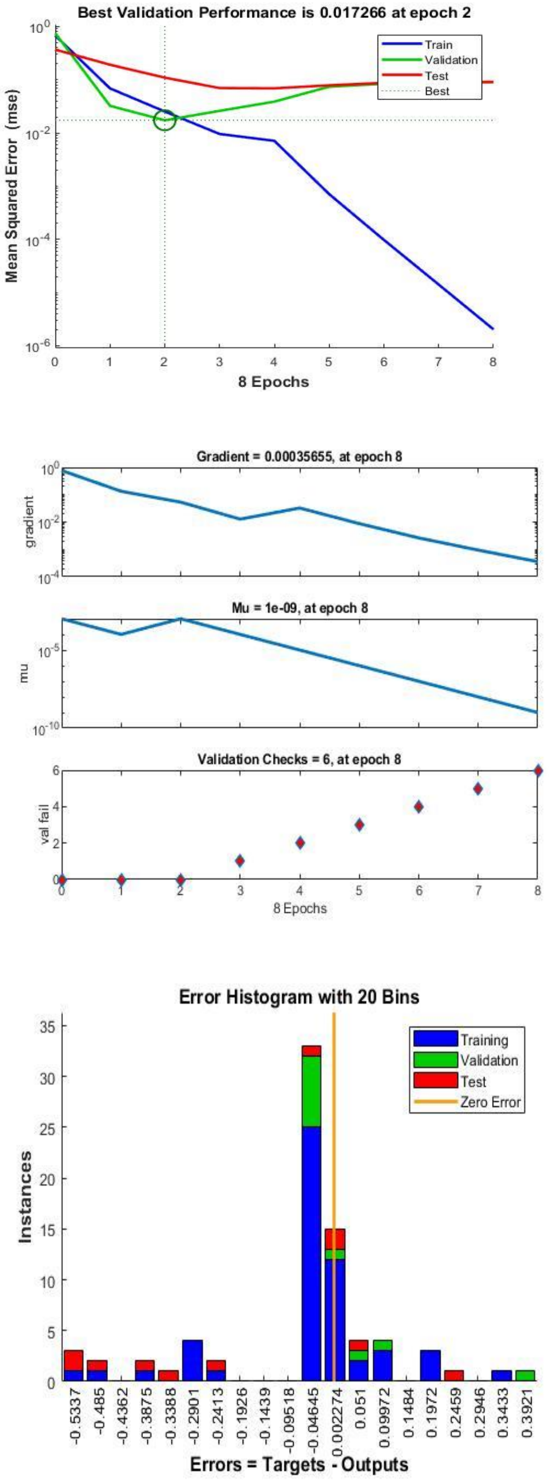
Economic factors	**1**	Independent variables	Input layer
Social factors	**2**		
environmental	**3**		
cultural	**4**		
4		The number of input layers	
Standardization		Scaling method	
1		The number of middle layers	Middle layer
3		The number of units in the middle layer	
Sustainable supply chain	**1**	**The dependent variable**	Output layer
1		The number of middle layers	
mse		Error function	

To train the artificial neural network in this research, the settings in Table 1 were applied. As it can be seen, the type of training function used is the Levenberg-Marquardt algorithm. Also, a hidden layer and the number of 1-10 neurons in the layer have been used. Also, the distribution of training, validation and test data was determined as 70, 15 and 15% respectively. The left part of Table 1 shows an example of artificial neural network training tool in MATLAB software for the case of 1 hidden layer and 10 neurons.

***Table 2.** Type of parameters used and corresponding values for artificial neural network training*

<table>
<tr><th>An example of an artificial neural network training tool</th><th>Amount</th><th>Parameter type</th></tr>
<tr><td rowspan="8">
</td><td>feedforwardnet</td><td>Neural Network Type</td></tr>
<tr><td>1</td><td>Hidden Layer</td></tr>
<tr><td>10-1</td><td>hiddenSizes</td></tr>
<tr><td>trainlm (Levenberg-Marquardt)</td><td>trainFcn</td></tr>
<tr><td>0.7</td><td>trainRatio</td></tr>
<tr><td>0.15</td><td>valRatio</td></tr>
<tr><td>0.15</td><td>testRatio</td></tr>
<tr><td>1000</td><td>epochs</td></tr>
</table>

Figures 1 to 10 show the performance results, training status, error histogram and regression of the artificial neural network with 1 neuron and 1 to 10 hidden layers.



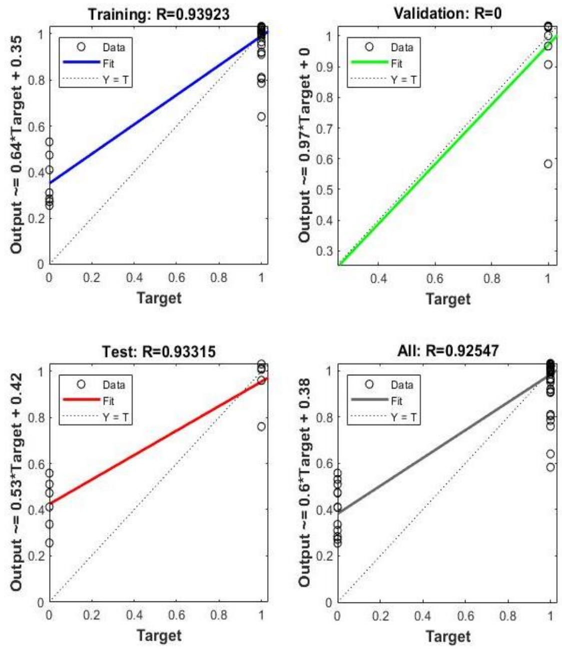
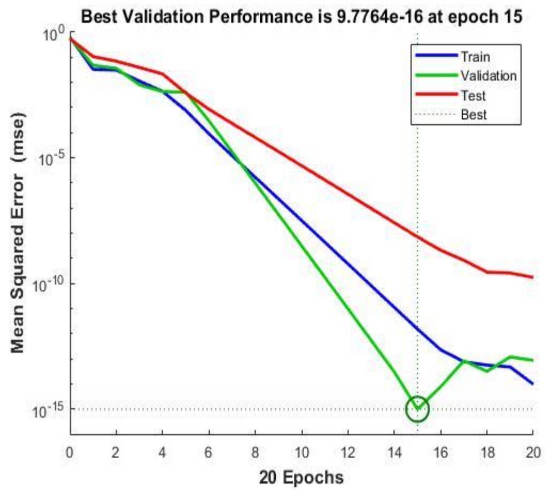


Figure 1. *Performance results presentation, training status, error histogram and regression of artificial neural network with 1 neuron and 1 hidden layer*

Figure 1 shows the results related to efficiency, training status, error histogram and regression of artificial neural network with 1 neuron and 1 hidden layer. The results showed that the MSE value is equal to 0.0173. Also, R values for training, validation, test and overall data are 0.9392, 0, 0.9331 and 0.9255 respectively.



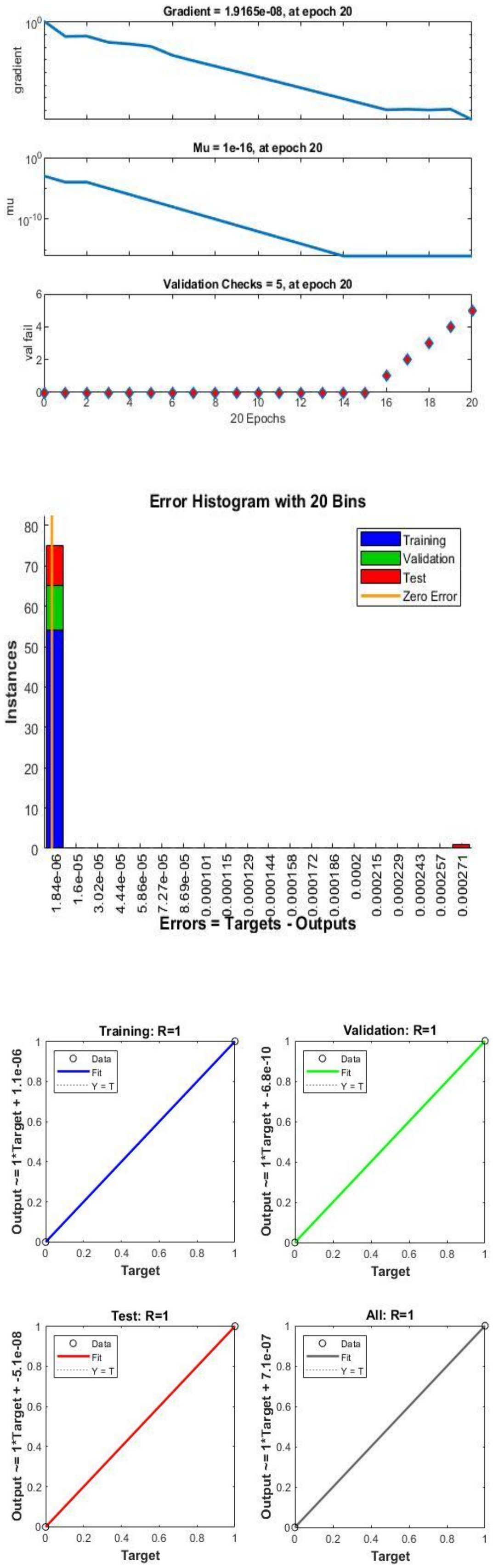
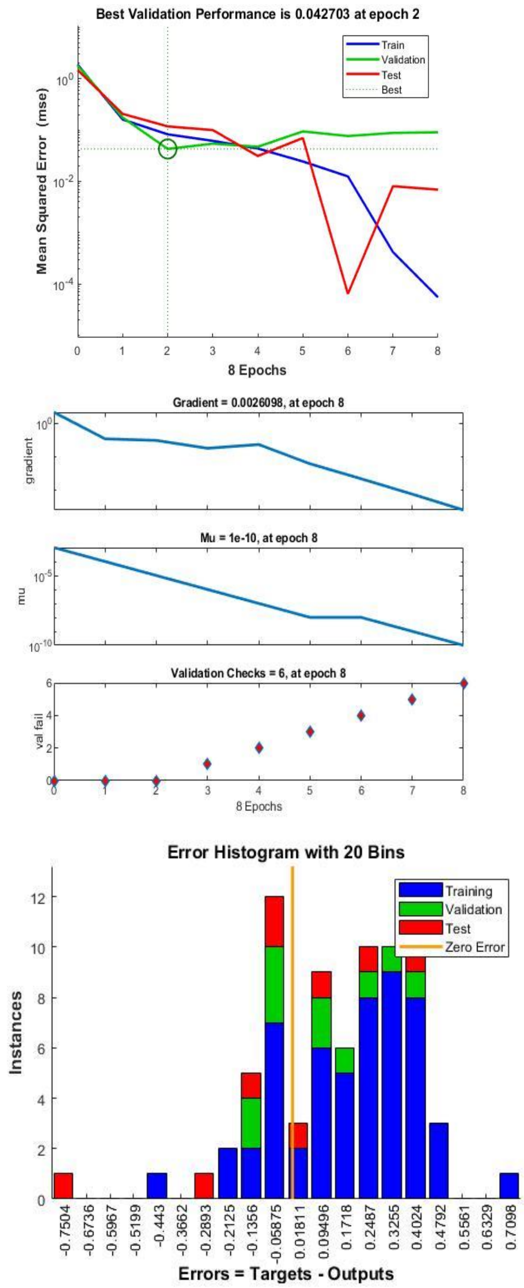


Figure 2. *Performance results presentation, training status, error histogram and regression of the artificial neural network with 2 neurons and 1 hidden layer*

Figure 2 shows the results related to efficiency, training status, error histogram and regression of artificial neural network with 2 neurons and 1 hidden layer. The results showed that the value of MSE is equal to 16e-9.776. Also, R values for training, validation, test and overall data are 1, 1, 1 and 1, respectively.



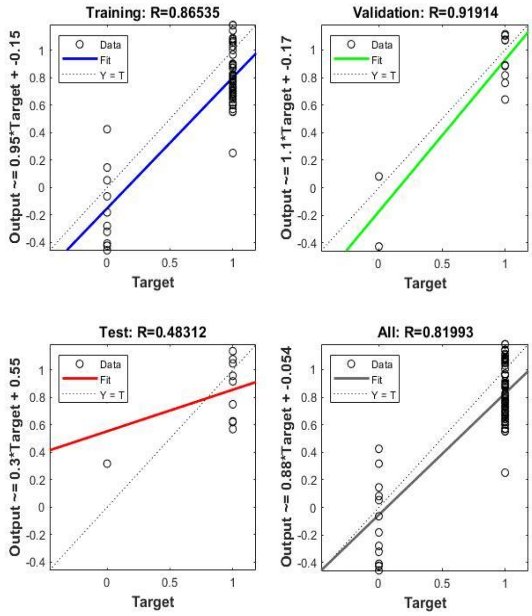
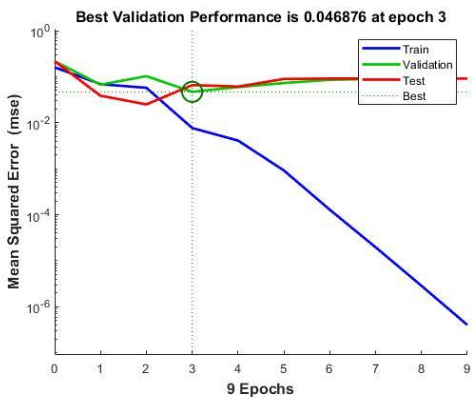
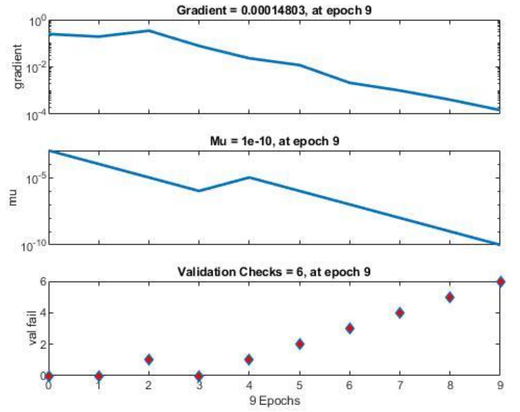
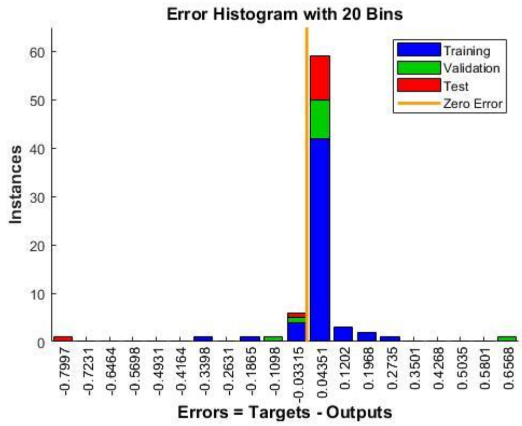


Figure 3. *Performance results presentation, training status, error histogram and regression of artificial neural network with 3 neurons and 1 hidden layer*

Figure 3 shows the results related to the efficiency, training status, error histogram and regression of the artificial neural network with 3 neurons and 1 hidden layer. The results showed that the value of MSE is equal to 0.0427. Also, R values for training, validation, test and overall data are 0.8653, 0.9191, 0.4831 and 0.8199 respectively.







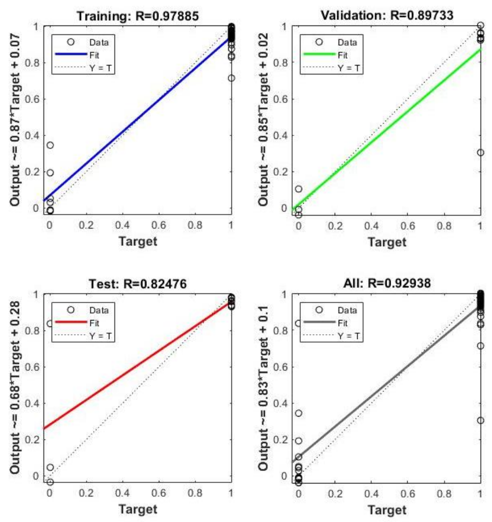


Figure 4. *Performance results presentation, training status, error histogram and regression of the artificial neural network with 4 neurons and 1 hidden layer.*

Figure 4 shows the results related to efficiency, training status, error histogram and regression of artificial neural network with 4 neurons and 1 hidden layer.

The results showed that the value of MSE is equal to 0.0469. Also, R values for training, validation, test and overall data are 0.9788, 0.8973, 0.8248 and 0.9294 respectively.

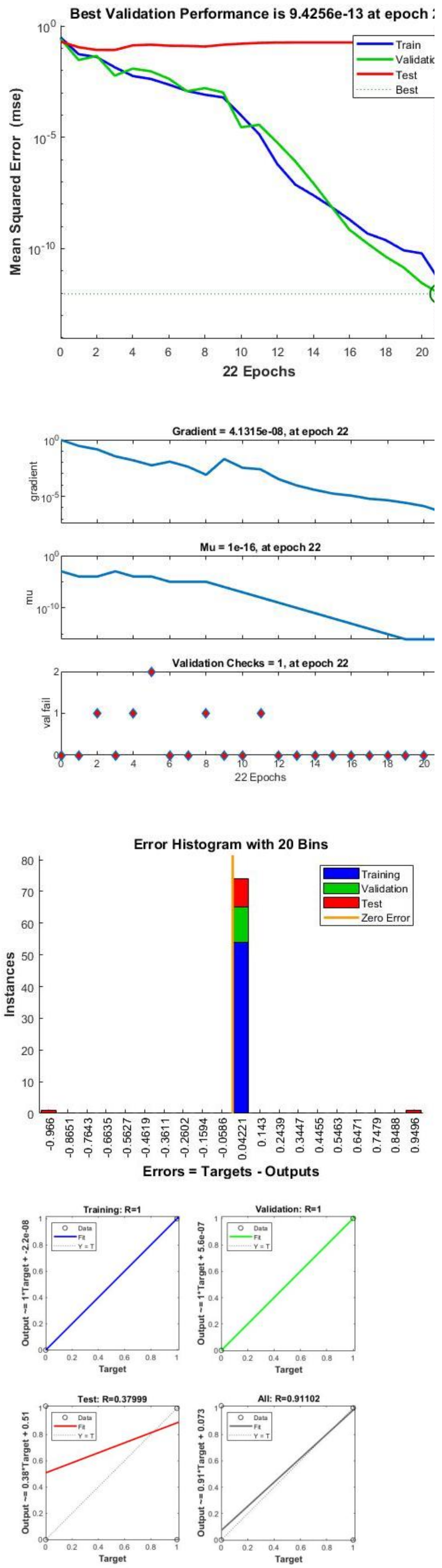
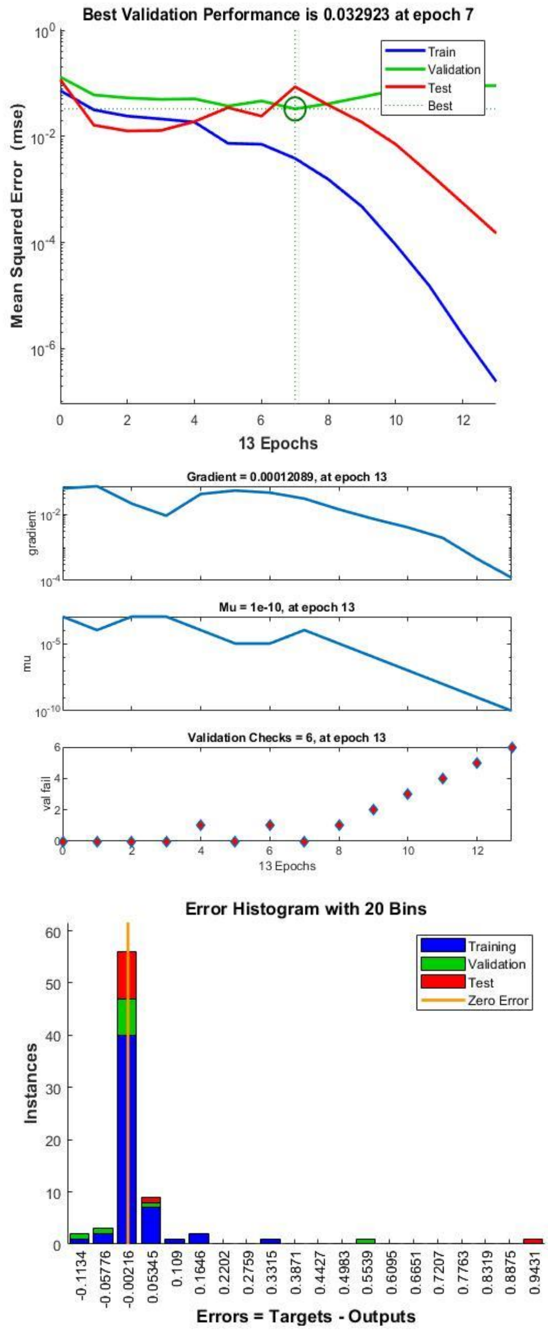


Figure 5. *Performance results presentation, training status, error histogram and regression of artificial neural network with 5 neurons and 1 hidden layer*

Figure 5 shows the results related to efficiency, training status, error histogram and regression of artificial neural network with 5 neurons and 1 hidden layer. The results showed that the value of MSE is equal to 9.426-13e. Also, R values for training, validation, test and overall data are 1, 1, 0.3799 and 0.9110 respectively.



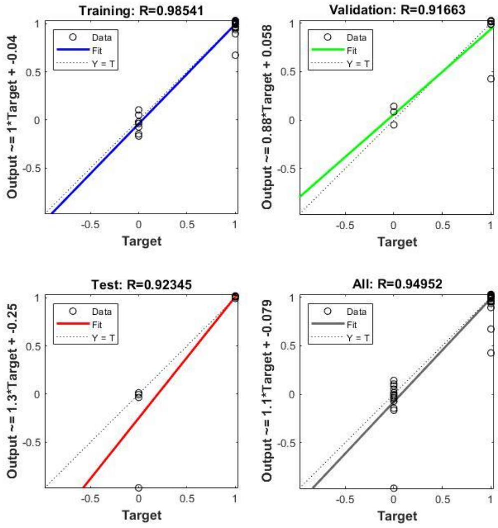
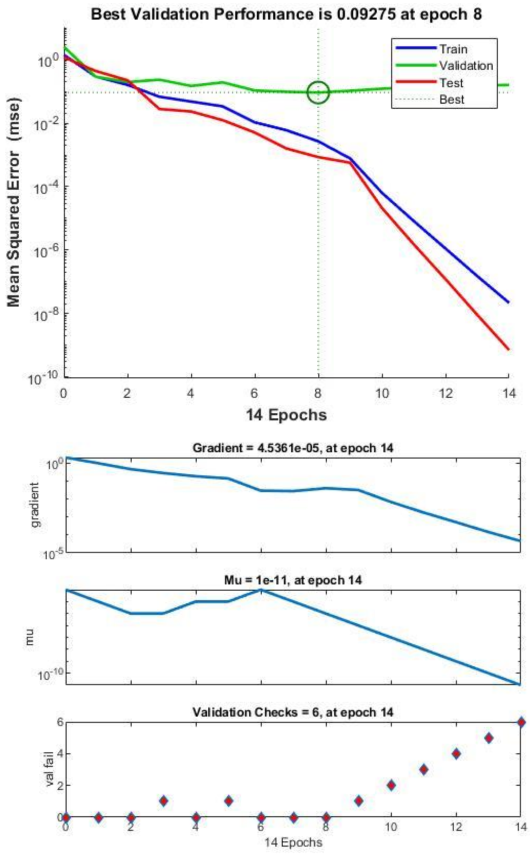
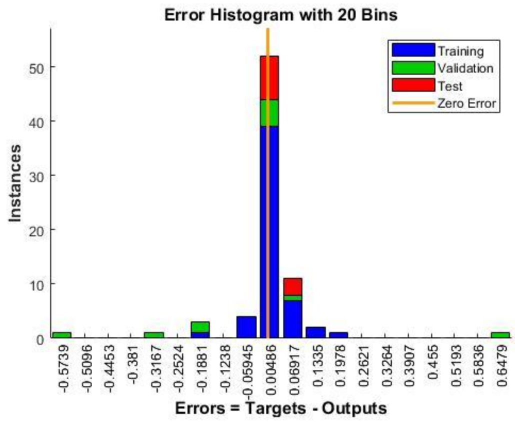


Figure 6. *Performance results presentation, training status, error histogram and regression of the artificial neural network with 6 neurons and 1 hidden layer.*

Figure 6 shows the results related to the efficiency, training status, error histogram and regression of the artificial neural network with 6 neurons and 1 hidden layer. The results showed that the MSE value is equal to 0.03292. Also, R values for training, validation, test and general data are 0.9854, 0.9166, 0.9234 and 0.9495 respectively.





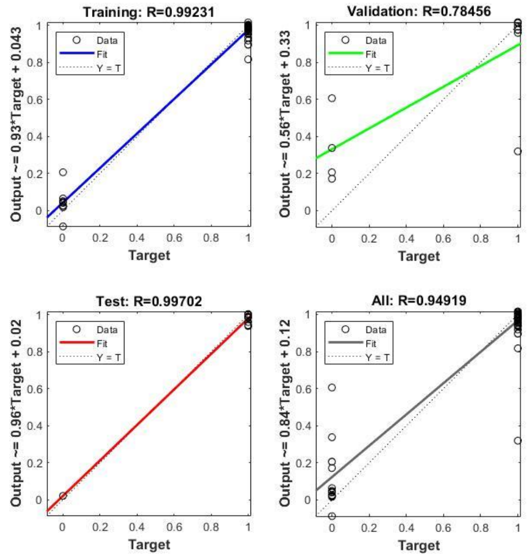
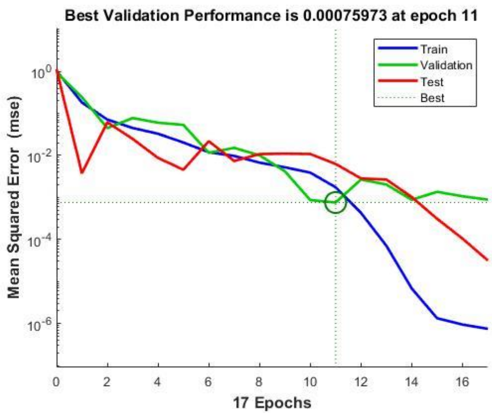


Figure 7*. Performance results presentation, training status, error histogram, and regression of artificial neural network with 7 neurons and 1 hidden layer*

Figure 7 shows the results related to efficiency, training status, error histogram and regression of artificial neural network with 7 neurons and 1 hidden layer. The results showed that the MSE value is equal to 0.0927. Also, R values for training, validation, test and general data are 0.9923, 0.7846, 0.9970 and 0.9492 respectively.



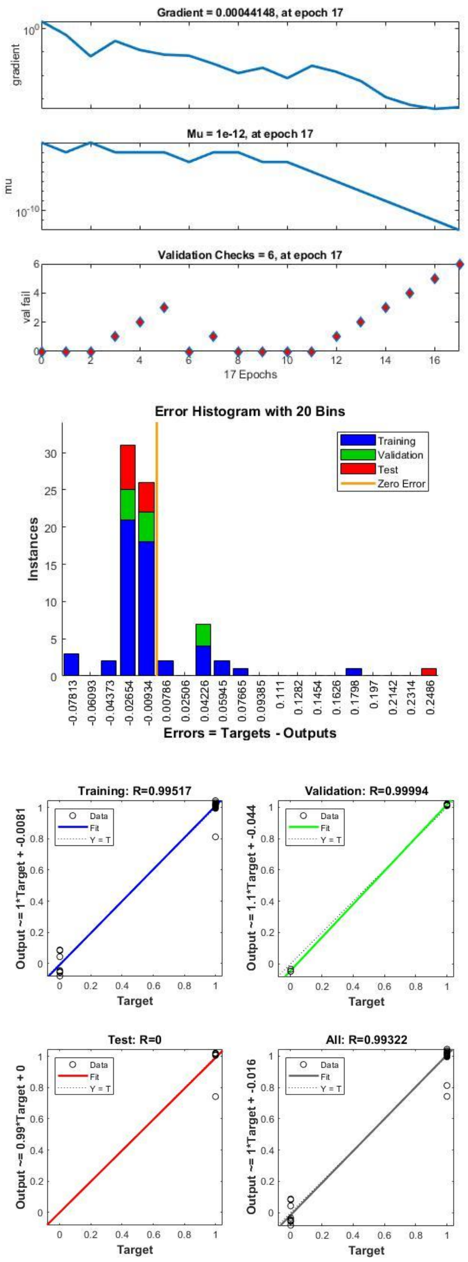


Figure 8. Performance results presentation, training status, error histogram and regression of artificial neural network with 8 neurons and 1 hidden layer

Figure 8 shows the results related to efficiency, training status, error histogram and regression of artificial neural network with 8 neurons and 1 hidden layer. The results showed that the MSE value is equal to 0.0008. Also, R values for training, validation, test and overall data are 0.9952, 0.9999, 0 and 0.9932 respectively.

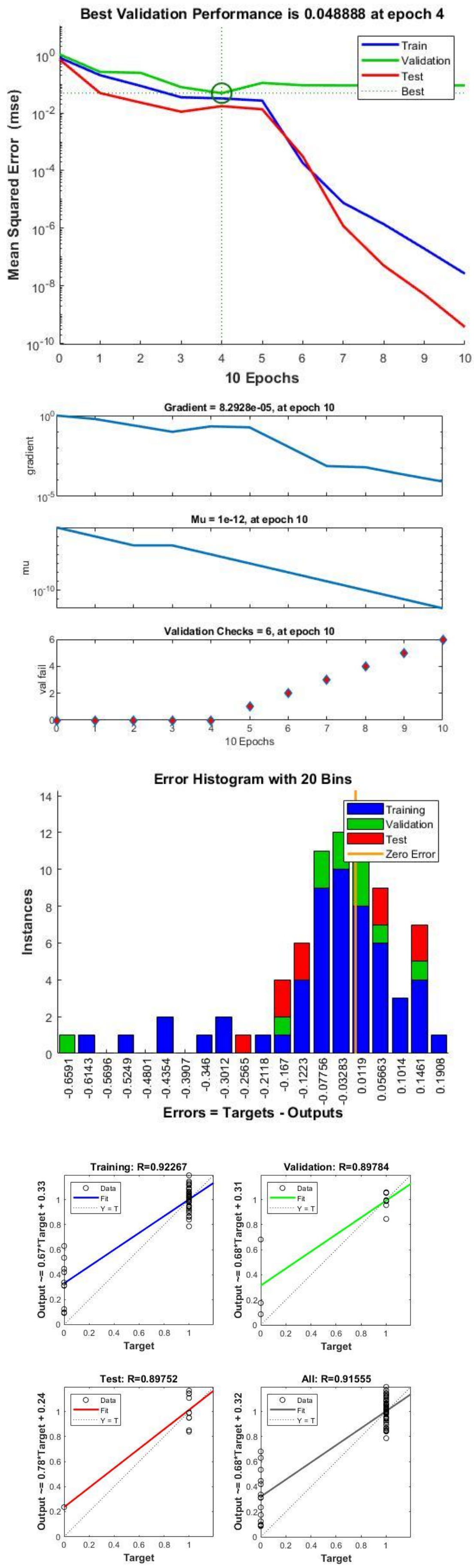
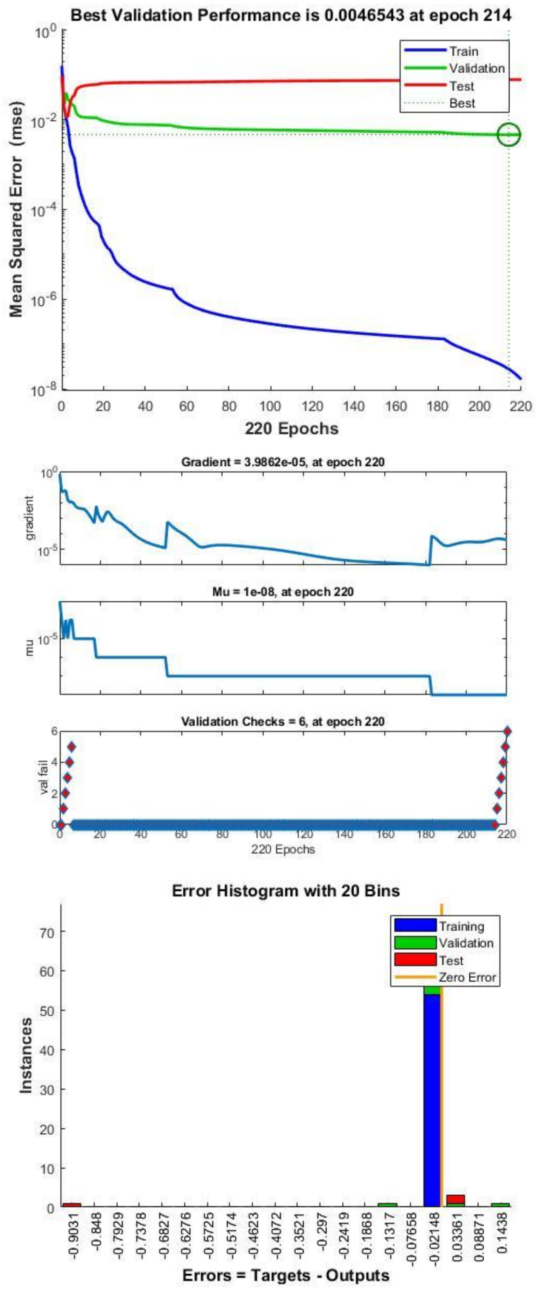


Figure 9. Performance results presentation, training status, training status, error histogram

and regression of artificial neural network with 9 neurons and 1 hidden layer

Figure 9 shows the results related to the efficiency, training status, error histogram and regression of the artificial neural network with 9 neurons and 1 hidden layer. The results showed that the MSE value is equal to 0.0489. Also, R values for training, validation, test and overall data are 0.9227, 0.8978, 0.8975 and 0.9155 respectively.



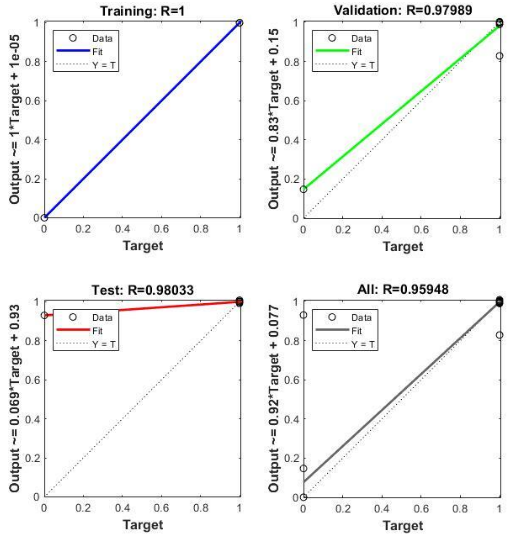


Figure 10. *Showing the performance results, training status, error histogram and regression of artificial neural network with 10 neurons and 1 hidden layer*

Figure 10 shows the results related to efficiency, training status, error histogram and regression of artificial neural network with 10 neurons and 1 hidden layer. The results showed that the MSE value is equal to 0.0046. Also, R values for training, validation, test and overall data are 1, 0.9799, 0.9803 and 0.9594 respectively.

As can be seen in Table 2, the best results are related to the mode of 1 hidden layer and 2 neurons. In this case, as seen in Figure 2, the amount of R is very close to one and the amount of MSE is also very close to zero.

Now, using the sum of the absolute values of the weights of each input layer, the importance of each layer was calculated as in Table 3.

Table 2. *Comparison of R and MSE results of artificial neural network with 1 to 10 neurons and 1 hidden layer*

The amount of MSE	R				Number of neurons in the hidden layer
	overall	Test	Validation	Training	
0.0173	0.9255	0.9331	0	0.9392	1
9.776e-16	1	1	1	1	2
0.0427	0.8199	0.4831	0.9191	0.8653	3
0.0469	0.9294	0.8248	0.8973	0.9788	4

9.426e-13	0.9110	0.3799	1	1	5
0.03292	0.9495	0.9234	0.9166	0.9854	6
0.0927	0.9492	0.9970	0.7846	0.9923	7
0.0008	0.9932	0	0.9999	0.9952	8
0.0489	0.9155	0.8975	0.8978	0.9227	9
0.0046	0.9594	0.9803	0.9799	1	10

Then the values of these weights were normalized and the importance of each input layer was determined. As can be seen, the most important layers are cultural factors, environmental factors, economic factors and social factors. Finally, Figure 11 shows the comparison between input layers in terms of importance.

Table 3. *Comparison of the total weights of the input layers, their importance and ranking*

Variable	The sum of the weights related to the layer	Importance	ranking
social factors	13.0967	0.0638	4
Economic factors	46.7055	0.2275	3
Environmental factors	66.6894	0.3248	2
cultural factors	78.8273	0.3839	1

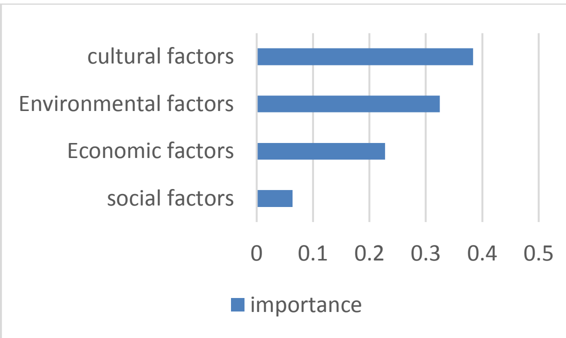


Figure 11. *Importance of different inputs of the artificial neural network for the case of 1 hidden layer with 2 neurons*

5. Discussion

The use of intelligent technologies and sustainability components based on organizational knowledge in the product supply chain not only improves the information level of the supply chain but also reduces the risk of product security problems, especially perishable products, by controlling the supply chain. Furthermore, when a product security problem occurs, companies can help solve this problem through intelligence and knowledge management. Likewise, consumers can access product information and reduce their purchase costs through electronic product labels. The supply chain for short-lived and perishable goods has always been one of the most important and challenging management topics at different times. Short-life goods, especially food, are the ones that cause the most challenges for the supply chain management. These challenges arise mainly due to the variety in the number of these goods, the special need to track and follow the flow of goods during the supply chain, the short life of the products, and the need to control the temperature in the supply chain.

In addition, the high volumes of goods that move along the supply chain make it imperative to make decisions regarding the selection of processes with the highest efficiency.

Therefore, efficient supply chain management is of the highest importance for short-life goods, especially food. Since increasing capital efficiency is one of the main goals of every industry, creating continuity as a result of rapid movement in the chain is considered one of the most basic needs of the food supply chain. In the food supply chain, we usually deal with a high volume of raw materials for products, this issue makes any kind of savings in the time spent on moving goods and managing the activities of the chain somehow become an important competitive advantage.

From the point of view of heat control, all operations that are performed in an environment other than refrigerated or frozen environments must be done very quickly. For example, speeding up the loading and unloading of trucks and cargo trailers reduces the risk of contamination or spoilage of goods.

Nowadays, due to the increase in the provision of ready-made foods and packaged meat and non-meat products, the variety of perishable and short-lived goods is increasing rapidly. It is obvious that the variety of goods greatly increases the complexity of supply chain control. As a result, with the complexity of warehouse management and warehouse capacity planning, and production scheduling, supply chain efficiency is faced with stagnation. For example, predicting the amount of consumption of all types of these goods will be a very difficult and time-consuming task; Due to the limited use-by date of food, only a limited amount of the optimum point (confidence point) can be kept in the warehouses, and as a result, it cannot be guaranteed that a certain product is always available in the warehouse at any time and requests can be answered immediately.

Another problem in the food supply chain is waste. Wastes are more than anything else from the turnover of surplus inventory and current inventory. Therefore, the efficient warehouse rotation should be able to guarantee that the goods are removed from the warehouses based on correct and correct orders and according to what was predicted in their use-by date. Unfortunately, one of the biggest problems that can be seen in many supply chains is that the various links of the supply chain, such as the manufacturer, distributor, seller, and other components, do not have accurate information about the expiring inventory and the exact date of consumption of the contents of their warehouses; We can see that the scope of this problem is somewhat wider than the previous problems. For example, in a retail store, waste costs account for about 10% of the total costs of all short-lived products. In the European grocery sector, it is estimated that the goods that are not sold before their expiry date, cost several billion dollars of damage to different parts of the chain every year. The correct circulation of goods and reducing the amount of storage in the supply chain are the key points to reducing the amount of waste. Rani et al. (2021) also showed that cultural factors are very important in the application of information technology and the adoption of technology in the supply chain.

6. Conclusion

Based on the analysis, it is obvious that a correct information collection system can help to solve the challenges and problems of food supply chain management and other perishable materials. Accurate data recording helps us track inventory and sales throughout the supply chain channel.

This brings transparency to the supply chain and therefore helps with more accurate forecasting and supports the optimization of warehouse procurement; Also, by expanding the field of vision in the distribution chain, it is possible to plan for stocking warehouses. Optimum procurement while keeping the inventory at an acceptable level also reduces the amount of waste in the warehouse. The ability to see and check the distribution chain also allows managers to be informed of shortages or excess stock of warehouses at the time of occurrence and react to them before the threats become apparent and make the necessary decisions.

The sustainable supply chain in the field of food industry includes local, regional, national, and international arenas and creates a series of shorter and independent transactions between producers, processors, manufacturers, and retailers. Therefore, regarding this importance, in this research, the impact of various factors on the sustainable supply chain was compared using the artificial intelligence approach in the food industries of East Azerbaijan Province. Due to the ever-increasing growth of technology and intelligence and the necessity of knowledge application, in priority applications, the amount of knowledge functions can be increased in different parts of the supply chain. Due to budget constraints and available resources, companies and supply chains cannot implement all these programs in their business.

Declaration of Competing Interest

The author declares that he has no competing financial interests or known personal relationships that would influence the report presented in this article.

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