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Research Article

COMPARATIVE STUDY OF INVENTORY CLASSIFICATION (CASE STUDY: AN AFTER-SALES SERVICES COMPANY RELATED TO HEPCO COMPANY)

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ABSTRACT
Today classification of inventory through scientific techniques constitutes main part of productive and service systems activities. Organizations believe that considering different criteria and using techniques and methods with the least error is necessary for inventory classification and Regulation of stock. In this study, focuses on the multi criteria classification of inventory of Hesco After-Sales Services Company. The classification is performed considering four criteria including unit price, demand, ordering cost and lead time. The inventory of stock is classified using a neural network with one hidden layer and Back Propagation and Genetic algorithm. 800 items of stock of Hesco Company are embedded in three groups A,B and C. There are 192 items in group A, 173 items in group B and 435 items in group C. Using the traditional method of ABC classification we classified inventory in group A with 209 items, group B with 154 items and group C with 437 items. Eigenvector technique is also used to weigh the criteria, and final scores are ranked using Simple Additive Weighting Method (SAW). Using this method, the inventory includes 160 items in group A, 240 items in group B and 400 items in group C. Then using goodness-of-fit Average Method we prioritized the three used methods.

Keywords: *ABC Inventory Classification, Neural Network, Genetic Algorithm, Back Propagation Algorithm, Traditional Classification, Classification Using Eigenvectors Techniques And Simple Additive Weighting Method, Goodness-Of-Fit Average*

INTRODUCTION
In organizations where thousands of different material and additional sections exist, efficient management many not will be done. In order to an organization avoid inefficient allocation of materials, planning & control systems should be used in resource management. A planning and purchase control system can make a balance between the two opposing forces. The system has to protect company against lack of raw material inventory during consumption and lack of produced goods and to keep current prices at the lowest level (Partovi and Anandarajan, 2002). Today with the development of computer technology, more data is available. Therefore, advanced data base methodologies are developed increasingly to help decision making management, so human involvement is decreased in this process. In return, they increase accuracy and consistency of decision making process, at the same time they reduce processing time. One of the classification methods of multi criteria inventory is using artificial intelligence (Guvenir and Erel, 1988). Artificial neural network (ANN) of an artificial intelligence based on a technique which is applicable in classification process. Many researchers applied AHP, proposed by Saaty (1980), in ABC classification. The advantage of AHP method is that it can integrate most of qualitative and quantitative criteria classify, also it is easy to use and has the least dependence on extensive accounting and measuring system (Partovi and Anandarajan, 2002). Guvenir and Erel proposed a substitute method in which a genetic algorithm is used to find criteria weights. First, they discussed hierarchic process framework and it 's application in inventory classification, then explained genetic algorithm application in multi criteria inventory classification problems (Guvenir and Erel, 1988). Torabi *et al.,* (2012), proposed a reformed model resulted from DEA models which considered qualitative and quantitative criteria at the same time, these criteria are essential in understanding ABC inventory classification (Torabi *et al.*, 2012).
Nazemi *et al.,* (2012) provided a model using ABC-FUZZY method to classify types of materials and inventories of Hamoon Panel building factory. First, they divided 77 items of row materials into 3 groups

based on ABC method, 11 items in group A, 16 items in group B and the remained 50 items in group C. Then they applied criteria such as consumption criteria, scarcity and criticality of items using ABC method in combination with fuzzy classification to classify 77 types of used items. It was revealed that 14 items are very important, 20 items are important and 43 items are not important.
Vencheh (2009) performed a study that focused on an improvement to multi criteria ABC inventory classification.
Paliwal (2007) provided a review of neural network applications and statistical techniques in which neural networks are used for prediction and classification, where statistical methods are used in traditional way.
Ramanathan (2004) performed a study on ABC inventory classification using weighted linear optimization and proposed a simple classification model with weighted linear optimization application.
Guvenir and Erel (1998) performed a study on multi criteria inventory classification using a genetic algorithm. One of the genetic algorithm applications is parameter optimization. Crossover technique is used for multi criteria inventory classification problem and the results are compared with classical inventory classification techniques using AHP. A new approach of genetic algorithm application in multi criteria classification is proposed.
Vencheh (2009) performed a study on amendment of inventory classification with multi criteria. The aim of this study was to propose a model for multi criteria inventory classification to amend N.G model in ABC analysis, the proposed model determines a linear programming model which is a common set of weights for all of the items. The results of this model show that the proposed model is more reasonable and contains more indices of time of using weights for each item. A simple example is presented to compare the proposed model with N.G model.

MATERIALS AND METHODS

Inventory Classification based on Neural Network

Each data contains four type of information: unit price, ordering cost, demand and lead time. Unit price (less than 10 million Rial, more than 10 million Rial), ordering cost (between 10 thousand Rial to 1 million Rial, more than 1 million Rial), demand (below 10, between 10 to 50, more than 50), lead time (between 1 to 30 days, between 30 to 60 days, more than 60 days).

Table 1.3: Information range of each criterion for data

Criterion	High	Medium	Low
Unit price	More than 10000000 Rial		Less than 10000000 Rial
Ordering cost	More than 1000000 Rial		Between 10000-1000000 Rial
demand	More than 50	Between 10-50 pcs	Less than 10
Lead time	More than 60 days	Between 30-60 days	Between 1-30 days

In this study 600 data was considered as the training set and 200 data as the experimental set.
Neural networks used in this study are in Matlab software, in the form of multi layer perceptrons including one input layer, a hidden layer and an output layer. The network consists of 4 input neurons (one for each characteristic), 19 hidden neurons and 3 output neurons (i.e. A, B, C items).
The results are improved based on Genetic algorithm in such a way that decrease error in the network and implement more effective and efficient classification.
1) Providing items
2) Selection Criteria
3) Creating a neural network model
4) Training Network
5) Using genetic algorithm to improve the prediction

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Classification Based on Traditional Method

Pareto principle states that for many events, 80% of effects are due to 20% of causes. The rule was first proposed by Vilfredo Pareto (known Italian economist) and then Joseph Juran called it Pareto principle. One of the common applications of this principle is at inventory classification. In this kind of classification goods are classified in descending order based on their dollar value per unit multiplied by annual usage rate. Then goods are divided into A,B,C class. Goods of A class have the highest value. The class includes a small number of total goods and the monetary value consists 70 to 80 percent of total inventory annual dollar usage. As a general rule, 20% of the items consist 80% of the annual dollar usage of the inventories. Items of class B have medium value, typically consist 30-40% of items and their annual dollar usage consists 15% of total inventory dollar value. Items of class C have less value. The goods consist main part of inventory; their annual dollar value is little. It consists 5-10% of inventory annual dollar value (Rezaee and Ismaeilzade, 2010).

Classification based on using Weighted Data and Final Score Ranking

Decision-making process using the nominal group technique consists of four distinct steps that can be changed depending on different situations. The steps are:

Step 1: Creating Ideas
Step 2: Recording Ideas
Step 3: Explaining Ideas
Step 4: Voting on Ideas

Then criteria are weighted using eigenvector technique and inventory items are ranked using SAW technique. Based on Pareto principle, inventory items are categorized in A,B,C class.

Simple Additive Weighting SAW (Simple Additive Weighting Method) Method

This is one of the oldest methods used in multi criteria decision making,
given W vector (indices importance weights), the best choice (A^*) is calculated as: (Asgharpur, 2010)

$$A^* = \left\{ A_i \middle| \max_i \frac{\sum_j W_j . r_{ij}}{\sum_j W_j} \right\}$$

Where $\sum_j W_j = 1$:

$$A^* = \left\{ A_i \middle| \max_i \sum_j W_j . r_{ij} \right\}$$

Models Comparison

As in ABC classification there is no method as a benchmark, a novel method, entitled "goodness-of-fit average method", is used. One can use this method in comparison with similar methods in different areas (Rezaee and Ismaeilzade, 2010).

Method Explanation

If we show the compared models with Dj, (j = 1,2, ..., J) and the number of items with Ni, (i = 1,2, ..., N). This method involves the following stages:

Stage one: First the following table is designed to write in A to K categories, methods used to assign item i in related category

categories / **items**	A	B	C	………..	K
1 2 . . . . N	Methods that assign item i in category B	Methods that assign item i in category C			Methods that assign item i in category K

Stage two: According to the table we calculate the score of each method of each item (goodness-of-fit rate in allocation of each item to triple categories) using below equation:

$$\mu_{jik} = \frac{D_{ik}}{.J} \quad for \quad (i = 1,2,\ldots,N \quad , \quad k = A,B,C,\ldots,K \quad , \quad j = 1,2,\ldots,J)$$

Where M_{jik} is goodness-of-fit rate of J in allocating item I to category k, D_{ik} is the number of methods that put item I in K category, and J is total number of methods used in item classification.
Stage three: In this stage, goodness-of-fit average of each method is calculated using below equation:

$$\mu_j = \frac{\sum_{i=1}^{N}\sum_{k=1}^{K} M_{jik}}{N} \quad for \ j = 1,2,\ldots, J$$

In this equation $\sum M_{jik}$ is the score of method J for item I. It is obvious that there is only one nonzero M_{jik} for each I and J. They are arranged in a descending order, and the highest one determines the best method (Rezaee and Ismaeilzade, 2010).

RESULTS AND DISCUSSION

Results

Table: Characteristic of applied neural network

The number of training data	600
The number of test data	200
Transfer function	tansig
The number of input layers	1
The number of hidden layers	1
The number of output layers	1
The number of input layer's neuron	4
The number of hidden layer's neuron	19
The number of output layer's neuron	2
Type of training algorithm	Backpropagation error, genetic

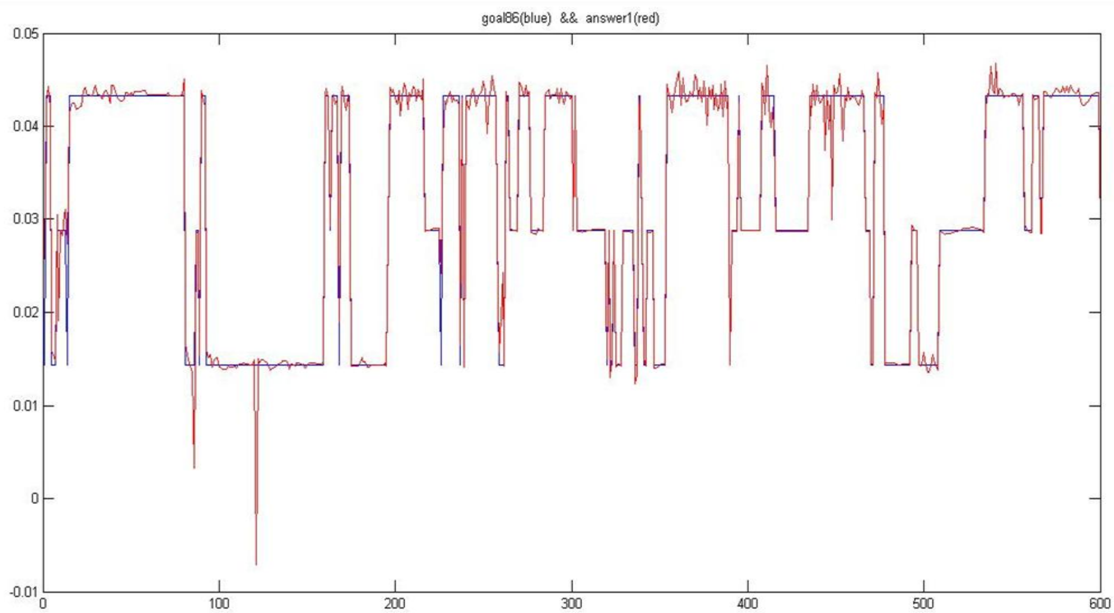
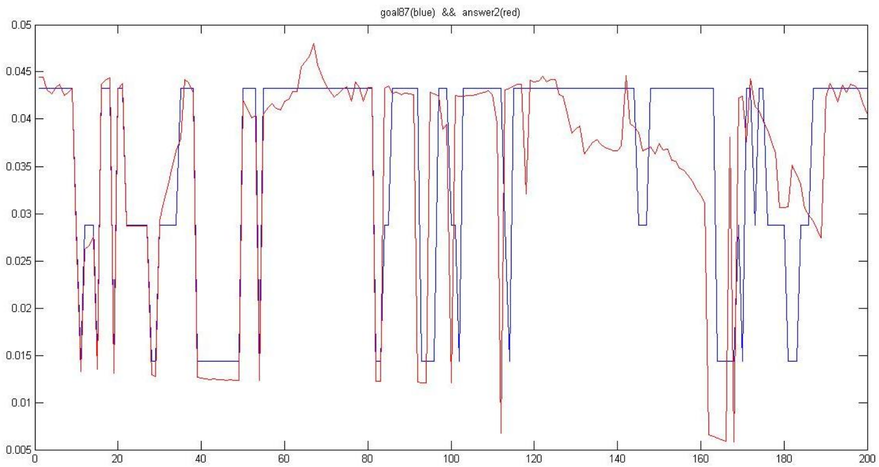


Diagram 2.4: The output of the software resulted from prediction and date training
Source: the output of the software

The diagram represents results of the data which was trained to neural network model. The number of items for training to neural network is 600 and blue lines represent trained data, and red lines represent prediction results trained to the network.



Source: calculated output of software

The diagram represents 200 items of inventory which are tested by the network.
An error, for example, is 0.0034.
Then they are optimized by genetic algorithm.
After implementation of genetic algorithm, stimulation error equals: 1.158*10^(-5)
The results of the inventory classification are:
The number of items in group A: 192
The number of items in group B: 173
The number of items in group C: 435
The number of items in group C are more than items of group A and B. The items of group A are more important and Hesco company has to focus on this group to prevent related loss.

Network Results after Genetic Algorithm Implementation

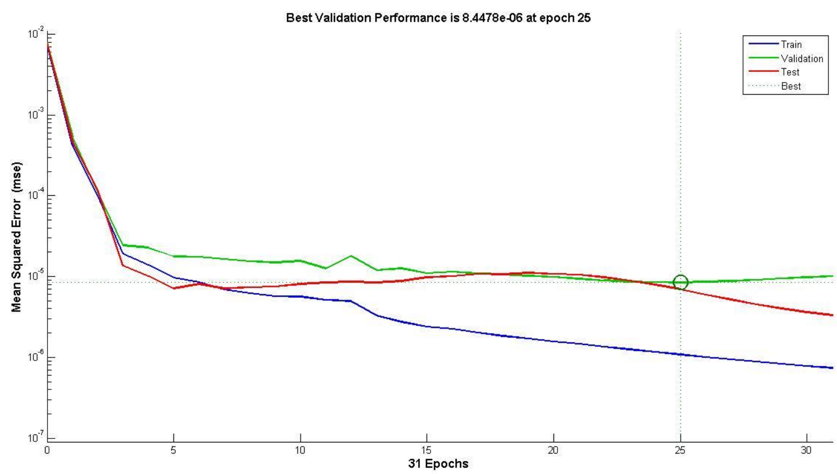


Diagram 4.4: Curve of least square error in training stages and validation

In diagram 4.4 the selected circle is on 10^{-5} which in Epochs is 25.

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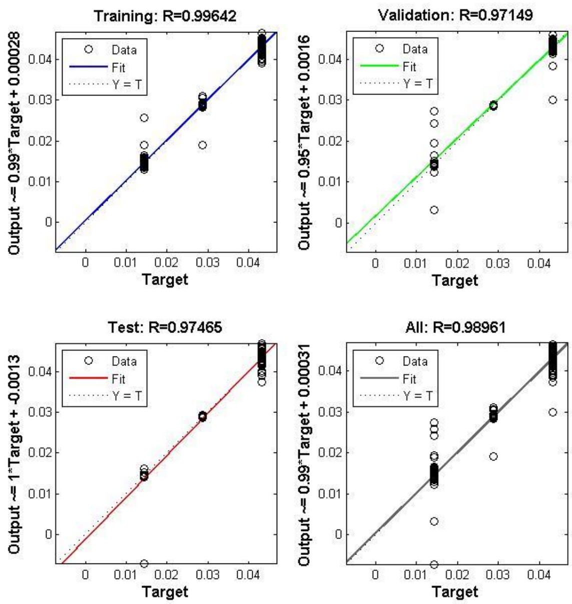

Diagram 5.4: Regression curves

ABC Data Classification using Traditional Method

Results of this categorization are:
The number of items of group A: 209
The number of items of group B: 154
The number of items of group C: 437

Data Classification using Weighted Data and Final Ranking

Using nominal group technique, pair-wise comparison of criteria was implemented. Assessment was done based on Saaty's 9 unit decision making who was inventor of ANP method. In this assessment 1 is equal preference, 3 is small preference, 5 is medium preference, 7 is high preference and 9 is absolute preference and numbers 2, 4, 6 and 8 are considered as "between preferences values", relatively. The results are provided in the following table:

	Unit price	Ordering cost	demand	Lead time
Unit price	1	3	7	5
Ordering cost		1	3	1
demand			1	1/3
Lead time				1

$$D = \begin{bmatrix} 1 & 3 & 7 & 5 \\ 1/3 & 1 & 3 & 1 \\ 1/7 & 1/3 & 1 & 1/3 \\ 1/5 & 1 & 3 & 1 \end{bmatrix}$$

First transfer:

$$D^1.e = \begin{bmatrix} 16 \\ 5.333 \\ 1.81 \\ 5.2 \end{bmatrix} ;\ e^t.D^1.e = (1,1,1).\begin{bmatrix} 16 \\ 5.333 \\ 1.81 \\ 5.2 \end{bmatrix} = (28.343)$$

$$W^1 = D^1.e \,/\, e^t.D^1\,.e = (0.565,0.188,0.064,0.183)$$

Second transfer:

$$D^2 = D.D = \begin{bmatrix} 4 & 13.33 & 38 & 15.33 \\ 1.30 & 4 & 11.33 & 4.67 \\ 0.46 & 1.43 & 4 & 1.71 \\ 1.16 & 3.6 & 10.4 & 4 \end{bmatrix}$$

$$W^2 = D^2.e \; / \; e^t.D^2.e = (0.595, 0.179, 0.064, 0.161)$$

Third transfer:

$$D^3 = D^2.D = \begin{bmatrix} 16.94 & 53.33 & 152 & 61.33 \\ 5.18 & 16.33 & 46.4 & 18.92 \\ 1.85 & 5.87 & 16.67 & 6.79 \\ 4.65 & 14.55 & 41.33 & 16.88 \end{bmatrix}$$

$$W^3 = D^3.e \; / \; e^t.D^3.e = (0.592, 0.181, 0.065, 0.162)$$

Fourth transfer:

$$D^4 = D^3.D = \begin{bmatrix} 68.70 & 216.15 & 614.58 & 250.032 \\ 21.037 & 66.26 & 188.42 & 76.62 \\ 7.55 & 23.78 & 67.63 & 27.49 \\ 18.78 & 19.15 & 168.15 & 64.44 \end{bmatrix}$$

$$W^4 = D^4.e \; / \; e^t.D^4.e = (0.592, 0.181, 0.065, 0.162)$$

It can be seen that process convergence occurred in the fourth transfer and the calculation is demonstrated i.e. W^4 determines final vector and weights for the indices of the given problem (Asgharpur, 2010).
Now we calculate compatibility degree.

$$\lambda_{max} = \frac{\sum_j a_{ij} W_{ij}}{W_i} = \frac{1*(0.592) + 3*(0.181) + 7*0.065 + 5*(0.162)}{0.592}$$

As a result:

$$C.I = \frac{4.054 - 4}{4 - 1} = 0.018$$

$$C.R = \frac{C.I}{R.I} = \frac{0.018}{0.9} = 0.02$$

Therefore we can see that the stability of the matrix D is acceptable and it has high compatibility (Asgharpur, 2010).
The results from this classification are:
The number of items of group A consists 20% of items, 160 items
The number of items of group B consists 30% of items, 240 items
The number of items of group C consists 50% of items, 400 items

Methods Comparison

In this part inventory items are classified using neural network models, traditional and eigenvector technique considering four criteria: demand, unit price, ordering cost and lead time. Then they are compared and prioritized (Rezaee and Ismaeilzade, 2010).

Prioritization of applied methods based on goodness-of-fit

Methods	**Goodness-of-fit**	**Method's rank**
Classification based on neural network	0.684619	First
Classification based on weighting criteria	0.410836	Third
Traditional classification	0.682497	Second

Discussion and Conclusions

Since organizations consider importance of different criteria for each inventory as well as large number of inventory items, ordering stock is an important issue for them. Also, as organization's inventory consists part of the organizations investment focusing on it is one of organization's activities. Importance and

necessity of this study is that it can be applied in organizations and one can consider more important criteria for strategic and operational purposes. The inventories Hesco company are classified using three classification methods which in two methods we used four criteria at neural network and eigenvector technique. Comparison of the three method shows that classification error is lower when we use neural network compared with two other methods and classification error is higher in weighting criteria.
We used a multilayer Preceptron neural network with back propagation learning algorithm and the learning algorithm and genetic optimization to implement inventory classification and ordering stock, the results from the classification using Matlab software are:

The number of group A	192
The number of group B	173
The number of group C	435

Inventory classification carried out using traditional method, according to results from implementing this classification in Excel software, the result are:

The number of group A	209
The number of group B	154
The number of group C	437

Inventory classification using weighted data and the final score ranking was carried out. According to the results from this classification method implemented in Excel software, the results are:

The number of group A	160
The number of group B	240
The number of group C	400

Further studies can be investigated considering other qualitative and quantitative criteria that may have a significant impact on the classification of inventory including inventory maintenance cost for each unit, sensitivity, diversity, refill storage, replacement, scarcity, durability, etc. Other researchers can use more hidden layers in the model.
Providing an effective and satisfying learning algorithm in neural network has been a controversial issue, especially for problems that require a great deal of data. Thus, reducing training time and increasing the accuracy of the model is important.

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