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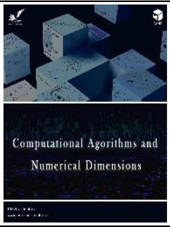

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Extracting Knowledge of Preventive Maintenance Using Data Mining Technique in Interaction with Production within Textile Industry

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Abstract

In the current research, the dataset for conducting data mining calculations was generated based on a sample with 2,000 data, reports of the general manager of the textile industry of Iran's Ministry of Industry, Mine and Trade (information from 240 industrial units and 630 spinning and weaving units were collected), and textile industry plants in Borujerd as the place for implementing the plan between 2015 and 2019, a period 6 month each year. Due to extensive information from the textile industry (with the help of the Ministry of Industry, Mine and Trade), the current research is unique. Using IBM SPSS Modeler 18, the most significant results of datamining calculations to extract knowledge are as follows, which are arranged based on main predictors of the research: predicting models of "strategy innovation in net with data code (A5)" with the prediction wight of 0.34; "technology innovation in net with data code (A1)" with the prediction wight of 0.30; "work environment innovation in net with data code (A3)" with the prediction wight of 0.16; Quality innovation in net with data code (A4)" with the prediction wight of 0.15; "employe innovation in net with data code (A2)" with the prediction wight of 0.10 are utilized to accurately analyze preventive maintenance in interaction with production.

Keywords: Preventive maintenance systems, Data mining, IBM MODELER, Textile industry.

1 | Introduction

The main reason for conducting the current research is to extract knowledge of preventive maintenance using sophisticated data mining techniques in interaction with production within Iran's textile industry in order to increase productivity and decrease innovation-based losses, to decrease losses based on the operation of equipment health indicators, make smart decisions on the prediction of remaining shelf life of equipment, and the chance of equipment failure and reliability. The main goal of the research is to design a smart model of preventive maintenance using data mining techniques in interaction with production operations. To implement artificial intelligence model, and innovation-based smart model with help of knowledge extracted by designing and utilizing data mining techniques. Availability of vast information regarding equipment in the production line and exploiting those using data mining software along with learning knowledge can innovate in the use of extraction.

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Maintenance is significantly increasing the amount of budget within production industries. However, researchers claim that the position of maintenance has shifted from a strong focus on costs to a strategic organizational capability. This important matter can be realized only when production issues are being dealt with from a logical, scientific, and accurate point of view with suitable planning.

Keeping equipment, machinery, and facilities ready and operational is one of the important matters and the most normative solution to this problem is by using a maintenance planning system. Establishing such a system in an industry or organization requires a comprehensive review of the organization's superior goals and strategies instead of factors such as manpower, resources, environmental culture, machinery and equipment, and quality. In the current research, these factors are being reviewed. It is worth mentioning that preventive maintenance can improve the productivity of the production system and this issue has been reviewed by utilizing an integrated model of production planning, maintenance planning, and simultaneous preventive repairs. A machine can fail due to its application and breakdown. Also, the period in which equipment will not be available due to repair, replacement, and troubleshooting, will disrupt production planning. Hence, the way maintenance and repair planning are carried out to keep the equipment in suitable operational conditions with high reliability will be considered and production planning will be also taken into account based on maintenance of equipment to achieve smart production.

2 | Foreign Literature Review

Reviewing preventive maintenance can include resource management, optimization of maintenance strategy, and required assessments. Recently, mathematical models are presented to describe preventive maintenance by taking spare parts inventory into account.

For example presented an algorithm of the optimal solution for a common matter (level of repair analysis) and spare parts inventory.

Linnéusson et al. [1] showed a joint optimization approach to control spare parts inventory and inspection interval of preventive maintenance. In all these studies, joint optimization approach, preventive maintenance, and spare parts inventory are included. Hence, in the current concepts, maintenance is carried out by focusing on optimization of spare parts inventory and maintenance strategies only develop system conditions.

In the study of Kuboki and Takata [2], an optimal inspection approach was chosen for preventive maintenance. With technological advancements, our lives have become increasingly dependent on different facilities. Recognition of failure signs by using inspection and control machines for preventive maintenance in order to keep the machines running is considered important.

3 | Domestic Literature Review

In Koushaki and Bahari [3], a set of effective strategies in maintenance are required so that a pure production system can be achieved. These effective strategies are chosen among several net strategies and exited and this action requires complete knowledge regarding the system. These strategies are applicable considering the data collection type and goal. These data are obtained considering daily inspections and standards, cause and effect and analysis of effects and breakdown among several machines and equipment within a number of study phases.

In the research of Kamali and Amin Doost [4], risk-based maintenance has been utilized to plan gas turbine repairs in processing units, and ISO and Navier standards are applied to categorize the subsystems, systems and gas turbine parts, and to analyze failures risk, respectively. Also, analysis of maintenance. Programs is applied to optimize reliability, price premium, and time.

In Firuzi's [5] research, due to the complicated and structured decisionmaking process and judgment about the choice of maintenance strategies, this process is facing multiple views. Also, due to interdependent criteria, the Fuzzy DEMATEL method was used to rate the most important substandard and, to accurately choose criteria, the Grey VIKOR method was used to prioritize the maintenance strategies.

4 | Research Method

In the current research, the dataset for conducting data mining calculations was generated based on a sample with 2,000 data, reports of the general manager of the textile industry of Iran's Ministry of Industry, Mine and Trade (information from 240 industrial units and 630 spinning and weaving units were collected), and textile industry plants in Borujerd as the place for implementing the plan between 2019 and 2020, a period 6 month each year. In the current research, the conceptual model is a model that shows the reality about preventive maintenance, describes and draws certain aspects of real-world that are in relation to problems under the review, and illustrated significant relation between different aspects of significant factors of preventive maintenance. The logical criterion to stop the preparation and formulation of the conceptual model of the research is the principle of information poverty1.

In other words, the researcher, by taking remarks, possibilities, and research period into account will continue collecting the theoretical data in the field of effective factors of preventive maintenance, and review and study domestic and foreign references until the data collected become repetitive and null vicious circle starts. After analyzing influential elements on the design of the dynamic smart model of preventive maintenance, the most significant elements and criteria of the research are illustrated according to *Table 1* in the form of the initial model of the research. Then, they were presented according to the theoretical framework of the research to design a dynamic smart model of preventive maintenance.

Factors as follows were chosen in this research as the most important factors of preventive maintenance: technology in net, employees in net, the work environment in net, quality in net, strategy in net.

After reviewing theoretical basics of research and literature review, and research gaps in the fields of modelling, it was determined that the most important factors are as follows: strategy factor in net, work environment factor in net, quality factor in net, strategy factor due to preventive maintenance within textile industry exclusively industry plants in Borujerd as the place for implementing the plan. Lack of a suitable model of preventive maintenance to give a recommendation to managers within Iran's textile industry managers, and removal of gaps in prior researchers conducted by textile industry managers and teachers, paving the way for innovation by students of industrial engineering and IT in the current research.

In the current research, sophisticated data mining methods were used as follows with the help of the IBM MODELER 18 program.

In the Bayesian inference approach, an initial estimation of the unknown or unknowns is required. The estimation is the researcher's initial information or beliefs that can be stated in the form of a mathematical probability function. After the observations, information regarding intended unknowns was gathered by the researcher and the initial probability function was updated using this new information. By gathering more information and updating the probability function correspondent to unknowns, a more accurate probability distribution function and more suitable estimation were obtained. Regression analysis is commonly used for prediction. Also, regression analysis is utilized to find out about the relationship between the independent and dependent variable and the form of these relations. In special cases, this approach can be used to draw superior relations between independent and dependent variables. However, this can result in false or null relations. Hence, being cautious is recommended.

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Table 1. Theoretical framework of the research.

To maximize the integrated value of maintenance in accordance with the strategic domain of organizational learning: Preventive domain (organizational discipline) with the aim of maximizing the access to equipment; planned domain with the aim of planning and anticipating prior to equipment failure; responsive domain (response to events) with the aim of troubleshooting after the equipment failure	Preventive maintenance data: Real-time condition of the equipment: How is the performance of this part at this moment? Equipment records data: How was the performance of this part in the past? Data of similar equipment: How is the performance of similar equipment? Maintenance records: When was this part replaced or repaired? Plans for maintenance: What maintenance plans do the manufacturer recommend? Inspection logs: What technical inspectors observed during the inspection? Service delivery logs: What have engineers and technicians learn during work?	Elements of preventive maintenance systems: Equipment sensors: To monitor equipment health – preventive maintenance (evaluating the level of maintenance effectiveness, net strategy optimization, and determining the remaining shelf life of the equipment) Maintenance records: Recognizing unusual cases-analyzing the risk of technical inspections records: to recognize sophisticated problems-management of supply chain
Analysis systems of maintenance data: Managerial analysis in preventive maintenance. Analysis of decision-making in preventive maintenance. Statistical analysis in preventive maintenance.	Steps to improve storage service delivery, spare parts, and optimization: To manage low- power consumption (non-active) and high-power consumption parts (active) in the chosen storages. To optimize order point and order volume in high- power consumption items in terms of chance of failure. To optimize the amount of inventory and safety inventory in low- power consumption items in terms of chance of failure.	Influential factors in decreasing losses in maintenance: Smart recognition of problems and preventive maintenance. Assessing the level of effectiveness of maintenance activities by utilizing equipment health indices.

Artificial Neural Networks

They are a network of units called operators or small processors that each of them has unique and small local memory. They are connected to each other through communication channels that usually transfer numbers by certain methods.

K-Nearest Neighbours Algorithm

It is one of the data mining approaches, a type of lazy learning algorithms. This algorithm became popular when computational power of the computer increased. One of the common uses of this algorithm is pattern recognition. For experimental data, the algorithm, which seeks k, will search for the nearest samples (K similar sample). The proximity of two samples is calculated by obtaining the similarity or distance between two samples. Each sample can consist of different data and their similarity must be assessed [10].

The process of conducting current research for preventive maintenance is as follows:

I. To extract information from several data sources (database).
II. To integrate information and remove excess data.
III. To place corrected information into the data warehouse.
IV. To conduct the data-mining operation.
V. To show the results in an understandable manner such as a report or graph.

The process of conducting current research to improve preventive maintenance using data mining technique is as follows:

Step 1. To extract information from several data sources (database).

To extract information from several data sources after conducting quality case study within the textile industry and reaching a final model based on data items, i.e., the target variable of the research "preventive maintenance in textile industry plants in Borujerd with data code (Y)".

For components of a mixed preventive maintenance framework: In accordance with the smart decision made based on innovation, "technology innovation in net with data code (A1)", "employee innovation in net with data code (A2)", "work environment innovation in net with data code (A3)", "quality innovation in net with data code (A4)", and "strategy innovation in net with data code (A5)".

For the component of smart decision making by "managing preventive maintenance data": Real-time condition of the equipment with data code (B1), equipment records data with data code (B2), maintenance records with data code (B3), inspection logs (B4), and service delivery logs (B5).

For the component of smart decision making "to decrease losses in preventive maintenance": Smart decision-making about preventive maintenance using equipment health indices with data code (C1), remaining shelf life of the equipment (C2), chance of failure and reliability of equipment with data code (C3).

This research was formulated to improve preventive maintenance within the textile industry by utilizing data mining technique. The whole design of the preventive maintenance pattern can be seen in *Fig. 1* and *Table 2*.

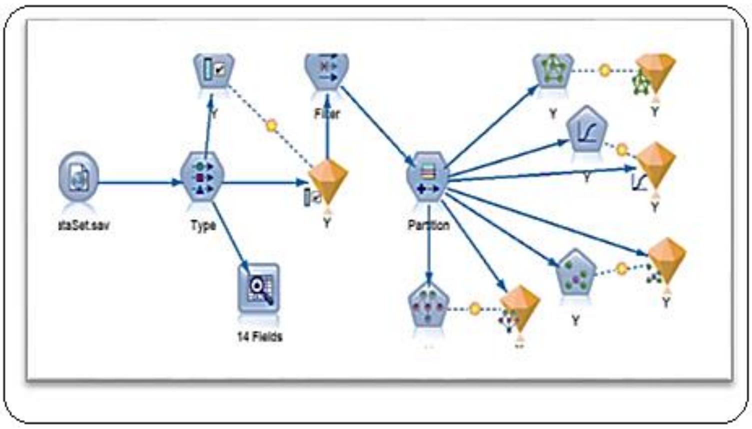


Fig. 1. The whole design of the preventive maintenance pattern.

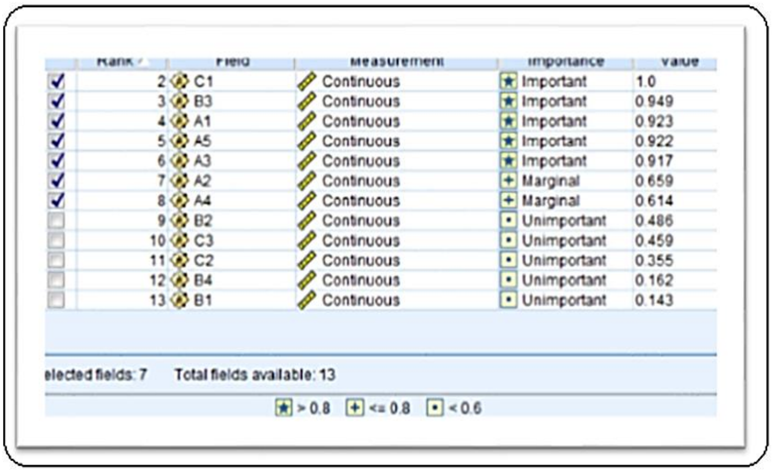
Table 2. Corrected information inside data warehouse.

Vriable Data	Average Data	Maximum Data	Minimum Data	Date Items
12	59.917	80	27	Technology innovation in net (A1)
12	78.083	121	59	Employee innovation in net (A2)
12	80.167	122	31	Work environment innovation in net (A3)
12	76.25	168	31	Quality innovation in net (A4)
12	57.333	80	36	Strategy innovation in net (A5)
12	70.57	105	34	Net records (B3)
12	54.917	77	41	Service delivery logs (B5)
12	48.417	73	27	Smart decision making about prediction of equipment shelf life (C1)

Step 2. To integrate the information and remove excess data (data removal).

To transform data types and to carry out more complicated transformations and defining new traits by conducting logical and mathematical operations on current traits, *Fig. 2* was utilized for data integration and removal of excess data (data removal) in preventive maintenance.

After the analysis, integration of information, and removal of excess data (data removal), it was found that data items of smart decision making about preventive maintenance have the value equal to 1 (100%) for equipment health indices with data code (C1) and service delivery logs with data code (B5), 0.949 for maintenance records with data code (B3), 0.923 for technology innovation in net with data code (A1), 0.922 for strategy innovation in net with data code (A5), 0.917 for environment innovation in net with data code (A3), and marginal values equal to 0.659 and 0.614 for employee innovation and quality innovation, respectively.



Rank	Field	Measurement	Importance	Value
2	C1	Continuous	Important	1.0
3	B3	Continuous	Important	0.949
4	A1	Continuous	Important	0.923
5	A5	Continuous	Important	0.922
6	A3	Continuous	Important	0.917
7	A2	Continuous	Marginal	0.659
8	A4	Continuous	Marginal	0.614
9	B2	Continuous	Unimportant	0.486
10	C3	Continuous	Unimportant	0.459
11	C2	Continuous	Unimportant	0.355
12	B4	Continuous	Unimportant	0.162
13	B1	Continuous	Unimportant	0.143

elected fields: 7 Total fields available: 13

> 0.8 <= 0.8 < 0.6

Fig. 2. Integration of data and removal of excess data (data removal).

And therefore, they were chosen as the data items of preventive maintenance based on the dataset of the textile industry. Also, equipment records data with data code (B2), inspection logs (B4), real-time condition of the equipment with (B1), remaining shelf life of equipment, smart decision making about equipment chance of failure and reliability (C3) were removed from research model due to the value of less than 0.5

Step 3. Placing the corrected information inside the data warehouse.

By utilizing research data audit along with data mining to improve preventive maintenance, it was found that the number of valid data based on 12 data has optimal conditions. Accessing cohesive and accurate information is one of the necessities of data mining technique. The existence of wrong and lack of accurate information will result in false conclusion and therefore, making wrong decisions in the production units. This will in turn result in dangerous results that have been seen before.

After analyzing the research data audits to improve preventive maintenance, it was found that all research data (12 data items) were 100% valid (12 processes among 12 data) and work environment innovation in net (A3), employee innovation in net (A2), and quality innovation in net (A4) were the most important preventive maintenance indices and their average data were calculated to be 80.167, 78.083, and 76.25, respectively. On the other hand, the purpose of the process of storing research data is to provide an integrated environment to process the information. In this process, analytical and brief information is organized and stored within time periods so that this information will be utilized in decision-making research data, which is one of the requirements of data mining. In fact, refining research data is crucial to improve preventive maintenance. After analyzing the data mining model based on reports and documentaries of the textile industry, exclusively textile plants in Borujerd between 2015 and 2019, it was found that the research model has significantly high accuracy. In partitioning research data, the inputs were divided into training data (80% of the data) and test (20% of the data). In the first place, training data are used to determine the optimal model via the simulation process and then, they are tested in the second phase. Next, the rank of each category is determined. Information related to chosen data items (inputs) is determined in the form of codes in preventive maintenance.

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In fact, the prediction power of preventive maintenance, regression model, and Bayesian network are shown in *Fig. 3*.

After analyzing the prediction power of preventive maintenance based on the dataset of the textile industry, it was found that the research model has a scientifically high prediction power since data items of technology innovation in net (A1) and quality innovation in net (A4) were determined to be the most important predictors of regression model and research Bayesian network and their power was calculated to be 0.50 during the calculation of regression model.

Step 4. Conducting sophisticated operations of data mining.

To finish the data-mining operation, data mining technique, K-Nearest Neighbours (KNN) method was utilized for pattern recognition in preventive maintenance based on the dataset of the textile industry. In *Fig. 4*, the output of KNN techniques is shown.

Based on reports and documentation of the textile industry from 2009 to 2019, the data mining technique, k-nearest neighbours for pattern recognition in preventive maintenance showed that 8 predictor of research model, multidimensional generalization of predictor space of preventive maintenance, have optimal conditions. Using k-nearest neighbours in the current research, a group of K record among the set of educational records and the closest ones to the experimental record will be chosen and the decision will be made based on the superiority of the class or label related to each regarding the class of mentioned experimental record. Three predictors, i.e., work environment innovation (A3) on X-axis, technology innovation in the net (A1) on Y-axis, and employee innovation in the net on Zaxis are calculated as the closest neighbours in the KNN model.

On the other hand, to accurately analyse the data mining model based on reports and documentation of textile plants in Borujerd plan between 2015 and 2019, Artificial Neural Networks (ANNs) was conducted to perform data mining operations using data mining technique. In this part of the research, modern computational methods for machine learning, knowledge representation, and applying the obtained knowledge are required in order to predict output responses from complicated systems since neurons correct each other in a collaborative manner. In the prior step, partitioning research data, training data (80% of data) and test data (20% of data) were prepared and then training data determined the optimal model via simulation process. Next, they were tested in *Step 2*. The output of ANNs with data mining technique is presented in *Fig. 5* to accurately analyze preventive maintenance.

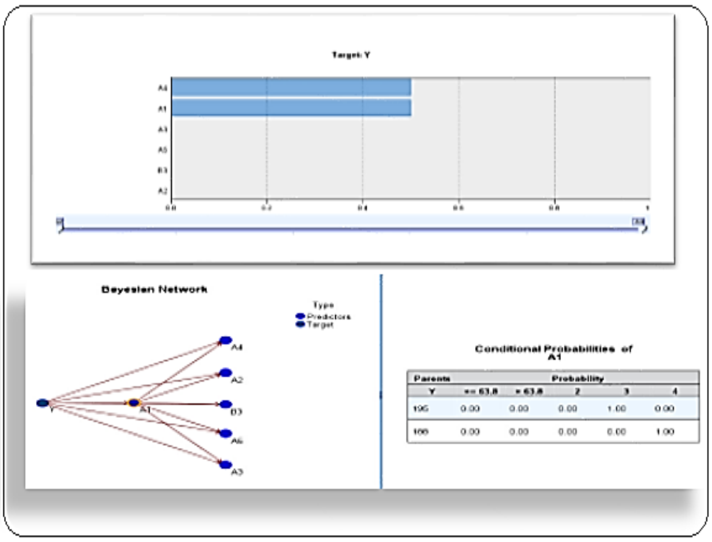

Fig. 3. The prediction power of the research models.

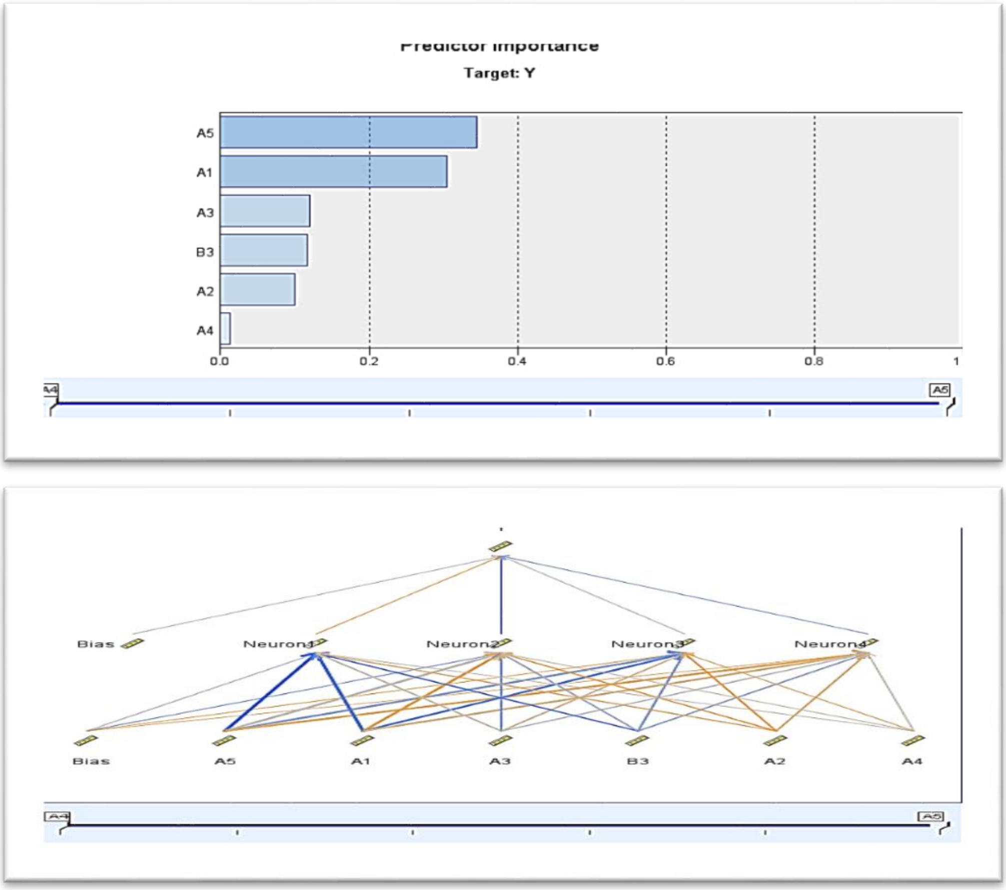

Fig. 4. The output of the KNN technique of the research model.

Based on reports and documentation of the textile industry from 2019 to 2019, the data mining technique of k-nearest neighbours for pattern recognition in preventive maintenance showed that 8 predictors of the research model, multidimensional generalization of predictor space of preventive maintenance, have optimal conditions.

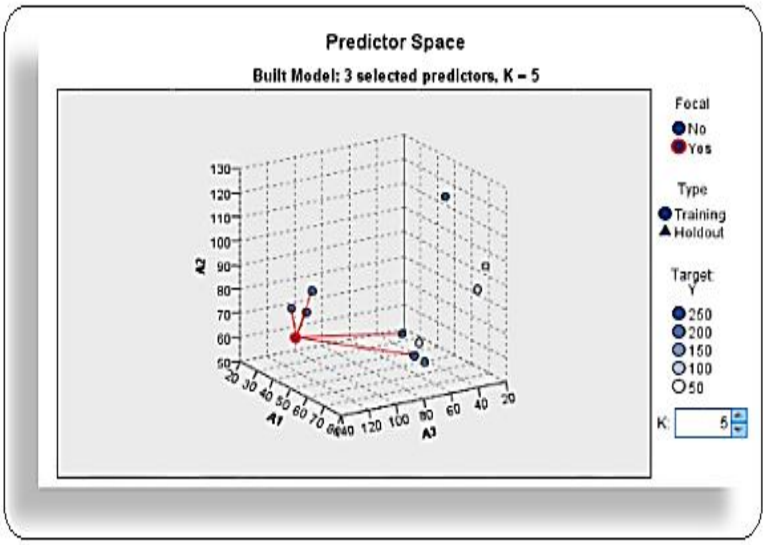

Fig. 5. The output of ANNs of the research model.

After analyzing the output of ANNs to accurately analyze preventive maintenance, it was found that 'blue' colours have positive estimations that are arranged as follows:

Main predictors, i.e., strategy innovation in net with data code (A5)" with the prediction wight of 0.34; "technology innovation in net with data code (A1)" with the prediction wight of 0.30; "work environment innovation in net with data code (A3)" with the prediction wight of 0.16; "quality inovation net with data code (A4)" with the prediction wight of 0.15; "employee innovation in net with data code (A2)" with the prediction wight of 0.10, have accurately analyzed preventive maintenance.

After modellingthe processing traits of the human mind in preventive maintenance in order to estimate usual computational methods using the bioprocess approach, it was found that mentioned predictors can predict data mining model with an accuracy of up to 86%.

Ultimately, based on mentioned calculations and after removing, completing, standardizing, and deleting noises, data were divided into two categories, training data for the learning process and pattern recognition, and test data for evaluating the results that were obtained in the training step. In other words, superior service delivery units are units that were determined to be in their best operational conditions (prior to the research) based on items as follows: technology innovation in net (A1), employee innovation in net (A2), work environment innovation in net (A3), quality innovation in net (A4), strategy innovation in net (A5), maintenance records (B3), delivery logs (B5), and smart decision-making about remaining shelf life of equipment (C1).

5 | Conclusion

Ultimately, superior service delivery units were determined by utilizing an average data model (refer to calculations of corrected information within the information warehouse). In fact, it was determined that:

I. Superior service delivery units, class A: First main predictor of the research (strategy factor in net) with 34% of the ability to improve preventive maintenance.
II. Superior service delivery units, class B: Second main predictor of the research (technology factor in net) with 30% of the ability to improve preventive maintenance.
III. Superior service delivery units, class C: Third main predictor of the research (work environment factor in net) with 16% of the ability to improve preventive maintenance.
IV. Superior service delivery units, class D: Fourth main predictor of the research (maintenance employees) with 10% of the ability to improve preventive maintenance.
V. Superior service delivery units, class H: Fifth main predictor of the research (quality factor in net) with 8% of the ability to improve preventive maintenance.
VI. Superior service delivery units, class V: Sixth main predictor of the research (records factor in net) with 2% of the ability to improve preventive maintenance.

Ultimately, the current research was conducted in order to design a dynamic smart model of preventive maintenance using the dataset of the textile industry.

6 | Suggestions

I. Based on the current research, preventive maintenance can be utilized in interaction with other units of Iran's textile industry by general managers of general manager of the textile industry of Iran's Ministry of Industry, Mine and Trade in line with this industry's productivity.
II. Following up and renovating and redeveloping industries under the coverage, and presenting strategies, recommendations, and connected instructions.
III. To present necessary recommendations to pave the way for the development of research and applicable activities along with necessary reviews and studies to improve product competitiveness in industries under the coverage.
IV. To collaborate with the Institute of Standards and Industrial Research of Iran and other respective authorities to formulate or review required standards (in terms of quality, environment, and management).

V. To collaborate in required studies and reviews for optimized use of energy resources, decreased losses, and to present specialized strategies to units in order to recover the losses.
VI. To collaborate with industrial assemblies and associations for the formulation of industry renovation and redevelopment (in the framework of the general plan for Iran's industry renovation and redevelopment) and to follow up for their approval and implementation.
VII. Strategic support and giving technical guidance to industry owners to be used within respective industries.
VIII. To monitor the process of developing Iran's respective industries in order to realize the policies, plans, and long-term goals of reaching sophisticated industries.
IX. To provide and recommend bills for the removal of restrictions and amend rules that are preventing empowering of Iran's respective industries.
X. To conduct necessary studies and reviews in order to formulate and recommend transfer, absorption and connected industries improvement strategies.
XI. To improve the quality and standard of products, processes, and competitiveness of production, absorb domestic and foreign investment of sophisticated industries, and improve the managerial level of country industries.
XII. One of the most important recommendations of current research for managers within industry plants in Borujerd is that they should, by utilizing research results, make smart decisions about maintenance activities based on innovation to decrease losses in maintenance by utilizing equipment health indices, the predication of equipment remaining shelf life, and equipment failure chance and reliability.

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