Using Stochastic DEA for Identifying and ranking factors affecting the quality of metal structures construction (case study of metal structures factory)

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ABSTRACT

This research investigates key quality factors in the construction of metal structures, a critical aspect within the construction industry given the significance of metal structures. The implementation of quality standards in metal construction enhances performance and reduces costs. Employing a combined qualitative and quantitative approach, this study analyzes and prioritizes factors influencing the quality of metal structure construction. The methodology involves network analysis and coverage analysis of random data gathered from manufacturing facilities, supplemented by information sourced from both academic literature and field observations. Data collection methods include questionnaires and interviews. The findings highlight cost, time, production efficiency, quality standards, labor resources, and technological advancements as the most influential factors in ensuring manufacturing quality. These findings provide valuable insights for future research endeavors and initiatives aimed at enhancing the quality of metal structures.

1 Introduction

In the metal structures construction industry, many companies operate in the field of building all kinds of bridges, building frames, fluid tanks and other structures, and therefore, to improve their performance and compete with others, it is very important for them to provide quality services. Therefore, in this process, it is important and vital to identify the influencing factors in evaluating the quality of metal structures. Construction quality is one of the key criteria for evaluating the performance of metal structures construction projects, and its effect on the period of exploitation of the project product gives its special place. Good execution quality is one of the important factors in reducing construction costs. The conducted studies confirm the fact that quality management in construction projects can greatly reduce the additional costs caused by the lack of quality.

Based on this, this research studies and identifies factors affecting the quality of metal structures. Therefore, the important factors influencing the quality of metal structures construction will be identified and then by considering these influencing factors, the performance of active production lines in this field will be evaluated. In this regard, first, by collecting the existing literature in this field, the influencing factors on the quality of construction of structures will be identified. Then, by using appropriate methods such as interviewing experts and completing standard questionnaires, the necessary information will be collected to analyze and review the factors.

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Then, the Dimtel method is used to determine the internal relationship between the criteria, and finally, the network analysis method (ANP) is used for the final ranking of the criteria and identifying the most important influencing factors. Based on this, the most important factors affecting the quality of construction of structures are identified and analyzed. Finally, by combining the results obtained from different methods, the final results will be obtained and the factors affecting the quality of construction of structures will be ranked according to the importance and role of each one. After the most important influencing factors in the quality of metal structures are identified, data envelopment analysis method is used to rank and evaluate the performance of active production lines in the field of metal structures construction.

In this research, comprehensive factors regarding the quality of metal structures have been identified, which were not predicted in previous researches. Also, in previous researches, ANP or data envelopment analysis was used to identify and rank the factors affecting the quality of metal structures, while in this research, DEMATEL methods were used to identify and rank the factors affecting the quality of metal structures. ANP and random data envelopment analysis have been used and the production lines will also be ranked. The subject area of this research is the identification and ranking of factors affecting the construction of metal structures. The information and data are related to the five-year period of 1396-1401. The spatial scope of this research includes metal structures factories.

2 Research background

The researches and studies conducted regarding the quality of metal structures construction, quantitative and qualitative assessment criteria and indices of metal structures, research methods and models for identification and ranking of factors affecting the quality of metal structures are given below.

No.	Researchers	Year	The issue under consideration	Method	Evaluated indicators
١	Abtahi et al.	١٣٩٤	Analyzing and examining the benefits of quality management and obstacles in the construction industry	Principles of quality management	Improving product quality, increasing customer satisfaction, reducing costs, increasing productivity and increasing competitiveness
٢	Grami et al.	٢٠١٥	Investigation of quality management in the implementation of metal structures	statistical analysis	Design, implementation and construction supervision, staff training and use of quality equipment and materials
٣	Nazimi et al.	١٣٩٢	Enhancing total quality through assessment and improvement: Key factors in a manufacturing industry	Content analysis method	The method of analysis is based on past research and a case study of a manufacturing industry to identify key factors in improving comprehensive quality
٤	Esmailpour et al.	١٣٩٣	Designing a model to control total quality costs using an interpretive structural approach	Confirmatory factor analysis	Key variables of quality cost control

٥	Khaki Renani et al.	١٣٩٦	Quality control and quality assurance in the construction management of steel structures		The quality of materials and equipment, communication with manufacturers and suppliers, training and upgrading the knowledge and experience of employees, occupational safety and health
٦	Karbasian et al.	١٣٩٥	Designing a model to estimate the quality costs of defective products in the workshop flow processes		Defective product referral fees

3 Literature Review

In this research, modeling and computational methods and techniques have been used.

3.1 ANP method

The ANP method or the network analysis process method was presented in 1996 by Saati. The ANP method is one of the multi-criteria decision-making methods, which is similar to the Analytical Hierarchy Process (AHP) method, with the difference that in this method, criteria, sub-criteria and options are related. AHP method is one of the modes of network process technique. If the criteria are related to each other in a problem or there are internal relationships between the sub-criteria. This problem cannot be solved by the AHP method, because this problem has changed from the hierarchical state to the network state and must be calculated by the ANP method. In fact, network analysis is a complete and effective method for making accurate decisions with the help of personal experience and judgments, which organizes different criteria and evaluates their importance and provides the preference of each option over other options, and hence It makes decision making easy. The process of network analysis is a mathematical technique that systematically deals with a variety of dependencies and has been successfully applied in various fields. The ANP method is based on the analysis of the human brain for complex problems with a non-categorical structure and in order to improve the AHP method. In this method, the structure of the problem is in the form of a network where the nodes are the main objective, criteria, sub-criteria and options.

3.2 Data Envelopment Analysis

Data envelopment analysis is a technique for calculating the relative efficiency of a set of similar organizational units with the same inputs and outputs, such as bank branches and insurance branches, etc., which is done using mathematical programming. Data envelopment analysis is a non-parametric method to evaluate the efficiency or calculate the efficiency of a finite number of homogeneous decision-making units in multi-input and multi-output mode (Jehanshahlou et al. (2007)). In this method, there is no need to determine the explicit form of the production function, and linear programming is used to construct a linear segmental surface (or boundary) to cover (the name of data coverage analysis originates from this feature) all the data, and in the performance result of each decision-making unit is measured against this boundary (Izadikhah (2013)).

Today, data envelopment analysis models have been highly welcomed by decision makers, managers, engineers and operations research specialists. Probably part of this welcome is due to the following three features:

1- A relative efficiency score is assigned to each observation.

2- Suggesting the necessary improvements and reforms in the consumption of inputs or the production of outputs to achieve the relative efficiency of those observations that are considered ineffective.

3- It is independent of statistical methods.

4 Research Method

According to the review of the background of the research conducted in this research, comprehensive factors regarding the quality of the construction of metal structures have been identified, which have not been used in previous researches. Also, in previous researches, ANP or data envelopment analysis has been used to identify and rank factors affecting the quality of metal structures. Also, in this research, DEMATEL, ANP and random data envelopment analysis were used to identify and rank the factors affecting the quality of metal structures and production lines. In short, the following processes are used to identify and rank the factors affecting the quality of metal structures. The studied research is applied research in terms of its purpose and results. Because when we do research with the aim of enjoying the results of the research findings to solve the problems in the organization, that research is considered practical. On the other hand, the research method is a descriptive method, because library studies have been used in it, and in terms of type, it is placed in the group of applied research.

Table 1: Basic criteria and indicators

Row	symbol	Criterion		Row	symbol	Criterion	
1	M 1	Criterion١	Quality	11	M 11	Criterion١١	Manpower
2	M 2	Criterion٢	Services	12	M 2	Criterion١٢	Designing
3	M 3	Criterion٣	Cost	13	M 13	Criterion١٣	Experience
4	M 4	Criterion٤	Management	14	M 14	Criterion١٤	ISO
5	M 5	Criterion٥	Production	15	M 15	Criterion١٥	Time
6	M 6	Criterion٦	Strategic barriers	16	M 16	Criterion١٦	Materials
7	M 7	Criterion٧	Education	17	M 17	Criterion١٧	Standard
8	M 8	Criterion٨	Technology	18	M 18	Criterion١٨	Equipment
9	M 9	Criterion٩	Agility	19	M 19	Criterion١٩	the experiment
10	M 10	Criterion١٠	Delivery	20	M 20	Criterion٢٠	Quality control system

The main purpose of this research is to identify and rank the factors affecting the quality of metal structures construction using random DEA for the years 1396~1401. The case of research includes metal structures factories. Therefore, the factors influencing the quality of metal structures are identified and ranked in metal structures factories. With the help of reading related articles, questionnaires, experts' opinion, primary criteria were identified according to the results of Table 1. In this section, with the help of ANP method and Super Decision software, the main factors and characteristics will be determined, and with the help of random data coverage analysis method and GAMS software, criteria and production lines will be ranked.

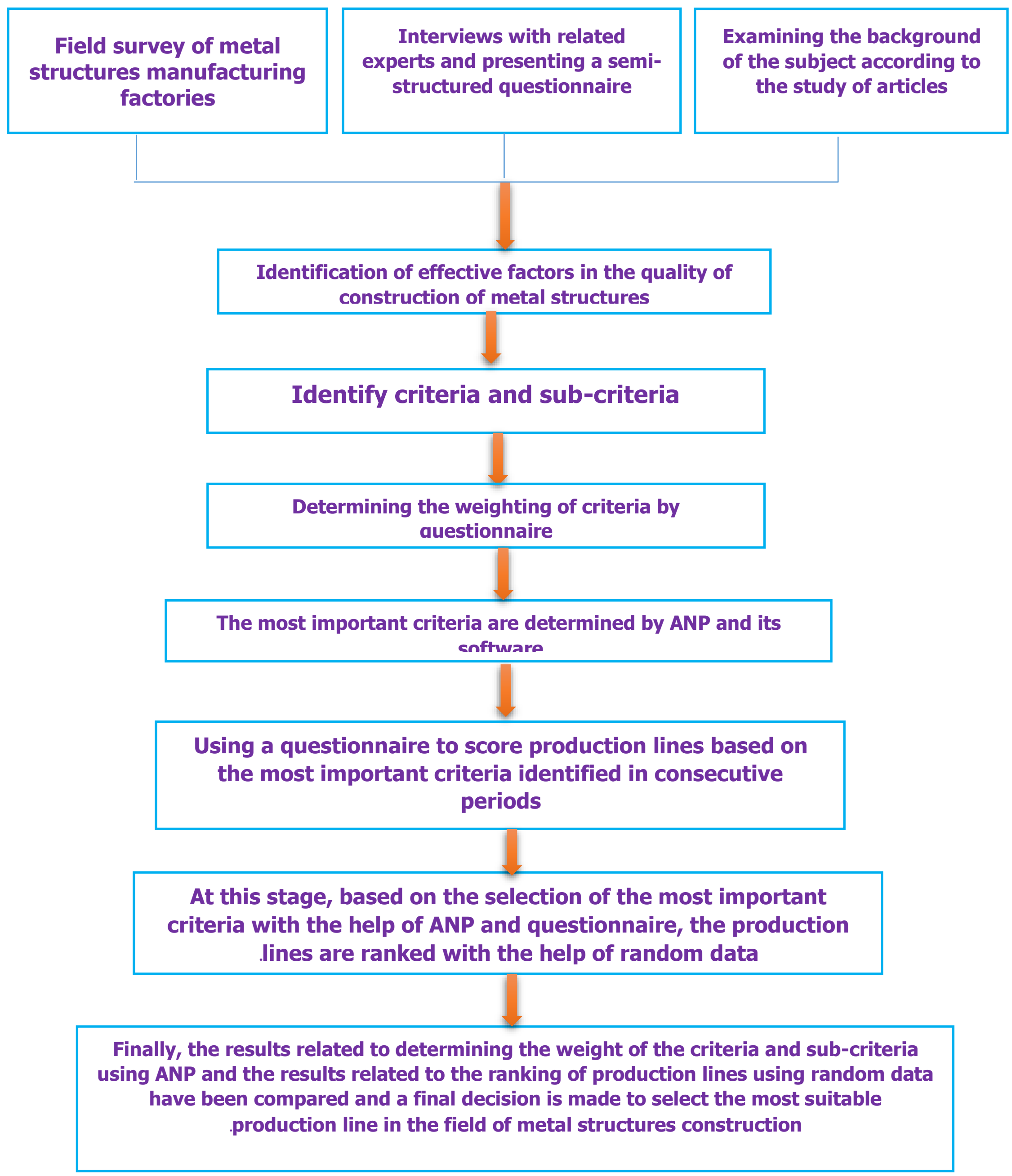

Fig. 1: the Flowchart of the method

5 Data analysis and results of research implementation

5.1 Determining the priority of model elements using the ANP technique

In this research, the technique of network analysis (ANP) has been used to determine the weight of the criteria. The network pattern of the model is designed using the ANP technique in the Super Decision software. Based on this model, the diagram of the network analysis process (ANP) will be as follows.

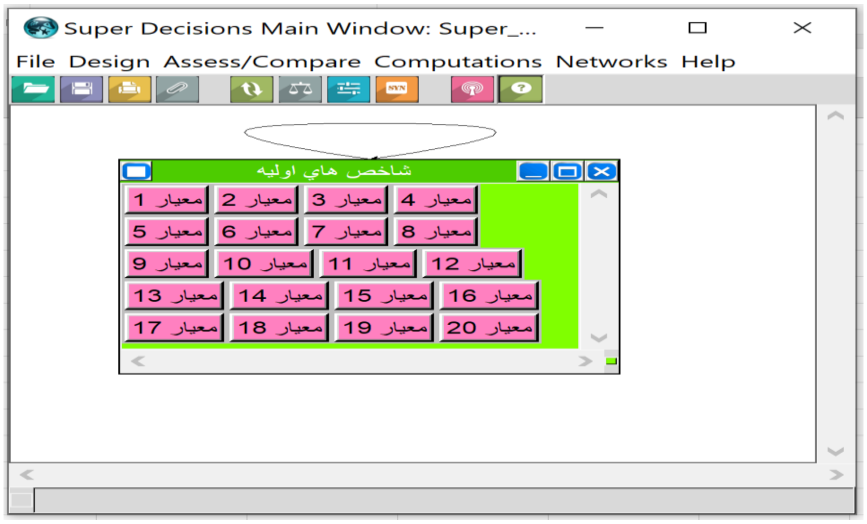

Fig. 2: ANP diagram of priority of indicators and options in Super Decision software

The matrix of pairwise comparisons of criteria compared to criterion 1 is as Fig. 3.

(Internal relations), it shows both the cause and effect relationship between the factors and the influence of the variables. In the following, the steps of the ANP method are presented.

Calculation of direct correlation matrix (M ̂)

When the opinion of several experts is used, the simple arithmetic mean of the opinions is used and we form the direct correlation matrix or (M ̂).

Calculation of normal direct correlation matrix: M = α*M ̂

First, the sum of all rows and columns is calculated. The inverse of the largest number of rows and columns forms k. It is based on the largest number, 52, and all values in the table are multiplied by the inverse of this number to normalize the matrix.

$$\alpha = \frac{1}{\max \sum_{j=1}^{n} a\ ij} = \frac{1}{52}$$

$$\Rightarrow M = 0.0194 * \widehat{M}$$

Calculation of the complete correlation matrix

To calculate the complete correlation matrix, the same matrix (I) is formed first. Then we subtract the same matrix from the normal matrix and invert the resulting matrix. Finally, we multiply the normal matrix by the inverse matrix:

$$T = M\left(I - M\right)^{-1}$$

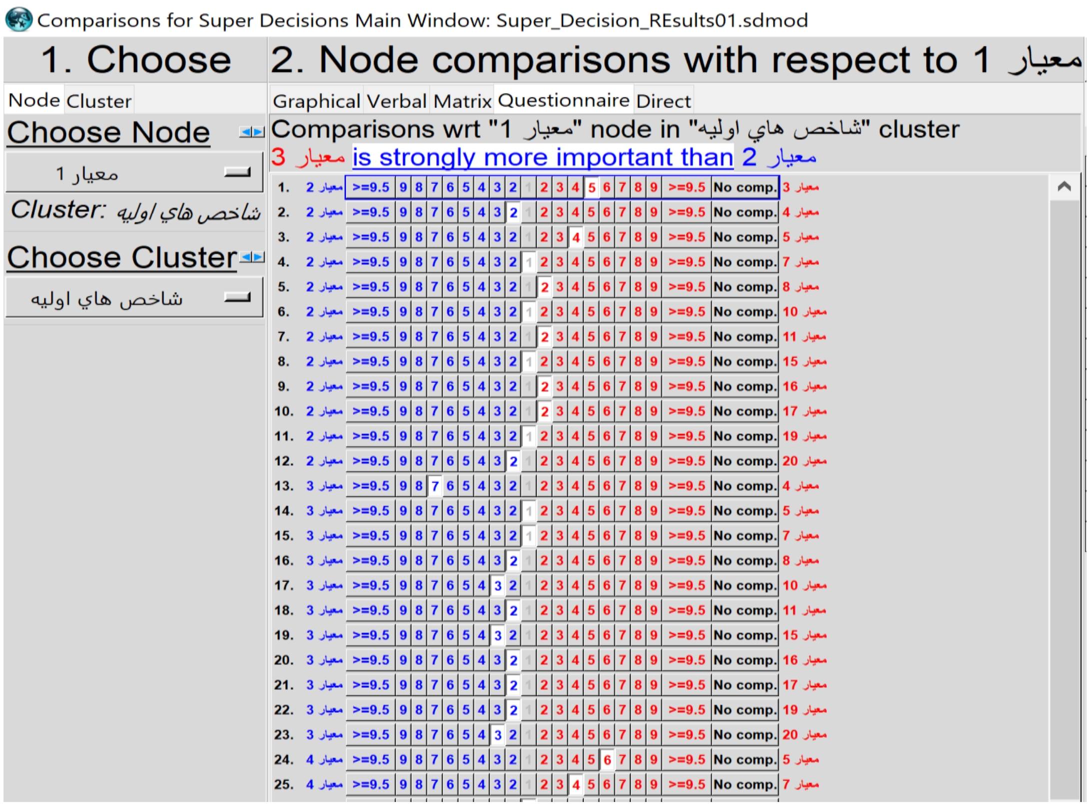

Fig. 3: Pair wise comparisons in Super Decision software

Display the map of network relations

To determine the network relationship map (NRM), the threshold value must be calculated. With this method, partial relationships can be ignored and the network of significant relationships can be drawn. Only relations whose values in matrix T are greater than the threshold value will be displayed in NRM. To calculate the threshold value of relationships, it is enough to calculate the average values of the matrix T. After the intensity of the threshold is calculated, all the values of the complete correlation matrix that are smaller than the threshold value become zero, that is, the causal relationship is not considered. In this study, the threshold value equal to 0.1868 has been obtained.

Considering its role and importance in the construction of metal structures, the quality criterion has an effect on many main criteria and does not have a direct effect on only a few criteria. The above pattern shows strong relationships between quality criteria and other criteria. According to the examination of the cost criterion pattern, it is clear that this criterion has the greatest influence on other criteria and this pattern shows very strong internal relationships between the cost criterion and other criteria. Technology criteria play an important role in the quality of metal structures and influence many main criteria. The use of advanced devices in production lines can play a vital role in improving the quality of metal structures.

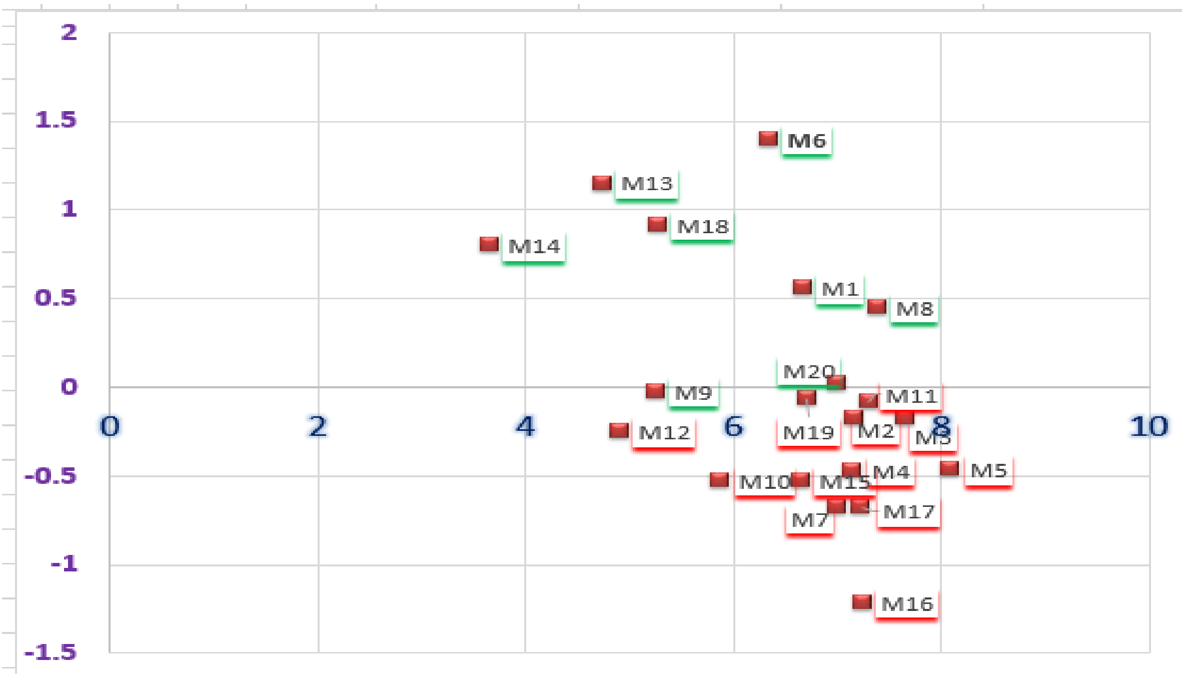

Fig. 4: Cartesian coordinate plot of DEMATEL output for main criteria

The sum of the elements of each row (Di) indicates the influence of that factor on other factors of the system. Therefore, the cost criterion M3 is the most effective. The equipment criterion is in the second place, the quality criterion is in the third place, and the agility criterion is the least effective. The sum of the elements of the column (R) for each factor indicates the degree of influence of that factor on other factors of the system. Therefore, the production standard M5 has a very high level of effectiveness. The criterion of strategic obstacles is also the least effective than other criteria. The horizontal vector (D + R) is the degree of influence of the desired factor in the system. In other words, the higher the D + R value of a factor, the more interaction that factor has with other system factors. Therefore, M1 quality criterion has the most interaction with other studied criteria, and ISO criterion has the least interaction with other variables.

The vertical vector (D - R) shows the influence of each factor. In general, if D - R is positive, the variable is considered a causal variable, and if it is negative, it is considered an effect. In this model, the quality criteria, cost, management, strategic obstacles, training, technology, manpower, ISO, standard, quality control system are the causal variables and services, production, delivery, agility, design, experience, time, materials, equipment and The test is disabled.

The super matrix of the limit and the final weight of the criteria

- Calculation of unbalanced super matrix, balanced super matrix and limit super matrix

To determine the final weight, the output of the comparison of the main criteria based on the objective and internal relationships between the criteria is presented in a super matrix. This super matrix is called primary or unbalanced super matrix. In order to reach the final priority, the general vectors in a system with mutual effects, the vectors of internal priorities (that is, the calculated w's) must be entered in the appropriate columns of a matrix. As a result, a super matrix (actually a partitioned matrix) is obtained, where each part of this matrix shows the relationship between two clusters in one system. (Zobardest, 1389: 81) According to the relationships identified in the present study, the initial super matrix of this study will be as follows:

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22} & 0 & 0 \\ 0 & W_{32} & W_{33} & 0 \\ 0 & 0 & W_{43} & W_{44} \end{bmatrix}$$

In this super matrix, the W21 vector shows the importance of each of the main criteria based on the goal. The W22 vector represents the pairwise comparison of the relationships between the main criteria derived from the output of the Dimatel technique. The vector W32 shows the effect of each criterion on sub-criteria. W33 vector indicates the pairwise comparison of relationships between sub-criteria. W_43 shows the effect of each sub-criteria on the low-level sub-criteria. W_44 shows the pairwise comparison of the relationships between the sub-criteria of the lower level. Zero coefficients also indicate that the factors have no effect on each other at the intersection of rows and columns.

By using the concept of normalization, the unbalanced super matrix is transformed into a balanced (normal) super matrix. In the balanced super matrix, the sum of the elements of all the columns is equal to one. The next step is to calculate the limit super matrix. The limit super matrix is obtained by exponentiating all elements of the balanced super matrix. This operation is repeated until the elements of the super matrix converge to a similar value. In this case, all the vectors related to each criterion will be a constant and identical number. The limit super matrix calculated with Super Decision software is as Tabl2 2. Based on the calculations and the limit super matrix, the output of the Super Decision software can be used to determine the final priority of the criteria. The final priority of the main criteria is drawn by adapting the limit super matrix.

According to the results related to the final priority of the criteria, the technology criterion is ranked first in this prioritization. It is known that the use of devices with new technologies for the construction of metal structures is highly effective in improving the quality of construction of metal structures. The cost criterion is ranked second in this prioritization. It is clear that construction costs are also a priority. The cost of purchasing raw materials, transportation costs, design costs, product return costs and inspection costs are among the factors affecting the cost of goods or products. The criterion of manpower is in the third place of this priority. Employing skilled and experienced manpower increases the quality of metal structures construction. The production criterion is in the fourth place of this priority. Production capacity, development of new products and production capability are among the influential factors in choosing the production criterion. The time criterion is in the fifth place of this priority, the timely provision of raw materials and equipment, timely performance of construction tests, timely verification and delivery of goods/products are among the factors affecting the quality of construction of metal structures.

Table 2: Limit super matrix

	معیار ۱	معیار ۲	معیار ۳	معیار ۴	معیار ۵	معیار ۶	معیار ۷	معیار ۸	معیار ۹	معیار ۱۰	معیار ۱۱	معیار ۱۲	معیار ۱۳	معیار ۱۴	معیار ۱۵	معیار ۱۶	معیار ۱۷	معیار ۱۸	معیار ۱۹	معیار ۲۰
معیار ۱	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064	0.00000	0.13064	0.13064	0.13064	0.13064	0.13064	0.13064
معیار ۲	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863	0.00000	0.03863	0.03863	0.03863	0.03863	0.03863	0.03863
معیار ۳	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086	0.00000	0.19086	0.19086	0.19086	0.19086	0.19086	0.19086
معیار ۴	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435	0.00000	0.02435	0.02435	0.02435	0.02435	0.02435	0.02435
معیار ۵	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428	0.00000	0.16428	0.16428	0.16428	0.16428	0.16428	0.16428
معیار ۶	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
معیار ۷	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786	0.00000	0.07786	0.07786	0.07786	0.07786	0.07786	0.07786
معیار ۸	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869	0.00000	0.03869	0.03869	0.03869	0.03869	0.03869	0.03869
معیار ۹	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254	0.00000	0.00254	0.00254	0.00254	0.00254	0.00254	0.00254
معیار ۱۰	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363	0.00000	0.01363	0.01363	0.01363	0.01363	0.01363	0.01363
معیار ۱۱	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084	0.00000	0.05084	0.05084	0.05084	0.05084	0.05084	0.05084
معیار ۱۲	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128	0.00000	0.00128	0.00128	0.00128	0.00128	0.00128	0.00128
معیار ۱۳	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
معیار ۱۴	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
معیار ۱۵	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783	0.00000	0.02783	0.02783	0.02783	0.02783	0.02783	0.02783
معیار ۱۶	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517	0.00000	0.09517	0.09517	0.09517	0.09517	0.09517	0.09517
معیار ۱۷	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584	0.00000	0.07584	0.07584	0.07584	0.07584	0.07584	0.07584
معیار ۱۸	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327	0.00000	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327
معیار ۱۹	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188	0.00000	0.04188	0.04188	0.04188	0.04188	0.04188	0.04188
معیار ۲۰	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240	0.00000	0.02240	0.02240	0.02240	0.02240	0.02240	0.02240

The quality criterion is ranked sixth. Quality program, quality assurance, quality improvement are among the influencing factors on the quality of metal structures construction. Criteria such as design, agility and strategic obstacles are ranked at the lowest in this prioritization.

5.2 Ranking with the help of random data envelopment analysis

The selection of the variables of this research is based on the study of the set of research conducted in the metal structures factory. We define inputs and outputs as Table 3.

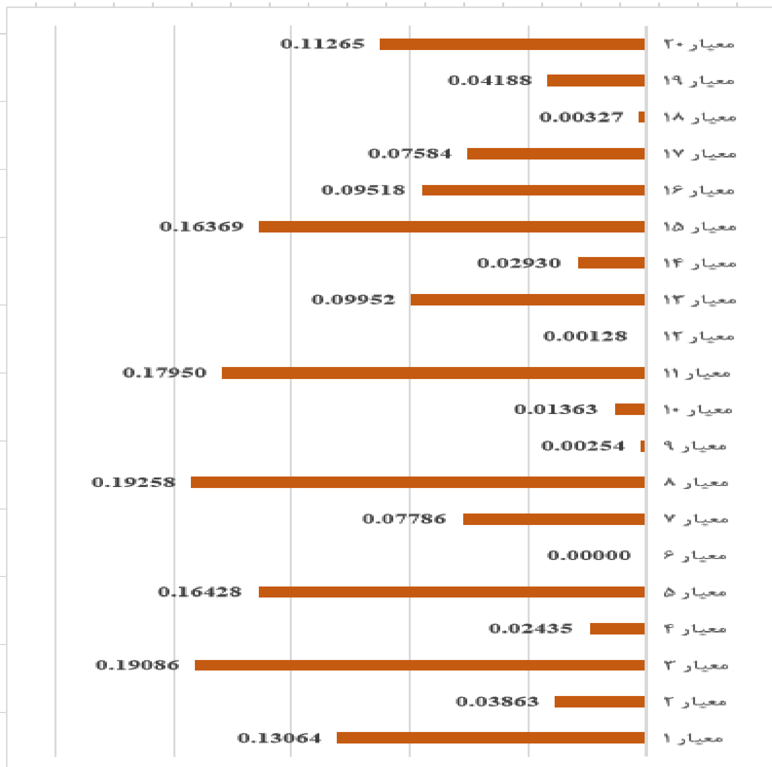

Fig. 5: Final priority of criteria with ANP technique, Super Decision output

Table 3: Input and output variables

Input variables (X_i)		**Output variables (Y_r)**	
Variable name	**variable description**	**Variable name**	**variable description**
Time	Build on schedule	Quality	Providing products according to customer standards and demands
Cost	Made at a reasonable price	Production	The capacity to produce and develop new products
		Technology	Using advanced devices in production lines
		Manpower	Use of qualified labor

Based on the information collected from 6 production lines and according to the obtained results, the final matrix for evaluating the production lines based on the data coverage analysis model will be based on the following table:

Table 4: Final data for random data coverage analysis

The final matrix												
Manpower		Technology		Production		Time		Cost		Quality		
Variance	Average	Variance	Average	Variance	Average	Variance	Average	Variance	Average	Variance	Average	
3.7683	27.8000	3.7815	31.6000	4.2071	29.2000	٦,١٨٨٧	٢٦,٤٠٠٠	٣,٩١١٥	٢٢,٦٠٠٠	8.1670	٢٤,٨٠٠٠	Production line 1
4.8785	29.6000	6.4031	30.0000	2.7749	24.8000	6.0663	29.4000	2.6077	28.6000	4.9800	24.6000	Production line ٢
3.2094	32.4000	6.9498	30.4000	3.1145	22.8000	5.1478	22.0000	2.1213	28.0000	1.5166	23.6000	Production line ٣
5.0695	31.2000	9.8843	34.2000	4.0373	26.4000	1.0954	26.8000	2.7019	29.4000	4.4159	27.0000	Production line ٤
5.1672	31.2000	5.4955	31.8000	5.7706	27.4000	4.0000	23.0000	1.6432	29.8000	7.0214	28.6000	Production line ٥
4.9295	33.4000	4.2426	33.0000	5.2631	26.8000	2.6833	21.2000	1.1402	28.6000	4.4497	28.4000	Production line ٦

According to the results obtained from the final matrix, it is clear that:

Table 8: The results of the criteria

Rating criteria			Production Line
third rank	**Second place**	**First Place**	
Manpower	Production	Technology	Production Line 1
Time	Manpower	Technology	Production Line 1
Cost	Technology	Manpower	Production Line 1
Cost	Manpower	Technology	Production Line 1
Cost	Manpower	Technology	Production Line 1
Cost	Technology	Manpower	Production Line 1

5.3 Data Analysis

To analyze the data in the tables, we use the random CCR model to evaluate the criteria affecting the quality of the construction of metal structures. To solve the model, use EXCEL software as well as GAMS software, which is a powerful and comprehensive tool for solving mathematical models even in large dimensions, and it is very powerful for solving complex problems of data envelopment analysis optimization. Day by day, it plays a more colorful role in engineering fields, we use it. By running the GAMS program using random data for α = 0.1 α =0.2 = α= 0.3 α =0.4 α =0.5 random efficiency results and ranking of decision-making units with data that follows a normal distribution.

Results at the level of α = 0.۱ ~ 0.۵

At this stage, using the random input-oriented CCR model, we obtain the efficiency values of the units at the α=۰,۱ level, the relationship between the normal cumulative distribution function and the α confidence level is as follows.

$$\varphi(z) = \alpha \Rightarrow z = \varphi^{-1}(\alpha)$$

At the confidence level α=۰,۱, the inverse of the cumulative distribution function is (-1.285) or in mathematical language we can say:

$$\varphi^{-1}(0.1) = -1.285$$

Therefore, in order to obtain the efficiency values of the units at this level, it is enough to put the number (-1.285) instead of the variable Z in the random CCR model and run the model. The results obtained using GAMS software are as follows:

Table 5: Efficiency at levels α = 0.1 α =0.2 = α= 0.3 = α =0.4 = α= 0.5

	ALPHA=0.1	ALPHA=0.2	ALPHA=0.3	ALPHA=0.4	ALPHA=0.5
DMU1	1	1	1	1	1
DMU2	0.9376	0.9095	0.8891	0.8719	0.8556
DMU3	1	1	1	0.9993	0.9854
DMU4	1	1	0.9745	0.9514	0.9296
DMU5	1	1	1	0.9819	0.9593
DMU6	1	1	1	1	1

As can be seen in the table above, in the five levels α =0.1 α= 0.2 α= 0.3 α =0.4 = α= 0.5 we had two efficient units and the rest of the units became ineffective, in the five mentioned levels, Production line number 1 and production line number 6 were recognized as efficient units according to the efficiency score, and production line number 2, production line number 3, production line number 4 and production line number 5 were recognized as the most inefficient decision making units. It can be seen that production line 2 has not worked to any significant level and this indicates the relatively poor performance of this production line compared to other production lines. On the other hand, production lines 1 and 6 have been effective for all significant levels, which indicates the optimal performance of these lines in all desired uncertainty conditions. Using EXCEL software, we depict the column charts of the decision-making units, or in other words, the production lines.

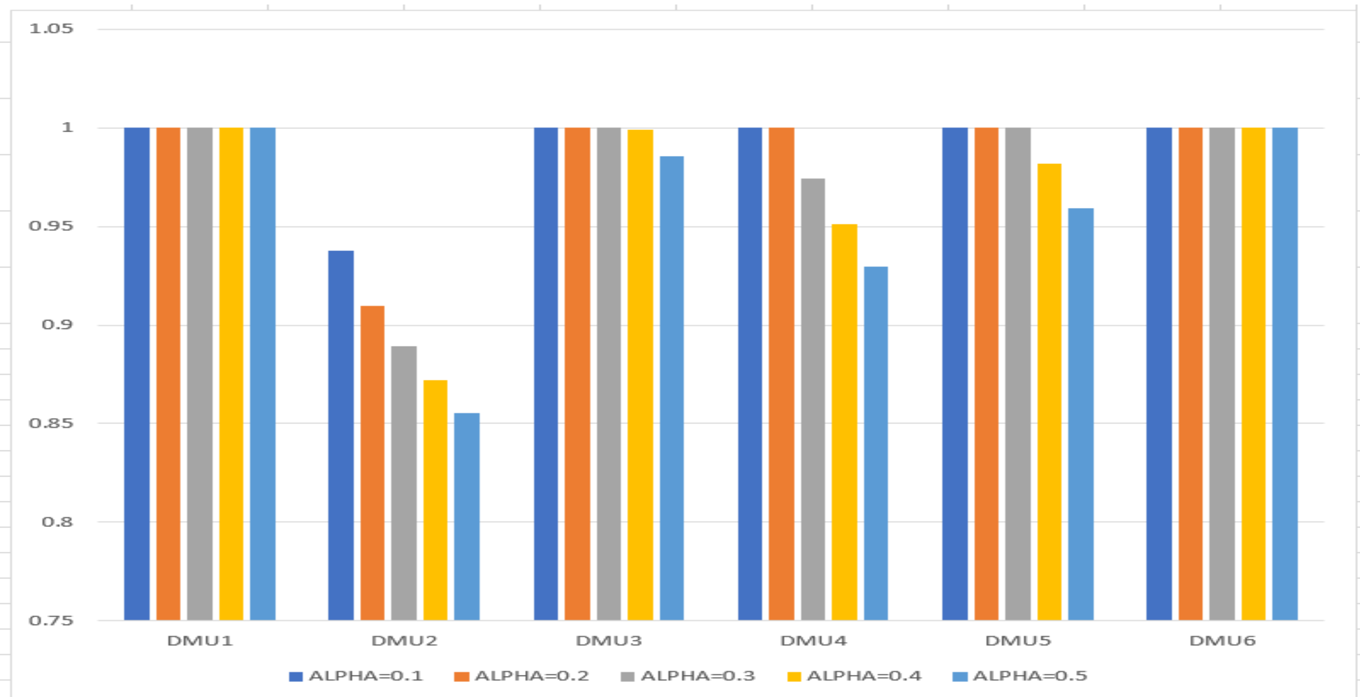

Fig. 6: Column chart of the efficiency of production lines in five levels: α =0.1 α =0.2 α= 0.3 α= 0.4 = α= 0.5

As it is clear from the bar chart above, with the increase of α, the efficiency decreases. Only in production line No. 1 and production line No. 6, efficiency does not change and remains constant with the increase of α. In more general terms, as the value of α increases, the value of the efficiency score does not increase, that is, it either decreases or remains constant.

6 Conclusions and suggestions

According to the results related to the final priority of the criteria, the technology criterion is ranked first in this prioritization. It is known that the use of devices with new technologies for the construction of metal structures is highly effective in improving the quality of construction of metal structures. The cost criterion is ranked second in this prioritization. It is clear that construction costs are also a priority. The cost of purchasing raw materials, transportation costs, design costs, product return costs and inspection costs are among the factors affecting the cost of goods or products. The criterion of manpower is in the third place of this priority. Employing skilled and experienced manpower increases the quality of metal structures construction.

In production lines, production line No. 1 and production line No. 6 are known as efficient units according to the efficiency score, and production line No. 2, production line No. 3, production line No. 4, and production line No. 5 as the most inefficient units. Decision making was recognized. It can be seen that production line number 2 has not worked to any significant level and this indicates the relatively weak performance of this production line compared to other production lines. On the other hand, production lines No. 1 and 6 have been effective for all significant levels, which indicates the optimal performance of these lines in all desired uncertainty conditions.

Table 6: Final priority of criteria with ANP technique, Super Decision output

Row	Criterion	rank	Description
1	Technology	First	CNC cutting and drilling machines, band saw machines, guillotine machines, semi-automatic parts assembly machine, CO2 welding machine - electroslag and automatic subpowder, H machine
2	Cost	Second	Costs related to the purchase of raw materials, design costs, product return costs, inspection and testing costs during and after construction, transportation costs.
3	Manpower	Third	Skilled cutter, driller, welder and assembly personnel, sufficient qualified labor force, sufficient quality control personnel, sufficient engineering personnel, non-destructive testing personnel, qualified contractor personnel

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