IRMES 2022 Research and Development of Mechanical Elements and Systems PROCEEDINGS "Machine design in the context of Industry 4.0 -Intelligent products"

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UNIVERSITY OF BELGRADE
Faculty of Mechanical Engineering

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PROCEEDINGS

"Machine design in the context of Industry 4.0 – Intelligent products"

Association for Design, Elements and Constructions

26 May 2022, Faculty of Mechanical Engineering, Belgrade, Serbia

10th International Scientific Conference - IRMES 2022

Research and Development of Mechanical Elements and Systems

PROCEEDINGS

Machine design in the context of Industry I4.0 – Intelligent products

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Dear Ladies and Gentlemen, Colleagues, Participants and Friends of IRMES 2022

The International Conference on Research and Development of Mechanical Elements and Systems – IRMES is organized under the auspices of the Association for Design, Elements and Constructions (ADEKO). The Conference has a long tradition of gathering scientists, researchers, academics, engineers and industry representatives, intending to exchange and share knowledge, ideas, experiences, innovations and research results in the field of engineering design, machine elements and systems.

So far, there have been nine editions, organized by several universities – members of the ADEKO association:

1995 – University of Niš, Faculty of Mechanical Engineering
1998 – University of Belgrade, Faculty of Mechanical Engineering
2000 – University of Podgorica, Faculty of Mechanical Engineering
2022 – University of East Sarajevo, Faculty of Mechanical Engineering
2004 – University of Kragujevac, Faculty of Mechanical Engineering
2006 – University of Banja Luka, Faculty of Mechanical Engineering
2011 – University of Niš, Faculty of Mechanical Engineering
2017 – University of Montenegro, Faculty of Mechanical Engineering
2019 – University of Kragujevac, Faculty of Engineering

More than a thousand authors participated in previous IRMES conferences, with more than a thousand papers published in total. The current IRMES conference was supposed to be held in 2021. However, due to the COVID-19 epidemic, it was postponed to 2022.

The main topic of the IRMES 2022 conference is „Machine design in the context of Industry 4.0 – Intelligent products“. For sociologists and philosophers of science, the question remains whether the concept today, most commonly called Industry 4.0, is the true fourth technological revolution or the development/continuation of the third technological revolution – through further application of computers in production and logistics. It is indisputable that the essential question of this concept is the following: how do we introduce intelligent production in the industry? This consequently opens up new questions in the field of engineering design, theory and practice of technical systems and machine elements, and innovative product development – in the environment of the now global comprehensive Industry 4.0 concept or the Japanese answer to this concept – Society 5.0.

Teaching subjects and modules, such as Mechanical Elements, Machine Design, Innovative Product Development and others, has been the basis and generator of previous technological revolutions. Therefore, the question arises as to how to develop and improve the existing content of these subjects, but, also, what the best way for knowledge transfer is to keep the listed subjects as a driving force behind further development and improvement of philosophy and concept of Industry 4.0 (ie. how to implement new teaching methods, lessons, exercises, student projects, laboratory work, evaluation).

Taking into account the previously described facts, it is clear why an exchange of opinions, experiences and results between experts in the Industry 4.0 area is essential for social and industrial development. One of the best ways to do that is via public debate at international conferences, such as IRMES 2022, which we are very glad and proud to host and organize this year.

Belgrade, 26 May 2022

Prof. Dr. Radivoje Mitrović

University of Belgrade
Faculty of Mechanical Engineering
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ANALYZING THE BARRIERS RELATED TO SMART MANUFACTURING SYSTEMS UNDER NEUTROSOPHIC ENVIRONMENT

Ahmet AYTEKİN
Selçuk KORUCUK
Çağlar KARAMAŞA

Abstract: *More productive processes have come into the forefront with flexible production, cost effectiveness and business process improvement through developing technology. Smart systems have gained more importance in information society via Industry 4.0 and the smart concept is emphasized for innovative manufacturing systems. In other words, competitive power for businesses is being provided with integrated innovative automations and digitalized solutions. Accordingly the usage of smart manufacturing systems in providing efficient and exigible manufacturing process can be considered as critical components for businesses. But businesses encounter various barriers in transition process and applying smart manufacturing systems. With respect to productivity and efficiency, it is important and necessary for businesses to remove barriers or reduce them to the lowest level. In this study it is aimed to determine and prioritize the barriers related to smart manufacturing systems for plastic industry enterprises operated in Samsun via Neutrosophic AHP method. According to the findings cost of smart manufacturing systems was found as the most important barrier in terms of the judgments of experts. On the other hand top management's negative viewpoint towards smart systems was obtained as the least important barrier related to smart manufacturing systems.*

Keywords: *smart manufacturing; barriers to smart manufacturing systems; neutrosophic AHP*

1. INTRODUCTION

The most commonly used performance indicator in manufacturing enterprises, as well as in all sectors, is efficiency, which is defined as the effective use of raw materials, capital, energy, land, and information resources required for the introduction of various goods and services in enterprises. Efficiency, on the other hand, is defined as producing more with a given amount of input or obtaining a given output with a given amount of input [12,9]. Smart production systems are an indicator of increased efficiency and performance in businesses. High-value-added production opportunities are provided by this production model. In other words, smart manufacturing has a positive impact on employment, added value, resource efficiency, competitiveness, trade, financial stability, and economic welfare [6].
Smart production, according to [5], has a structure that radically transforms Industry 4.0 manufacturing systems. This transformation is made possible by Industry 4.0 technologies. Factories that have been modernized with these technologies are referred to as smart factories, and production that has been realized with these technologies is referred to as production realized with these technologies. Smart manufacturing systems, on the other hand, link all aspects of production, including supply chain, production, product, logistics, and service [3]. Because of their advanced automation, smart production systems, in particular, enable high efficiency and flexible production processes in production [7]. At the same time, because of its smart manufacturing processes, it provides greater access to data across the entire supply chain network.
Smart manufacturing systems help to increase productivity while lowering costs. Another effect of cost reduction is reflected in prices. Smart manufacturing systems enable the establishment of a transparent and flexible manufacturing system. When viewed from a macroeconomic standpoint, it is possible to conclude that the innovative production style based on smart production will have a positive impact on long-term development. Smart manufacturing technologies can help to reduce the use of unnecessary raw materials and resources. At the same time, businesses that produce environmentally friendly products now see this as a strategic value and are revising their marketing strategies to reflect this [4].
However, there are a number of barriers to the implementation of smart manufacturing systems in

businesses. These obstacles are generally expressed as the problem of leaving the traditional production method, lack of technological infrastructure, senior management's negative perspective on smart systems, unemployment problems that may occur with the use of smart manufacturing systems, cost of smart manufacturing systems, technology intensive business process planning problem, anxiety against smart manufacturing systems (such as cyber-attack), the problem of skilled workforce for smart manufacturing systems and the presence of unexpected stops and failures in smart devices [1,4]. In this context, the literature review on smart manufacturing and smart manufacturing systems is given below.

According to [10], relevant standards on which future smart manufacturing systems will be based are lacking, and current standards should be reviewed for better understanding. [8] used Time Series Analysis to study the concept of smart manufacturing and basic technologies and included various definitions of smart manufacturing systems in their studies. [2] defined smart manufacturing as factories where workers, machines, and resources can easily communicate and objects in the virtual and physical worlds can be connected to each other. [15] studied SMEs and large corporations in South Korea and Sweden to see how they embody the concept of smart manufacturing. [16] examined the use of technologies such as smart manufacturing, cloud services, big data, and analytics and discovered that industry 4.0 is critical to smart manufacturing. [11] identified the challenges that businesses faced as they transitioned to the smart manufacturing model. [5] investigated the impact of "Smart Manufacturing," which was implemented with the industry 4.0 vision, on business performance. In the context of Industry 4.0, [14] proposed a model for smart manufacturing system integration in apparel businesses.

At this point, the aim is to discover and rank the barriers to smart production systems for plastic industry enterprises in Samsun province by using multi-criteria decision-making (MCDM) methods. The factors obtained from the literature review were evaluated for this purpose by using the Neutrosophic AHP method, which is one of the MCDM methods. The theoretical explanations of the Neutrophic AHP method, which constitutes the study's method, will be expressed in the following sections of the study, and information about the findings by applying the method in Samsun will be provided. The final section of the study includes the conclusion, limitations of the study, and suggestions.

2. METHODOLOGY

2.1. Neutrosophic Set

Neutrosophic Sets (NS) are introduced by [18] with having the degree of truth, indeterminacy, and falsity membership functions that are independent. Neutrosophic sets provide an efficient and flexible approach for assessing alternatives by using these membership functions.

A universe of discourse can be shown as U and $x \in U$. N as NS can be identified by truth $T_N(x)$, indeterminacy $I_N(x)$and falsity membership functions $F_N(x)$, and represented as $N=\{<x:T_N(x), I_N(x),F_N(x)>x \in U\}$. Also, the functions of $T_N(x)$, $I_N(x)$ and $F_N(x)$ are real standard or real nonstandard subsets of $]0^-,1^+[$and can be presented as $T,I,F:U \to]0^-,1^+[$. The sum of the functions of $T_N(x)$, $I_N(x)$ and $F_N(x)$ can be written as $0^- \leq supT_N(x)+supI_N(x)+supF_N(x) \leq 3^+$[22].

The complement of NS N is represented by N^C and described as below:

$$T_N^C(x) = 1^+ \ominus T_N(x), \quad (1)$$

$$I_N^C(x) = 1^+ \ominus I_N(x), \quad (2)$$

$$F_N^C(x) = 1^+ \ominus F_N(x) \text{ for all } x \in U. \quad (3)$$

N as NS is contained in other NS V shows, $N \subseteq V$ if and only if $infT_N(x) \leq infT_V(x)$, $supT_N(x) \leq supT_V(x)$, $infI_N(x) \geq infI_V(x)$, $supI_N(x) \geq supI_V(x)$, $infF_N(x) \geq infF_V(x)$, $supF_N(x) \geq supF_V(x)$ for all $x \in U$ [17,19].

2.2. Single Valued Neutrosophic Sets (SVNS)

SVNS are developed by [24] for solving real-life problems in an environment having inconsistent, indeterminate and incomplete information. The interval of [0,1] are handled for real-life applications rather than$]0^-,1^+[$. A universe of discourse can be represented as U and $x \in U$. A SVNS C in U can be described by truth $T_C(x)$, indeterminacy $I_C(x)$ and falsity membership functions $F_C(x)$. A SVNS C can be indicated as $C = \int_x < T_C(x), I_C(x), F_C(x) > / x : x \in U$ for continuous values of U. On the other hand, a SVNS C can be shown as $C = \sum_{i=1}^{n} \int_x < T_C(x), I_C(x), F_C(x) > / x_i : x_i \in U$ for discrete values of U [17,19,22]. $T_C(x)$, $I_C(x)$ and $F_C(x)$ functions are real standard subsets of [0,1] that is $T_C(x):U \to [0,1]$, $I_C(x):U \to [0,1]$, and $F_C(x):U \to [0,1]$. Besides, the sum of $T_C(x)$, $I_C(x)$ and $F_C(x)$, are in [0,3] and this can be showns as $0 \leq T_B(x)+ I_B(x)+ F_B(x) \leq 3$ [19].

Let a single-valued neutrosophic triangular number $\tilde{a} = <(a_1, a_2, a_3); \alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}}>$ is a special neutrosophic set on R. In addition $\alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}} \in [0,1]$ and $a_1,a_2,a_3 \in R$ where $a_1 \leq a_2 \leq a_3$.Truth, indeterminacy and falsity membership functions of this number can be obtained as follows [20,22]:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right) & (a_1 \leq x \leq a_2) \\ \alpha_{\tilde{a}} & (x = a_2) \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right) & (a_2 < x \leq a_3) \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$I_{\tilde{a}}(x) = \begin{cases} \left(\frac{a_2-x+\theta_{\tilde{a}}(x-a_1)}{a_2-a_1}\right) & (a_1 \leq x \leq a_2) \\ \theta_{\tilde{a}} & (x = a_2) \\ \left(\frac{x-a_2+\theta_{\tilde{a}}(a_3-x)}{a_3-a_2}\right) & (a_2 < x \leq a_3) \\ 1 & \text{otherwise} \end{cases} \quad (5)$$

$$F_{\tilde{a}}(x) = \begin{cases} \left(\frac{a_2-x+\beta_{\tilde{a}}(x-a_1)}{a_2-a_1}\right) & (a_1 \leq x \leq a_2) \\ \beta_{\tilde{a}} & (x = a_2) \\ \left(\frac{x-a_2+\beta_{\tilde{a}}(a_3-x)}{a_3-a_2}\right) & (a_2 < x \leq a_3) \\ 1 & \text{otherwise} \end{cases} \quad (6)$$

Maximum truth, minimum indeterminacy and minimum falsity membership degrees are indicated by $\alpha_{\tilde{a}}$, $\theta_{\tilde{a}}$ and $\beta_{\tilde{a}}$ respectively according to the Eqs. (4-6).

Suppose $\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}} \rangle$ and $\tilde{n} = \langle (n_1, n_2, n_3); \alpha_{\tilde{n}}, \theta_{\tilde{n}}, \beta_{\tilde{n}} \rangle$ as two single-valued triangular neutrosophic numbers and $\lambda \neq 0$ as a real number. Handling the above-mentioned conditions, addition of two single-valued triangular neutrosophic numbers are shown as follows [20,22]:

$$\tilde{a} + \tilde{n} = \langle (a_1 + n_1, a_2 + n_2, a_3 + n_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{\tilde{a}} \vee \beta_{\tilde{n}} \rangle. \quad (7)$$

Subtraction of two single-valued triangular neutrosophic numbers is obtained as Eq. (8):

$$\tilde{a} - \tilde{n} = \langle (a_1 - n_3, a_2 - n_2, a_3 - n_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{\tilde{a}} \vee \beta_{\tilde{n}} \rangle. \quad (8)$$

The inverse of a single-valued triangular neutrosophic number $(\tilde{a} \neq 0)$ can be shown as below:

$$\tilde{a}^{-1} = \left\langle \left(\frac{1}{a_3}, \frac{1}{a_2}, \frac{1}{a_1}\right); \alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}} \right\rangle. \quad (9)$$

Multiplication of a single-valued triangular neutrosophic number by a constant value are denoted as follows:

$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3); \alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}} \rangle \text{ if } (\lambda > 0) \\ \langle (\lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}} \rangle \text{ if } (\lambda < 0) \end{cases}. \quad (10)$$

Division of a single-valued triangular neutrosophic number by a constant value are represented as Eq. (11):

$$\frac{\tilde{a}}{\lambda} = \begin{cases} \left\langle \left(\frac{a_1}{\lambda}, \frac{a_2}{\lambda}, \frac{a_3}{\lambda}\right); \alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}} \right\rangle \text{ if } (\lambda > 0) \\ \left\langle \left(\frac{a_3}{\lambda}, \frac{a_2}{\lambda}, \frac{a_1}{\lambda}\right); \alpha_{\tilde{a}}, \theta_{\tilde{a}}, \beta_{\tilde{a}} \right\rangle \text{ if } (\lambda < 0) \end{cases}. \quad (11)$$

Multiplication of two single-valued triangular neutrosophic numbers can be shown as follows:

$$\tilde{a}.\tilde{n} = \begin{cases} \langle (b_1c_1, b_2c_2, b_3c_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{\tilde{a}} \vee \beta_{\tilde{n}} \rangle \text{ if } (b_3 > 0, c_3 > 0) \\ \langle (b_1c_3, b_2c_2, b_3c_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{\tilde{a}} \vee \beta_{\tilde{n}} \rangle \text{ if } (b_3 < 0, c_3 > 0) \\ \langle (b_3c_3, b_2c_2, b_1c_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{\tilde{a}} \vee \beta_{\tilde{n}} \rangle \text{ if } (b_3 < 0, c_3 < 0) \end{cases}. \quad (12)$$

Division of two single-valued triangular neutrosophic numbers can be computed as Eq. (13):

$$\frac{\tilde{a}}{\tilde{n}} = \begin{cases} \left\langle \left(\frac{a_1}{n_3}, \frac{a_2}{n_2}, \frac{a_3}{n_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{a} \vee \beta_{\tilde{n}} \right\rangle \text{ if } (a_3 > 0, n_3 > 0) \\ \left\langle \left(\frac{a_3}{n_3}, \frac{a_2}{n_2}, \frac{a_1}{n_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{\tilde{a}} \vee \beta_{\tilde{n}} \right\rangle \text{ if } (a_3 < 0, n_3 > 0) \\ \left\langle \left(\frac{a_3}{n_1}, \frac{a_2}{n_2}, \frac{a_1}{n_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{n}}, \theta_{\tilde{a}} \vee \theta_{\tilde{n}}, \beta_{\tilde{a}} \vee \beta_{\tilde{n}} \right\rangle \text{ if } (a_3 < 0, n_3 < 0) \end{cases}. \quad (13)$$

Score function (s_b) for a single-valued triangular neutrosophic number $b=(b_1,b_2,b_3)$ can be obtained as follows [21,22]:

$$s_b = (1 + b_1 - 2 * b_2 - b_3)/2, \quad (14)$$

where $s_b \in [-1,1]$.

The maximum distance $e_{max}(a,b)$ between two single-valued triangular neutrosophic numbers such as $a = (a_1,a_2,a_3)$ and $b = (b_1,b_2,b_3)$ can be calculated as below [21,22]:

$$e_{max}(a,b) = \begin{cases} |a_1 - b_1| & a_1, b_1 \in \Omega_{max} \\ |a_3 - b_3| & a_3, b_3 \in \Omega_{min} \end{cases}. \quad (15)$$

2.3. Neutrosophic AHP

Steps of neutrosophic AHP can be summarized as below [21,22,23]:

1. Decision problem is formed in terms of hierarchical view including goal, criteria, sub-criteria and alternatives, respectively.

2. Neutrosophic evaluation matrix including triangular neutrosophic number is constructed in terms of pairwise comparisons. Neutrosophic pairwise evaluation matrix $(\tilde{O})$ is seen as below:

$$\tilde{O} = \begin{bmatrix} \tilde{1} & \tilde{o}_{12} & \cdots & \tilde{o}_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{o}_{n1} & \tilde{o}_{n2} & \cdots & \tilde{1} \end{bmatrix}. \quad (16)$$

where $\tilde{o}_{ji} = (\tilde{o}_{ij})^{-1}$ is valid for Eq. (16).

3. Neutrosophic pairwise evaluation matrix is obtained via scale seen as Table 1 that shows a set of linguistic variables used by decision makers as well as an importance weight based on neutrosophic values [13,22].

Table 1. Linguistic Terms

Saaty Fundamental Scale	**Lingusitic Terms for Importance Levels**	**Neutrosophic Triangular Set with Reciprocals**
1	Equally influential	<(1,1,1);0.5,0.5,0.5>
2	Intermediate value	<(1,2,3); 0.4,0.65,0.6>
3	Slightly influential	<(2,3,4); 0.3,0.75,0.7>
4	Intermediate value	<(3,4,5); 0.6,0.35,0.4>
5	Strongly influential	<(4,5,6); 0.8,0.15,0.2>
6	Intermediate value	<(5,6,7); 0.7,0.25,0.3>
7	Very strongly influential	<(6,7,8); 0.9,0.1,0.1>
8	Intermediate value	<(7,8,9); 0.85,0.1,0.15>
9	Absolutely influential	<(9,9,9); 1,0,0>

4. Neutrosophic pairwise evaluation matrix is transformed into the deterministic pairwise evaluation matrix for computing the weights of criteria as below:

Suppose $\tilde{o}_{ij} = \langle (d_1, e_1, f_1); \alpha_{\tilde{o}}, \theta_{\tilde{o}}, \beta_{\tilde{o}} \rangle$ as a single-valued neutrosophic number, then the score and accuracy degrees for $\tilde{o}_{ij}$ are obtained according to Eqs. (17-18):

$$S(\tilde{o}_{ij}) = \frac{1}{16}[d_1 + e_1 + f_1]x(2 + \alpha_{\tilde{o}} - \theta_{\tilde{o}} - \beta_{\tilde{o}}), \quad (17)$$

$$A\left(\tilde{o}_{ij}\right) = \frac{1}{16}\left[d_1 + e_1 + f_1\right]x\left(2 + \alpha_{\tilde{o}} - \theta_{\tilde{o}} + \beta_{\tilde{o}}\right). \quad (18)$$

The score and accuracy degree of $\tilde{o}_{ij}$ are calculated by using the Eqs. (19-20):

$$S\left(\tilde{o}_{ji}\right) = 1/S\left(\tilde{o}_{ij}\right), \quad (19)$$

$$A\left(\tilde{o}_{ji}\right) = 1/A\left(\tilde{o}_{ij}\right). \quad (20)$$

Then the deterministic pairwise evaluation matrix is obtained as below:

$$O = \begin{bmatrix} 1 & o_{12} & \cdots & o_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ o_{n1} & o_{n2} & \cdots & 1 \end{bmatrix}. \quad (21)$$

Ranking of priorities as eigenvector X is handled as follows:

a) Firstly column entries are normalized by dividing each entry to the sum of column

b) Then row averages are summed.

5. Consistency index *(CI)* and consistency ratio *(CR)* values are calculated. If *CR* is greater than 0.1, the process should be repeated due to unreliable decision-makers' judgments.

CI is calculated as below:

a) Each value in the first column of the pairwise evaluation matrix is multiplied by the priority of the first criterion and this process is applied for all columns. Values are summed across the rows in order to obtain the weighted sum vector.

b) The components of the weighted sum vector are divided by corresponding to the priority of each criterion. Then the average of values are handled and shown by λ_{max}.

c) The value of *CI* is obtained according to Eq. (22):

$$CI = \frac{\lambda_{max} - n}{n - 1}. \quad (22)$$

The number of components being compared is represented by n.

After finding the value of *CI* as above, *CR* is calculated as Eq. (23):

$$CR = \frac{CI}{RI} \quad (23)$$

where *RI* shows the consistency index for randomly generated pairwise evaluation matrix and seen as Table 2.

Table 2. RI table considered for obtaining CR value

Order of random matrix (n)	**Related RI Value**
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.4
9	1.45
10	1.49

6. Alternatives are ranked according to overall priority values.

3. RESULTS

Nine criteria were evaluated by consulting the opinions of five experts in analysing the barriers related to smart manufacturing systems. Due to the ease of representation, the expert evaluations (DM1,...,DM5) regarding the criteria are expressed in Table 3 by Saaty's Fundamental Scale values.

Table 3. Linguistic Evaluations of Experts

DM1	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1/5	5	3	1	1/3	1/4	1/3	4
C2	5	1	7	6	3	1/3	3	3	4
C3	1/5	1/7	1	3	1/4	1/3	3	3	2
C4	1/3	1/6	1/3	1	1/6	3	3	1/3	1/4
C5	1	1/3	4	6	1	4	6	5	7
C6	3	3	3	1/3	1/4	1	5	4	5
C7	4	1/3	1/3	1/3	1/6	1/5	1	1/6	1/5
C8	3	1/3	1/3	3	1/5	1/4	6	1	1/3
C9	1/4	1/4	1/2	4	1/7	1/5	5	3	1

DM2	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1/5	5	3	1/5	1/5	1/5	5	1/3
C2	5	1	5	5	1/5	4	5	5	5
C3	1/5	1/5	1	5	1/5	1/3	1/3	1/3	1/6
C4	1/3	1/5	1/5	1	1/7	1/6	1/4	6	1/3
C5	5	5	5	7	1	6	7	8	8
C6	5	1/4	3	6	1/6	1	3	4	1/3
C7	5	1/5	3	4	1/7	1/3	1	1/3	1/4
C8	1/5	1/5	3	1/6	1/8	1/4	3	1	1/4
C9	3	1/5	6	3	1/8	3	4	4	1

DM3	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1/5	1/3	1	1/3	1/3	1/5	1/3	3
C2	5	1	6	7	1/3	1/3	1/3	3	6
C3	3	1/6	1	1/3	1/7	1/7	1/7	1/6	1/7
C4	1	1/7	3	1	1/7	1/5	1/3	1/3	1/3
C5	3	3	7	7	1	3	7	5	8
C6	3	3	7	5	1/3	1	4	1/4	1
C7	5	3	7	3	1/7	1/4	1	1	1
C8	3	1/3	6	3	1/5	4	1	1	2
C9	1/3	1/6	7	3	1/8	1	1	1/2	1

DM4	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1/7	6	5	1/4	1/5	1/4	4	1/3
C2	7	1	7	4	1/4	4	4	4	1
C3	1/6	1/7	1	5	1/7	1/5	1/3	1/2	1/2
C4	1/5	1/4	1/5	1	1/7	1/6	3	2	1/4
C5	4	4	7	7	1	9	5	8	8
C6	5	1/4	5	6	1/9	1	4	4	1/5
C7	4	1/4	3	1/3	1/5	1/4	1	1/2	1/6

C8	1/4	1/4	2	1/2	1/8	1/4	2	1	1/6
C9	3	1	2	4	1/8	5	6	6	1

DM5	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	3	2	1/2	3	1/3	1/3	1/2	3
C2	1/3	1	6	4	3	1/3	1/2	1/6	1/4
C3	1/2	1/6	1	4	2	1/5	1/3	1/5	1/4
C4	2	1/4	1/4	1	2	1	1/2	6	2
C5	1/3	1/3	1/2	1/2	1	4	4	4	4
C6	3	3	5	1	1/4	1	2	3	1/3
C7	3	2	3	2	1/4	1/2	1	1/5	3
C8	2	6	5	1/6	1/4	1/3	5	1	1/4
C9	1/3	4	4	1/2	1/4	3	1/3	4	1

By integrating the experts' assessments and completing other steps, the crisp values are obtained as Table 4.

Table 4. Deterministic Pairwise Evaluation Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1,00	0,41	1,63	0,81	0,62	1,12	0,73	2,00	1,07
C2	2,46	1,00	2,79	2,07	0,68	1,77	1,62	0,79	1,09
C3	0,61	0,36	1,00	1,49	0,40	0,75	1,04	0,84	0,61
C4	1,24	0,48	0,67	1,00	0,33	0,40	0,96	1,62	1,00
C5	1,63	1,46	2,47	3,02	1,00	1,62	2,50	2,57	3,83
C6	0,90	0,56	1,34	2,51	0,62	1,00	0,98	0,98	1,04
C7	1,37	0,62	0,96	1,05	0,40	1,02	1,00	0,76	0,44
C8	0,50	1,27	1,19	0,62	0,39	1,02	1,32	1,00	0,72
C9	0,94	0,91	1,64	1,00	0,26	0,96	2,25	1,39	1,00

Finally, the weight values for the criteria are determined, as shown in Table 5.

Table 5. Weights of criteria

Code	Criteria	Weight	Importance Ranking
C1	The problem of giving up traditional manufacturing methods	0.1002	5
C2	Insufficient technical infrastructure	0.1506	2
C3	Senior management's negative view of smart manufacturing systems	0.0739	9
C4	Unemployment issues that may occur because of the use of smart manufacturing systems	0.0804	8
C5	Smart manufacturing systems costs	0.2126	1
C6	Technology intensive business process planning problem	0.1044	4
C7	Anxiety about smart manufacturing systems (such as cyber-attack)	0.0821	7
C8	The problem of a skilled workforce for smart manufacturing systems	0.0894	6
C9	The presence of sudden stops and malfunctions in smart devices	0.1063	3

As seen in Table 5, the most important barrier related to smart manufacturing systems is “smart manufacturing systems costs”. Also, the importance order of criteria is determined as C5>C2>C9>C6>C1>C8>C7>C4>C3.

4. CONCLUSIONS

Today, new technologies such as smart manufacturing systems are used in almost every industry and are rapidly spreading throughout the world. It is well understood that changes brought about by new technologies have a positive impact on business performance. Simultaneously, it is seen that it increases its competitive power through cost advantage and increases customer satisfaction. However, there are numerous barriers, problems, and difficulties in implementing smart manufacturing systems in businesses. In this context, the barriers to smart manufacturing systems in plastic industry enterprises were identified and evaluated using the Neutrosophic AHP in this study. According to the findings, the most important barrier to smart manufacturing systems is "Smart Manufacturing Systems Cost." Because new technologies, such as smart manufacturing systems, require significant resources when first installed, imposing a significant cost burden on businesses.

However, it is necessary to explain that allocating this resource in the medium and long term will result in much higher returns, as well as to support these systems with business strategies, plans, and programs. Furthermore, it is a fact that this burden will be reduced through publicly supported grants and long-term loans. Another barrier is the "the Lack of Technological Infrastructure." It is true that old technological infrastructure is insufficient, particularly during the transition period of enterprises to new technologies, and eliminating this deficiency is a critical issue in terms of efficiency and productivity. It is obvious that another barrier, "the Existence of Unexpected Situations and Failures in Smart Devices," can be overcome by increasing the level of trained and qualified personnel in the applications of smart production systems in enterprises.

In this context, experts who were thought to be parties to the research subject were interviewed, but due to time constraints, the number could not be increased. In future studies involving more businesses, the results of smart manufacturing systems and efficiency, productivity, and capacity variables can be compared.

In the future, the study can be improved by combining fuzzy logic extensions with other MCDM methods and/or other parametric or non-parametric methods, and an implication can be pointed by comparing the results.

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