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WASPA Neutrosophic Environment Applied to Optimization of Parameters in Milling Thin-Walled Parts

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Abstract: Traditionally, the planning of tasks that condition the manufacturing of parts in machine shops is done by experts. This condition causes inconsistencies in the information for both the planning and the manufacturing of the final product. In order to solve this problem in the following work, a solution based on the combination of the Weighted Aggregated Sum Product Assessment (WASPAS) and neutrosophy multicriteria method is used. The parameters surface roughness in the feed direction (RaFd), surface roughness in the transverse direction RaTd, and Deformation of thin aluminum parts are established in this model. The case study to perform the test, the conditions of the input values: S = 15000 rpm, doc = 0.10 mm, ts = 3.0 mm, F = 3600 m/min and the blank of thin-structured aluminum alloy material. By applying the waspas-neutrosophy strategy, it was possible to determine the best alternative with the optimum parameters to obtain a final product with the economic and competitive requirements required for the completion of the part according to the planned design process.

Keywords: Milling, Thin-Walled, Multi-criteria Optimization, WASPAS, Neutrosophy, HSM

1. Introduction

In today's organizations, prioritizing solutions to problems is a priority. One of the best and most widely used tools is the MCDM. This paper shows several authors who in one way or another have used the Weighted Aggregated Sum Product Assessment (WASPAS) method and its combinations to achieve this goal. [1] studies the combination of Although Failure Mode and Effect Analysis (FMEA) and WASPAS for the definition and assessment of risks related to systems, products and services. Hierarchies of possible corrective and preventive strategies are defined. [2, 3] incorporate the analysis of sustainability and how this is interrelated with economic processes, the first one; analyzes 41 indicators in 10 dimensions and subsequently manages to establish the order by countries with the best performance of the sustainability indicator, the result is established from the methods: WASPAS, MABAC, CODAS, and VIKOR, demonstrating its effectiveness. The second enriches his research by incorporating Fuzzy uncertainty analysis in manufacturing processes; in this case he uses WASPAS-SECA as a tool [4] to analyze the impact on the environment of the supply chain activity, identify the most important criteria and their weights, and establish the priorities of the different strategies, using a combination of entropy tools, Fuzzy and the MCDM method of WASPAS. Faced with the tasks of logistics resource planning, there are a group of barriers, government policies [5] in response to this problem, contributes as the objective of his research a framework with the use of Modified Step-Wise Weight Assessment Ratio Analysis (SWARA) and Weighted Aggregated Sum Product Assessment (WASPAS), finally its solution is effective, improving decision making and leads to improve the organizational activity of logistics. [6] approaches to answer the problematic of the manufacture of parts of complex structures in which the conventional machining is difficult to be accurate, its solution focuses on using the uncertainty analysis with the techniques and methods: Full Consistency Method (FUCOM), Similarity to Ideal Solution method fuzzy TOPSIS and fuzzy WASPAS. The planning of sustainable energy utilization is another area of study where MCDM has been used, [7] evaluates the impact of the utilization of energy generation technologies, for which it combines three techniques: Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), the Evaluation Based on Distance from Average Solution (EDAS) and the (WASPAS); with new principles related to the microgeneration stations with the energy technologies: solar thermal, solar panel, biomass boilers and micro wind. The research of [8] takes into consideration the importance of the use of renewable energy technologies, uses a MCDM methodology, where it identifies the risk criteria using Delphi method in a first stage, the framework in two following stages employs AHP and using Fuzzy Weighted Aggregated Sum Product Assessment (FWASPAS), as final result they obtain six strategies that define the best renewable energy technologies. [9] in the same way develops a program to establish the policies of how the society uses the energy, the multicriteria analysis model establishes: Level Based Weight Assessment (LBWA) with Weighted Aggregated Sum Product Assessment (WASPAS). Its study covers conventional and non-conventional forms, including biomass production, natural gas and diesel fuel. It integrates the Weighted Power Heronian (WPHA) and Weight Geometric Power Heronian (WGPHA) functions to the Waspas method. The development of production systems presents an opportunity to standardize tasks in order to obtain high productions, [10] establishes from the uncertainty in the qualitative evaluations of indicators that prevail in industrial processes, in the internet of things (IoT), robotics and automation; for this it is supported in the decision-making processes the spherical fuzzy sets (SFSs) are used for the applicability of the available data for the WASPAS method, and it is carried out to solve the contract processes that are carried out between companies.

As can be seen, there are several ways in which the Weighted Aggregated Sum Product Assessment (WASPAS) multicriteria analysis method is used, however, its use does not appear through the neutrosophy, which constitutes a novelty applicable to the manufacturing process in thin pieces and in which the best quality is sought in the finishing of the pieces and without suffering deformation.

2. Definition

2.1. Sequential Interactive Model for Weighted Aggregated Sum Product Assessment (WASPAS)

The WASPAS method is a unique combination of two well-known MCDM approaches, i.e. weighted sum model (WSM) and weighted product model (WPM). Its application first requires development of a decision/evaluation matrix, X=[x_{ij}] m×n where x_{ij} is the performance of i^{th} alternative with respect to j^{th} criterion, m is the number of alternatives and n is the number of criteria.

2.2. Neutrosophic Environment

Neutrosophy is a new branch of philosophy that studies the origin, nature and scope of neutralities created by Professor Florentin Smarandache. Its incorporation guarantees that the uncertainty of decision-making is taken into account [11-16]. The truth value in the neutrosophic set is as follow [7-11]:

Definition 1 [14, 17, 18]: Be X a universe of discourse, a Neutrosophic Set (NS) is characterized by three membership.

Functions, $u_A(X):, r_A(X):, V_A(X): X \to]0^-, 1^+[$, which satisfy the condition $-0 \leq inf u_A(x) + inf r_A(x) + inf v_A(x) \ \leq sup u_A(x) + sup r_A(x) + \ sup v_A(x) \leq 3 + x \in X \ \leq \ 3 \ + \ x \in X \ \forall u_A(x), r_A(x) and \ v_A(x)$ denote the membership functions of true, indeterminate, and false of x in A, respectively, and their images are standard or non-standard subsets of $]0, 1^+[$ Let $N = \{(T, I, F): T, I, F \subseteq [0,1]\}n$ be a neutrosophic evaluation of a mapping of a group of formulas propositional to N, and for each sentence p:

$$v(p) = (T, I, F) \tag{1}$$

To facilitate the practical application in real-world problems [7], the use of Single-Value Neutrosophic Sets (SVNS) was proposed, through which it is likely to use linguistic terms to obtain greater interpretability of the results [8]. Let X be a universe of discourse, an SVNS A over X has the following form [2]:

$$A = \{\langle x, u_a(x), r_a(x), v_a(x)\rangle : x \in X\} \tag{2}$$

Where

$$u_a(x): X \to [0,1], r_a(x): X \to [0,1] \ y \ v_a(x): X \to [0,1] \tag{3}$$

With

$$0 \leq u_a(x), r_a(x), v_a(x) \leq 3, \forall \ x \in X \tag{4}$$

The intervals denote the memberships related to true, indeterminate and false from x in A, respectively $u_a(x), r_a(x)$ y $v_a(x)$ [10]. For convenience reasons, a Single-Value Neutrosophic Number (SVNN) is expressed as A = (a, b, c), where a, b, c∈ [0.1] and 0 ≤ a + b + c ≤ 3.

Table 1. *Linguistic terms used. Source: [19].*

Linguistic terms	SVNN numbers
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0,15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MDG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Moderately bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Let A = (a, b, c) be a single valued neutrosophic number, a score function S related to a single valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsehood membership degree is defined [20]:

$$s(V_i) = 2 + T_i - F_i - I_j \tag{5}$$

2.3. Method Development

Weighted Aggregated Sum Product Assessment (WASPAS), a method developed by [21], groups two methods Weighted Sum Method (WSM) (MacCrimon, 1968) and Weighted Product Method (WPM), the procedures to perform the WASPA method are described below: To make the performance measures comparable and dimensionless, all the elements in the decision matrix are normalized using the following two equations:

Step 1. Initialize the matrix for solving the selection problem.

Step 2. Normalize the decision matrix.

$$\bar{X}_{ij} = \frac{x_{ij}}{max_i x_{ij}} \text{ for beneficial criteria,} \quad (6)$$

$$\bar{X}_{ij} = \frac{max_i x_{ij}}{x_{il}} \text{ for non-beneficial criteria,} \quad (7)$$

Where *xij* is the normalized value of *xij*.

In WASPAS method, a joint criterion of optimality is sought based on two criteria of optimality. The first criterion of optimality, i.e. criterion of a mean weighted success is similar to WSM method. It is a popular and well accepted MCDM approach applied for evaluating a number of alternatives with respect to a set of decision criteria. Based on WSM method (MacCrimon, 1968; Triantaphyllou and Mann, 1989), the total relative importance of *i*th alternative is calculated as follows:

Step 3: Calculate the total relative importance based on the WSM method using equation.

$$Q_i^{(1)} = \sum_{j=1}^{n} \bar{X}_{ij} w_j \quad (8)$$

where *wj* is weight (relative importance) of *j*th criterion. On the other hand, according to WPM method (Miller and Starr, 1969; Triantaphyllou and Mann, 1989), the total relative importance of *i*th alternative is evaluated using the following equation:

Step 4: Calculate the total relative importance based on WPM method using equation.

$$Q_i^{(2)} = \prod_{j=1}^{n} \left(\bar{X}_{ij}\right)^{wj} \quad (9)$$

Step 5: A joint generalized weighted summative and multiplicative methods proposed by [21] is shown in equation.

A joint generalized criterion of weighted aggregation of additive and multiplicative methods is then proposed as follows:

$$Q_i = 0.5Q_i^{(1)} + 0.5Q_i^{(2)} = 0.5\prod_{j=1}^{n} \bar{X}_{ij} w_j + 0.5\prod_{j=1}^{n} \left(\bar{X}_{ij}\right)^{wj} \quad (10)$$

In order to have increased ranking accuracy and effectiveness of the decision making process, in WASPAS method, a more generalized equation for determining the total relative importance of *i*th alternative is developed [21] as below:

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda) Q_i^{(2)} = \lambda \sum_{j=1}^{n} \bar{X}_{ij} w_j + (1-\lambda)\prod_{j=1}^{n} \left(\bar{X}_{ij}\right)^{wj}, \lambda = 0, 0.1, \ldots, 1 \quad (11)$$

The feasible alternatives are now ranked based on the *Q* values and the best alternative has the highest *Q* value. In Eq. (6), when the value of λ is 0, WASPAS method is transformed to WPM, and when λ is 1, it becomes WSM method. It has been applied for solving MCDM problems for increasing ranking accuracy and it has the capability to reach the highest accuracy of estimation [3, 21-23]. For a given decision-making problem, the optimal values of λ can be determined while searching the following extreme function [24]:

$$\lambda = \frac{\sigma^2\left(Q_i^{(2)}\right)}{\sigma^2\left(Q_i^{(1)}\right) + \sigma^2\left(Q_i^{(2)}\right)} \quad (12)$$

The variances σ2(*Qi*(1)) and σ2(*Qi*(2)) can be computed with the respective equations 13 and 14:

$$\sigma^2\left(Q_i^{(1)}\right) = \sum_{j=1}^{n} W_j^2 \sigma^2\left(\bar{X}_{ij}\right) \quad (13)$$

$$\sigma^2\left(Q_i^{(2)}\right) = \sum_{j=1}^{n} \left(\frac{\prod_{j=1}^{n} \left(\bar{X}_{ij}\right)^{wj}}{\left(\bar{X}_{ij}\right)^{W_j} \left(\bar{X}_{ij}\right)^{\left(1-W_j\right)}}\right)^2 \sigma^2 \left(\bar{X}_{ij}\right)^{W_j} \quad (14)$$

The estimates of variances of the normalized initial criteria values are calculated as follows:

$$\sigma^2\left(\bar{X}_{ij}\right) = \left(0.05\bar{X}_{ij}\right)^2 \quad (15)$$

Variances of estimates of alternatives in WASPAS method depend of the variances of WSM and WPM approaches as well as on the value of λ. It may be worthwhile to compute the optimal values of λ and assure the maximum accuracy of estimation. It may also be important to study the effects of optimal λ values on the final ranking of the alternatives.

3. Case Study

High-speed milling operations were performed on Quick Machining Center Jet AV1612, equipped with HEI-CNC-System from DENHAIN for precise machining control with a maximum spindle speed of 20,000 rpm and feed speed of 25 m / min. The workpiece for the experiment was selected from Al 5083 alloy in rectangular shape with dimensions of 140 mm × 70 mm × 5 mm. The workpiece was mounted in a special fixture applying 6 bolts, additionally clamped on the bed of the machine tool. The chemical composition and physical properties of the workpiece material are given in Tables 1 and 2 respectively [25].

Table 2. *Chemical Composition of the Aluminum Alloy 5083.*

Element	% Present
Si	0.4
Fe	0.4
Cu	0.1
Mn	0.4-1.0
Mg	4.0-4.9
Zn	0.25
Ti	0.15
Cr	0.05-0.25
Al	Balance

Table 3. *Physical Properties of 5083 Aluminum Alloy.*

Properties	Value
Density	2650 kg/m^3
Melting point	570°C
Modulus of elasticity	72 GPa
Electrical resistivity	0.058 x 10^{-6} Ω-m
Thermal conductivity	121 W/m-K
Thermal expansion	25 x 10^{-6} /K

Table 4. *Mechanical Properties of Aluminum Alloy 5083.*

Temper	H32	0/HIII
Proof stress 0.2% (MPa)	240	145
Tensile strength	330	300
Shear strength (MPa)	185	175
Elongation A5 (%)	17	23
Hardness Vickers	95	75

4. Determination of the Weights of the Criteria with Neutrosophic Numbers

To run the model, by stating the established criteria and using the equations of the neutrosophic numbers, the weights of the criteria are evaluated and the dimensional deviation is taken into account. Table 5 shows the initial decision matrix, in which the criteria are evaluated, then the neutrosophic values of the criteria weights for the alternatives are represented in Table 6. Table 7 shows the results that showed lateral deviation as the criterion with the highest weight: W_{RaFd} = 0.28808, W_{RaTd} = 0.35065 y $W_{Deformation}$ = 0.39021.

Table 5. *Initial decision matrix.*

	DE1	DE2	DE3	DE4	DE5
RaFd (µm)	G	VG	MG	G	VVB
RaTd (µm)	MG	MB	VG	M	MB
Deformation	M	MB	MB	M	MG

Table 6. *Decision matrix of weights.*

	DE1	DE2	DE3	DE4	DE5
RaFd (µm)	(0.70,0.25,0.30)	(0.80,0.15,0.20)	(0.60,0.35,0.40)	(0.70,0.25,0.30)	(0.90,0.10,0.10)
RaTd (µm)	(0.60,0.35,0.40)	(0.40,0.65,0.60)	(0.80,0.15,0.20)	(0.50,0.50,0.50)	(0.40,0.65,0.60)
Deformation	(0.50,0.50,0.50)	(0.40,0.65,0.60)	(0.40,0.65,0.60)	(0.50,0.50,0.50)	(0.60,0.35,0.40)

Table 7. *Result of the hierarchy of weights.*

	Wi	Hierarchy
RaFd (µm)	0,28808	3
RaTd (µm)	0,35065	2
Deformation	0,39021	1

5. WASPAS with a Single Value Neutrosophic

The solution of the WASPAS method begins with the normalization of the data in Table 8 [25], taking the values of the results of the experimental work with the initial parameters, as shown in Table 9.

The results establish that the hierarchy for λ=0.5, behave as follows:

10-1-20-24-15-14-13-18-18-19-21-4-2-17-5-11-7- 9-25-23-16-22-12-6-8-3, related in Table 10.

Table 8. *Matrix of experimental data and results. Source: [25].*

No.	Cutting values				Results		
	S (rpm)	doc (mm)	ts (mm)	F (m/min)	RaFd (µm)	RaTd (µm)	Deforma-tion
1	12,431	0,21	4,00	3600	4,583	3,952	0,060
2	14,490	0,22	5,26	6668	5,457	4,742	0,066
3	15,000	0,30	7,00	9000	6,540	4,979	0,105
4	12,840	0,10	4,96	9000	5,716	5,169	0,059
5	11,935	0,15	3,00	8892	5,394	5,527	0,060
6	12,780	0,30	3,00	6192	5,356	5,275	0,100
7	9000	0,10	3,00	8055	5,174	5,432	0,064
8	9000	0,30	3,00	9000	5,833	6,264	0,084
9	9000	0,22	5,44	6867	6,019	5,173	0,061
10	15,000	0,10	3,00	3600	4,263	4,028	0,051
11	9000	0,30	7,00	3600	5,594	4,028	0,079
12	9000	0,10	7,00	9000	5,987	5,394	0,086
13	12,810	0,20	7,00	3600	5,262	3,844	0,069
14	14,490	0,22	5,26	6668	5,591	4,825	0,052

No.	Cutting values				Results		
	S (rpm)	doc (mm)	ts (mm)	F (m/min)	RaFd (µm)	RaTd (µm)	Deforma-tion
15	11,400	0,10	4,34	5652	5,055	4,640	0,056
16	12,000	0,20	6,92	8783	6,056	5,053	0,071
17	11,400	0,10	4,34	5652	5,081	4,372	0,077
18	9000	0,26	3,00	3600	4,495	4,353	0,070
19	15,000	0,20	3,00	9000	5,290	5,179	0,055
20	15,000	0,10	7,00	6354	5,510	4,038	0,052
21	12,840	0,10	4,96	9000	5,386	5,005	0,062
22	12,780	0,30	3,00	6192	4,885	4,788	0,106
23	15,000	0,30	5,08	3600	4,864	3,854	0,105
24	9000	0,10	6,26	3600	4,653	3,918	0,067
25	9000	0,22	5,44	6867	5,764	5,044	0,066

Table 9. *FMS normalized data of milling process parameters.*

STANDARDIZED DECISION MATRIX		
RaFd (µm)	RaTd (µm)	Deformation
0,93018	0,97267	0,85000
0,78120	0,81063	0,77273
0,65183	0,77204	0,48571
0,74580	0,74366	0,86441
0,79032	0,69549	0,85000
0,79593	0,72872	0,51000
0,82393	0,70766	0,79688
0,73084	0,61367	0,60714
0,70826	0,74309	0,83607
1,00000	0,95432	1,00000
0,76207	0,95432	0,64557
0,71204	0,71264	0,59302
0,81015	1,00000	0,73913
0,76248	0,79668	0,98077
0,84332	0,82845	0,91071
0,70393	0,76074	0,71831
0,83901	0,87923	0,66234
0,94839	0,88307	0,72857
0,80586	0,74223	0,92727
0,77368	0,95196	0,98077
0,79150	0,76803	0,82258
0,87267	0,80284	0,48113
0,87644	0,99741	0,48571
0,91618	0,98111	0,76119
0,73959	0,76209	0,77273

Table 10. *Optimum values per hierarchy for λ=0.5.*

Alternative	RaFd (µm)	RaTd (µm)	Deformation	Q_1	Q_2	Q	Score
1	0,9302	0,9727	0,8500	0,9407	0,9103	0,9255	2
2	0,7812	0,8106	0,7727	0,8108	0,7824	0,7966	12
3	0,6518	0,7720	0,4857	0,6480	0,6091	0,6286	25
4	0,7458	0,7437	0,8644	0,8129	0,7825	0,7977	11
5	0,7903	0,6955	0,8500	0,8032	0,7722	0,7877	14
6	0,7959	0,7287	0,5100	0,6838	0,6444	0,6641	23
7	0,8239	0,7077	0,7969	0,7964	0,7667	0,7816	16
8	0,7308	0,6137	0,6071	0,6626	0,6336	0,6481	24
9	0,7083	0,7431	0,8361	0,7908	0,7608	0,7758	17
10	1,0000	0,9543	1,0000	1,0129	0,9837	0,9983	1
11	0,7621	0,9543	0,6456	0,8061	0,7669	0,7865	15
12	0,7120	0,7126	0,5930	0,6864	0,6567	0,6716	22
13	0,8101	1,0000	0,7391	0,8725	0,8364	0,8544	7
14	0,7625	0,7967	0,9808	0,8817	0,8476	0,8646	6
15	0,8433	0,8284	0,9107	0,8888	0,8594	0,8741	5
16	0,7039	0,7607	0,7183	0,7498	0,7217	0,7358	20
17	0,8390	0,8792	0,6623	0,8085	0,7738	0,7911	13
18	0,9484	0,8831	0,7286	0,8672	0,8332	0,8502	8
19	0,8059	0,7422	0,9273	0,8542	0,8219	0,8381	9
20	0,7737	0,9520	0,9808	0,9394	0,9060	0,9227	3

Alternative	RaFd (μm)	RaTd (μm)	Deformation	Q_1	Q_2	Q	Score
21	0,7915	0,7680	0,8226	0,8183	0,7897	0,8040	10
22	0,8727	0,8028	0,4811	0,7207	0,6692	0,6949	21
23	0,8764	0,9974	0,4857	0,7918	0,7256	0,7587	19
24	0,9162	0,9811	0,7612	0,9050	0,8708	0,8879	4
25	0,7396	0,7621	0,7727	0,7818	0,7537	0,7678	18

6. Conclusions

Nowadays it is of utmost importance to incorporate tools in the decision making in manufacturing processes. Among the most important processes is the correct selection of parameters for high speed machining processes. The following work shows how the use of multi-criteria methods gives an answer to this objective, in this case it is possible to establish the best alternative in a fast way, also prevails the criteria of businessmen and engineers to maintain the quality and low costs of the productions. In the evaluation of the criteria, the neutrosophy method was applied, which allowed to evaluate that, within the optimal solution, the deformation criterion of the piece of thin structure (Deformation), is the most important with value: W_{TWD} = 0.39021. From the above, the use of the WASPAS method establishes the hierarchy and the highest value establishes that the alternative 10 offers with the input values S = 15,000 rpm, doc=0.10 mm, ts = 3.0 mm and the F=3600 m/min, the guarantee of the results for a better quality and without deforming the piece of aluminum material AL 5083. This method of decision making using neutosophic language terms and SVNN constitutes a novelty within the planning processes for high speed milling.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] G. F. Can, "An intutionistic approach based on failure mode and effect analysis for prioritizing corrective and preventive strategies," Human Factors and Ergonomics in Manufacturing & Service Industries, vol. 28, pp. 130-147, 2018.

[2] F. Ecer, D. Pamucar, S. H. Zolfani, and M. K. Eshkalag, "Sustainability assessment of OPEC countries: Application of a multiple attribute decision making tool," Journal of Cleaner Production, vol. 241, p. 118324, 2019.

[3] M. Keshavarz-Ghorabaee, K. Govindan, M. Amiri, E. K. Zavadskas, and J. Antuchevičienė, "An integrated type-2 fuzzy decision model based on WASPAS and SECA for evaluation of sustainable manufacturing strategies," Journal of Environmental Engineering and Landscape Management, vol. 27, pp. 187-200, 2019.

[4] A. R. Mishra, P. Rani, K. R. Pardasani, and A. Mardani, "A novel hesitant fuzzy WASPAS method for assessment of green supplier problem based on exponential information measures," Journal of Cleaner Production, vol. 238, p. 117901, 2019.

[5] H. Prajapati, R. Kant, and R. Shankar, "Prioritizing the solutions of reverse logistics implementation to mitigate its barriers: A hybrid modified SWARA and WASPAS approach," Journal of Cleaner Production, vol. 240, p. 118219, 2019.

[6] M. A. Sofuoğlu, "Fuzzy Applications of FUCOM Method in Manufacturing Environment," Journal of Polytechnic, 2019.

[7] C. Zhang, Q. Wang, S. Zeng, T. Baležentis, D. Štreimikienė, I. Ališauskaitė-Šeškienė, et al., "Probabilistic multi-criteria assessment of renewable micro-generation technologies in households," Journal of Cleaner Production, vol. 212, pp. 582-592, 2019.

[8] C. Kul, L. Zhang, and Y. A. Solangi, "Assessing the renewable energy investment risk factors for sustainable development in Turkey," Journal of Cleaner Production, vol. 276, p. 124164, 2020.

[9] D. Pamučar, M. Behzad, D. Božanić, and M. Behzad, "Decision making to support sustainable energy policies corresponding to agriculture sector: Case study in Iran's Caspian Sea coastline," Journal of Cleaner Production, vol. 292, p. 125302, 2021.

[10] E. Boltürk and F. Kutlu Gündoğdu, "Prioritizing Manufacturing Challenges of a Contract Manufacturing Company for Personal Auto by Using Spherical WASPAS Method," in Decision Making with Spherical Fuzzy Sets, ed, 2021, pp. 259-275.

[11] Q. Li, Y. Ma, and S. Zhu, "Single valued Neutrosophic clustering algorithm Based on Tsallis Entropy Maximization," MDPI, 2018.

[12] F. Samarandache, "Introduction to Neutrosophic Statistics," Sitech & Education Publishing 2014.

[13] F. Smarandache, "A Unifying Field in Logics: Neutrosophic Logic. Neutrosophy, Neutrosophic Set, Neutrosophic Probability: Neutrsophic Logic. Neutrosophy, Neutrosophic Set, Neutrosophic Probability: Infinite Study.," 2005.

[14] M. Leyva Vázquez and F. Smarandache, "Neutrosofía: Nuevos avances en el tratamiento de la incertidumbre," Pons, Bruselas., 2018.

[15] J. L. a. F. S. Salmerona, "Redesigning Decision Matrix Method with an indeterminacy-based inference process. Multispace and Multistructure.," Neutrosophic Transdisciplinarity (100 Collected Papers of Sciences), vol. 4, p. 151, 2010.

[16] M. Ali, Shabir, M., Smarandache, F., and Vladareanu, L., "Neutrosophic LA-semigroup Rings," Neutrosophic Sets and Systems, vol. 7, pp. 81-88, 2015.

[17] W. V. Kandasamy and F. Smarandache, "Fuzzy Neutrosophic Models for Social Scientists". Education Publisher Inc., (2013).

[18] W. B. V. a. F. S. Kandasamy, "Fuzzy cognitive maps and neutrosophic cognitive maps.," American Research Press., 2003.

[19] R. Şahin and M. Yiğider, "A Multi-criteria neutrosophic group decision making metod based TOPSIS for supplier selection," arXiv preprint arXiv: 1412.5077., 2014.

[20] M. Leyva-Vázquez, M. A. Quiroz-Martínez, Y. Portilla-Castell, J. R. Hechavarría-Hernández, and E. González-Caballero, "A New Model for the Selection of Information Technology Project in a Neutrosophic Environment," Neutrosophic Sets Syst., p. 344.

[21] E. K. Zavadskas, M. H. Aghdaie, and S. H. Zolfani, "Decision making in machine tool selection: An integrated approach with SWARA and COPRAS-G methods," Engineering Economics, vol. 24, pp. 5-17, 2013.

[22] M. MadiĆ, J. Antucheviciene, M. RadovanoviĆ, and D. PetkoviĆ, "Determination of Manufacturing Process Conditions by Using MCDM Methods: Application in Laser Cutting," Engineering Economics, vol. 27, pp. 144-150, 2016.

[23] P. P. Das and S. Chakraborty, "Application of grey correlation-based EDAS method for parametric optimization of non-traditional machining processes," Scientia Iranica, vol. 0, pp. 0-0, 2020.

[24] M. Yazdani, E. K. Zavadskas, J. Ignatius, and M. D. Abad, "Sensitivity Analysis in MADM Methods: Application of Material Selection," Engineering Economics, vol. 27, pp. 382-391, 2016.

[25] R. P. R. Hiovanis Castillo Pantoja. Ángel Infante Haynes, Ricardo Ávila Rondón, "Application of Fuzzy-AHP and COPRAS in the selection of the best alternative for high-speed machining of thin structures in aluminum alloys Al 5083," rte, vol. 33, p. 12, 2021.