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Information for Authors and Subscribers

*"***Neutrosophic Systems with Applications** *"* has been created for publications on advanced studies in neutrosophy, neutrosophic set, neutrosophic logic, neutrosophic probability, neutrosophic statistics that started in 1995 and their applications in any field, such as the neutrosophic structures developed in algebra, geometry, topology, etc.

The submitted papers should be professional, in good English, containing a brief review of a problem and obtained results.

Neutrosophy is a new branch of philosophy that studies the origin, nature, and scope of neutralities, as well as their interactions with different ideational spectra.

This theory considers every notion or idea <A> together with its opposite or negation <antiA> and with their spectrum of neutralities <neutA> in between them (i.e., notions or ideas supporting neither <A> nor <antiA>). The <neutA> and <antiA> ideas together are referred to as <nonA>.

Neutrosophy is a generalization of Hegel's dialectics (the last one is based on <A> and <antiA> only). According to this theory every idea <A> tends to be neutralized and balanced by <antiA> and <nonA> ideas - as a state of equilibrium.

In a classical way <A>, <neutA>, <antiA> are disjointed two by two. But, since in many cases the borders between notions are vague, imprecise, Sorites, it is possible that <A>, <neutA>, <antiA> (and <nonA> of course) have common parts two by two, or even all three of them as well.

Neutrosophic Set and Neutrosophic Logic are generalizations of the fuzzy set and respectively fuzzy logic (especially of intuitionistic fuzzy set and respectively intuitionistic fuzzy logic). In neutrosophic logic a proposition has a degree of truth (T), a degree of indeterminacy (I), and a degree of falsity (F), where T, I, F are standard or non-standard subsets of $]^-0, 1^+[$.

Neutrosophic Probability is a generalization of the classical probability and imprecise probability.

Neutrosophic Statistics is a generalization of classical statistics.

What distinguishes neutrosophic from other fields is the <neutA>, which means neither <A> nor <antiA>.

<neutA>, which of course depends on <A>, can be indeterminacy, neutrality, tie game, unknown, contradiction, ignorance, imprecision, etc.

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New Types of Topologies and Neutrosophic Topologies

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Abstract: In this paper, we recall the six new types of topologies that we introduced in the last years (2019-2022), such as: Refined Neutrosophic Topology, Refined Neutrosophic Crisp Topology, NeutroTopology, AntiTopology, SuperHyperTopology, and Neutrosophic SuperHyperTopology.

Keywords: Refined Neutrosophic Topology; Refined Neutrosophic Crisp Topology; NeutroTopology; AntiTopology; SuperHyperTopology.

1. Refined Neutrosophic Topology

The neutrosophic set has been extended to the Refined Neutrosophic Set (Logic, Probability) [1], where there are multiple parts of the neutrosophic components, as such T was split into subcomponents $T_1, T_2, \ldots, T_p$, and I into $I_1, I_2, \ldots, I_r$, and F into $F_1, F_2, \ldots, F_s$, with $p + r + s = n \geq 2$ and integers t, r, $s \geq 0$ and at least one of them is ≥ 2. Even more: the subcomponents T_j, I_k, and/or F_l can be countable or uncountable infinite subsets of [0, 1].

This definition also includes the Refined Fuzzy Set, when $r = s = 0$ and $p \geq 2$; and the definition of the Refined Intuitionistic Fuzzy Set, when $r = 0$, and either $p \geq 2$ and $s \geq 1$, or $p \geq 1$ and $s \geq 2$.

All other fuzzy extension sets can be refined in a similar way.
The *Refined Neutrosophic Topology* is a topology defined on a Refined Neutrosophic Set.

{Similarly, the Refined Fuzzy Topology is defined on a Refined Fuzzy Set, while the Refined Intuitionistic Fuzzy Topology is defined on a Refined Intuitionistic Fuzzy Set.

And, as a generalization, on any type of fuzzy extension set [such as: Pythagorean Fuzzy Set, Spherical Fuzzy Set, Fermatean Fuzzy Set, etc.] one can define a corresponding fuzzy extension topology.}

2. Refined Neutrosophic Crisp Topology

The *Neutrosophic Crisp Set* was defined by Salama and Smarandache in 2014 and 2015.
Let X be a non-empty fixed space. And let D be a Neutrosophic Crisp Set [2], where $D = \langle A, B, C \rangle$, with A, B, C as subsets of X.
Depending on the intersections and unions between these three sets A, B, C one gets several:
Types of Neutrosophic Crisp Sets [2, 3]
The object having the form D = is called:

1. A neutrosophic crisp set of Type 1 (NCS-Type1) if it satisfies: $A \cap B = B \cap C = C \cap A = \emptyset$ (empty set).

2. A neutrosophic crisp set of Type 2 (NCS-Type2) if it satisfies: A ∩ B = B ∩ C = C ∩ A = ∅ and A ∪ B ∪ C = X.
3. A neutrosophic crisp set of Type 3 (NCS-Type 3) if it satisfies: A ∩ B ∩ C = ∅ and A ∪ B ∪ C = X.

Of course, more types of Neutrosophic Crisp Sets may be defined by modifying the intersections and unions of the subsets A, B, and C.

The *Refined Neutrosophic Crisp Set* was introduced by Smarandache in 2019, by refining/splitting D (and denoting it by RD = Refined D) by refining/splitting its sets A, B, and C into sub-subsets as follows:

RD = (A_1, ..., A_p; B_1, .., B_r; C_1, .., C_s), with p, r, s ≥ 1 be positive integers and at least one of them be ≥ 2,

and $A = \bigcup_{i=1}^{p}, B = \bigcup_{j=1}^{r}, C = \bigcup_{k=1}^{s}$, and many Types of Refined Neutrosophic Crisp.

Therefore, the Refined Neutrosophic Crisp Topology is a topology defined on the Refined Neutrosophic Crisp Set.

3. NeutroTopology

NeutroTopology [3] is a topology that has at least one topological axiom which is partially true, partially indeterminate, and partially false, or (T, I, F), where T = True, I = Indeterminacy, F = False, and no topological axiom is totally false, in other words: $(T, I, F) \notin \{(1,0,0),(0,0,1)\}$, where (1, 0, 0) represents the classical Topology, while (0, 0, 1) represents the below AntiTopology.

Therefore, NeutroTopology is a topology in between classical Topology and AntiTopology.

4. AntiTopology

AntiTopology [3] is a topology that has at least one topological axiom that is 100% false (T, I, F) = (0, 0, 1).

The NeutroTopology and AntiTopology are particular cases of NeutroAlgebra and AntiAlgebra [3] and, in general, they all are particular cases of the NeutroStructure and AntiStructure respectively, since we consider "Structure" in any field of knowledge [4].

5. SuperHyperTopology

SuperHyperTopology [5] is a topology build on the nth-PowerSet of a given non-empty set H that excludes the empty set. Therefore: $P_*(H)$ is the first powerset of the set H, without the empty set (∅); $P_*^{\,2}(H) = P_*(P_*(H))$, is the second powerset of H (or the powerset of the powerset of H), without the empty sets; and so on, the n-th powerset of H,

$$\mathbf{P}_*^{n}(\mathbf{H}) = \mathbf{P}_*(\mathbf{P}_*^{n-1}(\mathbf{H})) = \underbrace{\mathbf{P}_*\left(\mathbf{P}_*\left(\ldots\left(\mathbf{P}_*(\mathbf{H})\right)\ldots\right)\right)}_{n}$$

, where P_* is repeated n times (n ≥ 2), and without the empty sets.

6. Neutrosophic SuperHyperTopology

Neutrosophic SuperHyperTopology [6] is, similarly, a topology build on the nth-PowerSet of a given non-empty set H, but includes the empty sets [that represent indeterminaciesy] too.

As such, in the above formulas, $P_*(H)$ that excludes the empty set, is replaced by $P(H)$ which includes the empty set. $P(H)$, is the first powerset of the set H, including the empty set (∅); $P_*^{\,2}(H) = P(P(H))$ is the second powerset of H (or the powerset of the powerset of H), which includes the empty sets; and so on, the n-th powerset of H,

$$P^n(H) = P(P^{n-1}(H)) = \underbrace{P\Big(P\Big(\ldots\Big(P(H)\Big)\ldots\Big)\Big)}_{n}$$

, where P is repeated n times (n ≥ 2), and includes the empty-sets.

7. Conclusion

These six new types of topologies were introduced by Smarandache in 2019-2022, but they have not yet been much studied and applied, except the NeutroTopology and AntiTopology which got some attention from researchers.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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Inspection Assignment Form for Product Quality Control Using Neutrosophic Logic

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Abstract: During the production process, production companies need to monitor the finished products and ensure their quality, which imposes on them the appointment of inspectors for auditing, and this appointment costs the company amounts that affect the general profit, so it strives to make this cost as low as possible and that the audit process is carried out with high accuracy because in case that the finished products do not conform to the basic specifications of the product, the company is required to pay a fine. In this research, we will formulate the text of the problem appropriately for such a case and then we will build the appropriate mathematical model through which we can obtain the lowest possible cost of inspection, and we will present the study using classical values and neutrosophic values, and we will demonstrate them through an example that shows us the difference between them.

Keywords: Mathematical models; Neutrosophic science; Inspection issue; Product quality control.

1. Introduction

Since the genesis of the science of operations research, it has been providing solutions to the problems faced by companies through studies presented by scientists and researchers in all fields using the methods of this science, in this research we will use the method of linear programming to build a mathematical model that enables us to ensure the quality of products using inspectors and at the lowest possible cost where we will formulate the appropriate issue for that and build the mathematical model that by finding the optimal solution to it and using the methods of solution provided by the science of operations research we get on the lowest cost of inspection and high-quality products, where the matter will be displayed

First : Using classical values based on references [1,2,3]

Second: Neutrosophic values based on what researchers and those interested in this science have presented and developed through studies and research that have been published in references [4, 16]

Discussion:

1- Studying using classical values:

Formulating the problem and building the mathematical model:

Text of the issue: Through the available information about the functioning of companies, we can develop the following text:

The company has a rank for inspectors and wants to assign the task of quality control to them, and a piece of product should be audited daily during an hour of work per day, in the following table we explain the full information about the inspectors and for all mattresses nKS.

Table 1. Information on inspectors using classical values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspectors	The fine paid by the company for each fault to the inspector
1	M_1	D_1	G_1	A_1	R
2	M_2	D_2	G_2	A_2	R
----			-		-----
n	M_n	D_n	G_n	A_n	R

Required: Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible.

Building the Mathematical Model:

To build the mathematical model, we impose the number of inspectors of each rank on the order assigned to the inspection task, then the following inequality must be met:

$x_{1,}x_2, ----x_n$

$$x_j \leq A_j \quad ; \quad j = 1,2,--,n$$

Since the company needs to audit K piece daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} SM_j x_j \geq K$$

To obtain the target follower we note that the company bears two types of costs during the inspection process, the inspector's wage and the fine corresponding to the error committed by the inspector to write the target follower note the following:

The cost of the inspector from rank j hourly salary is calculated through the following relationship

$$C_j = G_j + M_j R_j \left(\frac{100 - D_j}{100}\right) \quad ; \quad j = 1,2,---,n$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

The target function is then written as follows:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

From the above, we can develop the following mathematical model:
We want to find the smallest possible value for the function:

$$Z = S\sum_{j=1}^{n}\left[G_j + M_j R_j\left(\frac{100 - D_j}{100}\right)\right]x_j \rightarrow Min$$

Within Restrictions

$$x_j \leq A_j \quad ; \quad j = 1,2,--,n$$

$$\sum_{j=1}^{n} SM_j x_j \geq K$$

$$x_j \geq 0 \ ; \ j = 1,2,----n$$

Example:

The company has three ranks for inspectors and wants to assign the task of quality control to them, and 1500piece should be audited daily during 8working hours per day, in the following table we explain the full information about the inspectors and for all mattresses.

Table 2. Information on inspectors using classical values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspector s	The fine paid by the company for each fault to the inspector
1	15	95	4	10	2
2	10	90	3	6	2
3	25	98	5	8	2

Required : Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible

To build the mathematical model, we impose the number of inspectors from the three ranks in the order assigned to the inspection task, then the following in equations must be fulfilled. $x_{1,}x_2, x_3$

$$x_1 \leq 10$$
$$x_2 \leq 6$$
$$x_3 \leq 8$$

Since the company needs to audit 1500 pieces daily during 8working hours a day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} 8M_j x_j \geq 1500$$

That is

$$8(M_1x_1 + M_2x_2 + M_3x_3) \geq 1500$$

From it we get the following restriction:

$$120x_1 + 80x_2 + 200x_3 \geq 1500$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target function will be written as follows:
Then the cost of the inspector's hourly salary from rank j is calculated through the following relationship :

$$C_j = G_j + M_j R_j \left(\frac{100 - D_j}{100}\right) \quad ; \ j = 1,2,---,n$$

From them we get

$$C_1 = 4 + 15 \times 2 \times \left(\frac{100 - 95}{100}\right) = 5.5$$

$$C_2 = 3 + 10 \times 2 \times \left(\frac{100 - 90}{100}\right) = 5$$

$$C_3 = 5 + 25 \times 2 \times \left(\frac{100 - 98}{100}\right) = 6$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

We substitute the values available to us and we get:

$$TC_j = 5.5x_1 + 5x_2 + 6x_3$$

substituting the following target phrase:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

We get:

$$Z = 44x_1 + 40x_2 + 48x_3$$

From the above, we can develop the following mathematical model:
We want to find :

$$MinZ = 44x_1 + 40x_2 + 48x_3$$

Within Restrictions

$$x_1 \le 10$$
$$x_2 \le 6$$
$$x_3 \le 8$$
$$120x_1 + 80x_2 + 200x_3 \ge 1500$$
$$x_j \ge 0 \ ; \ j = 1,2,3$$

To obtain the optimal solution, we use the simplex method, which is sufficiently explained in the references [1,2,3]

2- Formulation of the problem and the construction of mathematical model according to neutrosophic values:

The study concluded in the research [12] shows us how to construct neutrosophic linear models, (the linear model is a neutrosophic model if at least one of the likes of variables in the target function or neutrosophic value constraints)

The text of the issue:

The company has n rank for inspectors and wants to assign the task of quality control to them, and K pieces should be audited daily during an S hour of work per day, in the following table we explain the full information about the inspectors and for all ranks:

Table 3. Information on inspectors using neutrosophic values

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspector s	The fine paid by the company for each fault to the inspector
1	NM_1	ND_1	G_1	A_1	R
2	NM_2	ND_2	G_2	A_2	R
-----	--		-		-----
n	NM_n	ND_n	G_n	A_n	R

The number of pieces is a neutrosophic value $NM_j = M_j + \varepsilon_j$ where ε_j is the indeterminacy on the number of pieces, it can take one of the shapes $[\lambda_{j1}, \lambda_{j2}]$ or $\{\lambda_{j1}, \lambda_{j2}\}$or any value close to M_j as well as the precision, neutrosophic values $ND_j = D_j + \delta_j$ where δ_j is the indeterminacy on the precision that can take one of the shapes $[\mu_{j1}, \mu_{j2}]$ or $\{\mu_{j1}, \mu_{j2}\}$ or any value close to D_j.

Required: Formulate the appropriate mathematical model through which we can assign the optimal support to the inspectors so that the cost of inspection is as low as possible

Building the neutrosophic mathematical model:

To build the mathematical model, we impose $x_1, x_2, ----, x_n$ the number of inspectors of each rank on the order assigned to the inspection task, then the following inequality must be met:

$$x_j \leq A_j \quad ; \quad j = 1,2,--,n$$

Since the company needs to audit K piece daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} S(NM_j)x_j \geq K$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target follower writes as follows:

$$Z = S\sum_{j=1}^{n} G_j + NM_jR_j\left[\frac{100 - ND_j}{100}\right]x_j$$

Then the mathematical model is written as follows:

$$Z = S\sum_{j=1}^{n} G_j + NM_jR_j\left[\frac{100 - ND_j}{100}\right]x_j \ \rightarrow Min$$

Within Restrictions

$$x_j \leq A_j \quad ; \quad j = 1,2,--,n$$

$$\sum_{j=1}^{n} S(NM_j)x_j \geq K$$

$$x_j \geq 0 \ ; \ j = 1,2,----n$$

Example 1:

A company has three ranks for inspectors and wants to assign the task of quality control to them, and 1500 pieces should be audited daily during 8 working hours per day, in the following table we explain the full information about the inspectors and for all ranks, in this example we will take the number of pieces checked by the inspectors from each rank as neutrosophic values

Table 4. Information on inspectors using neutrosophic values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspector s	The fine paid by the company for each fault to the inspector
1	{15,16}	95	4	10	2
2	{10,11}	90	3	6	2
3	{25,26}	98	5	8	2

Required : Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible

To build the mathematical model, we impose $x_{1,}x_2, x_3$ as the number of inspectors from the three ranks in the order assigned to the inspection task, then the following inequality must be met:

$$x_1 \leq \ 10$$

$$x_2 \leq \ 6$$

$$x_3 \leq \ 8$$

Since the company needs to audit K pieces daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} 8M_jx_j \geq 1500$$

That is

$$8(M_1x_1 + M_2x_2 + M_3x_3) \geq 1500$$

From it we get the following restriction:

$$8\{15,16\}x_1 + 8\{10,11\}x_2 + 8\{25,26\}x_3 \geq 1500$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target follower writes as follows:
Then the cost of the inspector is calculated from j the hourly rank through the following relationship:

$$C_j = G_j + M_j R_j \left(\frac{100 - D_j}{100}\right) \;\; ; \; j = 1,2,---,n$$

From that we get

$$C_1 = 4 + \{15,16\} \times 2 \times \left(\frac{100 - 95}{100}\right) = \{5.5,5.6\}$$

$$C_2 = 3 + \{10,11\} \times 2 \times \left(\frac{100 - 90}{100}\right) = \{5,5.2\}$$

$$C_3 = 5 + \{25,26\} \times 2 \times \left(\frac{100 - 98}{100}\right) = \{6,6.04\}$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

$$TC_j = \{5.5,5.6\}x_1 + \{5,5.2\}x_2 + \{6,6.04\}x_3$$

substituting the following target phrase:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

We get:

$$Z = \{44,44.8\}x_1 + \{40,41,6\}x_2 + \{48,48.32\}x_3$$

From the above, we can develop the following mathematical model:
We want to find:

$$MinZ = \{44,44.8\}x_1 + \{40,41,6\}x_2 + \{48,48.32\}x_3$$

Within Restrictions

$$x_1 \leq 10$$
$$x_2 \leq 6$$
$$x_3 \leq 8$$
$$8\{15,16\}x_1 + 8\{10,11\}x_2 + 8\{25,26\}x_3 \geq 1500$$
$$x_j \geq 0 \;\; ; \; j = 1,2,3$$

Example 2:
A company has three ranks for inspectors and wants to assign the task of quality control to them, and 1500 pieces should be checked daily during 8working hours per day, in the following table we explain the full information about inspectors and for all ranks, in this example we will take the accuracy of inspection for each inspector as neutrosophic values in the form of areas whose minimum range is less accurate and the highest range is the highest accuracy that the inspector reaches by rank.

Table 5. Information on inspectors using neutrosophic values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (monetary unit per hour)	Number of inspectors	The fine paid by the company for each fault to the inspector
1	15	[95,97]	4	10	2
2	10	[90,92]	3	6	2
3	25	[98,99.5]	5	8	2

Required : Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible.

To build the mathematical model, we impose $x_{1,}x_2, x_3$ the number of inspectors from the three ranks in the order assigned to the inspection task, then the following inequality must be met:

$$x_1 \leq 10$$
$$x_2 \leq 6$$
$$x_3 \leq 8$$

Since the company needs to audit K pieces daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} 8M_j x_j \geq 1500$$

That is

$$8(M_1x_1 + M_2x_2 + M_3x_3) \geq 1500$$

From it, we get the following entry:

$$120x_1 + 80x_2 + 200x_3 \geq 1500$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target follower writes as follows:

Then the cost of the inspector is calculated from j the hourly rank through the following relationship:

$$C_j = G_j + M_j R_j \left(\frac{100 - ND_j}{100}\right) \;\; ; \;\; j = 1,2, - - -, n$$

From that we get

$$C_1 = 4 + 15 \times 2 \times \left(\frac{100 - [95,97]}{100}\right) = [4.9,5.5]$$

$$C_2 = 3 + 10 \times 2 \times \left(\frac{100 - [90,92]}{100}\right) = [4.6,5]$$

$$C_3 = 5 + 25 \times 2 \times \left(\frac{100 - [98,99.5]}{100}\right) = [5.25,6]$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - ND_j}{100} \right) \right] x_j$$

$$TC_j = [4.9,5.5]x_1 + [4.6,5]x_2 + [5.25,6]x_3$$

Substituting the following target phrase:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - ND_j}{100} \right) \right] x_j$$

We get:

$$Z = [39.2,44]x_1 + [36.8,40]x_2 + [42,48]x_3$$

From the above, we can develop the following mathematical model:

We want to find:

$$MinZ = [39.2,44]x_1 + [36.8,40]x_2 + [42,48]x_3$$

Within Restrictions

$$x_1 \leq 10$$

$$x_2 \leq 6$$

$$x_3 \leq 8$$

$$120x_1 + 80x_2 + 200x_3 \geq 1500$$

$$x_j \geq 0 \ ; \ j = 1,2,3$$

In the two examples, and two for the optimal solution we use the neutrosophic simplex method sufficiently explained in the reference [13].

2. Conclusion and Results

Through the previous study, we note that by using the linear programming method, we can provide the optimal solution to most of the problems that can face the production companies by formulating the situation under treatment with an issue that can be converted into a linear model by solving it using the ideal solution for it, the company achieves the highest profit, and in order to obtain solutions that enjoy a margin of freedom, the concepts of neutrosophic science can be used because the indeterminacy enjoyed by the neutrosophic values can be responsible for managing the company and developing alternative plans that suit all working conditions.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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Toward Sustainable Emerging Economics based on Industry 5.0: Leveraging Neutrosophic Theory in Appraisal Decision Framework

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Abstract: Entrepreneurs in emerging economies (EEs) need to expand to survive in a climate of intense competition. Additionally, it must be innovative, imaginative, and open to absorbing new business techniques. Prior studies proved that Entrepreneur's success hinges on its capacity to deliver innovative items through employing cutting-edge technologies more quickly than its rivals. In recent decades, digitization—the widespread use of connected digital services by governments, businesses, and consumers—has emerged as a major economic engine that spurs expansion and makes it easier to create jobs. For instance, the next major technological shift is thought to be Industry 5.0 (Ind 5.0). In contrast to Industry 4.0, its goal is to provide manufacturing techniques that are resource-efficient and user-preferred through leveraging the creativity of human specialists in combination with effective, intelligent, and precise machines. Hence, the current study seeks to compile a comprehensive list of obstacles that suppress implementing Ind5.0, to experimentally appraise those obstacles. We construct Appraisal Decision Framework (ADF) generated from deploying Analytic Hierarchy Process (AHP) as method of multi-criteria decision-making (MCDM). Whilst AHP work with aids of neutrosophic set to overcome the vague information in the process of evaluation. Herein, interval-valued neutrosophic numbers (IVNSs) apprise the obstacles of Ind 5.0 in EEs. The neutrosophic AHP method is used to compute the weights of risks, then rank it. The findings of ADF show that cost and fund are the highest in all 12-obstacle followed by scalability, Lack of Socio-technological Planning, security, and privacy.

Keywords: Emerging Economies (EEs); Interval Valued Neutrosophic Sets (IVNSs); Industry 5.0 (Ind 5.0); Analytic Hierarchy Process (AHP); multi-criteria decision-making (MCDM); Obstacles.

1. Introduction

Emerging economies (EEs) have recently made considerable contributions to the world's gross domestic product (GDP). Evidence that this is true [1] In 2016, the growth rate for EEs is 4.2%, whereas the growth rate for developed economies is just 1.6%, according to the World Economic Outlook Report. Pursuant to this analysis, developing economies will not contribute as much to the expansion of the global economy as EEs would. EEs described by [2] as tremendous growth despite little income nations that rely on economic liberalization as their main source of growth.

Due to intense rivalry and risks from rivals brought on by accelerating technological progress, the world economy is changing quickly, relying on [3] it is necessitating and requiring organizations to be creative . In similar vein [4] the ability of businesses to innovate, invent, and uncover new business models is crucial to their survival and success. That is why organizations in [5] must concentrate on creating resources and competences to compete effectively. Organizations that can strategically expand their technology capabilities and produce novel goods and technologies faster and cheaper than their rivals will do better in a competitive climate. Thereby [6] showcased that Information communication technology (IT) and telecommunications infrastructure are the foundation of the modern world economy, are increasingly used as a platform for regional and international growth.

To put it another way [7] emphasized that the only way to thrive in the rapidly evolving business climate , is to constantly launch new goods and services that may benefit both the company and its clients is abetted by industry 5.0 (Ind 5.0) technologies as branch of Information Communications and Technologies (ICT). Due to [8] where the collaboration of emerging technologies, such as industrial robots, 3D printers, etc., with human beings in businesses with the belief that "we use these tools as tools, do not give them the function and brain to WORK FOR US, but WORK WITH US". This results from Ind 5.0 has several technologies summarized in Figure 1.

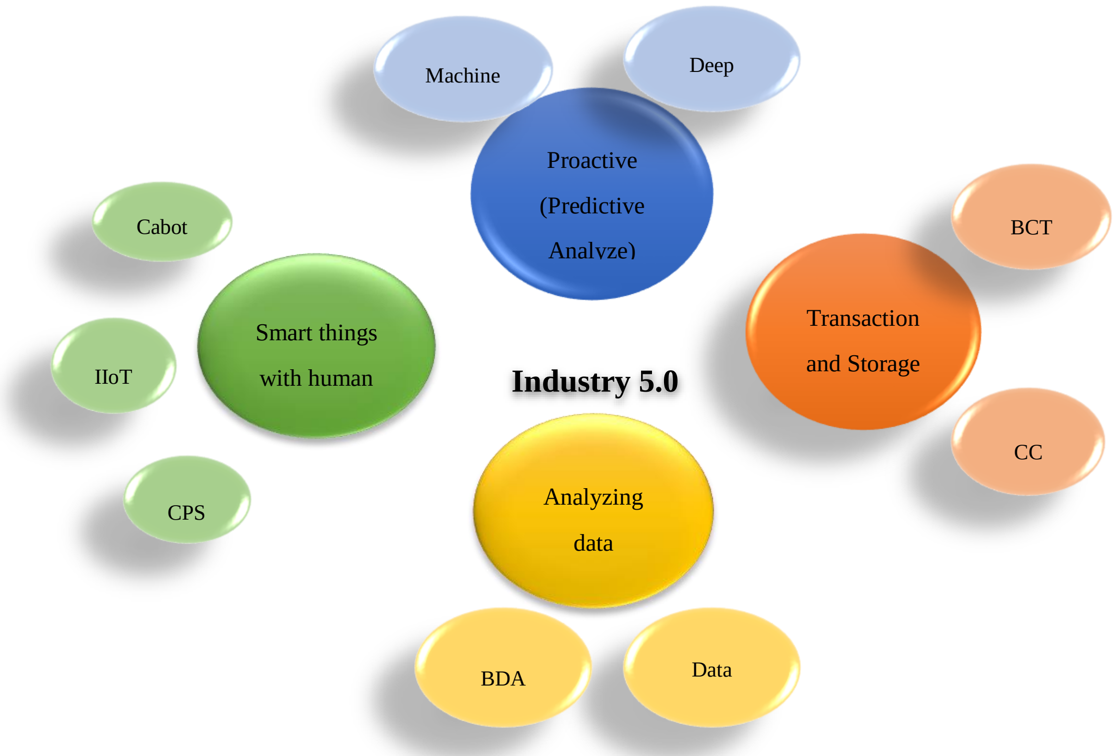

Figure 1. Role of Industry 5.0 technologies in emerging economics.

Notwithstanding the crucial act for deploying Ind 5.0 in businesses and EEs, [6] illustrated the obstacles are faced Ind 5.0 in emerging nations. Consequently, these countries' development is sluggish. Thence, this study suggests a theoretical framework that managers may utilize to overcome the obstacles preventing the broad adoption of Ind 5.0.

The suggested framework is deploying Multi-Criteria Decision-Making (MCDM). Since several apps have found success with various MCDM variations, scholars have adopted them. Since uncertainty heightens the difficulty of selecting choices, there is usually not enough data to arrive at a definitive solution to a real-world problem[9, 10, 11]. Hence, Analytic Hierarchy Process (AHP) is employed as method of MCDM and has been boosted by neutrosophic theory. Due to this theory can treat with uncertainty situations through measuring degree of truth, falsehood, and indeterminacy rather than numbers since it is usually hard to exactly discern the proportion of truth and falsity.

Herein, we are volunteering AHP in this study under neutrosophic theory especially, interval-valued neutrosophic sets (IVN) to generate robust hybrid framework so-called Appraisal Decision Framework (ADF). The objective of this framework is appraising the obstacles facing Ind 5.0 in EEs.

2. Appraisal Decision Framework (ADF)

This section clarified the proposed framework to rank and identify Ind 5.0 obstacles in EEs. Figure 2 summarized procedures of ADF. Whereas AHP method is used to compute the weights of determined obstacles. The idea of this method is building the matrix between criteria with each other's to generate the comparison matrix as following:

Procedure 1: Estimating Ind 5.0 obstacles in EEs.

Procedure 2: Obtain the scale of IVNSs. This scale is used IVNSs scale in [12] by experts for appraising Ind 5.0 obstacles.

This procedure introduced the goal and risks as a hierarchical building. The goal of this study is to rank Ind 5.0 obstacles in EEC.

Procedure 3: Setting up pairwise matrices based on experts' rates.

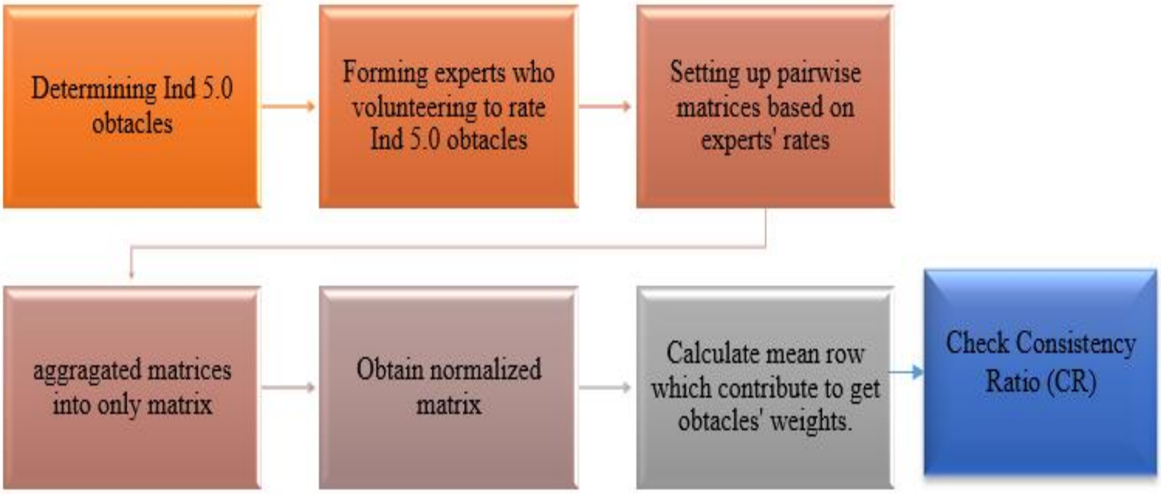

Figure 2. Summarized appraisal decision framework procedures.

This procedure is used to build the pairwise comparison matrices between obstacles as in Eq. (1). The value of this matrix is a number of IVNSs.

$$P = \begin{pmatrix} [X_{11}^L, X_{11}^U], [Y_{11}^L, Y_{11}^U], [Z_{11}^L, Z_{11}^U] & \cdots & [X_{1n}^L, X_{1n}^U], [Y_{1n}^L, Y_{1n}^U], [Z_{1n}^L, Z_{1n}^U] \\ \vdots & \ddots & \vdots \\ [X_{n1}^L, X_{n1}^U], [Y_{n1}^L, Y_{n1}^U], [Z_{n1}^L, Z_{n1}^U] & \cdots & [X_{nn}^L, X_{nn}^U], [Y_{nn}^L, Y_{nn}^U], [Z_{nn}^L, Z_{nn}^U] \end{pmatrix} \quad (1)$$

Where X, Y, Z refer to the truth, indeterminacy, and falsity values, and n refers to the number of obstacles.

Procedure 4: Convert the values of X,Y, and Z to the one value based on Eq.(2) applied in [12]

$$d = \left(\frac{X^L + X^U}{2}\right) + \left(\left(1 - \frac{(Y^L + Y^U)}{2}\right) \times Y^U\right) - \left(\left(\frac{Z^L + Z^U}{2}\right) \times (1 - Z^U)\right) \quad (2)$$

Procedure 5: Normalize the pairwise comparison matrix.

$$P_{ij}^* = \left[\left[\frac{X_{ij}^L}{\sum_{k=1}^n X_{Kj}^L}, \frac{X_{ij}^U}{\sum_{k=1}^n X_{Kj}^U}\right], \left[\frac{Y_{ij}^L}{\sum_{k=1}^n Y_{Kj}^L}, \frac{Y_{ij}^U}{\sum_{k=1}^n Y_{Kj}^U}\right], \left[\frac{Z_{ij}^L}{\sum_{k=1}^n Z_{Kj}^L}, \frac{Z_{ij}^U}{\sum_{k=1}^n Z_{Kj}^U}\right]\right] \quad (3)$$

$$P_{ij}^* = \left[[X_{ij}^{*L}, X_{ij}^{*U}], [Y_{ij}^{*L}, Y_{ij}^{*U}], [Z_{ij}^{*L}, Z_{ij}^{*U}]\right]$$

The normalization matrix can be represented as:

$$P^* = \begin{pmatrix} [X_{11}^{*L}, X_{11}^{*U}], [Y_{11}^{*L}, Y_{11}^{*U}], [Z_{11}^{*L}, Z_{11}^{*U}] & \cdots & [X_{1n}^{*L}, X_{1n}^{*U}], [Y_{1n}^{*L}, Y_{1n}^{*U}], [Z_{1n}^{*L}, Z_{1n}^{*U}] \\ \vdots & \ddots & \vdots \\ [X_{n1}^{*L}, X_{n1}^{*U}], [Y_{n1}^{*L}, Y_{n1}^{*U}], [Z_{n1}^{*L}, Z_{n1}^{*U}] & \cdots & [X_{nn}^{*L}, X_{nn}^{*U}], [Y_{nn}^{*L}, Y_{nn}^{*U}], [Z_{nn}^{*L}, Z_{nn}^{*U}] \end{pmatrix} \quad (4)$$

Procedure 6: Calculate the mean row in normalization matrix

$$P^{**} = \begin{bmatrix} \left[\frac{\sum_j X_{1j}^{*L}}{n}, \frac{\sum_j X_{1j}^{*U}}{n}\right], \left[\frac{\sum_j Y_{1j}^{*L}}{n}, \frac{\sum_j Y_{1j}^{*U}}{n}\right], \left[\frac{\sum_j Z_{1j}^{*L}}{n}, \frac{\sum_j Z_{1j}^{*U}}{n}\right] \\ \cdots \\ \cdots \\ \cdots \\ \left[\frac{\sum_j X_{nj}^{*L}}{n}, \frac{\sum_j X_{nj}^{*U}}{n}\right], \left[\frac{\sum_j Y_{nj}^{*L}}{n}, \frac{\sum_j Y_{nj}^{*U}}{n}\right], \left[\frac{\sum_j Z_{nj}^{*L}}{n}, \frac{\sum_j Z_{nj}^{*U}}{n}\right] \end{bmatrix} \quad (5)$$

$$P^{**} = \begin{bmatrix} [X_1^{**L}, X_1^{**U}], [Y_1^{**L}, Y_1^{**U}], [Z_1^{**L}, Z_1^{**U}] \\ \cdots \\ \cdots \\ \cdots \\ [X_n^{**L}, X_n^{**U}], [Y_n^{**L}, Y_n^{**U}], [Z_n^{**L}, Z_n^{**U}] \end{bmatrix} \quad (6)$$

Procedure 7: Compute the weights of Ind 5.0 obstacles.

$$w_j = \frac{d_j}{\sum_{i=1}^{n} d_i} \quad (7)$$

Procedure 8: check the consistency ratio (CR) based on Eq. (8).

$$CR = \frac{CI}{RI} \quad (8)$$

Where, $CI = \frac{\lambda_{max} - n}{n-1}$

3. Validation of appraisal decision framework

Herein, we introduced the application of constructed framework. Relying on conducted surveys for earlier studies, we gathered the obstacles of Ind 5.0 in EEs which stated in Figure 3. After that we appraise these obstacles and rank it. For achieving the study's objectives, we are making course of actions as following:

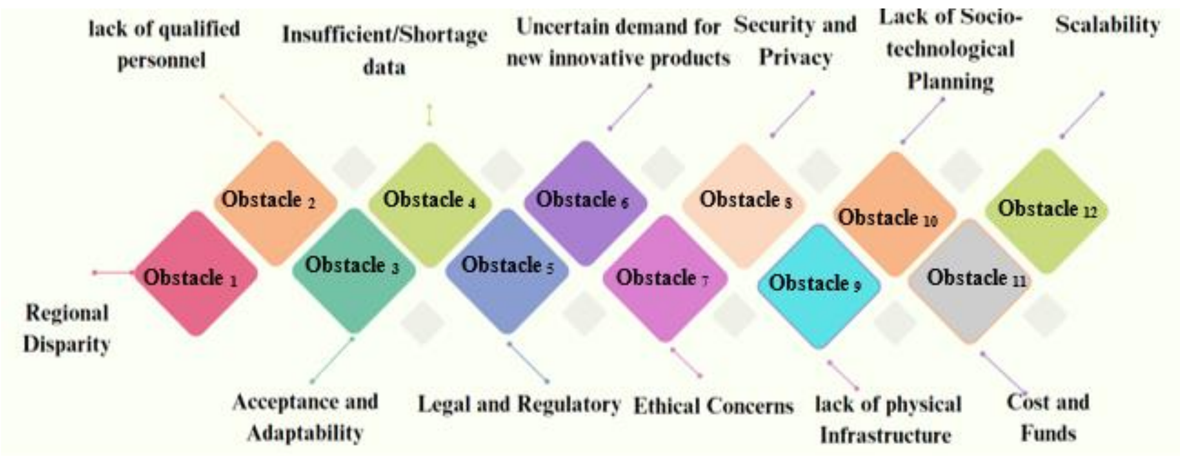

Figure 3. Applied Industry 5.0 obstacles in appraisal decision framework.

- ✓ Action 1: We conducted interviews with three experts to evaluate these risks. The experts build the pairwise comparison matrix between risks. Table 1 shows aggregated matrix.
- ✓ Action 2: We generate the normalized pairwise comparison matrix as shown in Table 2.
- ✓ Action 3: consequently, we compute the mean row in the normalization matrix. Then compute the weights of Ind 5.0 obstacles.
- ✓ Final Action: we test the CR and if its value is less than 0.1, so we sure matrix is consistent. After that we showcase the final weight for Ind 5.0 obstacles in Figure 4 and rank it based on weights' values.

Table 1. Aggregated matrix.

Obstacles	**Obstacle$_1$**	**Obstacle$_2$**	**Obstacle$_3$**	**Obtsacle$_4$**	**Obstacle$_5$**	**Obstacle$_6$**
Obstacle$_1$	1	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	[[0.60,0.70],[0.25,0.35] ,[0.30,0.40]]	[[0.65,0.75],[0.20,0.30],[0.25,0.35]]
Obstacle$_2$	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1	[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.80,0.90],[0.05,0.10], [0.10,0.20]]	[[0.80,0.90],[0.05,0.10],[0.10,0.20]]
Obstacle$_3$	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	1	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.50,0.6],[0.35,0.45] ,[0.40,0.50]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]
Obstacle$_4$	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1	[[0.50,0.50],[0.50,0.50], [0.50,0.50]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]
Obstacle$_5$	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	1/[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1	[[0.80,0.90],[0.05,0.10],[0.10,0.20]]
Obstacle$_6$	1/[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	1/[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.80,0.90],[0.05,0.10], [0.10,0.20]]	1
Obstacle$_7$	1/[[0.70,0.80],[0.15,0.25],[0.20,0.30]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	1/[[0.90,0.95],[0.00,0.05], [0.05,0.15]]	1/[[0.50,0.50], [0.50,0.50],[0.50,0.50]]
Obstacle$_8$	1/[[0.75,0.85],[0.10,0.20],[0.15,0.25]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	1/[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	1/[[0.65,0.75],[0.20,0.30], [0.25,0.35]]	1/[[0.55,0.65], [0.30,0.40],[0.35,0.45]]
Obstacle$_9$	1/[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	1/[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	1/[[0.70,0.80],[0.15,0.25], [0.20,0.30]]	1/[[0.60,0.70], [0.25,0.35],[0.30,0.40]]
Obstacle$_{10}$	1/[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.70,0.80],[0.15,0.25],[0.20,0.30]]	1/[[0.70,0.80],[0.15,0.25],[0.20,0.30]]	1/[[0.50,0.50],[0.50,0.50], [0.50,0.50]]	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]
Obstacle$_{11}$	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.55,0.65],[0.30,0.40], [0.35,0.45]]	1/[[0.60,0.70], [0.25,0.35],[0.30,0.40]]
Obstacle$_{12}$	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.50,0.6],[0.35,0.45] ,[0.40,0.50]]	1/[[0.55,0.65], [0.30,0.40],[0.35,0.45]]
	Obstacle$_7$	**Obstacle$_8$**	**Obstacle$_9$**	**Obstacle$_{10}$**	**Obstacle$_{11}$**	**Obstacle$_{12}$**
Obstacle$_1$	[[0.70,0.80],[0.15,0.25],[0.20,0.30]]	[[0.75,0.85],[0.10,0.20],[0.15,0.25]]	[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.50,0.6],[0.35,0.45],[0.40, 0.50]]
Obstacle$_2$	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]
Obstacle$_3$	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	[[0.70,0.80],[0.15,0.25],[0.20,0.30]]	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]
Obstacle$_4$	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.70,0.80],[0.15,0.25],[0.20,0.30]]	[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]
Obstacle$_5$	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	[[0.70,0.80],[0.15,0.25],[0.20,0.30]]	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	[[0.50,0.6],[0.35,0.45],[0.40, 0.50]]
Obstacle$_6$	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	[[0.50,0.6],[0.35, 0.45],[0.40,0.50]]	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]
Obstacle$_7$	1	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]
Obstacle$_8$	1/[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	1	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.50,0.50],[0.50,0.50],[0.50,0.50]]

Obstacle$_9$	1/[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	1/[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	1	[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	[[0.90,0.95],[0.00,0.05],[0.05,0.15]]	[[0.50,0.6],[0.35,0.45],[0.40,0.50]]
Obstacle$_{10}$	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	1/[[0.65,0.75],[0.20,0.30],[0.25,0.35]]	1	[[0.80,0.90],[0.05,0.10],[0.10,0.20]]	[[0.55,0.65],[0.30,0.40],[0.35,0.45]]
Obstacle$_{11}$	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]
Obstacle$_{12}$	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]	1/[[0.60,0.70],[0.25,0.35],[0.30,0.40]]	1/[[0.50,0.50],[0.50,0.50],[0.50,0.50]]	1/[[0.50,0.6],[0.35,0.45],[0.40,0.50]]	1/[[0.55,0.65],[0.30,0.40],[0.35,0.45]]

Table 2. The normalization pairwise comparison matrix.

Obstacles	Obstacle$_1$	Obstacle$_2$	Obstacle$_3$	Obtsacle$_4$	Obstacle$_5$	Obstacle$_6$	Obstacle$_7$	Obstacle$_8$	Obstacle$_9$	Obstacle$_{10}$	Obstacle$_{11}$	Obstacle$_{12}$
Obstacle$_1$	0.059098	0.032876	0.041935	0.045732	0.038806	0.054389	0.069377	0.07347	0.072243	0.084332	0.061671	0.07364
Obstacle$_2$	0.111906	0.061835	0.051416	0.059263	0.046523	0.055581	0.059574	0.04437	0.052367	0.066408	0.069836	0.072065
Obstacle$_3$	0.090167	0.075179	0.062512	0.035452	0.037621	0.054508	0.06162	0.060788	0.069529	0.076815	0.052116	0.08447
Obstacle$_4$	0.087839	0.069575	0.118371	0.066681	0.03015	0.050095	0.064206	0.064781	0.071546	0.075329	0.066709	0.066552
Obstacle$_5$	0.084032	0.071443	0.090775	0.121356	0.05368	0.058861	0.054259	0.059456	0.064248	0.064756	0.072963	0.08634
Obstacle$_6$	0.077995	0.08021	0.083227	0.095858	0.065265	0.071564	0.043091	0.067443	0.068209	0.052697	0.08078	0.090721
Obstacle$_7$	0.073466	0.094505	0.087726	0.089808	0.091707	0.143128	0.086182	0.078869	0.072389	0.063435	0.082518	0.088014
Obstacle$_8$	0.071608	0.12367	0.091259	0.091344	0.080706	0.095455	0.09697	0.088741	0.07822	0.069382	0.092637	0.080729
Obstacle$_9$	0.071998	0.103924	0.079367	0.082369	0.073721	0.093007	0.104781	0.099849	0.088011	0.072355	0.087121	0.077381
Obstacle$_{10}$	0.069749	0.092647	0.080661	0.087808	0.08481	0.135511	0.13466	0.126887	0.120564	0.099116	0.085731	0.075609
Obstacle$_{11}$	0.104216	0.092647	0.125025	0.105161	0.322096	0.093007	0.109207	0.099849	0.106207	0.120506	0.104233	0.08634
Obstacle$_{12}$	0.097926	0.101489	0.087726	0.119167	0.074916	0.094894	0.116073	0.135497	0.136467	0.15487	0.143685	0.118139

According to Figure 4, the cost and funding risks are the highest obstacle followed by scalability, Lack of Socio-technological Planning, and security and privacy. Otherwise, Regional Disparity is the lowest obstacle among12 obstacles.

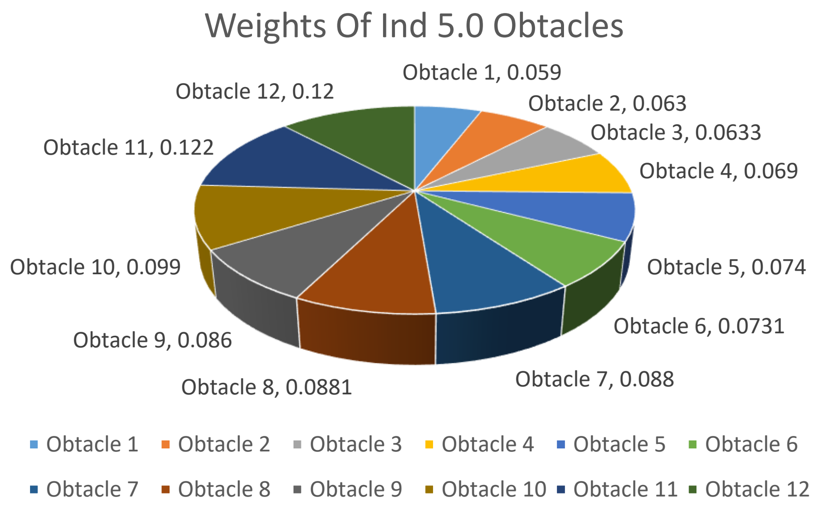

Figure 4. Final ind 5.0 obstacles' weights based on appraisal decision framework.

4. Conclusions

The current study is an ongoing investigation into and analysis and appraising of obstacles and impediments to the widespread utilization of ICT in EEs. Ind 5.0 is one of the technologies of ICT. Also, it considered the focus of current studies due to its high ability to communicate between things and people using a variety of technologies that fall under the scope of Ind 5.0. Hence, this study deployed robust approaches which contribute to generate ADF for ranking determined obstacles of implementing and employing Ind 5.0 n businesses especially, EEs. Herein, we utilize AHP as one of MCDM methods as ranker for determined obstacles through computing Ind 5.0 obstacles' weights. AHP works with aids of IVNSs as one of approaches has ability to treat of inconsistent information. Due to IVNSs that fall under neutrosophic theory. Through findings of ADF cost and funding obstacle are the highest while Regional Disparity is the lowest one.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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An Integrated Neutrosophic Regional Management Ranking Method for Agricultural Water Management

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Abstract: The development of global warming adaptation principles is a crucial issue to resilience to climate change. Due to the consequences of global warming on land and water management. The persistence to determine the adaptation procedures is a demanded challenging process corresponding to the current climate change issues. Climate change has a direct impact on the water cycle that results in unpredictable cases of pollution and rare of water. In order to provide viable options for enormous-scale water supply structures, the study presents a new planning approach that incorporates multi-criteria decision-making (MCDM). The agriculture water management (AWM) relies on MCDM with various criteria and alternatives. The study ranks regional management alternatives with respect to groundwater resources. In addition, study adopts neutrosophic theory to handle unpredictable cases. The proposed decision-making approach integrates neutrosophic sets with the MARCOS method for achieving optimal solutions. A detailed numerical case study that illustrates eight criteria and ten alternatives to examine the applicability for the proposed method.

Keywords: Agriculture Water Management; Global Warming; Climate Change Neutrosophic sets; MCDM; MARCOS Method.

1. Introduction

Climate change pose to challenges and risks on the financial systems and industries [1]. The manufacturing, agriculture, water supplies, and ecology have a direct relation with any catastrophes of climate impact related financial risks. The population inflation and climate change are susceptible to water shortages and precarious circumstances. Consequently, a potential techniques are used to identify and to assess for adapting and managing climate change to lessen the potential devastating impacts[1-3].

Global climate change affects the farming industry and water supplies. The acquired tremendous relevance given the significance of agricultural policy for the availability of food and the reality that over 92% of world water (global groundwater) is utilized by farming looked at how weather shifts affect farmers' need for water. In addition, the impacts of global warming on agricultural output were investigated and analyzed in [4, 5].

In agriculture, plans and decisions are utilized to accommodate climate change and global warming. In addition, Governments, farming industry executives, freshwater resources supervisors, and consumers adjust to novel circumstances in light of agriculture's central position in certain emerging nations and scarcity of water supplies, particularly in arid and semi-arid areas[6, 7]. Recently, adaptive techniques have been developed to assist in increasing awareness of dangers and decreasing exposure of global warming. Moreover, emerging technologies and expert systems for evaluation the management of agriculture water during the current complex nature issues [8–10].

The adjustment researches utilize from MCDM methodologies to choose and to assess recommended solutions with respect to several objectives[11, 12]. The adaptability solutions are useful and efficient for subsequent planning due to diverse aims of the participants and standards, and the necessity to include the views of experts in critical vital aspects e.g., water supply, farming, and ecology. The MCDM methodologies use an assessment tool to determine the objectives of long-term aims and to provide light on the relative merits of various adaption options[13, 14].

Regional management is the procedures for supervising an organization's business operations in a designated geographic area. In order to priorities sustainability in regional management, a new fuzzy multi-criteria assessment technique is developed, with foundation in a novel neutrosophic fuzzy method for capturing ambiguity in human judgements. To deal with such vague and unreliable data, the study illustrates the generalizations of fuzzy sets (FSs) and intuitionistic fuzzy sets (IFSs) to achieve appropriate solutions. However, many forms of fuzzy (MCDM) are classified to be inadequate for handling the ambiguity and incoherence of real-world data[15–17].

Hence, Smarandache proposed a new area of mathematics of neutrosophy focuses on "the source, the environment, and the extent of neutralities, in addition to relationships with various ideational spectra." In neutrosophy principal ideas are partially true, false, and indeterminate. The neutrosophic set (NS) is associated with philosophy alongside a very complex representation in practical contexts such as science and engineering. A single-valued neutrosophic set (SVNS) are illustrated with attributes as a means of addressing issue [18].

In selecting long-term partners in the medical field in Bosnia and Herzegovina, Stevi, et al. recently presented the MARCOS method. In the steel industry, this process is used to choose suppliers. Milling, crushing, and rotating are all ways in which it has been utilized in MCDM operations [19].

The remainder of the paper is structured as follows: Section 2 shows the proposed method that will be used to rank regional management alternatives with respect to groundwater resources. Section 3 introduces a numerical application with optimal ranking of alternatives to aid decision makers. Section 4 concludes the summary and the future work of the current study.

2. Neutrosophic MARCOS Method

The study ranks regional management alternatives with respect to groundwater resources. In addition, study adopts neutrosophic theory to handle unpredictable cases. The proposed decision-making approach integrates neutrosophic sets with the MARCOS method for achieving optimal solutions. The study presents a novel MARCOS method under neutrosophic sets to rank relational management alternatives. The study introduces the single valued neutrosophic sets to evaluate the criteria and alternatives [20, 21]. The steps of the neutrosophic MARCOS method are mentioned as follows and modeled in Figure 1:

Step 1: Identify study objective. Decompose problem hierarchy to represent the goal, criteria, and the possibility of alternatives.

Step 2: Build the decision matrix by aggregating decision maker's perspectives.

The formulation to build matrix between criteria and alternatives mentioned as follows:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \quad (1)$$

Step 3: Determine the ideal and anti-ideal solutions. The decision matrix is extended by inserting ideal and anti-ideal solutions into a decision matrix as follows:

$$A = \begin{matrix} \beta \\ \vdots \\ \gamma \end{matrix} \begin{bmatrix} a_{\beta 1} & \cdots & a_{\beta n} \\ \vdots & \ddots & \vdots \\ a_{\gamma 1} & \cdots & a_{\gamma n} \end{bmatrix} \tag{2}$$

$$\begin{pmatrix} \beta = \min a_{ij} \ , \gamma = \max a_{ij} \, , for\ benefit\ criteria \\ \beta = \max a_{ij} \ , \gamma = \min a_{ij} \, , for\ cost\ criteria \end{pmatrix} \tag{3}$$

Step 4: Compute the normalization extended decision matrix and defined as:

$$N_{ij} = \begin{bmatrix} \left(\frac{a_\gamma}{a_{ij}}\right) for\ cost\ criteria \\ \left(\frac{a_{ij}}{a_\gamma}\right) for\ benefit\ criteria \end{bmatrix} \tag{4}$$

Step 5: Compute the weighted normalized decision matrix presented as:

$$E_{ij} = (N_{ij} \cdot w_j) \tag{5}$$

Step 6: Compute the values of utility degree as follows:

$$U_i^- = \frac{D_i}{D_\beta} \tag{6}$$

$$U_i^+ = \frac{D_i}{D_\gamma} \tag{7}$$

$$D_i = \sum_{i=1}^{m} E_{ij} \tag{8}$$

Step 7: Compute the function of utility degree which defined as:

$$F(U_i) = \frac{U_i^+ + U_i^-}{1 + \frac{1 - FU_i^+}{FU_i^+} + \frac{1 - FU_i^-}{FU_i^-}} \tag{9}$$

$$FU_i^- = \frac{U_i^+}{U_i^+ + U_i^-} \tag{10}$$

$$FU_i^+ = \frac{U_i^-}{U_i^+ + U_i^-} \tag{11}$$

Step 8: Rank alternatives and choose the optimal decision alternative.

Figure 1. The neutrosophic MARCOS method.

3. Application

This section illustrates an application of single valued neutrosophic MARCOS method in real world problems. The study aims to rank and to recommend the best regional management in AWM. The study invited two experts to evaluate the criteria and alternatives. The experts' perspectives are gathered to detect the main criteria and organized as follow: acceptance, resource consumption, social, economy, ecological, feasibility, effectiveness, and flexibility with ten regions. The economy is the cost criteria, and all other criteria are benefit criteria.

Initial experts are evaluated the criteria and alternatives to build the decision matrix as shown in Table 1. Then compute the weights of criteria to give rank of importance criteria. The ecological criterion is the highest importance followed by feasibility and effectiveness. The flexibility criterion is the lowest importance criterion. Figure 2 shows the importance of all criteria.

Table 1. The initial decision matrix.

AWMAs	$AWMC_1$	$AWMC_2$	$AWMC_3$	$AWMC_4$	$AWMC_5$	$AWMC_6$	$AWMC_7$	$AWMC_8$
$AWMA_1$	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(1.0,0.1,0.1)
$AWMA_2$	(0.9,0.1,0.2)	(0.4,0.5,0.6)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.9,0.1,0.2)
$AWMA_3$	(1.0,0.1,0.1)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.7,0.3,0.4)	(0.8,0.2,0.3)
$AWMA_4$	(0.8,0.2,0.3)	(1.0,0.1,0.1)	(0.6,0.4,0.5)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(1.0,0.1,0.1)
$AWMA_5$	(1.0,0.1,0.1)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.4,0.5,0.6)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(1.0,0.1,0.1)	(0.7,0.3,0.4)
$AWMA_6$	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.3,0.6,0.7)	(0.6,0.4,0.5)	(0.9,0.1,0.2)	(0.8,0.2,0.3)
$AWMA_7$	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.6,0.4,0.5)
$AWMA_8$	(1.0,0.1,0.1)	(0.2,0.7,0.8)	(0.8,0.2,0.3)	(0.3,0.6,0.7)	(1.0,0.1,0.1)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(1.0,0.1,0.1)
$AWMA_9$	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.2,0.7,0.8)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.7,0.3,0.4)
$AWMA_{10}$	(1.0,0.1,0.1)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(1.0,0.1,0.1)

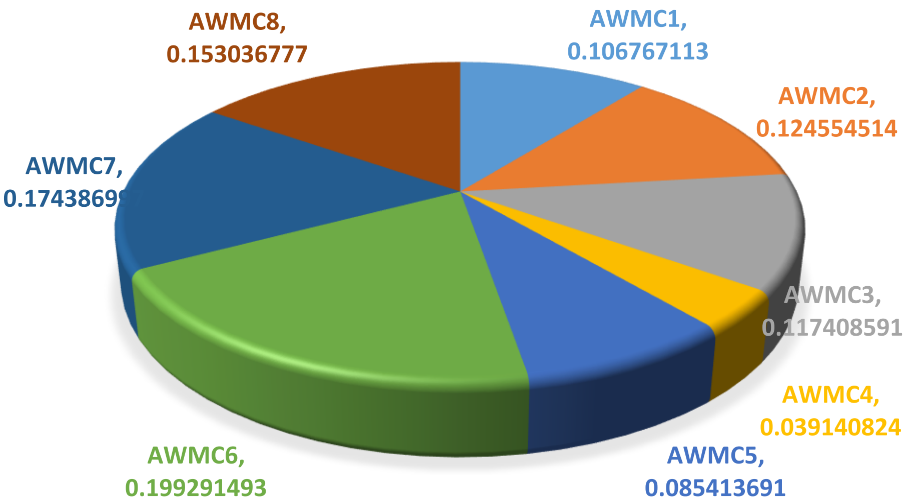

Figure 2. The importance of eight criteria.

Then extended the decision matrix by adding the ideal and anti-ideal solution. Then normalize the decision matrix by using Eq. (4) by using cost and benefit criteria. The normalization of extended decision matrix is shown in Table 2.

Table 2. The normalization of extended decision matrix.

AWMAs	$AWMC_1$	$AWMC_2$	$AWMC_3$	$AWMC_4$	$AWMC_5$	$AWMC_6$	$AWMC_7$	$AWMC_8$
$AWMA_1$	0.61534	0.589307	0.760823	0.535749	3.71472	0.61534	0.535717	0.571429
$AWMA_2$	0.576918	0.464267	0.586954	0.714347	4.000171	1	0.714347	0.92864
$AWMA_3$	0.673013	0.48216	0.760823	0.535749	1.928723	0.61534	0.48216	0.821461

AWMA₄	0.519211	1	0.45652	1	1.928723	0.76924	0.48216	0.571429
AWMA₅	0.673013	0.607168	1	0.464267	2.500054	0.884585	0.571429	0.714347
AWMA₆	0.519211	0.48216	0.869605	0.92864	1	0.653825	0.535749	0.48216
AWMA₇	1	0.571429	0.521756	1	2.142961	0.76924	1	0.607168
AWMA₈	0.673013	0.249973	0.64563	0.249989	2.285815	0.653825	0.48216	1
AWMA₉	0.519211	0.428603	0.304303	0.92864	1.928723	0.884585	0.589307	0.714347
AWMA₁₀	0.61534	0.571429	0.586954	0.571429	3.71472	0.61534	0.535749	1

Then multiply the weights of criteria by the normalized extended decision matrix by using Eq. (5) as shown in Table 3.

Table 3. The weighted normalization of extended decision matrix.

AWMAs	$AWMC_1$	$AWMC_2$	$AWMC_3$	$AWMC_4$	$AWMC_5$	$AWMC_6$	$AWMC_7$	$AWMC_8$
$AWMA_1$	0.065698	0.073401	0.089327	0.02097	0.317288	0.122632	0.093422	0.08745
$AWMA_2$	0.061596	0.057826	0.068913	0.02796	0.341669	0.199291	0.124573	0.142116
$AWMA_3$	0.071856	0.060055	0.089327	0.02097	0.164739	0.122632	0.084082	0.125714
$AWMA_4$	0.055435	0.124555	0.053599	0.039141	0.164739	0.153303	0.084082	0.08745
$AWMA_5$	0.071856	0.075626	0.117409	0.018172	0.213539	0.17629	0.09965	0.109321
$AWMA_6$	0.055435	0.060055	0.102099	0.036348	0.085414	0.130302	0.093428	0.073788
$AWMA_7$	0.106767	0.071174	0.061259	0.039141	0.183038	0.153303	0.174387	0.092919
$AWMA_8$	0.071856	0.031135	0.075802	0.009785	0.19524	0.130302	0.084082	0.153037
$AWMA_9$	0.055435	0.053384	0.035728	0.036348	0.164739	0.17629	0.102767	0.109321
$AWMA_{10}$	0.065698	0.071174	0.068913	0.022366	0.317288	0.122632	0.093428	0.153037

Then compute the utility of degrees using Eqs. (6), (7), and (8). Then compute the function of utility degree using Eqs. (9), (10), and (11). Then order the alternatives as shown in Figure 3. The alternative ten is the highest score followed by alternative eight then alternative two. The lowest score of alternatives is one.

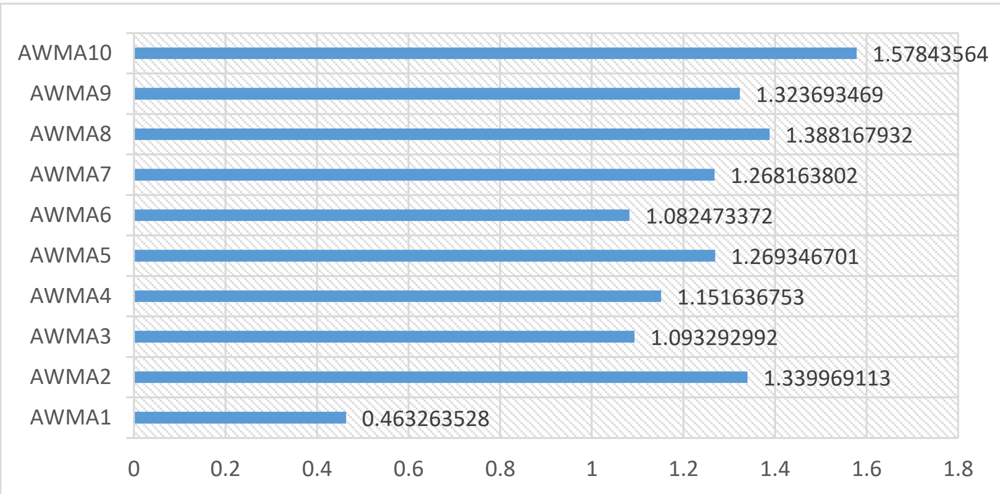

Figure 3. The order of ten options in AWM.

4. Conclusions

This research creates and employs a theoretical structure of planning and MCDM for efficient and environmentally friendly use of water resources in agriculture. In addition, a multi-factor analytical approach was created to predict water for agriculture purposes. Regional management alternatives for handling agriculture water demand as well as supply were defined based on the findings of an investigation of water usage in agriculture and the identification of both internal and outside factors affecting the administration of water resources for farming.

The usage of a procedure takes into consideration ambiguity and uncertainty during decision-making. Consequently, eight water supply standards were established: social, economic, ecological, and water use administration. The proposed approach was applied to ten alternatives with respect to the impact of criterion strengths in MCDM. The given approach integrated the neutrosophic sets with the MARCOS method to aid decision makers to achieve the optimal solutions. Hence, the results show the alternative 10 as the best and alternative 1 is the worst.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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