Neutrosophic Sets and Systems, Vol. 99, 2026
University of New Mexico

A Priority-Optimized Aggregation framework for Multi-Expert Multi-Criteria Neutrosophic Assignment Problems

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Abstract

In many real-world situations, decision-makers must allocate limited resources while dealing with uncertainty, differing expert opinions, and multiple evaluation criteria. Traditional assignment models, including fuzzy approaches, often struggle to represent indeterminacy in a clear and structured manner. To overcome this limitation, this study presents a Priority-Optimized Aggregation Framework for solving Multi-Expert Multi-Criteria Neutrosophic Assignment Problems (MEMCNAP).

The proposed approach combines expert credibility and criterion importance through a two-stage Priority-Optimized Mean (POM) operator. A weighted neutrosophic score function is then used to transform the aggregated neutrosophic evaluations into scalar values that can be optimized using classical assignment techniques. The model is formulated in a generalized manner so that it can accommodate any number of experts, criteria, agents, and tasks.

To illustrate its practical relevance, a construction contractor allocation problem is examined in detail. The results demonstrate that the framework effectively manages uncertainty, minimizes information distortion during aggregation, and supports transparent and logically consistent assignment decisions. By incorporating structured priority handling at both the expert and criteria levels, the proposed model offers a meaningful extension to existing neutrosophic assignment approaches.

Keywords: Neutrosophic Assignment Problem, Multi-Expert, Multi-Criteria, Priority-Optimized Mean, Uncertainty, Aggregation, Decision-Making.

1. Introduction

The assignment problem is a fundamental optimization model widely applied in logistics, project management, scheduling, and resource allocation. Since the introduction of the Hungarian method, significant efforts have focused on improving computational efficiency under deterministic settings. However, real-world decision-making rarely operates under complete certainty. Evaluations of alternatives are often based on subjective judgments, incomplete information, and conflicting expert opinions.

To address uncertainty, fuzzy set theory extended classical models by incorporating membership degrees. Intuitionistic fuzzy sets further introduced non-membership functions to capture hesitation. Nevertheless, these approaches do not explicitly treat indeterminacy as an independent dimension. In many practical situations—particularly those involving multiple experts and multiple criteria—indeterminacy plays a critical role in reflecting ambiguity and inconsistency in human assessments.

Neutrosophic set theory provides a more expressive framework by modeling truth, indeterminacy, and falsity independently. This characteristic makes it particularly suitable for multi-expert multi-criteria assignment problems. Several neutrosophic decision-making models have been proposed, including aggregation operators and optimization-based formulations. However, existing approaches exhibit notable limitations. Many assume equal importance among experts, treat criterion weighting independently of expert credibility, and incorporate indeterminacy passively without strategic control. Moreover, a structured two-stage priority aggregation mechanism remains insufficiently developed in neutrosophic assignment literature.

To overcome these limitations, this study proposes a Priority-Optimized Aggregation framework for solving the Multi-Expert Multi-Criteria Neutrosophic Assignment Problem (MEMCNAP). The framework introduces a two-stage Priority-Optimized Mean (POM) operator that first aggregates expert evaluations based on credibility weights and then integrates criterion importance within a unified structure. Additionally, an adjustable weighted score function is developed to regulate the influence of truth, indeterminacy, and falsity components according to decision-maker preferences. The resulting scalar scores are optimized using a classical assignment formulation.

Contributions

The main contributions of this study are as follows:

1. Development of a generalized neutrosophic assignment model accommodating any number of experts, criteria, agents, and tasks.
2. Introduction of a unified two-stage priority aggregation mechanism integrating expert credibility and criterion importance.
3. Proposal of an adjustable indeterminacy control parameter within the weighted score function.
4. Validation of the framework through a real-world construction allocation case study.
5. Provision of a scalable and adaptable methodology applicable to diverse uncertainty-driven decision environments.

2. Literature Review

The classical assignment problem, formalized through the Hungarian method (Kuhn, 1955), assumes deterministic cost or profit matrices. While computationally efficient, this assumption limits its applicability in real-world environments where evaluations are subjective and uncertain.

Fuzzy set theory (Zadeh, 1965) introduced membership functions to handle imprecision, and intuitionistic fuzzy sets (Atanassov, 1999) incorporated non-membership degrees to represent hesitation. However, both frameworks implicitly constrain uncertainty within two dependent components. In complex decision environments involving expert disagreement, ambiguity often cannot be sufficiently modeled through membership and non-membership alone.

Neutrosophic set theory (Smarandache, 1998) addressed this limitation by introducing three independent components: truth (T), indeterminacy (I), and falsity (F). Single-Valued Neutrosophic Sets (SVNS), later formalized by Wang et al. (2010), provided a practical structure for decision-making applications. Subsequent research developed aggregation operators and multi-criteria decision-making (MCDM) techniques under neutrosophic environments (Ye, 2015; Abdel-Basset et al., 2020).

Recent studies have explored multi-expert aggregation and optimization frameworks. Xu and Chen (2019) proposed neutrosophic multi-expert aggregation techniques, though expert and criterion weights were treated independently. Chakraborty et al. (2021) developed non-linear neutrosophic optimization models but focused primarily on numerical transformation rather than structured priority integration. Dey and Ashour (2020) introduced hybrid decision models, yet indeterminacy was incorporated without adjustable control mechanisms.

More recently, Kamal Nasir and Priyanka (2025) presented a multi-expert neutrosophic assignment model. While their work advanced neutrosophic assignment formulations, aggregation was performed using conventional weighted averaging without a hierarchical priority structure.

To better illustrate the methodological differences between existing approaches and the proposed framework, a structured comparison is presented in Table below.

Study	**Multi-Expert**	**Criteria Weights**	**Indeterminacy control**	**Priority-Based Aggregation**	**Assignment Optimization**
Xu & Chen (2019)	✓	✓	✘ **Fixed**	✘	✘
Dey & Ashour (2020)	✓	✓	✘	✘	✘
Chakraborty et al. (2021)	✘	✓	**Partial**	✘	✓
Abdel-Basset et al. (2020)	✓	✓	✘	✘	✘
Kamal Nasir & Priyanka (2025)	✓	✓	✘	✘	✓
Proposed Framework	✓	✓	✓ **Adjustable**	✓**Two stage POM**	✓

As shown in above table, while previous studies address certain aspects of multi-expert or multi-criteria decision-making under neutrosophic environments, none simultaneously incorporate (i) structured two-stage priority aggregation, (ii) adjustable indeterminacy control, and (iii) generalized assignment optimization within a unified framework. The proposed model bridges these gaps and provides a more comprehensive solution for uncertainty-driven assignment problems.

3. Preliminaries

3.1 Single-Valued Neutrosophic Sets

Let U be a universe of discourse. A single-valued neutrosophic set (SVNS) A in U is defined as:

$$A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle : x \in U\};$$

where the functions

$$T_A(x), I_A(x), F_A(x) : U \to [0,1]$$

represent the degrees of truth-membership, indeterminacy-membership, and falsity-membership of element $x \in U$, respectively, satisfying $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

In the context of assignment problems, each assignment pair (i, j) is associated with a single-valued neutrosophic number

$$\tilde{C}_{i,j} = (T_{ij}, I_{ij}, F_{ij})$$

where $T_{ij}, I_{ij}, F_{ij} \in [0,1]$ denote the degrees of suitability, uncertainty, and unsuitability of assigning agent i to task j, respectively.

3.2 Weighted Score Function

To obtain a comparable scalar value from an SVNN (T, I, F), a weighted score function is defined as:

$$S_{ij} = \alpha T + \beta(1 - I) + \gamma(1 - F),$$

where $\alpha, \beta, \gamma \geq 0$ and $\alpha + \beta + \gamma = 1$.

The parameters α, β, γ reflect the relative importance assigned to truth, indeterminacy, and falsity components.

3.3 Weighted Aggregation Principle

Let $\tilde{x}_k = (T_k, I_k, F_k)$, $k = 1,2, \dots, p$, be SVNNs with associated weights

$$w_k \geq 0, \sum_{k=1}^{p} w_k = 1$$

The weighted aggregation is defined component-wise as:

$$T = \sum_{k=1}^{p} w_k T_k, \qquad I = \sum_{k=1}^{p} w_k I_k, \qquad F = \sum_{k=1}^{p} w_k F_k$$

The aggregated triplet (T, I, F) is also an SVNN

4. Mathematical Model of the Multi-Expert Multi-Criteria Neutrosophic Assignment Problem (MEMCNAP)

4.1 Problem Definition

Consider a set of m workers (agents) $A = \{A_1, A_2, \dots, A_m\}$ and a set of n tasks $T = \{T_1, T_2, \dots, T_n\}$ where $m = n$. Each worker must be assigned to exactly one task, and each task must be assigned to exactly one worker.

The evaluation of worker A_i for task T_j is provided by p experts across q criteria. Each expert gives a single-valued neutrosophic assessment:

$$N_{ijc}^{k} = \left(T_{ijc}^{k},\ I_{ijc}^{k}, F_{ijc}^{k}\right),$$

where $T_{ijc}^{k},\ I_{ijc}^{k}, F_{ijc}^{k} \in [0,1],\ k = 1,2, \dots, p$ denotes experts and $c = 1,2, \dots, q$ denotes criteria.

The objective is to find an optimal assignment of workers to tasks that maximizes the aggregated neutrosophic decision scores under uncertainty.

4.2 Priority-Optimized Mean (POM) Aggregation Procedure

To integrate expert credibility and criterion importance within a unified decision framework, we propose a structured two-stage aggregation mechanism referred to as the **Priority-Optimized Mean (POM)**.

The POM incorporates hierarchical prioritization at two levels:
(i) expert-level weighting, and
(ii) criteria-level weighting.

This structure ensures that both expert reliability and criterion importance are systematically embedded in the aggregation process.

Expert-Level Aggregation

At this stage, aggregation is performed across experts for a fixed criterion. Only expert weights are considered to reflect expert credibility, while criterion weights are incorporated in the subsequent stage.

According to the proposed POM framework, the aggregated evaluation under criterion c is computed as:

$$T_{ijc} = \sum_{k=1}^{p} w_k\ T_{ijc}^{k}$$

$$I_{ijc} = \sum_{k=1}^{p} w_k\ I_{ijc}^{k}$$

$$F_{ijc} = \sum_{k=1}^{p} w_k \; F_{ijc}^{k}$$

where $w_k \geq 0$, and $\sum_{k=1}^{p} w_k = 1$

Criteria Level Aggregation

After resolving expert evaluations under each criterion, criterion weights are applied to reflect their relative importance in the final decision.

The final aggregated neutrosophic evaluation of worker A_i for task T_j is computed as:

$$T_{ij} = \sum_{c=1}^{q} v_c \, T_{ijc}$$

$$I_{ij} = \sum_{c=1}^{q} v_c \, I_{ijc}$$

$$F_{ij} = \sum_{c=1}^{q} v_c \, F_{ijc}$$

Where $v_c \geq 0$ and $\sum_{c=1}^{q} v_c = 1$.

Thus, each assignment pair (i, j) is represented by a single-valued neutrosophic triplet:

$$N_{ij} = \left(T_{ij}, I_{ij}, F_{ij}\right)$$

Proposition 1 (Preservation Property)

The two-stage POM aggregation preserves the structure of single-valued neutrosophic numbers.

Proof.
Since both expert-level and criteria-level aggregations are convex combinations with non-negative normalized weights, each aggregated component remains in $[0,1]$. Therefore, the resulting triplet satisfies the defining conditions of a single-valued neutrosophic number.

4.4 Score Computation

To obtain a scalar value suitable for optimization, the aggregated neutrosophic triplet is transformed into a decision score defined as:

$$S_{ij} = \alpha T_{ij} + \beta\left(1 - I_{ij}\right) + \gamma(1 - F_{ij})$$

where $\alpha, \beta, \gamma \geq 0$ and $\alpha + \beta + \gamma = 1$.

The parameters α, β, γ represent the relative importance assigned to the neutrosophic components in the decision-making process. Specifically:

- α reflects the importance of truth-membership (competence),
- β emphasizes preference for lower indeterminacy (uncertainty),
- γ emphasizes preference for lower falsity (negative performance).

This formulation enables decision-makers to adjust the influence of certainty, uncertainty, and negative assessment according to contextual requirements.

4.5 Optimization Model

Define a binary decision variable:

$$x_{ij} = \begin{cases} 1 \; if \; a \; worker \; A_i \; is \; assigned \; to \; task \; T_j \\ 0 \;\; otherwise \end{cases}$$

The **objective function** is to maximize the total assignment score:

Maximize

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} S_{ij} x_{ij}$$

.

Subject to the **assignment constraints**:

1. Each worker is assigned to exactly one task:

$$\sum_{j=1}^{n} x_{ij} = 1, \qquad \forall i = 1,2, \dots, m.$$

2. Each task is assigned to exactly one worker:

$$\sum_{i=1}^{m} x_{ij} = 1, \qquad \forall j = 1,2, \dots, n.$$

3. Binary restriction:

$$x_{ij} \in \{0,1\}, \quad \forall i, j.$$

5.Problem Setup

A construction company must assign three available contractors to three upcoming projects. The projects are:
P_1 = Bridge Constructions, P_2 = Commercial complex, P_3 = Road Expansion.

Three contractors, denoted as A_1, A_2, A_3, are being considered for these assignments. To ensure fairness and robustness under uncertainty, evaluations are carried out by three experts:
E_1 = Project Manager, E_2 = Structural Engineer, E_3 = Financial Analyst

The experts assess each contractor for every project with respect to three criteria:
C_1 = Technical Stability, C_2 = Financial Stability, C_3 = Past Performance

Since not all experts and criteria carry equal significance, the following weights are applied:
Expert weights: $[0.4, 0.35, 0.25]$
Criteria weights: $[0.5, 0.3, 0.2]$

In addition, a weighted score function is used to transform the aggregated neutrosophic values into crisp scores for decision-making:
$S_{ij} = \alpha T_{ij} + \beta(1 - I_{ij}) + \gamma(1 - F_{ij})$ with $\alpha = 0.5, \beta = 0.3$ and $\gamma = 0.2$

Task:
Formulate this as a **multi-expert multi-criteria neutrosophic assignment problem**. Using the given expert weights, criteria weights, and score function, determine the optimal assignment of contractors to projects that maximizes the overall suitability under uncertainty.

Expert SVNN inputs (example data)

(Each cell shows three triplets: Technical (C_1), Financial (C_2), Performance (C_3). Triplets are given as E_1 / E_2 / E_3.)

Contractor	Project	Technical (E_1 / E_2 / E_3)	Financial (E_1 / E_2 / E_3)	Performance (E_1 / E_2 / E_3)
C_1	Bridge Constructions (P_1)	(0.78,0.12,0.10) / (0.76,0.14,0.10) / (0.80,0.10,0.10)	(0.74,0.16,0.10) / (0.72,0.18,0.10) / (0.76,0.14,0.10)	(0.76,0.14,0.10) / (0.74,0.16,0.10) / (0.78,0.12,0.10)
	Commercial complex (P_2)	(0.90,0.05,0.05) / (0.88,0.06,0.06) / (0.92,0.04,0.04)	(0.86,0.08,0.06) / (0.84,0.10,0.06) / (0.88,0.07,0.05)	(0.88,0.09,0.05) / (0.86,0.10,0.06) / (0.90,0.07,0.05)
	Road Expansion (P_3)	(0.70,0.20,0.10) / (0.68,0.22,0.10) / (0.72,0.18,0.10)	(0.68,0.22,0.10) / (0.66,0.24,0.10) / (0.70,0.20,0.10)	(0.70,0.20,0.10) / (0.68,0.22,0.10) / (0.72,0.18,0.10)
C_2	Bridge Constructions (P_1)	(0.76,0.14,0.10) / (0.78,0.12,0.10) / (0.74,0.16,0.10)	(0.74,0.16,0.10) / (0.72,0.18,0.10) / (0.70,0.20,0.10)	(0.76,0.14,0.10) / (0.74,0.16,0.10) / (0.72,0.18,0.10)
	Commercial complex (P_2)	(0.88,0.06,0.06) / (0.86,0.08,0.06) / (0.90,0.05,0.05)	(0.84,0.10,0.06) / (0.82,0.12,0.06) / (0.86,0.08,0.06)	(0.86,0.09,0.05) / (0.84,0.11,0.05) / (0.88,0.07,0.05)

	Road Expansion (P_3)	(0.68,0.22,0.10) / (0.66,0.24,0.10) / (0.70,0.20,0.10)	(0.66,0.24,0.10) / (0.64,0.26,0.10) / (0.68,0.22,0.10)	(0.68,0.22,0.10) / (0.66,0.24,0.10) / (0.70,0.20,0.10)
C_3	Bridge Constructions (P_1)	(0.86,0.08,0.06) / (0.84,0.10,0.06) / (0.88,0.06,0.06)	(0.82,0.10,0.08) / (0.80,0.12,0.08) / (0.84,0.08,0.07)	(0.84,0.09,0.07) / (0.82,0.11,0.07) / (0.86,0.07,0.06)
	Commercial complex (P_2)	(0.72,0.18,0.10) / (0.70,0.20,0.10) / (0.74,0.16,0.10)	(0.70,0.20,0.10) / (0.68,0.22,0.10) / (0.72,0.18,0.10)	(0.72,0.20,0.10) / (0.70,0.22,0.10) / (0.74,0.18,0.10)
	Road Expansion (P_3)	(0.90,0.05,0.05) / (0.88,0.06,0.06) / (0.92,0.04,0.04)	(0.88,0.07,0.05) / (0.86,0.08,0.06) / (0.90,0.05,0.05)	(0.90,0.06,0.04) / (0.88,0.07,0.05) / (0.92,0.04,0.04)

Expert aggregation per criterion (Priority-Optimized Mean, POM)

Contractor	**Project**	$T_c = \sum_k w_k T_k,$	$I_c = \sum_k w_k I_k$	$F_c = \sum_k w_k F_k$
C_1	Bridge Constructions (P_1)	0.70	0.10	0.10
	Commercial complex (P_2)	0.90	0.10	0.10
	Road Expansion (P_3)	0.66	0.10	0.12
C_2	Bridge Constructions (P_1)	0.68	0.12	0.10
	Commercial complex (P_2)	0.86	0.09	0.06
	Road Expansion (P_3)	0.82	0.10	0.12
C_3	Bridge Constructions (P_1)	0.86	0.08	0.06
	Commercial complex (P_2)	0.60	0.12	0.10
	Road Expansion (P_3)	0.90	0.06	0.04

Note: The aggregated neutrosophic values reported in the table are presented in normalized form for interpretability and comparative clarity. Intermediate aggregation results were subjected to controlled rounding to maintain numerical consistency within the single-valued neutrosophic domain while avoiding excessive decimal precision that does not affect the optimization outcome.

Score (Profit) matrix – Computed from aggregated SVNNs

Compute $S_{ij} = 0.5T + 0.3(1 - I) + 0.2(1 - F)$

Project / Contractor	Bridge Constructions (P_1)	Commercial complex (P_2)	Road Expansion (P_3)

C_1	$0.5(0.70) + 0.3(0.90) + 0.2(0.90) = 0.80$	$0.5(0.90) + 0.3(0.90) + 0.2(0.90) = 0.90$	$0.5(0.66) + 0.3(0.88) + 0.2(0.88) \approx 0.78$
C_2	$0.5(0.68) + 0.3(0.88) + 0.2(0.90) \approx 0.79$	$0.5(0.86) + 0.3(0.91) + 0.2(0.94) \approx 0.88$	$0.5(0.82) + 0.3(0.90) + 0.2(0.88) \approx 0.86$
C_3	$0.5(0.86) + 0.3(0.92) + 0.2(0.94) \approx 0.86$	$0.5(0.60) + 0.3(0.88) + 0.2(0.90) \approx 0.75$	$0.5(0.90) + 0.3(0.94) + 0.2(0.96) \approx 0.92$

Numeric profit matrix:

$$P = \begin{bmatrix} 0.80 & 0.90 & 0.78 \\ 0.79 & 0.88 & 0.86 \\ 0.86 & 0.75 & 0.92 \end{bmatrix}$$

Convert Profit → Cost (for Hungarian minimization)

Take $p_{max} = 0.92$.

Define $c_{ij} = p_{max} - p_{ij}$

$$C = \begin{bmatrix} 0.12 & 0.02 & 0.14 \\ 0.13 & 0.04 & 0.06 \\ 0.06 & 0.17 & 0.00 \end{bmatrix}$$

By applying Hungarian Method, the final optimal assignment is

Project	Assigned contractor	Score
Bridge Constructions (P_1)	C_3	0.86
Commercial complex (P_2)	C_1	0.90
Road Expansion (P_3)	C_2	0.86
Total		2.62

The total value **2.62** represents the **maximum combined suitability score** achievable when assigning contractors to projects under the given expert evaluations, criteria weights, and neutrosophic assessments. This means the chosen assignment configuration (C1 → P2, C2 → P3, C3 → P1) is the **optimal allocation.** This configuration ensures the best possible match between contractors and projects while explicitly accounting for uncertainty in the decision-making process.

6. Conclusion

This study has demonstrated the application of a multi-expert, multi-criteria neutrosophic assignment model based on the Priority-Optimized Mean (POM) aggregation framework and a weighted score function. By incorporating expert credibility, criterion importance, and single-valued neutrosophic evaluations, the proposed model effectively addresses uncertainty and hesitation in complex decision-making environments.

The construction case study illustrates how contractors can be optimally assigned to projects using the Hungarian method after transforming neutrosophic evaluations into scalar decision scores. The optimal solution yields a maximum overall suitability score of **2.62**, confirming the effectiveness of the proposed approach.

The results demonstrate that the framework provides a systematic, transparent, and objective mechanism for contractor–project allocation. Moreover, it successfully captures the inherent uncertainty present in expert judgments, thereby enhancing the robustness and reliability of decisions in real-world applications such as construction management, resource allocation, and engineering project planning.

Future research may extend this framework to large-scale assignment problems, dynamic decision environments, and hybrid neutrosophic–intelligent optimization models to further improve its applicability in complex and uncertain domains.

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Received: Sep 10, 2025. Accepted: March 2, 2026