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A Framework of Type-2 Neutrosophic for Requirements Prioritization

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Abstract
Addressing the relative importance and urgency of different requirements to cope with the limited resources of projects such as budget and time is called Requirements Prioritization (RP), and it is a crucial step in the project management process, it involves several stakeholders deciding between multiple requirements based on several criteria, which is a multi-criteria decision making (MCDM). Different organizations use different requirements prioritization methods depending on the scope and level of the project. But the challenge arises when the number of requirements is large, and multiple stakeholders with conflicting goals are involved, which makes it hard to get consensus on the project direction. Another challenge in the prioritization process is that the judgement of the different stakeholders can be vague and imprecise, making it difficult to be represented in exact numbers. Therefore, this paper presents a MCDM framework based on the type-2 neutrosophic numbers (T2NNs) for the prioritization of requirements using T2NNs Decision making trial and evaluation laboratory (DEMATEL) and T2NNs technique for order of preference by similarity to ideal solution (TOPSIS). T2NNs are used to deal with the uncertainty and vagueness in stakeholders' preferences. The initial step of the proposed RP framework is to identify the relevant stakeholders, the goals, and the requirements. Second, we use the T2NN-based DEMATEL method to compute and rank the criteria importance. Then the T2NN-based TOPSIS is used to rank the requirements. Finally, the applicability of the proposed framework is demonstrated with the help of a numeric case study.

Keywords
Requirements Prioritization; Requirements Selection; MCDM; DEMETAL; TOPSIS; T2NN.

1.Introduction

The ultimate goal of any project, system or service is to meet the users and stakeholders needs and expectations, by effectively identifying the requirements and using them as a guide in the project development process. But in most projects, there are more requirements than we can address within the projects constrains. Thus, it becomes a major challenge for user experience designers, product managers and business analysts during the initial phase of project development to find out the list of requirements or features to develop and prioritize some requirements to be implemented immediately and some to be reserved for a later release while still producing a system that meets the essential needs of users and stakeholders. [1]. Requirements prioritization (RP) is the process of addressing the relative importance and urgency of different requirements to cope with the limited resources of projects such as budget and time, so prioritization of requirements is a way of maximizing the benefits from finite resources allotted to a particular iteration or release of a project. Requirements prioritization is an essential aspect of software release planning. The requirements that make the top of this list are given top priority, and the work for these requirements takes precedence over others. Prioritization is an essential and ongoing process during any product development process as it is the only way to deal with competing demands from stakeholders, clients, end users for limited resources.

However, Requirements prioritization is a daunting task. Different criteria of software requirements must be considered when prioritizing requirements, such as dependency, cost–value, risk, and other criteria [2]. And this only gets even more complicated when stakeholders with different levels of expertise, understanding, and opinions are involved, so the prioritized requirements would need to align with different goals such as business, user and technical goals which can often be conflicting. That's why making an informed decision on what to prioritize can be challenging.

Many useful methods have been successfully developed to execute the RP process, including MoSCoW analysis, Ranking Method, Value-Oriented Prioritization (VOP), Planning Game, Weighted Sum Method, Impact-Effort Matrix, Feasibility-Desirability-Viability Scorecard, RICE method, Kano model, NUF test, Analytical Hierarchy Process (AHP), Minimal spanning tree, Cumulative Voting (CV), Multi-factor matrix etc. In the systematic literature review on requirements prioritization techniques by [3], 40 techniques have been identified for requirements prioritization from 2009 to 2017. The choice of the appropriate RP technique depends on the scope and level of the project as some techniques are too simple to deal with large number of requirements, conflicted goals, and multiple decision makers.

Requirements prioritization is a multi-criteria decision making (MCDM) problem whose objective is to prioritize the requirements on the basis of different criteria. As the prioritization process includes the judgement and preferences of different stakeholders which can be vague, imprecise, and difficult to represent in exact numbers (like most of the prioritization techniques), stakeholders may then use linguistic terminologies instead of exact numbers to specify their preferences. Therefore, this paper focuses on implementing a type-2 neutrosophic framework to prioritize requirements by considering the different criteria as well as uncertainty and vagueness in stakeholders' preferences by using the neutrosophic approach which is a promising method to deal with uncertainty. The initial step of the proposed RP framework is to identify the relevant stakeholders, their goals, and requirements. Second, we use a technique called T2NN-based DEMATEL to compute and rank the criteria importance, and we use another technique called T2NN-based TOPSIS to rank the requirements.

The remainder of the paper is organized as follows. Technical background and literature review in Section 2. Section 3 presents the proposed framework methodology. Section 4 presents a numeric case study to demonstrate the applicability of the proposed framework. Finally, we conclude this paper in Section 5.

2. Technical background and literature review

In this section, we give a quick overview of requirements prioritization methods then a literature review of previous work.

2.1 Concepts and terminologies

Business requirements:

These are the requirements related to what the business wants to achieve from the project, they define the business needs and the success criteria. Business requirements include Project timeline and scope, Branding rules, marketing, sales, customer services, Competitors, and Stakeholder expectations. [4]

User requirements:

User requirements gathering is a process used to understand what typical users will need from a service or a product which is about to be designed, it involves understanding the needs, goals, and expectations of the users to identify a list of requirements, features, and functionality the new service must have. This helps to ensure that the product or service meets the user's needs and expectations. This process answers questions like: Who are the target users, and what are their needs and pain points? What usability or accessibility issues that designers need to consider?

Technical requirements:

Technical requirements are related to how the project will be implemented, they answer key technical questions and address technical limitations, and they fall into two categories:

Functional (FRs): Outlines the product's specifications, technical capabilities, and limitations.

Non-functional (NFRs): Describes the product's performance, such as usability, performance, data integrity, and maintenance.

2.2 Requirements prioritization techniques:

There are several methods to assess the priorities of requirements, [5], for clarity, we classify them into three categories: visual plots, Scoreboards, and comparison-based methods.

Visual Plots:

Visual plots techniques are a quick, flexible, collaborative, and simplified approach for prioritization, they can work with large number of features involving different stakeholders. But their simplicity can have a downside when we need a more structured approach for decision making. Some of the techniques are:

A. Impact-Effort or Value-Complexity Matrix

This is a four-quadrant prioritization technique that prioritizes the requirements regarding their impact and the effort needed to implement them [1]. requirements that have high impact but need low effort, are done right away, on the other hand, requirements having a low impact, but high effort are not worth it. Requirements that have high impact but need high effort too, are strategic and defensible. And lastly, the requirements that need low effort, and have low impact are kept for later in case they become needed.

B. MoSCoW analysis

MoSCoW analysis was created by Dai Clegg and is used in many Agile frameworks. It breaks requirements into four groups: Must Have, Should Have, Could Have, and Will Not Have. Must have requirements represents the mandatory requirements that are vital to the product or project. Should have, represents requirements that support core functionality and are important to the project or context, but the project or product will still work without them. Could have, refers to requirements that are not essential, but wanted and nice to have. Will not have, are requirements that are not needed. They don't present enough value and can be left out. [6]

C. Eisenhower decision matrix

This technique by Steven Covey [7] breaks requirements into four groups: DO, Schedule, Delegate, Don't do. based on their urgency and importance. Urgent refers to requirements that need immediate action. Failing to address an urgent requirement often results in clear consequences. And Important refers to the requirements that contribute to the long-term goals and require planning and careful action.

D. Kano Model

This technique by Dr. Noriaki Kano 1984 prioritizes requirements based on the degree they are likely to satisfy and delight the end user, by weighing a high satisfactory feature against its implementation investment to determine whether to include it in the product roadmap. It clusters the requirements into five categories: Basic features, Performance features, Excitement features, Indifferent features, and Dissatisfaction features. [8]

Scoreboards or weighted sum methods (WSM):

Sometimes features are complicated and need to be prioritized with more detail than a simple visual plot can do. In this case, the scoreboards methods are a great way to score priorities, scoreboards or score matrix can be customized according to the specific needs and criteria of the different stakeholders involved, each criteria can be assigned a relative weight representing its importance [9]. Some of the famous scoreboard techniques:

E. Feasibility, Desirability, and Viability Scorecard (FDV)

FDV was invented by IDEO in the early 2000s [6], it ranks requirements based on feasibility, desirability, and viability. Feasibility refers to the degree to which the requirement can be technically feasible. Desirability refers to the degree to which the user desires the feature. Finally, viability relates to the benefit the feature will bring to the business. A matrix is made with rows representing each of the features and columns representing the three categories, then each of the stakeholders assigns a score to each of the feature regarding each category on an importance scale from 1 to 10, then, a total score is calculated, and the features are ranked.

F. NUF test

Similar to the feasibility, desirability and viability scoreboard, this technique developed by Dave Gray [10] prioritizes requirements based on three criteria: New, Useful, Usable. New refers to the degree to which the feature is new and innovative. Useful refers to how useful a feature is in solving and addressing the user. Feasible assesses the features in terms of the resources and effort needed to get implemented.

G. RICE Method

This prioritization framework developed by Intercom [11] considers four factors: Reach, Impact, Confidence, and Effort to prioritize which features to implement. Each feature has a score calculated by multiplying Reach (the number of users affected by the feature) by Impact (the value the feature has on users) and Confidence (how valid these estimates are). Then dividing the resulting number by Effort (the effort it will take to implement the feature).

Comparison based methods:

The comparison-based prioritization techniques can lead to the most accurate results [12] [13] , but as the requirements list gets bigger, these methods become more complex and time consuming to implement. Two of the most popular comparison methods are:

H. AHP:

This feature prioritization method is used to identify the most important features of a product or service based on multiple objectives. All possible pairs of features are compared, to determine the relative importance of each feature. Usually, this is done with a scale from 1 to 9 where 1 represents equal importance and 9 represents that the feature is a lot more important.

AHP is considered the most promising prioritization method in comparison with other methods, as it yields the most trustworthy results due to the comparison redundancies that makes it less sensitive to judgment errors, it provides consistency check and the results are based on a ratio scale to compare the requirements instead of an ordinal scale, which is more meaningful, thus the priority distance between the requirements is given [14], [15]. But to come up with a prioritization, many comparisons have to be made, which requires a lot of time and effort and can be a challenge task for User Experience (UX) teams with limited resources. [16]

I. Bubble Sorting

This technique is based on the comparison of two requirements and swapping the one with the most importance to have more priority than the other one. The comparison is carried out until the last item is prioritized and sorted. [12] [17]. This method can be time consuming when the feature list is large and challenging when different stakeholders are involved.

Each of these prioritization techniques has its own strengths and weaknesses, but a common limitation is that none of these methods considers the interdependency between the criteria when weighing them, also, it's not an easy process to define requirements in numeric values as in the scoreboards' methods, instead it's more meaningful to use linguistic terms.

2.3 Requirements Prioritization studies:

Different MCDM techniques have been used for the prioritization and selection of requirements i.e., Analytic Hierarchy Process (AHP), TOPSIS, etc. The previous studies on MCDM for requirements prioritization can be classified into single methods studies and combined methods, either using crisp or fuzzy values in the prioritization process.

[18] Presented a prioritization method using fuzzy AHP to assess the goal-oriented requirements elicitation process, this method used binary sort to get the prioritized list of requirements, this method was demonstrated on a case study of ten functional requirements, three criteria, for the prioritization of requirements and ten stakeholders' and five Decision makers (DM) participating to prioritize the requirements. [19] proposed a fuzzy based MoSCoW method for software requirements prioritization, they applied their proposed method to prioritize the requirements of Library Management System (LMS), using the "goal-oriented requirements elicitation process" (GOREP) to determine the ten functional requirements and using three non-functional requirements as the criteria. This study didn't include multiple stakeholders' opinions in the prioritization. [20] proposed a prioritization method combining Planning Games (PG) and analytical hierarchy process (AHP) techniques. The proposed method was applied on a Library Management System case study. This method reduced the number of pairwise comparisons from 105 to 31 for the same number of FRS and NFRs. Another study by [21] used the fuzzy TOPSIS method to rank 10 FRs functional requirements of an Institute Examination System (IES), based on 3 NFRs, by five decision makers. [22] Proposed a combined method of fuzzy AHP and fuzzy TOPSIS for requirements prioritization. This method was applied for the selection of the requirements of Institute Examination Systems, where 16 FRs were identified, 3 NFRs as the criteria and 4 DMs. Fuzzy AHP was used for computing the requirements weights and Fuzzy TOPSIS was used to compute the ranking. [23] proposed another combined method using MoScoW and AHP, this technique has combined the benefits of both MOSCOW and AHP. It performs categorization of 21 requirements using MOSCOW and then ranking using AHP, using AHP in MOSCOW reduced the number of comparisons from 210 to 45. [24] conducted a comparative study between fuzzy AHP and fuzzy TOPSIS for software requitements selection as they're the most used methods in this domain, the results of their study stated that both fuzzy AHP and fuzzy TOPSIS methods produce the same set of functional requirements, but AHP causes the rank reversal issue; unlike TOPSIS. Fuzzy TOPSIS requires less judgment by decision makers compared to fuzzy AHP and there is no limit in the FRs and NFRs when using fuzzy TOPSIS, on the other hand, the fuzzy AHP is limited to the number of FRs and NFRs as it requires large number of comparisons to be made.

3. Proposed methodology

In this study, the T2NNs are used to rank the requirements by using the DEMATEL[25] and TOPSIS[26] methods. The DEMATEL method is used to compute the weights of criteria taking into account the interdependency between them, and the TOPSIS method is used to rank the requirements. This section shows the steps of the proposed methodology. A summary of the proposed methodology is depicted in figure 1.

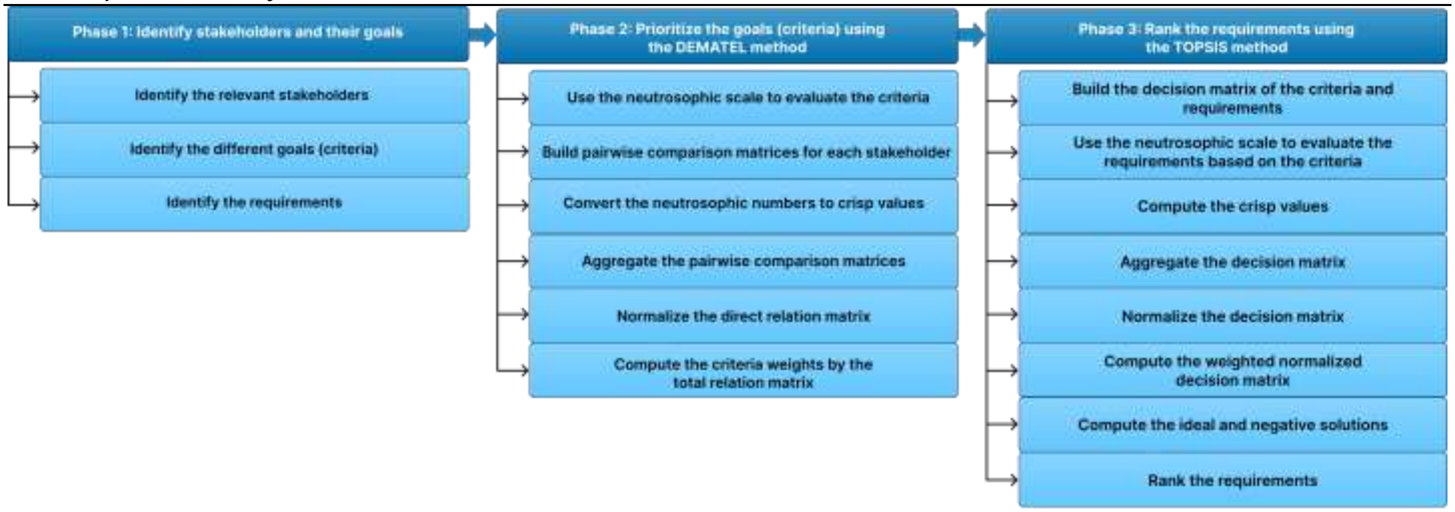


Fig 1. The proposed methodology.

Phase 1: Identify the relevant stakeholders and their goals

Step 1: Identify the relevant stakeholders to take part on the prioritization process.

Step 2: Identify the different goals (Criteria).

Step 3: Identify the requirements.

Phase 2: Compute the weights of the criteria using DEMATEL method

The T2NN-based DEMATEL addresses the vagueness and uncertainty in the stakeholders' judgements, using the indeterminacy degree, DEMATEL is helpful in handling interrelated problems, as all criteria fall into two categories: cause and effect, making it a perfect choice for computing the weights of the criteria as in most cases the different criteria are interrelated and affect one another, i.e., customer satisfaction can cause higher revenues.

Step 4: Use the neutrosophic scale to evaluate the different criteria.

Step 5: Build the pairwise comparison matrix for each stakeholder.

Step 6: Convert the neutrosophic numbers to crisp values [27].

Step 7: Aggregate the pairwise comparison matrix by the average method to obtain direct relation matrix.

Step 8: Normalize the direct relation matrix [25].

$$N = \frac{1}{\max\limits_{1\le i\le n} \sum_{j=1}^{n} x_{ij}} \quad (1)$$

Where $i = 1,2,3 \ldots\ldots m\ (alternatives); j = 1,2,3 \ldots.\, n\ (criteria)$

Step 9: Compute the total relation matrix as:

$$R = N \times (I - N)^{-1} \quad (2)$$

Step 10: Compute the weights of criteria by the total relation matrix.

Phase 3: Rank the requirements by the TOPSIS method

In T2NN-based TOPSIS, the set of requirements are scored against the set of criteria using linguistic terms for each criterion. Each criteria have a direction of preference based on whether more or less of that criterion is preferred. This makes the T2NN-based TOPSIS a good choice for requirements prioritization as it simulates the real prioritization process where we score a set of requirements against cost/value criteria.

Step 11: Build the decision matrix of the criteria and requirements.

Step 12: Use the neutrosophic scale to evaluate the requirements based on the criteria.

Step 13: Compute the crisp values [27].

Step 14: Aggregate the decision matrix.

Step 15: Normalize the decision matrix [26].

$$N_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2} \quad (3)$$

Step 16: Compute the weighted normalized decision matrix as:

$$WN_{ij} = N_{ij} \times W_j \quad (4)$$

Step 17: Compute the ideal and negative solution

$$P_i^+ = \sqrt{\sum_{j=1}^{n}\left(WN_{ij} - \max WN_{ij}\right)^2} \quad (5)$$

$$P_i^- = \sqrt{\sum_{j=1}^{n}\left(WN_{ij} - \min WN_{ij}\right)^2} \quad (6)$$

Step 18: Rank the requirements (alternatives) by the highest value of S as:

$$S_i = \frac{P_i^-}{P_i^- + P_i^+} \quad (7)$$

4 Numeric case study

The aim of this section is to apply the steps of the proposed framework and show the results of the DEMATEL and TOPSIS methods for the prioritization and selection of the requirements of an online banking system (OBS) [2]. We take five main online banking requirements as an example, they'll be referred to as OBSR1, OBSR2, etc. And five NFRs as the criteria, they'll be referred to as OBSC1, OBSC2, etc.

Phase 1: Identify the stakeholders and their goals

Step 1: Three stakeholders were chosen to evaluate the criteria and requirements.

Step 2: Five criteria were identified as the project's priorities, namely speed, integrity, security, customer satisfaction, and services.

Phase 2: Compute the weights of the criteria using DEMATEL method

Step 3: T2NNs were used by stakeholders to evaluate the criteria [27].

Step 4: The pairwise comparison matrix for the five criteria were constructed using linguistic terms, by each of the three stakeholders.

Step 5: The linguistic terms were converted to T2NNs then into crisp values by the score function [27].

Step 6: The direct relation matrix is computed by the aggregation matrix as in table 1.

Step 7: The normalized matrix is built by Eq. (1) as in table 2.

Step 8: Using Eq. (2) the total relation matrix is built as shown in table 3.

Step 9: The weights of criteria were computed by the relation matrix as in Fig. 2. From Fig. 2 we can see that security is the most important criteria followed by speed, and the criteria with the lowest weight being services.

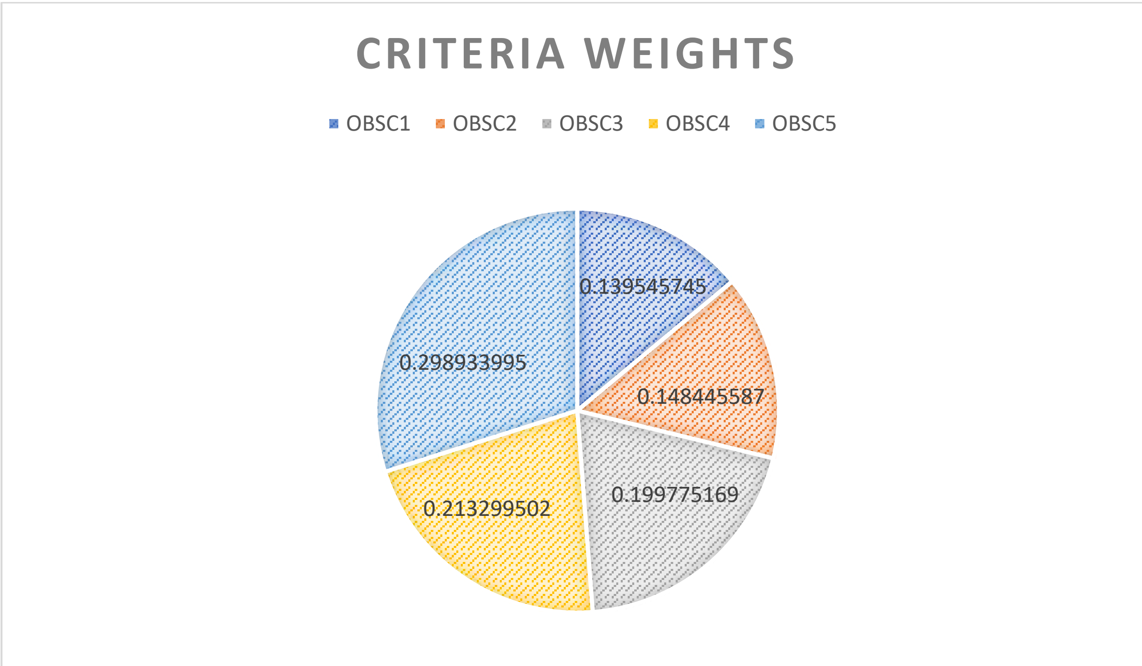


Fig 2. The weights of criteria.

Table 1. Aggregated pairwise comparison matrix

	OBSC1	OBSC2	OBSC3	OBSC4	OBSC5
OBSC1	1	0.513333	0.663333	0.686667	0.536667
OBSC2	2.415825	1	0.62	0.606667	0.576667
OBSC3	2.411569	3.79283	1	0.493333	0.78
OBSC4	1.477273	1.847643	2.713805	1	0.55
OBSC5	2.55635	2.238366	1.282051	2.020202	1

Table 2. Normalized pairwise comparison matrix

	OBSC1	OBSC2	OBSC3	OBSC4	OBSC5
OBSC1	0.391183	0.135343	0.244429	0.3399	0.536667
OBSC2	0.945029	0.263655	0.228462	0.3003	0.576667
OBSC3	0.943364	1	0.368486	0.2442	0.78
OBSC4	0.577884	0.487141	1	0.495	0.55
OBSC5	1	0.590157	0.472418	1	1

Table 3. Total relation matrix

	OBSC1	OBSC2	OBSC3	OBSC4	OBSC5
OBSC1	-0.37166	-0.27894	-0.14724	-0.11183	-0.15032
OBSC2	-0.03338	-0.36486	-0.29251	-0.21853	-0.21831
OBSC3	-0.20654	0.027849	-0.52124	-0.50664	-0.31093
OBSC4	-0.51107	-0.10905	0.093692	-0.51986	-0.57395
OBSC5	-0.72436	-0.42023	-0.37067	-0.1451	-0.61035

Phase 3: Rank the requirements by the TOPSIS method

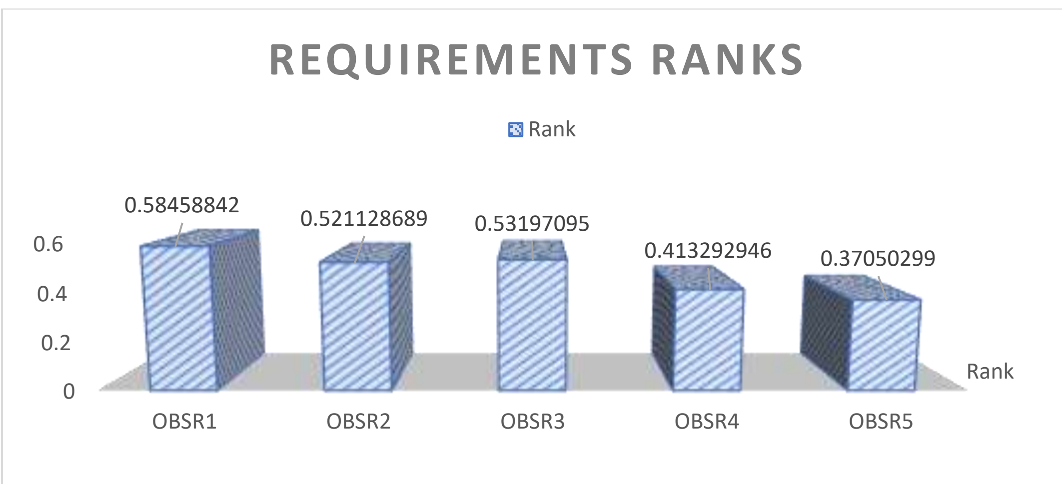
Step 10: The decision matrix for evaluating the requirements against the criteria were built by each stakeholder using linguistic terms, then converted to T2NNs then to crisp values. Then the aggregated decision matrix was calculated as in table 4.

Step 11: The aggregated decision matrix was normalized by Eq. (3) as in table 5.

Step 12: The weights of criteria were multiplied by the normalization matrix by using Eq. (4) as in table 6.

Step 13: Then the ideal and negative solutions were computed by Eqs. (5,6).

Step 14: To get the requirements ranks, we use the values of S computed by Eq. (7), the requirement with the highest value of S being the most important one etc., as shown in Fig. 3. From Fig. 3 we see that requirement 1 is the most important requirement, followed by requirement 3, and the least important requirement is requirement 5.



	OBSR1	OBSR2	OBSR3	OBSR4	OBSR5
Rank	0.58458842	0.521128689	0.53197095	0.413292946	0.37050299

Fig 3. The rank of requirements

Table 4. Aggregated decision matrix

	OBSC1	OBSC2	OBSC3	OBSC4	OBSC5
OBSR1	0.6	0.513333	0.663333	0.686667	0.53
OBSR2	0.48	0.436667	0.62	0.62	0.58
OBSR3	0.28	0.32	0.72	0.476667	0.786667
OBSR4	0.472333	0.35	0.32	0.833333	0.52
OBSR5	0.28	0.366667	0.286667	0.433333	0.826667

Table 5. Normalized decision matrix

	OBSC1	OBSC2	OBSC3	OBSC4	OBSC5
OBSR1	0.609114	0.56913	0.536731	0.489809	0.358147
OBSR2	0.487291	0.48413	0.501669	0.442255	0.391935
OBSR3	0.284253	0.354783	0.582583	0.340013	0.53159
OBSR4	0.479508	0.388043	0.258926	0.594428	0.35139
OBSR5	0.284253	0.406522	0.231954	0.309103	0.558619

Table 6. Weighted normalized decision matrix

	OBSC1	OBSC2	OBSC3	OBSC4	OBSC5
OBSR1	0.084999	0.084485	0.107226	0.104476	0.107062
OBSR2	0.067999	0.071867	0.100221	0.094333	0.117163
OBSR3	0.039666	0.052666	0.116386	0.072525	0.15891
OBSR4	0.066913	0.057603	0.051727	0.126791	0.105042
OBSR5	0.039666	0.060346	0.046339	0.065931	0.16699

Conclusions

In this work, we present a new framework for requirements prioritization using the DEMATEL and TOPSIS methods under the neutrosophic environment. The DEMATEL method is used to compute the criteria weights, while the TOPSIS method was later used to rank the requirements based on the identified criteria. The proposed framework was explained using a numeric case study of an OBS, where three stakeholders were chosen to participate in the RP process, five criteria and five requirements were selected to be used as an example. The proposed framework has shown few interesting advantages over previous methods, The DEMATEL method used in the framework addresses the interdependency between the different criteria, as some criteria can influence and cause other criteria. The TOPSIS method used requires few stakeholders' judgements compared to other method such as AHP, making it the perfect choice for dealing with large number of requirements, it's also more meaningful and easier for stakeholders as it simulates the basic prioritization matrix where a set of requirements are evaluated against a set of criteria. The TOPSIS method also avoids the rank reversal issue, thus, making the proposed framework more dynamic. The neutrosophic approach used in this framework addresses the imprecision and vagueness in the stakeholders' judgements, making it possible for stakeholders to use linguistic terms instead of numbers and scales which can be understood differently by everyone, which can drive inaccurate results. For future research, we plan to test this framework on a large project to further validate its results.

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