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Evaluation the Impact Potentials of Materials and Systems with Specific Criteria under Neutrosophic Set

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Abstract: Energy, healthcare, electronics, transportation, ecology, and infrastructure are just a few of the areas that might greatly benefit from the use of new materials and systems. This study delves into the factors that should be taken into account when determining the possible effect of a certain substance or system. This analysis takes into account ecological, monetary, technical, health and safety, regulatory, commercial, and cooperative factors. Stakeholders may make more well-informed decisions and ensure that materials and systems are used to their maximum capacity if they take these into account. This paper used the concept of multi-criteria decision-making (MCDM) to deal with various criteria and factors. The VIKOR method is used as an MCDM method to rank the materials according to various criteria. The VIKOR method is integrated with the single-valued neutrosophic set to overcome uncertain information. This paper used eight criteria and ten materials to select the best one. The results show the cost criteria is the height weight in all criteria.

Keywords: Neutrosophic Set, Materials, Evaluation, MCDM, Uncertainty.

1. Introduction

Our contemporary world owes much to the materials and processes that drive technological progress and revolutionize several sectors. These materials and systems have the potential to have a huge impact on a variety of fields. Understanding and utilizing the potential of materials and systems is essential for tackling societal concerns, promoting sustainability, and supporting innovation in fields ranging from energy and healthcare to transportation and infrastructure[1], [2].

Potential impacts are evaluated using a multifaceted set of criteria and characteristics. Materials and systems should aim to decrease carbon emissions, energy consumption, and waste creation over their entire lifespan to minimize their environmental effect. Improving people's quality of life, their sense of security, and their ability to access resources are all examples of social effects. Material and system development should be cost-effective and promote economic growth to have a positive economic impact[3], [4].

The effect possibilities of materials and systems are being pushed forward by technological development. New materials with enhanced performance qualities like strength, durability, and conductivity may be created because of developments in materials science. These developments pave the way for the development of novel systems that are more functional and have more capacities[5], [6].

When calculating impact probabilities, health, and safety must take precedence. Human health and safety must be the priority while designing and developing new materials and systems. Promoting sustainability and aligning with global objectives, such as cutting carbon emissions or bolstering circular economy practices, necessitates compliance with policies and regulations.

Considerable thought must be given to the market's prospective interest and uptake. Market demands, client specifications, and competitive advantages should all be taken into account when designing materials and systems. Determining the economic feasibility and long-term success of materials and systems requires an analysis of market size, growth potential, and obstacles to entry[7], [8].

Last but not least, maximizing the effect of materials and systems requires teamwork and the participation of key stakeholders. To maximize the impact potentials of materials and systems, it is essential to encourage multidisciplinary cooperation among academics, industrial partners, policymakers, and end-users[9], [10].

In this work, we explore the factors and criteria used to calculate the potential effect of various materials and systems. We hope that by investigating these issues, we may shed light on the advantages and disadvantages of different materials and methods. To make smart choices, spur innovation, and build a future that is both sustainable and technologically advanced, it is essential to have a firm grasp on these impact potentials. So, the concept of MCDM is used to deal with these criteria and factors. The VIKOR method used an MCDM method to compute the weights of these factors and rank the materials. The VIKOR method is integrated with the neutrosophic set to deal with uncertain information.

In such contexts, decision-maker preferences are seldom quantifiable, stable, and consistent. Memberships in traditional set theory are inadequate here[11]. Zadeh proposed using fuzzy sets (FSs) for dealing with uncertainty in cognitive processes, with memberships of the proposed technique ranging from 0 to 1 [12], [13].

Atanassov developed the intuitionistic fuzzy set (IFS) as a solution to the hesitancy issue of decision-makers since incorporating fuzziness into DM problems is not sufficient. Each element's degree of non-membership is represented by a number between 0 and 1. IFSs have seen widespread use in DM issues[14], [15].

To properly describe the indeterminacy, Smarandache has proposed the neutrosophic set (NS), an enlarged and generic variant of the classical fuzzy set and the intuitionistic fuzzy set. Neutrosophic set elements include T for truth, I for indeterminacy, and F for falsehood[16], [17].

2. Examples of Materials Process and its Impacts

A few sectors that have benefited greatly from new materials and methods are listed below.

Modern materials, such as high-efficiency solar cells, have caused a paradigm shift in the renewable energy industry. Materials like perovskite solar cells have the potential to boost solar energy production due to their high light absorption and conversion rates. Similarly, the widespread adoption of electric cars and grid-scale energy storage solutions has been made possible by breakthroughs in battery technology and the utilization of materials like lithium-ion[18], [19].

Materials and systems have had a significant influence on healthcare, especially in the area of medical devices. Orthopedic implants made from biocompatible materials, such as titanium alloys, have improved patient outcomes and prolonged implant longevity. Smart materials, such as shape-memory alloys, have also been developed, allowing for less intrusive surgical techniques and enhancing patient comfort during medical treatments.

Improvements in materials and processes have allowed the electronics industry to shrink gadgets and boost their performance. Silicon and other similar materials have been crucial to the development of integrated circuits and microprocessors in the semiconductor industry. New opportunities for wearable electronics, flexible displays, and electronic textiles have emerged because of the advancement of flexible and stretchy electronics made possible by materials such as graphene and conductive polymers[20], [21].

The transportation sector has been profoundly affected by the use of lightweight materials like carbon fiber composites and aluminum alloys. The high strength-to-weight ratios of these materials let vehicles go further on a single tank of gas and produce less greenhouse gas emissions. Battery technology improvements, such as those seen in lithium-ion and solid-state batteries, have also contributed to increased electric vehicle range and a rise in their popularity.

Improvements in structural integrity, energy efficiency, and sustainability have resulted from advances in materials and technologies used in the building industry. Fiber-reinforced composites and ultra-high-strength concrete are two examples of high-performance materials that may benefit infrastructure projects with longer lifespans and lower maintenance costs. Building automation and energy management systems are only two examples of smart technologies that have improved building efficiency and occupant comfort.

The environmental sector has made significant progress in tackling environmental concerns thanks in large part to the use of sustainable materials and technologies. Waste has been cut down and the environmental effect of the packaging and building sectors has been lessened thanks to the use of recycled and eco-friendly materials. Water and air purification have benefited greatly from the use of cutting-edge filtration technologies and materials, which in turn has helped to enhance environmental quality[22], [23].

These cases show how materials and systems have had far-reaching effects in a variety of sectors, fostering innovation, enhancing performance, and resolving social issues. Future sustainable development and profoundly reshaping our planet may be enabled by further developments in materials science and engineering[24], [25].

3. Challenges of Impact Potentials of Materials and Systems

Although materials and systems might have far-reaching effects, several obstacles stand in the way of reaping such rewards. Key difficulties include, among others:

The environmental effect of materials and systems is a major obstacle that must be overcome. Many economic sectors depend heavily on nonrenewable resources or produce enormous amounts of trash and pollutants during their operations. To overcome these difficulties, it is crucial to implement circular economy concepts and seek sustainable alternatives, as well as to reduce energy consumption, waste production, and waste disposal costs[26], [27].

The price tag associated with creating and deploying cutting-edge infrastructure might be prohibitive for certain people. Large sums of money are often needed for R&D, production, and increasing output. Especially in areas where cost is a major factor in adoption, like healthcare and renewable energy, making these technologies inexpensive and accessible is vital.

Technological Readiness: It might be difficult to transition materials and systems from the research and development phase to practical applications. Scalability, dependability, and backward compatibility with current infrastructure are all technical hurdles that must be cleared. For materials and systems to be widely used, their long-term performance and durability must be guaranteed[28], [29].

There is a correlation between regulatory and policy frameworks and the pace of innovation in materials and systems. Promoting safety, sustainability, and market acceptance requires the establishment of suitable rules, standards, and incentives. However, complying with many local, state, federal, and international regulations may be difficult.

The degree to which the public embraces and uses novel technologies depends greatly on how they are received in the marketplace. Safety issues, ethical considerations, and the potential for industry upheaval are all valid concerns. To alleviate these worries and restore confidence among stakeholders, open dialogue, public participation, and clear information sharing are essential.

The full effect potential of materials and systems is seldom realized without the combined efforts of academics, industry professionals, policymakers, and end-users from a wide range of backgrounds and disciplines. Bridging knowledge gaps, aligning interests, and coordinating efforts across multiple industries and disciplines are all obstacles that may make interdisciplinary cooperation difficult. To face these difficulties, it is essential to construct efficient networks and platforms for cooperation[29], [30].

Taking into account a product's whole lifespan, from mining for basic materials to final disposal, is essential when assessing its potential effect. It is a difficult effort to evaluate resource depletion, waste management, and social equality at every step of the process. It is crucial to develop whole lifecycle assessment methods and embed sustainability concepts into all stages of the lifecycle.

Research and development, legislative interventions, industry cooperation, and public awareness are all necessary to effectively tackle these issues. If we can get beyond these roadblocks, we can use materials and systems to their fullest extent, promoting long-term growth and social progress[28], [31].

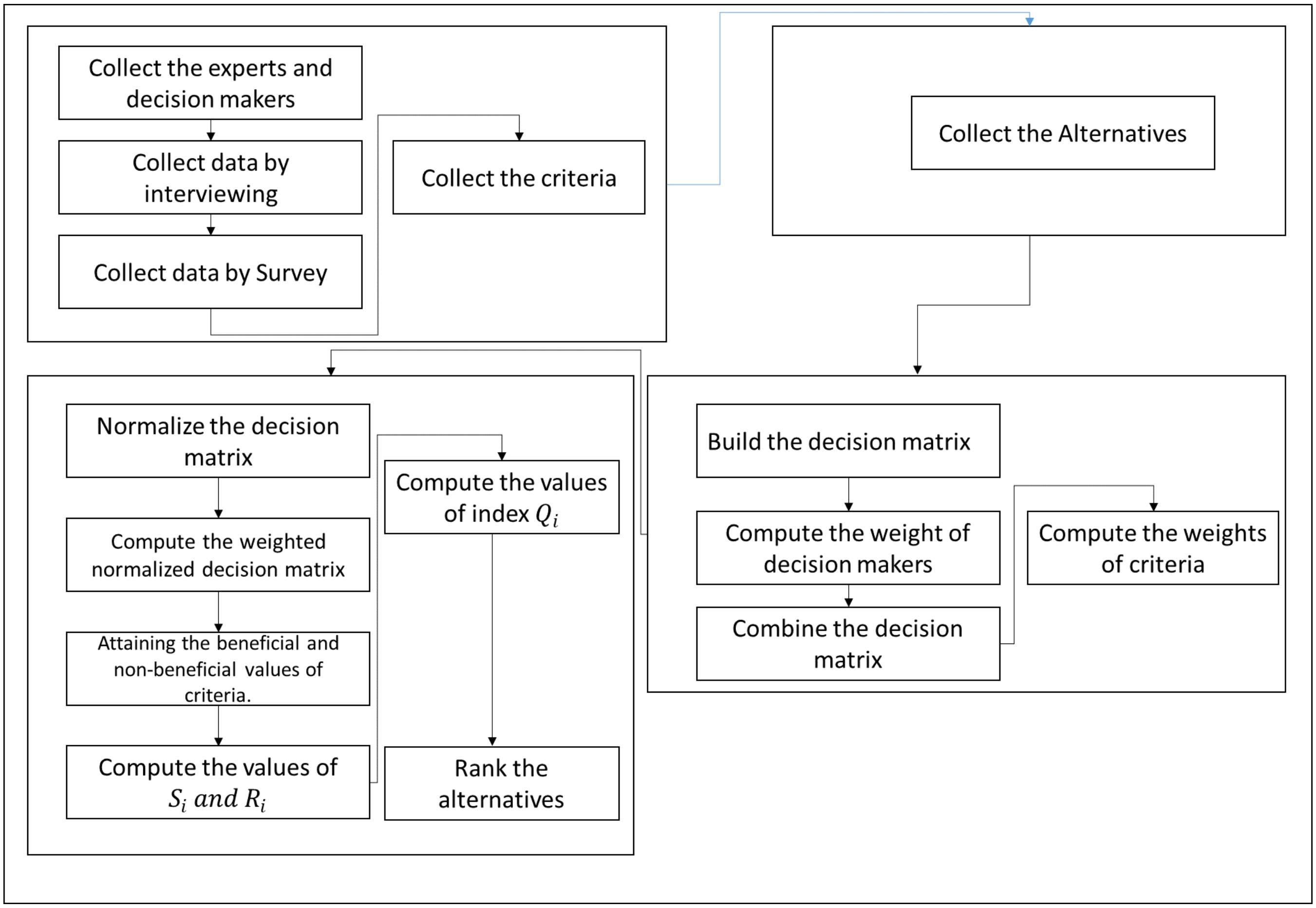

Figure 1. The framework of single valued neutrosophic set.

4. Neutrosophic VIKOR Method

In 2004, Opricovic and Tzeng were the first to publish the VIKOR technique. The fundamental idea behind the strategy is to choose the best option by ranking them according to competing criteria[32], [33] as shown in Figure 1.

Step 1. Build the decision matrix

The whole matrix of VIKOR method can be computed as:

$$T_{pj} = \left(\sum_{i=1}^{n}\left(w_i \frac{f_i^* - f_{ij}}{f_i^* - f_i^-}\right)\right)^{\frac{1}{p}} \quad (1)$$

Step 2. Compute the weight of decision makers

$A^e = (a_{ij}^e)$

Where e refers to the decision maker and experts.

Step 3. Combine the decision matrix

$$a_{ij} = < 1 - \prod_{e=1}^{k}\left(1 - T_{ij}^{(e)}\right), \prod_{e=1}^{k} I_{ij}^{(e)}, \prod_{e=1}^{k} F_{ij}^{(e)} > \quad (2)$$

Step 4. Compute the weights of criteria

Step 5. Normalize the decision matrix

Step 6. Compute the weighted normalized decision matrix

$$d = A_{ij} * w_j \quad (3)$$

Step 7. Attaining the beneficial and non-beneficial values of criteria.

$$T_j^{w+} = \left\{\left(\max T_{ij}^{w}\right), \left(\min T_{ij}^{w}\right)\right\} \quad (4)$$

$$I_j^{w+} = \left\{\left(\max I_{ij}^{w}\right), \left(\min I_{ij}^{w}\right)\right\} \quad (5)$$

$$F_j^{w+} = \left\{\left(\max F_{ij}^{w}\right), \left(\min F_{ij}^{w}\right)\right\} \quad (6)$$

$$T_j^{w-} = \left\{\left(\max T_{ij}^{w}\right), \left(\min T_{ij}^{w}\right)\right\} \quad (7)$$

$$I_j^{w-} = \left\{\left(\max I_{ij}^{w}\right), \left(\min I_{ij}^{w}\right)\right\} \quad (8)$$

$$F_j^{w-} = \left\{\left(\max F_{ij}^{w}\right), \left(\min F_{ij}^{w}\right)\right\} \quad (9)$$

Step 8. Compute the values of $S_i \; and \; R_i$

$$S_i = \sum_{j=1}^{n} w_j \frac{|| w_j^{+} - w_{ij} ||}{|| w_j^{+} - w_j^{-} ||} \quad (10)$$

$$R_i = \max w_j \frac{|| w_j^{+} - w_{ij} ||}{|| w_j^{+} - w_j^{-} ||} \quad (11)$$

Step 9. Compute the values of index Q_i

$$Q_i = \partial \left[\frac{S_i - S^{+}}{S^{-} - S^{+}}\right] + (1 - \partial)\left[\frac{R_i - R^{+}}{R^{-} - R^{+}}\right] \quad (12)$$

Step 10. Rank the alternatives

The alternatives are ranked according to the lowest value of Q_i

5. Results

This section introduces the results of the proposed method. This paper use eight criteria and ten materials. The following are eight criteria.

Material and system impact assessment entails considering both the positive and negative outcomes that might result from using the material or system. When assessing the possible effects, it is important to keep in mind the following:

Evaluate the environmental effects of materials and systems across their whole lifespan, from the gathering of raw materials to the final disposal of waste. Think about your impact on the environment in terms of things like your carbon footprint, energy use, trash output, and pollution risks. The potential effect of materials and systems is greater if they have a low environmental impact and help promote sustainability, such renewable materials or recyclable systems.

Consider the effects that materials and systems may have on people, groups, and the larger society. Think on how things can be better in terms of price, accessibility, and quality of life. Think about how you can help local economies and create employment. The potential influence of a material or system increases when it is used to solve social problems, broaden participation, or better people's lives.

Assess the financial effects of proposed materials and systems by analysing their costs, benefits, scalability, marketability, and growth prospects. Think about how you can save money, open up new markets, and stimulate creativity. The potential influence of a material or system increases as it provides economic advantages, stimulates industries, and aids in long-term economic growth.

Technological Breakthroughs and Improvements Evaluate the Possibilities Opened Up by Materials and Systems. Think of ways to boost performance, add new features, and create new capabilities. Determine whether there is a chance that a new technology will significantly improve upon current methods. High-impact materials and systems are those that propel technological progress and usher in new possibilities.

Assess how materials and setups could endanger people's health and safety. Think about the manufacture, using, and disposal stages from the perspective of toxicity, exposure hazards, and possible damage. Examine the opportunities for better health, medical progress, and increased safety in a variety of contexts. The health and safety impacts of materials and systems that pose low threats to human health and actually promote health and safety are greater.

Think about how well your products and systems conform to any applicable laws, regulations, and industry standards. Think about how they may help achieve policy goals like lowering waste or increasing energy efficiency, or achieving environmental goals. The potential effect of a material or system increases when it is both regulatory compliant and helps to achieve policy goals.

Examine the potential for materials and systems to be adopted in the market, as well as the demand for them. Think about the current size of the market, its potential for expansion, the level of competition, and any obstacles to entrance. Determine whether there is a chance to meet market demands, please customers, and give your company a leg up on the competition. The potential influence of a material or system increases as its market demand and rate of adoption increase.

Collaboration and Stakeholder Engagement: Analyze the Prospects for Working Together and Involving Stakeholders in the Design and Implementation of Resources and Tools. Think about how to include a wide range of people, such as companies, universities, government agencies, and end consumers. Think about how you may increase your effect by working together with others and sharing what you know.

Impact assessment is difficult and context-dependent, so keep that in mind. There may be varying priorities or requirements depending on the application or industry. To evaluate materials and systems in their whole, it is necessary to take into account a wide variety of criteria, adapt them to the individual situation, and include several points of view.

We applied the single valued neutrosophic VIKOR method on the eight criteria and ten alternatives.

Step 1. Build the decision matrix

The decision matrix is built based on the opinions of experts and single valued neutrosophic numbers.

Step 2. Compute the weight of decision makers

We compute the weights of criteria. The weights of criteria are equal.

Step 3. Combine the decision matrix

There are three experts and decision makers evaluate the criteria and alternatives, so we have three decision matrices. So, we combined these matrices to obtain the one matrix as shown in Table 1.

Step 4. Compute the weights of criteria

Then compute the weights of criteria as shown in Figure 2.

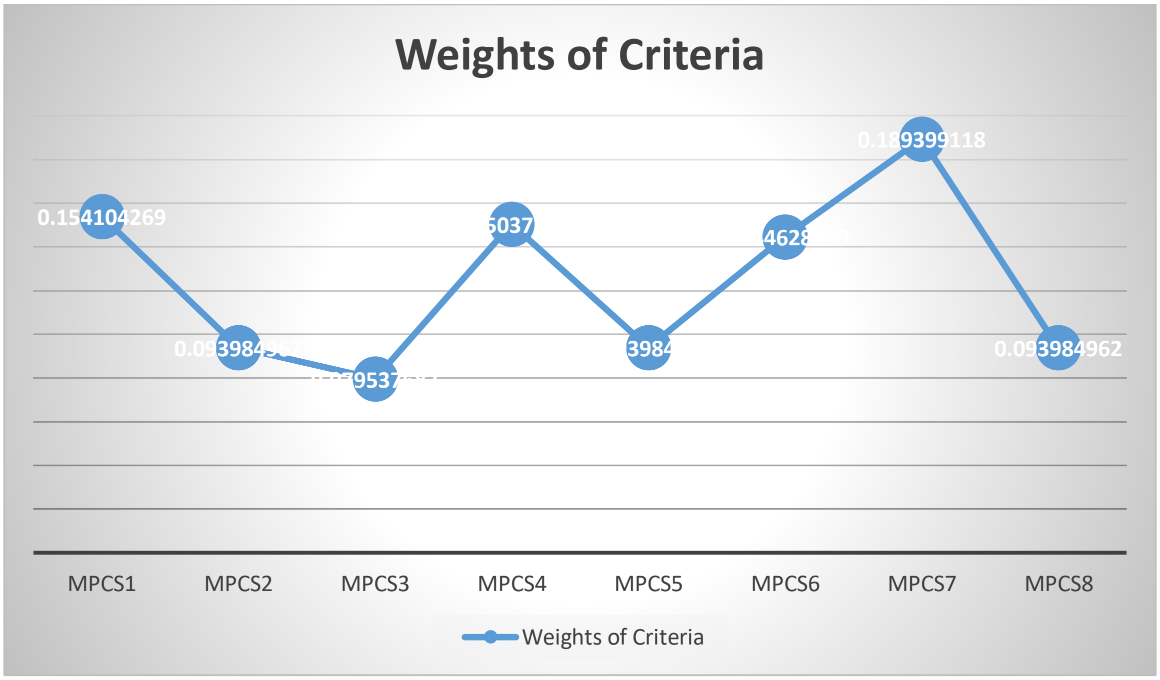

Figure 2. The weights of the eight criteria.

Step 5. Normalize the decision matrix

Then normalize the decision matrix.

Table 1. The combined decision matrix by the VIJOR method

	$MPCS_1$	$MPCS_2$	$MPCS_3$	$MPCS_4$	$MPCS_5$	$MPCS_6$	$MPCS_7$	$MPCS_8$
$MPMS_1$	0.369	0.236	0.256	0.452	0.369	0.562	0.9632	0.369
$MPMS_2$	0.623	0.369	0.256	0.516	0.236	0.369	0.256	0.236
$MPMS_3$	0.745	0.369	0.962	0.632	0.256	0.513	0.369	0.2563
$MPMS_4$	0.8526	0.7456	0.526	0.962	0.256	0.369	0.256	0.245
$MPMS_5$	0.369	0.856	0.826	0.625	0.263	0.2563	0.369	0.562
$MPMS_6$	0.512	0.963	0.963	0.256	0.26	0.856	0.526	0.2563
$MPMS_7$	0.369	0.236	0.526	0.256	0.562	0.962	0.263	0.526
$MPMS_8$	0.852	0.563	0.2569	0.695	0.256	0.856	0.236	0.632
$MPMS_9$	0.369	0.369	0.756	0.856	0.96	0.856	0.596	0.752
$MPMS_{10}$	0.256	0.256	0.963	0.256	0.415	0.526	0.236	0.523

Step 6. Compute the weighted normalized decision matrix

$$d = A_{ij} * w_j \tag{3}$$

We compete the weighted normalized decision matrix as shown in Table 2 by sing Eq. (3)

Table 2. The weighted normalization decision matrix by the VIJOR method

	$MPCS_1$	$MPCS_2$	$MPCS_3$	$MPCS_4$	$MPCS_5$	$MPCS_6$	$MPCS_7$	$MPCS_8$
$MPMS_1$	0.124916	0.093985	0.079538	0.108629	0.07672	0.062651	0	0.06976
$MPMS_2$	0.059307	0.076791	0.079538	0.094997	0.093985	0.023097	0.18419	0.093985
$MPMS_3$	0.027794	0.076791	0.000113	0.070289	0.091389	0.052609	0.154759	0.090287
$MPMS_4$	0	0.028105	0.049163	0	0.091389	0.023097	0.18419	0.092346
$MPMS_5$	0.124916	0.013833	0.015413	0.07178	0.09048	0	0.154759	0.034607
$MPMS_6$	0.087978	0	0	0.150376	0.090869	0.122904	0.113869	0.090287
$MPMS_7$	0.124916	0.093985	0.049163	0.150376	0.051666	0.144628	0.182367	0.041164
$MPMS_8$	0.000155	0.051711	0.079436	0.05687	0.091389	0.122904	0.189399	0.021857
$MPMS_9$	0.124916	0.076791	0.023288	0.022578	0	0.122904	0.095637	0
$MPMS_{10}$	0.154104	0.091399	0	0.150376	0.070748	0.055273	0.189399	0.04171

Step 7. Attaining the beneficial and non-beneficial values of criteria.

Obtain the beneficial and non- beneficial criteria by using Eqs. (4-9). The cost criterion is non-beneficial and other criteria are beneficial.

Step 8. Compute the values of S_i and R_i

Compute the values of S_i and R_i by using Eqs. (10 and 11)

Step 9. Compute the values of index Q_i

Then compute the value of Q_i by using Eq. (12)

Step 10. Rank the alternatives

Then alternatives are ranked according to the lowest value of Q_i as shown in Figure 3. The best material is 9, and the worst material is 7.

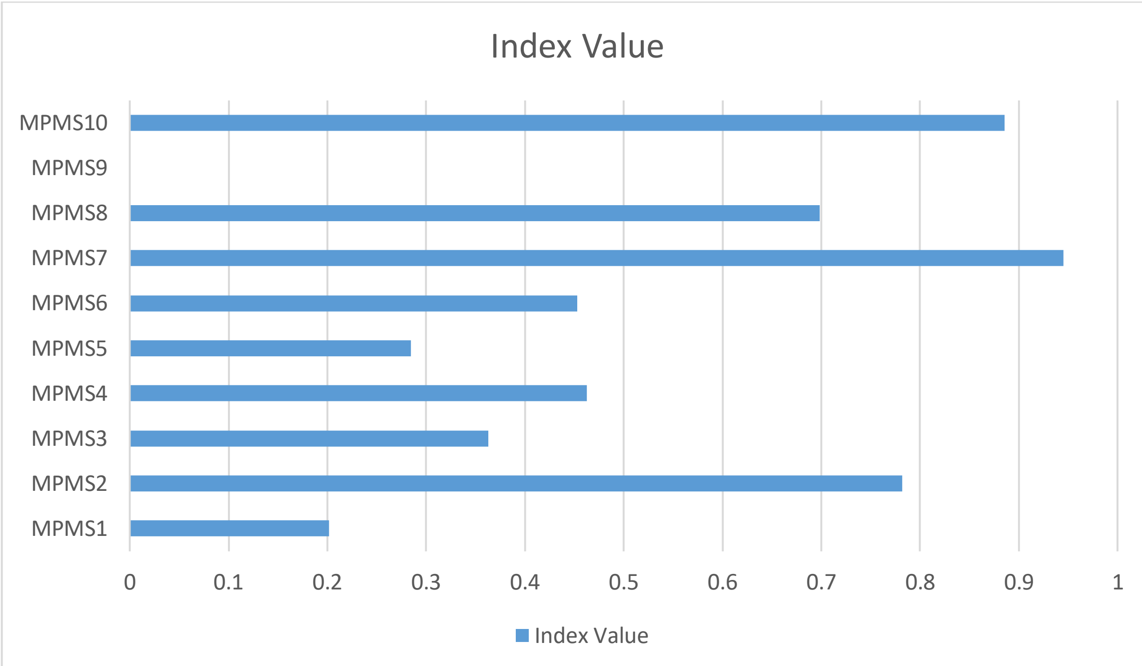

Figure 3. The value of Q_i.

6. Conclusions

Materials and systems may have far-reaching effects in a wide variety of ways. The environmental, social, economic, technical, health and safety, policy, market, and collaborative factors must all be taken into account in order to provide an accurate assessment of these possibilities. By evaluating these factors, stakeholders may learn more about the pros and cons of various materials and systems, increasing the likelihood of effective choices being made. Fostering innovation, tackling difficult issues, and promoting sustainable development are all possible via multidisciplinary cooperation and stakeholder involvement, which are essential for realizing their full potential. This paper used the concept of MCDM to deal with various factors and criteria. The VIKOR is an MCDM method used to rank the various materials based on various criteria. The VIKOR method is integrated with the single-valued neutrosophic set to deal with uncertain information. We applied the proposed method to eight criteria and ten materials. We obtained the cost criteria as the highest important of all criteria.

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