Neutrosophic Optimization and Intelligent systems

SCIENCES FORCE
International Academic Publisher

Journal Homepage: sciencesforce.com/nois

Neutrosophic Opt. Int. Syst. Vol. 1 (2024) 1–13

Paper Type: Original Article

A Combined Compromise Solution (CoCoSo) of MCDM Problems for Selection of Medical Best Bearing Ring

Nada A. Nabeeh [1],* and Karam M. Sallam [2,3]

[1] Information Systems Department, Faculty of Computers and Information Sciences, Mansoura University, Mansoura 35516, Egypt; nadaadel@mans.edu.eg.

[2] School of IT and Systems, Faculty of Science and Technology, University of Canberra, Canberra, Australia; karam.sallam@canberra.edu.au.

[3] Department of Computer Science, University of Sharjah, Sharjah, United Arab Emirates; KSallam@sharjah.ac.ae.

Received: 01 Oct 2023 **Revised:** 18 Dec 2023 **Accepted:** 28 Dec 2023 **Published:** 05 Jan 2024

Abstract

Bearings offers a variety of products designed to meet the rigorous requirements of the medical sector for patient safety, such as diagnostic and laboratory equipment, surgical and dental instruments, ventilators and heart pumps, etc. In the field of medical instruments, the bearing rings compromise from superior quality metals to perform surgical operations safely. The selection of the best bearing ring materials for medical applications is a critical task that involves considering various factors to ensure optimal performance, reliability, and safety. The study explores challenges and criteria in selecting the ideal bearing ring for medical devices and equipment. The criteria discussed encompass material compatibility, biocompatibility, lubrication requirements, precision, cleanliness, durability, noise and vibration control, size and dimension, load capacity, temperature and environmental conditions, regulatory compliance, manufacturing considerations, compatibility with adjacent components, maintenance, and serviceability. The challenges mainly include biocompatibility validation, material selection, performance requirements, regulatory compliance, size limitations, cost considerations, supply chain reliability, long-term stability, maintenance, expertise, and collaboration. To address the current challenges of medical bearing the study needs to understand the medical requirements, and engagement with trusted suppliers and regulatory bodies. The study presents a multi-criteria decision-making methodology (MCDM) problem with various criteria and alternatives with uncertainty conditions. The decision maker's perspectives evaluate the importance of criteria and alternatives. The neutrosophic set is used to deal with uncertainty conditions. The study illustrates a solution to select the best bearing ring to ensure the success and safety of medical applications. The MCDM provides solutions to choose the best bearing ring. A Combined Compromised Solution (CoCoSo) method is used as an MCDM method with neutrosophic theory to select the best alternatives. A numerical case study is presented to show the applicability and availability of the proposed methodology.

Keywords: Neutrosophic Sets, MCDM, CoCoSo, Decision Making, Medical Bearing Rings.

1 | Introduction

Bearing rings are crucial in various mechanical systems and medical applications. The selection of appropriate bearing ring is paramount in the medical field to achieve essential issues of precision, reliability, and patient

Corresponding Author: nadaadel@mans.edu.eg

https://doi.org/10.61356/j.nois.2024.16089

safety. Bearing rings facilitate smooth and accurate rotation, reduce friction and enable the efficient functioning of medical devices and equipment. Medical applications encompass various devices and equipment, such as surgical instruments, diagnostic tools, imaging systems, prosthetics, and patient support systems. The medical applications often require bearings that can withstand rigorous conditions, including repeated sterilization processes, bodily fluids and medications exposure, and stringent cleanliness requirements [1, 2]. The bearing ring in a medical application must adhere to specific criteria and address unique challenges. Biocompatibility is critical, ensuring that the material used in the bearing ring does not cause adverse reactions or toxicity when in contact with living tissues. Additionally, the bearing ring must be compatible with sterilization methods commonly employed in medical settings [3-5].

Precision and performance are vital attributes for bearing rings in medical applications. The vital attributes must provide accurate and reliable rotation, allowing precise movements and measurements during medical procedures. The bearing ring should minimize noise and vibrations, ensuring patient comfort and facilitating proper diagnostic outcomes. Durability and longevity are essential in medical applications, as equipment and devices are often subjected to frequent use and demand conditions [6, 7]. The bearing ring should withstand the anticipated loads and forces, requiring minimal maintenance and replacement to ensure uninterrupted functionality. Regulatory compliance is another crucial aspect to consider in the medical field. Bearing rings must meet standards and regulations, such as biocompatibility certifications and adherence to industry-specific guidelines, to ensure patient safety and regulatory compliance [8-10].

The selection process for the best bearing ring in medical applications involves various challenges. The current challenges include validating biocompatibility, choosing the most suitable material, balancing performance requirements and cost considerations, ensuring a reliable supply chain, and addressing long-term stability and maintenance needs. Bearing rings in medical applications facilitates device and equipment's smooth and precise operation. The selection of the appropriate bearing ring requires careful consideration of biocompatibility, precision, durability, regulatory compliance, and various other factors. By overcoming the challenges associated with bearing ring selection, medical professionals and engineers can ensure the optimal performance, reliability, and safety of medical devices, ultimately contributing to improved patient care and outcomes. We use the MCDM methodology to deal with these various criteria [11-14].

The difficulty of precisely classifying every material under evaluation across various performance characteristics lead to the challenges in selection of the best material for bearing rings. The complex issue calls for a sophisticated material selection method that considers a wide range of variables and standards. Variations in actual operating circumstances and the possibility of unforeseen events can lead to uncertainty. The concerns impact the dependability of conventional material selection techniques. Furthermore, uncertainty arises when evaluating material test and assessment findings. Hence, the challenge is to choose the best material with the existence of comparable performance qualities. The study illustrate the use the neutrosophic set to deal with the uncertainty conditions [15-17].

The remainder of the paper is structured as follows: Section 2 shows the proposed methodology that will be used to rank the medical best bearing rings according to decision maker's perspectives. Section 3 introduces the results of numerical application with optimal ranking of alternatives to aid decision makers in the selection of best bearing rings. Section 4 presents the current challenges and analysis. Section 5 represents sensitivity analysis to examine how each input parameter affects the model's output. Section 6 represents managerial insights to show the effectiveness of the proposed study. Section 7 concludes the summary and the future work of the current study.

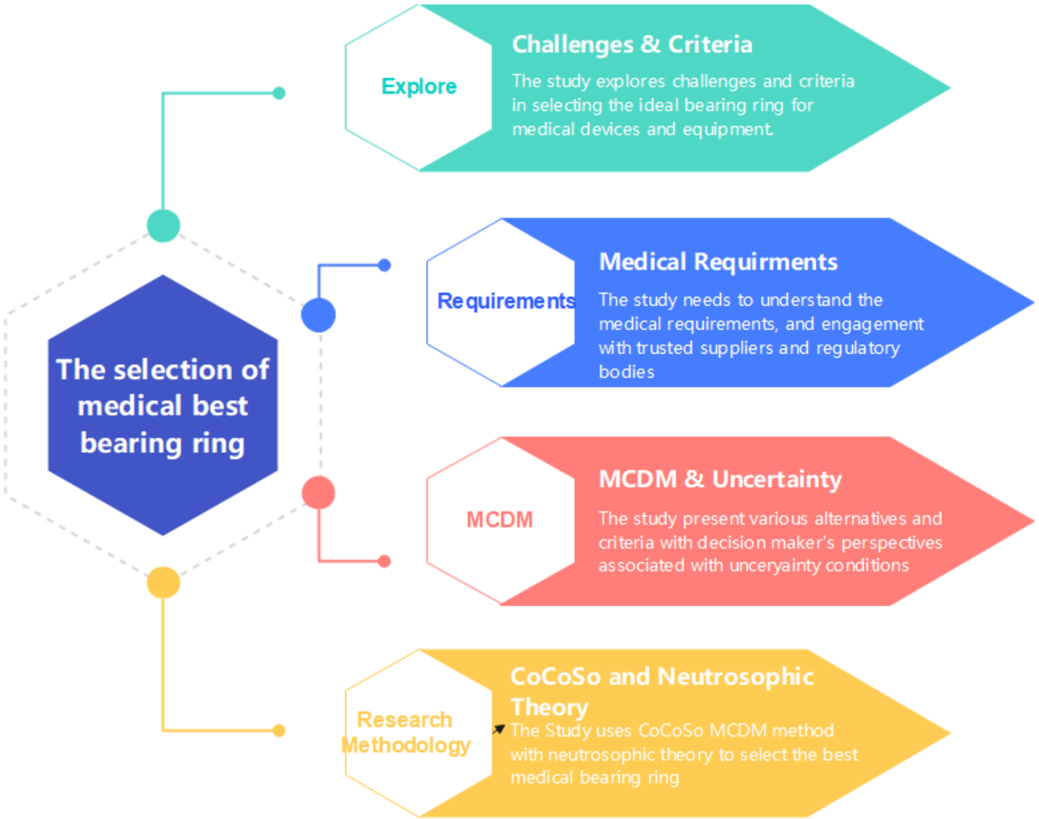

Figure 1. The model for selection of medical best bearing ring.

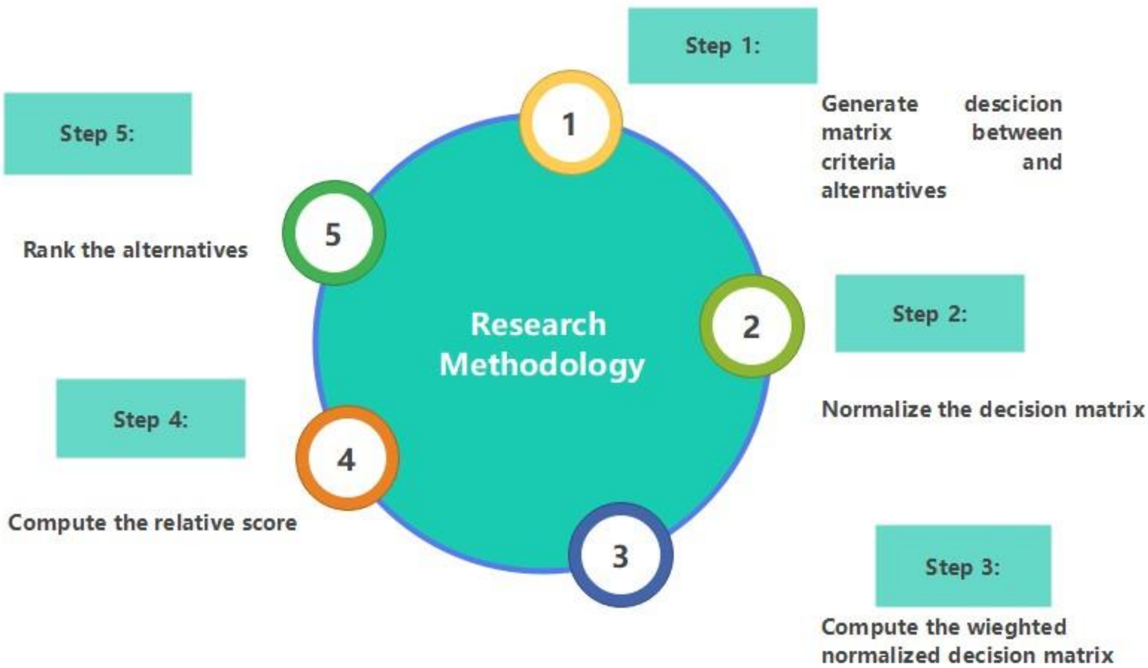

Figure 2. The phases of research methodology.

2 | Research Methodology

This section introduces some definitions of single valued neutrosophic set as:

Definition 1. Let Y be a space points with generic elements in A obtained by x. Neutrosophic set A in Y in donated by truth membership function $T_A(Y)$, indeterminacy membership function $I_A(Y)$, and falsity membership function $F_A(Y)$. The function $T_A(Y), I_A(Y), and\ F_A(Y)$ are subsets of $]-0,1+[$. where $T_A(Y) \rightarrow]-0,1+[, I_A(Y) \rightarrow]-0,1+[, and\ F_A(Y) \rightarrow]-0,1+[.$ $0 \leq \sup(T_A(Y) + \sup(I_A(Y) + \sup(F_A(Y) \leq 3)$.

Definition 2. Let Y be a space points with generic elements in A obtained by x. Neutrosophic set A in Y in donated by truth membership function $T_A(Y)$, indeterminacy membership function $I_A(Y)$, and falsity membership function $F_A(Y)$. The SVNS $A = \{< y, T_A(Y), I_A(Y), F_A(Y)\ > y \in Y\} T_A(Y), T_A(Y), T_A(Y) \in [0,1]$. $0 \leq T_A(Y) + I_A(Y) + F_A(Y) \leq 3$.

Definition 3. Let $y_1 = (T_1, I_1, F_1)\ and\ y_2 = (T_2, I_2, F_2)$ be SVNNs and

$y_1 \oplus y_2 = (T_1 + T_2 - T_1T_2, I_1I_2, F_1F_2)$

$y_1 \otimes y_2 = (T_1T_2, I_1 + I_2 - I_1I_2, F_1 + F_2 - F_1F_2)$

$\curlywedge y_1 = (1 - (1 - T_1)^{\curlywedge}, I_1^{\curlywedge}, F_1^{\curlywedge})$

$y_1^{\curlywedge} = \left(T_1^{\curlywedge}, (1 - I_1^{\curlywedge}), (1 - F_1^{\curlywedge})\right)$

Definition 4.

Commutative: $y_1 \cup y_2 = (T_1, I_1, F_1) \cup (T_2, I_2, F_2) = (T_2, I_2, F_2) \cup (T_1, I_1, F_1) = y_2 \cup y_1$

Idempotent:

$y_1 \cup y_1 = (T_1, I_1, F_1) \cup (T_1, I_1, F_1) = (T_1, I_1, F_1) = y_1$

$y_2 \cup y_2 = (T_2, I_2, F_2) \cup (T_2, I_2, F_2) = (T_2, I_2, F_2) = y_2$

$y_1 \cap y_1 = (T_1, I_1, F_1) \cap (T_1, I_1, F_1) = (T_1, I_1, F_1) = y_1$

$y_2 \cap y_2 = (T_2, I_2, F_2) \cap (T_2, I_2, F_2) = (T_2, I_2, F_2) = y_2$

Absorption: $y_1 \cup y_1 \cap y_2 = (T_1, I_1, F_1) \cup (T_1, I_1, F_1) \cap (T_2, I_2, F_2) = (T_1, I_1, F_1) = y_1$

De Morgan's Law:

$p(y_1 \cup y_2) = P\big((T_1, I_1, F_1) \cap (T_2, I_2, F_2)\big)$

$p(y_1 \cap y_2) = P\big((T_1, I_1, F_1) \cup (T_2, I_2, F_2)\big)$, where P is constant.

Involution: $P\big(P(y_1)\big) = P\left(P\big((T_1, I_1, F_1)\big)\right) = (T_1, I_1, F_1) = Y_1$, where P is constant.

In this study, the single valued neutrosophic CoCoSo method is used to select best bearing ring in the medical application [18-21]. Figure 1 shows model for selection of medical best bearing ring with analysis of criteria and challenges in uncertainty conditions, in addition to various decision maker's perspectives. The research methodology is used to rank the alternatives based on decision maker's perspectives. The neutrosophic set used to deal with uncertain and vague data [22-24]. This study used the below single valued neutrosophic numbers:

Linguistic variables	Single valued neutrosophic numbers
No Power	(0.00,1.00,1.00)
Very Low Power	(0.20,0.85,0.80)
Low Power	(0.40,0.65,0.60)
High Power	(0.60,0.35,0.40)
Very High Power	(0.80,0.15,0.20)

The proposed methodology is applied to select the most appropriate medical bearing rings as mentioned in Figure 2 according to the following steps:

Step 1: Generate the decision matrix between criteria and alternatives as presented in form (1):

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

Step 2: Normalize the decision matrix using Eq. (2):

$$no_{ij} = \frac{d_{ij} - \min_i d_{ij}}{\max_i d_{ij} - \min_i d_{ij}} \quad (2)$$

$$no_{ij} = \frac{\max_i d_{ij} - d_{ij}}{\max_i d_{ij} - \min_i d_{ij}} \quad (3)$$

Where $i = 1,2,3, \dots m; j = 1,2,3, \dots n$

Step 3: Compute the weighted normalized decision matrix as mentioned in Eqs. (4) and (5):

$$S_i = \sum_{j=1}^{n} \left(no_{ij} w_j \right) \quad (4)$$

$$P_i = \sum_{j=1}^{n} \left(no_{ij} \right)^{w_j} \quad (5)$$

Step 4: Compute the relative score as follows in in Eqs. (6-9):

$$\exists_{ia} = \frac{S_i + P_i}{\sum_{i=1}^{m} (S_i + P_i)} \quad (6)$$

$$\exists_{ib} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i} \quad (7)$$

$$\exists_{ic} = \frac{\nabla S_i + (1-\nabla) P_i}{\nabla \max_i S_i + (1-\nabla) \max_i P_i} \quad (8)$$

$$\exists_i = \frac{1}{3} (\exists_{ia} + \exists_{ib} + \exists_{ic}) + (\exists_{ia} \cdot \exists_{ib} \cdot \exists_{ic})^{\frac{1}{3}} \quad (9)$$

Where $\nabla = 0.5$

3 | Results

In this section, the proposed methodology is presented for the selection of the best bearing ring in the medical application. The study focused and gathered 16 criteria and ten alternatives as follows:

- **Material Compatibility**: The bearing ring material should be compatible with the medical environment, including any chemicals or substances that may contact. The bearing ring should resist corrosion, sterilization processes, and potential bodily fluids or medication reactions.
- **Biocompatibility:** In medical applications, it is crucial to ensure that the bearing ring material is biocompatible, that does not cause adverse reactions or toxicity when in contact with living tissues. The material should be approved for medical use and meet relevant standards and regulations.
- **Lubrication Requirements:** Consider the lubrication requirements of the bearing ring in the medical application. Some applications may require lubrication with specific types of lubricants, while others may need to be self-lubricating or operate without lubrication altogether.
- **Precision and Performance:** Medical applications often require high precision and performance. The bearing ring must provide smooth and accurate rotation with minimal friction, ensuring reliable operation and minimizing the risk of damage or wear.

- **Cleanliness and Sterility:** In medical environments, cleanliness and sterility are critical. The bearing ring should be easy to clean, sterilize, and maintain in a sterile condition to prevent the introduction of contaminants or infection risks.
- **Durability and Longevity**: The bearing ring should withstand the anticipated loads, forces, and operating conditions in the medical application. It should have a long lifespan and require minimal maintenance or replacement.
- **Noise and Vibration**: Depending on the specific medical application, noise and vibration levels may be important considerations. The bearing ring should minimize noise and vibrations that could interfere with sensitive medical procedures or patient comfort.
- **Cost:** While not compromising on quality and performance, the bearing ring's cost should also be considered, such as budget constraints and the overall value offered for the medical application.
- **Size and Dimensional Requirements:** The bearing ring should meet the necessary size and dimensional specifications for the specific medical device or equipment. In addition, the bearing ring should fit properly and integrate seamlessly into the overall design.
- **Load Capacity:** Evaluate the load capacity requirements for the bearing ring in the medical application. Consider factors such as expected axial and radial loads and any potential dynamic or static forces that the bearing will need to withstand.
- **Temperature and Environmental Conditions**: Assess the temperature and environmental conditions in which the bearing will operate. In medical applications, temperature control and stability are often necessary. The bearing ring should withstand the specific temperature range and environmental factors, such as humidity or exposure to sterilization processes.
- **FDA Compliance**: If the medical application falls under the purview of regulatory bodies such as the U.S. Food and Drug Administration (FDA), ensure that the selected bearing ring complies with the relevant regulations and standards. In addition, verify the material's biocompatibility and necessary certifications or documentation.
- **Manufacturing and Supply Chain Considerations:** Evaluate the bearing ring's manufacturing process and supply chain. Consider factors such as lead times, availability, and reliability of the supplier, as well as any potential impact on production timelines and costs.
- **Compatibility with Adjacent Components**: Consider the compatibility of the bearing ring with other components within the medical device or equipment. The bearing ring should integrate smoothly and work effectively with the surrounding system without causing interference or compatibility issues.
- **Maintenance and Serviceability:** Assess the bearing ring's ease of maintenance and serviceability. In some medical applications, routine maintenance or bearing replacement may be necessary. Choose a bearing ring that allows convenient access, inspection, and potential replacement without significantly disrupting the system.
- **Regulatory Compliance:** Ensure the selected bearing ring complies with all relevant regulations and standards applicable to the medical industry. This includes safety standards, quality control, and any specific industry requirements.

Generate the decision matrix between 16 criteria and 10 alternatives by Eq. (1).

Normalize the decision matrix by Eqs. (2) and (3) for cost and positive criteria as shown in Table 1.

Table 1. The normalization decision matrix.

	BRA_1	BRA_2	BRA_3	BRA_4	BRA_5	BRA_6	BRA_7	BRA_8	BRA_9	BRA_{10}
BRC_1	0.377652	0.282885	0.381895	1	0.381895	1	0.381895	0.531825	0	0.381895
BRC_2	0.47771	0.604398	0.345763	0.13111	0.02235	0.070874	0.604398	0	0.155372	1
BRC_3	1	0.478274	0.581432	0.478274	0.307909	0	0.312598	0.478274	0.307909	0.312598
BRC_4	0.821963	0.454243	0.272879	0.267887	1	0.272879	0	0.272879	0.460899	1
BRC_5	0.011609	0.271973	0.447761	0.996683	0.271973	1	0	0.996683	0.271973	0.271973
BRC_6	0.389785	1	0.837366	0.532258	0	0.68414	0.385753	0.389785	0.532258	0.532258
BRC_7	0	0.773451	0.380531	0.072566	0.384071	1	0.431858	0.19646	0.192212	0.495575
BRC_8	0.912607	0.39446	0.478032	0.478032	0.628462	0.478032	0	0.604585	0.683381	1
BRC_9	0.258581	0.243707	0.242563	0.243707	1	0.242563	0	0.393593	0.002059	0.243707
BRC_{10}	0.732323	0.732323	1	0.732323	0	1	1	0.555556	0.545455	0.545455
BRC_{11}	0.99375	0.325893	0.008929	0.345238	0.324405	0	1	0.008929	0.324405	0.008929
BRC_{12}	0.242563	1	0	0.242563	0.077803	0.242563	0	0.242563	0.258581	0.501144
BRC_{13}	1	0.46506	0.212851	0.359036	0	0.635341	0.46506	0.635341	0.460241	0.995181
BRC_{14}	0.244536	0.396175	0.396175	0.396175	0	0.027322	0.181694	0.396175	0.993169	1
BRC_{15}	0.530324	0.159379	0	0.530324	0.380818	1	0.953456	0.380818	0.380818	0.380818
BRC_{16}	0.999635	0.201607	0.013514	0.999635	0.201607	0.804237	0	1	0.395179	0.999635

We compute the weights of criteria by the mean method as shown in Figure 3. The regulatory is the least weight and material compatibility is the highest weight.

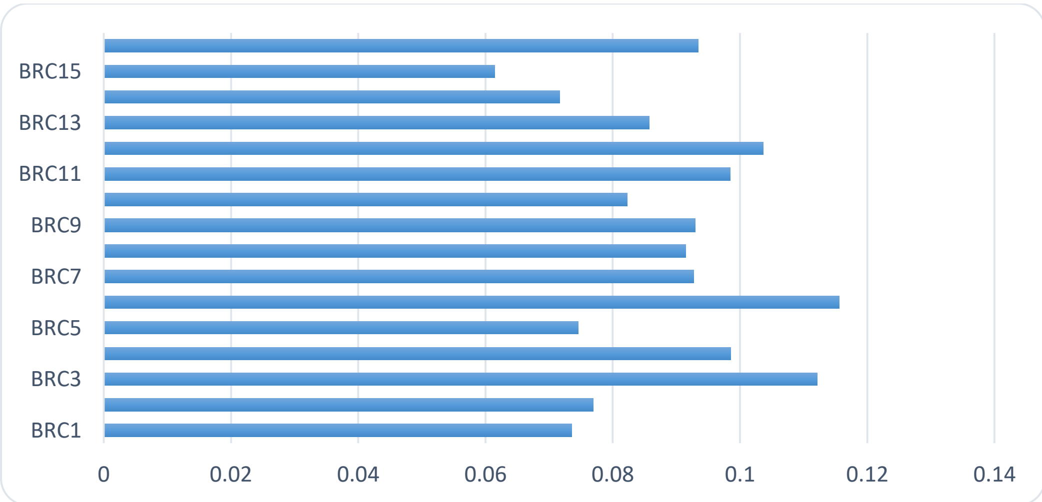

Figure 3. The weights of criteria of bearing rings material in medical application.

Compute the weighted normalized decision matrix as shown in Table 2 and 3 using Eqs. (4) and (5). Compute the relative score by Eqs. (6)-(9) as shown in Figure 4. We show the alternative 10 is the best and alternative 7 is the worst.

Table 2. The weighted sum normalization decision matrix.

	BRA_1	BRA_2	BRA_3	BRA_4	BRA_5	BRA_6	BRA_7	BRA_8	BRA_9	BRA_{10}
BRC_1	0.027774	0.020805	0.028086	0.073545	0.028086	0.073545	0.028086	0.039113	0	0.028086
BRC_2	0.036735	0.046476	0.026588	0.010082	0.001719	0.00545	0.046476	0	0.011948	0.076897
BRC_3	0.112189	0.053657	0.06523	0.053657	0.034544	0	0.03507	0.053657	0.034544	0.03507
BRC_4	0.081017	0.044772	0.026896	0.026404	0.098565	0.026896	0	0.026896	0.045428	0.098565
BRC_5	0.000866	0.020295	0.033412	0.074372	0.020295	0.07462	0	0.074372	0.020295	0.020295
BRC_6	0.045048	0.11557	0.096775	0.061513	0	0.079066	0.044582	0.045048	0.061513	0.061513
BRC_7	0	0.0717	0.035276	0.006727	0.035604	0.092701	0.040034	0.018212	0.017818	0.04594
BRC_8	0.083484	0.036085	0.04373	0.04373	0.057491	0.04373	0	0.055307	0.062515	0.091479
BRC_9	0.024053	0.022669	0.022563	0.022669	0.093018	0.022563	0	0.036611	0.000192	0.022669
BRC_{10}	0.060264	0.060264	0.082292	0.060264	0	0.082292	0.082292	0.045718	0.044887	0.044887
BRC_{11}	0.097871	0.032096	0.000879	0.034001	0.03195	0	0.098487	0.000879	0.03195	0.000879
BRC_{12}	0.025141	0.103647	0	0.025141	0.008064	0.025141	0	0.025141	0.026801	0.051942
BRC_{13}	0.085713	0.039862	0.018244	0.030774	0	0.054457	0.039862	0.054457	0.039449	0.0853
BRC_{14}	0.01753	0.028401	0.028401	0.028401	0	0.001959	0.013025	0.028401	0.071198	0.071688
BRC_{15}	0.032576	0.00979	0	0.032576	0.023392	0.061426	0.058567	0.023392	0.023392	0.023392
BRC_{16}	0.0934	0.018837	0.001263	0.0934	0.018837	0.075143	0	0.093434	0.036923	0.0934

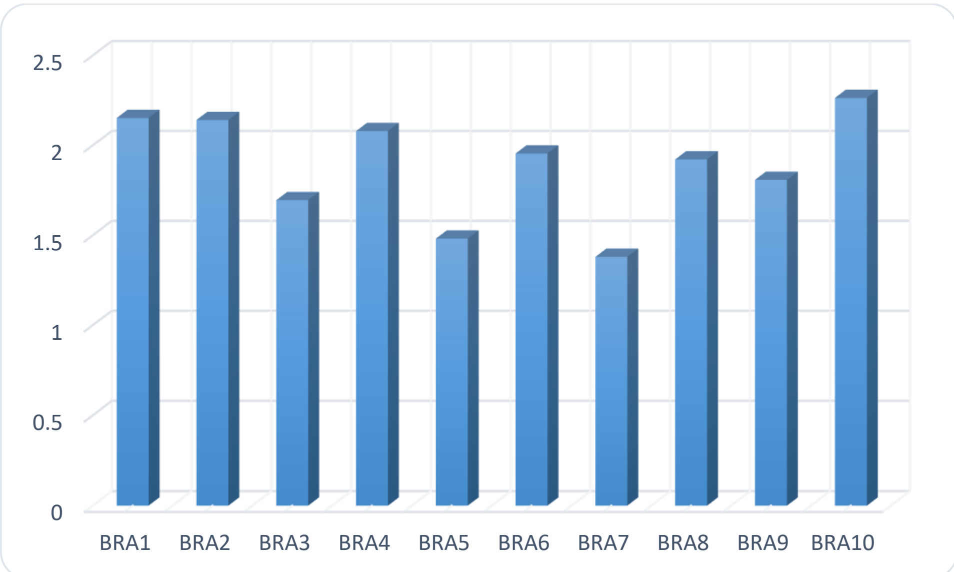

Figure 4. The relative score of alternatives.

Table 3. The weighted product normalization decision matrix.

	BRA_1	BRA_2	BRA_3	BRA_4	BRA_5	BRA_6	BRA_7	BRA_8	BRA_9	BRA_{10}
BRC_1	0.930888	0.911316	0.931653	1	0.931653	1	0.931653	0.954623	0	0.931653
BRC_2	0.944776	0.962021	0.921581	0.85536	0.746558	0.815841	0.962021	0	0.866601	1
BRC_3	1	0.920584	0.940978	0.920584	0.876207	0	0.877694	0.920584	0.876207	0.877694
BRC_4	0.980861	0.925168	0.879846	0.878246	1	0.879846	0	0.879846	0.926496	1
BRC_5	0.717124	0.907412	0.941805	0.999752	0.907412	1	0	0.999752	0.907412	0.907412
BRC_6	0.896833	1	0.979696	0.929711	0	0.957079	0.895756	0.896833	0.929711	0.929711
BRC_7	0	0.976467	0.914328	0.784132	0.915113	1	0.925115	0.859975	0.858235	0.936993
BRC_8	0.991669	0.918423	0.93471	0.93471	0.9584	0.93471	0	0.95501	0.965773	1
BRC_9	0.881781	0.876935	0.876551	0.876935	1	0.876551	0	0.916921	0.56251	0.876935
BRC_{10}	0.974689	0.974689	1	0.974689	0	1	1	0.952781	0.951343	0.951343
BRC_{11}	0.999383	0.895456	0.628318	0.900556	0.895053	0	1	0.628318	0.895053	0.628318
BRC_{12}	0.863453	1	0	0.863453	0.767459	0.863453	0	0.863453	0.869196	0.930898
BRC_{13}	1	0.936486	0.875805	0.915946	0	0.961867	0.936486	0.961867	0.93565	0.999586
BRC_{14}	0.903965	0.935779	0.935779	0.935779	0	0.772533	0.884919	0.935779	0.999509	1
BRC_{15}	0.961789	0.893323	0	0.961789	0.942422	1	0.997077	0.942422	0.942422	0.942422
BRC_{16}	0.999966	0.861028	0.668884	0.999966	0.861028	0.97985	0	1	0.91691	0.999966

4 | Challenges and Analysis

Selecting the best bearing ring for a medical application comes with several challenges. The common challenges are mentioned as follows:

- **Biocompatibility:** Ensuring the biocompatibility of the bearing ring material. The material must be safe for sake of use in the human body and should not cause any adverse reactions. Extensive testing and certifications may be required to validate the material's biocompatibility.

- **Material Selection:** Identifying the most suitable bearing ring material for a medical application can be challenging. A wide range of materials are available, each with its advantages and limitations. Factors such as compatibility with sterilization methods, corrosion resistance, and mechanical properties must be carefully considered.

- **Performance Requirements:** Medical applications often have stringent performance requirements. The bearing ring must provide precise and reliable rotation, even under demanding conditions. Meeting stringent performance criteria while maintaining biocompatibility and durability leads to a critical challenging issue.

- **Regulatory Compliance:** The medical industry is highly regulated, and compliance with relevant standards and regulations is essential. Selecting a bearing ring obtaining the necessary certifications can be time-consuming and complex.
- **Size and Space Limitations:** Medical devices and equipment often have space constraints. Finding a bearing ring that fits within the available space while still meeting the load capacity and performance requirements can be challenging.

5 | Sensitivity Analysis

Overcoming the current challenges requires a thorough understanding of the specific requirements of the medical application, close collaboration with experts, and careful evaluation of available options. Therefore, it is essential to work closely with suppliers, manufacturers, and regulatory bodies to address challenges and select the most suitable bearing ring for the medical application. A sensitivity analysis examines how each input measure's variation affects the model's output. It helps to prioritize the process of choosing the best options. It is considered that the model is accurate enough to replicate the system's behavior during a sensitivity analysis. A sensitivity analysis of the criteria ranking is carried out in this study. It shows how the ultimate ranking of the alternatives is influenced by the order in which the criteria are prioritized.

The study illustrates 11 random cases for the sensitivity analysis in order to produce effective and accurate results. The sensitivity analysis used to change the value in ∇ parameter to show different ranks [25]. The value of ∇ is presented with values between 0 and 1 to show the stability of the results. Figure 5 shows the different ranks under different values of ∇ parameter. The rank of alternative is showed stable under different values.

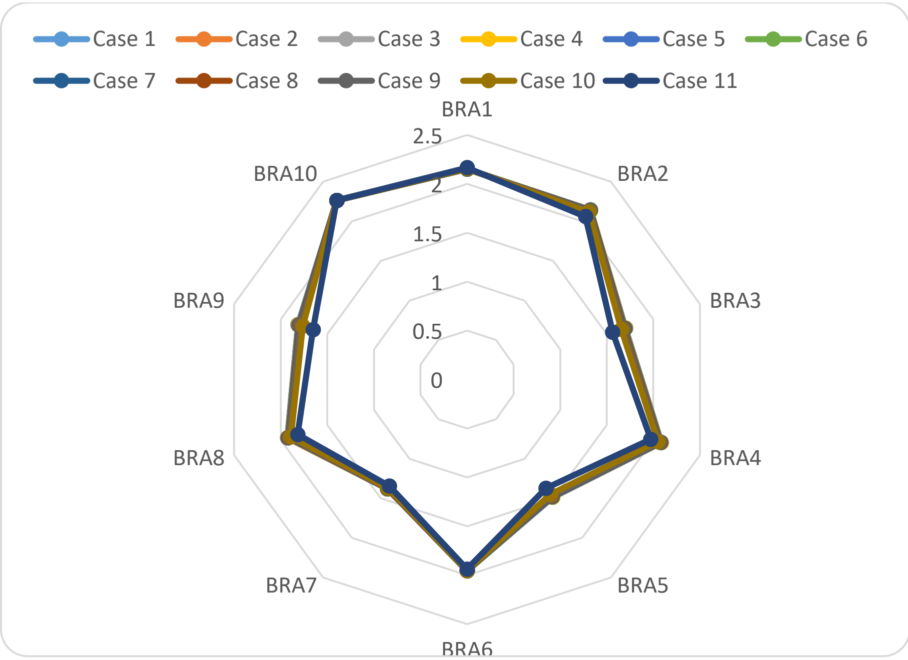

Figure 5. The rank of ten alternatives under different value in ∇ parameter.

6 | Managerial Insights

The study proposes a research methodology for selection of the best medical bearing rings. The research methodology is applied based on the current challenges and criteria to understand medical requirements that engagement with trusted suppler regulatory bodies [26] and [27]. The study handles various criteria and alternatives with different decision maker's perspectives with the existence of uncertainty conditions [28]. The research methodology integrates CoCoSo [29], as an MCDM method with neutrosophic theory to achieve the best medical bearing rings. Hence the proposed research is variable such that, other researchers can assign any decision judgments, criteria, and alternatives according to the case study and application. The proposed study not only evaluates criteria but also recommends the best alternatives to aid decision makers to achieve the best solutions. The proposed study can be used in many real problems. The study provides suitable accommodation of alternatives according to the decision maker's judgments to reach an optimum decision. Therefore, currently the proposed methodology is applicable, flexible, variant to a wide range of practical issues in addition to the ease of implementation in many applications.

7 | Conclusions

The selection the best bearing ring for medical applications is a complex process that requires careful consideration of multiple factors. The criteria discussed in this study provide a comprehensive guide for evaluating and choosing the most suitable bearing ring. Material compatibility, biocompatibility, lubrication requirements, precision, cleanliness, durability, noise and vibration control, size and dimension, load capacity, temperature and environmental conditions, regulatory compliance, manufacturing considerations, compatibility with adjacent components, maintenance, and serviceability are all crucial aspects to consider. The challenges faced in this process, including biocompatibility validation, material selection, performance requirements, regulatory compliance, size limitations, cost considerations, supply chain reliability, long-term stability, maintenance, expertise, and collaboration, highlight the intricacies of selecting the best bearing ring for medical applications.

By addressing the current challenges and thoroughly assessing the criteria, medical professionals and engineers can make informed decisions that ensure optimal performance, reliability, and safety in medical devices and equipment. Collaboration with experts, engagement with trusted suppliers, and compliance with regulatory standards are vital for successful bearing ring selection. The study presents a neutrosophic model for MCDM problem for the selection of appropriate medical bearing ring. The CoCoSo method is used as an MCDM method with neutrosophic theory to rank alternatives. The numerical case study recommends the alternative 10 is the best and alternative 7 is the worst to aid decision makers to achieve to the appropriate solutions. Future work could include the use of additional methodologies and technologies to analyze the challenges of bearing rings in medical sectors to attain sustainability and patient safety.

Acknowledgments

The author is grateful to the editorial and reviewers, as well as the correspondent author, who offered assistance in the form of advice, assessment, and checking during the study period.

Author Contributaion

All authors contributed equally to this work.

Funding

This research has no funding source.

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.

Conflicts 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.

References

[1] M. Mohorčič et al., "Surface with antimicrobial activity obtained through silane coating with covalently bound polymyxin B," Journal of Materials Science: Materials in Medicine, vol. 21, pp. 2775–2782, 2010.

[2] H. Xu, H. Pan, and J. Li, "Surface defect detection of bearing rings based on an improved YOLOv5 network," Sensors, vol. 23, no. 17, p. 7443, 2023.

[3] N. Gaaliche and D. A. Abdularahman, "A Fuzzy Logic Approach for Selecting Bearing Ring Materials in Pharmaceutical Applications," Available at SSRN 4633030.

[4] J. Stasiak, S. Nair, and G. D. Moggridge, "Mechanical strength of sutured block copolymers films for load bearing medical applications," Bio-medical materials and engineering, vol. 24, no. 1, pp. 563–569, 2014.

[5] S. Fox and R. W. Boyle, "Synthetic routes to porphyrins bearing fused rings," Tetrahedron, vol. 62, no. 43, pp. 10039–10054, 2006.

[6] S. Sutthasupa, M. Shiotsuki, and F. Sanda, "Recent advances in ring-opening metathesis polymerization, and application to synthesis of functional materials," Polymer journal, vol. 42, no. 12, pp. 905–915, 2010.

[7] J. W. Stansbury, "Ring-opening polymerization of a 2-methylene spiro orthocarbonate bearing a pendant methacrylate group," ACS Publications, 1994.

[8] M. Z. Ma et al., "Wear resistance of Zr-based bulk metallic glass applied in bearing rollers," Materials Science and Engineering: A, vol. 386, no. 1–2, pp. 326–330, 2004.

[9] R. Hauert, "An overview on the tribological behavior of diamond-like carbon in technical and medical applications," Tribology International, vol. 37, no. 11–12, pp. 991–1003, 2004.

[10] Z. Yu, M. Wang, X. Chen, S. Huang, and H. Yang, "Ring-Opening Metathesis Polymerization of a Macrobicyclic Olefin Bearing a Sacrificial Silyloxide Bridge," Angewandte Chemie International Edition, vol. 61, no. 2, p. e202112526, 2022.

[11] D. K. Tripathi, S. K. Nigam, P. Rani, and A. R. Shah, "New intuitionistic fuzzy parametric divergence measures and score function-based CoCoSo method for decision-making problems," Decision Making: Applications in Management and Engineering, vol. 6, no. 1, pp. 535–563, 2023.

[12] M. Yazdani, Z. Wen, H. Liao, A. Banaitis, and Z. Turskis, "A grey combined compromise solution (CoCoSo-G) method for supplier selection in construction management," Journal of Civil Engineering and Management, vol. 25, no. 8, pp. 858–874, 2019.

[13] A. Barua, S. Jeet, D. K. Bagal, P. Satapathy, and P. K. Agrawal, "Evaluation of mechanical behavior of hybrid natural fiber reinforced nano sic particles composite using hybrid Taguchi-CoCoSo method," International Journal of Innovative Technology and Exploring Engineering, vol. 8, no. 10, pp. 3341–3345, 2019.

[14] V. Choudhary and A. Mishra, "Analyzing the critical success enablers of industry 4.0 using hybrid fuzzy AHP–CoCoSo method," Journal of Industrial Integration and Management, vol. 7, no. 04, pp. 493–514, 2022.

[15] R. Mohamed and M. M. Ismail, "Harness Ambition of Soft Computing in Multi-Factors of Decision-Making Toward Sustainable Supply Chain in the Realm of Unpredictability," Multicriteria Algorithms with Applications, vol. 2, pp. 29–42, 2024.

[16] A. H. Abdel-aziem, H. K. Mohamed, and A. Abdelhafeez, "Neutrosophic Decision Making Model for Investment Portfolios Selection and Optimizing based on Wide Variety of Investment Opportunities and Many Criteria in Market," Neutrosophic Systems with Applications, vol. 6, pp. 32–38, 2023.

[17] K. M. Sallam and A. W. Mohamed, "Single Valued Neutrosophic Sets for Assessment Quality of Suppliers under Uncertainty Environment," Multicriteria Algorithms with Applications, vol. 1, no. 1, pp. 1–10, 2023.

[18] M. Qiyas, M. Naeem, S. Khan, S. Abdullah, T. Botmart, and T. Shah, "Decision support system based on CoCoSo method with the picture fuzzy information," Journal of Mathematics, vol. 2022, pp. 1–11, 2022.

[19] H. Lai, H. Liao, Y. Long, and E. K. Zavadskas, "A hesitant Fermatean fuzzy CoCoSo method for group decision-making and an application to blockchain platform evaluation," International Journal of Fuzzy Systems, vol. 24, no. 6, pp. 2643–2661, 2022.

[20] G. Demir, M. Damjanović, B. Matović, and R. Vujadinović, "Toward sustainable urban mobility by using fuzzy-FUCOM and fuzzy-CoCoSo methods: the case of the SUMP podgorica," Sustainability, vol. 14, no. 9, p. 4972, 2022.

[21] S. J. Ghoushchi, S. M. Jalalat, S. R. Bonab, A. M. Ghiaci, G. Haseli, and H. Tomaskova, "Evaluation of wind turbine failure modes using the developed SWARA-CoCoSo methods based on the spherical fuzzy environment," IEEE Access, vol. 10, pp. 86750–86764, 2022.

[22] M. Ali and F. Smarandache, "Complex neutrosophic set," Neural computing and applications, vol. 28, pp. 1817–1834, 2017.

[23] N. El-Hefenawy, M. A. Metwally, Z. M. Ahmed, and I. M. El-Henawy, "A review on the applications of neutrosophic sets," Journal of Computational and Theoretical Nanoscience, vol. 13, no. 1, pp. 936–944, 2016.

[24] R. Şahin and A. Küçük, "Subsethood measure for single valued neutrosophic sets," Journal of Intelligent & Fuzzy Systems, vol. 29, no. 2, pp. 525–530, 2015.
[25] M. Elshahawy, N. A Nabeeh, A. Aboelfetouh, H. M El-Bakr. Neutrosophic model for vehicular malfunction detection. Neutrosophic Sets and Systems, Vol. 53.2023.
[26] I. Emovon, O. S. Oghenenyerovwho. Application of MCDM method in material selection for optimal design: A review, Results in Materials, Volume 7, 2020, 100115, ISSN 2590-048X, https://doi.org/10.1016/j.rinma.2020.100115., 2020.
[27] S. Sangli, A. Raj, N. Aravind, S. Ranganathan Selection of suitable material for journal bearing by tribology Int. J. Recent Technol. Eng., 8. 2020.
[28] R. Yadav, H.H. Lee. Ranking and selection of dental restorative composite materials using FAHP-FTOPSIS technique: an application of multi criteria decision making technique J. Mech. Behav. Biomed. Mater., 132 , Article 105298, 2022.
[29] M. Yazdani ,P.Zarate , E. Zavadskas . A combined compromise solution (CoCoSo) method for multi-criteria decision-making problems. Management Decision ISSN: 0025-1747, 2018.