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Risk Management for Smart Healthcare System: A Hybrid MCDM Framework

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Smart healthcare management systems (SHMS) play a vital role in medical centers. SHMS has various risks and threats that affect patient care. So, risk management is the best choice to identify and mitigate these risks. This study proposed a multi-criteria decision-making (MCDM) framework for identifying risks in SHMS and selecting the best project in SHMS to reduce risks. This study used the MCDM method to deal with conflict criteria. There are two MCDM methods: CRiteria Importance Through Intercriteria Correlation (CRITIC) and Additive Ration Assessment (ARAS). The CRITIC approach is used to compute the criteria weights, and the ARAS algorithm is used to select the appropriate projects in SHMS. The neutrosophic set (NS) was applied with MCDM methods to deal with inconsistent data in the evaluation process. The results show the Health Data Informational System project is the best. Sensitivity analysis was conducted to show the stability of the rank. The comparative study was conducted to show the effectiveness of the proposed methodology. The outcomes demonstrate the rank of projects is stable through all scenarios, and the proposed methodology is effective compared with others MCDM methods.

Keywords: *risk management, portfolio management, smart healthcare, neutrosophic set, MCDM*

Introduction

The increasing population worldwide faces the development of recent technologies in medical centers and healthcare organizations. People need demands of medical care and a better quality of life (Yang et al. 2020). So, medical centers and healthcare systems are essential to provide solutions for improving patient care. Various medical centers have developed smart healthcare management systems (SHMS) to aid them in medical processes, operations, and healthcare assignments and activities. SHMS has multiple risks faced by various resources. So, risk management is used to identify and reduce these risks (Yang et al. 2022). So, choosing the greatest SHMS is a decision-making issue. This problem has various criteria and alternatives.

Fuzzy set (FS) deals with uncertainty and vague information. The intuitionistic fuzzy set (IFS) generalizes FS as membership and non-membership degrees. IFS cannot deal with indeterminate information and only deals with ambiguous data. The neutrosophic set (NS) was generalized with three degrees: truth, indeterminacy, and falsity membership degrees (Broumi et al. 2018, Wang et al. 2010). NS is a generalization of classical fuzzy set and their extensions. Ns were applied in various decision-making problems like transportation systems (Nabeeh 2023), evaluating students' performance (Adebisi & Broumi 2024), heart disease (El-Douh et al. 2023a),

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evaluating the quality of suppliers (Sallam & Mohamed 2023), and evaluating health sustainability (El-Douh et al. 2023b).

The single-valued neutrosophic sets (SVNSs) are a subset of NS that deal with vague and uncertain information. SVNSs are integrated with a multi-criteria decision-making method to overcome uncertain information. MCDM deals with conflicting criteria (Aruldoss et al. 2013).

The CRiteria Importance Through Intercriteria Correlation (CRITIC) approach was applied to obtain the weights of the criteria. the feature weights are obtained by applying a decision matrix instead of a pairwise comparison matrix. The CRITIC method is applied to decision-making problems. The CRITIC method has various benefits such as no need for independence of criteria and qualitative criteria can be converted to quantitative criteria (Alinezhad & Khalili 2019).

The Additive Ration Assessment (ARAS) method was introduced in 2010 as an MCDM algorithm to show the greatest alternatives from various projects. The ARAS algorithm was applied to decision-making problems to rank the projects. The ARAS algorithm ranks the alternatives based on the utility degree of every alternative. The ARAS method has various benefits: it is the compensatory method, converts the qualitative criteria into quantitative criteria, and the criteria are independent (Liu & Xu 2021).

This study proposed a decision-making methodology for risk management in the healthcare system by identifying criteria and alternatives. The CRITIC method is used to obtain criteria weights. The ARAS approach is applied to rank the other options. The neutrosophic set integrated with MCDM methods to overcome uncertainty in the evaluation process.

Risk Management

Risk management is the process of controlling and managing risks by performing some criteria like identifying, evaluating, and controlling risks. Risks in systems and organizations come from various sources like financial uncertainties, strategic risks, and technology risks. Risk management can identify the relationship between various elements of systems and organizations and show effects on systems goals. Risk management aims to minimize the risks and preserve the safety and value of the system by making a smart system (Akindote et al. 2024).

The healthcare system faces various risks that affect system performance and patient health. Risk management can control risks to improve patient care. Patient information can be attacked by attackers across all systems. Hence, this information must be preserved and maintained. The risks of patients in healthcare systems can be controlled by risk management healthcare. Risk management can be developed, implemented, and processed to address risks in healthcare to reduce and overcome these risks. Healthcare staff and managers must cooperate to face the risks in healthcare to provide risk management (Niv & Tal 2024).

Risk management in healthcare can identify, evaluate, and minimize the risks to patients, visitors, staff, and organizational assets. Risk management in healthcare can control and mitigate risks through various staff, such as healthcare practitioners, and cybersecurity systems to protect health data. Risk management in healthcare systems aims to identify potential risks and take all necessary measures to reduce and mitigate them.

There are five basic steps in risk management in healthcare systems: establishing context, identifying, analyzing, evaluating, and managing risks. In this study, we identify some of the risks in healthcare systems: threats and patient care. Then, we analyze and evaluate these risks using MCDM methods to show the highest and most minor importance. Then, these risks are reduced by developing four projects and selecting the best one to minimize these risks.

Portfolio Management

Portfolio management chooses, ranks, and controls programs and projects for organizations and systems using strategic objectives. Portfolio management aims to show the strengths, weaknesses, opportunities, and risks and how to develop a project to overcome these risks. There are various strategic management programs and projects in healthcare systems to obtain all objects. Portfolio management can aid in ranking projects in healthcare systems to show their goals and impacts, increase and improve the value of projects and programs, and how these projects affect patient care (Elsayed et al. 2024, Odeyemi et al. 2024).

Implementing Portfolio management in healthcare systems and organizations can improve the system's ability to obtain patient care and improve management effectiveness. The projects and programs can enhance patient care in the healthcare system. This study developed four projects in Portfolio management to show the best project to reduce risks in healthcare systems and improve safety and patient care.

Contributions of this Study

The contributions are:

- This study proposed a framework for risk management in healthcare systems and portfolio management.
- This study meticulously identifies a comprehensive set of risks in healthcare and evaluates them using the rigorous MCDM methods, specifically the CRITIC method for computing the weights of criteria.
- This study identifies a set of projects in healthcare to minimize the risk in healthcare by applying MCDM to select the best project to reduce risks. The ARAS method ranks the alternatives (projects) and selects the best project.
- This study used the NS to deal with the uncertainty in assessment criteria and alternatives. The neutrosophic set is integrated with MCDM methods like CRITIC and ARAS.
- The sensitivity and comparative analysis were performed in this work. A sensitivity analysis was performed to display the stability of the ranking of alternatives. The comparative analysis shows the effectiveness of the proposed methods compared with other MCDM methods

Literature Review

This section shows the previous studies on risk management in healthcare systems. Healthcare systems are affected by the innovative and recent technology to select the best quality care in complex systems. Risk management is used to do a complete analysis to uncover the root cause of adverse events.

Cagliano et al. (2011) presented a systematic methodology to introduce the risks and their impacts on healthcare and patients in medical centers. They introduced the human reliability evaluation steps with elements of healthcare systems. Their methodology can minimize the risks and waste and enhance healthcare organizations and systems to obtain risk management. They applied their methodology to pharmacy systems.

Mendes and França (2024) analyzed the literature to discuss risk management in healthcare systems. Healthcare systems are faced with various issues like high costs and low-efficiency inpatient services. Healthcare management systems are the best solution to improve patient service quality, minimize risks, and minimize costs. They found that risk management can improve patient safety and services, employee safety, the importance of criteria to reduce risks, and combinations of tools and methods to improve healthcare systems.

Bunting Jr & Groszkruger (2016) introduced the transition into the focus on detecting errors and recommendations to improve healthcare systems. They introduced risk managers and other healthcare personnel to enhance healthcare systems.

La Pietra et al. (2005) provided an overview of the problems in healthcare systems. They discuss how to detect medical errors and clinical risk management to improve and increase patient safety. Their methodology uses better organizational performance to obtain better results. Various strategies, such as technology, communication, and information accessibility, can reduce risks and improve patient safety in healthcare systems.

Verbano and Venturini (2011) identified and characterized new directions for developing academic and managerial literature. Their methodology can aid risk management in identifying the most suitable directions. They applied their risk management to supply chain healthcare systems. Parker (2009) provided a framework to aid healthcare organizations in evaluating potential usefulness. Evaluating safety culture in risk management is essential to maximizing the interests of healthcare organizations. They applied his methodology in patient safety to evaluate the safety culture. His methodology covered various criteria of safety culture and five levels of safety.

Tukamuhabwa et al. (2023) provided a framework for exploring the link between supplier performance and other criteria, such as supply chain risk management abilities, logistic abilities, and internal social capital. They found that internal capital and supply chain risk management are significant for supplier performance. Ksibi et al. (2023) provided a complete review of the Internet of Medical Things (IoMT) and discussed the common risk evaluation approaches. Their proposed methodology improves trust and helps with risk exposure. It was built based on risk assessment and is applied in the risk assessment e-health context. Cybersecurity risk evaluation methods are deployed in various systems and organizations.

Ordunez et al. (2023) proposed a framework to minimize risk management in healthcare. They provide their methodology for enhancing the accuracy of blood pressure measurement. Their methods provide a set of solutions to create a more effective health system.

Proposed Methodology

This section presents the steps of the neutrosophic approach integrated with two MCDM methods: CRITIC and ARAS. Single-Valued Neutrosophic Sets (SVNS) are employed to handle the uncertainty associated with the evaluation factors and alternatives. Figure 1 illustrates the proposed methodology. Additionally, this section provides key definitions related to SVNS. (Peng & Dai 2018):

Definition 1: The neutrosophic set has three elements such as truth \ $\left(A_T(x)\right)$, indeterminacy $A_I(x)$, and falsity $A_F(x)$. The sum of the three elements should be as

$$0 \leq \sup A_T(x) + \sup A_I(x) + \sup A_F(x) \leq 3 \quad (1)$$

Definition 2: SVN N can be presented as:

$$N = \{< x, T_N(x), I_N(x), F_N(x) > | x \in X \} \quad (2)$$

Definition 3: Let two SVNNs as $x = (T_x, I_x, F_x)\ and\ y = \left(T_y, I_y, F_y\right)$ Then their operations are presented as:

$$x^c = (F_x, 1 - I_x, T_x) \quad (3)$$

$$x \cup y = \left(\max\{T_x, T_y\}, \min\{I_x, I_y\}, \min\{F_x, F_y\}\ \right) \quad (4)$$

$$x \cap y = \left(\min\{T_x, T_y\}, \max\{I_x, I_y\}, \max\{F_x, F_y\}\ \right) \quad (5)$$

$$x \oplus y = \left(T_x + T_y - T_x * T_y, I_x * I_y, F_x * F_y\right) \quad (6)$$

$$x \otimes y = \left(T_x * T_y, I_x + I_y - I_x * I_y, F_x + F_y - F_x * F_y\right) \quad (7)$$

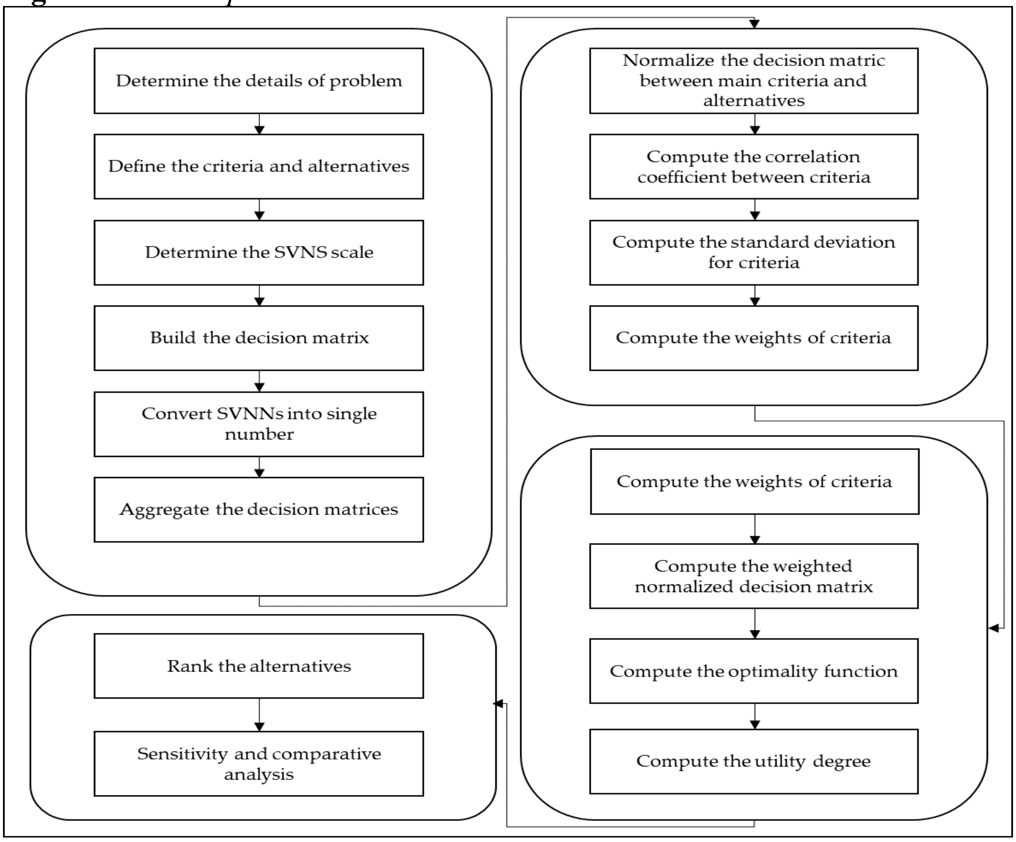
$$\leftthreetimes x = (1 - (1 - T_x)^{\leftthreetimes}, (I_x)^{\leftthreetimes}, 1 - (F_x)^{\leftthreetimes}\ ), \leftthreetimes > 0 \quad (8)$$

$$x^{\rightthreetimes} = \left((T_x^{\rightthreetimes}), (1 - I_x)^{\rightthreetimes}, (1 - F_x)^{\rightthreetimes}\ \right) \rightthreetimes > 0 \quad (9)$$

Definition 4: The score function of SVN can be computed as:

$$S(x) = \frac{2}{3} + \frac{T_x}{3} - \frac{I_x}{3} - \frac{F_x}{3} \quad (10)$$

Figure 1. *The Proposed Framework*



SVN-CRITIC-ARAS Method

This part introduces the steps of the SVN-CRITIC approach to obtain the weights of factors.

Step 1. Determine the details of the problem

This step studies the problem and computes all details of the problem. Define the main criteria to affect the selection of the best alternatives. Experts are invited to assess the factors and options. These experts have expertise in the risk management field and details of these experts are shown in Table 1. We define the criteria and alternatives and data is collected to assess the factors and options.

Step 2. Define the criteria and alternatives

The criteria and alternatives are determined based on previous studies and relevant literature. The opinions of experts are used to evaluate the factors and options. The factors of this work are defined as: $MMC_j = (MMC_1, MMC_2, \dots, MMC_n)\ with\ j = 1,2,\dots,n$. The weights of the criteria are defined as $W_j = (w_1, w_1, \dots, w_n); w_j > 0;\ \sum_{j=1}^{n} w_j = 1$. The set of alternatives are defined as $MMA_i = (MMA_1, MMA_2, \dots, MMA_m)\ with\ i = 1,2,\dots,m$.

Step 3. Determine the SVNS scale

Define the set of SVNS linguistic terms and their single-valued neutrosophic numbers (SVNNs). These terms are used by experts to assess the factors, compute the factors' weights, and the best alternatives.

Step 4. Build the assessment matrix

The decision matrices are built between factors and options by a set of experts.

$$X = \begin{bmatrix} (T_{x_{11}}, I_{x_{11}}, F_{x_{11}}) & \cdots & (T_{x_{1n}}, I_{x_{1n}}, F_{x_{1n}}) \\ \vdots & \ddots & \vdots \\ (T_{x_{m1}}, I_{x_{m1}}, F_{x_{m1}}) & \cdots & (T_{x_{mn}}, I_{x_{mn}}, F_{x_{mn}}) \end{bmatrix}_{m \times n} \quad (11)$$

Step 5. Convert SVNNs into a single number

The score function is applied to obtain one number.

Step 6. Aggregate the decision matrices

The decision matrices between criteria and alternatives are aggregated into a single matrix.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}_{m \times n} \quad (12)$$

Step 7. Normalize the decision matrix between the main criteria and alternatives.

$$NX_{ij} = \frac{x_{ij} - x_{worst}}{x_{best} - x_{worst}}; i = 1,2,..,m; j = 1,2,\dots,n \quad (13)$$

Where $x_{worst} = \min x_i$ *and* $x_{best} = \max x_i$.

Step 8. Compute the correlation coefficient between criteria

$$CC_{jk} = \frac{\sum_{i=1}^{m}(NX_{ij} - \overline{NX_j})(NX_{ik} - \overline{NX_k})}{\sqrt{\sum_{i=1}^{m}(NX_{ij} - \overline{NX_j})^2 \sum_{i=1}^{m}(NX_{ik} - \overline{NX_k})^2}} \quad (14)$$

Where $\overline{NX_j}$ can be computed as:

$$\overline{NX_j} = \frac{1}{n}\sum_{j}^{n} x_{ij}, i = 1,2,\dots,m \quad (15)$$

Step 9. Compute the standard deviation for criteria

$$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(NX_{ij} - \overline{NX_j})^2}, i = 1,2,..,m; j = 1,2,\dots,n \quad (16)$$

And compute the amount of information for the criteria

$$R_j = \sigma_j \sum_{k=1}^{n}(1 - CC_{jk}), j = 1,2,\dots,n \quad (17)$$

Step 10. Compute the weights of the criteria

$$w_j = \frac{R_j}{\sum_{j=1}^{n} R_j} \quad (18)$$

Step 11. Compute the normalized decision matrix by ARAS method

$$U_{ij}^* = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (19)$$

Step 12. Compute the weighted normalized decision matrix

$$L_{ij} = U_{ij}^* w_j \quad (20)$$

Step 13. Compute the optimality function

$$O_i = \sum_{j=1}^{n} L_{ij} \quad (21)$$

Step 14. Compute the utility degree

$$T_i = \frac{O_i}{E_0} \quad (22)$$

Where E_0 is the optimality value of O_i.

Step 15. Rank the projects.

The options are ordered based on the larger number of T_i.

Table 1. *Information of Experts in this Study*

	Experience	Field	Academic degree
Expert 1	30	Industry	PhD
Expert 2	15	Industry	M.SC
Expert 3	28	Industry	PhD
Expert 4	17	Academia	M.SC
Expert 5	25	Academia	PhD
Expert 6	20	Academia	M.SC

Results and Discussion

The main aim of this section is to apply the proposed methodology steps to obtain the weights of criteria and rank the alternatives. Figure 2 shows the criteria and alternatives of this study. This study used four alternatives:

Pro1: Device and Drug Management System

This project aims to digitalize medical products to enhance the effectiveness of the asset inventory and to minimize the number of duplicate data. This project has assets systems and materials systems.

Pro2: Health Operation Management System

This project aims to offer patients high-quality inpatient care. This project has a testing system, remote home care, and smart wards.

Pro3: Health Data Informational System

This project aims to combine information into computer hardware network communication and software. So, all information can be shared across all medical centers. This project has various benefits like cyber security, big data analysis, and artificial intelligence models.

Pro4: Health Administrative Information System

This project aims to combine various systems like administrative management, financial management, medical centers, medical administrative, and medical centers.

Step 1. The problem is determined, and all information is collected. The main aim of this study is to select the best SHMS with fewer risks. Six experts were identified as shown in Table 1.

Step 2. The set of criteria and alternatives are defined in this step as shown in Figure 2.

Step 3. Nine terms with their SVNNs are determined to evaluate the criteria and alternatives. These terms are used by experts and decision-makers to obtain the weights of criteria and rank the alternatives.

Step 4. The decision matrices between criteria and alternatives are built by Eq. (11) through six experts. These experts used the information in Table 1 to assess the factors and options. Table 2 shows the decision matrices between criteria and alternatives and Table 3 shows other opinions of experts.

Step 5. The SVNNs are converted by using the score function to obtain a single value.

Step 6. Combined the decision matrices into a single matrix.

Step 7. The normalized assessment matrix is obtained by Eq. (13) as presented in Table 4. There are only three criteria that are worst operation cost, investment cost, and maintenance cost and other criteria are best.

Step 8. The correlation coefficient between criteria is obtained by Eq. (14).

Step 9. The standard deviation of every criterion is computed by Eq. (16). The amount of information for the main criteria is obtained by Eq. (17).

Step 10. The weights of the criteria are obtained by Eq. (18) as shown in Figure 3.

Step 11. We applied the steps of the SVN-ARAS method to rank the alternatives. The normalized decision matrix is obtained by Eq. (19) as presented in Table 5.

Step 12. The weighted normalized assessment matrix is obtained by Eq. (20) as presented in Table 6.

Step 13. The optimality function is obtained by Eq. (21).

Step 14. The utility degree is obtained using Eq. (22).

Step 15. The rank of the alternatives is shown in Figure 4.

Figure 2. *The Criteria and Alternatives of this Study*

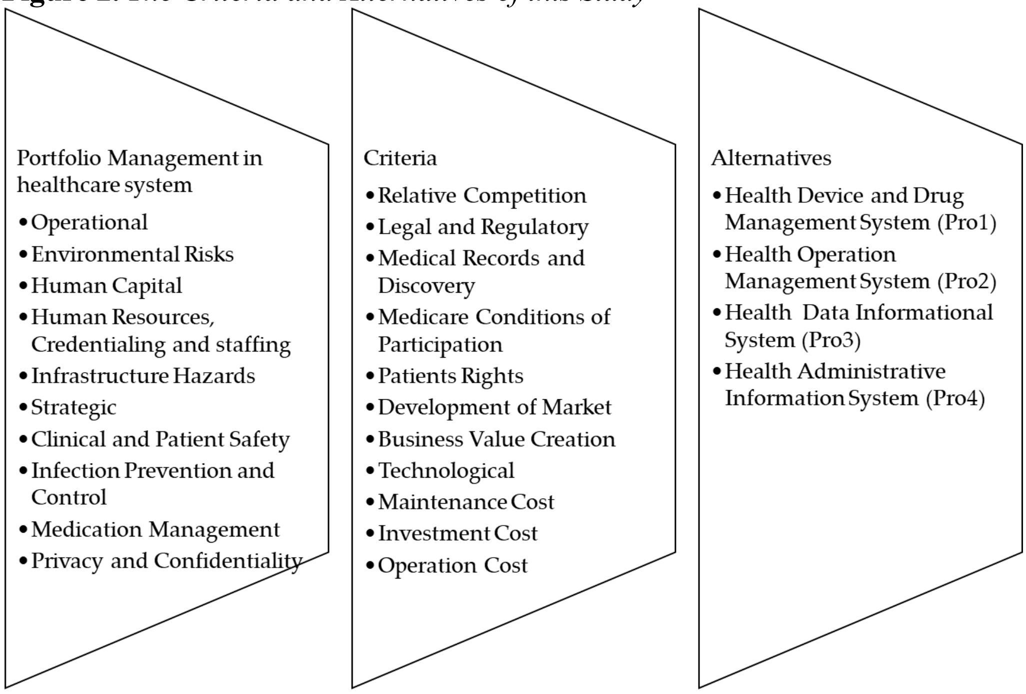


Figure 3. *The Weights of the Main Criteria*

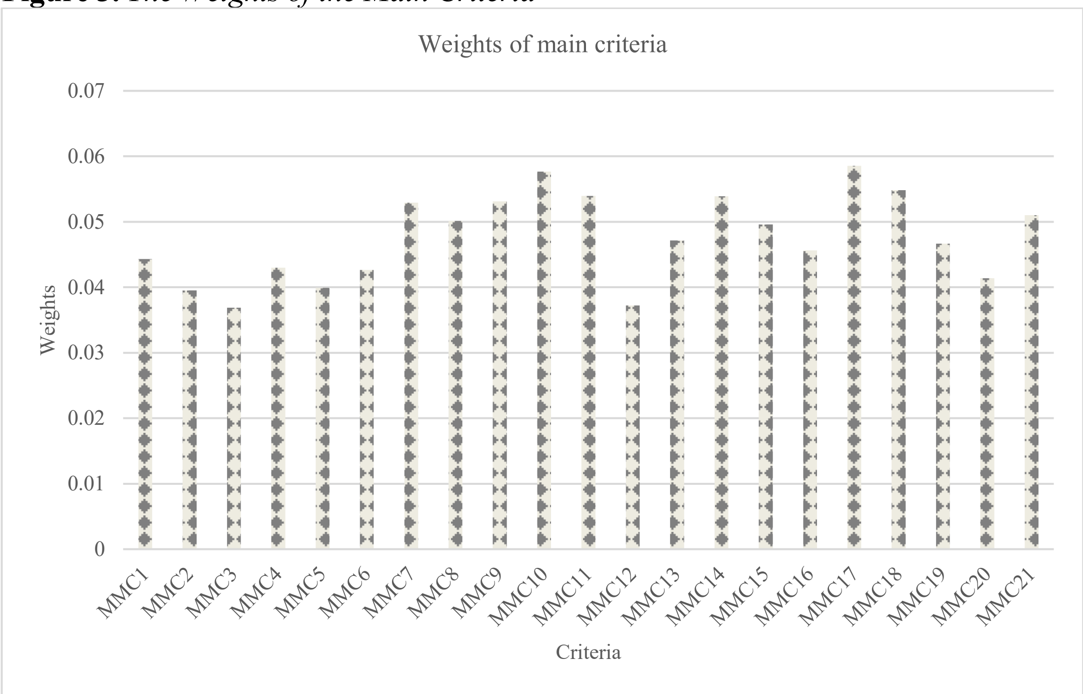


Figure 4. *The Utility Degree Values*

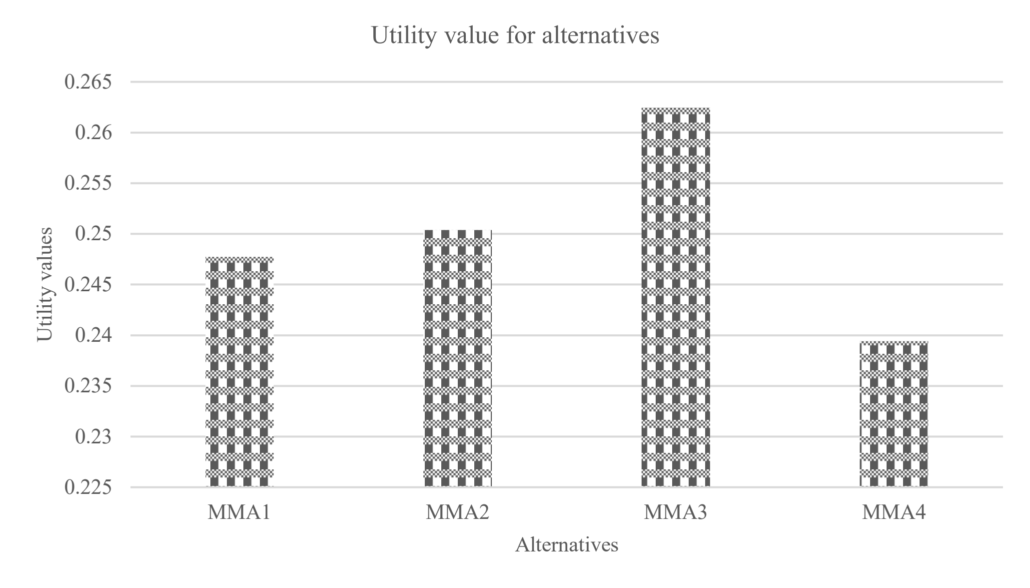


Table 2. *Decision Matrices by Opinions of First Experts*

	MMA_1	MMA_2	MMA_3	MMA_4
MMC_1	(0.9,0.1,0.2)	(0.5,0.5,0.5)	(0.9,0.1,0.2)	(0.1,0.9,0.9)
MMC_2	(0.8,0.2,0.3)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.2,0.8,0.9)
MMC_3	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.3,0.7,0.8)
MMC_4	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.6,0.4,0.5)	(0.5,0.5,0.5)
MMC_5	(0.6,0.4,0.5)	(0.9,0.1,0.2)	(0.5,0.5,0.5)	(0.4,0.6,0.7)
MMC_6	(0.5,0.5,0.5)	(0.3,0.7,0.8)	(0.4,0.6,0.7)	(0.3,0.7,0.8)
MMC_7	(0.5,0.5,0.5)	(0.3,0.7,0.8)	(0.4,0.6,0.7)	(0.2,0.8,0.9)
MMC_8	(0.4,0.6,0.7)	(0.4,0.6,0.7)	(0.3,0.7,0.8)	(0.1,0.9,0.9)
MMC_9	(0.3,0.7,0.8)	(0.4,0.6,0.7)	(0.2,0.8,0.9)	(0.9,0.1,0.2)
MMC_{10}	(0.2,0.8,0.9)	(0.8,0.2,0.3)	(0.1,0.9,0.9)	(0.8,0.2,0.3)
MMC_{11}	(0.1,0.9,0.9)	(0.1,0.9,0.9)	(0.9,0.1,0.2)	(0.6,0.4,0.5)
MMC_{12}	(0.9,0.1,0.2)	(0.2,0.8,0.9)	(0.9,0.1,0.2)	(0.5,0.5,0.5)
MMC_{13}	(0.8,0.2,0.3)	(0.3,0.7,0.8)	(0.8,0.2,0.3)	(0.4,0.6,0.7)
MMC_{14}	(0.7,0.3,0.4)	(0.4,0.6,0.7)	(0.8,0.2,0.3)	(0.9,0.1,0.2)
MMC_{15}	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.7,0.3,0.4)	(0.9,0.1,0.2)
MMC_{16}	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.7,0.3,0.4)
MMC_{17}	(0.4,0.6,0.7)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.7,0.3,0.4)
MMC_{18}	(0.3,0.7,0.8)	(0.8,0.2,0.3)	(0.6,0.4,0.5)	(0.6,0.4,0.5)
MMC_{19}	(0.2,0.8,0.9)	(0.9,0.1,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
MMC_{20}	(0.2,0.8,0.9)	(0.3,0.7,0.8)	(0.3,0.7,0.8)	(0.4,0.6,0.7)
MMC_{21}	(0.1,0.9,0.9)	(0.1,0.9,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)

Table 3. *Decision Matrices by Opinions of Experts*

Second Expert	MMA_1	MMA_2	MMA_3	MMA_4
MMC_1	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)
MMC_2	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.8,0.2,0.3)
MMC_3	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.6,0.4,0.5)
MMC_4	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.4,0.6,0.7)
MMC_5	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.2,0.8,0.9)
MMC_6	(0.2,0.8,0.9)	(0.4,0.6,0.7)	(0.4,0.6,0.7)	(0.1,0.9,0.9)
MMC_7	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.2,0.8,0.9)	(0.9,0.1,0.2)
MMC_8	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.1,0.9,0.9)	(0.7,0.3,0.4)
MMC_9	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.6,0.4,0.5)
MMC_{10}	(0.6,0.4,0.5)	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.9,0.1,0.2)
MMC_{11}	(0.1,0.9,0.9)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.8,0.2,0.3)
MMC_{12}	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.6,0.4,0.5)
MMC_{13}	(0.9,0.1,0.2)	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.9,0.1,0.2)
MMC_{14}	(0.8,0.2,0.3)	(0.2,0.8,0.9)	(0.4,0.6,0.7)	(0.8,0.2,0.3)
MMC_{15}	(0.6,0.4,0.5)	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.6,0.4,0.5)
MMC_{16}	(0.4,0.6,0.7)	(0.9,0.1,0.2)	(0.1,0.9,0.9)	(0.4,0.6,0.7)
MMC_{17}	(0.2,0.8,0.9)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.2,0.8,0.9)
MMC_{18}	(0.1,0.9,0.9)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.1,0.9,0.9)
MMC_{19}	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.9,0.1,0.2)
MMC_{20}	(0.7,0.3,0.4)	(0.3,0.7,0.8)	(0.6,0.4,0.5)	(0.7,0.3,0.4)
MMC_{21}	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.6,0.4,0.5)
Third Expert				
MMC_1	(0.2,0.8,0.9)	(0.5,0.5,0.5)	(0.2,0.8,0.9)	(0.1,0.9,0.9)
MMC_2	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.1,0.9,0.9)	(0.2,0.8,0.9)
MMC_3	(0.4,0.6,0.7)	(0.1,0.9,0.9)	(0.4,0.6,0.7)	(0.2,0.8,0.9)
MMC_4	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.1,0.9,0.9)
MMC_5	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.4,0.6,0.7)
MMC_6	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.6,0.4,0.5)
MMC_7	(0.4,0.6,0.7)	(0.5,0.5,0.5)	(0.4,0.6,0.7)	(0.6,0.4,0.5)
MMC_8	(0.7,0.3,0.4)	(0.4,0.6,0.7)	(0.7,0.3,0.4)	(0.5,0.5,0.5)
MMC_9	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.4,0.6,0.7)
MMC_{10}	(0.2,0.8,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.7,0.3,0.4)
MMC_{11}	(0.1,0.9,0.9)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.9,0.1,0.2)
MMC_{12}	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.2,0.8,0.9)
MMC_{13}	(0.2,0.8,0.9)	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.1,0.9,0.9)
MMC_{14}	(0.1,0.9,0.9)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.4,0.6,0.7)
MMC_{15}	(0.4,0.6,0.7)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.6,0.4,0.5)
MMC_{16}	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.6,0.4,0.5)
MMC_{17}	(0.6,0.4,0.5)	(0.9,0.1,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
MMC_{18}	(0.5,0.5,0.5)	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.4,0.6,0.7)
MMC_{19}	(0.4,0.6,0.7)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.7,0.3,0.4)
MMC_{20}	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.3,0.7,0.8)	(0.9,0.1,0.2)
MMC_{21}	(0.9,0.1,0.2)	(0.1,0.9,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)
Fourth Expert				
MMC_1	(0.9,0.1,0.2)	(0.5,0.5,0.5)	(0.9,0.1,0.2)	(0.1,0.9,0.9)
MMC_2	(0.8,0.2,0.3)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.2,0.8,0.9)
MMC_3	(0.2,0.8,0.9)	(0.2,0.8,0.9)	(0.7,0.3,0.4)	(0.2,0.8,0.9)

MMC_4	(0.1,0.9,0.9)	(0.1,0.9,0.9)	(0.6,0.4,0.5)	(0.1,0.9,0.9)
MMC_5	(0.4,0.6,0.7)	(0.4,0.6,0.7)	(0.5,0.5,0.5)	(0.4,0.6,0.7)
MMC_6	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.6,0.4,0.5)
MMC_7	(0.2,0.8,0.9)	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.6,0.4,0.5)
MMC_8	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.3,0.7,0.8)	(0.5,0.5,0.5)
MMC_9	(0.4,0.6,0.7)	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.4,0.6,0.7)
MMC_{10}	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.2,0.8,0.9)	(0.2,0.8,0.9)
MMC_{11}	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.1,0.9,0.9)	(0.1,0.9,0.9)
MMC_{12}	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.4,0.6,0.7)
MMC_{13}	(0.4,0.6,0.7)	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.6,0.4,0.5)
MMC_{14}	(0.7,0.3,0.4)	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.6,0.4,0.5)
MMC_{15}	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
MMC_{16}	(0.5,0.5,0.5)	(0.9,0.1,0.2)	(0.4,0.6,0.7)	(0.4,0.6,0.7)
MMC_{17}	(0.4,0.6,0.7)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.7,0.3,0.4)
MMC_{18}	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)
MMC_{19}	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
MMC_{20}	(0.2,0.8,0.9)	(0.3,0.7,0.8)	(0.3,0.7,0.8)	(0.4,0.6,0.7)
MMC_{21}	(0.1,0.9,0.9)	(0.1,0.9,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)
Fifth Expert				
MMC_1	(0.9,0.1,0.2)	(0.2,0.8,0.9)	(0.9,0.1,0.2)	(0.2,0.8,0.9)
MMC_2	(0.8,0.2,0.3)	(0.1,0.9,0.9)	(0.8,0.2,0.3)	(0.1,0.9,0.9)
MMC_3	(0.8,0.2,0.3)	(0.4,0.6,0.7)	(0.2,0.8,0.9)	(0.2,0.8,0.9)
MMC_4	(0.7,0.3,0.4)	(0.2,0.8,0.9)	(0.1,0.9,0.9)	(0.2,0.8,0.9)
MMC_5	(0.6,0.4,0.5)	(0.1,0.9,0.9)	(0.4,0.6,0.7)	(0.1,0.9,0.9)
MMC_6	(0.5,0.5,0.5)	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.4,0.6,0.7)
MMC_7	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.2,0.8,0.9)
MMC_8	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.2,0.8,0.9)	(0.1,0.9,0.9)
MMC_9	(0.2,0.8,0.9)	(0.5,0.5,0.5)	(0.1,0.9,0.9)	(0.4,0.6,0.7)
MMC_{10}	(0.1,0.9,0.9)	(0.4,0.6,0.7)	(0.4,0.6,0.7)	(0.6,0.4,0.5)
MMC_{11}	(0.4,0.6,0.7)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.2,0.8,0.9)
MMC_{12}	(0.6,0.4,0.5)	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.1,0.9,0.9)
MMC_{13}	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.4,0.6,0.7)
MMC_{14}	(0.5,0.5,0.5)	(0.9,0.1,0.2)	(0.4,0.6,0.7)	(0.6,0.4,0.5)
MMC_{15}	(0.4,0.6,0.7)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.6,0.4,0.5)
MMC_{16}	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.9,0.1,0.2)	(0.5,0.5,0.5)
MMC_{17}	(0.9,0.1,0.2)	(0.5,0.5,0.5)	(0.9,0.1,0.2)	(0.4,0.6,0.7)
MMC_{18}	(0.4,0.6,0.7)	(0.4,0.6,0.7)	(0.4,0.6,0.7)	(0.7,0.3,0.4)
MMC_{19}	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.9,0.1,0.2)
MMC_{20}	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.4,0.6,0.7)
MMC_{21}	(0.1,0.9,0.9)	(0.1,0.9,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)
Sixth Expert				
MMC_1	(0.9,0.1,0.2)	(0.2,0.8,0.9)	(0.9,0.1,0.2)	(0.2,0.8,0.9)
MMC_2	(0.8,0.2,0.3)	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.1,0.9,0.9)
MMC_3	(0.8,0.2,0.3)	(0.4,0.6,0.7)	(0.1,0.9,0.9)	(0.2,0.8,0.9)
MMC_4	(0.2,0.8,0.9)	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.1,0.9,0.9)
MMC_5	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.6,0.4,0.5)	(0.4,0.6,0.7)
MMC_6	(0.4,0.6,0.7)	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.6,0.4,0.5)
MMC_7	(0.6,0.4,0.5)	(0.2,0.8,0.9)	(0.1,0.9,0.9)	(0.6,0.4,0.5)

MMC_8	(0.2,0.8,0.9)	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.5,0.5,0.5)
MMC_9	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.1,0.9,0.9)	(0.4,0.6,0.7)
MMC_{10}	(0.4,0.6,0.7)	(0.1,0.9,0.9)	(0.4,0.6,0.7)	(0.2,0.8,0.9)
MMC_{11}	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.2,0.8,0.9)	(0.1,0.9,0.9)
MMC_{12}	(0.6,0.4,0.5)	(0.2,0.8,0.9)	(0.1,0.9,0.9)	(0.4,0.6,0.7)
MMC_{13}	(0.5,0.5,0.5)	(0.1,0.9,0.9)	(0.2,0.8,0.9)	(0.6,0.4,0.5)
MMC_{14}	(0.4,0.6,0.7)	(0.4,0.6,0.7)	(0.1,0.9,0.9)	(0.6,0.4,0.5)
MMC_{15}	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.4,0.6,0.7)	(0.5,0.5,0.5)
MMC_{16}	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.4,0.6,0.7)
MMC_{17}	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.7,0.3,0.4)
MMC_{18}	(0.9,0.1,0.2)	(0.4,0.6,0.7)	(0.5,0.5,0.5)	(0.9,0.1,0.2)
MMC_{19}	(0.2,0.8,0.9)	(0.7,0.3,0.4)	(0.4,0.6,0.7)	(0.5,0.5,0.5)
MMC_{20}	(0.2,0.8,0.9)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.4,0.6,0.7)
MMC_{21}	(0.1,0.9,0.9)	(0.1,0.9,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)

Table 4. *Normalized Decision Matrix by Critic Methods*

	MMA_1	MMA_2	MMA_3	MMA_4
MMC_1	1	0.4	1	0
MMC_2	1	0.311688	0.727273	0
MMC_3	1	0.492063	0.634921	0
MMC_4	0.875	0.875	1	0
MMC_5	0.6	0.675	1	0
MMC_6	1	0	0.272727	0.545455
MMC_7	0.275862	0.310345	0	1
MMC_8	1	0.888889	0	0.814815
MMC_9	0.263158	0.473684	0	1
MMC_{10}	0	1	0.5	0.904762
MMC_{11}	0	0.930233	1	0.534884
MMC_{12}	1	0.523077	0.676923	0
MMC_{13}	0.823529	0	1	0.117647
MMC_{14}	0.296296	0	0.148148	1
MMC_{15}	0.6875	0.4375	0	1
MMC_{16}	0.5	1	0.157895	0
MMC_{17}	0	0.896552	1	0.034483
MMC_{18}	0	0.695652	1	0.869565
MMC_{19}	1	0	1	0.466667
MMC_{20}	1	0	0.714286	0.571429
MMC_{21}	0.8	1	0.052174	0

Table 5. *Normalized Decision Matrix by Aras Methods*

	MMA_1	MMA_2	MMA_3	MMA_4
MMC_1	0.340909	0.204545	0.340909	0.113636
MMC_2	0.363363	0.204204	0.3003	0.132132
MMC_3	0.343949	0.242038	0.270701	0.143312
MMC_4	0.280822	0.280822	0.30137	0.136986
MMC_5	0.254181	0.264214	0.307692	0.173913
MMC_6	0.270833	0.232639	0.243056	0.253472
MMC_7	0.23741	0.241007	0.208633	0.31295

MMC_8	0.282528	0.271375	0.182156	0.263941
MMC_9	0.239344	0.252459	0.222951	0.285246
MMC_{10}	0.174174	0.3003	0.237237	0.288288
MMC_{11}	0.167702	0.291925	0.301242	0.23913
MMC_{12}	0.324808	0.245524	0.2711	0.158568
MMC_{13}	0.265753	0.227397	0.273973	0.232877
MMC_{14}	0.245333	0.224	0.234667	0.296
MMC_{15}	0.256281	0.246231	0.228643	0.268844
MMC_{16}	0.258065	0.305211	0.225806	0.210918
MMC_{17}	0.216346	0.278846	0.286058	0.21875
MMC_{18}	0.212276	0.253197	0.2711	0.263427
MMC_{19}	0.210884	0.312925	0.210884	0.265306
MMC_{20}	0.225	0.283333	0.241667	0.25
MMC_{21}	0.146667	0.085333	0.376	0.392

Table 6. *The Weighted Normalized Decision Matrix*

	MMA_1	MMA_2	MMA_3	MMA_4
MMC_1	0.015111	0.009067	0.015111	0.005037
MMC_2	0.014362	0.008071	0.01187	0.005223
MMC_3	0.012694	0.008933	0.009991	0.005289
MMC_4	0.012075	0.012075	0.012958	0.00589
MMC_5	0.010144	0.010544	0.012279	0.006941
MMC_6	0.011557	0.009927	0.010372	0.010816
MMC_7	0.01257	0.01276	0.011046	0.016569
MMC_8	0.014161	0.013602	0.00913	0.013229
MMC_9	0.012716	0.013413	0.011845	0.015154
MMC_{10}	0.010045	0.017319	0.013682	0.016626
MMC_{11}	0.009044	0.015743	0.016245	0.012896
MMC_{12}	0.012084	0.009135	0.010086	0.005899
MMC_{13}	0.012529	0.01072	0.012916	0.010979
MMC_{14}	0.013221	0.012071	0.012646	0.015951
MMC_{15}	0.012709	0.012211	0.011338	0.013332
MMC_{16}	0.011776	0.013927	0.010304	0.009624
MMC_{17}	0.012665	0.016323	0.016745	0.012805
MMC_{18}	0.011634	0.013877	0.014858	0.014438
MMC_{19}	0.009839	0.0146	0.009839	0.012378
MMC_{20}	0.009311	0.011725	0.010001	0.010346
MMC_{21}	0.007484	0.004354	0.019186	0.020002

Analysis

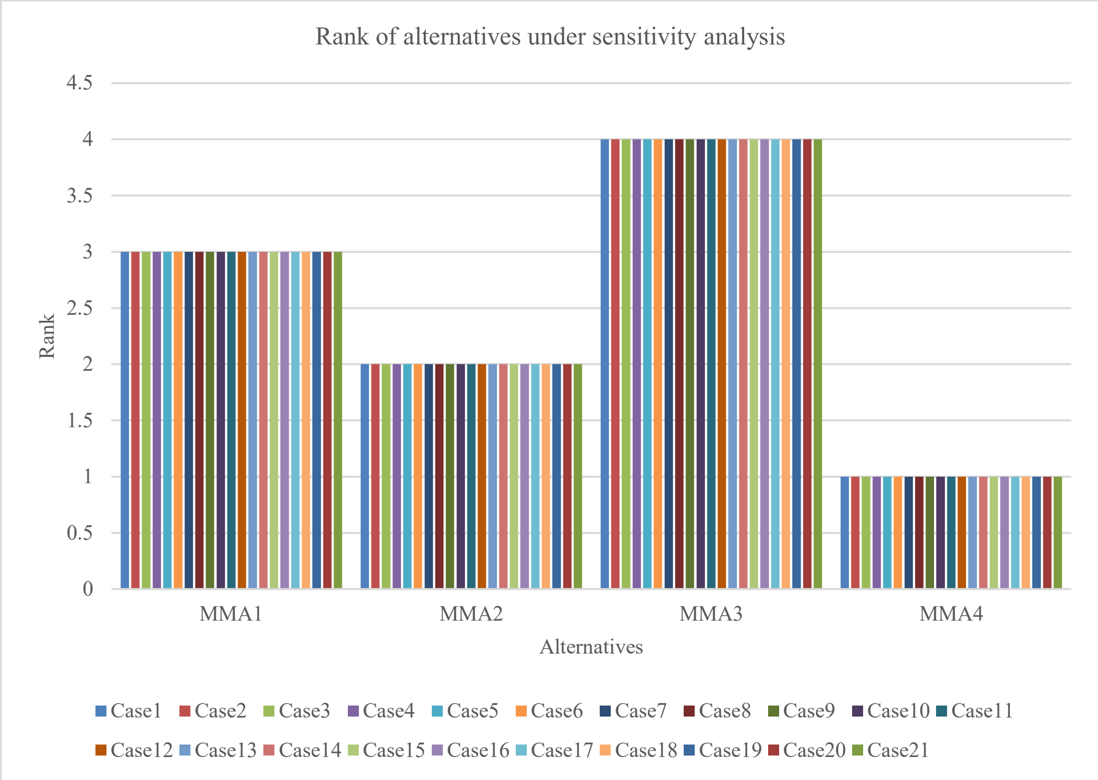
This part introduces the results of sensitivity and comparative analysis.

Sensitivity Analysis

This part introduces the sensitivity analysis to display the stability of order. We proposed 21 cases to alter the weights of factors. We put the first criterion with 0.05

weight and others are equal. In the second case, we put the second criterion with 0.05 and other factors are equal. Then we rank the projects under different cases as shown in Figure 5. We demonstrate the order of projects is stable through various cases.

Figure 5. *The Order of Projects through Sensitivity Analysis*



Comparative Analysis

This part compares the rank of the proposed method with other MCDM methods as shown in Table 7. We compare the proposed method with other MCDM methods like TOPSIS, VIKOR, MABAC, and COPRAS. These methods are compared under SVNS. We used the weights of criteria in the CRITIC method in all methods. We show the effectiveness of the proposed approach with other MCDM approaches.

Table 7. *Results Comparative Analysis*

	Proposed method	SVN-TOPSIS	SVN-VIKOR	SVN-MABAC	SVN-COPRAS
MMA_1	2	3	1	2	2
MMA_2	3	2	3	3	3
MMA_3	4	4	4	4	4
MMA_4	1	1	2	1	1

Conclusions

This study proposed an MCDM methodology for selecting the best project for SHMS to reduce risk in healthcare systems. Risk management is the best process for identifying and mitigating risks in SHMS. So, we recognize the risks of SHMS and select the best project with fewer risks. We applied the MCDM framework to deal with conflict factors. We used the CRITIC and ARAS methods. The CRITIC approach is applied to obtain the factors' weights, and the ARAS approach is used to order the projects. The MCDM methods are integrated with SVNSs to deal with uncertain information. We invited six experts to evaluate the criteria and options using linguistic terms. Then, we used their SVNNs to assess the requirements and projects. The decision matrix is used to compute the criteria weights using CRITIC methods. We collected 21 criteria and 4 alternatives. The ARAS method used the decision matrix and normalization decision matrix to rank the other options. The results show that the Health Data Informational System is the best project with fewer risks. The sensitivity analysis presents the order of alternatives as stable through multiple cases. The comparative study shows that the proposed method is more effective than the MCDM methods.

The various NS extensions can be applied in this study in rework, like Type-2 neutrosophic sets. There are various MCDM methods can be applied to show the weights of factors and rank the alternatives like AHP, TOPSIS, and VIKOR

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