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Collaboration of Vague Theory and Mathematical Techniques for Optimizing Healthcare by Recommending Optimal Blockchain Supplier

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Abstract: The Internet of Medical Things (IoMTs) has the potential to revolutionize healthcare delivery by connecting medical devices and applications to healthcare IT systems via the internet. This connectivity enables the collection, transmission, and analysis of patient data, facilitating remote healthcare delivery and enhancing patient outcomes. However, the security and privacy of the data transmitted and stored within IoMT systems remain critical concerns. Blockchain technology offers a promising solution to address these challenges in IoMTs applications. Blockchain provides a decentralized and immutable ledger where transactions, in this case, patient data, are securely recorded and cannot be altered retroactively. This ensures the integrity and confidentiality of sensitive medical information while eliminating the need for a central authority to manage data exchange. This study proposes a comprehensive fuzzy decision-making framework for selecting the best blockchain provider in the IoMT field. The framework comprises two main steps: Determining the relative importance weights of the criteria utilizing the Stepwise Weight Assessment Ratio Analysis (SWARA) method. Determining the most suitable supplier for blockchain services providers employing the Ranking Alternatives with the Fuzzy ROOT Assessment Method (RAM) technique. A comparison between Fuzzy Multi-Criteria Decision-Making (MCDM) methods is employed to ensure the robustness and validity of the proposed framework.

Keywords: Blockchain technology, Internet of Medical Things (IoMT), Decision-making, Fuzzy logic, Provider selection, Healthcare industry, medical data security, MCDM, Risk management.

1. Introduction

Recently released studies as [1] demonstrated that contemporary information and communications technology (ICT) is giving us prospects to prevail over crises and life's fluctuations as artificial intelligence(AI) and collaborative robotics-human (cobot)[2].Whilst IoTs [3] that stands for Internet of Things, which includes wearable smart gadgets that can access and deliver real-time information. Therefore, it is intriguing to consider that anything might be connected at any moment. Also, this technology has been embraced in healthcare services[4] through connecting the internet with medical equipment that supplies services that pertain to health. Similarly[5] to increase illness prevention and diagnosis, this technology is paired with a smartphone application that allows individuals to send their medical information to medical practitioners. Hence, IoTs extended to Internet of Medical Things (IoMTs) where this technology is beneficial in many sectors, especially healthcare. More effective diagnosis and lower treatment costs are all provided by IoMTs[6], IoMTs allow doctors and other stakeholders to monitor patients' daily health throughout the COVID-19 epidemic while avoiding contact with patients directly[7].In the same vein [8] described IoMTs as the network of medical devices and applications that are connected to healthcare IT systems through the internet. Moreover [9] stated that IoMTs have the potential to boost efficiency in medical facilities, cut healthcare expenses, and improve patient care.

Even while IoMTs have many benefits and help automate the medical sector by gathering data where this data is processed, and keeping track of patients [10], there are several issues which this technology suffers from. Furthermore Ananth et al.[11] indicated that due to emerging sophisticated security issues, protecting IoMTs have become extremely difficult. As well as [12] medical security concerns are emerging, including safeguarding data exchanged for processing by several devices. As well [13], the insufficiency of openness and data protection requirements in the accessibility and utilization of data poses legal and regulatory challenges.

Correspondingly, scholars are leveraging modern technologies of ICT. For instance[14] where blockchain technology (BCT) is emerged with IoMTs for bolstering and securing collected data of IoMTs. Harassing this technology in IoMTs is achieving transparency and decentralization for data in the healthcare sector [14].Hence, BCT plays a vital role in securing manner for data where each block in BCT considers secure trustee for patient's data stored on it[15]. Confirming for that [16] where BCT is preventing destructive and malicious data through monitoring measurements taken by sensors. Overall, BCT has brought new opportunities for advancements in medical and health services through embracing terms of security, privacy, data integrity data encryption and privacy, immutable data Storage, decentralized, smart Contracts for access control, audibility and transparency, interoperability and data sharing, consent management, resilience and security[17].

Given the importance of leveraging BCT when collecting data through IoMTs for guaranteeing highly secure and impenetrable data through cryptocurrency. This catalyst for studies to suggest frameworks to evaluate utilized BC platforms as Ismail Erol et, al.[18] constructed framework for selecting the most feasible BBC platform for healthcare. Also, Ömer Faruk Görçün et,al [19] proposed a novel decision-making model that combines the FUCOM-MAIRCA-PROBID techniques based on Fermatean fuzzy sets to evaluate and select the most optimal BCT provider.

Although selecting the optimal BCT provider is vital, it is a complicated process. Due to this process is related to various aspects as determining the criteria that providers of BC are evaluating based on it.also, the experts who contribute to evaluating criteria-based BC providers.

Herein, we take into consideration these aspects and construct a novel decision-making model to treat the criteria by utilizing MCDM techniques as SWARA techniques for weighting criteria where these weights have been deployed in RAM for ranking BC providers and recommending the optimal and worst BC providers. Broadly speaking, utilized techniques of MCDM are implemented in an ambiguous environment and perplexing circumstances when there is incomplete information through supporting Fuzzy theory in the constructed decision-making model.

1.1 Holistic Methodology of Study

This section showcases study's methodology and steps are implemented for achieving the study's objectives through covering set of questions as mentioned in Fig 1.

Q1:What are utilized methodologies and techniques in healthcare sector for optimizing the services?

Q2:How BCT haranessed in IoMTs for automating and securing healthcare data against attacks for IoMTS devices?

Q3:How decision making techniques have been leveraged under control of Fuzzy to evaluate BC providers?

Q4: How the constructed model validate its efficiency and serving the society?

Q5: How accurate and effective is the model adopted to choose the best provider?

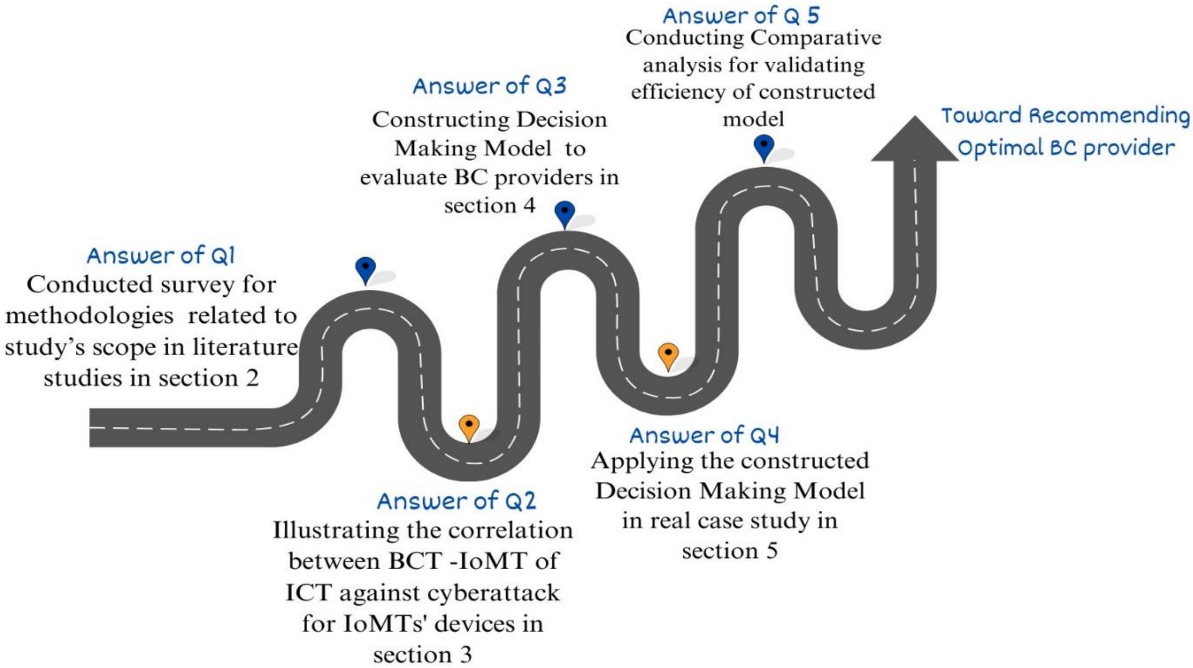

Fig.1. Holistic Methodology Toward Study Objective

1.2 Responsibility of study's Sections

Herein, each section provides important knowledge. For instance, section 2 represents review of existing literature on IoMT and blockchain and review of existing literature on MCDM methods used in similar contexts. Section 3 collected and showcased the different prepectives for the IoMTs' challenges and the suggested solutions. Section 4 showcases the methodology in detailed explanation of the approach used in the paper. Section 5 application of the methodology to a specific case and detailed explanation of the process and results in section 6. Section 7 presents comparative aanalysis for our utilized methods in decision model with other Fuzzy MCDM Methods finally, we summerized the finding of our study in Conclusion section 8.

2. Literature Review

This section covered many techniques which haranessed in evaluation process through surveying the prior studies which related to our study area.

Fuzzy Multi-Criteria Decision-Making (FMCDM) [20] described as a method that combines fuzzy set theory with multi-criteria decision-making. It's used to handle decision-making problems with multiple criteria under uncertainty or vagueness. Also, Fuzzy set theory is used in [21] for representing the uncertainty in human opinions with MCDM methods for evaluating alternatives with different perspectives in terms of several conflicting criteria. In the same vein [22] leveraged Fuzzy in MCDM (i.e.Analytic Hierarchy Process (AHP) , fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Trial and Evaluation Laboratory (DEMATEL)) for helping decision-makers and investors to make concrete, and realistic decisions by considering various factors and uncertainties. Fuzzy MCDM supported scholars in [23] for selecting the optimal portfolio. Fermatean Fuzzy Sets (FFSs) is utilized by Hakan Aydoğan et, al in [24] is employed in selection and ranking decisions in Multiple Criteria Decision Making (MCDM) problems.

Shubhendu Mandal et, al. employed Interval-Valued Intuitionistic Fuzzy and Analytic Hierarchy Process (IVIF AHP) in [25] to prioritize the criteria and Interval-Valued Intuitionistic Fuzzy Technique for Order Preference by Similarity to Ideal Solution (IVIF TOPSIS) to rank the available supervisors based on the criteria weight. spherical fuzzy (SF) is combined with MCDM method by

Abduallah Gamal et, al. in [26] for applying the hybrid techniques to account for uncertainty. The novel decision-making framework developed in[27] through the combination of Fuzzy SWARA and Hierarchical Additive Ratio Assessment (ARAS-H) methods for supporting the stakeholders in selecting renewable energy systems. The scholars in [28] addressed the complex problem of distribution center location selection by combining Fuzzy SWARA and Fuzzy Complex Proportional Assessment of Distance from Ideal Solution (CRADIS). The Pythagorean Fuzzy combined with SWARA- VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) to develop the decision framework for evaluating and selecting of solar panels[29]. SWARA-COPRAS methods are applied under the environment of Fuzzy [30] for constructing a supplier selection model to select the best supplier based on several criteria, such as quality, delivery, price, and service level. Shabnam Rahnamay Bonab et.al [31]proposed an integrated approach based on the extended version of MCDM methods in a spherical fuzzy environment which entailed in Spherical Fuzzy Best-Worst Method (SF-BWM) for generating weights' main criteria and these weights are employed for ranking the alternatives through using the Compromise Solution (MARCOS) to analyze and rank 15 blockchain platforms. Also, SWOT analysis and Grey Step-wise Weight Assessment Ratio Analysis of MCDM approaches are combined in [32] to obtain criteria weights and utilize these weights by Grey Combined Compromise Solution (CoCoSo-G) approaches for evaluating BC strategies and find the most suitable strategy amongst set of alternatives for mitigating risk.

3. Implications of BCT in IoMTs against vulnerabilities

The objective of embracing contemporary technologies as IoMTs in the healthcare sector [33] is permitting clinicians and patients to access real-time data while decreasing the cost and energy consumption of digital healthcare systems.Whereas, IoMTs are considered rescuers in the era of disasters and epidemics where [34]discussed the role of IoMTs in preventing infection and mitigating its spread by not dealing directly with the infected person and monitoring the patients remotely.

Nevertheless, Rafique et al. [35]advanced a viewpoint that the incorporation of IoMTs in healthcare was unavoidable given its significance for improving and automating healthcare. The situation at hand aided in bringing up concerns about privacy disclosure. To substantiate that [36, 37] indicated that fraud in patient data and trickery in diagnosis and treatment resulted from any unlawful access to private information, including medical envision data, private data, health records, and information on sickness diagnosis. These issues are catalysts for embracing the encryption techniques for securing and protecting privacy from any encroach and infringe. The most evidance for that is [38] discussed various security challenges in IoMT, such as data privacy, data integrity, data confidentiality, and data access control. They have also discussed the vulnerabilities in IoMT devices and the potential threats to the healthcare system . One of the effective solutions is cooperation one of the edge computing techniques is BC with IoMTs. One of the suggested studies that applied BC is [39] to reduce the possibility of IoMT devices being hacked and to effectively handle smart contracts. Others as [40] exploited the capabilities of BC in security by suggesting a secure method for transmitting data between edge cloudlets and IoMTs . Qinyong Lin et al. proposed framework for secure data storage and transmission in the Internet of Medical Things (IoMT) using blockchain technology the proposed framework aims to address data privacy issues in IoMT by providing legal authentication for users to access the blockchain networking (BCN) and avoiding large data storage [41].

According to conducted surveys for previous studies related to the study's scope, we summarized the influence of BC in IoMTS to secure transactions that exchange between partners in the healthcare chain in Fig 2.

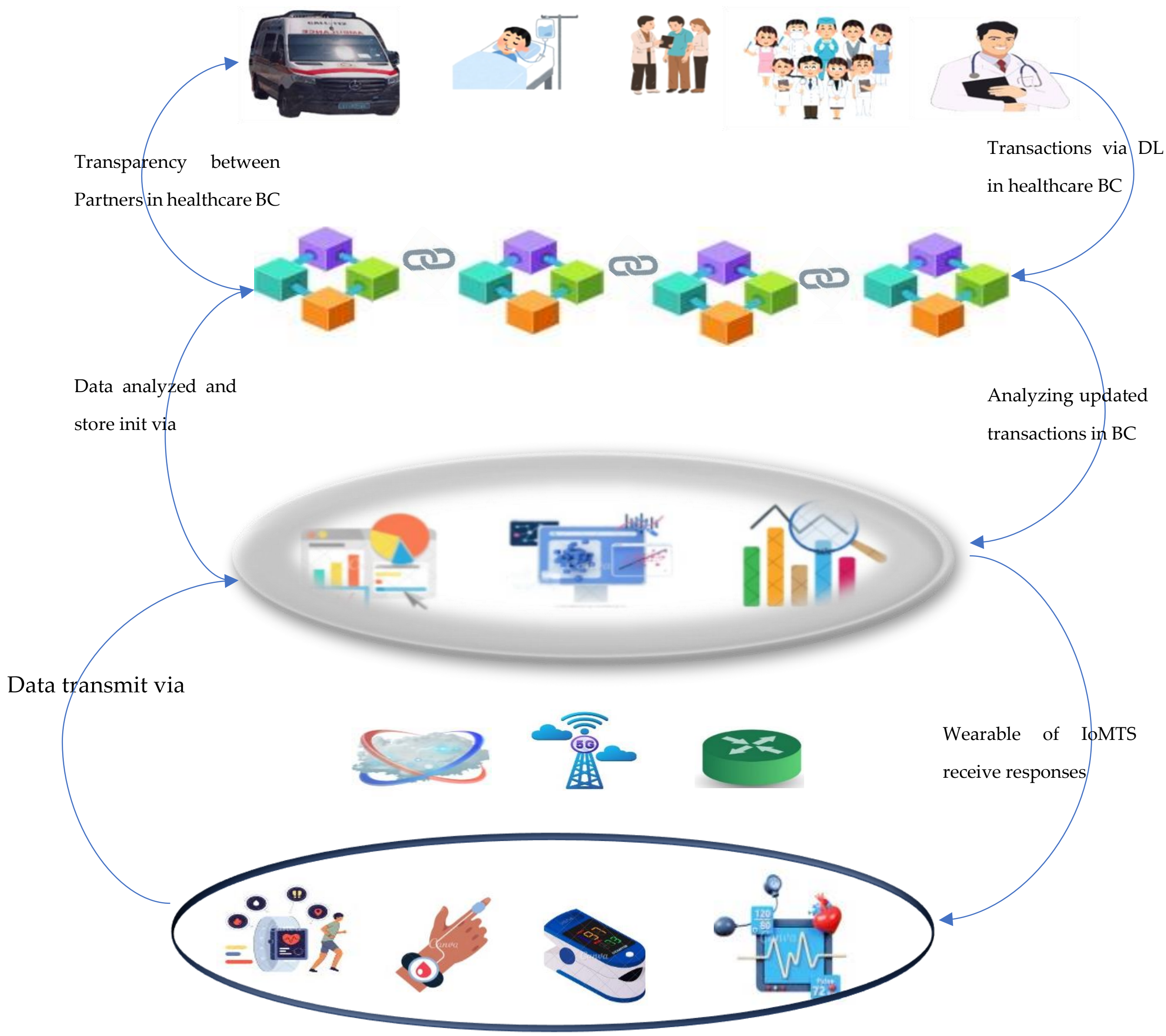

Fig.2 Implications of Blockchain as secure technique in Internet of Medical Things

4. Methodology of evaluating secured Blockchain Supplier

Herein, we showcase the basic concepts for techniques which contributed to building the decision model for evaluating BC supplier for obtaining the most secured supplier

Vague Theory: Fuzzy Sets

The phenomena of vague theory represented by Zadeh[42] for treating with uncertainity and vagueness problems.given the importance of this theory, advanced extensions of FSs are introduced as Intuitionistic Fuzzy Sets(INFSs) [43] and other extensions as Pythagorean FS, Spherical FS, and q-Rung Orthopair FS[44].Also, [45] utilized Triangular Fuzzy Numbers (T FNs) to address the ambiguity of language evaluations and to facilitate computation. Whilst FNs presented in the triplet (l, m, u), where 'l' indicated to the lower value, 'm' is the median value, whereas 'u' is the upper value. The membership function of a fuzzy number F(x) is typically defined as a piecewise function as eq (1) [45].

$$f(x)=\begin{cases}\frac{x-l}{m-l}, & l\le x\le m\\ \frac{u-x}{u-m}, & m\le x\le u\\ otherwise & \end{cases} \quad (1)$$

Let we have two TFNs, $A_1 = (l_1, m_1, u_1)$ and $A_2 = (l_2, m_2, u_2)$. hence, the basic operations which conducting between two TFNs as:

Addition of two TFNs:

$$A_1 \oplus A_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

Subtraction of two TFNs:

$$A_1 \ominus A_2 = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \quad (3)$$

Multiplication of two TFNs:

$$A_1 \otimes A_2 = (l_1l_2, m_1m_2, u_1u_2) \quad (4)$$

Division of two TFNs:

$$A_1 \oslash A_2 = (l_1/u_2, m_1/m_2, u_1/l_2) \quad (5)$$

Scalar Multiplication: If k is a positive real number, then the scalar multiplication is defined as:

$$kA_1 = (kl_1, km_1, ku_1) \quad (6)$$

Defuzzied the relative weight of evaluation criteria using:

$$d(\acute{A}) = \frac{1}{3}(l+m+u) \quad (7)$$

Fuzzy SWARA

The Stepwise Weight Assessment Ratio Analysis (SWARA) is method of MCDM methods that plys an important role for determining the weights of criteria [46]. The following steps is presenting generating criteria's weights by F-SWARA as following :

Arrange the evaluation criteria in descending order based on the expected significant opinions of decision makers.

Determine the relative importance ratio $\mathcal{S}_j$ with respect to the previous criteria by using linguistic terms starting from second criteria.

Aggregate the relative importance ratio $\mathcal{S}_j$ from all DMs by using arithmetic mean $\mathcal{S}_j = ({\mathcal{S}_j}^l, {\mathcal{S}_j}^m, {\mathcal{S}_j}^u)$.

The coefficient $\mathcal{K}_j$, which is a function of the relative importance value of each criterion, is calculated by Eq (8)

$$\mathcal{K}_j = \begin{cases} 1 & if\ j=1\\ \mathcal{S}_j+1 & if\ j>1\end{cases} \text{ where } \mathcal{K}_j = ({\mathcal{K}_j}^l, {\mathcal{K}_j}^m, {\mathcal{K}_j}^u) \quad (8)$$

Compute the significant weight (q_j) for each criterion.

$$q_j = \begin{cases} 1 & if\ j=1\\ \frac{q_{j-1}}{\mathcal{K}_j} & if\ j>1\end{cases} \text{ where } q_j = ({q_j}^l, {q_j}^m, {q_j}^u) \quad (9)$$

The relative weight of the indicators ($\mathcal{W}_j$) is determined using

$$\mathcal{W}_j = \frac{q_j}{\sum_{j=1}^{n} q_j} \quad \text{where } \mathcal{W}_j = ({\mathcal{W}_j}^l, {\mathcal{W}_j}^m, {\mathcal{W}_j}^u) \quad (10)$$

Convert the fuzzy relative importance weight to non-fuzzy (crisp numbers) using

$$\mathcal{W}_j^{non} = \frac{(\mathcal{W}_j^u - \mathcal{W}_j^l) + (\mathcal{W}_j^m - \mathcal{W}_j^l)}{3} + \mathcal{W}_j^l \quad (11)$$

Fuzzy RAM

The weights generated from F-SWARA are haranessed in F-RAM for ranking alternatives of BC supplirs for recommending most secured BC supplier. The ranking procedure for alternatives rating steps is as follow.

Identify the fuzzy decision matrix for alternatives rating by using TFNsas

$$\mathcal{X}_k = \begin{bmatrix} (x_{11k}{}^l, x_{11k}{}^m, x_{11k}{}^u) & (x_{12k}{}^l, x_{12k}{}^m, x_{12k}{}^u) \dots & (x_{1nk}{}^l, x_{1nk}{}^m, x_{1nk}{}^u) \\ \dots & \dots \dots \quad \dots & \\ (x_{m1k}{}^l, x_{m1k}{}^m, x_{m1k}{}^u) & (x_{m2k}{}^l, x_{m2k}{}^m, x_{m2k}{}^u) \cdots & (x_{mnk}{}^l, x_{mnk}{}^m, x_{mnk}{}^u) \end{bmatrix} \quad (12)$$

Where n is number of criteria and m is number of alternatives and $(x_{ijk}{}^l, x_{ijk}{}^m, x_{ijk}{}^u)$ is stand for rating score using linguistic terms

Obtain the fuzzy aggregated matrix from all DMs using

$$x_{ij}{}^l = \frac{\sum_{k=1}^{k} x_{ij}{}^l}{k}, x_{ij}{}^m = \frac{\sum_{k=1}^{k} x_{ij}{}^m}{k}, x_{ij}{}^u = \frac{\sum_{k=1}^{k} x_{ij}{}^u}{k} \quad (13)$$

where k number of DMs

Normalize the matrix using

$$\boldsymbol{r}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (14)$$

Use the fuzzy SWARA to Compute the weighted normalized matrix

$$\boldsymbol{\mathcal{Y}}_{ij} = \boldsymbol{r}_{ij} . \boldsymbol{\mathcal{W}}_j \quad (15)$$

Where $\mathcal{W}_j$ the weighted values for each criteria calculated by F-SWARA method

Calculate the summation for beneficial criteria and non-beneficial criteria using

$$\boldsymbol{\mathcal{S}}_{+i} = \sum_{j=1}^{n} \boldsymbol{\mathcal{Y}}_{+ij} \quad \text{for beneficial} \quad (16)$$

$$\boldsymbol{\mathcal{S}}_{-i} = \sum_{j=1}^{n} \boldsymbol{\mathcal{Y}}_{-ij} \quad \text{for non- beneficial} \quad (17)$$

Calculate the overall score for each alternative by

$$\boldsymbol{\mathcal{RI}}_i = \sqrt[2+\mathcal{S}_{-i}]{2 + \boldsymbol{\mathcal{S}}_{+i}} \quad (18)$$

Finally, Ranking alternatives based on the value of $\mathcal{RI}_i$ as the bigst value of $\mathcal{RI}_i$ the higher priority of its alternatives. It usually that small gab between the overall score of $\mathcal{RI}_i$ value as results are very close to each other so they cannot be ranked. To solve this problem, we must equalize the $\mathcal{RI}_i$ value to be in the range of [0,1] and normalized it using min-max normalization method.

5. Decision Model Validation: Real-Case Study

A. problem Definition:

IoMTs and Healthcare 4.0 are two interconnected concepts that are revolutionizing the healthcare industry. IoMT refers to the network of medical devices and applications connected to healthcare IT systems through online computer networks, while Healthcare 4.0 is a recent e-health paradigm associated with the concept of Industry 4.0, providing approaches to achieving precision medicine and enabling telemedicine, including telesurgery, early predictions, and diagnosis of diseases [47]. Moreover, IoMTs aims to improve healthcare management and patient care through personalized services, data-driven treatments, and early detection of potential health crises. To analyze data properly, it must be accurate and correct, and to protect it from hacking or loss, we must use one of the advanced technologies. As we mentioned before, utilizing BC as secure mechanismis best choices that can protect data. Hence, for selecting optimal and secured BC supplier , Fuzzy theory based MCDM methods are combined for serving and achieving the study's objective through implementing set of procedures as Identify the Criteria: The first step is to identify the important criteria for selecting a blockchain service supplier. These could include factors like cost, security, scalability, interoperability and Customizability with existing systems. Assign Weights to the Criteria: Once we have identified the criteria, we need to assign weights to them based on their importance. This is where the fuzzy SWARA (Step-wise Weight Assessment Ratio Analysis) method comes in. It allows us to deal with the uncertainty and vagueness that often exists in decision-making processes. Rank the suppliers: Finally, we can use a method like the Fuzzy ROOT Assesment Method (FRAM) to rank the providers and select the best one. This method takes into account the SWARA fuzzy weights and evaluations to provide a comprehensive ranking of the providers.

B. Definition of criteria and alternatives:

We have 3 alternatives and five criteria

C1 +: Security: The provider should have robust security measures in place to protect sensitive medical data.

C2 +: Scalability: The provider should be able to handle a large volume of data and transactions.

C3 -: Cost: The provider should offer competitive pricing.

C4 -: Customizability: The provider should offer customizable solutions to meet the specific needs of IoMT applications.

C5 +: Interoperability: The provider should be able to integrate with different medical devices and systems.

6. Results

Phase 1: Determine the relative importance weight using SWARA method:

Based on table 1 the decision makers expressed their opinions to determine the importance of the criteria as shown in table 2. then aggregate decision matrix is evaluated. Then using eqs (8-11) the relative weight is computed as shown in table 3.

Table 1 fuzzy scale for criteria

Linguistic Term for criteria	Triangular Fuzzy Number
Equally Important (EI)	(1, 1, 1)
Moderately less important (MI)	(2/3, 1, 3/2)
Less Important (LI)	(2/5, 1/2, 2/3)
Very Less Important (VI)	(2/7, 1/3, 2/5)
Much Less Important (MuI)	(2/9, 1/4, 2/7)

Table 2 DMs linguistic terms

The relative importance weight of each criteria in linguistic term				
Criteria	DM1	DM2	DM3	DM4
C1	-	-	-	-
C2	EI	MI	MI	LI
C3	MI	MI	LI	MI
C4	VI	LI	LI	VI
C5	LI	LI	VI	MI

Table 3 FSWARA steps

Criteria	$\mathcal{S}_j$			$\mathcal{K}_j$			q_j			w_j			Non-fuuzy
	L	M	U	L	M	U	L	M	U	L	M	U	
C1				1.000	1.000	1.000	1.000	1.000	1.000	0.411	0.466	0.536	0.471
C2	0.683	0.875	1.167	1.683	1.875	2.167	0.594	0.533	0.461	0.244	0.249	0.247	0.247
C3	0.600	0.875	1.292	1.600	1.875	2.292	0.371	0.284	0.201	0.153	0.133	0.108	0.131
C4	0.343	0.417	0.533	1.343	1.417	1.533	0.277	0.201	0.131	0.114	0.094	0.070	0.093
C5	0.438	0.583	0.808	1.438	1.583	1.808	0.192	0.127	0.073	0.079	0.059	0.039	0.059

Phase 2: Rank the alternatives using RAM method:

Three alternatives are used in this case to rank between them RAM method is applied. Table 5 represent the DMs opinions based on table 4 to use fuzzy numbers. Then using eq (13) the aggregated matrix is computed as table 6. The normalized decision matrix is calculated eq (14) as shown in table 7. Using SWARA method and eq (15) the weighted matrix is represented in table 8. Using eqs (16-18) The final rank is evaluated as table 9.

Table 4 fuzzy scale for alternatives

Linguistic Term for alternatives	Triangular Fuzzy Number
Very Low (VL)	(0, 0, 0.25)
Low (L)	(0, 0.25, 0.5)
Medium (M)	(0.25, 0.5, 0.75)
High (H)	(0.5, 0.75, 1)
Very High (VH)	(0.75, 1, 1)

Table 5 DMs linguistic terms

Decision matrix					
DM1	**C1**	**C2**	**C3**	**C4**	**C5**
Alt1	M	H	L	H	L
Alt2	VL	M	M	L	M
Alt3	L	M	L	VH	VH
DM2	**C1**	**C2**	**C3**	**C4**	**C5**
Alt1	L	H	M	M	M
Alt2	VH	M	M	VH	H
Alt3	M	H	L	H	M
DM3	**C1**	**C2**	**C3**	**C4**	**C5**
Alt1	M	VH	M	VH	M
Alt2	VL	M	L	H	L
Alt3	VL	M	H	H	H
DM4	**C1**	**C2**	**C3**	**C4**	**C5**
Alt1	M	VH	M	M	L
Alt2	VL	VL	H	H	H
Alt3	H	VH	H	VL	VL

Table 6 Aggregated matrix

Fuzzy aggregated decision matrix				
		Alt1	**Alt2**	**Alt3**
	L	0.188	0.188	0.188
C1	M	0.438	0.250	0.375
	U	0.688	0.438	0.625
	L	0.625	0.188	0.438
C2	M	0.875	0.375	0.688
	U	1.000	0.625	0.875
	L	0.188	0.250	0.250
C3	M	0.438	0.500	0.500
	U	0.688	0.750	0.750
	L	0.438	0.438	0.438
C4	M	0.688	0.688	0.625
	U	0.875	0.875	0.813
	L	0.125	0.313	0.375
C5	M	0.375	0.563	0.563
	U	0.625	0.813	0.750

Table 7 Normalized matrix

Normalized decision matrix				
		Alt1	**Alt2**	**Alt3**
	L	0.023	0.026	0.023
C1	M	0.053	0.034	0.045
	U	0.083	0.060	0.076
	L	0.076	0.026	0.053
C2	M	0.106	0.052	0.083
	U	0.121	0.086	0.106
	L	0.023	0.034	0.030
C3	M	0.053	0.069	0.061
	U	0.083	0.103	0.091
	L	0.053	0.060	0.053
C4	M	0.083	0.095	0.076
	U	0.106	0.121	0.099
	L	0.015	0.043	0.045
C5	M	0.045	0.078	0.068
	U	0.076	0.112	0.091

Table 8 weighted matrix

weight normalized decision matrix				
		Alt1	**Alt2**	**Alt3**
	L	0.009	0.011	0.009
C1 +	M	0.025	0.016	0.021
	U	0.045	0.032	0.041

C2 +	L	0.018	0.006	0.013
	M	0.026	0.013	0.021
	U	0.030	0.021	0.026
C3 -	L	0.003	0.005	0.005
	M	0.007	0.009	0.008
	U	0.009	0.011	0.010
C4 -	L	0.006	0.007	0.006
	M	0.008	0.009	0.007
	U	0.007	0.008	0.007
C5 +	L	0.001	0.003	0.004
	M	0.003	0.005	0.004
	U	0.003	0.004	0.004

Table 9 Final RAM Rank

	$\mathcal{S}_{+i}$			$\mathcal{S}_{-i}$							
	L	M	U	L	M	U	Def $\mathcal{S}_{+i}$	$Def\ \mathcal{S}_{-i}$	$\mathcal{R}_i$	Normalized $\mathcal{R}_i$	Rank
Alt1	0.029	0.054	0.078	0.010	0.015	0.016	0.053452	0.013595	1.429511	1	1
Alt2	0.020	0.034	0.058	0.012	0.018	0.020	0.037296	0.016589	1.423167	0	3
Alt3	0.026	0.046	0.070	0.011	0.015	0.017	0.047383	0.014167	1.427267	0.64627995	2

7. Comparison with other F-MCDM method

In this paper FCOPRAS utilized as comparative method with methods which utilized in proposed decision model. The COPRAS (COmplex PRoportional ASsessment) method is MCDM method used to rank available choices based on various criteria and their related weights. It's used to find a solution with the ratio to the ideal solution and the ratio with the ideal-worst solution. According to Table 10, BC supplier 1 is the most secured supplier for IoMTs in healthcare sector. Overall, the RAM and COPRAS method are close and very similar in steps and results.

Table 10 Final COPRAS Rank

	$\mathcal{P}_i +$			$\mathcal{R}_i$			$\mathcal{Q}_i$					
	L	M	U	L	M	U	L	M	U	Non-fuzzy $\mathcal{Q}_i$	$\mathcal{N}_i$i	Rank
Alt1	0.029	0.054	0.078	0.010	0.015	0.016	0.115	0.188	0.227	0.177	100.000	1
Alt2	0.020	0.034	0.058	0.012	0.018	0.020	0.088	0.144	0.183	0.138	78.306	3
Alt3	0.026	0.046	0.070	0.011	0.015	0.017	0.103	0.178	0.217	0.166	93.859	2

8. Conclusion

The Internet of Medical Things (IoMT) holds significant potential in transforming healthcare delivery by enabling the collection, transmission, and analysis of patient data through interconnected medical devices and applications. However, ensuring the security and privacy of data within IoMT systems remains a paramount concern. To address these challenges, integrating blockchain technology into IoMT applications offers a promising solution. Blockchain provides a decentralized and immutable ledger, ensuring the integrity and confidentiality of sensitive medical information. This paper proposes a comprehensive fuzzy decision-making framework for selecting the best blockchain provider in the IoMT field. The framework introduces a fuzzy decision-making approach tailored to the IoMT domain, determines the relative importance weights of criteria using the Stepwise Weight Assessment Ratio Analysis (SWARA) method, and selects the most suitable blockchain services provider employing the Ranking Alternatives with the Fuzzy ROOT Assessment Method (RAM) technique. A comparison between Fuzzy Multiple Criteria Decision Making (MCDM) methods is conducted to evaluate their effectiveness in the context of IoMT.

The proposed framework offers several advantages over traditional decision-making approaches. Firstly, the use of fuzzy logic allows for the consideration of uncertainty and ambiguity in the decision-making process. Secondly, the SWARA method provides a systematic and transparent approach for determining the criteria weights. Finally, the RAM technique provides a comprehensive ranking of the blockchain providers based on their overall performance, considering all the criteria. The utilization of FCOPRAS haranessed as comparative method for evaluating and ranking of blockchain providers for IoMT applications. Through a comparative analysis, the similarities between the RAM and COPRAS methods are highlighted, underscoring their utility in facilitating informed decision-making processes in the selection of BC supplier for IoMT implementations

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