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IM4.0EF: Tele-Medical Realization via Integrating Vague T2NSs with OWCM-RAM Toward Intelligent Medical 4.0 Evaluator Framework

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Abstract

In the modern world, when nearly everyone considers the Internet to be indispensable, there is a constant desire to discover new applications for the technologies that are already in place. As well, recent research has found several synonyms for the adoption of information and communication technology. Industry 4.0, Industry 5.0, and modern technologies are some of these synonyms. Harnessing these technologies in important domains such as medical services and healthcare is vital. Wherein, the medical field has undergone changes, going from version 1.0 to version 4.0 currently. Medical 4.0 represents a significant advancement in medical practices and systems, leveraging cutting-edge digital technology, data analytics, automation, and artificial intelligence (AI) within the healthcare sector. Therefore, it is essential to give priority to important enabling aspects (EAs) that influence these cutting-edge technologies adoption into the healthcare industry in a methodical and successful manner. Inspired by these facts, the prioritizing of the determined EAs is robust motivator in this study. Hence, we constructed intelligent Medical 4.0 evaluator framework (IM4.0EF) which responsible for prioritizing EAs based in a set of benchmarks (Bs) through leveraging Opinion Weight Criteria Method (OWCM) as a novel multi-criteria decision-making (MCDM) technique to obtain benchmarks' weights. Wherein these weights are utilized in Root Assessment Method (RAM) as a novel MCDM to rank EAs and recommending the most influence and optimal EA as well as the worst EA.

Keywords: Medical 4.0; Cutting-edge Technologies; Opinion Weight Criteria Method; Root Assessment Method; Type-2 Neutrosophic Theory.

1 | Introduction

1.1 | Thorough View

In light of contemporary technology, handling a wide range of application sectors has become more precise and easier. In the realm of medicine and health services, human beings frequently disregard their health because they are so focused on getting by in their busy everyday lives. Therefore, health declines and then

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human effectiveness is impacted. Hence, this matter directly affects overall growth, a nation's aspirations for progress cannot ignore the rights of its citizens.

Providing individuals with cutting-edge healthcare facilities is an urgent need to improve their quality of life. To enhance people's lives, many technologies have developed and are now available to the public via the internet or other networks. These technologies may enable people to receive a proper diagnosis quickly and affordably [1]. In the modern world, when nearly everyone considers the Internet to be an indispensable aspect of their existence, there is a constant desire to discover new applications for the technologies that are already in place. The medical field It has undergone changes, going from version 1.0 to version 4.0 at this time [2]. Medical 4.0 represents a significant advancement in medical practices and systems, leveraging cutting-edge digital technology, data analytics, automation, and artificial intelligence (AI) within the healthcare sector [3]. It covers patient interaction, digital health records, data management, telemedicine, remote patient monitoring, data privacy [4]. Medical 4.0 has the potential to revolutionize the way healthcare is delivered by raising overall satisfaction, cutting costs, and improving patient outcomes. But to maximize the advantages of these new technologies while addressing ethical, legal, and technical concerns, lawmakers, regulatory agencies, and healthcare providers must work together [4]. To meet these objectives, sensor-based patient monitoring systems are being employed, and they have the capacity to provide enormous amounts of data regarding the health of the patients daily. In this instance, the cloud computing concept was used for data analysis and storage [5]. Healthcare systems encounter significant obstacles including security breaches, latency, and the need to cut expenses without sacrificing the provision of high-quality patient care. These days, technological developments and breakthroughs in the healthcare industry are becoming more and more well-known [6]. However, cloud-based systems may result in misdiagnosis, unhappiness with therapeutic frameworks, and delays in application communication. Fogging, which anticipates delays by bringing capacities and abilities closer to applications and information sources, is therefore currently considered an alternative to cloud computing. Using fog, increasingly potent therapeutic innovation configurations can be created [5]. Fog computing, which is carefully considered as the addition of cloud computing to the edge of the network, is a highly virtualized perspective of the resource group that provides nearby end users with networking, processing, and data storage options [7].

1.2 | Study Motives

According to the previous perspectives as [4], there are various enabling aspects should take into consideration for embracing edge computing paradigms in healthcare domain. It is highly significant to provide stakeholders with a road map outlining how to implement this technology in the field of healthcare. As well, identifying obligations and enabling aspects that must be considered to avoid obstacles to achieving medical 4.0 is imperative.

Accordingly, this study was keen to adopt this matter of obligations and enabling aspects (EAs) and deal with it through a set of aspects. Theoretically, through conducted surveys for earlier studies [8] where human responsibilities is the main in this aspect. These responsibilities involved strategic and source planning, culture, and the ability to eliminate complexity through flexibility and proactivity for next events. Practically, taken innovations, practical deployment and leveraging resources toward optimization and achieving medical 4.0 is important EAs. Scientifically, determining the most influence EA for embracing edge computing and industry 4.0 is crucial matter. Hence, we developed IM4.0EF for evaluating these enabling aspects and its benchmarks were enabling aspects evaluating based on. Thus, MCDM techniques are utilized in prioritizing for enabling aspects through a set of benchmarks. To ensure the ability to deal with uncertain and ambiguous circumstances during judgements, T2NSs collaborated by utilizing MCDM as branch of neutrosophic vague theory.

2 | Related Work

Various researchers use different technology and methodologies to give distinct studies about healthcare issues and how they are monitored. This part considers the studies in order to provide a deeper knowledge of the problems and difficulties that the healthcare industry and people confront [1]. Medical 4.0 is the integration of digital solutions, data analytics, and state-of-the-art technologies into medical and healthcare. The core of a Medical 4.0 application idea is to operationalize these technological developments in the healthcare and medical fields [4]. The studies presented by Silva et al. [9] demonstrate the rationale behind the fog model's implementation in healthcare through a state-of-the-art study. It was observed in the study that there is still more work to be done on the fog layer's distribution of restorative data [10]. Security and protection are key components of this approach and are frequently mentioned in [5]. Apart from the cloud, another barrier is storage capacity due to its limited space [11]. This constraint must thus be met by the fog-based storage systems. Furthermore, the review [12] validates the findings linked to the lack of healthcare knowledge by the board method in fog, asserting that no appropriate information is available. In the meantime, the review [13] views the presentation related to the control of data in applications as the main driver for the use of fog computing in the healthcare industry. Dealing with Fog's managing max is a common task. Depending on the scope of the project, timeframe for completion, and capacity limit, a management assignment and fog resource allocation strategy are recommended [14]. George et al. talked about using a smartphone as a sensor to continuously monitor a patient's health in [15]. They talked about the benefits of FC over CC in identifying a patient's health issues and employed the FC technique to analyze patient health data more quickly. They considered three different patient categories, including those who were seriously hurt, were typically hospitalized, and required future guidance for routine checkups.

Kraemer et al. [16] talked about many healthcare informatics use cases. To manage the inventory of applications utilized for a certain job, they employed the FC approach. The author also covered the various tasks that FC performs at various network levels to provide tradeoffs regarding the intended needs necessary for healthcare.

3 | Evaluation Based on MCDM-T2NSs: Intelligent Medical 4.0 Evaluator Framework

Herein, we are leveraging the ability of MCDM techniques to handle the conflict criteria that our problem is characterized by. Accordingly, OWCM [16] is utilized for obtaining benchmarks' weights where these weights have been leveraged in RAM for ranking alternatives of enabling aspects (EAs). The mentioned methods are collaborated by T2NSs and this collaboration is illustrated in the following procedures of the intelligent Medical 4.0 evaluator framework (IM4.0EF).

Procedure 1 **Consider the primary ingredients for the evaluation**

The benchmarks (Bs) that influence EAs for implementing Medical 4.0 are realized.

Decision makers (DMs) who volunteering for evaluating EAs based on Bs are opted.

T2N matrices are erected based on evaluations of volunteered DMs though using scales in Table 1 [17].

Converting erected T2N matrices into crisp matrices using Eq. (1).

$$S(\tilde{Z_i}) = \frac{1}{12}\left(8 + \left(T_{T_{Z_1}}(x) + 2\left(T_{I_{Z_1}}(x)\right) + T_{F_{Z_1}}(x)\right) - \left(I_{T_{Z_1}}(x) + 2\left(I_{I_{Z_1}}(x)\right) + I_{F_{Z_1}}(x)\right) - \left(F_{T_{Z_1}}(x) + 2\left(F_{I_{Z_1}}(x)\right) + F_{F_{Z_1}}(x)\right)\right) \quad (1)$$

Procedure 2 **Figuring out the weights of benchmarks: OWCM-T2NSs [18]**

Merging the crisp metrices into an aggregated matrix based on Eq. (2):

$$x_{ij} = \frac{\sum_{j=1}^{N} s(z_i^{\sim})}{N} \tag{2}$$

Generate normalized matrix by employing Eq. (3) in an aggregated matrix based on Eq.(3):

$$R_{ij} = \frac{x_{ij}}{\underset{x_j}{max}} \tag{3}$$

x_j^{max} refers to max number in x_{ij} matrix per column.

The average score of the decision matrix is calculated as following.

$$\text{Ɓ} = \frac{1}{S}\sum_{i=1}^{m} R_{ij} \tag{4}$$

S refers to number of EAs.

Preference variation for each benchmark is calculate as in Eq. (5).

$$\mho_j = \sum_{j=1}^{m}[R_{ij} - \text{Ɓ}]^2$$

The deviation in preference values is calculate based on Eq. (6)

$$\mathcal{E}_j = 1 - \mho_j \tag{6}$$

weights for benchmarks is calculate as in Eq. (7).

$$\omega_j = \frac{\mathcal{E}_j}{\sum_{j=1}^{m} \mathcal{E}_j} \tag{7}$$

Table 1. Linguistic variables for classification.

Linguistic Variables	T2N scale < $(T_T, T_I, T_F), (I_T, I_I, I_F), (F_T, F_I, F_F)$ >
Very Bad (VB)	⟨(0.20, 0.20, 0.10),(0.65, 0.80, 0.85),(0.45, 0.80, 0.70)⟩
Bad (B)	⟨(0.35, 0.35, 0.10),(0.50, 0.75, 0.80),(0.50, 0.75, 0.65)⟩
Medium Bad (MB)	⟨(0.50, 0.30, 0.50),(0.50, 0.35, 0.45),(0.45, 0.30, 0.60)⟩
Medium (M)	⟨(0.40, 0.45, 0.50),(0.40, 0.45, 0.50),(0.35, 0.40, 0.45)⟩
Medium Good (MG)	⟨(0.60, 0.45, 0.50),(0.20, 0.15, 0.25),(0.10, 0.25, 0.15)⟩
Good (G)	⟨(0.70, 0.75, 0.80),(0.15, 0.20, 0.25),(0.10, 0.15, 0.20)⟩
Very Good (VG)	⟨(0.95, 0.90, 0.95),(0.10, 0.10, 0.05),(0.05, 0.05, 0.05)⟩

Ranking enabling aspects: RAM- T2NSs [19]

Procedure 3

Normalize the aggregated matrix in previous step using Eq. (7):

$$Nor_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (j = 1,2,\ldots,n) \quad (7)$$

Calculate the weighted decision matrix using Eq. (8):

$$y_{ij} = Nor_{ij} w_{ij} \quad (i = 1,2,..m : j = 1,2 \ldots n) \quad (8)$$

Calculate the sums of weighted normalized scores by Eqs. (9) and (10):

$$s_{+i} = \sum_{j=1}^{n} y_{+ij}, \text{ beneficial} \quad (9)$$

$$s_{-i} = \sum_{i=1}^{n} y_{-ij} \quad , \text{non-beneficial} \quad (10)$$

Determine the overall score of each alternative by Eq. (11):

$$RI_i = \sqrt[2+s_{-i}]{2+s_{+i}} \quad (i = 1, 2, \ldots, m) \quad (11)$$

Rank the alternatives using the value of RI_i

4 | Illustrative Case Study

We implemented the constructed IM4.0EF on real medical field to validate the efficiency of this framework. Herein, the main ingredients as Bs and EAs are determined in this study through surveying for earlier studies as [3, 4] which resulted ten benchmarks which utilized in evaluating five enabling aspects based on five DMs as in Table 2.

4.1 | Valuating Benchmarks: OWCM-T2NSs

- Five T2NSs matrices are constructed and converted to crisp matrices using Eq. (1).
- Using Eq. (2) to blend these matrices into an aggregated matrix as in Table 3.
- Normalizing the aggregated matrix using Eq. (3) to generate normalized matrix as in Table 4.
- Final weights for Bs are generated after computing $\mathcal{B}, \mho_j$, $\mathcal{E}_j$ through deploying Eqs. (4) , (5) and (6) as shown in table 5. Figure 1 represents the valuation weights for Bs where B6 and B10 have highest weight but B2 has lowest weight.

Table 2. Main enabling aspects and its benchmarks.

Role in evaluation	Enabling Aspects (EAs)
EA1	Controlling complexity
EA2	Practical readiness
EA3	Resource Optimizing
EA4	Regulation and polices
EA5	Partner Compatibility
Benchmarks (Bs)	
B1	Environmental sustainability
B2	Compliance and deployment
B3	Cost
B4	Communication efficiency
B5	Flexibility
B6	Eliminating Uncertainty and hazard
B7	Complications
B8	Adaptation
B9	Proactivity
B10	Security and privacy

Table 3. Aggregated decision matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
EA1	0.4375	0.5025	0.5158	0.6742	0.5300	0.4725	0.5017	0.7283	0.5017	0.4725
EA2	0.5283	0.6008	0.5408	0.6400	0.4992	0.5067	0.6350	0.6667	0.6350	0.5067
EA3	0.5917	0.4375	0.7092	0.6817	0.5850	0.5967	0.6725	0.6100	0.6725	0.5967
EA4	0.3825	0.8333	0.5317	0.3375	0.5300	0.5400	0.5317	0.4483	0.5317	0.5400
EA5	0.7892	0.3825	0.4808	0.5708	0.7008	0.6183	0.5067	0.6442	0.5067	0.6183

Table 4. Normalizing the aggregated decision matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
EA1	0.5544	0.6030	0.7274	0.9890	0.7562	0.7642	0.7460	1.0000	0.7460	0.7642
EA2	0.6695	0.7210	0.7626	0.9389	0.7122	0.8194	0.9442	0.9153	0.9442	0.8194
EA3	0.7497	0.5250	1.0000	1.0000	0.8347	0.9650	1.0000	0.8375	1.0000	0.9650
EA4	0.4847	1.0000	0.7497	0.4951	0.7562	0.8733	0.7906	0.6156	0.7906	0.8733
EA5	1.0000	0.4590	0.6780	0.8374	1.0000	1.0000	0.7534	0.8844	0.7534	1.0000

Table 5. Average score and Preference variation.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
$\mathcal{B}$	0.6917	0.6616	0.7835	0.8521	0.8119	0.8844	0.8468	0.8506	0.8468	0.8844
$\mho_j$	0.1606	0.1812	0.0627	0.1758	0.0520	0.0387	0.0550	0.0831	0.0550	0.0387
$\mathcal{E}_j$	0.8394	0.8188	0.9373	0.8242	0.9480	0.9613	0.9450	0.9169	0.9450	0.9613

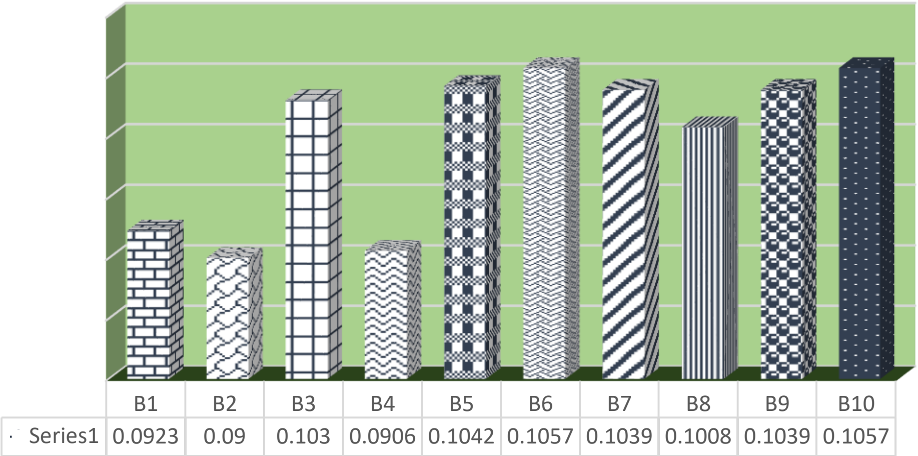

Figure 1. Final Benchmarks' weights.

4.2 | Ranking Alternatives of Enabling Aspects using RAM-T2NSs

Digital twin technology is considered one of the vital tools for smart cities, although it can also be applied in other fields.

- Eq. (7) implemented in the previous aggregated matrix to obtain normalized matrix as in Table 6.
- Table 7 represents weighted decision matrix based on Eq. (8).
- Sums of weighted normalized scores are calculated based on Eqs. (9) and (10) as in Table 8.
- The overall score of each alternative is calculated based on Eq. (11). Figure 2 show cases that partner compatibility is optimal otherwise regulations and compliance is the worst.

Table 6. Normalizing the aggregated decision matrix.

	B1 (+)	B2 (+)	B3 (-)	B4 (+)	B5 (+)	B6 (+)	B7 (-)	B8 (+)	B9 (+)	B10 (+)
EA1	0.1603	0.1823	0.1857	0.2321	0.1863	0.1728	0.1762	0.2351	0.1762	0.1728
EA2	0.1936	0.2180	0.1947	0.2204	0.1755	0.1853	0.2230	0.2152	0.2230	0.1853
EA3	0.2168	0.1587	0.2552	0.2347	0.2056	0.2182	0.2362	0.1969	0.2362	0.2182
EA4	0.1402	0.3023	0.1914	0.1162	0.1863	0.1975	0.1867	0.1447	0.1867	0.1975
EA5	0.2892	0.1388	0.1731	0.1966	0.2463	0.2262	0.1779	0.2080	0.1779	0.2262

Table 7. Weighted decision matrix.

	B1 (+)	B2 (+)	B3 (-)	B4 (+)	B5 (+)	B6 (+)	B7 (-)	B8 (+)	B9 (+)	B10 (+)
EA1	0.0148	0.0164	0.0191	0.0210	0.0194	0.0183	0.0183	0.0237	0.0183	0.0183
EA2	0.0179	0.0196	0.0201	0.0200	0.0183	0.0196	0.0232	0.0217	0.0232	0.0196
EA3	0.0200	0.0143	0.0263	0.0213	0.0214	0.0231	0.0245	0.0198	0.0245	0.0231
EA4	0.0129	0.0272	0.0197	0.0105	0.0194	0.0209	0.0194	0.0146	0.0194	0.0209
EA5	0.0267	0.0125	0.0178	0.0178	0.0257	0.0239	0.0185	0.0210	0.0185	0.0239

Table 8. Sums of weighted normalized scores and overall scores.

	s+i	s-i	RI	N-RI	Rank
EA1	0.1502	0.0374	1.4561	0.21721	4
EA2	0.1598	0.0432	1.4577	0.40248	3
EA3	0.1675	0.0508	1.4582	0.45989	2
EA4	0.1458	0.0391	1.4542	0	5
EA5	0.1699	0.0363	1.4629	1	1

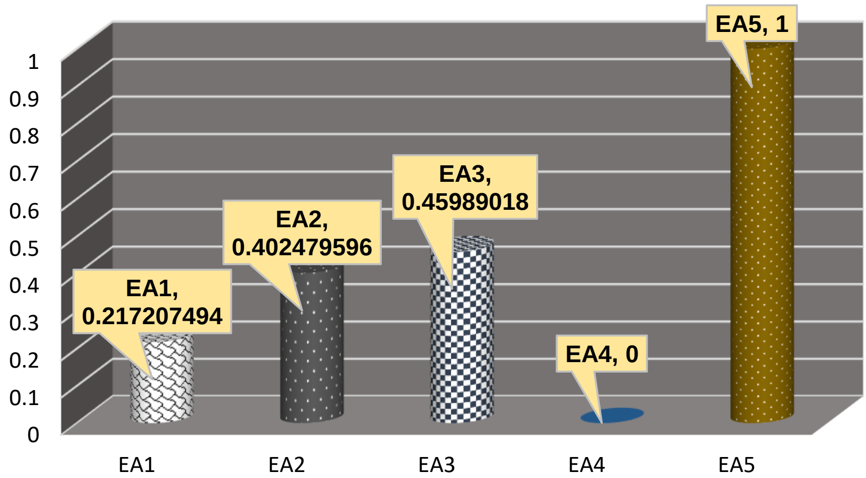

Figure 2. Ranking of enabling aspects.

5 | Conclusion

The present study enhances our comprehension of the factors propelling the adoption of digital technologies in Medical toward Medical 4.0. As well. This study provides valuable insights to facilitate the realization of the complete potential of technologically enabled advancements in healthcare. Because technologies as big data, cloud computing, 5G, digital twin...etc. are offering proximity to data sources, data offloading and processing, resilience to network outages, enhanced security and privacy, scalability, interoperability, cost optimization, Real-Time Decision Making and Regulatory Compliance. It plays a significant role in influencing the selection of Medical 4.0 enablers. Enablers can provide effective, dependable, and secure healthcare solutions that satisfy the changing requirements of contemporary healthcare systems by utilizing fog computing capabilities. Moreover, we are constructing an evaluation model for evaluating enabling aspects in Medical 4.0 based on a set of benchmarks through Multi-Criteria Decision Making (MCDM) techniques where each technique is responsible for a certain function. For instance, Opinion Weight Criteria Method (OWCM) is utilized for obtaining the benchmarks' weights and Root Assessment Method (RAM) leverages the obtained weights from OWCM for ranking the alternatives and recommends the most sustainable and worst alternative. The evaluation for alternatives is performed based on rating ten benchmarks. Finally, the utilized MCDM techniques are working under T2NSs.

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Author Contributions

All authors contributed equally to this work.

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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 author declares 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.

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