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Abstract: The referral cooperation hospital choice has been studied to better rationalize the allocation of healthcare assets and enhance the efficacy of resource utilization. Choosing hospitals to work within a collaborative referral arrangement is a crucial step in the patient-referral process. A referral cooperative hospital is chosen after careful consideration of these aspects to guarantee that patients will get the kind of detailed treatment that is appropriate for their condition. The concept of multi-criteria decision-making (MCDM) is used due to various criteria. The VIKOR method is the MCDM method used in this paper to rank the referral cooperation hospitals. The VIKOR method is integrated with the single-valued neutrosophic set to overcome uncertain information. The single-valued neutrosophic VIKOR method is applied to a case study in Egypt. We achieved quality of care as the best criterion from the eleven criteria used.

Keywords: Neutrosophic Set, VIKOR Method, Healthcare, Referral Cooperative Hospital, Patient Care.

1. Introduction

As the world's population becomes older, the healthcare system will be put to the test in new ways. Establishing a trustworthy healthcare system to improve human health has long been an important and engaging issue. Budgetary restraints prevent hospitals from purchasing the necessary number of high-priced yet in-demand medical devices, leading to inequitable distribution of these devices and extended wait periods for patients. As a result, several nations are adopting the medical consortium model to boost the efficacy of their healthcare systems and increase the effectiveness with which their healthcare resources are being use[1], [2].

Providing patients with access to specialized treatment and resources that may be lacking at other hospitals or medical practices, referral cooperative hospitals play a crucial role in the healthcare system. These facilities also aid in ensuring that patients get the best treatment possible by connecting them with other facilities or practices that better suit their requirements.

Hospitals are carefully chosen throughout the referral cooperative selection process to form a cooperative connection for the referral of patients. This step is essential for providing treatment that consistently exceeds patients' expectations. Care quality, service availability, location, insurance coverage, cost, communication and coordination, and cultural competence are just a few of the variables considered when choosing a referral cooperative hospital[3], [4].

Choosing a referral cooperative hospital is a multi-step procedure that must consider a wide range of considerations. The quality of care offered by the facility is a crucial consideration. The hospital's reputation, accreditation, results, and patient happiness all play a role. Referrals tend to choose hospitals with a solid reputation for offering excellent treatment.

Consideration must also be given to the accessibility of the hospital's services. Diagnostic and imaging services, as well as specialized care in fields like cardiology, cancer, and neurology, should all be available at the hospital. The hospital should also have enough beds and medical personnel to care for its patients[5], [6].

When deciding on a referral cooperative hospital, it is also crucial to take location into account. Many patients prefer to get care at a hospital that is conveniently situated near the facility or clinic that is recommended to them. This may also aid improve inter-hospital communication and cooperation. When choosing a referral cooperative hospital, insurance coverage is an important consideration. For the patient's convenience, the hospital should take the same insurance plans as the facility or clinic recommending them. Patients' financial contributions may be kept to a minimum and they can get the treatment they need with fewer issues if this is implemented[7], [8].

When choosing a referral cooperative hospital, cost should be considered. The hospital's price policy should be made clear to patients, and the cost of treatment should be affordable. This may make it easier for people to get the treatment they need without having to worry about how to pay for it. When deciding on a referral cooperative hospital, it is also important to think about how well you and the facility can communicate and work together. The hospital's communication and coordination systems, including the transmission of patient information, should be efficient and timely. This may aid in ensuring that patients get the treatment they need with little disruption to their schedules[9], [10].

Overcoming the conceptual ambiguity associated with human expert judgments has been accomplished via the application of neutrosophic logic[11], [12].

The Neutrosophic Set generalizes the intuitionistic set, classical set, fuzzy set, paraconsistent set, dialetheist set, paradoxist set, and tautological set, whereas the Neutrosophic Logic generalizes fuzzy logic based on Neutrosophy[13], [14].

The usual problem selection is the greatest suit for the Neutrosophic representation of uncertainty and indeterminacy[15], [16].

2. Referral Cooperative Hospitals

A referral cooperative hospital has partnered with another facility or clinic to facilitate patient referrals. This kind of partnership is often formed to guarantee top-notch treatment for patients by connecting them with clinics or hospitals that can provide the right services for them.

Hospitals that are part of referral cooperatives have earned a stellar reputation within their communities and are well-equipped to satisfy the diverse demands of their patients. These hospitals may feature specialized technology and personnel to treat patients with certain conditions, such as those requiring cardiology, cancer, or neurological treatment[17], [18].

In most cases, a doctor at one facility will send a patient to another facility that is part of a referral cooperative to get specialized care. The cooperative hospital receives the patient, assesses their condition, and treats them accordingly. To ensure that patients get the best possible treatment, the referring hospital or medical practice must communicate and coordinates with the referral cooperative hospital[19], [20].

3. Insurance Coverage of Referral Cooperative Hospitals

Most hospitals that participate in referral networks have systems in place to assist patients with understanding their insurance coverage for treatment received at an out-of-network facility. The following are examples of procedures:

Hospitals participating in a referral network may coordinate with insurance providers to get prior approval for treating patients who are not in their networks. The patient's out-of-pocket expenses may be reduced if their insurance covers the necessary medical procedures.

Claims help Referral hospitals may also help patients through the insurance claims process. This may improve the likelihood that the claims will be paid in full and that the patient will get the most out of their insurance[21], [22].

Hospitals participating in referral networks may provide patients with access to financial counselors who can answer questions about insurance and other healthcare financing concerns. Payment plan negotiations and applications for government aid are examples of the kinds of services that may fall under this category.

To better serve their patients, hospitals in referral networks may try to negotiate in-network status with insurance providers.

Patients should check with their insurance providers and learn about any out-of-pocket charges before seeking treatment at a referral cooperative hospital. Patients should contact their insurance companies to learn more about out-of-network coverage and whether prior permission is needed for any upcoming medical procedures. If a patient has questions regarding their health insurance, they should ask their doctor or the hospital that made the recommendation[23], [24].

4. Neutrosophic VIKOR method

Opricovic recommended the use of VIKOR. VIKOR is a compromise ranking approach that chooses many options when competing criteria are present. The compromise answer is the best approximation to the

optimal answer[25]–[27]. The VIKOR method is integrated with the single-valued neutrosophic set to select the best referral cooperative hospital with a set of criteria. Figure 1 shows the proposed framework.

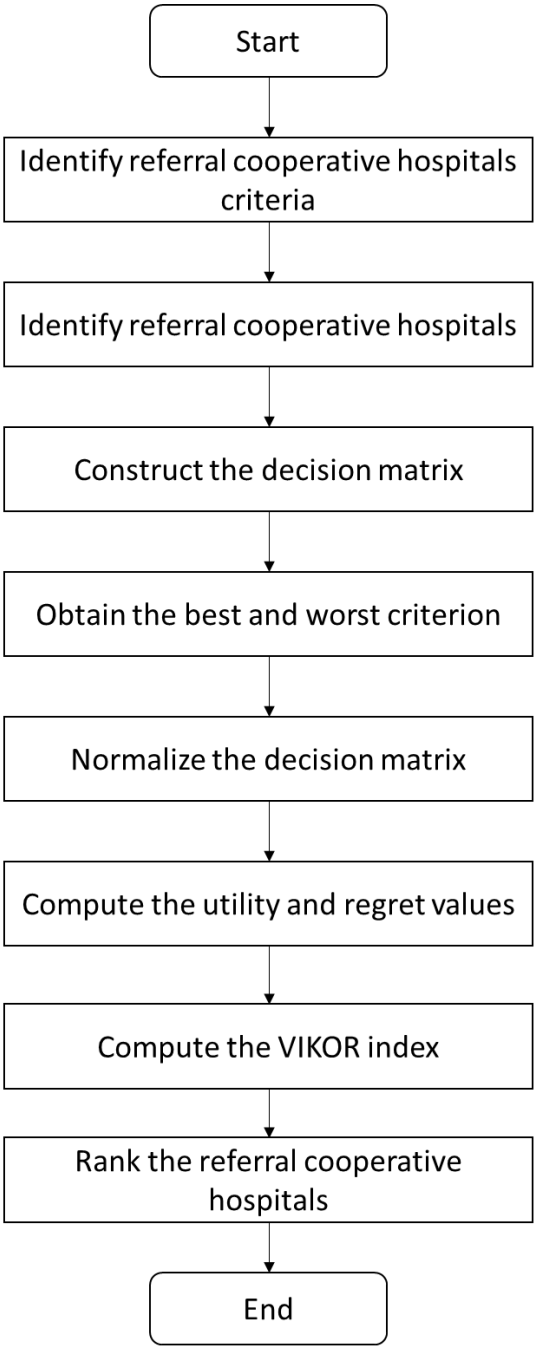

Figure 1. Steps of the neutrosophic VIKOR method.

A) Construct the decision matrix

B) Obtain the best and worst criterion

The ideal best and worst criterion are computed by:

$$y_j^+ = \max_i y_{ij} \quad (1)$$

$$y_j^- = \min_i y_{ij} \quad (2)$$

C) Normalize the decision matrix

$$r_{ij} = \frac{y_{ij} - y_j^-}{y_j^+ - y_j^-} \quad (3)$$

D) Compute the utility and regret values

The utility measures and regret measures are computed by using Manhattan and Chebyshev distances as:

$$U_i = \sum_{j=1}^{n} \left(w_j \frac{r_j^+ - r_{ij}}{r_j^+ - r_j^-} \right) \quad (4)$$

$$G_i = \max_j \left(w_j \frac{r_j^+ - r_{ij}}{r_j^+ - r_j^-} \right) \quad (5)$$

E) Compute the VIKOR index

$$V_i = \frac{U_i - U_i^-}{U_i^- + U_i^+} + (1 - p) \frac{G_i - G_i^-}{G_i^- + G_i^+} \quad (6)$$

Where $p = 0.5$

5. Case Study

This section introduces the selection of referral cooperative hospitals in Egypt. This study used eight hospitals to be ranked and eleven criteria.

When choosing hospitals to work with on patient referrals, it is important to find a balance between the needs of both parties. To guarantee high-quality treatment and patient happiness, this method seeks institutions that satisfy criteria and features.

Referral hospitals are chosen using the following criteria and factors:

Consideration should be given to the hospital's reputation for providing high-quality treatment. The hospital's reputation, accreditation, results, and patient happiness all play a role.

The hospital should provide all the resources and tools required to care for its patients. This comprises diagnostic and imaging services in addition to specialized care in areas like cardiology, cancer, and neurology.

Hospitals that are geographically near to the referral hospital or medical practice are chosen so that patients may spend less time traveling.

For the patient's convenience, the hospital should accept the same insurance plans as the facility making the referral.

The hospital's price policy should be made clear to patients, and the cost of treatment should be affordable.

The hospital should have efficient communication and coordination mechanisms in place to guarantee that all patients get consistent, high-quality treatment.

The hospital's ability to offer treatment that is culturally competent and respectful of the needs of all patients is essential.

When choosing a referral cooperative hospital, it is important to take all these considerations into account to provide patients with the best chance of receiving treatment that is up to par with their standards.

Table 1. Referral cooperative hospital data.

	$RCHC_1$	$RCHC_2$	$RCHC_3$	$RCHC_4$	$RCHC_5$	$RCHC_6$	$RCHC_7$	$RCHC_8$	$RCHC_9$	$RCHC_{10}$	$RCHC_{11}$
RCH_1	(0.9,0.15,0.15)	(0.35,0.70,0.60)	(0.8,0.25,0.20)	(0.9,0.15,0.15)	(0.75,0.30,0.20)	(0.8,0.25,0.20)	(0.9,0.15,0.15)	(0.75,0.30,0.20)	(0.9,0.15,0.15)	(0.8,0.25,0.20)	(0.9,0.15,0.15)
RCH_2	(0.8,0.25,0.20)	(0.75,0.30,0.20)	(0.8,0.25,0.20)	(0.35,0.70,0.60)	(0.35,0.70,0.60)	(0.75,0.30,0.20)	(0.35,0.70,0.60)	(0.15,0.90,0.80)	(0.8,0.25,0.20)	(0.15,0.90,0.80)	(0.8,0.25,0.20)
RCH_3	(0.75,0.30,0.20)	(0.15,0.90,0.80)	(0.9,0.15,0.15)	(0.35,0.70,0.60)	(0.9,0.15,0.15)	(0.15,0.90,0.80)	(0.9,0.15,0.15)	(0.8,0.25,0.20)	(0.35,0.70,0.60)	(0.9,0.15,0.15)	(0.8,0.25,0.20)
RCH_4	(0.8,0.25,0.20)	(0.75,0.30,0.20)	(0.15,0.90,0.80)	(0.8,0.25,0.20)	(0.15,0.90,0.80)	(0.8,0.25,0.20)	(0.15,0.90,0.80)	(0.75,0.30,0.20)	(0.15,0.90,0.80)	(0.15,0.90,0.80)	(0.75,0.30,0.20)
RCH_5	(0.9,0.15,0.15)	(0.15,0.90,0.80)	(0.15,0.90,0.80)	(0.9,0.15,0.15)	(0.15,0.90,0.80)	(0.75,0.30,0.20)	(0.9,0.15,0.15)	(0.75,0.30,0.20)	(0.15,0.90,0.80)	(0.9,0.15,0.15)	(0.35,0.70,0.60)
RCH_6	(0.75,0.30,0.20)	(0.75,0.30,0.20)	(0.8,0.25,0.20)	(0.15,0.90,0.80)	(0.8,0.25,0.20)	(0.15,0.90,0.80)	(0.8,0.25,0.20)	(0.8,0.25,0.20)	(0.15,0.90,0.80)	(0.75,0.30,0.20)	(0.8,0.25,0.20)
RCH_7	(0.8,0.25,0.20)	(0.35,0.70,0.60)	(0.9,0.15,0.15)	(0.35,0.70,0.60)	(0.15,0.90,0.80)	(0.9,0.15,0.15)	(0.15,0.90,0.80)	(0.9,0.15,0.15)	(0.35,0.70,0.60)	(0.9,0.15,0.15)	(0.75,0.30,0.20)
RCH_8	(0.9,0.15,0.15)	(0.75,0.30,0.20)	(0.8,0.25,0.20)	(0.35,0.70,0.60)	(0.75,0.30,0.20)	(0.8,0.25,0.20)	(0.35,0.70,0.60)	(0.75,0.30,0.20)	(0.35,0.70,0.60)	(0.8,0.25,0.20)	(0.9,0.15,0.15)

Experts and decision-makers used the single-valued neutrosophic numbers to evaluate the criteria and referral cooperative hospitals as shown in Table 1. Then by using Equation. (3), the data are normalized as shown in Table 2 based on the best and worst criterion. Then compute the utility and regret measures by using Equations. (4-5). Then compute the VIKOR index by using Equation. (6) as shown in Figure 2.

Table 2. Referral cooperative hospital normalization data.

	$RCHC_1$	$RCHC_2$	$RCHC_3$	$RCHC_4$	$RCHC_5$	$RCHC_6$	$RCHC_7$	$RCHC_8$	$RCHC_9$	$RCHC_{10}$	$RCHC_{11}$
RCH_1	0	0.027344	0.010675	0	0.014308	0.081122	0	0.014308	0	0.081122	0
RCH_2	0.072549	0	0.010675	0.07322	0.063363	0.076852	0.07322	0.087891	0.011811	0	0.016382
RCH_3	0.101563	0.041016	0	0.07322	0	0	0	0.010221	0.07322	0.091796	0.016382
RCH_4	0.072549	0	0.091796	0.011811	0.087891	0.081122	0.101563	0.014308	0.101563	0	0.022934
RCH_5	0	0.041016	0.091796	0	0.087891	0.076852	0	0.014308	0.101563	0.091796	0.101563
RCH_6	0.101563	0	0.010675	0.101563	0.010221	0	0.011811	0.010221	0.101563	0.076852	0.016382

RCH_7	0.072549	0.027344	0	0.07322	0.087891	0.091796	0.101563	0	0.07322	0.091796	0.022934
RCH_8	0	0	0.010675	0.07322	0.014308	0.081122	0.07322	0.014308	0.07322	0.081122	0

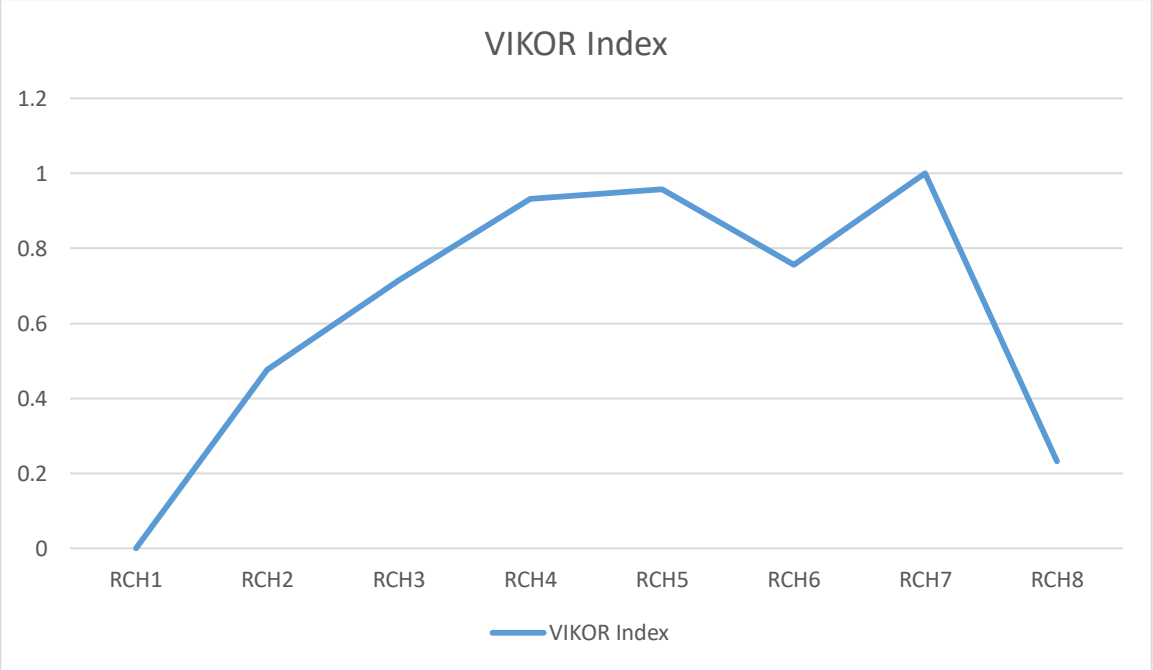

Figure 2. The referral cooperative hospital ranking.

There are many challenges of referral cooperative hospitals, benefits, and drawbacks. Care coordination between many providers and various locations is a significant difficulty for referral cooperative hospitals. Cultural, linguistic, and technological barriers may make this process more difficult than it must be. Satisfaction of Patients: Patients may be unsatisfied with the referral procedure if they find it cumbersome or if they must wait an extended period before they get treatment. Referral cooperative hospitals may be costlier than choices, depending on the complexity and rarity of the patient's disease. While hospitals in a referral cooperative may be selected for their specialization, patients may have doubts about the quality of treatment they would get there. Care at a referral cooperative hospital may not be covered by insurance if it is located outside of the patient's plan's coverage area.

Advantages of Hospitals Working Together to Refer Patients:

Referral cooperative hospitals provide access to specialized treatment that may be unavailable at general medical facilities. Care of a higher level is provided by the referral cooperative hospitals, which have earned a solid reputation for excellence in patient care and provide a full range of specialized medical services. Patients who are treated in hospitals that are members of a referral cooperative may have better results than those treated elsewhere, especially if they have a complicated or uncommon ailment. Better patient outcomes and care coordination are possible when diverse clinicians and institutions work together, as is encouraged by referral cooperative hospitals.

Consequences of Hospitals Working Together to Refer Patients:

Referral cooperative hospitals may charge more than average, depending on the complexity or rarity of the patient's illness. Patients may have to travel farther to reach the referral cooperative hospitals, which may be difficult and time-consuming. Appointments and operations at referral cooperation hospitals may have lengthier wait periods, especially during times of high demand. Care at a referral cooperative hospital may not be covered by insurance if it is located outside of the patient's plan's coverage area. Referrals to certain medical facilities might make patients feel as if they have fewer choices in where to get treatment.

6. Conclusions

Choosing a hospital for a referral cooperative is a crucial step that must consider several variables. Care quality, service availability, location, insurance coverage, cost, communication and coordination, and cultural competence are just a few of the variables considered when choosing a referral cooperative hospital. Hospitals that can deliver high-quality, all-encompassing care that is up to patients' requirements and expectations are given preference when establishing referral connections. However, the process of choosing a referral cooperative hospital is difficult, and there is always the chance that something may go wrong in terms of communication or coordination. This paper used the single-valued neutrosophic set with a MCDM methodology to overcome the uncertain data. The VIKOR method is the MCDM method used to rank the hospitals for a referral cooperative. This method is applied to Egypt as a case study.

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