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An Extended Application of Fuzzy Complex Proportional Assessment Decision-Making Approach to Diagnose Vector-Borne Diseases

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Abstract: Making medical decisions can be challenging because they heavily rely on the knowledge, expertise, and judgement of the doctor. A Physician needs to be knowledgeable, but they also need to understand many other things. Medical diagnosis employs a variety of multi-criteria decision-making approaches. The core goal of this study work is to present an appropriate decision-making model, Fuzzy Complex Proportional Assessment (F-COPRAS) to diagnose vector-borne diseases.

Key Words- Multi-criteria Decision making, Fuzzy COPRAS, Vector-Borne Diseases, Pair-wise comparison method.

Mathematics Subject Classification (2020) – 03B52, 03E72.

1. Introduction

The multi-criteria decision-making (MCDM) process is a powerful and effective approach for addressing complex problems. For problems requiring ambiguous and linguistic data, conventional multi-criteria decision-making (MCDM) methods that include deterministic or random processes are insufficient. As a result, fuzzy MCDM techniques have been used in real-world decision-making scenarios for the past 20 years. These methods are applied in decision support systems to address problems with multiple criteria decision-making.

It can be used to support thorough assessments, according to real-world examples of proper MCDM used in healthcare decision-making from all angles to improve the quality of healthcare. These methods should be extensively considered as a tool to assist healthcare decision-making in order to encourage transparency, equity, and teamwork and arrive at the best outcome.

Although the use of fuzzy decision-making procedures is widespread across many different disciplines, there are very few fuzzy MCDM methods that have been published in the literature in the field of healthcare. Among them is the fuzzy COPRAS method. Hence the application of MCDM in healthcare plays a significant part in the current era of the field. These emerging technologies in medical applications will have benefits for researchers, physicians/clinicians in diagnosis, healthcare managers, and consultants.

Human illnesses caused by parasites, viruses, and bacteria that are spread by vectors are known as Vector-Borne Diseases (VBDs). More than 700,000 people die each year from illnesses like yellow fever, dengue fever, malaria, Japanese encephalitis, and onchocerciasis.

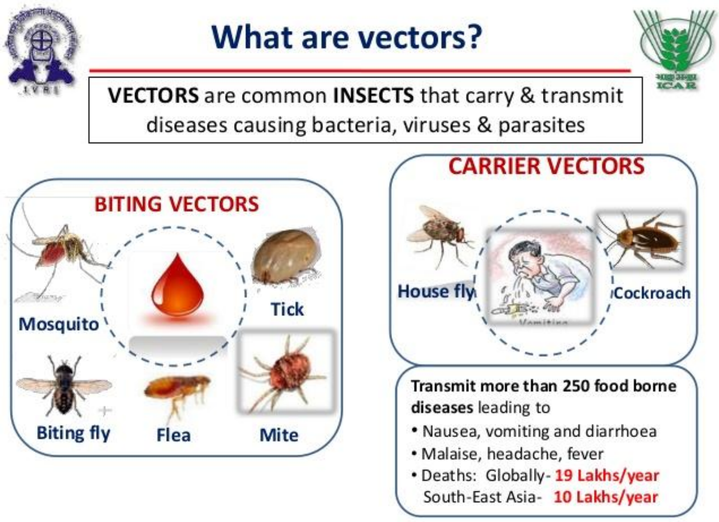

Figure 1. Types of Vectors [Source: NVBDC]

The burden of these diseases is highest in tropical and subtropical areas, and they disproportionately affect the poorest populations **[Source: WHO]**. As a new threat and difficulty for ongoing attempts to control vector-borne diseases, climate change has come to light. The potential effects of climate change on VBDs are becoming more widely known in India, and research organisations and national authorities have started taking measures to evaluate those effects. Hence it is a serious health issue to be addressed. Figure 2 shows the regions which are affected by these diseases. [Source-NVBDC].

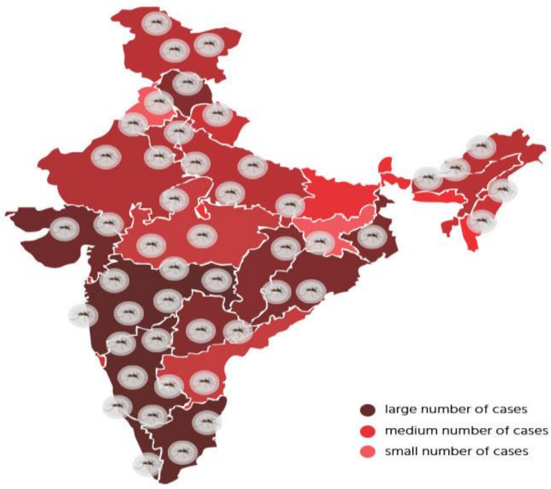

Figure 2. Regions affected by VBDs in India [Source: NVBDC]

In this context, we are trying to extend the fuzzy COPRAS method to diagnose vector-borne diseases.
The rest of the paper is organized as follows: Section 1 presents some of the basic notions needed for the following sections. Section 2 discusses a method for determining the weights to be assigned to the criteria. Section 3 describes the methodology used. Section 4 illustrates the fuzzy COPRAS method and the last section discusses the application of the above-mentioned method in diagnosing vector-borne diseases.

2. Preliminaries

We briefly review some basic terminology in this part.

Definition 1. (Linguistic Variable) [**Zadeh, 1973**] Variables whose values are words or sentences in a natural or artificial language.

Table1. Fuzzy ratings for linguistic variables

Linguistic Variables	Triangular Fuzzy numbers
Extremely Insignificant	(1, 1, 3)
Insignificant	(1, 3, 5)
Significant	(3, 5, 7)
Moderately Significant	(5, 7, 9)
Extremely Significant	(7, 9, 9)

Definition 2. (Defuzzification) This technique turns the fuzzy set (fuzzy output) into the crisp set (crisp output). Fuzzy numbers are the end result of fuzzy decisions. As a result, ranking fuzzy numbers may become an issue in MCDM. This issue needs to be defuzzified so that it can be resolved.

Defuzzification techniques like mean-of-maximum, centre-of-area, and sustainability are available. The centre-of-area approach is applied in this study. The following equation would be applied to a fuzzy number to determine its defuzzified value:

$$Q_i = f_1 + \frac{[(f_3 - f_1) + (f_2 - f_1)]}{3} \qquad (1)$$

where f_1 and f_3 are the lower and upper limits of triangular fuzzy number f respectively and f_2 is the mode [3].

3. Methodology

In this study, firstly we fixed the alternatives and then identified the various criteria. Thereafter, a survey was developed to achieve the objectives of this study. For administering the survey, a team of three decision-makers who are experts in the medical field was selected. From the responses of decision-makers obtained, we built an initial fuzzy decision-making matrix by taking the average. The questionnaire can be found here https://docs.google.com/spreadsheets/d/1KRTfpzB4-xsX80jUthnbxBntYNDSQQj2Q86UOJ51eAU/edit?usp=sharing

Then the ranking of alternatives was done by the fuzzy COPRAS method as illustrated below.

4. The Fuzzy COPRAS Method

By taking into account the dependency factor of the priority and the utility degree of the objects under the opposing characteristics [2], this part discusses the COPRAS approach, which was originally developed by Zavadskas et al. Numerous academics have recognized the COPRAS method's correctness and reliability, and it is now employed to resolve various multi-attribute engineering and management challenges [9]. Zavadskas and Antucheviciene introduced COPRAS with fuzzy sets information, a created method for resolving decision-making issues in uncertain circumstances, in order to evaluate and rank the crucial elements of environmental sustainability in modern rural buildings [10]. Later, Zavadskas and Kaklauskas proposed a framework for creating construction and engineering multi-objectives and multi-attribute issues starting in 1996 [11]. The steps of the process are as follows: [3].

Step 1: Construct the initial fuzzy decision matrix as follows.

$$\tilde{D} = \begin{matrix} & C_1 & C_2 & \cdots & C_n \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \qquad (2)$$

Here, x_{ij} demonstrates the i^{th} alternative in the j^{th}criterion, and m presents the number of alternatives and that n stands for criteria.

Step 2: Compute the criteria weights by pairwise comparison method.

$w_i = [w_1, w_2, \ldots w_n]$ where w_i illustrates the weight of i^{th} criteria.

Note that $\sum_{i=1}^{n} w_i = 1$. (3)

The values of weight are usually determined based on the experts' point of view.

Step 3: Calculate the normalized decision matrix using the below equation.

$$n_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad , i = 1,2, \ldots, m \qquad (4)$$

Step 4: Determine the normalized weight matrix N_{ij} by $N_{ij} = w_i * n_{ij}$ (5)

Step 5: Compute the sum $\widetilde{B_i}$ of benefit criteria and sum $\widetilde{C_i}$of cost criteria.

Here, $\widetilde{B_i}$ represents the Benefit criteria that need to be maximized, and $\widetilde{C_i}$denotes the Cost criteria that need to be minimized.

$$\widetilde{B}_i = \sum N_{ij}^{+} \qquad (6)$$

$$\tilde{C}_i = \sum N_{ij}^{-} \qquad i = 1, 2, \ldots, m \qquad (7)$$

Step 6: Find the relative significance $\tilde{Q}_i$ of each alternative.

$$\tilde{Q}_i = \widetilde{B_i} + \frac{\min(\tilde{C}_i) . \sum_{i=1}^{m} \tilde{C}_i}{\tilde{C}_i \sum_{i=1}^{m} \left(\frac{\min(\tilde{C}_i)}{\tilde{C}_i} \right)} \qquad (8)$$

Step 7: Defuzzify $\tilde{Q}_i$ using equation (5) to get the crisp Q_i.

Step 8: Determine the utility degree for each alternative.

$$UD_i = \frac{Q_i}{\max(Q_i)} \times 100\% \qquad (9)$$

Step 9: Rank the alternatives based on the utility degree.

5. An Application of Fuzzy COPRAS Method to a Decision-Making Problem Concerning the Diagnoses of Vector-Borne Diseases.

In this section, we apply the fuzzy COPRAS method to diagnose vector-borne diseases. This study mainly focussed on four vector-borne diseases such as Dengue, Malaria, Chikungunya, and Yellow Fever which we considered as the alternatives A_1, $A_2, A_3,$ and A_4 . Based on the information collected from medical experts, it was observed that some of these diseases are having the same symptoms such as Fever, Headache, Muscle Pain, Vomiting, and Nausea which we selected as the various criteria C_1,$C_{2,}C_{3,}$ and C_4.

As mentioned earlier, initially a survey had been conducted by preparing a questionnaire comprising 10 questions which were given to a team of medical experts. The following table illustrates the alternative ratings to the different criteria according to experts.

Table 2. Alternative ratings by the medical expert

ALTERNATIVES	**CRITERIA**				
	C1	**C2**	**C3**	**C4**	**C5**
A1	**(7,9,9)**	**(5,7,9)**	**(7,9,9)**	**(3,5,7)**	**(3,5,7)**
A2	**(7,9,9)**	**(3,5,7)**	**(1,3,5)**	**(3,5,7)**	**(3,5,7)**
A3	**(7,9,9)**	**(5,7,9)**	**(7,9,9)**	**(1,3,5)**	**(1,3,5)**
A4	**(7,9,9)**	**(7,9,9)**	**(5,7,9)**	**(5,7,9)**	**(5,7,9)**

The criteria weights by pairwise comparison method are w $(C_1) = 0.4306$, w $(C_2) = 0.19944$, w $(C_3) = 0.3014$, w $(C_4) = 0.0342$, w $(C_5) = 0.0342$.

On application of the fuzzy COPRAS method, we obtained the following results:

Table 3. Fuzzy Normalised Decision Matrix n_{ij}

ALTERNATIVES	CRITERIA				
	C1	C2	C3	C4	C5
A1	(0.194, 0.25, 0.321)	(0.147, 0.25, 0.45)	(0.219, 0.321, 0.45)	(0.107, 0.25, 0.583)	(0.107,0.25, 0.583)
A2	(0.194, 0.25, 0.321)	(0.088, 0.179, 0.35)	(0.031, 0.107, 0.25)	(0.107, 0.25, 0.583)	(0.107,0.25, 0.583)
A3	(0.194, 0.25, 0.321)	(0.147, 0.25, 0.45)	(0.219, 0.321, 0.45)	(0.036, 0.15, 0.417)	(0.036,0.15, 0.417)
A4	(0.194, 0.25, 0.321)	(0.206, 0.321, 0.45)	(0.156, 0.25, 0.45)	(0.179, 0.35, 0.75)	(0.179, 0.35, 0.75)

Table 4. Fuzzy Normalised Weighted Decision Matrix N_{ij}

ALTERNATIVES	CRITERIA				
	C1	C2	C3	C4	C5
A1	(0.08, 0.11, 0.14)	(0.03, 0.05, 0.09)	(0.07, 0.097, 0.14)	(0.004, 0.01, 0.02)	(0.004, 0.01, 0.02)
A2	(0.08, 0.11, 0.14)	0.02, 0.04, 0.07)	(0.01, 0.03, 0.08)	(0.004, 0.01, 0.02)	(0.004, 0.01, 0.02)
A3	(0.08, 0.11, 0.14)	(0.03, 0.05, 0.09)	(0.07, 0.097, 0.14)	(0.001, 0.01, 0.01)	(0.001, 0.01, 0.01)
A4	(0.08, 0.11, 0.14)	(0.04, 0.06, 0.09)	(0.05, 0.08, 0.14)	(0.01, 0.01, 0.03)	(0.01, 0.01, 0.03)

Table 5. Matrix of $\tilde{B}_i$ and $\tilde{C}_i$

	$\tilde{B}_i$	$\tilde{C}_i$
A_1	(0.18, 0.26, 0.37)	(0.008, 0.02, 0.04)
A_2	(0.11, 0.18, 0.29)	(0.008, 0.02, 0.04)
A_3	(0.18, 0.26, 0.37)	(0.002, 0.02, 0.02)
A_4	(0.17, 0.25, 0.37)	(0.02, 0.02, 0.06)

Table 6. Matrix of $\tilde{Q}_i$, Q_i and UD_i

	$\tilde{Q}_i$	Q_i	UD_i	Priority

A_1	**(0.180, 0.285, 1.44)**	**0.635**	**47.2%**	**3**
A_2	**(0.110, 0.205, 1.36)**	**0.558**	**41.49%**	**4**
A_3	**(0.180, 0.285, 3.57)**	**1.345**	**100%**	**1**
A_4	**(0.170, 0.275, 3.57)**	**1.338**	**99.48%**	**2**

As table 6 reveals, the priority goes to alternative 3. This indicates that the disease can be diagnosed as chikungunya.

6. Conclusion

In this paper, we have extended the fuzzy COPRAS decision-making technique to a new area in the medical field which is medical diagnoses. The advantage of the developed model is that even though the patient exhibits the symptoms which are common to all vector-borne diseases, using this method the medical expert could easily diagnose the exact disease. In the future, instead of the pairwise comparison method, one can make use of any other weighing methods such as Best Worst Method, Entropy method, etc. in the same context. Moreover, we may develop a fuzzy COPRAS model using tools like MATLAB.

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