

Research Article

Evaluation of Influenza Intervention Strategies in Turkey with Fuzzy AHP-VIKOR

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In this study, a fuzzy AHP-VIKOR method is presented to help decision makers (DMs), especially physicians, evaluate and rank intervention strategies for influenza. Selecting the best intervention strategy is a sophisticated multiple criteria decision-making (MCDM) problem with potentially competing criteria. Two fuzzy MCDM methods, fuzzy analytic hierarchy process (F-AHP) and fuzzy VIsekriterijumska optimizacija i KOmpromisno Resenje (F-VIKOR), are integrated to evaluate and rank influenza intervention strategies. In fuzzy AHP-VIKOR, F-AHP is used to determine the fuzzy criteria weights and F-VIKOR is implemented to rank the strategies with respect to the presented criteria. A case study is given where a professor of infectious diseases and clinical microbiology, an internal medicine physician, an ENT physician, a family physician, and a cardiologist in Turkey act as DMs in the process.

1. Introduction

The 2009 A(H1N1) influenza pandemic caused a global alert, and all countries implemented various intervention strategies. Some measures across communities were pharmaceutical such as antivirals and vaccination and some were nonpharmaceutical such as limiting public gatherings, closing schools, and restricting travel [1, 2]. Union Health Security Committee recommended to vaccinate risk and target groups such as pregnant women, healthcare workers, and people older than six months with chronic illnesses [3, 4]. Unless an effective intervention strategy is applied, influenza spreads rapidly in seasonal epidemics and costs society a substantial amount in terms of healthcare expenses, lost productivity, and loss of life.

During the 2009 A(H1N1) influenza pandemic, in EU, Hungary started vaccination first, and by July 2010, about 9% was vaccinated in EU/EEA [3]. However, in most of the countries, vaccination campaigns were not as effective as planned due to the timing and the percentage of coverage [5]. Norway and Sweden were compared in terms of their vaccination strategies in a previous study [5]. In Sweden, vaccination campaign was more effective than Norway. Even

though vaccination started almost the same time in both countries and although about 40% of population got vaccinated, in Norway, it was too late to be effective due to the relative timing of the starting time of vaccination and its location in the epidemic wave [5–7]. As discussed in Samanlioglu and Bilge's study [5], for the vaccination campaign to be effective, vaccination should start in the early phases of the epidemic, but it does not need to continue over the peak of the epidemic. The effect of vaccination timing and sales of antivirals in Norway were analysed, and they showed that the countermeasures only prevented 11-12% of the potential cases relative to an unmitigated pandemic, and that if the campaign would have started 6 weeks earlier, the vaccination alone might have reduced the clinical attack rate by 50% [6]. The interventions in France and Germany were discussed in a previous study, and even though Germany and France have similar vaccination policies, the relative fatalities were higher in France [5]. The peak of the epidemic was delayed in France due to the timing of school holidays [8]. The difference can be explained by epidemic-specific precautions and healthcare procedures applied in Germany [9].

As realized from 2009 A(H1N1) pandemic, a systematic approach is needed for effective health planning and making

decisions related to intervention strategies during an influenza pandemic, especially for transparency and accountability of the decision-making process. Evaluation of intervention strategies is a significant MCDM problem that requires expertise and competency since there are various potentially conflicting criteria to take into consideration. In the literature, there are a few studies that utilize MCDM methods for evaluation of intervention strategies. Shin et al. [10] used AHP to evaluate the expanded Korean immunization programs and assess two policies: weather private clinics and hospitals or public health centers should offer free vaccination services to children. Mourits et al. [11] applied the EVAMIX (evaluations with mixed data) MCDM method to rank alternative strategies to control classical swine fever epidemics in EU. Aenishaenslin et al. [12] implemented D-Sight which uses PROMETHEE methods (Preference Ranking Organization Method for Enrichment Evaluations) and gives access to the GAIA (Geometrical Analysis for Interactive Aid) to assess various prevention and control strategies for the Lyme disease in Quebec, Canada. They developed two MCDM models, one for surveillance interventions and one for control interventions, and conducted the analysis under a disease emergence and an epidemic scenario. Pooripussarakul et al. [13] implemented best-worst scaling to assess and rank-order vaccines for introduction into the expanded program on immunization in Thailand.

In this study, various influenza intervention strategies are evaluated, taking into consideration potentially conflicting criteria, by five physicians with different expertises acting as consultants and decision makers (DMs). As the MCDM method and integrated method, fuzzy AHP-VIKOR is implemented to evaluate and rank the strategies. In fuzzy AHP-VIKOR, F-AHP is implemented to find the fuzzy criteria weights and F-VIKOR is utilized to rank alternatives using these weights. Here, an integrated method is used to have both methods' advantages. F-VIKOR is easy to use for MCDM problems with especially conflicting criteria; however, it does not include guidelines for determining the weights of criteria, and with F-AHP, through pairwise comparisons, reliable fuzzy weights can be obtained. With the integrated fuzzy AHP-VIKOR, intervention strategies are ranked without too many repetitive pairwise comparisons and complicated calculations.

The fuzzy set theory is a mathematical theory designed to model the vagueness or imprecision of human cognitive processes. It is a theory of classes with unsharp boundaries, and any crisp theory can be fuzzified by generalizing the concept of a set within that theory to the concept of a fuzzy set [14]. Fuzzy extensions of AHP (F-AHP) and VIKOR (F-VIKOR) are used to capture the uncertainty and vagueness on judgments of DMs.

In AHP [15], alternatives are evaluated based on various criteria in a hierarchical and multilevel structure, and then alternatives are ranked based on a calculated total weighted score. AHP is used widely in real-life applications, i.e., for decisions related to machine shops [16], for evaluation of machine tools [17, 18], and for evaluation of medical devices and materials [19]. The VIKOR method was introduced mainly for MCDM problems with competing or

noncommensurable criteria. In VIKOR, compromise ranking is performed, and alternatives are compared according to the closeness to the ideal solution [20–23]. To reflect the uncertainty and vagueness on judgments of DMs, their fuzzy extensions, F-AHP and F-VIKOR, have been developed. With F-VIKOR, an accepted compromise solution is obtained with a maximum group utility of the majority and a minimum of individual regret of the opponent [22, 24]. In the literature, different versions of F-VIKOR exist such as F-VIKOR with: Triangular fuzzy numbers [24, 25], triangular intuitionistic fuzzy numbers [26], 2-tuple group decision-making linguistic model [27], an attitudinal-based interval 2-tuple linguistic model [28], type-2 fuzzy model [29, 30], and an intuitionistic hesitant model using entropy weights [31]. Several real-life applications of F-AHP, F-VIKOR, and fuzzy AHP-VIKOR are given in Table 1.

At present, there does not appear to be a research paper in the literature that focuses on evaluation and ranking of influenza intervention strategies. Moreover, fuzzy AHP-VIKOR has never been used in the evaluation of intervention strategies for a pandemic. In the next sections, fuzzy AHP-VIKOR steps and a case study are presented.

2. Proposed Fuzzy AHP-VIKOR Approach

2.1. Definitions. In fuzzy set theory, there are classes with unsharp boundaries [61, 62]. Any crisp theory can be fuzzified using the concept of a fuzzy set [14]. In the proposed fuzzy AHP-VIKOR, triangular fuzzy numbers (TFNs) are used due to its simplicity. A fuzzy number is a special fuzzy set $F = \{(x, \mu_F(x)), x \in R\}$. Here, $R : -\infty < x < +\infty$ and $\mu_F(x)$ is from R to $[0, 1]$. A TFN denoted as $\tilde{M} = (l, m, u)$, where $l \leq m \leq u$, has the membership function:

$$\mu_F(x) = \begin{cases} 0, & x < l, \\ \frac{x-l}{m-l}, & l \leq x \leq m, \\ \frac{u-x}{u-m}, & m \leq x \leq u, \\ 0, & x > u. \end{cases} \quad (1)$$

Basic operations between two positive TFNs $\tilde{A} = (l_1, m_1, u_1)$, $\tilde{B} = (l_2, m_2, u_2)$, $l_1 \leq m_1 \leq u_1, l_2 \leq m_2 \leq u_2$, and a crisp number $C (C \geq 0)$ are explained as follows:

$$\tilde{A} + \tilde{B} = (l_1 + l_2, m_1 + m_2, u_1 + u_2),$$

$$\tilde{A} + C = (l_1 + C, m_1 + C, u_1 + C),$$

$$\tilde{A} - \tilde{B} = (l_1 - u_2, m_1 - m_2, u_1 - l_2),$$

$$\tilde{A} - C = (l_1 - C, m_1 - C, u_1 - C),$$

$$\tilde{A} * \tilde{B} = (l_1 * l_2, m_1 * m_2, u_1 * u_2),$$

$$\tilde{A} * C = (l_1 * C, m_1 * C, u_1 * C),$$

$$\frac{\tilde{A}}{\tilde{B}} = \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2} \right),$$

TABLE 1: Fuzzy AHP, fuzzy VIKOR, and fuzzy AHP-VIKOR applications.

| | |
|------------------------------|--|
| Fuzzy AHP applications | (i) Selection of concepts in an NPD environment [32] (ii) Evaluation of machine tools in a manufacturing system [33, 34] (iii) Evaluation of notebook computers for buyers [35] (iv) Evaluation of disassembly line balancing solutions [36] (v) Selection of power substation locations [37] (vi) Selection of thermal power plant locations [38] (vii) Selection of biodiesel blend for IC engines [39] |
| Fuzzy VIKOR applications | (i) Water resources planning [25] (ii) Evaluation of the vulnerability of the water supply to climate change and variability in South Korea [40] (iii) Material selection in an engineering application [41] (iv) Reverse logistics [42] (v) Site selection in waste management [28] (vi) Evaluation of hospital services in Taiwan [43] (vii) Selection of CNC machine tools [44] (viii) Evaluation of schools' academic performance [45] (ix) Selection of green supplier development programs [46] (x) Review papers about VIKOR and fuzzy VIKOR applications [47, 48] (xi) Selection of a managed security service provider [49] (xii) Selection of measures for prevention and reduction of "smog" (smoke and fog) in Pakistan [50] (xiii) Risk assessment of China-Pakistan fiber optic project (CPFOP) [51] |
| Fuzzy AHP-VIKOR applications | (i) Selection of the best renewable energy alternative and the best energy production site for Istanbul [52] (ii) Selection of machine tool alternative for the manufacturing sector [53] (iii) Evaluation of the performance levels of Turkish banks registered in Borsa Istanbul (AHP and F-VIKOR) [54] (iv) Ranking the financial performance of several Iranian companies [55] (v) Evaluation of performance of Iranian cement firms (F-AHP and VIKOR) [56] (vi) Selection of pipe material in sugar industry (F-AHP and VIKOR) [57] (vii) Evaluation of busses for public transportation [58] (viii) Selection of the best knowledge flow practicing organization [59] (ix) Evaluation of compliant polishing tool (AHP and F-VIKOR) [60] |

$$\frac{\tilde{A}}{\tilde{B}} = \left(\min \left(\frac{l_1}{l_2}, \frac{l_1}{u_2}, \frac{u_1}{l_2}, \frac{u_1}{u_2} \right), \frac{m_1}{m_2}, \max \left(\frac{l_1}{l_2}, \frac{l_1}{u_2}, \frac{u_1}{l_2}, \frac{u_1}{u_2} \right) \right),$$

if \tilde{A} and \tilde{B} are TFNs (not necessarily positive TFNs),

$$\frac{\tilde{A}}{C} = \left(\frac{l_1}{C}, \frac{m_1}{C}, \frac{u_1}{C} \right), \quad \text{for } C > 0,$$

$$\tilde{A}^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1} \right),$$

$$\max(\tilde{A} + \tilde{B}) = (\max(l_1, l_2), \max(m_1, m_2), \max(u_1, u_2)),$$

$$\min(\tilde{A} + \tilde{B}) = (\min(l_1, l_2), \min(m_1, m_2), \min(u_1, u_2)).$$

(2)

The graded mean integration approach [63] is used as the defuzzification method to convert TFNs into crisp numbers. Here,

$$\text{crisp}(\tilde{A}) = \frac{(4m_1 + l_1 + u_1)}{6}. \quad (3)$$

2.2. Finding the Important Weights of Criteria with F-AHP. After constructing the hierarchical structure of the problem, the DMs make pairwise comparisons of the criteria and estimate their relative importance in relation to the element at the immediate preceding level. During the

process of evaluation of criteria, the pairwise comparisons are made by using the linguistic terms and scale presented in Table 2.

2.2.1. Computational Steps of F-AHP.

Step 1. Form a decision group of K people. Identify n criteria and select the suitable linguistic terms for the pairwise comparison of criteria. Calculate the aggregated $\tilde{x}_{ij} = (1/K)(\tilde{x}_{ij}^1(+)\tilde{x}_{ij}^2(+)\cdots(+)\tilde{x}_{ij}^K)$ where $\tilde{x}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$, in which $\forall i, j, k$ is the TFN corresponding to the evaluation of the K^{th} DM.

$$\text{Step 2. } \tilde{X} = \begin{bmatrix} (1, 1, 1) & \tilde{x}_{12} & \cdots & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & (1, 1, 1) & \cdots & \cdots & \tilde{x}_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \cdots & (1, 1, 1) \end{bmatrix} \text{ with ele-}$$

ments $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ is normalized and \tilde{S} is obtained.

$$\tilde{S} = \begin{bmatrix} \tilde{s}_{11} & \tilde{s}_{12} & \cdots & \cdots & \tilde{s}_{1n} \\ \tilde{s}_{21} & \tilde{s}_{22} & \cdots & \cdots & \tilde{s}_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \tilde{s}_{n1} & \tilde{s}_{n2} & \cdots & \cdots & \tilde{s}_{nn} \end{bmatrix}, \quad \text{where } \tilde{s}_{ij} = (a_{ij}/\sum_i c_{ij}, b_{ij}/\sum_i b_{ij}, c_{ij}/\sum_i a_{ij}).$$

Fuzzy priority weight vector $\tilde{w}_{\text{criteria}} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)$ is calculated by averaging the entries on each row of \tilde{S} .

TABLE 2: Linguistic terms and TFNs for the evaluation of criteria in F-AHP.

| Linguistic terms | Triangular fuzzy number (TFN) |
|------------------------|-------------------------------|
| Absolutely strong (AS) | (2, 5/2, 3) |
| Very strong (VS) | (3/2, 2, 5/2) |
| Fairly strong (FS) | (1, 3/2, 2) |
| Slightly strong (SS) | (1, 1, 3/2) |
| Equal (E) | (1, 1, 1) |
| Slightly weak (SW) | (2/3, 1, 1) |
| Fairly weak (FW) | (1/2, 2/3, 1) |
| Very weak (VW) | (2/5, 1/2, 2/3) |
| Absolutely weak (AW) | (1/3, 2/5, 1/2) |

Step 3. \tilde{X} is defuzzified by using equation (3), and $w_{cr} = (w_1, w_2, \dots, w_n)$ (approximate crisp criteria weights) is calculated by averaging the entries on each row of normalized X . So the normalized principal eigen vector is w_{cr} . The largest eigenvalue, called the principal eigenvalue (λ_{max}), is determined with the following equation:

$$Xw_{cr}^T = \lambda_{max}w_{cr}^T \quad (4)$$

The measure of inconsistency of pairwise comparisons is called the consistency index (CI), and it is calculated as

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

The consistency ratio (CR) is used to estimate the consistency of pairwise comparisons, and the CR is calculated by dividing CI by the random consistency index (RI):

$$CR = \frac{CI}{RI} \quad (6)$$

RI is the average index for randomly generated weights [15]. If the CR is less than 0.10, the comparisons are acceptable; otherwise, they are not.

2.3. Ranking of Alternatives with F-VIKOR. In the previous section, fuzzy priority weight vector $\tilde{w}_{criteria} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)$ was obtained with F-AHP. After the determination of $\tilde{w}_{criteria}$ with F-AHP, in order to rank the alternatives, F-VIKOR is used. During the process of evaluation of alternatives with F-VIKOR, the linguistic terms and scale presented in Table 3 is used.

2.3.1. Computational Steps of F-VIKOR.

Step 1. Identify the m alternatives and select the suitable linguistic terms for the evaluations of alternatives with respect to each criterion. Calculate the aggregated $\tilde{r}_{ij} = (1/K)(\tilde{r}_{ij}^1(+) \tilde{r}_{ij}^2(+) \dots (+) \tilde{r}_{ij}^K)$ where $\tilde{r}_{ij}^K = (a_{ij}^K, b_{ij}^K, c_{ij}^K)$ is the TFN for the evaluation of the K^{th} DM. After the aggregation, the fuzzy MCDM problem with m alternatives that are evaluated in terms of n criteria can be expressed in a fuzzy

TABLE 3: Linguistic terms and TFNs for the ratings of alternatives in F-VIKOR.

| Linguistic terms | Triangular fuzzy number (TFN) |
|------------------|-------------------------------|
| Very poor (VP) | (0, 0, 1) |
| Poor (P) | (0, 1, 3) |
| Medium poor (MP) | (1, 3, 5) |
| Fair (F) | (3, 5, 7) |
| Medium good (MG) | (5, 7, 9) |
| Good (G) | (7, 9, 10) |
| Very good (VG) | (9, 10, 10) |

matrix format as $\tilde{D} = \begin{bmatrix} \tilde{r}_{11} & \tilde{r}_{12} & \dots & \dots & \tilde{r}_{1n} \\ \tilde{r}_{21} & \tilde{r}_{22} & \dots & \dots & \tilde{r}_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \tilde{r}_{n1} & \tilde{r}_{n2} & \dots & \dots & \tilde{r}_{nn} \end{bmatrix}$, where

$\tilde{r}_{ij} = (a_{ij}, b_{ij}, c_{ij})$, $\forall i, j$, are positive TFNs.

Step 2. Find the fuzzy best value (FBV; \tilde{f}_j^*) and the fuzzy worst value (FWV; \tilde{f}_j^-) for each criterion:

$$\begin{aligned} \tilde{f}_j^* &= \max_i \tilde{r}_{ij}, \quad \forall j, \\ \tilde{f}_j^- &= \min_i \tilde{r}_{ij}, \quad \forall j. \end{aligned} \quad (7)$$

Step 3. Calculate the separation measures of each alternative from the FBV (\tilde{S}_i) and FWV (\tilde{R}_i):

$$\tilde{S}_i = \sum_{j=1}^n \tilde{w}_j \frac{(\tilde{f}_j^* - \tilde{r}_{ij})}{(\tilde{f}_j^* - \tilde{f}_j^-)}, \quad \forall i, \quad (8)$$

$$\tilde{R}_i = \max_j \left[\frac{\tilde{w}_j (\tilde{f}_j^* - \tilde{r}_{ij})}{\tilde{f}_j^* - \tilde{f}_j^-} \right], \quad \forall i.$$

Step 4. Calculate \tilde{S}^* , \tilde{S}^- , \tilde{R}^* , and \tilde{R}^- values as

$$\begin{aligned} \tilde{S}^* &= \min_i \tilde{S}_i, \\ \tilde{S}^- &= \max_i \tilde{S}_i, \\ \tilde{R}^* &= \min_i \tilde{R}_i, \\ \tilde{R}^- &= \max_i \tilde{R}_i. \end{aligned} \quad (9)$$

Step 5. Calculate \tilde{Q}_i values for each alternative:

$$\tilde{Q}_i = \nu \frac{\tilde{S}_i - \tilde{S}^*}{\tilde{S}^- - \tilde{S}^*} + (1 - \nu) \frac{\tilde{R}_i - \tilde{R}^*}{\tilde{R}^- - \tilde{R}^*}, \quad \forall i, \quad (10)$$

where ν is the weight of the strategy of the maximum group utility (majority of criteria) and $1 - \nu$ is the weight of the individual regret. ν is usually assumed to be 0.5 (by consensus) [52, 57].

Step 6. Defuzzify the \tilde{Q}_i values with equation (3) and rank the alternatives based on crisp Q_i values. Consequently, the smaller the Q_i , the better the alternative.

Step 7. Determine a compromise solution. Assume that two conditions below are acceptable. Then, by using Q_i , a single optimal solution $A^{(1)}$ is determined.

Condition 1 (acceptable advantage). $Q(A^{(2)}) - Q(A^{(1)}) \geq DQ$ and $DQ = 1/(m - 1)$ but $DQ = 0.25$ if $m < 4$. Here, $A^{(1)}$ is the first ranked alternative and $A^{(2)}$ is the second ranked alternative based on crisp Q_i values, and m is the number of alternatives.

Condition 2 (acceptable stability in decision-making). $Q(A^{(1)})$ must be $S(A^{(1)})$ and/or $R(A^{(1)})$ under this condition.

If Condition 1 is not accepted and $Q(A^{(m)}) - Q(A^{(1)}) < DQ$, then $A^{(m)}$ and $A^{(1)}$ are the same compromise solution. $A^{(1)}$ does not have a comparative advantage, so the compromise solutions $A^{(1)}, A^{(2)}, \dots, A^{(m)}$ are the same. If Condition 2 is not accepted, the stability of decision-making is deficient although $A^{(1)}$ has a comparative advantage. Hence, compromise solutions $A^{(1)}$ and $A^{(2)}$ are same [51, 64, 65].

3. Case Study

In this study, DMs are a professor of infectious diseases and clinical microbiology (DM1), an internal medicine physician (DM2), an ENT physician (DM3), a family physician (DM4), and a cardiologist (DM5) in Turkey. 8 benefit criteria are determined by the DMs for the evaluation of influenza intervention strategies. These are listed in Table 4.

The alternatives that are going to be ranked are mass vaccination (A1), antiviral treatment and isolation of infected individuals (A2), and exclusion of people from high risk areas (mass measurements to reduce the contact rate, i.e. school closures, and closure of public places) (A3).

In order to determine the fuzzy criteria weights, F-AHP is used. In F-AHP, first DMs do pairwise comparison of criteria using the linguistic terms presented in Table 2. Comparisons of 5 DMs are presented in Table 5. After the aggregation of the corresponding TFNs of the DMs evaluations, in Table 6, \tilde{X} is given. Afterwards, fuzzy priority weight vector $\tilde{w}_{\text{criteria}} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)$ is calculated by averaging the entries on each row of normalized $\tilde{X}(\tilde{S})$. $\tilde{w}_{\text{criteria}}$ is presented in Table 7. In order to calculate the CR of \tilde{X} , equation (3) is utilized for defuzzification. CR is determined as 0.0483, and since it is less than 0.1, the comparison results are considered to be consistent.

$\tilde{w}_{\text{criteria}} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)$ determined with F-AHP is used in F-VIKOR to rank intervention alternatives. In F-VIKOR, first DMs evaluate alternatives with respect to evaluation criteria using the linguistic terms presented in Table 3. These evaluations are presented in Table 8. After the aggregation of the corresponding TFNs of the DMs' evaluations, in Table 9, \tilde{D} is presented. Also, in Table 9, the FBV (\tilde{f}_j^*) and the FWV (\tilde{f}_j^-) for each criterion are presented. The separation measures of each alternative \tilde{S}_i and \tilde{R}_i are given in

TABLE 4: Evaluation criteria for influenza intervention strategies.

| | |
|----|--|
| C1 | Effectiveness (reduction of incidence of cases) |
| C2 | Lack of health side effects |
| C3 | Cost-effectiveness |
| C4 | Feasibility and timing (minimum delay before results) |
| C5 | Public acceptance |
| C6 | Equity and availability (proportion of population benefitting) |
| C7 | Applicability (easiness and minimum complexity) |
| C8 | Lack of unintended effects about work and social life |

TABLE 5: 5 DMs' pairwise comparison of evaluation criteria.

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|----|----|----|----|----|----|----|----|----|
| C1 | E | AS | VS | VS | AS | SS | VS | FS |
| | E | AS | FS | VS | VS | SS | VS | VS |
| | E | E | FS | VS | SS | E | E | SS |
| | E | VS | E | SW | VW | E | SW | E |
| | E | AS | S | VS | VS | E | E | SS |
| C2 | | E | FS | VS | FS | FS | FS | FS |
| | | E | FS | FS | SS | SS | SS | E |
| | | E | FS | SS | AS | SW | FW | SW |
| | | E | VS | SS | SS | SS | E | FS |
| | | E | FS | FS | AS | SS | FS | FS |
| C3 | | | E | FS | VW | FS | E | E |
| | | | E | FS | SS | FS | E | FS |
| | | | E | E | VS | E | SW | VW |
| | | | E | FS | SW | E | E | FS |
| | | | E | SS | FW | SS | E | E |
| C4 | | | | E | FW | FS | E | E |
| | | | | E | SW | VS | SS | E |
| | | | | E | SS | E | SS | FW |
| | | | | E | SW | SW | SW | SW |
| | | | | E | SW | FS | E | E |
| C5 | | | | | E | VS | FS | FS |
| | | | | | E | AS | FS | VS |
| | | | | | E | VS | VS | VS |
| | | | | | E | FW | FS | FS |
| | | | | | E | VS | VS | SS |
| C6 | | | | | | E | E | E |
| | | | | | | E | SS | E |
| | | | | | | E | E | VW |
| | | | | | | E | FS | FS |
| | | | | | | E | E | E |
| C7 | | | | | | | E | E |
| | | | | | | | E | SS |
| | | | | | | | E | E |
| | | | | | | | E | VS |
| | | | | | | | E | E |
| C8 | | | | | | | | E |
| | | | | | | | | E |
| | | | | | | | | E |
| | | | | | | | | E |
| | | | | | | | | E |

Table 10, along with \tilde{S}^* , \tilde{S}^- , \tilde{R}^* , and \tilde{R}^- values. Based on these, \tilde{Q}_i value for each alternative is calculated and presented in Table 10. Afterwards, \tilde{Q}_i , \tilde{S}_i , and \tilde{R}_i values are defuzzified with equation (3), and ranking of alternatives with respect to S_i , R_i , and Q_i are shown in Table 11.

TABLE 6: Fuzzy evaluation matrix for the criteria weights (\tilde{X}).

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| C1 | (1.000, 1.000, 1.000) | (1.700, 2.100, 2.500) | (0.900, 1.200, 1.500) | (1.334, 1.800, 2.200) | (1.280, 1.600, 2.034) | (1.000, 1.000, 1.200) | (1.134, 1.400, 1.600) | (1.100, 1.300, 1.700) |
| C2 | (0.478, 0.540, 0.634) | (1.000, 1.000, 1.000) | (1.100, 1.600, 2.100) | (1.100, 1.400, 1.900) | (1.400, 1.700, 2.200) | (0.934, 1.100, 1.500) | (0.900, 1.134, 1.500) | (0.934, 1.300, 1.600) |
| C3 | (0.480, 0.568, 0.734) | (0.480, 0.636, 0.934) | (1.000, 1.000, 1.000) | (1.000, 1.300, 1.700) | (0.814, 1.034, 1.334) | (1.000, 1.200, 1.500) | (0.934, 1.000, 1.000) | (0.880, 1.100, 1.334) |
| C4 | (0.520, 0.600, 0.836) | (0.548, 0.768, 0.934) | (0.634, 0.802, 1.000) | (1.000, 1.000, 1.000) | (0.702, 0.934, 1.100) | (1.034, 1.400, 1.700) | (0.934, 1.000, 1.200) | (0.834, 0.934, 1.000) |
| C5 | (0.660, 0.880, 1.068) | (0.500, 0.694, 0.800) | (0.914, 1.200, 1.534) | (0.934, 1.100, 1.500) | (1.000, 1.000, 1.000) | (1.400, 1.834, 2.300) | (1.200, 1.700, 2.200) | (1.200, 1.600, 2.100) |
| C6 | (0.868, 1.000, 1.000) | (0.702, 0.934, 1.100) | (0.734, 0.868, 1.000) | (0.680, 0.768, 1.034) | (0.506, 0.680, 0.902) | (1.000, 1.000, 1.000) | (1.000, 1.100, 1.300) | (0.880, 1.000, 1.134) |
| C7 | (0.760, 0.800, 0.968) | (0.734, 0.968, 1.200) | (1.000, 1.000, 1.100) | (0.868, 1.000, 1.100) | (0.460, 0.602, 0.868) | (0.834, 0.934, 1.000) | (1.000, 1.000, 1.000) | (1.100, 1.200, 1.400) |
| C8 | (0.648, 0.834, 0.934) | (0.700, 0.802, 1.100) | (0.900, 1.068, 1.300) | (1.000, 1.100, 1.300) | (0.494, 0.668, 0.868) | (1.000, 1.134, 1.300) | (0.814, 0.900, 0.934) | (1.000, 1.000, 1.000) |

TABLE 7: Fuzzy criteria weights $\tilde{w}_{\text{criteria}} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)$ determined with F-AHP.

| Criteria | Fuzzy weights |
|----------|-----------------------|
| C1 | (0.116, 0.168, 0.242) |
| C2 | (0.094, 0.141, 0.214) |
| C3 | (0.079, 0.112, 0.164) |
| C4 | (0.074, 0.107, 0.152) |
| C5 | (0.093, 0.144, 0.212) |
| C6 | (0.079, 0.109, 0.149) |
| C7 | (0.082, 0.110, 0.152) |
| C8 | (0.079, 0.110, 0.153) |

TABLE 8: 5 DMs' evaluation scores of the influenza intervention alternatives with respect to each criterion.

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|----|----|----|----|----|----|----|----|----|
| A1 | MG | G | F | G | VP | VG | VP | MG |
| | G | G | MG | MG | MP | VG | G | G |
| | VG | VG | F | G | MP | F | G | G |
| | MG | MP | VG | F | G | MP | VG | G |
| | F | MG | MG | G | MP | G | G | G |
| A2 | VG | G | VG | VG | VG | VG | VG | G |
| | G | G | VG | VG | G | VG | VG | G |
| | MP | F | F | MG | G | MG | VG | G |
| | G | P | P | G | F | MP | G | G |
| | G | G | G | MG | VG | F | MG | MG |
| A3 | MP | VG | VG | P | MP | F | VP | F |
| | F | G | G | F | MP | VP | VP | MP |
| | VG | VG | VG | G | MP | P | VP | P |
| | G | VG | MP | F | P | F | F | VP |
| | VP | P | MP | MP | VP | P | P | VP |

Consequently, the smaller the Q_i , the better the alternative, so based on Q_i , alternatives are ranked from best to worst as mass vaccination (A1), antiviral treatment and isolation of infected individuals (A2), and exclusion of people from high risk areas (mass measurements to reduce the contact rate, i.e., school closures, closure of public places, etc.) (A3). However, to determine a compromise solution, Conditions 1 and 2 are checked. Condition 1 (acceptable advantage) is not satisfied when A1 and A2 are compared since $Q(A^{(2)}) - Q(A^{(1)}) = 0.171 - 0.085 = 0.086 < DQ = 0.25$.

Condition 2 (acceptable stability in decision-making) is satisfied since $Q(A^{(1)})$ is also $R(A^{(1)})$, as shown in Table 11. Compromise solutions A1 and A2 are the same. Since $Q(A^{(3)}) - Q(A^{(1)}) = 0.639 - 0.085 = 0.555 \geq DQ = 0.25$, A3 and A1 are not the same compromise solution and A1 has acceptable advantage over A3. Also, A1 is better ranked than A3 in terms of S_i and R_i values, as shown in Table 11, so there is acceptable stability in decision-making. Since $Q(A^{(3)}) - Q(A^{(2)}) = 0.639 - 0.171 = 0.468 \geq DQ = 0.25$, A3 and A2 are not the same compromise solution and A2 has acceptable

TABLE 9: Fuzzy evaluation matrix (\bar{D}) for the alternatives and fuzzy best values (FBV) and fuzzy worst values (FWV).

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| A1 | (5.800, 7.600, 9.000) | (5.800, 7.600, 8.800) | (5.000, 6.800, 8.400) | (5.800, 7.800, 9.200) | (2.000, 3.600, 5.200) | (5.800, 7.400, 8.400) | (6.000, 7.400, 8.200) | (6.600, 8.600, 9.800) |
| A2 | (6.200, 8.000, 9.000) | (4.800, 6.600, 8.000) | (5.600, 7.000, 8.000) | (7.000, 8.600, 9.600) | (7.000, 8.600, 9.400) | (5.400, 7.000, 8.200) | (7.800, 9.200, 9.800) | (6.600, 8.600, 9.800) |
| A3 | (4.000, 5.400, 6.600) | (6.800, 8.000, 8.600) | (5.400, 7.000, 8.000) | (2.800, 4.600, 6.400) | (0.600, 2.000, 3.800) | (1.200, 2.400, 4.200) | (0.600, 1.200, 2.600) | (0.800, 1.800, 3.400) |
| FBV | (6.200, 8.000, 9.000) | (6.800, 8.000, 8.800) | (5.600, 7.000, 8.400) | (7.000, 8.600, 9.600) | (7.000, 8.600, 9.400) | (5.800, 7.400, 8.400) | (7.800, 9.200, 9.800) | (6.600, 8.600, 9.800) |
| FWV | (4.000, 5.400, 6.600) | (4.800, 6.600, 8.000) | (5.000, 6.800, 8.000) | (2.800, 4.600, 6.400) | (0.600, 2.000, 3.800) | (1.200, 2.400, 4.200) | (0.600, 1.200, 2.600) | (0.800, 1.800, 3.400) |

TABLE 10: \bar{S}_i , \bar{R}_i , \bar{S}^* , \bar{S}^- , \bar{R}^* , and \bar{R}^- values.

| | \bar{S}_i | \bar{R}_i | \bar{Q}_i |
|---------------|------------------------|--------------------------------------|------------------------|
| A1 | (-1.744, 0.333, 4.200) | (0.019, 0.112, 1.691) | (-1.133, 0.150, 1.025) |
| A2 | (-1.841, 0.150, 3.379) | (-0.032, 0.141, 1.691) | (-1.050, 0.256, 1.050) |
| A3 | (-1.576, 0.747, 4.404) | (0.047, 0.168, 1.724) | (-1.164, 1.000, 1.000) |
| \bar{S}^* = | (-0.841, 0.150, 3.379) | \bar{R}^* = (-0.032, 0.112, 1.691) | |
| \bar{S}^- = | (-1.576, 0.747, 4.404) | \bar{R}^- = (0.047, 0.168, 1.724) | |

TABLE 11: Fuzzy AHP-VIKOR results for influenza intervention strategies.

| | S_i | Rank | R_i | Rank | Q_i | Rank |
|----|-------|------|-------|------|-------|------|
| A1 | 0.632 | 2 | 0.360 | 1 | 0.085 | 1 |
| A2 | 0.356 | 1 | 0.370 | 2 | 0.171 | 2 |
| A3 | 0.969 | 3 | 0.407 | 3 | 0.639 | 3 |

advantage over A3. Also, A2 is better ranked than A3 in terms of S_i and R_i values, as shown in Table 11, so there is acceptable stability in decision-making.

Although based on Q_i values A1 is better ranked than A2, A1 does not have comparative advantage over A2, so compromise solutions A1 and A2 are same and they both have comparative advantage over A3. So, based on these evaluations and calculations, mass vaccination strategy and antiviral treatment and isolation of infected individuals strategy are found to be the best intervention strategies with no reasonable difference, and exclusion of people from high risk areas strategy is determined to be worse than both of these strategies.

4. Conclusions

In this study, the results of a multicriteria decision analysis for effective management of a health issue-influenza are presented. More specifically, in this research, an integrated fuzzy AHP-VIKOR method is implemented to evaluate influenza intervention strategies. At present, there does not appear to be a MCDA in the literature for the evaluation of influenza intervention strategies. Expert opinion for the development of pairwise comparison matrices of criteria and evaluation of alternatives was needed in the fuzzy AHP-VIKOR method, so a professor of infectious diseases and clinical microbiology, an internal medicine physician, an ENT physician, a family physician, and a cardiologist in

Turkey acted as DMs in the study. Based on their evaluation, mass vaccination and antiviral treatment and isolation of infected individuals are determined as the best intervention strategies with no comparative advantage and exclusion of people from high risk areas (mass measurements to reduce the contact rate, i.e., school closures, and closure of public places) is determined to be the worst alternative among the evaluated.

For future research, the proposed fuzzy AHP-VIKOR method and determined evaluation criteria can be adopted and utilized by physicians for the evaluation and ranking of intervention strategies for similar diseases. Also, outer dependence, innerdependence, and feedback relationships between evaluation criteria can be investigated with the fuzzy analytic network process (F-ANP), and F-ANP can be integrated with F-VIKOR for healthcare-related evaluation and ranking problems such as drug selection and treatment selection.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

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