Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Different variants of pandemic and prevention strategies: A prioritizing framework in fuzzy environment

Oyoon Abdul Razzaq a,*, Muhammad Fahad b, Najeeb Alam Khan b

a Department of Humanities & Social Sciences, Bahria Humanities and Social Sciences School, Bahria University, Karachi 75260, Pakistan
b Department of Mathematics, University of Karachi, Karachi 75270, Pakistan

ARTICLE INFO

Keywords:
- Consistency ratio
- Decision making
- COVID 19
- Triangular fuzzy number
- Defuzzification

ABSTRACT

In this trying time for the world battling different variants of the COVID-19 pandemic, different intervention strategies are being taken by governments, to limit the spread of infection. Closing educational institutes, stay at home orders, campaigns for emphasis on vaccination, usage of medical mask and frequently sanitizing hands, etc. are the endeavors made by the authorities to decrease the number of cases in the country. In this regard, the contribution aims to help the decision-makers to identify a potential prevention strategy, based on public acceptance and intervention effectiveness. To achieve this objective, feasible judgments of professionals from three different sectors are brought together through meetings. Opinions, based on ten criteria, are recorded in linguistic form for prioritizing six alternatives. The linguistic terms are then evaluated and manipulated by entailing triangular fuzzy numbers and a group multi-criteria decision making (GMCDM) approach. After using the fuzzy analytical hierarchy process (F-AHP) for the complex decisions, the fuzzy VIKOR index is utilized to attain the closest ideal stratagem. Consequently, through the ranking orders of defuzzified scores, intuitive preference of compromise solutions is suggested. The tactic gaining more priority with respect to the group utility to the majority and F-VIKOR index is complete lockdown for the short term. Furthermore, a comparison analysis is also added in the discussion to verify the attained prioritized outcomes. This comparative study is carried out through the technique for order of preference by similarity to ideal solution (TOPSIS), which evidently produces the same preference of alternatives. In addition, this strategy can be apparently discovered to be an effective strategy adopted by different countries in successfully decreasing the number of cases.

Introduction

Corona virus disease (COVID’19) has now become the third leading cause of daily death behind heart disease and cancer. This virulence pandemic, which is now found in numerous countries with different variants, initiated from the Wuhan city, China and named as the SARS-CoV-2 virus [1]. For this reason the susceptible, suffering from any respiratory, cardiovascular or hypertensive problems are at more high risk of being infected. Worldwide countries are battling to decrease the reproduction number of this pandemic to lower the rate of morbidity and mortality. The policies made by the professions collaboratively with government have prevented the fatality to a great extent, but yet to be controlled completely [2–7]. However, the measures enacted to stop COVID’19 will have an impact on every aspect of global economy and lifestyle, but safe and healthy life is of paramount importance [8–10].

Tactics, such as closure of academic institutions, large-scale quarantines, social distancing, etc. are significant strategies that have been practiced by different countries. Some countries such as China and Italy, successfully reduced the number of cases on using these stratagems [11]. Besides, the underdeveloped countries and those which are already below the border line of poverty find it difficult to make strict policies, such as lockdown, since it will further cut the daily wages of labors and increase the unemployment rate in the country. Accordingly, the stakeholders formulate policies and treatments with multiple alternatives in the light of different criteria of health and economy of the society [12,13].

Multi-criteria decision analysis provides a structured way to professionally evaluate, assess and select an appropriate strategy among different alternatives [14,15]. This method uses a value measurement model to interpret the performance, followed by deliberation. The
preferences of stakeholders are specified a value function for each criterion, which translates the decision based on that criterion into a score. Later, these scores are weighted and manipulated through different methodologies of MCDMs and prioritize the final recommendation on the rank ordering of the elicit results. Practically, legislative bodies represent their opinions cognitively in a natural way that is, policies and operational decisions are linguistic informations. These linguistic terms are included and defined in the study through fuzzy numbers. Therefore, to deal with complex situations of linguistic data the fuzzy multi-criteria decision making methodologies are widely used nowadays, by incorporating different assumptions of fuzzy theory [16,17]. Although measures of AHP, calculations of consistency ratio, manipulation of weighted aggregate matrices and ranking of linguistic terms through fuzzy numbers are quite cumbrous, but yet more effective [18–20]. Among many, VIKOR and TOPSIS are significantly used methodologies in amalgamation with fuzzy theory in prioritization and selection of optimal alternatives [21–24]. Supply chain and project management, cloud services management, prevention strategies of any disease, etc. are a few highlights where the MCDMs with its different tools are extensively used in recent times [25–28].

In this endeavor, we aim to prioritize the strategies initiated by stakeholders in order to overcome the virulent COVID'19. Here, five strategies are taken into consideration as alternatives, which are evaluated under ten criteria. The strategies are taken as; short term complete lockdown, long term partial lockdown, closure of educational institutes, social distancing, usage of mask and sanitizing hands frequently in huge public gathering, home isolating that is avoiding unnecessary social activities and public gatherings. Each strategy seems to be effective from one side, but these also become a cause of an acrimonious dispute among law makers and public. To cope up with these complex situations, different criteria are developed to measure the significance of the strategies. Briefly, bearing in mind the societal parameters of people in any country, criteria are based on assumptions of health risks, job anxiety and quality education, acquisition of food and other basic necessities and overall performance of national and international markets. Thus the objective of this attempt is to mainly measure the aforementioned alternatives under these certain criteria. To achieve this novel purpose a group multi-criteria decision making (GMCDM) analysis [29–31] is undergone to select the optimal strategy. Here, the groups of decision makers from three different sectors, namely, academia, public health and business sectors are selected. Meetings with seven academicians, five epidemiologists and ten business persons are conducted. In these meetings, all professionals submitted their preferences for the different undertaken intervention strategies. These preferences are made by using linguistic terms, which are then converted into a value function by using triangular fuzzy numbers [20]. Moreover, after implication of AHP and calculation of consistency ratio of the data, we utilize the fuzzy VIKOR method to construct a realistic decision [32,33]. In addition, the priorities attained from this method are further scrutinized through a comparative analysis with the solutions obtained from TOPSIS [21,22]. The carried out analysis and obtained results are advantageous for policy makers while designing standard operating procedures for pandemic.

Furthermore, the layout of the remaining paper is as; section 2 structures the fuzzy AHP and fuzzy VIKOR process in detail, the implementation of the method on the prioritization of COVID'19 prevention strategies and comparative discussions are deliberated in section 3. Sequentially, the analysis is concluded with effective remarks opt from the GMCDM analysis in section 4.

Fig. 1. Portrayal description of F-AHP and F-VIKOR algorithms.
Methodology and computational tools

Fuzzy arithmetic

A fuzzy number $\tilde{A} = (a_1, b_1, c_1)$ of the universe of discourse $U$ may be characterized by a triangular distribution function, which is said to be the membership function of the triangular fuzzy number is defined as:

$$
\mu_{\tilde{A}}(x) = \begin{cases} 
\frac{x-a_1}{b_1-a_1}, & a_1 \leq x \leq b_1 \\
\frac{c_1-b_1}{c_1-b_1}, & b_1 < x \leq c_1 \\
0, & x < a_1 \text{ or } x > c_1
\end{cases}
$$

The fuzzy arithmetic operations between two fuzzy numbers can be carried in two ways, either through the vertices of the triangles i.e., for two fuzzy numbers $\tilde{A} = (a_1, b_1, c_1)$ and $\tilde{B} = (a_2, b_2, c_2)$, where $a_1 \leq b_1 \leq c_1$ and $a_2 \leq b_2 \leq c_2$,

- $\tilde{A} + \tilde{B} = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$
- $\tilde{A} - \tilde{B} = (a_1 - a_2, b_1 - b_2, c_1 - c_2)$
The analytical hierarchy process (AHP) is significantly used as a decision support method that breaks the assessments into groups and then arranges them into a hierarchical structure. This approach is further enhanced in order to make it capable to deal with the tangible...
Table 5

Normalized matrix of criteria.

|  |  |  |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 8 | 9 |
| 10 |  |  |

Table 6

Fuzzy criteria weights.

| Criteria | WI |
|----------|----|
| 1.       | (0.09,0.11,0.12) |
| 2.       | (0.09,0.11,0.13) |
| 3.       | (0.09,0.11,0.12) |
| 4.       | (0.09,0.09,0.11) |
| 5.       | (0.09,0.09,0.11) |
| 6.       | (0.09,0.10,0.12) |
| 7.       | (0.09,0.09,0.11) |
| 8.       | (0.08,0.09,0.10) |
| 9.       | (0.08,0.09,0.11) |
| 10.      | (0.08,0.09,0.10) |

opinions of the decision makers, which are in linguistic form. In this connection, fuzzy extensions of AHP become the most effective tool to sort out such complex situations. Variety of fuzzy analytical hierarchy process (F-AHP) have been developed with different types of fuzzy numbers and are considerably found in literature for different applications of MCDMs. In this section, the procedure of F-AHP is described with the triangular fuzzy numbers [18–20].

Step 1: Choose the convenient linguistic terms for the pairwise comparison of criteria and take average of each using:

\[
\hat{x}_j = \frac{1}{M} \left( \sum_{i=1}^{M} \hat{x}_{ij} \right)
\]

where \(\hat{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})\) and \(M\) is the number of decision makers.

Step 2: Construct the pairwise matrix,

\[
\hat{X}_y^M = \begin{bmatrix}
(1,1,1) & \hat{x}_{12} & \cdots & \hat{x}_{1n} \\
\hat{x}_{21} & (1,1,1) & \cdots & \hat{x}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\hat{x}_{n1} & \hat{x}_{n2} & \cdots & (1,1,1)
\end{bmatrix}
\]

with \(\hat{x}_j = (l_j, m_j, u_j)\) and normalize to the matrix \(\hat{V}\).

\[
\hat{V} = \begin{bmatrix}
\hat{v}_{11} & \hat{v}_{12} & \cdots & \hat{v}_{1n} \\
\hat{v}_{21} & \hat{v}_{22} & \cdots & \hat{v}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\hat{v}_{n1} & \hat{v}_{n2} & \cdots & \hat{v}_{nn}
\end{bmatrix}
\]

\[
\hat{v}_{ij} = \left( \frac{l_j}{\sum_{k=1}^{n} m_k} - m_j \frac{m_j}{\sum_{k=1}^{n} m_k} + u_j \frac{u_j}{\sum_{k=1}^{n} m_k} \right)
\]

Step 3: Fuzzy criteria weights \(\hat{w}_i\) for each \(i\) criteria are obtained by taking the average of each row of \(\hat{V}\).

Step 4: Next is to calculate the consistency index (CI). The largest eigenvector known as principle eigenvalue, denoted by \(\lambda_{max}\) is calculated using the following equation:

\[
XW_{CR} = \lambda_{max} W_{CR}
\]

After obtaining the principle eigenvalue, the value of CI can be obtained as:

\[
CI = \frac{\lambda_{max} - n}{n - 1}
\]

Eq. (5) depends on the matrix of order \(n\). The matrix is consistent, if the value of Eq. (5) is zero and it is expected to produce a decision close to validity. In addition, if the obtained value of Eq. (5) is greater than zero, then Saaty test [34] is applied for the limit of inconsistency. It is tested through consistency ratio (CR) between CI and random index (RI).

\[
CR = \frac{CI}{RI}
\]
Comparison matrix of alternatives in linguistics form.

Table 10

|   | D1  | D2  | D3  | D4  | D5  | D6  | D7  | D8  | D9  | D10 |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | 1   | 1.27| 1.1 | 1.11| 1.3 | 0.96| 1.2 | 1.2 | 1   | 1.04|
| 2 | 0.79| 1   | 1.27| 1.21| 1.27| 1.16| 1.2 | 1.2 | 1.27| 1.1 |
| 3 | 0.92| 0.79| 1   | 1.2 | 1.2 | 0.97| 1.2 | 1.3 | 1.03| 1.2 |
| 4 | 0.92| 0.84| 0.85| 1   | 1.21| 0.96| 1.1 | 1.1 | 1.04| 1   |
| 5 | 0.77| 0.97| 0.85| 0.84| 1   | 1.2 | 1.2 | 1.2 | 1.03| 1.2 |
| 6 | 1.10| 0.88| 1.09| 1.10| 0.85| 1   | 0.96| 1   | 1.03| 1.3 |
| 7 | 0.85| 0.85| 0.85| 0.92| 0.77| 1.1  | 1.0 | 1   | 1.08| 1.2 |
| 8 | 0.85| 0.85| 0.77| 0.92| 0.85| 0.85 | 0.85| 1   | 1.2 | 1.2 |
| 9 | 0.98| 0.79| 0.98| 0.98| 0.86| 1.04 | 0.96| 0.87| 1   | 1.04|
| 10| 1.07| 0.92| 0.85| 1.07| 0.99| 0.77 | 0.85| 0.85| 0.98| 1   |

Table 8

| Criteria | WI |
|----------|----|
| 1.       | 0.11|
| 2.       | 0.11|
| 3.       | 0.11|
| 4.       | 0.10|
| 5.       | 0.10|
| 6.       | 0.10|
| 7.       | 0.09|
| 8.       | 0.09|
| 9.       | 0.09|
| 10.      | 0.09|

The RI value also depends on the matrix of order. If the CR is less than 10% or 0.1, then inconsistency of each comparison is acceptable.

**Fuzzy VIKOR method**

The fuzzy VIKOR method (F-VIKOR), which is an enlargement of VIKOR method for linguistic data, has been constructed to investigate the compromise solution of the fuzzy multi criteria problem [23,29].

The procedure of F-VIKOR can be described meticulously as follows:

1. **Step1:** Identify $m$ alternatives and $n$ criteria rating the convenient linguistic terms and take average of each using following steps:

   \[
   \bar{z}_{ij} = \frac{1}{M} \left( \sum_{j=1}^{M} z_{ij}^M \right)
   \]  \hspace{1cm} (7)

   where $z_{ij}^M = (a_{ij}^M, b_{ij}^M, c_{ij}^M)$ and form the fuzzy matrix,

   \[
   \bar{Z} = \begin{bmatrix}
   \bar{z}_{11} & \cdots & \bar{z}_{1n} \\
   \vdots & \ddots & \vdots \\
   \bar{z}_{m1} & \cdots & \bar{z}_{mn}
   \end{bmatrix}
   \]  \hspace{1cm} (8)

2. **Step2:** Determine the fuzzy best value (FBV) and fuzzy worst value (FWV) respectively, i.e.

   \[
   \bar{f}_j^* = \max_{i=1:n} \bar{z}_{ij}
   \]  \hspace{1cm} (9)

   \[
   \bar{f}_j^- = \min_{i=1:n} \bar{z}_{ij}
   \]  \hspace{1cm} (10)

3. **Step3:** Determine the values of $\bar{S}_i$ and $\bar{R}_i$ by using the relations,
Table 11

| Alternatives | Fuzzy values |
|--------------|--------------|
| A1           | (10.33,12.33,13) |
| A2           | (10.67,12.67,14) |
| A3           | (11.00,13.00,15) |
| A4           | (11.33,13.33,15) |
| A5           | (11.67,13.67,15) |
| A6           | (12.00,14.00,15) |
| C1           | (13.00,15.00,17) |
| C2           | (13.33,15.33,17) |
| C3           | (13.67,15.67,17) |
| C4           | (14.00,16.00,18) |
| C5           | (14.33,16.33,18) |
| C6           | (14.67,16.67,18) |
| C7           | (15.00,17.00,19) |

Table 12

| Separation measures, utility \( \tilde{S}_i \), regret \( \tilde{R}_i \) and F-VIKOR index \( \tilde{Q}_i \). |
|---------------------------------|-------------|-------------|-------------|-------------|
| \( S_i \)                       | \( \tilde{R}_i \) | \( \tilde{Q}_i \) |
|---------------------------------|-------------|-------------|-------------|
| A1                             | (0.49,0.13,1.66) | (0.07,0.71) | (1.58,0.13,1.30) |
| A2                             | (0.37,0.42,2.14) | (0.03,0.11,0.56) | (1.57,0.41,1.23) |
| A3                             | (0.04,0.72,2.86) | (0.05,0.10,1.00) | (2.35,0.55,1.06) |
| A4                             | (0.41,0.54,2.18) | (0.04,0.09,0.48) | (1.48,0.41,1.23) |
| A5                             | (0.22,0.83,3.53) | (0.05,0.11,1.30) | (2.93,0.71,1.30) |
| A6                             | (0.35,0.62,2.29) | (0.04,0.11,0.48) | (1.53,0.52,1.20) |

\( S_{\min} \) and \( S_{\max} \):

\[ S_{\min} (0.49,0.13,1.66) \]
\[ S_{\max} (0.22,0.83,3.53) \]

Table 13

| Alternatives | Fuzzy values |
|--------------|--------------|
| A1           | (10.33,12.33,13) |
| A2           | (10.67,12.67,14) |
| A3           | (11.00,13.00,15) |
| A4           | (11.33,13.33,15) |
| A5           | (11.67,13.67,15) |
| A6           | (12.00,14.00,15) |
| C1           | (13.00,15.00,17) |
| C2           | (13.33,15.33,17) |
| C3           | (13.67,15.67,17) |
| C4           | (14.00,16.00,18) |
| C5           | (14.33,16.33,18) |
| C6           | (14.67,16.67,18) |
| C7           | (15.00,17.00,19) |

The robust ranking method converts the triangular fuzzy number into crisp number.

\[ \tilde{S}_i = \sum_{j=1}^{n} \tilde{w}_i (f_j - \tilde{z}_j) \]
\[ \tilde{R}_i = \max \left( \frac{\tilde{w}_i (f_j - \tilde{z}_j)}{(f_j - \tilde{f}_j)} \right) \]
\[ \tilde{Q}_i = a \frac{\tilde{S}_i - \tilde{S}_i^+}{\tilde{S}^+ - \tilde{S}} + (1 - a) \frac{\tilde{R}_i - \tilde{R}_i^+}{\tilde{R}^+ - \tilde{R}} \]

with the decision making strategy weight \( a \in [0, 1] \). Generally, this value is considered to be \( a = 0.5 \).

Step 5: Defuzzify the values \( \tilde{S}_i, \tilde{R}_i \) and \( \tilde{Q}_i \) by determining the crisp values respectively, on using robust ranking method, then rank the alternatives in decreasing order.

\[ \text{Crisp}(\tilde{X}) = \frac{1}{2} \int_{0}^{1} [\tilde{X}_1, \tilde{X}_2, \ldots, \tilde{X}_n] \, da \]

where \( A^1 \) and \( A^2 \) are the first and second highest ranked alternative and \( k \) is the number of alternatives.
Table 14  
Fuzzy combined decision matrix for TOPSIS.

|   | C1                      | C2                      | C3                      | C4                      | C5                      | C6                      | C7                      | C8                      | C9                      | C10                      |
|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| A1| (10.33,12.33,13)        | (10.33,12.33,13)        | (13.15,15)              | (13.15,15)              | (13.15,15)              | (10.33,12.33,13)        | (13.15,15)              | (12.33,14.33,15)        | (11.67,13.67,14.33)    | (11.67,13.67,14.33)    |
| A2| (9.11,11.67)            | (6.7,6.7)               | (10.33,12.33,13)        | (6.33,8.33,9.67)        | (10.33,12.33,13)        | (11.67,13.67,14.33)     | (9.67,11.67,13)         | (9.11,12.33)            | (11.13,14.33)           | (11.67,13.67,14.33)    |
| A3| (11.13,14.33)           | (10.33,12.33,13,67)     | (7.67,9.67,11)          | (3.33,5.7)              | (7.67,9.67,11)          | (8.67,10.33,11)         | (5.79)                  | (2.67,4.33,6.33)        | (3.5,7)                 | (4.33,6.33,8.33)        |
| A4| (13.15,15)              | (11.67,13.67,14.33)     | (6.33,8.33,9.67)        | (4.67,6.67,8.33)        | (5.79)                  | (11.67,13.67,14.33)     | (5.79)                  | (4.33,6.33,8.33)        | (5.7,6.7,6.7)           | (5.7,6.7,6.7)           |
| A5| (10.33,12.33,13)        | (5.67,7.67,9.67)        | (9.11,12.33)            | (3.67,5.67,7.67)        | (3.33,5.7)              | (7.9,11)                | (7.67,9.67,11,67)       | (3.57)                  | (3.67,5.67,7.67)        | (4.33,6.33,8.33)        |
| A6| (13.15,15)              | (11.67,13.67,14.33)     | (3.67,5.67,7.67)        | (3.67,5.67,7.67)        | (3.33,5.7)              | (7.9,11)                | (11.67,13.67,14.33)     | (5.67,7.67,9)           | (4.33,5.67,7.67)        | (4.67,6.7,6.7)           |

Table 15  
Normalized fuzzy decision matrix for TOPSIS.

|   | C1                      | C2                      | C3                      | C4                      | C5                      | C6                      | C7                      | C8                      | C9                      | C10                      |
|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| A1| (0.68,0.82,0.86)        | (0.72,0.86,0.90)        | (0.86,1.1)              | (0.86,1.1)              | (0.86,1.1)              | (0.72,0.86,0.90)        | (0.86,1.1)              | (0.82,0.95,1)            | (0.81,0.95,1)            | (0.81,0.95,1)            |
| A2| (0.6,0.73,0.78)         | (0.41,0.53,0.62)        | (0.68,0.82,0.86)        | (0.42,0.55,0.64)        | (0.68,0.82,0.86)        | (0.81,0.95,1)           | (0.64,0.78,0.86)        | (0.6,0.73,0.82)          | (0.76,0.90,1)            | (0.81,0.95,1)            |
| A3| (0.73,0.86,0.95)        | (0.72,0.86,0.95)        | (0.51,0.64,0.73)        | (0.22,0.33,0.47)        | (0.51,0.64,0.73)        | (0.60,0.72,0.76)        | (0.33,0.46,0.6)         | (0.17,0.28,0.42)         | (0.21,0.34,0.48)         | (0.31,0.44,0.58)         |
| A4| (0.86,1.1)              | (0.81,0.95,1)           | (0.42,0.55,0.64)        | (0.31,0.42,0.55)        | (0.81,0.95,1)           | (0.33,0.46,0.6)         | (0.28,0.42,0.55)        | (0.39,0.53,0.62)         | (0.34,0.48,0.58)         | (0.39,0.53,0.62)         |
| A5| (0.68,0.82,0.86)        | (0.39,0.53,0.67)        | (0.60,0.73,0.82)        | (0.24,0.37,0.51)        | (0.22,0.33,0.46)        | (0.48,0.62,0.76)        | (0.51,0.64,0.77)         | (0.2,0.33,0.46)           | (0.25,0.39,0.53)         | (0.30,0.44,0.58)         |
| A6| (0.86,1.1)              | (0.81,0.95,1)           | (0.24,0.37,0.51)        | (0.24,0.37,0.51)        | (0.35,0.44,0.51)        | (0.81,0.95,1)           | (0.37,0.51,0.6)         | (0.28,0.37,0.51)         | (0.32,0.41,0.53)         | (0.18,0.30,0.44)         |
Condition (2): acceptable stability, i.e. $S_i$ and $R_i$ or any other separation variable other than $Q_i$ must also rank $A^1$ to be the first ranked alternative.

If first condition is not satisfied, then all alternatives are assumed to be a set of compromise solutions $A^1, A^2, ..., A^K$, for maximum value of $k$ which are obtained according to $Q_i(A^1) - Q_i(A^k) < \frac{1}{x^k}$. Whereas, if the second criteria is not satisfied, then both $A^1$ and $A^2$ are considered as compromised possible solutions of the problem.

Moreover, the flowchart of the proposed algorithms is also sketched in Fig. 1, which show the major steps in one go.

Prioritization of strategies for COVID’19 prevention

Different strategies for the prevention of COVID’19 have been taken by stakeholders of different countries. Lawmakers and peoples from different sectors have different perceptions and level of acceptance for these strategams. These tactics are effective only when there is mutual understanding between lawmakers and peoples of different fields. Similarly, if a country successfully reduces the outbreak of COVID’19 by following a certain policy, might not be effective for any other country. These tactics are considered as six alternatives and then meetings are conducted among different decision makers (DMs) from three different sectors. Namely, seven experts are taken from academia (DM1), five from public health (DM2) and ten from business sector (DM3). These DMs submitted their preferences in linguistic form with respect to ten criteria involved to control the pandemic of COVID’19. These criteria are as follows,

$C1$: Medically effective as the strategy will reduce number of cases
$C2$: Reduce number of cases so reduction in hospitalization cost
$C3$: Effect the quality of education
$C4$: Loss in national and international market
$C5$: Psychological effect
$C6$: Reduce the risk of doctors and staff nurses being infected
$C7$: Anxiety of losing jobs and pay cuts
$C8$: Occurrence of crisis of foods and basic necessities
$C9$: Effect the visitors or workers travelling out of city
$C10$: Reduce the air pollution or other environmental pollution

Here, we have collected most of the common strategies taken by different countries in prevention of this virulent pandemic, defined as:

$A1$: Complete lock down for short-term
$A2$: Partial lock down for long-term (making time intervals each day)
$A3$: Social distancing (everything is opened in normal routine)
$A4$: Home isolation (public themselves avoid going out unnecessarily, while everything is opened in normal routine)
$A5$: Complete closure of education sectors (till this pandemic is completely subjugated)
$A6$: Mask and sanitizing (use of tools while everything is opened in normal routine)

Additionally, Fig. 2 illustrate the network of criteria to each alternative. Evaluations of each alternative under the above criteria by the experts are documented in linguistic form. These linguistic terms are then signified by triangular fuzzy numbers, as shown in Tables 1 and 2 accordingly for F-AHP and F-VIKOR.

Executing the GMCDM scheme on the constructed data of the governing problem, in the initial stage, the F-AHP algorithm is processed. Sequentially, after the fuzzy pairwise comparison matrix of ten criteria, as shown in Table 3 and 4, the matrix is normalized in Table 5. The fuzzy criteria weights for ten criteria, videlicet, $\tilde{w}_i$ for $i = 1, 2, ..., 10$, are tabulated in Table 6. On using the Eqs. (4) and (5), the consistency index of the proposed data is calculated to be $CI = 0.01935 > 0$. The defuzzified values of fuzzy normalized matrix and fuzzy criteria weights are demonstrated in Tables 7 and 8 accordingly, where the maximum eigenvalue is obtained as $\lambda_{max} = 10.1714$. Thus, after applying Saaty test [34] on employing Eq. (6) with the value $RI = 1.49$ taken from Table 9, we get $CR = 0.01298$, which implies that the inconsistency of
ranking is carried out by using the robust ranking method, outlined in Eq. (16). The ranks against each alternative with respect to utility, are the values of separation measures, attained through Eqs. (9) and (10). Next, manipulations illustrated in Table 12 are performed on the comparison matrix into triangular fuzzy numbers is represented in next step of GMCDM algorithm. Second stage of using F-VIKOR method is greatly acceptable.

Table 17

|        | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  | C9  | C10 | D*   |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| A1     | 0.09| 0.06| 0. 0| 0. 0| 0. 0| 0.06| 0. 0| 0. 0| 0. 0| 0. 0| 0.23 |
| A2     | 0.13| 0.18| 0.09| 0.17| 0.09| 0. 0| 0.11| 0.11| 0.03| 0. 0| 0.91 |
| A3     | 0.07| 0.06| 0.15| 0.22| 0.14| 0.11| 0.18| 0.21| 0.20| 0.18| 1.56 |
| A4     | 0. 0| 0. 0| 0.17| 0.19| 0.19| 0. 0| 0.18| 0.18| 0.16| 0.17| 1.27 |
| A5     | 0.09| 0.17| 0.12| 0.21| 0.22| 0.13| 0.13| 0.21| 0.19| 0.18| 1.69 |
| A6     | 0. 0| 0. 0| 0.22| 0.21| 0.20| 0. 0| 0.17| 0.19| 0.18| 0.21| 1.41 |

Table 18

|        | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  | C9  | C10 | D*   |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| A1     | 0.06| 0.15| 0.22| 0.22| 0.22| 0.11| 0.18| 0.21| 0.21| 0.21| 1.81 |
| A2     | 0. 0| 0.01| 0.17| 0.11| 0.18| 0.13| 0.13| 0.16| 0.19| 0.21| 1.33 |
| A3     | 0.09| 0.15| 0.12| 0. 0| 0.13| 0.05| 0. 0| 0. 0| 0.07| 0.65 |
| A4     | 0.13| 0.18| 0.09| 0.06| 0.07| 0.13| 0. 0| 0.07| 0.09| 0.08| 0.94 |
| A5     | 0.06| 0.03| 0.15| 0.03| 0. 0| 0. 0| 0.09| 0.03| 0.03| 0.07| 0.53 |
| A6     | 0.13| 0.18| 0. 0| 0.03| 0.06| 0.13| 0.03| 0.06| 0.05| 0. 0| 0.70 |

Table 19

|        | D1  | D2  | C1  | Rank |
|--------|-----|-----|-----|------|
| A1     | 0.23| 1.81| 0.88| 1    |
| A2     | 0.90| 1.33| 0.59| 2    |
| A3     | 1.56| 0.65| 0.29| 5    |
| A4     | 1.27| 0.94| 0.42| 3    |
| A5     | 1.69| 0.53| 0.24| 6    |
| A6     | 1.40| 0.70| 0.33| 4    |

The ranking in Table 13 for \( Q_\text{1} \) elaborates the prioritization of the strategies that are considered as six alternatives through ten evaluating criteria. The ranking quantifies the best to worst in descending order. Consequently, the acceptable value of consistency ratio leads to the next step of GMCDM algorithm. Second stage of using F-VIKOR method starts from the linguistic structure of comparison matrix of six alternatives with respect to three DMs as tabulated in Table 10. The conversion of comparison matrix into triangular fuzzy numbers is represented in Table 11. This table also summarizes the fuzzy best and fuzzy worst values, attained through Eqs. (9) and (10). Next, manipulations illustrated numerically in Table 12 are the values of separation measures, achieved by using Eqs. (11)-(15). On utilization of these, the last step of ranking is carried out by using the robust ranking method, outlined in Eq. (16). The ranks against each alternatives with respect to utility, regret and VIKOR index variables are explained in Table 13 as descending order.

Effectiveness of the proposed methodology

In recent times, fuzzy theory is playing a vital role in translating the linguistic terms into numerical form, to make the evaluation more realistic. As the survey of this research was composed with linguistic options, so the data collected from the inspection was to be converted to numerical values. In this regard, compromised solutions suggest the priority of strategies A1, A5 and A3 among the other. Furthermore, the ordered sequence of alternatives advocate the complete short term lockdown has gain the first priority by the three groups of DMs. Sequentially, complete closure of education sectors and social distancing are also next to the list of public acceptance and intervention effectiveness.

The evaluation of alternatives is also carried out using the algorithm of TOPSIS to further verify the attained prioritized outcomes of F-VIKOR. Tables 14–19 represent the calculations and results obtained using TOPSIS [22]. The ranking shown in Table 19 suggest the priority of strategies A1, A2 and A4 among the other. Thus, TOPSIS also prioritizes the complete short term lockdown intervention strategy to overcome this pandemic.

Conclusion

This study illustrates the current scenario of the worldwide countries in campaigning tenaciously, for the prevention of COVID’19 pandemic. While implementing any strategy in a country may indirectly effect, either positive or negative, the other major factors of the country. Bearing this in mind, we depicted the perspectives of group of decision makers about actions taken by stakeholders in averting the deadly transmission of COVID’19. The proposed groups constituted three principle sectors of any country, namely, academia, public health and business sectors. The opinions were collected by means of linguistic parameters through meetings with seven academicians, five epidemiologists and ten business persons. These meetings were to evaluate six strategies subjected to ten criteria, through which we got the public acceptance and effectiveness of the actions. Since the speculation is carried out in linguistic form, therefore F-AHP in combination with F-VIKOR algorithm of GMCDM approach was used. Inevitably, the facts and figures from the whole endeavor can be defined into the following two significant modes.

\[
\text{Effectiveness of the proposed methodology}
\]

\[
\text{In recent times, fuzzy theory is playing a vital role in translating the linguistic terms into numerical form, to make the evaluation more realistic. As the survey of this research was composed with linguistic options, so the data collected from the inspection was to be converted to numerical values. In this regard, compromised solutions suggest the priority of strategies A1, A5 and A3 among the other. Furthermore, the ordered sequence of alternatives advocate the complete short term lockdown has gain the first priority by the three groups of DMs. Sequentially, complete closure of education sectors and social distancing are also next to the list of public acceptance and intervention effectiveness.}
\]

\[
\text{The evaluation of alternatives is also carried out using the algorithm of TOPSIS to further verify the attained prioritized outcomes of F-VIKOR. Tables 14–19 represent the calculations and results obtained using TOPSIS [22]. The ranking shown in Table 19 suggest the priority of strategies A1, A2 and A4 among the other. Thus, TOPSIS also prioritizes the complete short term lockdown intervention strategy to overcome this pandemic.}
\]

\[
\text{Conclusion}
\]

\[
\text{This study illustrates the current scenario of the worldwide countries in campaigning tenaciously, for the prevention of COVID’19 pandemic. While implementing any strategy in a country may indirectly effect, either positive or negative, the other major factors of the country. Bearing this in mind, we depicted the perspectives of group of decision makers about actions taken by stakeholders in averting the deadly transmission of COVID’19. The proposed groups constituted three principle sectors of any country, namely, academia, public health and business sectors. The opinions were collected by means of linguistic parameters through meetings with seven academicians, five epidemiologists and ten business persons. These meetings were to evaluate six strategies subjected to ten criteria, through which we got the public acceptance and effectiveness of the actions. Since the speculation is carried out in linguistic form, therefore F-AHP in combination with F-VIKOR algorithm of GMCDM approach was used. Inevitably, the facts and figures from the whole endeavor can be defined into the following two significant modes.}
\]

\[
\text{Effectiveness of the proposed methodology}
\]

\[
\text{In recent times, fuzzy theory is playing a vital role in translating the linguistic terms into numerical form, to make the evaluation more realistic. As the survey of this research was composed with linguistic options, so the data collected from the inspection was to be converted to numerical values. In this regard,}
\]
After evaluating the opinions of different groups, we successfully prioritized three strategies among six on the basis of public acceptance and intervention effectiveness. Accordingly, it can be concluded as:

- Complete lockdown is more effective in preventing the pandemic, but for a short-term, as it will cause a negative effect on the economy of the country. Since during this action, business sector will be entirely in shutdown phase. Contrarily, education sectors will cope the loss through online classes. Whereas, in medical it is the best tactic to break the pandemic quickly and smoothly, but becomes worst if it goes for long term. In view of the fact that it will cause mental illness in individuals, due to which some other campaigns are taken into account to help such victims psychologically.

- In addition, complete closure of education sectors, while other places might be open. It will not negatively affect the economy to that extent, as the business sector is kept fully open. Moreover, it will mainly reduce the number of cases of small-age group people.

- Next strategic action is to be taken by public themselves is social distancing, avoiding unnecessary public gathering. During this the business sector will not be closed, but due to social distancing, existence of small number of customers, market might move to minor loss and ultimately the complete economy. In medical context, it will greatly reduce the transmission of the disease. Whereas, it is also useful in academic institutions but cumbersome to manage with limited resources.

The aforementioned points are prioritized strategies among six proposed strategies, yield by F-VIKOR. As the analysis is carried out through public acceptance and effectiveness, therefore it benefits the stakeholders to make decisions in effectively implementing the measures. Definitely, the measures to avert the transmission of the pandemic will cause negative effect in one way or the other. Nonetheless, with the perception of health comes first, the tactics regulated by the lawmakers need to be accepted and implemented by public to make the intervention campaign more effective.

CRediT authorship contribution statement

Oyoon Abdul Razzaq: Conceptualization, Methodology, Validation, Investigation, Writing - original draft, Writing - review & editing. Muhammad Fahad: Methodology, Software, Validation, Formal analysis, Investigation, Visualization. Najeeb Alam Khan: Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The author is thankful to Bahria University for supporting/facilitating this work. All the authors are grateful for the comments of the referees and editor.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] Ahmed A, Ali A, Hasan S. Comparison of epidemiological variations in COVID-19 patients inside and outside of China-a meta-analysis. Front Public Health 2020;8:193.
[2] Damian B, et al. Surgical tracheostomies in Covid-19 patients: important considerations and the “5Ts” of safety. Br J Oral Maxillofac Surg 2020.
[3] Gan Y, et al. The fight against COVID-19 and the restoration of trust in Chinese medical professionals. Asian J Psychiatry 2020;51:102072.
[4] Coccia M. Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID. Sci Total Environ 2020;729:138474.
[5] Baud D, Dimopoulou Agri V, Gibson GR, Reid G, Giannone E. Using probiotics to flatten the curve of coronavirus disease COVID-19 pandemic. Front Public Health 2020;8.
[6] Girona T. Confinement time required to avoid a quick rebound of COVID-19: predictions from a Monte Carlo stochastic model. Front Phys 2020;8:186.
[7] Seo-Crowe B, Mckenney M, Bonova D, Ebbilbi A. A state overview of COVID19 spread, interventions and preparedness. Am J Emergency Med 2020;38(7):1520-3.
[8] Ferneini EM. The financial impact of COVID-19 on our practice. J Oral Maxillofac Surg 2020;78(7):1047-8.
[9] Hiremath R, et al. COVID-19: impact of lock-down on mental health and tips to overcome. Asian J Psychiatry 2020;55:102088.
[10] Varalakshmi R, Arunachalam K. COVID-19 Role of faculty members to keep mental acuteness of students. Asian J Psychiatry 2020;51:102091.
[11] Kupferschmidt K, Cohen J. Can China’s COVID-19 strategy work elsewhere? 2020, American Association for the Advancement of Science.
[12] Yildirim FS, et al. Comparative evaluation of the treatment of COVID-19 with multicriteria decision-making techniques. J Healthcare Eng 2021;2021:8864522.
[13] Hezam IM, et al. COVID-19 Vaccine: a neutrosophic MCDM approach for determining the priority groups. Results Phys 2021;20:103654.
[14] Baltussen R, Marsh K, Thokala P, Diaby V, Castro H, Gleenput I, et al. Multicriteria decision analysis to support health technology assessment agencies: benefits, limitations, and the way forward. Value Health 2019;22(11):1281-8.
[15] Bianchini J, Humblet M-F, Cargnel M, Van der Steede V, Koemen P, Clercq K, et al. Prioritization of livestock transboundary diseases in Belgium using a multicriteria decision analysis tool based on drivers of emergence. Transboundary Emerg Dis 2020;7(1):344-76.
[16] Muangman J, Krootsong K, Polrong P, Yuhkunthorn W, Udomsap W, Fuzzy multicriteria decision-making for ranking intercrop in rubber plantations under social, economic, and environmental conditions. Adv Fuzzy Syst 2020;2020:1-8.
[17] Wang C-N, Yang C-Y, Cheng H-C. A fuzzy multicriteria decision-making (MCDM) model for sustainable supplier evaluation and selection based on triple bottom line approaches in the garment industry. Processes 2019;7(7):400.
[18] Letniak A, Kubek D, Plebanikiewicz E, Zima K, Belniak S. Fuzzy AHP application for supporting contractors’ bidding decision. Symmetry 2018;10(11):642.
[19] Khan AA, et al. Fuzzy AHP based prioritization and taxonomy of software process improvement success factors in global software development. Appl Soft Comput 2019;83:105648.
[20] Lyn-He, Sun W-L, Shen S-L, Zhou A-N. Risk assessment using a new consulting process in fuzzy AHP. J Constr Eng Manage 2020;146(3):04019112.
[21] Chattjee P, Stevic Ž. A two-phase fuzzy AHP-fuzzy TOPSIS model for supplier evaluation in manufacturing environment. Operat Res Eng Sci: Theory Appl 2019;2(1):72-90.
[22] Chou Y-C, Yen H-Y, Dang VT, Sun C-C. Assessing the human resource in science and technology for Asian countries: application of fuzzy AHP and fuzzy TOPSIS. Symmetry 2019;11(2):251.
[23] Jing S, Tang Y, Yan J. The application of fuzzy VIKOR for the design scheme selection in lean management. Mathem Problems Eng 2018;2018:1-15.
[24] Abdel-Bast M, Mohamed R, Elhoseny M. A model for the effective COVID-19 identification in uncertainty environment using primary symptoms and CT scans. Health Inf J 2020;26(4):3988-105.
[25] Mohammed MA, Abdulkareem KH, Al-Waisy AS, Mostafa SA, Al-Fahdawi S, Dinar AM, et al. Benchmarking methodology for selection of optimal COVID-19 diagnostic model based on entropy and TOPSIS methods. IEEE Access 2020;8:99163-31.
[26] Batur Sir GD, Sir E. Pain treatment evaluation in COVID-19 patients with hesitant fuzzy linguistic multicriteria decision-making. J Healthcare Eng 2021:9031114.
[27] Tiwari RK, Kumar R. A robust and efficient MCDM-based framework for cloud service selection using modified TOPSIS. Int J Cloud Appl Comp, 2021. (11): 21-51.
[28] Narwane VS, Yadav VS, Raut RD, Narkhede BE, Gardas BB. Sustainable development challenges of the biofuel industry in India based on integrated MCDM approach. Renewable Energy 2021:164:298-309.
[29] Shumaiza, Akram M, Al-Kenani AN, Alcantud JCR. Group decision-making based on the VIKOR method with trapezoidal bipolar fuzzy information. Symmetry 2019;11(10):1333.
[30] Akram M, Ilyas F, Garg H. Multi-criteria group decision making based on ELECTRE I method in Pythagorean fuzzy information. Soft Comput 2020;24(5):3425–53.

[31] Xiao J, Wang X, Zhang H. Managing personalized individual semantics and consensus in linguistic distribution large-scale group decision making. Inf Fus 2020;53:20–34.

[32] Gou X, Xu Z, Liao H, Herrera F. Multiple criteria decision making based on distance and similarity measures under double hierarchy hesitant fuzzy linguistic environment. Comput Ind Eng 2018;126:516–30.

[33] Gou X, et al., Probabilistic double hierarchy linguistic term set and its use in designing an improved VIKOR method: The application in smart healthcare. Journal of the Operational Research Society, 2020: p. 1–20.

[34] Vargas LG. An overview of the analytic hierarchy process and its applications. Eur J Oper Res 1990;48(1):2–8.