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How, When, & Where temporary hospitals fit in turbulent times: A hybrid MADM optimization in the middle east

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A B S T R A C T

Governments have been challenged to provide temporary hospitals and other types of facilities to face the COVID-19 pandemic. This research proposes a novel multi-attribute decision-making (MADM) model to help determine how, when, and where these temporary facilities should be installed based on a set of critical success factors (CSFs) mapped in an uncertain environment. We portray the available facilities for temporary hospitals based on the CSFs that must be considered to make critical decisions regarding the optimal position based on the government’s strategic decision-making process, thus indirectly providing better services and maximizing resources. In relation to earlier work, this research builds upon hybrid Pythagorean fuzzy numbers to find weights in Best-Worst Methods and rank temporary facilities based on evaluation by an area-based method for ranking. Policy implications and future directions are derived.

1. Introduction

The healthcare industry provides vital services to modern societies to integrate advanced and optimized operations (Mazloumian et al., 2022). However, healthcare has recently faced challenging circumstances in terms of operating robust operations vs services (Samadi et al., 2021). The far-reaching COVID-19 pandemic forces global industries to coordinate their efforts in supplying and transporting goods and services to help control the pandemic, including the hospital care industry. For instance, blockchain technology has been assessed (Samadi et al., 2021); new trends have been recognized (Hsu et al., 2021); business to business alliances have been formed (Madanaguli et al., 2021); six sigma projection and prioritization has been enumerated (Can et al., 2021); and sustainability-oriented innovation frameworks have been implemented (Elabad et al., 2021).

Admittedly, the responsiveness and propitiousness of healthcare operations significantly contribute to patient survival in global rural and urban areas (Can et al., 2021; Liu et al., 2021). Indeed, Hejazi (2021) called for “requirements to provide fast and quality services to patients and creation of value for health care centers.” Accordingly, we argued that the significance of hospitals in times the COVID-19 pandemic (a) leverages consumer rights for medical care and instituting temporary hospitals and (b) emerges as humanitarian and economic strategic pathways to serve and thrive. Therefore, this study aims to identify the strategic critical success factors (CSFs) to bolster temporary hospitals and significantly control operational and medical costs.

Strategic and operations developments in temporary hospitals comprise complex interfaces between various health care clusters that can overwhelm limited human resources, operations, and optimizations, as well as strategic decision-making (Hsu et al., 2021; Mazloumian et al., 2022). Such profound practices become more convoluted by the inherent variability of the various CSFs. In particular, the unplanned landscape of the CSFs and the uncertainty about patient recovery mean the temporary hospitals must have vibrant CSFs in place that can strongly stimulate instantaneous operations and strategic decision-making to alleviate poverty and economic vulnerability (Brandt et al., 2021; Lu et al., 2021). Therefore, this study intends to optimize and rank the strategic CSFs related to the site selection of temporary hospitals.

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during the turbulent waters of the COVID-19 pandemic.

Congestion of temporary hospitals is a matter of global import, and operations research techniques have been extensively utilized to conceal the dearth of relevant research. Therefore, this study proposed a novel combination of Pythagorean fuzzy numbers of the best-worst method (PFNBMW) with the Pythagorean fuzzy number evaluation area-based method ranking (PFNEAMR) method for selecting suitable hospitals to accommodate the unprecedented COVID-19 diseases. The key advantage of such a hybrid approach is that it can map the CSFs related to where such temporary hospitals might be set up and operated in a multidimensional fashion. Indeed, it is evident that providing the best type of services in temporary hospitals and managing referrals to medical personnel will gratify patients, especially in rural and urban communities (Yang et al., 2021; Zhang et al., 2020).

This study explores the optimal 16 potential CSFs for temporary hospitals to reduce waiting time and increase amenities according to diverse conditions, thus enhancing the productivity of temporary hospitals. Moreover, we pursue the strategic action plan to answer where such temporary hospitals should be located. This action plan strategy decreases the waiting time for triage, intensifies the utility of temporary hospitals, and reduces the patient uncertainty vis-a-vis the COVID-19 pandemic. As Sarkar et al. (2021) noted, the decision must to be taken swiftly because hospital capacity is in constant flux due to the increasing number of infected people. Therefore, we have answered this call by providing different scenarios to improve the potential CSFs of temporary hospitals and put in place a strategic action plan for instantaneous service delivery. In doing so, we used a hybrid multi-attribute decision-making (MADM) model to rank the selected CSFs by the PFNBWM and PFNEAMR methods and established a model to find an action plan strategy for temporary hospitals.

The rest of the article comprises the following sections. The literature review is presented in Section 2. Section 3 revisits the MADM and PFN methods. The research methodology is described in Section 4. Section 5 focuses on the data analysis while the final section sets out some managerial implications and conclusions of the study.

2. Literature review

2.1. Transitioning of temporary hospitals during the COVID-19 pandemic

The impact of the COVID-19 pandemic goes beyond the spread of the disease and other transitioning related to acute respiratory syndrome (Sarkar et al., 2021). The impact on the supply chain has been particularly significant in the Middle East, in countries such as Iran, where it has economically disrupted and debilitated particularly impoverished urban and rural communities (Moosavi & Hosseini, 2021). However, what is important is that controlling the disruptions requires maintaining temporary hospitals management and rapid responsiveness to healthcare and public welfare (Govindan et al., 2021). The economic downturn triggered by the COVID-19 pandemic in Iran coincides with the economic sanctions against the nation (Lotfi et al., 2022). Although various of these sanctions have been in place for the last four decades, since May 2019 (Danaei et al., 2019), the unilateral sanctions imposed using Fuzzy VIseKriterijumska Optimizacija I Kompromisno Resenje (FVIKOR). Building, cost, population density, prospective population, education level, economic conditions, accessibility, traffic, patients, cost, future considerations, climate conditions, and noise were factors for hospital site selection. In turn, Kahraman et al. (2019) used Fuzzy TOPSIS for hospital location selection, considering cost of land, land topography, building cost, population density, education level, economic conditions, proximity to transport, availability of infrastructure, and proximity to markets. Similarly, Mić and Antmen (2019) performed fuzzy TOPSIS (FTOPSIS) for healthcare location selection based on demographic structure, investment costs, environmental factors, travel time, travel costs, and infrastructure. Senvar et al. (2016) also presented a similar study using FTOPSIS.

Çelikbilek (2018) showed how hospital location can be selected using Fuzzy VšeKriterijumska Optimizacija I Kompromisno Resenje (FVIKOR). Building, cost, population density, prospective population, distance to the social center, distance to medical suppliers, distance to other institutions, easy access for ambulances, easy access to transportation, hospital demand at the location, and parking lot availability were the CSFs considered.

In contrast to previous authors, Kutlu Gündoğdu et al. (2018) presented hesitant fuzzy sets (HFS) and evaluation based on distance from average solution (EDAS) for hospital location selection. Site condition and surroundings, accessibility and traffic, patients, cost, future considerations, climate conditions, and noise were factors for hospital site selection. In turn, Kahraman et al. (2019) used Fuzzy TOPSIS for hospital location selection, considering cost of land, land topography, building cost, population density, education level, economic conditions, proximity to transport, availability of infrastructure, and proximity to markets. Similarly, Mić and Antmen (2019) performed fuzzy TOPSIS (FTOPSIS) for healthcare location selection based on demographic structure, investment costs, environmental factors, travel time, travel costs, and infrastructure. Senvar et al. (2016) also presented a similar study using FTOPSIS.
highest and lowest priority. Table 1 summarizes the previous studies on hospital location selection and state-of-the-art methods. Incorporating MADM methods for site selection projects is prevalent among operations researchers (Yang et al., 2021; Ye et al., 2021). We studied prior research on how MADM methods can be used for sustainable supplier evaluation (Lo et al., 2021), development of an integrated programming approach (D. Liu et al., 2020), and supply–demand resilience (Mohammed et al., 2021). Such potential MADM methods can be categorized into decision matrix and pairwise comparison methods. In contrast with previous studies, we applied new paradigms of MADAM to speculate on how, when, and where the temporary hospitals sites were established with robust proficiency and efficacy. Therefore this study used the best-worst method (BWM) (Muneeb et al., 2020) and evaluation area-based method for ranking (EAMR) to aid decision makers (DMs) in strategic decision making. With these tools, DMs can formulate strategic pathways to rapidly to select, identify, and optimize temporary hospital sites (Karbassi Yazdi et al., 2016; Rezaei, 2015; Yazdi et al., 2020; Karbassi Yazdi et al., 2021).

3. Multi-attribute decision-making methods

3.1. Best-Worst method

MADM methods incorporate decision-making processes that are more accurate than statistical methods. Indeed, some of them rely on pairwise alternative comparison approaches, while others are based on decision-matrix (D. Liu et al., 2020; Lo et al., 2021). Pairwise comparison approaches are used to obtain weights for alternatives, and decision matrix approaches are used to rank alternatives using multiple criteria directly (Muneeb et al., 2020; Ye et al., 2021). The best-worst method has several advantages compared to other methods and this is, discussed in Rezaei (2015), who first introduced this model. Two vectors are compared, one of which is the best vector (benefits) and the other the worst vector (costs). The nonlinear maximal absolute weighted ratio difference while simultaneously minimizing it. The following steps yield the weights of computing the maximal absolute weighted ratio difference while simultaneously minimizing it. The following steps yield the weights of computing the maximal absolute weighted ratio difference while simultaneously minimizing it.

**Step 1.** The criteria of the model must be determined. Criteria are shown as $C = \{c_1, c_2, \ldots, c_n\}$.

**Step 2.** The kind of criteria is determined. These criteria can be the best (maximization criteria) or the worst (minimization criteria).

**Step 3.** Allocate preferences to best criteria based on a 1–9 scale with the preferences of best criteria of B being indicated as $A_B = (a_{b1}, a_{b2}, \ldots, a_{bn})$. It is obvious that $a_{Bb} = 1$.

**Step 4.** The method for allocating preferences to the worst criterion is the same as for the best criterion. Preferences of the worst criterion of W are indicated as $A_w = (a_{w1}, a_{w2}, \ldots, a_{wn})$.

Again, it is obvious that $a_{wW} = 1$.

**Step 5.** Final weights are extracted based on the following model. These weights are shown as $(w_1, w_2, \ldots, w_n)$.

Maximum absolute differences $|\frac{a_{bj}}{a_{bw}} - a_{bj}|$ and $|\frac{a_{wj}}{a_{ww}} - a_{wj}|$ will be minimized for all j. The following equation shows this computation.

$$\min_{j} \max \left( \left| \frac{w_j}{w_B} - a_{bj} \right|, \left| \frac{w_j}{w_W} - a_{wj} \right| \right)$$

s.t.

$$\sum_{j} w_j = 1$$

for all $j$, $w_j \geq 0$. (1)
This model can be rewritten as follows.

\[
\begin{aligned}
\min \zeta \\
\text{s.t.} \\
\frac{w_j}{w_i} - d_i \leq \xi_j^e \\
w_j \geq 0 \text{ for all } j
\end{aligned}
\] (2)

After solving this model, the result shows the final weights of the BWM.

### 3.2. Evaluation by an area-based method of ranking (EAMR)

EAMR is a kind of decision matrix approach introduced by Keshavarz Ghorabaee et al. (2016). This model uses beneficial and non-beneficial criteria for ranking alternatives. Their steps are detailed as follows.

**Step 1.** A decision matrix \( M_d \) is created as:

\[
M_d = \begin{bmatrix} M_{d1}^t \\ \vdots \\ M_{dm}^t \end{bmatrix} = \begin{bmatrix} x_{11}^{d} & \cdots & x_{1m}^{d} \\ \vdots & \ddots & \vdots \\ x_{n1}^{d} & \cdots & x_{nm}^{d} \end{bmatrix}, \ 1 \leq i \leq n, \ 1 \leq j \leq m, \ 1 \leq d \leq k
\] (3)

Step 2. Eqs. (4) and (5) point out an average of the decision matrix \( M_d \).

\[
x_y = \frac{x_{11}^n + x_{21}^n + \ldots + x_{m1}^n}{k}
\] (4)

\[
Y = [x_y]
\] (5)

The number of decision-makers is represented as \( k \); \( d \) is the index for the \( d \)-th decision-maker, and the criterion value of alternative \( i \) for criterion \( j \) of \( d \) is \( M_{ij} \). \( n \) is the number of alternatives and \( m \) the number of criteria.

**Step 2.** Eqs. (4) and (5) point out an average of the decision matrix \( M_d \).

After solving this model, the result shows the final weights of the BWM.
alternative $i$ and criterion $j$ and $Y$ is the average decision matrix, such that $1 \leq i \leq n$, $1 \leq j \leq m$.

Step 3. The weighting matrix (weighting vector) $W_p$ is designed as follows:

$$w_p = [w_{pj}]_{m \times 1} = \begin{bmatrix} w_{p1} \\ w_{p2} \\ \vdots \\ w_{pm} \end{bmatrix} \quad 1 \leq j \leq m, \quad 1 \leq p \leq k, \quad (6)$$

$p$ is the index of the $p^{th}$ decision-maker and $w_{pj}$ is the respective weight of criterion $j$ for $1 \leq j \leq m, 1 \leq p \leq k$.

Table 2
DMs’ information.

| Expert No. | Work Experience (Years) | Education Level |
|------------|-------------------------|-----------------|
| 1          | 28                      | MD              |
| 2          | 26                      | PhD             |
| 3          | 27                      | MSc             |
| 4          | 28                      | PhD             |
| 5          | 29                      | MSc             |
| 6          | 32                      | MD              |

Table 3
State-of-the-art CSFs.

| Source                     | Abbreviation | Component                                                                                                                                 |
|---------------------------|--------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Cost                      | CO           | Sen (2017); Kahraman et al. (2019); Miç and Antmen (2019); Çelikbilek (2018)                                                            |
| Land Strategy             | LS           | Adalı & Tuş (2019)                                                                                                                     |
| Market condition          | MC           | Adalı & Tuş (2019)                                                                                                                     |
| Transportation            | TR           | Adalı & Tuş (2019); Çelikbilek (2018)                                                                                                   |
| Environmental             | EN           | Şahin et al. (2019); Miç and Antmen (2019)                                                                                              |
| Demographics              | DE           | Miç and Antmen (2019)                                                                                                                   |
| Geological factors        | GE           | Adalı & Tuş (2019); Kahraman et al. (2019); Miç and Antmen (2019)                                                                    |
| Financial support         | FS           | Kahraman et al. (2019)                                                                                                                 |
| Competitors               | CM           | Şahin et al. (2019)                                                                                                                     |
| Demand                    | DM           | Şahin et al. (2019); Çelikbilek (2018)                                                                                                   |
| Accessibility             | ACC          | Şahin et al. (2019); Sen (2017)                                                                                                        |
| Government                | GO           | Şahin et al. (2019); Sen (2017)                                                                                                        |
| Building structure        | BS           | Kahraman et al. (2019); Çelikbilek (2018); Şahin et al. (2019); Sen (2017)                                                             |
| Workers                   | WO           | Adalı & Tuş (2019)                                                                                                                     |
| Emergency access considerations | EAC   | Şahin et al. (2019); Sen (2017); Çelikbilek (2018)                                                                                  |
| Traffic                   | TA           | Sen (2017)                                                                                                                              |
| Waste disposal site       | WDS          | Kahraman et al. (2019)                                                                                                                 |
| Distance from center of province | DCP | Senvar et al. (2016); Çelikbilek (2018)                                                                                                  |
| Distance from two other cities | DTC    | Senvar et al. (2016); Çelikbilek (2018)                                                                                                 |
| Easy Access for Ambulances | EAA        | Çelikbilek (2018)                                                                                                                       |
| Availability of Parking Lot | APL         | Çelikbilek (2018)                                                                                                                       |

Table 4
Delphi results.

| Factors                      | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | Average | Accept/Reject |
|------------------------------|-----|-----|-----|-----|-----|-----|---------|---------------|
| 1 Cost                       | 5   | 4   | 5   | 4   | 3   | 5   | 4.333333333 | Accept        |
| 2 Land Strategy              | 5   | 4   | 5   | 3   | 3   | 4   | 4       | Accept        |
| 3 Market condition           | 3   | 4   | 3   | 5   | 3   | 3   | 3.5     | Reject        |
| 4 Transportation            | 5   | 5   | 4   | 5   | 4   | 5   | 4.666666667 | Accept        |
| 5 Environmental             | 4   | 5   | 5   | 4   | 3   | 5   | 4.333333333 | Accept        |
| 6 Demographics               | 5   | 5   | 4   | 3   | 4   | 4   | 4.166666667 | Accept        |
| 7 Geological factors         | 4   | 3   | 3   | 4   | 3   | 5   | 3.666666667 | Reject        |
| 8 Financial support          | 5   | 5   | 4   | 5   | 3   | 5   | 4.5     | Accept        |
| 9 Competitors                | 3   | 3   | 3   | 4   | 3   | 4   | 3.333333333 | Reject        |
| 10 Demand                    | 5   | 5   | 5   | 4   | 5   | 3   | 4.5     | Accept        |
| 11 Accessibility             | 5   | 5   | 4   | 4   | 5   | 3   | 4.333333333 | Accept        |
| 12 Government                | 4   | 5   | 4   | 3   | 4   | 3   | 4.166666667 | Accept        |
| 13 Building structure        | 3   | 3   | 3   | 4   | 3   | 5   | 3.5     | Reject        |
| 14 Workers                   | 3   | 3   | 4   | 3   | 4   | 5   | 3.666666667 | Reject        |
| 15 Emergency access considerations | 5   | 5   | 5   | 4   | 4   | 5   | 4.666666667 | Accept        |
| 16 Traffic                   | 5   | 5   | 4   | 5   | 3   | 5   | 4.5     | Accept        |
| 17 Waste disposal site       | 4   | 4   | 5   | 5   | 5   | 3   | 4.333333333 | Accept        |
| 18 Distance from center of province | 5   | 5   | 5   | 4   | 4   | 3   | 4.333333333 | Accept        |
| 19 Distance from two other cities | 5   | 5   | 4   | 4   | 3   | 5   | 4.666666667 | Accept        |
| 20 Easy Access for Ambulances | 5   | 4   | 5   | 3   | 5   | 5   | 4.5     | Accept        |
| 21 Availability of Parking Lot | 5   | 5   | 5   | 5   | 4   | 3   | 4.5     | Accept        |
Presenting the gray coefficients.

**Table 6**

| Meaning         | FPNs(μ, ν) |
|-----------------|------------|
| Very Very Low   | (0,1,0,99) |
| Very Low        | (0,1,0,97) |
| Low             | (0,25,0,92) |
| Moderate        | (0,4,0,87) |
| Fair-Moderate   | (0,5,0,8)  |
| Fair-Good       | (0,6,0,71) |
| Good            | (0,7,0,6)  |
| Very Good       | (0,8,0,44) |
| Very Very Good  | (1,0)      |

**Step 4.** The average weighting matrix (weighting vector) \( \mathbf{W} \) is calculated as follows:

\[
W_j = \left( w^j_1 + w^j_2 + \ldots + w^j_k \right) / k
\]

**Step 5.** The normalized average decision matrix from \( \mathbf{Y} \) denoted as \( \mathbf{N} \) is calculated by:

\[
n_{ij} = \frac{x_{ij}}{e_j}
\]

\[
e_j = \max_{i \in \{1,2,\ldots,n\}} (x_{i})
\]

\[
N = \left[ n_{ij} \right]_{i,j=1}^{n,m}
\]

where \( 1 \leq i \leq n, 1 \leq j \leq m \).

**Step 6.** The normalized weights of the decision matrix \( \mathbf{V} \) are:

\[
v_{ij} = n_{ij} \times w_j
\]

\[
V = \left[ v_{ij} \right]_{i,j=1}^{n,m}
\]

**Step 7.** The sum of normalized scores for beneficial criteria \( G_{1;i} \) and non-beneficial criteria \( G_{-i} \) are calculated as

\[
G_{1;i} = (v_{1;i1} + v_{1;i2} + \ldots + v_{1;in})
\]

\[
G_{-i} = (v_{-i;i1} + v_{-i;i2} + \ldots + v_{-i;in})
\]

\( v_{-i;j} \) and \( v_{-i;j} \) are normalized weighted values for beneficial and non-beneficial criteria.

**Step 8** (RV) is the rank of value based on \( G_{1;i} \) and \( G_{-i} \) (1 \( \leq i \leq n \)). They are ranked according to scores of alternatives that are shown by \( G_{1;i} \) and \( G_{-i} \).

**Step 9.** Calculate the appraisal score \( S_i \) based on the rank values:

\[
S_i = \frac{RV(\mathbf{G}_{1;i})}{RV(\mathbf{G}_{-i})}
\]

\( S_i \) is the score of the highest alternative (Amiri and Antucheviciene, 2016; Karbassi Yazdi et al., 2018).

**Table 7**

Presenting the decision matrix.

|   | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| A1 | 0.0773 | 0.0078 | 0.0773 | 0.3069 | 0.3069 | 0.1043 | 0.0115 | 0.0078 | 0.0773 | 0.1043 | 0.0078 | 0.0773 | 0.3069 | 0.3069 | 0.0115 |
| A2 | 0.0773 | 0.0077 | 0.0773 | 0.3069 | 0.3069 | 0.1043 | 0.0115 | 0.0078 | 0.0773 | 0.1043 | 0.0078 | 0.0773 | 0.3069 | 0.3069 | 0.0115 |
| A3 | 0.0115 | 0.0115 | 0.0078 | 0.0773 | 0.0773 | 0.3069 | 0.0115 | 0.0078 | 0.0773 | 0.3069 | 0.0078 | 0.0773 | 0.3069 | 0.0115 | 0.0078 |
| A4 | 0.0115 | 0.0115 | 0.0078 | 0.0773 | 0.0773 | 0.3069 | 0.0115 | 0.0078 | 0.0773 | 0.3069 | 0.0078 | 0.0773 | 0.3069 | 0.0115 | 0.0078 |
| A5 | 0.0078 | 0.0773 | 0.3069 | 0.0078 | 0.0773 | 0.3069 | 0.0115 | 0.0078 | 0.0773 | 0.3069 | 0.0078 | 0.0773 | 0.3069 | 0.0115 | 0.0078 |
| A6 | 0.0073 | 0.0773 | 0.3069 | 0.0078 | 0.0773 | 0.3069 | 0.0115 | 0.0078 | 0.0773 | 0.3069 | 0.0078 | 0.0773 | 0.3069 | 0.0115 | 0.0078 |
| Min | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Max | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 |
| Max-min | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Star | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |

|   | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| A1 | 0.07 | 0.07 | 0.07 | 0.3 | 0.3 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| A2 | 0.07 | 0.07 | 0.07 | 0.3 | 0.3 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| A3 | 0 | 0 | 0 | 0.07 | 0.07 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| A4 | 0 | 0 | 0 | 0.07 | 0.07 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| A5 | 0 | 0 | 0 | 0.07 | 0.07 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| A6 | 0 | 0 | 0 | 0.07 | 0.07 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Min | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Max | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 |
| Max-min | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Star | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
Presenting the DMs’ criteria.

| LS        | TR  | EN     | DE    | FS    | DM    | ACC   | GO    | EAC   | TA    | EAA   | DTC   | DCP   | WDS    | APL   |
|-----------|-----|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|
|           | (0.8,0.44) | (0.6,0.71) | (0.7,0.6) | (0.8,0.44) | (0.8,0.44) | (0.5,0.8) | (0.5,0.8) | (0.5,0.8) | (0.5,0.8) | (0.5,0.8) | (0.5,0.8) | (0.5,0.8) | (0.5,0.8) | (0.5,0.8) |

### 3.3. Pythagorean fuzzy sets (PFS)

Yager (2013) first introduced PFS, which is a method that describes the membership and non-membership degrees that satisfy the condition that the sum of the squares of the membership and non-membership degrees is equal to or less than one. In some cases, membership and non-membership degrees assigned by a decision-maker to a given alternative satisfy this inequality.

Let us first define the PFS $P$ in the fixed non-empty domain $X$, which can be denoted as:

$$ P = \{ x, \mu_p(x), \nu_p(x) \} $$

where $\mu_p(x)$ represents the membership degree function, such that $X \rightarrow [0,1]$ and $\nu_p(x)$ represents the non-membership degree function, such that $X \rightarrow [0,1]$ for all $x \in X$ of set $P$. The limiting conditions for the membership degree values are given next:

$$ 0 \leq (\mu_p(x))^2 + (\nu_p(x))^2 \leq 1 \quad \forall x \in X $$

The respective hesitant degree is denoted as $\pi_p(x)$ and computed as:

$$ \pi_p(x) = \sqrt{1 - (\mu_p(x))^2 - (\nu_p(x))^2} \quad \forall x \in X $$

Let us also consider two PFS numbers, such that $P_1 = (\mu_{p1}(x), \nu_{p1}(x))$ and $P_2 = (\mu_{p2}(x), \nu_{p2}(x))$, also assuming that $\lambda > 0$. PFS operations are defined as in Peng and Yang, (2015) and Yager (2016, 2013) such that:

$$ P_1 \oplus P_2 = (\mu_{p1}(x) + \mu_{p2}(x), \nu_{p1}(x) + \nu_{p2}(x)) $$

$$ P_1 \odot P_2 = (\mu_{p1}(x) \cdot \mu_{p2}(x), (1 - \nu_{p1}(x))^\frac{\pi_{p1}(x)}{\pi_{p2}(x)} \cdot (1 - \nu_{p2}(x))^\frac{\nu_{p2}(x)}{\pi_{p1}(x)}) $$

$$ \mu_{p1}(x) \geq \mu_{p2}(x), \nu_{p1}(x) \leq \nu_{p2}(x), \pi_{p1}(x) \geq \pi_{p2}(x) $$

$$ P_{\lambda} = (\mu_{p}(x), (1 - \nu_{p}(x))^\frac{\pi_{p}(x)}{\pi_{p}(x)} \cdot \frac{\nu_{p}(x)}{\lambda}) $$

$$ \lambda = \left(1 - \frac{1}{\pi_{p}(x)}\right)^\frac{\pi_{p}(x)}{\pi_{p}(x)} \cdot \frac{\nu_{p}(x)}{\lambda} $$

Computes analogously for the worst criterion.

| LS        | TR  | EN     | DE    | FS    | DM    | ACC   | GO    | EAC   | TA    | EAA   | DTC   | DCP   | WDS    | APL   |
|-----------|-----|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|
|           | (1.0) |        |       |       |       |       |       |       |       |       |       |       |        |       |
Presented the final weights of the criteria.

| Factors | LS  | TR  | EN  | DE  | FS  | DM  | ACC | GO  | EAC | TA  | WDS | DCP | EAA | APL |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Weight  | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 |

4. Research methodology

4.1. Problem description

Despite the limitations of higher hospitalization during the pandemic, attempts were made by the Iranian government to make the best use of the scarce resources available during the COVID-19 pandemic (Takian et al., 2020; Lotfi et al., 2022). The primary complications for all countries in providing facilities for treating patients are related to the deployment of physicians, nurses, medicines, and intensive care unit (ICU) equipment (Hejazi, 2021). Therefore, the current study maps the relative importance of the CSFs that influence principled site selection of locations for temporary hospitals.

4.2. Model procedure

Step 1. Identification of CSFs: The CSFs for selecting the best location for building temporary hospitals are extracted by studying previous research and conducting interviews with experts.

Step 2. Filtration of CSFs: A Delphi questionnaire was applied to experts to filter CSFs for selecting temporary hospital sites. Delphi methods were used for screening and customizing factors (reaching consensus). In this study, since many CSFs are extracted from previous studies, these factors must be adapted to the circumstances of this paper by using the Delphi method. A preliminary questionnaire for evaluating factors using a Likert scale was created and distributed among the experts. The minimum number of DMs needed to fill out this questionnaire is controversial among researchers. Some believe the minimum is 100, while others believe 5 to 15 is optimal (Brady, 2015; Dunham, 1998). In the questionnaire, DMs specify their preferences of the factors based on a Likert scale with values from 1 to 5, 7, or 9. The CSF is rejected if the average of DM preferences for it is less than an acceptance score; otherwise, it is accepted. In this research, a 5-point Likert scale was used, and if the average score of a CSF was more than four, it was considered acceptable; otherwise, it was rejected. Readers may refer to Gordon (1994) and Linstone and Turoff (1975).

Step 3. Allocate decision maker (DM) preferences by Pythagorean fuzzy numbers (PFN) for each criterion and transfer them to crisp data: Once PFN are defined, they are transferred to a crisp number after allocating them to each criterion.

Step 4. Test of independency of factors: When we want to use a decision-making method for ranking alternatives in the first step, we must take into account that these factors may depend on each other. Whenever factors present codependency, the result will not be reliable. Therefore, grey relational analysis is applied for handling this issue. The data do not present dependency when the degree of greyness is less than 0.6 and in this case, subsequent steps can be carried out.

Step 5. Finding weights by Pythagorean fuzzy numbers of the best-worst method (PFNBWM): Since EAMR uses a decision matrix, it needs weights for the criteria. PFNBWM was the approach chosen to compute these weights.

Step 6. Ranking possible temporary hospital building sites by Pythagorean fuzzy numbers evaluation area-based method for ranking (PFNEAMR): In this step, the possible hospital site is selected by ranking the DM preferences.

Step 7. Sensitivity Analysis: This helps DMs compare the results of this hybrid approach with other alternative approaches for finding the best solution.

Fig. 1 summarizes the research framework adopted in this research.

4.3. Sample of decision makers

Six DMs were selected for this research from civil engineering, physicians, and transportation experts. The information on the profiles of these DMs is shown in Table 2.

4.4. CSFs for selecting temporary hospital sites

The list of these CSFs is given in Table 3.

4.5. Delphi method and results

Table 4 reports the DM preferences for each CSF based on a 5-point Likert scale. Sixteen factors out of 21 factors were filtered based on DMs’ preferences.

Presented the transfer of PFN numbers to crisp numbers regarding the best criterion.

| Table 12 | Present the final weights of the criteria. |
|---------|------------------------------------------|
| Factors | LS  | TR  | EN  | DE  | FS  | DM  | ACC | GO  | EAC | TA  | WDS | DCP | EAA | APL |
| Weight  | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 | 0.0666 |
4.6. Advantages of the proposed hybrid approach

4.6.1. Advantages of best worst method

The BWM is one of the most widespread pairwise comparison methods used in research (Muneeb et al., 2020). Compared with traditional pairwise comparison methods such as AHP, REMBRANDT, and MACBETH, BWM needs fewer pairwise comparisons. However, recent advances of AHP, such as Parsimonious AHP, Cybernetic AHP, and Express AHP, have overcome the original disadvantage and require fewer pairwise comparisons than BWM. One of the merits of BWM compared to these AHP improvements is that it is less complex and more user-friendly in a big-data context. High consistency and compatibility when using big data are other BWM advantages (Aboutorab et al., 2018).

The advantageous positioning of BWM and its comprehensive fuzzy concepts are universally applicable to numerous fields, ranging from manufacturing and supply chains (Ahmadi et al., 2017), sustainable outsourcing, and partner selection (Garg and Sharma, 2020) to sustainable architecture. Nevertheless, the theoretical contributions remain salient for underpinning the COVID-19 context when contemplating the best locations for temporary hospitals. The primary purpose of the BWM method is to identify the best and worst weight vectors (Rezaei, 2015; Aboutorab et al., 2018). Furthermore, pairwise comparisons concerning the best for other weight vectors and the worst are employed. The final weights of alternatives can be obtained from these weighted vectors by through linear programming. The consistency of fuzzy preference relations is patterned and confers additive persistence and multiplicative consistency. Finally, an algorithm is deployed seeking to amplify the consistency of the fuzzy preference relationships when an anticipated consistency level is not accomplished. As argued by Rezaei (2016, p. 26), “BWM provides more information about the optimal solution.” Thus, this study posits that the BWM method might be fruitful for selecting and identifying the sites of temporary hospitals and confers advantages for implementing future managerial and practical strategies to combat the turbulent waters of the COVID-19 pandemic.

4.6.2. Advantages of Pythagorean fuzzy numbers

Because the PFN method uses distance measurement, its accuracy is better than that of other methods. As stated by Fei and Deng (2020), “Pythagorean fuzzy set, initially extended by Yager [2013] from intuitionistic fuzzy set, is capable of modeling information with more uncertainties in the process of MCDM, thus can be used on a wider range of conditions” (p. 1). Therefore, the current study used PFN to optimize the site selection of temporary hospitals. PFN is functional in several real-world complications involving more uncertainty than other approaches and extensions of the fuzzy set theory, such as intuitionistic fuzzy sets, hesitant fuzzy sets, and interval type-2 fuzzy sets (Alcantud, 2016; Torra, 2010). The intuitionistic fuzzy set was first put into practice by Atanassov (1999) and proved highly efficient in unpacking uncertain information. The intuitionistic fuzzy set is described by a membership grade and non-membership grade, given the situation that is less than or equal to 1. However, in other applications and under real-life conditions, the decision-makers may convey their preferences using concepts suitable to situations under uncertainty, such as fuzzy numbers including the specification of membership functions, which may pose multiple difficulties. Thus, to overcome this drawback, Yager (2013) planned the advantageous PFN to handle problems involving uncertainty.

4.6.3. Advantages of the EAMR method

In MADM methods based on a decision matrix, there is no way to identify whether the result is reliable or not, so data statistics methods must be employed to gauge their reliability. EAMR is a more reliable method than similar methods such as TOPSIS or VIKOR (Amiri & Antucheviciene, 2016; Karbassi Yazdi et al., 2018).

4.6.4. Advantages of using hybrid methods

The rationale for using such hybrid methods is that EAMR, as mentioned in Section 4.6.3, is one of most reliable MADM decision matrix methods. However, this method requires primary weight. To obtain primary weight, MADM methods based on pairwise comparison methods must be used. Many such pairwise comparison methods exist, and one of them is BWM, which is more friendly and less-complex than other similar methods (as noted in Section 4.6.1). Today, DMs must face many complex and vague environments, making decision-making all the more onerous, especially when they must make recommendations in terms of by exact numbers. Pythagorean fuzzy numbers is a fuzzy number type that has more accuracy because of the distance method. The combination of EAMR, BWM, and Pythagorean fuzzy numbers enable a strong approach with high computation accuracy for ranking alternatives in uncertainty environments.

5. Data analysis

5.1. Dependency analysis

Typically, numerous factors are affected when choosing the best alternatives. In other words, researchers do consider all relevant factors when analyzing alternatives, but this does not mean that these factors necessarily affect each other (Fargnoli & Haber, 2019). If factors have a dependent relationship, the result is not reliable. The only relationship allowed is that these factors affect alternatives. Grey relational analysis (GRA) is used to determine whether the factors in this research depend on each other. Before analyzing the data, the dependency rate of the CSFs is computed by GRA (Wu et al., 2020). Hence, in the first step, we have m alternatives with n criteria for Yᵢ:

\[ Yᵢ = \{yᵢ₁, yᵢ₂, \ldots, yᵢₙ\} \]  \hspace{1cm} (27)

Yᵢ is the degree of importance of alternative i based on criterion j. For normalization, Yᵢ must be transferred to Xᵢ:

\[ Xᵢ = \{xᵢ₁, xᵢ₂, \ldots, xᵢₙ\} \]  \hspace{1cm} (28)

One of these formulae (29)–(31) is used for this transfer:

\[ xᵢⱼ = \frac{yᵢⱼ - \min\{yᵢⱼ\}}{\max\{yᵢⱼ\} - \min\{yᵢⱼ\}} \]  \hspace{1cm} (29) \hspace{1cm} \text{the biggest is best}

\[ xᵢⱼ = \frac{\max\{yᵢⱼ\} - yᵢⱼ}{\max\{yᵢⱼ\} - \min\{yᵢⱼ\}} \]  \hspace{1cm} (30) \hspace{1cm} \text{the smallest is best}

\[ xᵢⱼ = \frac{|yᵢⱼ - y^*|}{\max\{\max\{yᵢⱼ\} - y^*, y^*-\min\{yᵢⱼ\}\}} \]  \hspace{1cm} (31) \hspace{1cm} \text{when the value closest to \( y^* \) is best}

The normalized dimensionless decision matrix is denoted by N, and each entry of the matrix is indicated by Gᵢⱼ.

For a benefit criterion, \( Gᵢⱼ^+ \) is calculated as follows:

\[ Gᵢⱼ^+ = \left[ \frac{Gᵢⱼ - \min\{Gᵢⱼ\}}{\max\{Gᵢⱼ\} - \min\{Gᵢⱼ\}} \right] \]  \hspace{1cm} (32)

\[ Gᵢⱼ^\text{max} = \max\{Gᵢⱼ\} \]  \hspace{1cm} (33)

For a cost criterion, \( Gᵢⱼ^- \) is calculated according to (32)–(33):
G_{ij}^{m} = \frac{G_{ij}^{mn} G_{ij}^{m}}{G_{ij}} \quad \text{ (34)}

G_{ij}^{mn} = \min_{1 \leq k \leq m} \left\{ G_{ij}^{k} \right\} \quad \text{ (35)}

In the last step, the GRA coefficients are computed based on the following formula:

\gamma(x_i, x_j) = \frac{\Delta_{min} - r \Delta_{max}}{\Delta_{ij} - r \Delta_{max}} \quad \text{ (36)}

The \Delta_{ij} must be determined before calculating these coefficients.

\Delta_{ij} = x_{ij} - x_{ij} \quad \text{ (37)}

Hence, \Delta_{min} is the smallest amount of \Delta_{ij} and \Delta_{max} is the largest amount of \Delta_{ij}, while \delta is a distinguished coefficient (Julong, 1989; Kuo et al., 2008). Table 6 presents the decision matrix after using Eqs. (27)–(37). A normalized matrix based on this is calculated.

A grey relational analysis was then conducted. Table 7 shows the GRA coefficients. The GRA result indicates that there is not any dependency among the CSFs.

5.2. Pythagorean fuzzy numbers best-worst method (PFNBWM)

Table 8 reports on the best criterion found using Eqs. (1), (2), and (17)–(26). Then, based on that, the resulting criterion is compared to other criteria, and the DM preferences are assigned to them in terms of PFN (Hendiani et al., 2021) (see Tables 9–12).

A pairwise comparison method must also be used for the required weights along with the PFNEAMR (Hendiani et al., 2021). One of them is BWM, and in this research, BWM is combined with PFN (Zhou & Chen, 2020). The linear programming method based on Eq (2) was used for finding the weights using PFNBWBM. The results show the weights of each alternative after solving this model with LINGO version 19. The criteria in this model are CSFs used for hospital site selection. This model consists of four parts. The first section is a set of constraints related to the best criterion, while the second section points to the constraints for the worst criterion. Section three deals with the constraint regarding the sum of the weights, which must be one. The final section shows a set of constraints that satisfies all positive weights. Eq. (38) shows the PFNBWBM linear model solved using LINGO version 24 software. To solve the model, it is converted into a standard linear model for formulating in LINGO. The solution of the model shows the weights of factors.

\begin{equation}
\text{Min } k^{*}
\end{equation}
All resulting weights of criteria equal 0.0666. The next step is ranking the temporary hospital sites by EAMR. Equation sets (3)–(16) and (17)–(26) were used to obtain the final ranking as reported in the next section.

5.3. Pythagorean fuzzy number evaluation area-based method for ranking (PFNEAMR)

First, the decision matrix is created, as presented in Table 13.

The transferred score from the Pythagorean fuzzy sets matrix is shown in Table 14.

The average decision matrix is presented in Table 15.

Table 16 describes the average weighted matrix.

The normalized matrix and the weighted normalized matrix are then calculated and the final ranking obtained, as shown in Table 17.

This study aims to propose a novel MADM model to help determine where temporary hospitals should be installed. For instance, we utilize BWM, EAMR, and PFN methods to help distinguish and analyze the optimal location temporary hospitals. Our results suggest the fundamental factors for calculating where such temporary hospitals should be set up. In doing so, we identified the 16 most significant CSFs from a pool of 21 relative CSFs. For example, a couple of CSFs selected from our findings (ambulance accessibility and availability of parking) are crucial factors and have major implications for official government and healthcare departments in relation to installing temporary hospitals.

The current study deployed PFNBWM and PFNEAMR to find the 9 most appropriate sites for temporary hospitals, as presented in Table 17. Moreover, by expanding and utilizing the current study and its findings, these sites can prompt the Iranian government and healthcare ministries in optimal location of temporary hospitals. This approach will not only help to combat COVID-19 but also have a significant indirect effect on rural communities and increased public welfare.

5.4. Sensitivity analysis

In this section on evaluating the reliability of our hybrid model, the results obtained are compared to those computed using alternative MADM methods resembling a similar computational structure. These methods are TOPSIS, VIKOR, and WASPAS. The final results are compared in terms of the Pearson coefficient correlation. When the significance level (denoted as \( \alpha \)) is less than 0.05, these correlation results can be considered correlated and thus similar in the case of a positive correlation coefficient. Our sensitivity analysis shows that the result of our model, representing a compromise solution among all these
individual methods, has the highest reliability because it has a linear relationship with all TOPSIS, VIKOR, and WASPAS methods. Table 18 and Fig. 2 show these sensitivity analysis results.

6. Conclusions

The healthcare industries in the 21st century era have faced severe challenges such as the COVID-19 pandemic. As such, temporary hospitals have been at the forefront of the fight against these challenges (Han et al., 2020; Govindan et al., 2021). Thus, rapidly providing temporary hospitals is of the utmost importance (Weiner et al., 2020). In response to such situations, the current study addresses the crucial questions as to how, when, and where to set up such temporary hospitals by utilizing the

![Fig. 2. Presented the sensitivity analysis.](image-url)
EAMR method in a combination of PFN with hybrid MADM methods.

The hybrid approach adopted in this research allowed the ranking of alternative locations for temporary hospitals by starting with the initial mapping of cost and benefit criteria in BWM. Although, GRA revealed independence among CSFs, alternatives and criteria weights are still endogenously related. This happens due to the perceptions of the decision-makers, since the trade-offs among location alternatives expressed by means of criterion weights cannot be clearly ascertained in terms of cause-effect relationships, but rather in terms of feedback relationships. Hence, a number of intermediate steps performed using EAMR were deemed necessary to remove this inherent bias. The fuzzification of EAMR steps via PFN helped in finding a better balance between membership and non-membership functions of a given alternative in light of positive and negative criteria based on the averaged perceptions, mitigating spurious feedbacks among alternatives and the respective weights assigned.

Our findings implicate “distance from the center of the province,” and “distance from two other cities” to be the top criteria for the Iranian government in installing temporary hospitals. Therefore, we suggest that these CSFs help support and assist in protecting the capital city from COVID-19 and guide in providing a better distribution of healthcare services. Additionally, this study suggested 16 potential CSFs for optimal location of temporary hospitals. These specific attributes include cost, land strategy, transport system, financial support, demand & accessibility, consideration of government within the emergency circumstances, distance from the capital, vehicle strategies, and parking lots.

In addition, such CSFs may provide support in combating crises and increasing economic integrity, both of which have significant indirect effects on poor communities and public welfare. As mentioned above, 20% of the overall Iranian budget for this year, approximately 10 trillion rials (US$ 237.5 million), has been allocated to combating the COVID-19 pandemic (Guler, 2020). Along with these efforts, the current research contributed to selecting sites for temporary hospitals, seeking to enhance healthcare services, public welfare. The study also contributes indirectly in combating future disasters and supporting the poor economically to maintain and improve their situation. The final CSFs presented in this study can improve performance in a context where resources are scarce and induce implementation synergies. For example, the current study finds that the most prominent factor is “waste disposal site,” a factor that has been neglected in prior studies.

6.1. Managerial implications

Despite the spread of COVID-19, decision-making plays a vital role when setting up temporary hospitals since the wrong decision could affect rural communities and the entire country. As argued by Sharfuddin (2020, p. 248), “it is ironic that this pandemic has attacked one thing most precious to modern civilization, which is human liberty.” Temporary hospitals have a critical role in fostering the comeback of human liberty and emergency readiness (Auener et al., 2020). Some advantages of temporary hospitals include the ability to rapidly triage large numbers of patients, provide emergency clinical services, support local clinics and laboratories, and decrease the risk of a virus. Policymakers and governments must keep these factors in mind to perform actions/controls for optimal decision-making in times of crises such as COVID-19 and to establish a strategic roadmap for temporary hospitals. This study, using MADM methods, provides such a road map for policymakers to use CSFs for effectively locating temporary hospitals.

The government and health authorities play a key role in the decision-making process and, therefore, should hire experienced healthcare managers to retain dynamic communication with several local and international hospitals, such as the Chinese hospital built in Wuhan. Healthcare managers should use a participatory policy approach and be acquainted with CSFs and their importance and implementation. Finally, the managers should also recognize when the time is right to set up temporary hospitals and where to offer that space.

By now, it is well established that distinct variants of COVID-19 (e.g., alpha, delta, and omicron) display different levels of infection severity and symptoms among the population. As the pandemic evolves into its third and distinct waves continue to emerge, decision-makers could revisit the hybrid approach depicted in this research for a better management of existing resources. While the availability and proximity of large and well-equipped ICUs were critical in the initial first phases of the pandemic, smaller and widely distributed family-health care clinics run by paramedics may now be desirable for purposes of vaccination and rapid testing. The experience brought by the Spanish flu pandemic in 1918 shows not only that a pandemic can last for several years, but also that the profile of victims in terms of gender and age and the severity of symptoms may vary substantially and even include a hemorrhagic component, something not thus far seen.

6.2. Future directions

Although our study already involves several DMs, future research could focus on diverse perspectives to compare the most relevant stakeholder groups, formal institutions, non-government organizations, and their supportive actions to establish temporary hospitals in times of crisis. In addition, future research could also involve a broader range of MADM methods and different approaches. For instance, the site selection problem could be formulated as a facility location problem usually done in logistics (Hanne & Dornberger, 2017), which may allow for an efficient selection from a nonfinite set of possible locations. Another future research stream, while broader than the temporary facility location issues, relates to the systematic treatment of the endogeneity issues among alternative criteria and weights, which are inherent in MADM applications. Hybrid approaches and exhaustive testing have proven to be critical for achieving robust results, not only in terms of ranking of alternatives, but also for mitigating bias that may emerge when decision-makers assign weights. The best combination of approaches, however, is still a matter of future debate and research.

CRediT authorship contribution statement

Amir Karbassi Yazdi: Conceptualization, Formal analysis, Investigation. Farhan Muhammad Muneeb: Formal analysis, Writing – original draft. Peter Fernandes Wanke: Writing – original draft, Supervision. Thomas Hanne: Writing – review & editing, Project administration. Adnan Ali: Formal analysis.

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.

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