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Article

Optimization Model for Selecting Temporary Hospital Locations During COVID-19 Pandemic

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Abstract: The two main approaches that countries are using to ease the strain on healthcare infrastructure is building temporary hospitals that are specialized in treating COVID-19 patients and promoting preventive measures. As such, the selection of the optimal location for a temporary hospital and the calculation of the prioritization of preventive measures are two of the most critical decisions during the pandemic, especially in densely populated areas where the risk of transmission of the virus is highest. If the location selection process or the prioritization of measures is poor, healthcare workers and patients can be harmed, and unnecessary costs may come into play. In this study, a decision support framework using a fuzzy analytic hierarchy process (FAHP) and a weighted aggregated sum product assessment model are proposed for selecting the location of a temporary hospital, and a FAHP model is proposed for calculating the prioritization of preventive measures against COVID-19. A case study is performed for Ho Chi Minh City using the proposed decision-making framework. The contribution of this work is to propose a multiple criteria decision-making model in a fuzzy environment for ranking potential locations for building temporary hospitals during the COVID-19 pandemic. The results of the study can be used to assist decision-makers, such as government authorities and infectious disease experts, in dealing with the current pandemic as well as other diseases in the future. With the entire world facing the global pandemic of COVID-19, many scientists have applied research achievements in practice to help decision-makers make accurate decisions to prevent the pandemic. As the number of cases increases exponentially, it is crucial that government authorities and infectious disease experts make optimal decisions while considering multiple quantitative and qualitative criteria. As such, the proposed approach can also be applied to support complex decision-making processes in a fuzzy environment in different countries.

Keywords: COVID-19; WHO; MCDM; preventive measures; fuzzy theory; FAHP; WASPAS

1 Introduction

COVID-19 first emerged in Wuhan, China, in December 2019. Since then, the virus has become a global health crisis causing dire social and economic consequences [1]. As of August 2020, COVID-19 has infected more than 22 million people, of which more than 700,000 died [2]. While the death rate fluctuates greatly by region [3], COVID-19's transmissibility and severe long-term health effects make it a dangerous threat to all countries, especially those with inadequate healthcare infrastructure. Active hotspot of Covid-19 cases as of April 1st 2021, shown in Fig. 1.

Several organizations, including the World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention (CDC), as well as national and federal governments, have provided warnings and guidelines to prevent the spread of COVID-19 [4]. These guidelines range from basic personal hygiene measures such as frequent washing and sanitizing of one's hands and promoting the use of face masks, to societal measures such as social distancing and shutting down public spaces [5]. While several vaccines have been developed for COVID-19, vaccine manufacturing and administration take time. Currently, public knowledge and social awareness still play important roles in limiting the spread of the deadly disease [6]. While different countries have different approaches to limiting the spread of COVID-19, it is important to identify the main way that COVID-19 spreads and to evaluate the available tools in order to prioritize effective preventive measures. This is a multicriteria decision-making problem, and to solve it requires the use of Multiple Criteria Decision-Making (MCDM) models.

Figure 1: Active hotspot of Covid-19 cases as of April 1st, 2021 [2]

Over the years, MCDM models have been developed in many fields, including ranking potential locations for renewable energy plants [7], ranking potential suppliers in various industries [8,9], and applications in healthcare [10]. Of these applications, location selection problems, which frequently involve multiple quantitative and qualitative criteria, are where MCDM models are most effective [11–14]. Location selection of a temporary hospital for COVID-19 patients is also a multicriteria decision-making problem that can be solved using an MCDM model. The incorporation of fuzzy theory allows an MCDM model to solve decision-making problems in uncertain environments.

2 Literature Review

With the entire world facing the global pandemic of COVID-19, many scientists have applied research achievements in practice to help decision-makers make accurate decisions to prevent the pandemic. As the number of cases increases exponentially, it is crucial that government authorities and infectious disease experts make optimal decisions while considering multiple quantitative and qualitative criteria. As such, MCDM models can be of great value in solving complex problems involving multiple criteria.

MCDM models have been used in many fields that involve complex decision-making problems, including third-party logistics service provider selection [15,16] green supplier evaluation and selection [17], and medial methods evaluation [18]. One disadvantage of traditional MCDM models is that they cannot convey the uncertain nature of the human decision-making process. In recent years, many researchers have integrated fuzzy set theory into their MCDM models in an attempt to overcome this disadvantage [19,20].

Through the years, many MCDM models have been developed to solve location selection problems. Chu et al. [21] have developed a fuzzy MCDM model to assist a distribution center location seclection process using fuzzy number theory. Villacreses et al. [22] developed MCDM model for deciding sustainable wind farm location using OWA, OCRA, and TOPSIS methods with intergration to Geographical Information System (GIS). Kabak et al. [23] introduced a GIS-based MCDM model for evaluation of bike-share stations. Sanchez-Lozano et al. [24] developed an GIS based Fuzzy MCDM model for deciding optimal onshore windfarm location. MDCM models are also widely applied in the healthcare sector. Afkham et al. [25] developed an MCDM model to support the service quality evaluation process of healthcare centers in Iran. Liou et al. [26] developed a hybrid DEMATEL-DANP-mVIKOR model to improve electronic health record service quality through better evaluation. Samanlioglu [27] developed a hybrid AHP-VIKOR model to evaluate influenza intervention strategies. Abbas et al. [28] introduced a framework for assessing key challenges of digital health interventions adoption during the COVID-19 pandemic under hesistant fuzzy sets. Torkzad et al. [29] created an MCDM model for evaluating and prioritizing hospital service quality.

Weighted Aggregated Sum Product Assessment (WASPAS) method was developed by Zavadskas et al. [30] in 2014 and has been applied in many decision-making problems. Zavadskas et al. [31] applied the WASPAS method to assist alternative sites for the construction of a waste incineration plant. Muhammet et al. [32] proposed a type-2 fuzzy MDCM model based on WASPAS and TOPSIS to assist in the a car sharing station selection process. Mehdi et al. [33] developed a type-2 fuzzy MCDM model using extended WASPAS method for the evaluation of green suppliers. Khubaib Amjad et al. [34] suggested a hybrid MCDM model using Fuzzy AHP-WASPAS to evaluate public cloud computing services.

Although several researchers have proposed MCDM models to investigate this problem, none have tried to solve it in a fuzzy environment. In this study, a decision support framework using fuzzy analytic hierarchy process (FAHP) and the weighted aggregated sum product assessment (WASPAS) model is proposed for selecting the location of a temporary hospital for COVID-19 patients and for the prioritization of preventive measures. The results of the study can be used to assist decision-makers, such as government authorities and infectious disease experts, in dealing with the current pandemic as well as other diseases in the future.

3 Methodology

3.1 Research Development

The model development process, shown in Fig. 2, consists of three steps:

Step 1: Analyze and evaluate the current practices (the process of selecting the location for a temporary hospital and prioritizing preventive measures). Collect additional criteria for each problem from scientific research and industry experts.

Step 2: FAHP is used to calculate the weights of all related criteria for each problem.

Step 3: Use the calculated weights from Stage 2 as the input for the rankings of potential temporary hospital locations and the COVID-19 preventive measures using WASPAS.

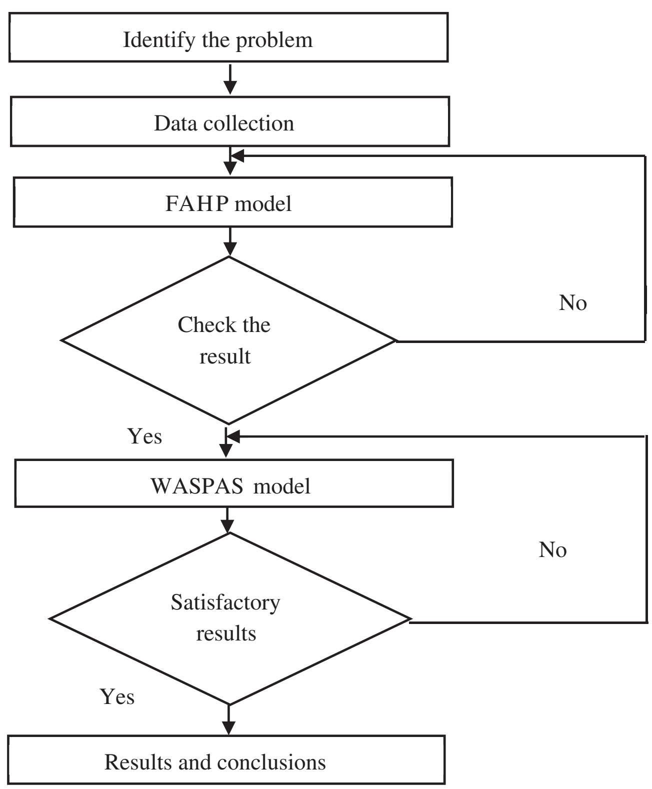

Figure 2: Research process

3.2 Basic Theory

3.2.1 Fuzzy Analytical Hierarchy Process

A Triangular Fuzzy Number (TFN) can be defined as (n, p, q), with n, p and q (n ≤p ≤ q) are parameters that specify the smallest likely value, the promising value and the largest possible value of the TFN. A typical TFN are shown in Fig. 3 and can be described as:

$$\mu\left(\frac{x}{\tilde{M}}\right)=\begin{cases}0, & x<p,\\ \frac{x-\mathrm{n}}{\mathrm{p}-\mathrm{q}} & n\le x\le p,\\ \frac{\mathrm{q}-x}{\mathrm{q}-\mathrm{p}} & p\le x\le q,\\ 0, & x>q,\end{cases} \tag{1}$$

A fuzzy number is given as:

$$\tilde{M}=(M^{o(y)},M^{i(y)})=[\mathrm{n}+(\mathrm{p}-\mathrm{q})y,\quad \mathrm{q}+(\mathrm{h}-\mathrm{q})y],\quad y\in[0,1] \tag{2}$$

With o(y) and i(y) represent the two sides (left and right) of the fuzzy number, respectively.

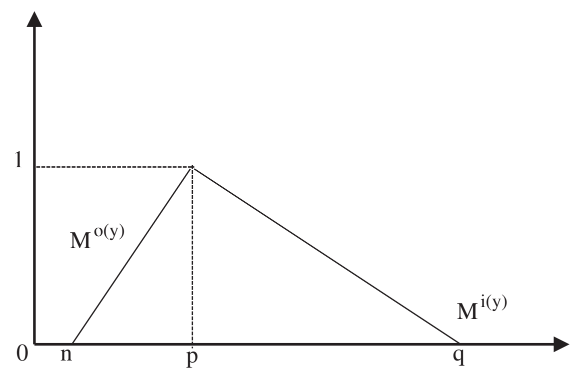

Figure 3: Triangular fuzzy number

Fuzzy Analytical Hierarchy Process (FAHP) is the fuzzy extension of AHP to handle its limitation in working with uncertain decision-making environments. Let X = {x_1, x_2,..., x_n} be the set of objects and K = {k_1, k_2,..., k_n} be the goal set. According to Chang [35] extent analysis method, each object is taken, and an extent analysis of its goals is performed. Therefore, the l extent analysis values for each object can be obtained. These values are denoted as:

$$L^1_{k_i},L^2_{k_i},\ldots,L^m_{k_i},\quad i=1,2,\ldots,n \tag{3}$$

where $L^j_k(j=1,2,\ldots,m)$ are the TFNs

Fuzzy synthetic extent vlaue of the i^{th} object is defined as:

$$S_i=\sum_{j=1}^{m}L^j_{k_i}\otimes\left[\sum_{i=1}^{n}\sum_{j=1}^{m}L^j_{k_i}\right]^{-1} \tag{4}$$

The possibility that $L_1 \geq L_2$ is defined as:

$$V(L_1 \geq L_2) = sup_{y \geq x}[min(\mu_{L_1}(x),), (\mu_{L_2}(y))] \tag{5}$$

where the pair (x, y) exists with $x \geq y$ and $\mu_{L_1}(x) = \mu_{L_2}(y)$, then we have $V(L_1 \geq L_2) = 1$.

Since L_1 and L_2 are convex fuzzy numbers, we have:

$$V(L_1 \geq L_2) = 1, \; if \; l_1 \geq l_2 \tag{6}$$

and

$$V(L_2 \geq L_1) = hgt(L_1 \cap L_2) = \mu_{L_1}(d) \tag{7}$$

where d is the ordinate of the highest intersection point L between μ_{L_1} and μ_{L_2}.

With $L_1 = (o_1, p_1, q_1)$ and $L_2 = (o_2, p_2, q_2)$, the ordinate of point V is calculated by (8):

$$V(L_2 \geq L_1) = hgt(L_1 \cap L_2) = \frac{l_1 - q_2}{(p_2 - q_2) - (p_1 - o_1)} \tag{8}$$

In order to compare L_1 and L_2, we need to calculate the values of $V(L_1 \geq L_2)$ and $V(L_2 \geq L_1)$.

The possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $L_i (i = 1, 2, \ldots k)$ is calculated as:

$$V(L \geq L_1, L_2, \ldots, L_k) = V[(L \geq L_1) \; and \; (L \geq L_2)\,] \tag{9}$$

and

$$V(L \geq L_k) = \min V(L \geq L_i), \; i = 1, 2, \ldots, \; k) \tag{10}$$

Under the assumption that:

$$d'(B_i) = min V(S_i \geq S_k) \tag{11}$$

For $k = 1, 2, \ldots n$ and k i, the weight vector is determined as:

$$W' = \left(d'(B_1), d'(B_2), \ldots d'(B_n)\right)^T \tag{12}$$

where B_i are n elements.

The normalized weight vectors are shown as:

$$W = (d(B_1), d(B_2), \ldots., d(B_n))^T \tag{13}$$

With W is a nonfuzzy number.

3.2.2 Fuzzy Analytical Hierarchy Process

One of the most utilized and efficient multicriteria decision making models for assessing multiple options in numerous criteria is the Weighted Sum Model (WSM). Firstly, there are $\boldsymbol{a}$ options and $\boldsymbol{b}$ decision criteria. We then define $\boldsymbol{z_b}$ as the importance for the criteria and $\boldsymbol{x_{ab}}$. is the performance level for option $\boldsymbol{a}$ evaluated in criterion $\boldsymbol{b}$. Finally, the overall relative importance of alternative $\boldsymbol{y}$, denoted as $\boldsymbol{P}_{\boldsymbol{y}}^{(1)}$, is defined as [36]:

$$P_y^{(1)} = \sum_{b=1}^{n} \bar{x}_{ab} z_b \tag{14}$$

where the linear normalization for each initial criteria value is calculated as follows,

$$\bar{\boldsymbol{x}}_{\boldsymbol{a}b} = \frac{\boldsymbol{x}_{\boldsymbol{a}b}}{\boldsymbol{max}_{\boldsymbol{a}}\boldsymbol{x}_{\boldsymbol{a}\boldsymbol{b}}} \tag{15}$$

if $\boldsymbol{max}_{\boldsymbol{a}}\boldsymbol{x}_{\boldsymbol{a}b}$ value is preferable or

$$\bar{\boldsymbol{x}}_{\boldsymbol{a}b} = \frac{\boldsymbol{min}_{\boldsymbol{a}}\boldsymbol{x}_{\boldsymbol{a}b}}{\boldsymbol{x}_{\boldsymbol{a}b}} \tag{16}$$

if $\boldsymbol{min}_{\boldsymbol{a}b}\boldsymbol{x}_{\boldsymbol{a}b}$. value is preferable.

Another method that is commonly used when assessing multiple options using the total relative importance of option $\boldsymbol{y}$, denoted as $\boldsymbol{P}_{\boldsymbol{y}}^{(2)}$ is the Weight Product Model (WPM). It is defined as follows [36]:

$$\boldsymbol{P}_{\boldsymbol{y}}^{(2)} = \prod_{\boldsymbol{b}=1}^{\boldsymbol{n}} (\bar{\boldsymbol{x}}_{\boldsymbol{a}b})^{\boldsymbol{z}_{\boldsymbol{b}}} \tag{17}$$

In order in incorporate both methods to evaluate further the importance of options, the weights of total relative importance are then equally divided between the WSM and WPM results for a total score:

$$\boldsymbol{P}_{\boldsymbol{y}} = 0.5\boldsymbol{P}_{\boldsymbol{y}}^{(1)} + 0.5\boldsymbol{P}_{\boldsymbol{y}}^{(2)} \tag{18}$$

From the study above and evaluating further regarding the accuracy and effectiveness in decision making, the coefficients that defined WSM and WPM can then be further changed in order to adapt suitably depending on the problem. This change in coefficients in called the Weighted Aggregated Sum Product Assessment method and it is used to rank the options in this research.

$$\boldsymbol{P}_{\boldsymbol{y}} = \boldsymbol{\lambda} \sum_{\boldsymbol{b}=1}^{\boldsymbol{n}} \bar{\boldsymbol{x}}_{\boldsymbol{a}b} \boldsymbol{z}_{\boldsymbol{b}} + (1-\boldsymbol{\lambda}) \prod_{\boldsymbol{j}=1}^{\boldsymbol{n}} (\bar{\boldsymbol{x}}_{\boldsymbol{a}b})^{\boldsymbol{z}_{\boldsymbol{b}}} \tag{19}$$

4 Case Study

Because healthcare infrastructure is such an important aspect of every country, the selection of a healthcare center's location is a critical process that involves multiple quantitative and qualitative criteria, which include economic, environmental and social factors. Such decision can become even more important and more complicated during a public health crisis, such as the COVID-19 pandemic.

Due to its extremely rapid rate of transmission, COVID-19 quickly placed immense pressure on the healthcare infrastructures of countries around the world. Hospitals struggled to have enough capacity to deal with the rapid increase in the number of patients. The transmission rate of the disease also causes additional risks when COVID-19 patients are treated at regular hospitals as it can spread to the patients in other wards. Therefore, many governments have constructed temporary hospitals that are dedicated to treating COVID-19 patients, while promoting preventive measures to reduce the transmission rate, thereby reducing the pressure on healthcare infrastructures.

From international experience in building field hospitals, such as China building two field hospitals for COVID-19 patients in Wuhan, England building a field hospital in London, and Russia constructing a field hospital in Moscow, we extrapolate that the construction of a field hospital to treat patients infected with COVID-19 requires meeting multiple criteria such as a convenient location, the availability of electricity, clean water, and drainage and the ability to meet the scale and necessary medical equipment, according to the service level [37]. Other requirements are rapid construction of the facility and installation of equipment; ensuring environmental sanitation and the safety of human health in the use of construction materials; and economic efficiency and construction cost [38].

Along with building specialized temporary hospitals, WHO and government bodies around the world also promoting preventive measures to limit the transmission rate of COVID-19. These measures include basic personal hygiene such as frequent hand washing and sanitizing and promoting the use of face masks, to broader measures such as social distancing and shutting down public spaces [5]. Success stories from countries such as Vietnam, South Korea, Germany, and New Zealand [39] show that with proper implementation, these measures can help significantly reduce the transmission rate of the COVID-19 virus.

Ho Chi Minh City is the most populous city in Vietnam, and its population is averaging 2.28% annual growth. Household size is 3.51 people, and 66.4% of households have two to four people. Ho Chi Minh City is also a city where 54 ethnic groups live and work [40]. Health services have made great efforts to improve quality in order to meet the criteria issued by the Ministry of Health, and 87% of the city's hospitals have increased quality scores compared to previous years. Most hospitals have actively re-allocated resources with a focus on service improvement, resulting in quality improvement in many areas of hospital operation [41].

Vietnam was one of the safest countries in the early days of the COVID-19 outbreak in Wuhan, China. However, recently, COVID-19 outbreaks have occurred rapidly in Vietnamese cities. Therefore, Ho Chi Minh City plans to take an active role in the preparation for the construction of field hospitals when there is an outbreak of COVID-19. In addition, preventive measures are being promoted in Vietnam, as their effectiveness was proven in the early days of the pandemic.

4.1 Temporary Hospital Location Selection Case Study

When the COVID-19 pandemic occurred, many countries discovered that they lacked the necessary facilities to screen and treat people infected with the virus and began building more field hospitals specifically for treating COVID-19. In this case study, the MCDM model is used to assist in locating temporary hospitals in Ho Chi Minh City. Design diagram of the screening area for COVID-19 patients who have signs of severe respiratory inflammation (SARI), shown in Fig. 4.

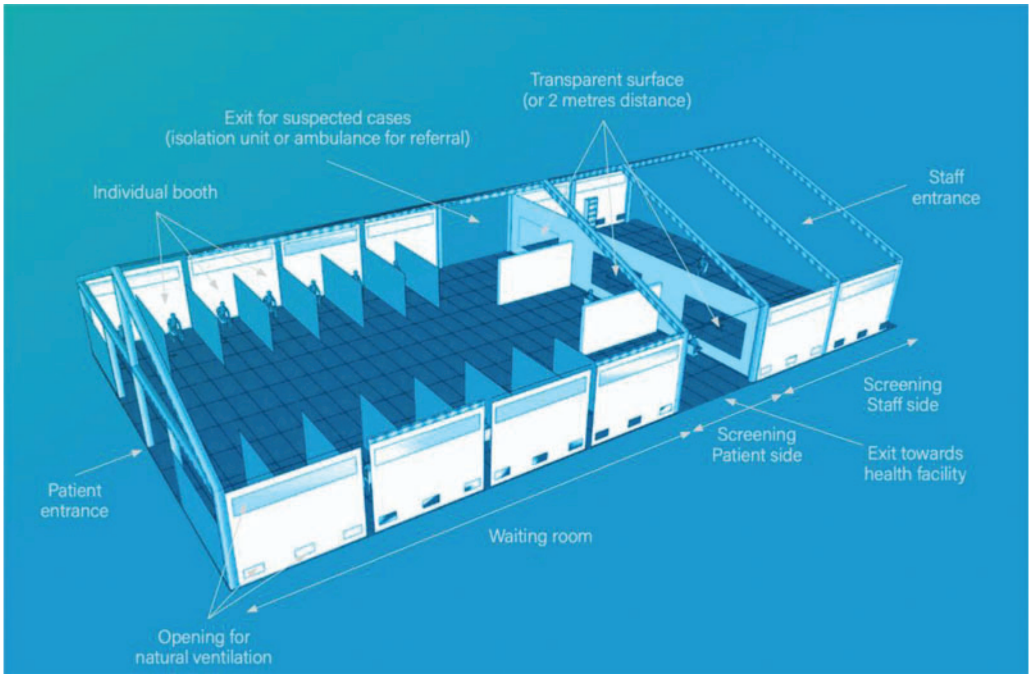

Figure 4: Design diagram of the screening area for COVID-19 patients who have signs of severe respiratory inflammation (SARI) [41]

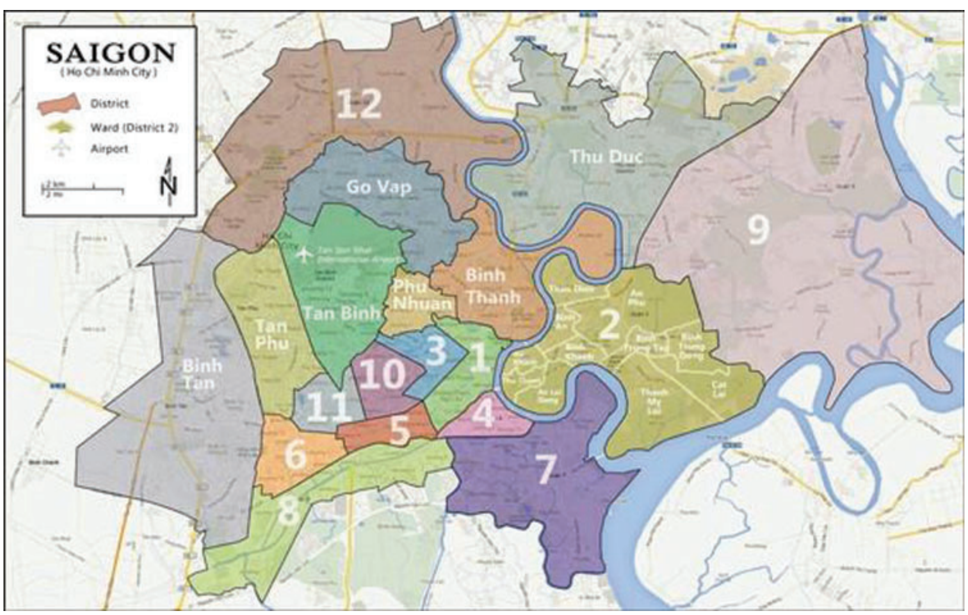

Figure 5: Detailed maps of Ho Chi Minh City [42]

Detailed maps of Ho Chi Minh City, shown in Fig. 5. Through surveys and evaluations by experts, five locations were considered, as shown in Tab. 1.

Table 1: List of potential locations for temporary hospital

No.	Location	Symbol
1	Cu Chi	TPOS01
2	Tan Binh	TPOS02
3	Binh Thanh	TPOS03
4	Go Vap	TPOS04
5	Binh Chanh	TPOS05

Based on the characteristics of the decision-making problem, several criteria were identified using location selection studies in the literature and experts' opinions. These are shown in Tab. 2.

Table 2: List of criteria

No.	Criteria	Symbol
1	Traffic congestion	HOP01
2	Accessibility via roads	HOP02
3	Accessibility via airports	HOP03
4	Health centers in the district	HOP04
5	The distance from populated residential	HOP05
6	Land prices	HOP06
7	Transportation cost	HOP07
8	Future expansion potential	HOP08
9	The distance from industrial areas	HOP09
10	Basic construction	HOP10
11	Work attitude of human resources	HOP11
12	Medical industry policy	HOP12

To determine the weight of each criteria, the author used an FAHP model. The weight of each criterion is shown in Tabs. 3 and 4:

In the final stages of the process, the WASPAS model was used to rank all potential locations. The normalized matrix and normalized weighted matrix are shown in Tabs. 5 and 6:

According to the proposed FAHP-WASPAS model, the optimal location for building a temporary hospital for COVID-19 patients in Ho Chi Minh City was in the Cu Chi District (TPOS01), which had the highest Q_i value of 0.928. The results from the case study showed the feasibility of the model, and that it can be used alongside other MCDM methods to support better decision-making.

4.2 Prioritizing Preventive Measures Case Study

In this case study, an FAHP model was used to calculate the weight of each preventive measure, based on expert opinions. These weights were then used to create the prioritized ranking of the measures.

Through literature reviews and experts' opinions, the list of 15 COVID-19 preventive measures is shown in Tab. 7:

Table 3: Results from FAHP model

Criteria	Fuzzy geometric mean of each row			Fuzzy weights			Non-fuzzy performance	Normalization
HOP01	0.8271	1.1504	1.5675	0.0497	0.0941	0.1754	0.1064	0.0939
HOP02	0.8007	1.1283	1.5266	0.0481	0.0923	0.1709	0.1038	0.0916
HOP03	0.9891	1.3633	1.8133	0.0594	0.1116	0.2030	0.1247	0.1100
HOP04	0.7592	1.0472	1.4309	0.0456	0.0857	0.1602	0.0972	0.0857
HOP05	0.9733	1.3191	1.7501	0.0585	0.1080	0.1959	0.1208	0.1066
HOP06	0.6090	0.8151	1.1254	0.0366	0.0667	0.1260	0.0764	0.0674
HOP07	0.6095	0.8116	1.1170	0.0366	0.0664	0.1250	0.0760	0.0671
HOP08	0.6724	0.9159	1.2455	0.0404	0.0750	0.1394	0.0849	0.0749
HOP09	0.7123	0.9543	1.2675	0.0428	0.0781	0.1419	0.0876	0.0773
HOP10	0.6367	0.8644	1.2036	0.0383	0.0707	0.1347	0.0812	0.0717
HOP11	0.5531	0.7402	1.0397	0.0332	0.0606	0.1164	0.0701	0.0618
HOP12	0.7920	1.1096	1.5544	0.0476	0.0908	0.1740	0.1041	0.0919

Table 4: The weight of all criteria

No.	Criteria	Symbol	Weight
1	Traffic congestion	HOP01	0.0939
2	Accessibility via roads	HOP02	0.0916
3	Accessibility via airports	HOP03	0.1100
4	Health centers in the district	HOP04	0.0857
5	The distance from populated residential	HOP05	0.1066
6	Land prices	HOP06	0.0674
7	Transportation cost	HOP07	0.0671
8	Future expansion potential	HOP08	0.0749
9	The distance from industrial areas	HOP09	0.0773
10	Basic construction	HOP10	0.0717
11	Work attitude of human resources	HOP11	0.0618
12	Medical industry policy	HOP12	0.0919

The FAHP model was used to determine the weight of all subcriteria. The calculated weights are shown in Tab. 8:

Finally, the prioritize ranking of the preventive measures are shown in Tab. 9:

According to the proposed FAHP model, the three most effective preventive measures were 1) limiting travel; 2) the use of face masks; and 3) frequent hand washing. The results from the case study show the feasibility of the FAHP model.

Table 5: Weighted normalized matrix from WASPAS model

		Location				
		TPOS01	TPOS02	TPOS03	TPOS04	TPOS05
Criteria	HOP01	0.0704	0.0704	0.0822	0.0822	0.0939
	HOP02	0.0916	0.0611	0.0712	0.0712	0.0814
	HOP03	0.1100	0.0963	0.0963	0.0825	0.0963
	HOP04	0.0857	0.0667	0.0857	0.0762	0.0667
	HOP05	0.1066	0.0959	0.0746	0.0746	0.0640
	HOP06	0.0590	0.0506	0.0590	0.0506	0.0674
	HOP07	0.0587	0.0587	0.0671	0.0587	0.0671
	HOP08	0.0749	0.0655	0.0562	0.0562	0.0749
	HOP09	0.0601	0.0773	0.0601	0.0601	0.0687
	HOP10	0.0717	0.0502	0.0430	0.0430	0.0574
	HOP11	0.0412	0.0481	0.0549	0.0618	0.0549
	HOP12	0.0919	0.0817	0.0715	0.0817	0.0817

Table 6: Results from WASPAS model

Alternatives	$Q_i^{(1)}$	$Q_i^{(2)}$	Q_i	Ranking
TPOS01	0.9218	0.9218	0.9218	1
TPOS02	0.8224	0.8224	0.8224	3
TPOS03	0.8218	0.8218	0.8218	4
TPOS04	0.7988	0.7988	0.7988	5
TPOS05	0.8743	0.8743	0.8743	2

Table 7: Hierarchy of criteria and their sub-criteria of COVID-19 preventive measures

No.	Sub-criteria	Symbol
1	Workplace sanitization	SD1
2	Healthy nutrition	SD2
3	Hand wash/Use of sanitizer	SD3
4	Handshake	HY1
5	Travel	HY2
6	Home door/Switch	HY3
7	Exercise	IF1
8	Enough sleep	IF2
9	Hugging	IF3
10	Own body parts	UT1
11	Public objects	UT2
12	Use of mask	UT3
13	Outside prepared food	FH1
14	Drinking/Eating at outside places	FH2
15	Packed food	FH3

Table 8: Weight of sub-criteria

Criteria	Fuzzy geometric mean of each row			Fuzzy weights			BNP	Weight
SD1	0.7343	1.0422	1.4676	0.0349	0.0684	0.1336	0.0790	0.0689
SD2	0.7398	1.0484	1.4668	0.0351	0.0688	0.1335	0.0792	0.0691
SD3	0.8606	1.2313	1.6957	0.0409	0.0808	0.1544	0.0920	0.0803
HY1	0.7934	1.1262	1.5701	0.0377	0.0739	0.1429	0.0848	0.0740
HY2	1.0048	1.4071	1.9115	0.0477	0.0924	0.1740	0.1047	0.0913
HY3	0.6762	0.9232	1.2717	0.0321	0.0606	0.1158	0.0695	0.0606
IF1	0.6498	0.8758	1.1953	0.0309	0.0575	0.1088	0.0657	0.0573
IF2	0.7366	1.0169	1.3747	0.0350	0.0667	0.1252	0.0756	0.0660
IF3	0.8125	1.1115	1.4800	0.0386	0.0730	0.1347	0.0821	0.0716
UT1	0.6681	0.9278	1.2912	0.0317	0.0609	0.1176	0.0701	0.0611
UT2	0.5720	0.7759	1.0918	0.0272	0.0509	0.0994	0.0592	0.0516
UT3	0.9249	1.2757	1.7376	0.0439	0.0837	0.1582	0.0953	0.0831
FH1	0.6063	0.8312	1.1759	0.0288	0.0546	0.1071	0.0635	0.0554
FH2	0.5740	0.7757	1.0968	0.0273	0.0509	0.0998	0.0593	0.0518
FH3	0.6311	0.8668	1.2276	0.0300	0.0569	0.1118	0.0662	0.0578

Table 9: Prioritize ranking of Covid-19 preventive measures

Criteria	Symbol	Weight	Prioritize ranking
Travel	HY2	0.0913	1
Use of mask	UT3	0.0831	2
Hand wash/Use of sanitizer	SD3	0.0803	3
Handshake	HY1	0.074	4
Hugging	IF3	0.0716	5
Healthy nutrition	SD2	0.0691	6
Workplace sanitization	SD1	0.0689	7
Enough sleep	IF2	0.066	8
Own body parts	UT1	0.0611	9
Home door/Switch	HY3	0.0606	10
Packed food	FH3	0.0578	11
Exercise	IF1	0.0573	12
Outside prepared food	FH1	0.0554	13
Drinking/Eating at outside places	FH2	0.0518	14
Public objects	UT2	0.0516	15

5 Conclusions

The global spread of the COVID-19 virus has created one of the worst pandemics in modern history. As the virus spread, healthcare infrastructures worldwide were faced with unprecedented pressures. COVID-19's transmissibility and severe long-term health effects make it a dangerous threat to all countries, but particularly those with inadequate healthcare infrastructure.

To lessen the strain of the pandemic on existing healthcare infrastructures, two approaches have been adopted by many countries: building specialized temporary hospitals and promoting preventive measures. Each of these approaches requires a sophisticate decision-making process. In the case of building temporary hospitals, location selection is critical to the effectiveness of the facilities and involves multiple quantitative and qualitative criteria, making it an MCDM problem. Similarly, the prioritization of preventive measures can greatly reduce the transmissibility of the virus, especially in the early stage of the pandemic, and can be calculated using proper MCDM methods.

This study proposed a hybrid Fuzzy AHP-WASPAS model for the problem of selecting the best location for a temporary hospital and a Fuzzy AHP model for calculating the prioritize ranking of preventive measures. In the case study of selecting the best location for a temporary hospital in Ho Chi Minh City, the optimal location proved to be the Cu Chi District (TPOS1). In the case study of determining the preventive measures, the three most effective were limiting travel, use of face masks, and frequent hand washing.

The two proposed models can act as guidelines for creating more effective decision-making processes for temporary hospital location selection and prioritization of COVID-19 preventive measures. Future research may expand the work to related fields of study or use the work as a base for further COVID-19 related studies.

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