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Selecting Effective Ways to Prevent COVID-19 Spread Using the Fuzzy Analytic Hierarchy Process (FAHP) Method

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HIGHLIGHTS

- The FAHP method was utilized to select effective measures for preventing the spread of COVID-19.
- The study involved three decision-makers who evaluated seven strategies for COVID-19 prevention.
- The Fuzzy AHP approach converted the AHP scale into a fuzzy triangle scale for analysis.

ABSTRACT

The COVID-19 pandemic has had a significant impact on global health and economies. This study aims to identify highly effective prevention strategies for mitigating the spread of COVID-19 using the Fuzzy Analytic Hierarchy Process (FAHP) method. The FAHP is a fuzzy logic-based extension of the Analytic Hierarchy Process (AHP) technique, allowing for the consideration of both tangible and intangible criteria. The study focuses on seven key criteria: social/physical measures, health monitoring, avoidance of unnecessary contact, hygiene practices, immunity/fitness, healthy diet, and sharing personal items. By involving three decision-makers, including a nurse, a Medical Officer (MO), and a Medical Assistant (MA), the relative weights of these criteria are calculated using pair-wise comparisons and Buckley's approach. The findings reveal that hygiene emerges as the most critical factor in preventing the spread of COVID-19, followed by social/physical measures and health monitoring. The study provides valuable insights for policymakers and healthcare professionals in selecting and implementing effective preventive measures to control the spread of COVID-19.

Keywords: *COVID-19, prevention strategies, Fuzzy Analytic Hierarchy Process (FAHP), pair-wise comparisons, hygiene, social/physical measures, health monitoring*

INTRODUCTION

The world has become infected with coronavirus disease 2019 (COVID-19), which is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). According to a study by Pazos (2020), the first cases were discovered in Wuhan, Hubei province. The employees at the Huanan Wholesale Seafood Market, which sold seafood, poultry, and birds, became ill with mysterious pneumonia, once again linking wild animal markets to severe acute respiratory syndrome (SARS). China notified the World Health Organization (WHO) about these instances for the first time on December 31, 2019, 23 days after the first patient sought medical treatment.

After that, the World Health Organization (WHO) declared COVID-19 a global pandemic. According to WHO (2020), the conference was convened following the announcement by WHO Director-General Dr. Tedros Adhanom Ghebreyesus that COVID-19 could be classified as a pandemic. This decision was made due to a significant increase in the number of cases outside of China in the past two weeks, affecting a growing number of countries. Dr. Hans Henri P. Kluge, WHO Regional Director for Europe, also noted that clusters of cases or community transmission were becoming more prevalent in several countries. He anticipated a continued steady increase in the number of cases and deaths in the coming days and weeks, emphasizing the need to enhance our response and implement preemptive measures wherever possible. Such measures can help delay the outbreak, providing healthcare systems with more time to plan for and manage its impact.

Moreover, Malaysia is also one of the countries that has been affected by the novel coronavirus. The first cases of coronavirus were confirmed among three Chinese nationals who were quarantined at Sungai Buloh Hospital. According to former Health Minister Datuk Seri Dr. Dzulkefly Ahmad, these three individuals were part of a group of eight Chinese nationals who were quarantined in a hotel in Johor Bahru. They were subsequently transferred to Sungai Buloh Hospital for further treatment. It is alleged that these three individuals had close contact with a 66-year-old Singaporean patient who tested positive for the virus. This marks the country's first reported case of the novel coronavirus, also known as 2019-nCoV (Ting, 2020).

Therefore, in collaboration with the Ministry of Health (MoH), the Malaysian government has made significant efforts to address and manage the outbreak situation (Shah et al., 2020). Another crucial step taken by the MoH and the government to curb the spread of COVID-19 was to increase the capacity of healthcare facilities to handle cases. Public and private institutions, including university hospitals and Ministry of Defense hospitals, collaborated to expand their capabilities and accommodate the rising number of infections (The Edge Markets, 2020).

However, this paper focuses on a study that aims to select effective ways to prevent the spread of COVID-19 using the Fuzzy Analytic Hierarchy Process (AHP) Method. The FAHP has been chosen due to its capability and ability to achieve better accuracy and consistency in the judgments of decision-makers (Idris et al., 2020). This method is often employed in solving various multi-criteria decision problems as it can effectively handle multiple criteria. The consistency of human thinking is structured in a hierarchical form (Zahrin et al., 2022). Several studies published since 2008 have applied fuzzy AHP to decision-making problems in various industries, particularly in addressing diverse selection problems. Fuzzy AHP has now gained popularity as a fuzzy multi-criteria decision-making (MCDM) method (Yan Liu et al., 2020).

According to the study conducted by Putra et al. (2018), the Fuzzy Analytic Hierarchy Process (FAHP) is an approach that combines fuzzy logic with the Analytic Hierarchy Process (AHP). The focus of this study is on prevention strategies specific to Malaysia. The FAHP approach shares similarities with the conventional AHP method but introduces a fuzzy triangular scale, which allows for more flexibility in evaluating criteria (Putra et al., 2018). In the FAHP, expert judgment plays a crucial role, and it is common to involve a small number of experts. Therefore, the data for this study were collected through a questionnaire and interview sessions with a limited number of experts (Zahrin et al., 2022).

METHODOLOGY

The Fuzzy Analytic Hierarchy Process (FAHP) is a technique based on fuzzy logic that extends the Analytic Hierarchy Process (AHP) methodology. The AHP method is similar to the FAHP approach, with the FAHP technique converting the AHP scale into a fuzzy triangular scale for initial assessment (Putra et al., 2018).

In this study, the relative weights of the criteria are estimated using Buckley's approach, although FAHP encompasses various other strategies (Ayhan, 2013). The technique involves several steps, which are as follows:

Step 1: The decision-maker (DM) compares the criteria or alternatives using the linguistic terms specified in Table 1.

Table 1: Linguistic terms and the corresponding triangular fuzzy numbers.

Saaty scale	Definition	Fuzzy Triangular Scale
1	Equally important (Eq. Imp.)	(1, 1, 1)
3	Weakly important (W. Imp.)	(2, 3, 4)
5	Fairly important (F. Imp.)	(4, 5, 6)
7	Strongly important (S. Imp.)	(6, 7, 8)
9	Absolutely important (A. Imp.)	(9, 9, 9)
2	The intermittent values between two adjacent scales	(1, 2, 3)
4		(3, 4, 5)
6		(5, 6, 7)
8		(7, 8, 9)

As an example, if the decision-maker states that "Criterion 1 (C1) is weakly important than Criterion 2 (C2)," the corresponding fuzzy triangular scale is taken as "Criterion 1 (C1) is weakly important than Criterion 2 (C2)" with values of (2, 3, 4). In the pairwise contribution matrix for the criterion, the comparison of C2 to C1 will be made on a fuzzy triangular scale of (1/4, 1/3, 1/2) (Ayhan, 2013).

The pair-wise contribution matrix is illustrated in Eq.1, where $\widetilde{d_{ij}^{k}}$ denotes the kth the preference of the decision-maker for the ith criterion over the jth criterion, expressed as fuzzy triangular numbers. In this situation, "tilde" denotes the triangular number demonstration, and $\widetilde{d_{12}^{1}}$ denotes the first preference of the decision-maker for the first criterion takes priority over the second and equals $\widetilde{d_{12}^{1}}$ = (2,3,4).

$$\widetilde{A^k} = \begin{bmatrix} \widetilde{d_{11}^{k}} & \widetilde{d_{12}^{k}} & \cdots & \widetilde{d_{1n}^{k}} \\ \widetilde{d_{21}^{k}} & \cdots & \cdots & \widetilde{d_{2n}^{k}} \\ \cdots & \cdots & \cdots & \cdots \\ \widetilde{d_{n1}^{k}} & \widetilde{d_{n2}^{k}} & \cdots & \widetilde{d_{nn}^{k}} \end{bmatrix}. \tag{1}$$

Step 2: Check the consistency (CR - Consistency Ratio).
The consistency of an evaluation is examined using the following formula to ensure the expert's judgments are consistent.

$$CI = \frac{\lambda_{max} - N}{N-1}. \quad (2)$$

Here, CI is the Consistency Index, λ_{max} is the largest eigenvalue of the comparison matrix, and N is the dimension of the matrix/number of criteria.

$$CR = \frac{CI}{RI}. \quad (3)$$

The following Table 2 shows the random inconsistency indices (RI) (Saaty, 1980).

Table 2: Random Inconsistency Indices (RI).

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Step 3: If there are many DM, the preferences of each ($\widetilde{d_{ij}^{k}}$) are averaged, while ($\widetilde{d_{ij}}$) is determined as in Eq.4.

$$\widetilde{d_{ij}} = \frac{\sum_{k-1}^{k} \widetilde{d_{ij}^{k}}}{K}. \quad (4)$$

Step 4: As indicated in Eq.5, the pair-wise contribution matrix is updated based on averaged preferences.

$$\tilde{A} = \begin{bmatrix} \widetilde{d_{11}} & \cdots & \widetilde{d_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{d_{n1}} & \cdots & \widetilde{d_{nn}} \end{bmatrix}. \quad (5)$$

Step 5: Buckley (1985) states that the geometric mean of each criterion's fuzzy comparison values is obtained as stated in Eq.6. Here, $\widetilde{r_i}$ stands for triangular values in this case.

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}}\right)^{1/n}, i = 1, 2, \ldots, n. \quad (6)$$

Step 6: By adding the next three substages to Eq.7, the fuzzy weights of each criterion may be found.

i) Find each $\widetilde{r_i}$ vector summation.
ii) Find the summation vector's (-1) power. To make it in ascending order, remove the fuzzily triangular number.
iii) Multiply each $\widetilde{r_i}$ by this reverse vector to get the fuzzy weight of criterion i ($\widetilde{w_i}$).

$$\begin{aligned} \widetilde{w_i} &= \widetilde{r_i} \otimes (\widetilde{r_1} \oplus \widetilde{r_2} \oplus \cdots \oplus \widetilde{r_n})^{-1}, \\ &= (lw_i, mw_i, uw_i). \end{aligned} \quad (7)$$

Step 7: $\widetilde{w_i}$ must be defuzzified using the Centre of Area method because they are still fuzzy triangular numbers Eq.8.

$$M_i = \frac{lw_i + mw_i + uw_i}{3}. \quad (8)$$

Step 8: M_i is not a fuzzy number. Nevertheless, it must be normalized using Eq.9.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}\,. \tag{9}$$

The normalized weights of the criteria are determined using these eight procedures. Based on these results, the decision-maker is recommended to choose the option with the highest score (Ayhan, 2013).

Application of Fuzzy AHP on COVID-19 Prevention Strategies

In this study, it is necessary to define the problem based on the criteria used to select the prevention strategies. The main criteria for selecting prevention strategies include social/physical distancing, health monitoring, avoiding unnecessary contact with objects, maintaining hygiene, improving immunity/fitness, adopting a healthy diet, and refraining from sharing personal items. At this stage, the weights of the criteria should be calculated using the aforementioned steps. Figure 1 illustrates the criteria for the prevention strategies.

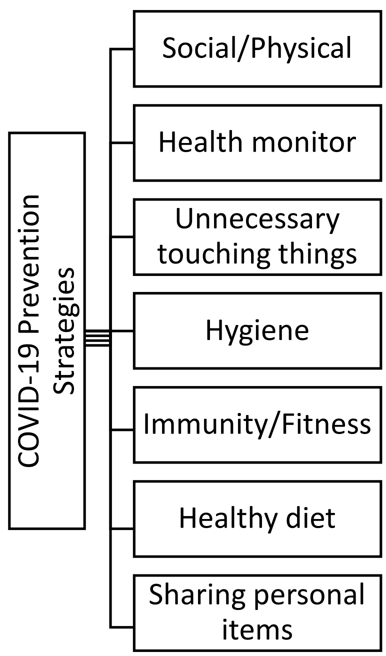

Figure 1: Criteria of COVID-19 Prevention Strategies.

FINDINGS AND DISCUSSIONS

The FAHP method has been utilized to its fullest extent in determining highly effective COVID-19 preventive measures. The input of three professionals in the field, including a nurse from Klinik Batu 10 Lekir, Perak, Malaysia, a Medical Officer (MO) from the Ministry of Health Malaysia (KKM), and a Medical Assistant (MA) from Hospital Jelebu, Negeri Sembilan, Malaysia, was obtained. Their expertise was instrumental in weighting the criteria used in this selection process. Table 3 presents the acronyms for each criterion employed in this study.

Table 3: Acronym of each criterion.

CRITERIA	DESCRIPTION
SP	Social/Physical
HM	Health Monitor
UT	Unnecessary touching things
H	Hygiene
IF	Immunity/Fitness
HD	Healthy diet
SI	Sharing personal items

Determining the Weights of Criteria

A conference involving three specialists is conducted to select the most suitable approach. Three decision-makers (DM) participate in the evaluation process, and each of them is provided with a questionnaire based on the hierarchy developed in Figure 1 for selecting effective ways to prevent the spread of COVID-19. Fuzzy triangular numbers are used to represent the relative strength of each pair of components within the same hierarchy, and pair-wise comparisons are generated for each criterion.

The pair-wise comparisons of the criteria from each decision-maker are determined based on their preferences. Accordingly, the pair-wise comparison matrices for the criteria are presented in Tables 4, 5, and 6. The values in these tables correspond to the fuzzy triangular scale specified in Table 1.

Table 4: Comparison matrices of criteria for decision-maker 1 ($\widetilde{d^1}$).

CRITERIA	SP	HM	UT	H	IF	HD	SI
SP	(1, 1, 1)	(1, 1, 1)	(2, 3, 4)	(1, 1, 1)	(4, 5, 6)	(9, 9, 9)	(1, 1, 1)
HM	(1, 1, 1)	(1, 1, 1)	(4, 5, 6)	(1, 1, 1)	(4, 5, 6)	(9, 9, 9)	(1, 1, 1)
UT	(1/4 ,1/3 ,1/2)	(1/6, 1/5, 1/4)	(1, 1, 1)	(1/4, 1/3, 1/2)	(4, 5, 6)	(4, 5, 6)	(1/4, 1/3, 1/2)
H	(1, 1, 1)	(1, 1, 1)	(2, 3, 4)	(1, 1, 1)	(4, 5, 6)	(9, 9, 9)	(1, 1, 1)
IF	(1/6, 1/5, 1/4)	(1/6, 1/5, 1/4)	(1/6, 1/5, 1/4)	(1/6, 1/5, 1/4)	(1, 1, 1)	(4, 5, 6)	(1/6, 1/5, 1/4)
HD	(1/9, 1/9, 1/9)	(1/9, 1/9, 1/9)	(1/6, 1/5, 1/4)	(1/9, 1/9, 1/9)	(1/6, 1/5, 1/4)	(1, 1, 1)	(1/9, 1/9, 1/9)
SI	(1, 1, 1)	(1, 1, 1)	(2, 3, 4)	(1, 1, 1)	(4, 5, 6)	(9, 9, 9)	(1, 1, 1)

Table 5: Comparison matrices of criteria for decision-maker 2 ($\widetilde{d^2}$).

CRITERIA	SP	HM	UT	H	IF	HD	SI
SP	(1, 1, 1)	(1, 1, 1)	(2, 3, 4)	(1/4, 1/3, 1/2)	(9, 9, 9)	(2, 3, 4)	(2, 3, 4)
HM	(1, 1, 1)	(1, 1, 1)	(2, 3, 4)	(1/6, 1/5, 1/4)	(9, 9, 9)	(4, 5, 6)	(2, 3, 4)
UT	(1/4 ,1/3 ,1/2)	(1/4 ,1/3 ,1/2)	(1, 1, 1)	(1/8, 1/7, 1/6)	(6, 7, 8)	(4, 5, 6)	(1, 1, 1)
H	(2, 3, 4)	(4, 5, 6)	(6, 7, 8)	(1, 1, 1)	(9, 9, 9)	(9, 9, 9)	(4, 5, 6)

IF	(1/9, 1/9, 1/9)	(1/9, 1/9, 1/9)	(1/8, 1/7, 1/6)	(1/9, 1/9, 1/9)	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/6, 1/5, 1/4)
HD	(1/4, 1/3, 1/2)	(1/6, 1/5, 1/4)	(1/6, 1/5, 1/4)	(1/9, 1/9, 1/9)	(2, 3, 4)	(1, 1, 1)	(1/4, 1/3, 1/2)
SI	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1/6, 1/5, 1/4)	(4, 5, 6)	(2, 3, 4)	(1, 1, 1)

Table 6: Comparison matrices of criteria for decision-maker 3 ($\widetilde{d^3}$).

CRITERIA	SP	HM	UT	H	IF	HD	SI
SP	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)	(1, 1, 1)	(9, 9, 9)	(6, 7, 8)	(2, 3, 4)
HM	(1/4 ,1/3 ,1/2)	(1, 1, 1)	(4, 5, 6)	(1/4 ,1/3 ,1/2)	(6, 7, 8)	(2, 3, 4)	(1, 1, 1)
UT	(1/6, 1/5, 1/4)	(1/6, 1/5, 1/4)	(1, 1, 1)	(1/6, 1/5, 1/4)	(2, 3, 4)	(2, 3, 4)	(1/4, 1/3, 1/2)
H	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)	(1, 1, 1)	(9, 9, 9)	(6, 7, 8)	(2, 3, 4)
IF	(1/9, 1/9, 1/9)	(1/8, 1/7, 1/6)	(1/4 ,1/3 ,1/2)	(1/9, 1/9, 1/9)	(1, 1, 1)	(1/6, 1/5, 1/4)	(1/8, 1/7, 1/6)
HD	(1/8, 1/7, 1/6)	(1/4 ,1/3 ,1/2)	(1/4 ,1/3 ,1/2)	(1/8, 1/7, 1/6)	(4, 5, 6)	(1, 1, 1)	(1/6, 1/5, 1/4)
SI	(1/4, 1/3, 1/2)	(1, 1, 1)	(2, 3, 4)	(1/4 ,1/3 ,1/2)	(6, 7, 8)	(4, 5, 6)	(1, 1, 1)

The consistency of the evaluation is assessed using Eq. 1 and Eq. 2 to ensure consistent judgments by the experts.

The comparison is deemed acceptable if the consistency ratio (CR) is equal to or less than 0.1. If the CR value exceeds 0.1, it indicates inconsistency in the judgment. Here is an example calculation for the consistency ratio of decision-maker 1:

$$A = \begin{bmatrix} 1 & 1 & 3 & 1 & 5 & 9 & 1 \\ 1 & 1 & 5 & 1 & 5 & 9 & 1 \\ 1/3 & 1/5 & 1 & 1/3 & 5 & 5 & 1/3 \\ 1 & 1 & 3 & 1 & 5 & 9 & 1 \\ 1/5 & 1/5 & 1/5 & 1/5 & 1 & 5 & 1/5 \\ 1/9 & 1/9 & 1/5 & 1/9 & 1/5 & 1 & 1/9 \\ 1 & 1 & 3 & 1 & 5 & 9 & 1 \end{bmatrix},$$

$$\lambda_{max} = 7.3458,$$

$$CI = \frac{7.3458 - 7}{7 - 1} = 0.0576,$$

$$CR = \frac{0.0576}{1.32} = 0.0437 < 0.1.$$

For decision-maker 2 and decision-maker 3, their CR values are 0.06 and 0.0586, respectively.

Since the CR values of both decision-makers are less than 0.1, the comparisons made by each decision-maker are considered acceptable and consistent.

Then, the average of three decision-makers preferences ($\tilde{d}_{ij}^{k}$) is determined, and ($\tilde{d}_{ij}$) is calculated as indicated follow.

$$\tilde{d}_{ij} = \left(\frac{\tilde{d}^1{}_{ij}+\tilde{d}^2{}_{ij}+\tilde{d}^3{}_{ij}}{3}, \frac{\tilde{d}^1{}_{ij}+\tilde{d}^2{}_{ij}+\tilde{d}^3{}_{ij}}{3}, \frac{\tilde{d}^1{}_{ij}+\tilde{d}^2{}_{ij}+\tilde{d}^3{}_{ij}}{3}, \frac{\tilde{d}^1{}_{ij}+\tilde{d}^2{}_{ij}+\tilde{d}^3{}_{ij}}{3}, \frac{\tilde{d}^1{}_{ij}+\tilde{d}^2{}_{ij}+\tilde{d}^3{}_{ij}}{3}, \frac{\tilde{d}^1{}_{ij}+\tilde{d}^2{}_{ij}+\tilde{d}^3{}_{ij}}{3}, \frac{\tilde{d}^1{}_{ij}+\tilde{d}^2{}_{ij}+\tilde{d}^3{}_{ij}}{3}\right). \quad (10)$$

Table 7 shows a table of each decision-maker's average choice of criterion based on the computations using Eq.10.

Table 7: Average Preference of Criteria of each decision-maker.

CRITERIA	SP	HM	UT	H	IF	HD	SI
SP	(1, 1, 1)	(1.33, 1.67, 2)	(2.67, 3.67, 4.67)	(0.75, 0.78, 0.83)	(7.33, 7.67, 8)	(5.67, 6.33, 7)	(1.67, 2.33, 3)
HM	(0.75, 0.78, 0.83)	(1, 1, 1)	(3.33, 4.33, 5.33)	(0.47, 0.51, 0.58)	(6.33, 7, 7.67)	(5, 5.67, 6.33)	(1.33, 1.67, 2)
UT	(0.22 ,0.29 ,0.42)	(0.19, 0.24, 0.33)	(1, 1, 1)	(0.18, 0.23, 0.31)	(4, 5, 6)	(3.33, 4.33, 5.33)	(0.5, 0.56, 0.67)
H	(1.33, 1.67, 2)	(2.33, 3, 3.67)	(4, 5, 6)	(1, 1, 1)	(7.33, 7.67, 8)	(8, 8.33, 8.67)	(2.33, 3, 3.67)
IF	(0.13, 0.14, 0.16)	(0.13, 0.15, 0.18)	(0.18, 0.23, 0.31)	(0.11, 0.11, 0.11)	(1, 1, 1)	(1.47, 1.84, 2.25)	(0.15, 0.18, 0.22)
HD	(0.16, 0.2, 0.26)	(0.18, 0.21, 0.29)	(0.19, 0.24, 0.33)	(0.12, 0.12, 0.13)	(2.06, 2.73, 3.42)	(1, 1, 1)	(0.18, 0.21, 0.29)
SI	(0.5, 0.56, 0.67)	(0.75, 0.78, 0.83)	(1.67, 2.33, 3)	(0.47, 0.51, 0.58)	(4.67, 5.67, 6.67)	(5, 5.67, 6.33)	(1, 1, 1)

Eq.6 is used to get the geometric mean of fuzzy comparison values of each criterion once the first three steps of the process have been completed. For instance, $\tilde{r}_i$ given in Eq.11 is used to find the geometric mean of fuzzy comparison values for the criterion.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{1/n} \quad (11)$$

$$= [(1 * 1.33 * 2.67 * 0.75 * 7.33 * 5.67 * 1.67)^{\frac{1}{7}}; (1 * 1.67 * 3.67 * 0.78 * 7.67 * 6.33 * 2.33)^{\frac{1}{7}}; (1 * 2 * 4.67 * 0.83 * 8 * 7 * 3)^{\frac{1}{7}}]$$

= [2.108; 2.456; 2.787].

As a result, Table 8 presents the geometric means of the fuzzy comparison values for all criteria. It also includes the total values and their reverse values. The numbers in the last row of Table 8 have been rearranged to ensure that the fuzzy triangular numbers are in increasing order.

Table 8: Geometric means of fuzzy comparison values of criteria.

CRITERIA	GEOMETRIC MEAN OF FUZZY (*ri*)		
SP	2.108	2.456	2.787

HM	1.748	1.967	2.203
UT	0.656	0.790	0.986
H	2.895	3.356	3.788
IF	0.259	0.291	0.335
HD	0.303	0.357	0.439
SI	1.317	1.493	1.700
Total	9.285	10.709	12.238
P (-1)	0.108	0.093	0.082
INCR	0.082	0.093	0.108

The fuzzy weight of the criterion ($\widetilde{w_i}$) is obtained in the fifth phase using Eq.7 and indicated in Eq.12.

$$w_i = [(2.108 * 0.082); (2.456 * 0.093); (2.787 * 0.108)] \quad (12)$$

$$= [0.172; 0.229; 0.300].$$

As a result, Table 9 shows the relative fuzzy weights of each criterion.

Table 9: Relative fuzzy weights of the criteria.

CRITERIA	FUZZY WEIGHT (w*i*)		
SP	0.172	0.229	0.300
HM	0.143	0.184	0.237
UT	0.054	0.074	0.106
H	0.237	0.313	0.408
IF	0.021	0.027	0.036
HD	0.025	0.033	0.047
SI	0.108	0.139	0.183

Taking the average of fuzzy numbers for each criterion, the relative non-fuzzy weight of each criterion (M_i) is derived in the sixth step. The normalized weights of each criterion are generated and summarized in Table 10 in the seventh phase, using non-fuzzy M_i's.

Table 10: Averaged and normalized relative weights of the criteria.

CRITERIA	Averaged weight criterion (Mi)	Normalized weight criterion (Ni)	Rank
SP	0.234	0.228	2
HM	0.188	0.183	3
UT	0.078	0.076	5
H	0.319	0.311	1
IF	0.028	0.027	7

HD	0.035	0.034	6
SI	0.143	0.140	4

According to Table 10, hygiene (H) has the highest normalized relative weight value of 0.311. This indicates that hygiene plays the most significant role in selecting effective ways to prevent the spread of COVID-19. It is well-known that wearing a mask is mandatory during outdoor activities to prevent the transmission of the virus. Additionally, practicing regular handwashing or sanitizing after touching public objects and covering coughs and sneezes are important preventive measures.

The second highest normalized relative weight is assigned to social/physical distancing (SP) with a value of 0.228. This emphasizes the importance of implementing movement control orders (MCO) when the infection rate of COVID-19 reaches a critical level. Furthermore, avoiding crowded places and maintaining a social distance of at least 1 meter is crucial in preventing the spread of the virus.

Health monitoring (HM) is ranked third with a normalized relative weight of 0.183. Temperature screening before entering public places such as supermarkets, restaurants, and mosques is essential. Individuals who have had close contact with someone infected with COVID-19 should undergo a 14-day quarantine period after their last exposure. Vaccination plays a significant role in boosting antibodies and achieving herd immunity. In Malaysia, approximately 79.8% of the population has received the first dose of the vaccine, while 78.7% have completed both doses (Vaccinations in Malaysia, n.d.). Herd immunity occurs when a large portion of the community becomes immune to a disease, thereby reducing the likelihood of disease transmission from person to person (Herd Immunity and COVID-19 (Coronavirus): What You Need to Know, 2021).

CONCLUSION AND RECOMMENDATIONS

The spread of COVID-19 is an important and continuously evolving topic, both in Malaysia and worldwide. This study aims to contribute to the understanding of effective ways to prevent the spread of COVID-19 by utilizing the Fuzzy Analytic Hierarchy Process (AHP) Method. According to Sarwar and Imran (2021), COVID-19 has affected people in 215 countries, with more than 11 million reported cases worldwide. To combat the spread of the virus, various organizations such as the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have issued guidelines and preventive measures, which are considered in this study.

The combination of the Analytical Hierarchy Process (AHP) technique and the fuzzy approach is employed to address the decision-making process in this study. The fuzzy approach is utilized because the decision-maker's preferences are often based on both tangible and intangible criteria. Thus, the Fuzzy AHP method is employed to select the most effective ways to prevent COVID-19. The study focuses on seven criteria: social/physical, health monitoring, unnecessary touching things, hygiene, immunity/fitness, healthy diet, and sharing personal items. Based on the findings of this study, it can be concluded that hygiene plays a crucial role in preventing the spread of COVID-19, including wearing masks, practicing proper hand hygiene, and covering coughs and sneezes. Additionally, social/physical distancing and health monitoring are also identified as important preventive measures.

In future studies examining the spread of the coronavirus, it would be beneficial to explore additional preventive measures and employ different decision-making methodologies. Techniques such as Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Elimination and Choice Expressing

Reality (ELECTRE), Preference ranking organization method for enrichment evaluation (PROMETHEE), Decision making trial and evaluation laboratory (DEMATEL), Analytic network process (ANP), among others, could be considered for application in this study. These methodologies may provide further insights and enhance the selection of effective preventive strategies for combating the spread of COVID-19.

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CONFLICT OF INTEREST DISCLOSURE

The authors affirm that they have no conflicts of interest to disclose.

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