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NON-PHARMACEUTICAL INTERVENTION STRATEGIES TO RESPOND TO THE COVID-19 PANDEMIC: PREFERENCE RANKING METHOD

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Abstract: *One of the hot topics of discussion today is coronavirus disease 2019 (COVID-19). The disease is easily transmitted from one person to another person. However, there are no specific drugs that can alleviate the disease thus non-pharmaceutical intervention strategies is a good option. This paper aims to apply the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) method to outrank the intervention strategies. A case study is presented where five experts were invited to rate ten alternatives and ten criteria using linguistic scales. Spreadsheet software and PROMETHEE-GAIA software were employed to establish outranking results and to provide evidence on the vigorousness of the outranking results. The final outranking indicates that the most and the least preferred intervention strategies are alternative* A_1 *(lockdown/quarantine) and alternative* A_{10} *(Practice of hand hygiene) respectively. The outranking results are further analyzed with distribution analysis and weights sensitivity analysis where these analyses provide evidence on the vigorous of the outranking results. It is found that these analyses confirm the position of* A_1 *as the most preferred intervention strategy to curtail the COVID-19 transmissions. The findings would be beneficial for public health authorities to deal with multiple challenges to curb the spread of COVID-19.*

Key words: *Preference function; decision making; COVID-19, public health; weight sensitivity*

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1. Introduction

One of the deadliest diseases of late 2019 was Coronavirus disease 2019 (COVID-19). According to the World Health Organization (WHO), COVID-19 was detected in Wuhan, Hubei Province, China, in December 2019. COVID-19 is a contagious disease caused by a novel coronavirus called SARS-CoV-2 and is also familiar with 2019-nCoV (Zhang et al., 2020). The virus of COVID-19 can spread from one person to another through respiratory droplets when an infected individual sneezes or coughs. The COVID-19 symptoms can make someone experience shortness of breathing, fever, dryness, cough, myalgia, diarrhea, fatigue, headache, rhinorrhea, or severe symptoms (Larsen, 2021). In some cases, people can die, and it will start appearing within two and fourteen days, with a median of five days after someone gets infected (WHO 2020). According to Rismanbaf (2020), there are still no specific treatments for COVID-19 patients. For people at increased risk for severe cases such as pneumonia and septic shock, the patients will refer to additional treatment that includes intubation or mechanical ventilation.

Initially, it may seem that the person involved with an infected animal or who eats the kind of animal in that market could be infected. However, the rapid transmission of 2019-nCoV from person to a person gives the result on such a large scale. The rise of COVID-19 supports these confirmed cases, and more proof that comes to light with the new clusters between a close person and family members has affirmed the likelihood of person-to-person transmission (Chan et al. 2020; Chen et al. 2020; Phan et al. 2020; Rothe et al. 2020). The COVID-19 virus spreads initially through inhaling when an infected person coughs or sneezes (Rothan & Byrareddy, 2020). Some claim that symptomatic humans are likely the most persistent cause of spreading 2019-nCoV. China's public health is finding three major transmission tracks of 2019-nCoV: droplet spreading, close contact transmission, and respiratory transmission (Adhikari et al. 2020).

A great deal of work has been involved in suggesting measures to stop the transmission of COVID-19. These include important measures, which are avoiding close contact with infected people, physical distancing, practicing good hygiene, isolation, and additional treatments (Güner et al. 2020). Recently, there is still no cure and specific drugs available (Cao et al. 2020). Despite the fact that there are still many tests to be done, as of this writing, the WHO has proclaimed COVID-19 to be a global pandemic that has spread quickly around the world. As the ongoing pandemic of COVID-19 has rapidly spread to the global community, it is crucial for countries, such as their policymakers, governors, and individuals that are responsible for this spread to understand the risk factors and provide responses to the COVID-19 pandemic. Countries around the world have suffered disruption from this pandemic. Ten million people have been infected, and as a result of this, social and economic structures have been badly affected (Ahlstrom & Wang 2021). Therefore, it is crucial to understand the response that may take to prevent this unnecessary suffering. Mahmud & Al-Mohaimeed (2020), in response to this problem, examined the effectiveness of local and international COVID-19 epidemic control measures and proposed the best global pandemic prevention and control techniques. In a different study, Maqbool & Khan (2020) identified the challenges of using social and public health interventions to stop the spread of COVID-19. Countries need adequate devising to hinder mass transmission and disaster, and efficient planning might help flatten the curve of a graph in the spike of the outbreak pandemic.

However, Samanlioglu & Kaya (2020) indicate that research about evaluating strategies is insufficient. Some academics have assessed non-pharmaceutical strategies for the COVID-19 pandemic based on a combined expert opinion to prepare for it and other pandemics of a similar nature (Aledort et al. 2007). A study on preventive strategies, for example, was conducted by Merler & Ajelli (2010). They used a survey approach to evaluate the diffusion of pandemic influenza and developed stochastic mathematical modeling. Data were collected from a large number of respondents which involved households' groups, workers, and students that highly been exposed to close contacts within Europe. Similar survey approaches were also adopted by Kohlhoff et al. (2012) and Russell et al. (2016) where data at hospitals and schools were used respectively to identify strategies in preventing the spread of high-scale pandemic influenza and transmission of influenza virus. The approaches were also used to assess the magnitude of an individual's condition, both physically and mentally, such as depression and anxiety as the consequences of the lockdown prevention strategy (Ahorsu et al. 2020). Coccia (2020) studies environmental elements that speed up the spread of COVID-19 using data from a sample of fifty-five Italians. She also offers a solution for dealing with COVID-19-like pandemic concerns in the future. Three series of statistical analyses were conducted to meet the research objectives. Preliminary statistical analysis such as mean and standard deviation was implemented followed by correlation and linear regression. These analyses are the typical basic statistics used in analyzing cause-effect relations between the factors and their effect on the diffusion of COVID-19. It can be seen that these statistical approaches were disregarded the collection of data through expert opinion.

In contrast to the methodology based on statistical analysis, this paragraph provides some light on multi-criteria decision-making approaches used in dealing with the COVID-19 pandemic of which research gaps between these reviews and the current approach used in this study can be filled in. The COVID-19 disease appeared in the world in late 2019 and since then numerous research has been conducted to investigate this pandemic from non-pharmaceutical preventing approaches perspectives. In order to determine the most effective course of action, Saeidpour & Rohani (2022) created an intervention policy model that included the relative human, implementation, and healthcare costs of non-pharmaceutical pandemic solutions. Maqbool & Khan (2020) for example, conducted research regarding analyzing barriers to implementing public health and social measures to prevent the transmission of the COVID-19 disease. They applied the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to suggest the barriers that prevent the implementation of public health and social measures in India. They suggested that the efficient execution of public health and social initiatives is dependent on the availability of appropriate resources such as medical facilities, the healthcare system, and financial relations. This research extends further in evaluating the barrier through similar work or using other decision-making methods in different countries. The method of DEMATEL was also applied by Altuntas & Gok (2021) to suggest a method on how to lower the impact of the COVID-19 pandemic on domestic tourism in Turkey. About the similar approach as Maqbool and Khan (2020), they suggested that quarantine resolution is the most influential strategy to slow down the spread of the COVID-19 disease. Similar multi-criteria decision-making was also extended in the field of the hospitality industry and quarantine disease. Yang et al. (2020) introduced a novel method to propose the decision support algorithm for selecting an antivirus mask to widen the use of masks in the era of the COVID-19 pandemic. They also developed a multi-criteria decision-making method based on Bonferroni mean operator in selecting medical consumer products during the COVID-19 outbreak, which is for selecting the antivirus masks over the COVID-19 era. Recently, Upadhyay et al. (2021) applied the multi-criteria analysis fuzzy-analytical hierarchical process method to identify the critical barriers in social isolation in India amid the COVID-19 outbreak.

Unlike survey and statistical approaches where huge data collection is involved, the current study intends to undertake a non-statistical approach where data are collected via expert judgment and the analysis is made using a preference based on level criterion function. Non-pharmaceutical strategies for preventing the spread of the COVID-19 pandemic are investigated from the perspective of multi-criteria decision making owing to the understanding that multiple strategies in preventing the spread are associated with multiple criteria. Specifically, this study aims to obtain the ranking of non-pharmaceutical intervention strategies in combating the COVID-19 using a preferred method. The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) method is applied to suggest the most viable intervention strategies in combating the COVID-19 pandemic. In addition, the sensitivity of the ranking results is investigated based on a variety of weights of the criteria.

In summary, this study provides several significant contributions to methodology and findings. First, this study suggests the method based on preference order to rank the non-pharmaceutical approaches in preventing the spread of the COVID-19. The method employs linguistic evaluation elicited from a group of experts in public health. Accordingly, the level criterion preference function of PROMETHEE provides a convenient way to compute linguistic information from experts. Second, the findings are derived from the multi-criteria decision aid PROMETHEE method of which the optimal solution in searching the non-pharmaceutical approaches is obtained through experts' opinions. The ranking results can provide a better understanding of the measures needed to curb the infectivity. Finally, the findings are affirmed with a sensitivity test of weight where the variations in weights of criteria are observed against the robustness of preference order of alternatives. This paper is structured as follows. A brief review on the use PROMETHEE in various fields is presented in Section 2. The methodology of this research is given in Section 3. The implementation of the case which includes detailed computational steps is presented in Section 4. Section 5 adds an analysis of the sensitivity of weight towards the final preference results. Section 6 concludes the outcomes of the study.

2. Related Research

This section presents a brief literature review of PROMETHEE and its applications. The PROMETHEE is one of the most often used methods in preference method selection analysis, which has recently attracted a lot of interest from decision making researchers (Arcidiacono et al. 2018). Therefore, the use of PROMETHEE in various applications is not something new and is increasingly growing. This pattern of growth can be noticed since the day it was published in 1985 (Brans & Vincke, 1985). The PROMETHEE has been effectively utilized in solving numerous decision making problems. A non-exhaustive list of scientific materials related to PROMETHEE method and its applications has been published since 2010 (Behzadian et al. 2010). It is primarily used in a wide range of decision-making scenarios and has a specific use in decision-making. In business and management related research, the POMETHEE has been used in bankruptcy prediction (Hu & Chen, 2011), and recently used in measuring key performance indicators (Demirdöğen, et al. 2022). By utilising PROMETHEE II, Mousavi & Lin (2020) expanded the use of expert systems to anticipate business credit risk and financial distress. In a corporate governance study, Guney et al. (2020) used PROMETHEE method and econometric analysis to obtain a relationship between firm performance and corporate governance quality. Recently, Kuncova & Seknickova (2021) evaluated the order of regions regarding economic indices using weighted PROMETHEE combines with preferences functions.

Not only the use of PROMETHEE in business and management research, this preference-based decision making method was also used in very specific or niche research areas. For example, Nassereddine et al. (2019) conducted research in evaluating emergency response systems. The interaction synergy of criteria and alternatives in the system was investigated using the PROMETHEE. The competitiveness of tourist destinations is a crucial topic in the tourism business since it allows destinations to understand their position or ranking in relation to other destinations. To solve this issue, Lopes et al. (2018) applied the PROMETHEE method to rank eight tourism destinations in the Northern Region of Portugal. About the similar application of PROMETHEE can be seen in the education sector (De Smet and Lidouh, 2013; Murat et al., 2015; Ningsih et al., 2019), in green building research (Hermoso-Orzáez et al., 2019), and biomass and biofuel energy research (Schröder et al., 2019; Mofijur et al., 2022; Genç et al., 2022). In industry-based research, PROMETHEE was used by Aydemir et al. (2019) to identify the mechanical, thermal, and morphological characteristics of heat-treated wood-polypropylene polymer composites and choose the composites with the best characteristics. Durin and Nad (2018) applied PROMETHEE in selecting the most appropriate variant of solar photovoltaic water supply systems.

Turning now to an application of PROMETHEE in health sciences where a group of researchers in Uruguay identified and ranked alternatives used in the national food mouth disease program illustrated using PROMETHEE (Corbellini et al., 2020). In healthcare education, recently, Saboktakin et al., (2021) used POMETHEE to educate hospitalized cardiovascular disease patients about lifestyle and behavior modification. In animal healthcare research, very recently, Guétin-Poirier et al., (2022) used PROMETHEE as a tool to aid decision-makers in choosing the appropriate protocol to apply to a group animal while considering the technical and socio-economic facets of the problem. As we can see, despite the considerable amount of research has been carried out on PROMETHEE and its various applications, to the best of the authors' knowledge, there has been little attention has been devoted to conclude the most preferred invention strategies in combating the spread of COVID-19.

3. Methodology

This section describes how this study is implemented. The first subsection explains the criteria and alternatives employed in this study. These criteria and alternatives are evaluated by a group of experts using five linguistic scales. Subsection 3.2 presents profiles of experts and the rating scales used in this study. More importantly, the computational procedures of the PROMETHEE method are presented in the final subsection.

3.1. Criteria and Alternatives

In this section, the criteria and alternatives are selected and retrieved from the work of Maqbool & Khan (2020). In their research, they used the term barriers instead of criteria to make it consistent with the term normally used in public health. These barriers are identified using a systematic literature review and, in the analysis, they employed the DEMATEL method to categorize the ten barriers. Their study's main objective is to classify the obstacles to putting social and public health measures in place to stop the spread of COVID-19. Unlike this objective, our current study aims to rank the barriers according to expert judgment using the PROMETHEE method. In the methodology of this study, we use the term criteria instead of barriers to fit with the conceptual definition of the PROMETHEE method. The ten criteria are adopted in this study where these criteria are believed to represent the factors to respond to the COVID-19 pandemic. These criteria and their brief descriptions are listed below.

i. Failure of Safety Engagement (C_1): The acknowledgment and awareness about COVID-19 from the public.

ii. Failure of safety practice (C_2): This criterion indicates that refer to safety practices to help from exposure to COVID-19

iii. Failure of bureaucratic and governmental commitment at society (C3): This criterion focuses on commitment from the government how to discover the opportunities to simplify the progress of lockdown, social distancing, and mass events.

iv. Poor of strict requirement of WHO regulation (C_4): The attribute that focuses on guidelines from WHO regulations because WHO is the only one that states regarding COVID-19

v. Inadequate resources for public health (C_5): This criterion indicates the capacity of public health in handling the COVID-19 cases in erecting the critical care or place for those who have severe cases of COVID-19.

vi. Lack of medical equipment (C_6): The demand for medical facilities due to the rise in infection of COVID-19.

vii. Lack of insight from government policies (C_7): This refers to government policies that require them to provide new update details of COVID-19 accurate, rational, timely according to human rights principles.

viii. Non-implementation of domestic instruction during quarantine (C_8): The criteria refer to non-fixed conditions for movement due to shortage of groceries and daily basis.

ix. Public censure (C_9): The statement and judgment from the public about a person who is infected with COVID-19 lead to someone enclosing and hiding their condition or illness.

x. Lack of appropriate information from public health (C_{10}): The awareness from public health regarding the importance and seriousness of COVID-19 to the public.

The community needs an efficient and systematic way to ascertain the best strategy to be implemented amid the COVID-19 outbreak. These strategies are retrieved from Samanlioglu & Kaya (2020) and Aledort et al. (2007) where it appraises the non-pharmaceuticals that are normally used in public health for pandemic influenza. For the purpose of tailoring with the PROMETHEE method used in this study, the words intervention strategies and alternatives are interchangeably used. The list of alternatives is given below.

i. Lockdown/quarantine (A_1): The alternative centers on everything from required geographic restrictions to optional rules that urge everyone in the nation to stay at home, shut down specific companies, and prohibit large-scale gatherings. Closure borders within a country (A_2): This alternative indicates keeping the measures by the closure of borders within the country.

ii. Physical distancing (A_3): This indicates limiting a massive group of people and keeping a particular distance from other people.

iii. Contact monitoring/tracing (A_4): This attribute focuses on a person who has close contact with someone that is infected with COVID-19.

iv. Isolation of infected patients (A_5): The alternative indicates that a person who got infected from COVID-19 must be quarantined in hospitals, other facilities, and in their own homes.

v. School closure (A_6): The shutdown of schools and other educational institutions.

vi. Restraint of nonessential business (A_7): This refers to discontinuing and closing the operation of their business.

vii. Prohibition/ban of internal and domestic travel (A_8): The alternative represents someone is not allowed to go out of the country.

viii. Abortion of group events and mass gatherings (A_9): The alternative represents the density of people that are involved in the limited space and recognized in other living areas.

ix. Practice of hand hygiene (A_{10}): This is the capacity to prevent the transmission of COVID-19 that is highly supposed to be used with an alcohol-based solution.

The criteria and alternatives are the main variables of this study in which their relationship and dependency in decision-making are evaluated by a group of experts. The relationships and dependency of the alternatives and criteria are illustrated in Figure 1.

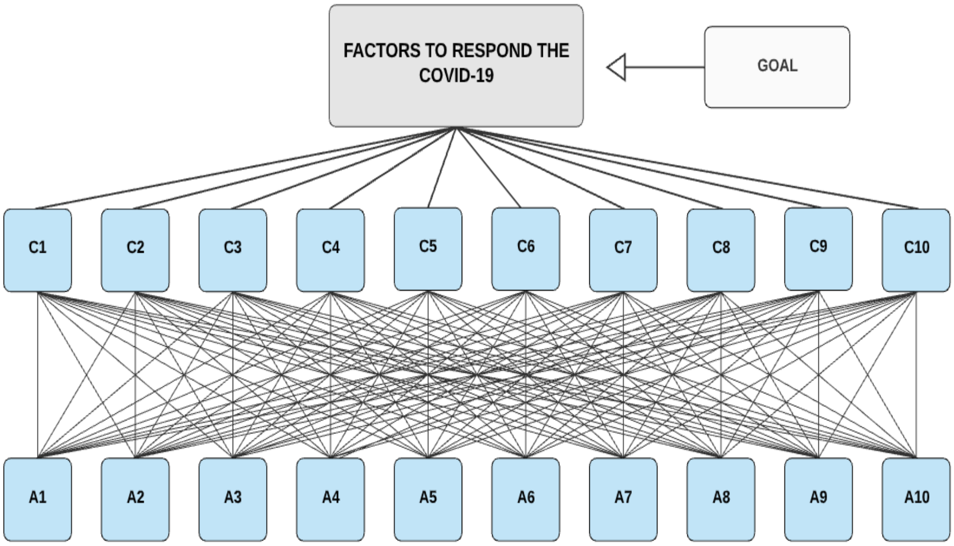

Figure 1. The dependency structure of alternatives and criteria

Expert judgment of alternatives with respect to criteria is guided by rating and linguistic scales. This type of evaluation is typically applied at the project planning stage, where decisions are made based on abilities, specializations, or knowledge in a given field. An individual's expertise may be based on their training, educational background, professional experience, or knowledge of a particular field. For instance, a nurse's professional judgment typically depends on the experience and knowledge of the nurse who is currently on duty (Burstein et al. 2006). The following subsection describes a brief biography of experts and linguistic ratings.

3.2. Experts and Linguistic Scales

The alternatives and criteria are evaluated by a group of experts. Five experts are invited to rate the importance of alternatives with respect to criteria using the rating scale as shown in Table 1.

Table 1. Five-point Likert scale and its linguistic scale.

Rating	Linguistic Scale
0	Certainly Low Importance (CLI)
1	Low Importance (LI)
2	Moderate Importance (MI)
3	High Importance (HI)
4	Very High Importance (VHI)

The brief biography of experts is summarized in Table 2.

Table 2. Biographical Data of Experts

Expert / Biodata	Expert 1 (D_1)	Expert 2 (D_2)	Expert 3 (D_3)	Expert 4 (D_4)	Expert 5 (D_5)
Field of Experts	Biomedicine	Nursing	Nursing	Public Health	Critical Care
Position	Senior Lecturer	Senior Staff Nurse	Staff Nurse	Senior Medical Officer	Medical Officer
Academic Qualification	Doctorate in Biomedicine	Bachelor of Nursing	Bachelor of Nursing	MBBS, MPH	MBBS
Years of Experience	7	17	8	15	6

The data that was collected via experts' judgments are gathered and then analyzed using the computational procedural of PROMETHEE. The detailed steps of computational procedures are given as follows.

3.3 Computational Procedures

Primarily, the PROMETHEE method proposed by Mousavi & Lin (2020) is used as the computational procedure tool in this research. This method is relatively new and is considered the latest version of PROMETHEE. The computational procedures begin with the degree of importance of criteria and a criterion-based evaluation of alternatives. These numerical data represent the relative importance of criteria and the difference between two alternatives using a preference function. The importance of criteria and the difference of two alternatives are aggregated to become a preference index. The whole computational procedures consist of nine steps of which the first step and second step are adopted from Bagherikahvarin et al. (2019). The first two steps are meant to ensure the correct fraction and normalization of data. The rest of the computational procedures remained as Mousavi & Lin (2020) where these authors applied the computational procedures to predict distress in finance. This study is the maiden attempt to solve the problem about alternatives and criteria of non-pharmaceutical approach in combating the COVID-19 pandemic. Given qualitative linguistic data used in this study, the type IV preference function is adopted while the indifferences between alternatives are set on an interval. The flow chart of the methodology is illustrated in Figure 2.

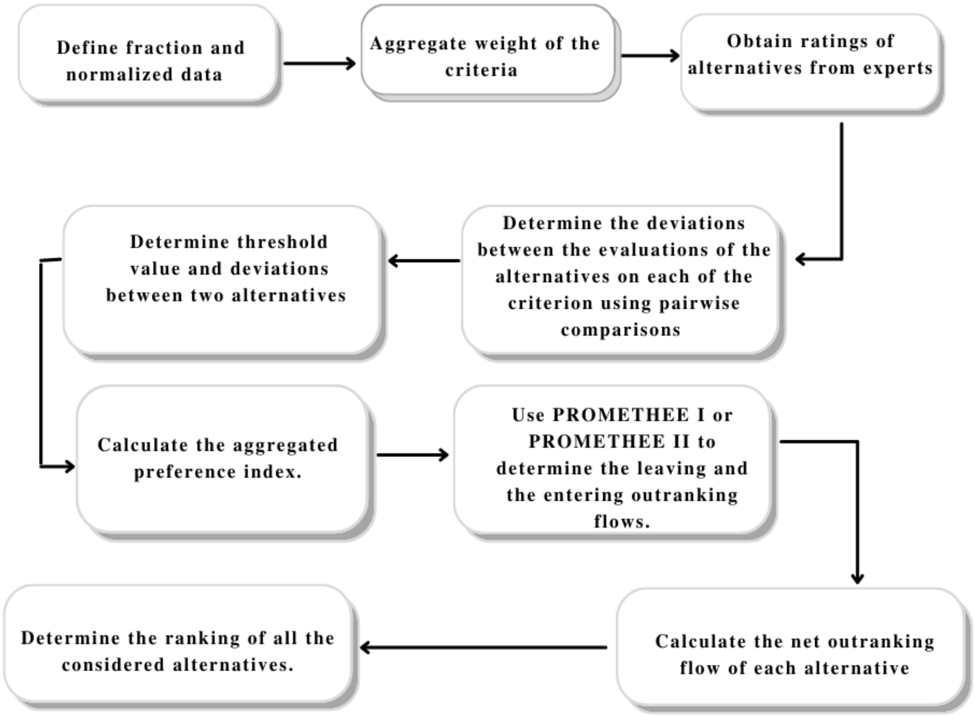

Figure 2. Flowchart of the proposed method

Details of the computational procedures are described as follows.

Step 1: Define Fraction and Normalized Data

Fraction data x_i is defined as quotient, in which responded scale is divided by largest scale whereas normalized data y_i is the ratio of x_i to a total of x_i,

Step 2: Aggregate weight of the criteria w where

$$\sum_{j}^{m} w_j = 1 \tag{1}$$

where w_j is the weight of the criteria j=1,2,...,m.

Step 3: Obtain ratings of alternatives from experts, R_{ij}

Aggregate the scale that represents expert judgment using equation (2).

$$R_{ij} = \frac{|X_{ij} - \min(X_{ij})|}{\left[|\max(X_{ij}) - \min(X_{ij})|\right]}, \ i=1,2,\ldots,n \ j = 1,2,\ldots,m \tag{2}$$

where X_{ij} denoted the evaluation values provided by the experts i=1,2,...,n and the number of criteria j=1,2,...,m. The average weight and average rating as shown below:

Average weight of criteria = $\frac{\sum_{i=0}^{m} C_{ji}}{m}$ (3)

Average rating = $\frac{\sum_{i=0}^{m} R_{ji}}{m}$ (4)

Step 4: Determine the deviations between the evaluations of *a* and *b* on each of the criterion using pairwise comparisons using equation (5)

$$d_j(a,b) = m_j(a) - m_j(b) \quad (5)$$

where d_j is the deviations while $m_j(a)$ and $m_j(b)$ are the evaluations of *a* and *b* on each criterion, respectively.

Step 5: Obtain threshold value and deviations between two alternatives

$$P_j(a,b) = F_j\left(d_j(a,b)\right), j=1,2,\ldots,m \quad (6)$$

where $P_j(a,b)$ represent the difference function between the alternative *b* of evaluations in each of the criterion into *a* degree 0 to 1.

F_j is type IV, level criterion function where the domain *q(x)* is given as

$$q(x) = \begin{cases} 0, & for\ x \le r \\ \frac{1}{2}, & for\ x < x \le r+s \\ 1, & for\ x > r+s \end{cases}$$

Step 6: Calculate the aggregated preference index.

$$\pi(a,b) = \sum_{j=1}^{m}\left(P_j(a,b)w_j\right) \Big/ \sum_{j=1}^{m} w_j \quad (7)$$

where $w_j > 0$ are the weights associated with each criterion. The symbol $\pi(a,b)$ indicates the degree of *a* is preferred to *b* over all the criteria.

$\pi(a,b) \approx 0$ implies a weak preference of *a* over *b*.

$\pi(a,b) \approx 1$ implies a strong preference of *a* over *b*.

Step 7: PROMETHEE I can be used to obtain partial ranking; if complete ranking is required, PROMETHEE II must be used for one more step in the computation.

Determine the leaving and the entering outranking flows

i. Leaving the (positive) flow *ath* alternatives, $\Phi^{+}(a)$

$$\frac{1}{n-1}\sum_{k=1}^{n}\pi(a,b) \qquad (a \neq b) \tag{8}$$

ii. Entering the (negative) flow *ath* alternatives, $\Phi^{-}(a)$

$$\frac{1}{n-1}\sum_{k=1}^{n}\pi(b,a) \qquad (a \neq b) \tag{9}$$

where *k* is alternative and *n* is the number of alternatives.

Step 8: Calculate the net outranking flow of each alternative

$$\Phi(a) = \Phi^{+}(a) - \Phi^{-}(a) \tag{10}$$

where $\phi(a)$ is net outranking flow.

Step 9: Determine the ranking of all the considered alternatives depending on the value $\phi^{net}(a)$. The higher leaving flow and the lower entering flow show the best alternative performance.

In accordance with the computational procedures, this study attempts to implement it in the case of the selection of alternatives of responses to the COVID-19 pandemic.

4. Implementation

In this section, data analysis using the PROMETHEE method is presented. These computations are implemented using spreadsheet software and PROMETHEE-GAIA software of which the alternatives or prevention strategies of the COVID-19 pandemic are evaluated. The following notation are used for a set of ten criteria: $\{c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_9, c_{10}\}$, a set of experts: $\{D_1, D_2, D_3, D_4, D_5\}$ and a set of alternatives: $\{A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9, A_{10}\}$. In accordance with the computational procedures given in Section 3, these computations are implemented as follows.

Step 1: Fraction and Normalization of the data of criterion.

Fraction $x_i = r_i - 1 / \max\{x_i - 1\}$. For example, x_i = 3-1/5-1= 0.5, and

Normalized data $y_i = \frac{x_i}{\sum_{i=1}^{10} x_i}$. For example,

$$y_1 = \frac{0.5}{0.5+0.5+\ldots+\ldots+\ldots+\ldots+\ldots+\ldots+0.75+0.5} = 0.090909$$

The fractioned and normalized data of each criterion given by experts are shown in Table 3 and Table 4, respectively.

Table 3. Fractioned Data of Criteria given by Experts

	D_1	D_2	D_3	D_4	D_5
C_1	0.5	0.5	0.5	0.5	0.5
C_2	0.5	0.5	0.5	0.75	0.75
C_3	0.5	0.5	0.25	0.5	0.5
C_4	0.5	0.5	0.25	0.75	0.75
C_5	0.5	0.5	0.5	0.75	0.5
C_6	0.5	0.5	0.5	0.75	0.25
C_7	0.75	0.5	0.25	0.75	0.75
C_8	0.5	0.5	0.25	0.75	0.5
C_9	0.75	0.5	0.25	0.75	0.75
C_{10}	0.5	0.5	0.5	0.5	0.75

Table 4. Normalized Data of Criteria and Experts

	D_1	D_2	D_3	D_4	D_5
C_1	0.090909	0.10	0.133333	0.074074	0.083333
C_2	0.090909	0.10	0.133333	0.111111	0.125
C_3	0.090909	0.10	0.066667	0.074074	0.083333
C_4	0.090909	0.10	0.066667	0.111111	0.125
C_5	0.090909	0.10	0.133333	0.111111	0.083333
C_6	0.090909	0.10	0.133333	0.111111	0.041667
C_7	0.136364	0.10	0.066667	0.111111	0.125
C_8	0.090909	0.10	0.066667	0.111111	0.083333
C_9	0.136364	0.10	0.066667	0.111111	0.125
C_{10}	0.090909	0.10	0.133333	0.074074	0.125

Step 2: Utilizing equation (1), aggregate each criterion's weight.

Table 5 summarizes the aggregated weight of the criteria.

Table 5. Aggregated Weight of Criteria

Criteria	Aggregate weight
C_1	0.09633
C_2	0.112071
C_3	0.082997
C_4	0.098737
C_5	0.103737
C_6	0.095404
C_7	0.107828
C_8	0.090404
C_9	0.107828
C_{10}	0.104663

Step 3: Rating of alternatives.

The rating of alternatives uses an averaging equation (see equation (3)) and normalization by using equation (4). The evaluations of these alternatives (A1,…,A10) corresponds to all criteria are shown in Table 6.

Table 6. Rating of alternatives with Respect to Criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	0.7	0.6	0.6	0.65	0.6	0.6	0.6	0.45	0.65	0.6
A_2	0.6	0.55	0.5	0.45	0.6	0.5	0.55	0.4	0.6	0.6
A_3	0.55	0.55	0.5	0.6	0.65	0.6	0.55	0.4	0.55	0.65
A_4	0.65	0.6	0.55	0.5	0.7	0.5	0.55	0.45	0.6	0.65
A_5	0.45	0.45	0.35	0.4	0.55	0.65	0.6	0.35	0.65	0.7
A_6	0.45	0.5	0.45	0.55	0.55	0.6	0.45	0.25	0.35	0.3
A_7	0.55	0.55	0.4	0.65	0.65	0.55	0.55	0.4	0.5	0.45
A_8	0.55	0.55	0.6	0.6	0.6	0.6	0.6	0.55	0.5	0.45
A_9	0.65	0.45	0.5	0.6	0.5	0.65	0.55	0.45	0.35	0.6
A_{10}	0.55	0.45	0.35	0.45	0.55	0.45	0.35	0.35	0.4	0.45

Step 4: Determination of deviation pairwise comparison

The computation comprises utilizing equation (5) to calculate the differences between the criteria value of A_i and other alternatives. Table 7 displays a summary of the deviations.

Table 7. Deviation of Two Alternatives with Respect to Criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1A_2	0.1	0.05	0.1	0.2	0	0.1	0.05	0.05	0.05	0
A_1A_3	0.15	0.05	0.1	0.05	-0.05	0	0.05	0.05	0.1	-0.05
A_1A_4	0.05	0	0.05	0.15	-0.1	0.1	0.05	0	0.05	-0.05
A_1A_5	0.25	0.15	0.25	0.25	0.05	-0.05	0	0.1	0	-0.1
A_1A_6	0.25	0.1	0.15	0.1	0.05	0	0.15	0.2	0.3	0.3
A_1A_7	0.15	0.05	0.2	0	-0.05	0.05	0.05	0.05	0.15	0.15
A_1A_8	0.15	0.05	0	0.05	0	0	0	-0.1	0.15	0.15
A_1A_9	0.05	0.15	0.1	0.05	0.1	-0.05	0.05	0	0.3	0
A_1A_{10}	0.15	0.15	0.25	0.2	0.05	0.15	0.25	0.1	0.25	0.15
A_2A_1	-0.1	-0.05	-0.1	-0.2	0	-0.1	-0.05	-0.05	-0.05	0
A_2A_3	0.05	0	-0.1	-0.15	-0.05	-0.1	0	0	0.05	-0.05
A_2A_4	-0.05	-0.05	0	-0.05	-0.1	0	0	-0.05	0	-0.05
A_2A_5	0.15	0.1	0.1	0.05	0.05	-0.15	-0.05	0.05	-0.05	-0.1
A_2A_6	0.15	0.05	-0.05	-0.1	0.05	-0.1	0.1	0.15	0.25	0.3
A_2A_7	0.05	0	-0.15	-0.2	-0.05	-0.05	0	0	0.1	0.15
A_2A_8	0.05	0	-0.1	-0.15	0	-0.1	-0.05	-0.15	0.1	0.15
A_2A_9	-0.05	0.1	-0.1	-0.15	0.1	-0.15	0	-0.05	0.25	0
A_2A_{10}	0.05	0.1	0.05	0	0.05	0.05	0.2	0.05	0.2	0.15

Step 5: Obtain Threshold Value

The level function (Type IV) is used to propose threshold values. The level function consists of indifference and preference thresholds where q represents the most significant value below sufficient to generate a full preference. In contrast, the preference threshold (p) indicates the smallest number above sufficient to generate a full preference. These values are selected based on their judgment and based on experts' evaluation in this study. The threshold value for all criteria is $p = 0.1$ and $q = 0.05$. These threshold values will determine a deviation between two alternatives with respect to criteria.

Step 6: Calculate the preference index

The index is calculated by using equation (7). For example,

$$\pi(A_1, A_2) = \sum_{j=1}^{10} \begin{matrix}(0.5*0.09633 + 0*0.11207 + 0.5*0.083 + 1*0.09874 + \\ 0*0.10374 + 0.5*0.0954 + 0*0.10783 + 0*0.0904 + \\ 0*0.10783 + 0*0.10466) = 0.2361\end{matrix}$$

Step 7: Find the alternative's positive and negative outranking flows (PROMETHEE I partial ranking).

The positive outranking is computed using equation (8) such as

$$\phi^+(A_1) = \frac{1}{9}\sum \begin{matrix}(0.236105 + 0.191745 + 0.14644 + 0.43534 + 0.695455 + \\ 0.39182 + 0.30882 + 0.31327 + 0.85106)\end{matrix}$$

Similarly, the negative outranking is computed using equation (9)

$$\phi^-(A_1) = \frac{1}{9}\sum (0 + 0 + 0.05187 + 0.05233 + 0 + 0 + 0.0452 + 0 + 0)$$

Step 8: Find the alternatives' net outranking flow (PROMETHEE II).

The net flows are obtained using equation (10). Table 8 shows the positive and negative outranking obtained using PROMETHEE I and the net flow of alternatives using PROMETHEE II.

Table 8. Results of PROMETHEE I and the Net Flow (PROMETHEE II)

Alternatives	Positive outranking $\phi^+(A_i)$	Negative Outranking $\phi^-(A_i)$	Net Flow	Ranking
A_1	0.396673	0.0166	0.380073	1
A_2	0.172916	0.138937	0.033978	4
A_3	0.251328	0.052654	0.198673	3
A_4	0.320057	0.085821	0.234236	2
A_5	0.195939	0.288839	-0.0929	8
A_6	0.058355	0.468532	-0.41018	9
A_7	0.182466	0.184657	-0.00219	7
A_8	0.286343	0.132887	0.153457	5
A_9	0.225944	0.205606	0.020338	6
A_{10}	0.02735	0.54284	-0.51549	10

Based on the value of net flow, the ranking of alternatives is finalized as in the last column of Table 8. The alternative with the highest net flow value, $\phi(A)$ which is A_1 is the most preferred intervention strategy.

As shown in Table 8, the alternative A_1 (lockdown/quarantine) is the most preferred intervention strategy in response to COVID-19. The other strategies are arranged as $A_4 \prec A_3 \prec A_8 \prec A_2 \prec A_9 \prec A_7 \prec A_5 \prec A_6 \prec A_{10}$ based on the degree of preference where $\prec$ represents 'is less preferred than'

The complete ranking results are further analyzed as these results are short in visualizing the distribution of the alternatives. The results are also not sufficient to demonstrate the effect of weights of criteria toward the alternatives. In response to these limitations, the complete ranking results are further analyzed using the GAIA plane and weight analysis. Detailed elucidations of these two analyses are given in the following section.

5. Distribution and Sensitivity

The outranking results obtained from the PROMETHEE are further discussed from the perspective of correlations between alternatives and the decision axis. This analysis provides some extend of distribution of alternatives and criteria and how these two variables correlate with the decision axis. The distribution of the criteria is analyzed to see the convergence of every criterion with respect to the decision axis. The variability of weights of criteria and how it affects the alternatives are also discussed in this section. The distribution and weight are two different analyses where their purposes of analyses are distinctive. The analysis of weight is meant to check the sensitivity of the weights of criteria toward the alternatives. These two analyses are further described in the following subsections.

5.1 Distribution of Criteria and Alternatives

The recognition of correlations, strengths and weaknesses of alternatives can be seen from the output of the GAIA plane. Lines on the plane reflect the criteria, whereas dots on the plane represent the alternatives. Figure 3 shows the position or distribution of alternatives and the criteria.

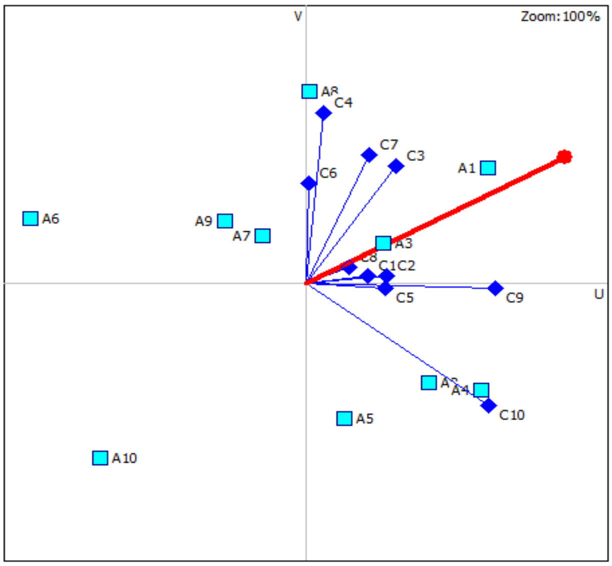

Figure 3. GAIA Plane

The GAIA plane’s distribution of criteria allows for a better understanding of the competitive panorama and the analysis of criteria concordance. They all have the same length, meaning they have a similar power of discrimination. We can observe that the alternative A_1 is ranked first. Furthermore, it occupies a distinct position from the other alternatives. This owes its position, 'lockdown/quarantine strategy' in the most preferred intervention strategies to be implemented during the COVID-19 pandemic. The figure also depicts the modeled plane indicating the decision axis (π) (the red line) where most of the criteria are converged to the quadrant. As can be seen in the figure, A_1 has established a high position, scoring in all measures of lockdown/quarantine from the origin to the direction of the decision axis.

The criteria C_{10} is noted as the conflicting criterion with C_9 and C_5 because they are aligned entirely in opposite directions. The other criteria are C_6, C_4, C_7, C_3 with either C_8 or C_1 with C_2, indicating that these criteria have the same effect on priority sequencing rule selection. Furthermore, the longer axis in blue lines of C_4, C_9, and C_{10} demonstrate that they have greater strength in distinguishing all options or strategies. The criteria C_8 has a comparatively shorter length as compared to the preferred measures, showing low distinguishing power between the alternatives. The distribution of criteria and alternatives and also their correlations with the decision axis provide supportive evidence of the outranking results obtained from the complete ranking of PROMETHEE II.

3.3 Sensitivity of Weights

Weights of criteria used in this study are normally assumed to be almost equal. In other words, the weight of the importance of Failure of Safety Engagement (C_1) for example, is assumed to be similar to the other nine criteria. It seems that this assumption warrants further investigation as weights of criteria is intuitively unequal in our daily life. This different treatment of weights is hypothesized to affect the outranking of alternatives. Therefore, in this analysis the variability of weights and how it affects the outranking is investigated.

In Section 4, the outranking results are given as A1≺ A4 ≺ A3≺ A8≺ A2≺ A9 ≺ A7 ≺A5 ≺A6 ≺ A10. This outranking is obtained using the nine-step computation where the weights of criteria are computed using equation (10) (see Table 8). Figure 4 depicts the outranking results and the weights of criteria.

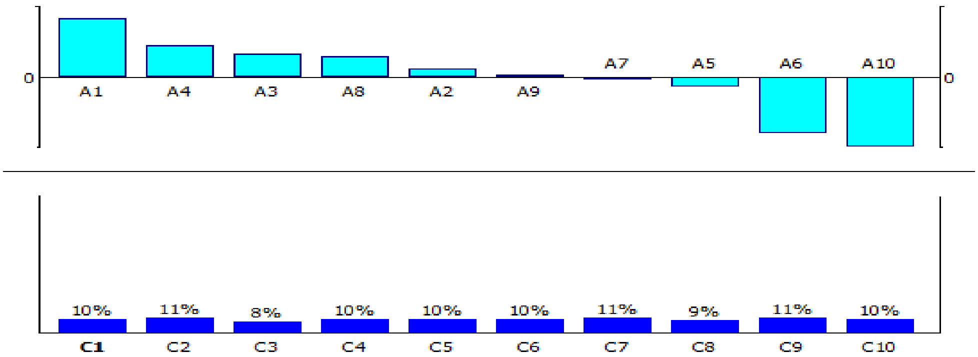

Figure 4. Outranking of alternatives and weights of criteria

This figure includes two bar charts where the top chart depicts the net-flow values of PROMETHEE II while the bottom chart depicts the weight of the criteria. It can be seen that the weight distribution is almost equal where A_1 dominates the others, while A_{10} remains at the bottom of the list.

The results of PROMETHEE II will be reviewed in accordance with the weights of criteria. The variability of weight is a sensitivity analysis technique for determining the effects of criterion weight on the final priority sequencing rule selection choice (Bari and Karande 2021). In the following analysis, we increase the weight of importance in C_{10} by 25% and this could lead to major changes in rankings of alternatives. Figure 5 illustrates the changes in weights and how it affects the ranking.

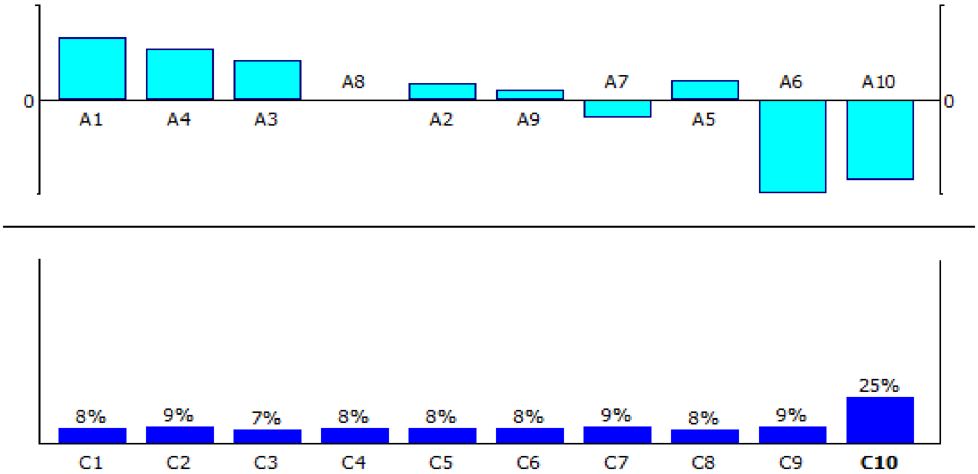

Figure 5. Weights of criteria and ranking of alternatives

The above figure demonstrates that increasing weight of C_{10} by 25% does not affect the first ranking of alternatives (A_1). However, the weights of other criteria have been changed by various percentages thereby the ranking of alternatives also has been changed accordingly. It is good to note that the change of weight of one criterion has little effect on the weights of other criteria. However, the ranking of alternatives has changed completely. In this context, the final ranking results are very sensitive to the weight of each criterion thereby should be dynamically and proportionally vigilant. This result provides evidence on the significance of the weight of criteria in the evaluation of alternatives. In this case study, when the weights of the criteria are changed, then the outranking of alternatives is also changed except A1 (lockdown/quarantine). In addition, the Spearman's rank correlation coefficient is also conducted to see the correlations between the net flow of alternative before and after the changes in criteria weights. Figure 6 shows the analysis of Spearman's rank correlation coefficient using the Statistical Package for the Social Sciences (SPSS) software.

Nonparametric Correlations

Correlations

			Netflow	Netflow_Changesinweight
Spearman's rho	Netflow	Correlation Coefficient	1.000	.794**
		Sig. (2-tailed)	.	.006
		N	10	10
	Netflow_Changesinweight	Correlation Coefficient	.794**	1.000
		Sig. (2-tailed)	.006	.
		N	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 6. Spearman's rank correlation coefficient results

The correlation coefficient between the net flow of alternatives before and after the modification of the criterion weights is 0.794, an indication of a substantial relationship. Since the significant value is 0.006 which is less than 0.01 tested value, we can say that the test is significant and there is a significant relationship between the net flow of alternatives before and after the changes of the criterion weights. Therefore, the changes of criterion weights do not have much effect on the outranking of alternatives.

6. Conclusion

In this study, the PROMETHEE method is introduced to determine the best intervention strategies during the COVID-19 pandemic by experts' judgments. To the best of authors' knowledge, this is the first application of the PROMETHEE method and its affiliated analysis to the case of non-pharmaceutical intervention strategies in dealing with the COVID-19 pandemic.

Final results have shown that the proposed method has its own benefits. The PROMETHEE method has been successfully identified the alternative A1 (lockdown/quarantine) as the most preferred intervention strategy in response to the COVID-19 pandemic. Further analysis of the PROMETHEE method strengthens the outranking results where distribution analysis indicates the alternative A1 is located at the distinct position from the other alternatives. The weighted analysis also adds another evidence on the optimized preference A1 when the first ranking remains despite changes in weights of criteria. Therefore, we can conclude that the PROMETHEE method can be attributed to the identification of the best non-pharmaceutical intervention strategies in dealing with the contagious COVID- 19 disease.

However, the results of the current study are subjected to limitations and scope of this study. The evaluation model PROMETHEE used in this study employs the level criterion function (Type IV) where its outcomes (domains) rely on the proposed threshold values. Different preference functions and threshold values might give different outcomes of indifferences between two alternatives. The results obtained using the PROMETHEE method also very much depend on the weight of the criteria. From the analysis, we can see that the weight of the criterion has a direct impact on the findings. This vulnerability of weights could undermine this study but more importantly this limitation may open a new opportunity in exploring weights. As for future research, different settings of the corresponding parameters such as preference functions and threshold value can be applied in order to discover different ability of the method. Yet, the value of weight also could be written in the continuous interval. In this way, an in-depth investigation could be implemented to discover how sensitivity of weights could affect the complete outranking.

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