Socio-Economic Planning Sciences 89 (2023) 101711

Contents lists available at ScienceDirect

Socio-Economic Planning Sciences

journal homepage: www.elsevier.com/locate/seps

A probabilistic hesitant fuzzy MCDM approach to evaluate India's intervention strategies against the COVID-19 pandemic

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ARTICLE INFO

Keywords:
India's intervention strategies
COVID-19
Probabilistic hesitant fuzzy set
F-MCDM
Entropy
PROMETHEE-II

ABSTRACT

The unprecedented coronavirus pandemic (COVID-19) has wreaked havoc across the globe. The Covid-19 pandemic has affected all countries, including government intervention programs, thus becoming a significant threat. This study aims to develop a hybrid fuzzy multi-criteria decision-making (F-MCDM) model in a constrained ecosystem in response to specific government strategies and the effectiveness of interventions used in different countries during the COVID-19 pandemic. An empirical case study is conducted in India with five prospective criteria: "high acceptance among the populace", "effectiveness in halting the COVID-19 epidemic", "compatibility by any other standard", "estimated total cost", and "simple to implement". Regarding the ranking of strategies, "vaccinations", "social isolation", and "development of an emergence" are the top three strategies. As a result, SARS-CoV-2 vaccines have reduced COVID-19-related hospitalizations in the elderly, which has reduced post-CoVID morbidity and mortality. Many countries have different recommendations for selecting possible government initiatives and implementing those decisions. India's strategies for developing public health policies, preventing misinformation, and managing behavior and response were ranked as the top three priorities among the listed strategies. Sensitivity analysis confirmed the validity of these results. In this work, the implications of these findings are discussed in terms of a developing nation.

1. Introduction

SARS-CoV-2 is the infectious agent that gives rise to COVID-19. The epidemic was still going strong after it was first discovered in Wuhan, China in December 2019. During the period of 2020, more than 7 million cases have been reported in 188 countries and territories, resulting in more than 405,000 deaths [1].

One of the epicenters of the world is India, a democratic country with a high population density and robust health system. India announced a strict nationwide lockdown from March 25 to May 31, 2020. After this, a phased lockdown for containment zones was in place till June 30, 2020, to curb the spread of the epidemic. As of June 11, India had a total of 298,000 confirmed cases, of which 146,972 have fully recovered and 8501 have died. This makes India fourth globally in terms of total number of confirmed cases [2]. After nine weeks of nationwide lockdown, the number of new cases in India has not decreased.

In April 2021, the World Health Organization (WHO) formally declared COVID-19 a pandemic as a result of its onset. The COVID-19 outbreak has put the world's economic activity at risk [3]. Additionally, tens of thousands of people lost their jobs, business values plummeted, and many service providers were forced to close their doors. Due to the lack of available treatments at the time, lockdowns, travel restrictions, and closing schools and workplaces were effective interventions [4].

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https://doi.org/10.1016/j.seps.2023.101711
Received 12 January 2023; Received in revised form 14 August 2023; Accepted 26 August 2023
Available online 30 August 2023

A number of guidelines were given, including detailed public health interventions such as how to use masks, wash hands, and clean surfaces. The Centers for Disease Control (CDC) noted that SARS-CoV-2 genetic mutations are evolving and spreading globally [5]. Compared to previous strains, the delta variant of the Covid-19 virus caused more infections. However, they have rarely been used to evaluate government actions and Covid-19 mitigation strategies [6]. As it is necessary to deal with the world, various methods and concepts have been developed to deal with uncertainty.

Due to the enormous public health interest in this topic, several data repositories and statistical models have been developed to study the impact of non-medical treatments for Covid-19. Prediction is not the primary goal of modeling; Instead, it now assesses the impact of various actions on virus transmission. At least 30 of the 4880 Covid-19 and SARS-CoV-2 preprints published on medRxiv and bioRxiv as of June 9 examined the effectiveness of non-clinical initiatives implemented by the Indian government [7].

They concluded that the lockdown has a good chance of reducing the overall number of cases in India in a short period of time. At the state level in India, researchers examined the spread of the virus and the subsequent impact of containment measures on it. They found that the lockdown had varied effects on daily infection rates in different states in India. The reproduction number (R0) across India was calculated using the traditional SIR (Susceptible–Infected–Recovery) model to simulate data from the Indian Ministry of Health. Similarly, important epidemiological parameters were evaluated using the dynamic compartment-based SEIR-QDPA modeling technique [8]. Additionally, they evaluated how containment strategies affected the COVID-19 outbreak in India and its states, highlighting that state-specific R0 values differ greatly from the national value of R0 [9]. But even after the global lockdown ended and the designed lockdown phase began, many more strategies were implemented.

Evaluating government solutions requires weighing several competing factors, such as cost savings, ease of implementation, and ability to contain the spread of Covid-19 [10,11]. To do this, multi-criteria decision-making methods were used. Therefore, F-MCDM approaches can be successfully used to assist governments in coming up with a better strategy [12]. F-MCDM, on the other hand, is a useful method to aid in detailed planning and better approaches to developing responses.

Zaheh [13] introduced the concept of a fuzzy set (FS) defined by a global set X on [0, 1]. Probabilistic Hesitant Fuzzy Set (PHFS) [14] combines the concept of HFS to augment the concept of Hesitant Fuzzy Set (HFS). F-MCDM procedures, benchmarks for achieving performance goals, have shown significant promise in recent years. Furthermore, the concept of PHFS has shown considerable promise in addressing these practices. For example, we defined the Hausdorff distance measure for probabilistic fuzzy elements (PHFEs) and then extended qualitative flexible multiple (QUALIFLEX) techniques to evaluate green suppliers [15].

The proposed hybrid methodology fills a research gap to evaluate India's intervention strategies against the Covid-19 pandemic. In addition, this paper reinforces decision-making research by identifying the most preferred F-MCDM method for investigating government approaches to the COVID-19 pandemic, making the selection process more rational and logical. In summary, this complex hybrid method provides more accurate and feasible results than other methods. The entropy weights method (EWM) is a commonly used information weighting method in decision-making. It is widely used in comprehensive evaluation studies using various evaluation indices. In these studies, the weights of different indices are determined depending on the degree of dispersion [16]. The greatest feature of the entropy method is that the information provided by the judgment matrix is directly used to calculate the weights. But the subjective judgment of the decision-maker should not be allowed to interfere with the outcome of the decision [17].

This proposed hybrid method is based on partial integration: all possible results are compared to each other by pair and ranking. After that, a better decision can be made. It assumes that the decision-maker is a well-versed expert in the problem domain to determine these weights, reflecting the importance of the criteria in ranking the alternatives. The entropy-PROMETHEE II method provided more realistic results and is more stable.

The remainder of this study is organized as follows: The literature review is discussed in Section 2. The basic concepts and methodology of the proposed method are presented in Section 3. A case study is applied to the methods and the results of the analysis are given in Section 4. Further, a discussion of the case study and public implications is provided in Sections 5 and 6. Finally, Section 7 presents conclusions, limitations, and future work.

2. Literature review

Decision-making methods and tools have been designed to handle this problem. In difficult situations, F-MCDM techniques empower individuals or groups of decision makers to make wise and honest choices. It helps in evaluating and selecting the best alternative based on multiple factors. It is used in a variety of fields, including renewable energy, engineering, economics, and the social sciences [18]. Emphasis is placed on integrating F-MCDM techniques to investigate selection concerns, as the obtained results are more reliable than those obtained by a single MCDM technique [19].

Fuzzy entropy, one of the many MCDM models proposed in the literature, has been widely adopted and improved using fuzzy logic to solve decision ambiguity [20]. Academics are now conducting additional research on the phenomenon of the widespread effects of the COVID-19 pandemic on global health, including its effects on the economy, society, and psychology [21,22]. In response to the rapid growth of the COVID-19 outbreak [23,24], countries have used a number of strategies, including mandating measures. The COVID-19 pandemic has affected all countries and has become a significant threat; Therefore, governments take many factors into account and determine the most effective strategy [25].

There are not many studies in the literature about government strategies. A combined AHP and fuzzy TOPSIS approach evaluated occupational health solutions for organizations during COVID-19 prevention measures. Additionally, PROMETHEE [17], ELimination Et Choix Traduisant la REalite (ELECTRE) [26], Multi-Objective Optimization based on Ratio Analysis (MOORA) [27,28], Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [29], COmplex PRoportional ASsessment (COPRAS) [30], Additive Ratio ASessment (ARAS) [31], Analytical Hierarchy Process (AHP) [32], and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [11] are the most popular MCDM techniques. An application of multi-attribute group decision-making to probabilistic hesitancy and change efficiency in ambiguous environments [33]. According to their findings, the best way to prevent the spread of Covid-19 is complete isolation and quarantine [16]. However, several interventional strategies have been proposed worldwide so far [34].

Due to the Covid-19 pandemic in India, this study comprehensively evaluates the best tactics including recent government initiatives. In addition, this is the first study to use a combined PHF-entropy and PROMETHEE-II approach to analyze intervention strategies used to prevent the Covid-19 pandemic in developing countries, particularly India. While integrating the range of real-world problems listed in Table 1, it prioritized the set of intervention strategies that different countries used to address the Covid-19 pandemic.

In implementing such a dynamic policy, states were facilitated to adopt successful strategies. Kerala's rapid response, Odisha's use of local governance structures and community health networks, and Punjab's data analysis have helped other states. In densely populated areas like Maharashtra, Gujarat and Delhi, resources can be mobilized and

Table 1
An emphasis in response to the list of evaluation strategies for India's COVID-19 pandemic intervention strategies.

Alternatives	A case study to evaluate India's intervention strategies against the COVID-19 pandemic
Limit of unnecessary business (H_1) [35]	The duration of coronavirus control is defined by confirmed cases
Curfew imposed (H_2) [36]	Depending on the level of food security in SA, the COVID-19 curfew's effects on eating and food intake are reported.
Social isolation (H_3) [37], [2]	The traditional public health strategies of quarantine, social exclusion, and community containment were crucial in the new coronavirus outbreak.
College and school closures (H_4) [38]	Pandemic influenza requires non-pharmaceutical interventions in non-healthcare settings, including precautions for foreign travel.
Keeping infected individuals and patients under observation (H_5) [39]	The World Health Organisation Group claims that national measures are necessary to combat the COVID-19 pandemic.
Monitoring of health (H_6) [40]	WHO Considerations for Putting Into Practice and Modifying Social and Public Health Measures in the Context of COVID-19
Camping for public awareness (H_7) [41]	The effect of recurrent COVID-19 mass antigens on disease prevalence.
Development of an emergence (H_8) [42]	Over two weeks, we converted a general hospital into an infectious disease center.
Vaccinations (H_9) [43]	The health belief measures for the COVID-19 vaccination were developed and have good psychometric qualities.
Improved administration of the nation's health infrastructure (H_{10}) [44]	The COVID-19 mortality analysis highlights the crucial need of prompt medical resource supply.
The limitation of internal/ external borders (H_{11}) [45]	Collecting global data on COVID-19-related restrictions on human mobility and evaluating COVID-19 pandemic response plans using hesitant fuzzy-AHP

utilized optimally to meet the dire situations. In all these endeavors, fine-grained state-level summaries provide utility.

Objective and contribution of the study

This study provides a general summary of treatment approaches used in different countries. From the reviewed literature, the probabilistic resident fuzzy set (PHFS) addresses the uncertainty in determining a unified method to address issues related to the effectiveness of interventions during the Covid-19 pandemic. The existing entropy and PROMETHEE-II method using PHFS is developed as a PHF-entropy-PROMETHEE-II approach for solving MCDM problems. The main objective of this study is that a thorough study is given to illustrate how the proposed hybrid method can be applied. This is referred to as a research gap conducted using the F-MCDM method to analyze a proposed framework for the COVID-19 pandemic. This study is the first to use the innovative PHF-entropy and PROMETHEE-II model to explore optimal intervention strategies to be used to combat the spread of the COVID-19 pandemic.

Based on relevant literature and discussions with experts, this study suggests five possible criteria for emerging countries, particularly India. These include "high acceptance among people", "effectiveness in preventing the COVID-19 pandemic", "applicability to any other standard", "estimated total cost", and "easy to implement". The weights of the recommended criteria use the fuzzy entropy method. The PROMETHEE-II approach is used to rank 11 government intervention options for the Covid-19 pandemic after a comprehensive review of current government protection measures.

3. Methodology

In this section, a fuzzy hybrid multi-criteria decision making (MCDM) algorithm is developed using fuzzy information fusion principles, basic concepts of PHFs, linguistic representation model and technique for order preference by entropy-PROMETHEE-II. The proposed method is suitable for managing information evaluated using both linguistic and numerical measures in a decision-making problem with multiple information sources.

(a) Fundamental concepts

Some definitions of probabilistic hesitation fuzzy sets and scoring functions of PHFS principles are introduced in this section.

Definition 1 (*[14]*)**.** If X be the universal set and a PHFS on X is a function that, when applied to X, yields a probabilistic variables with outcomes on a subset of [0,1].

$$^{\wp}H = \{\langle x, {}^{\wp}\hbar_x \rangle : x \in X\}$$
$$= \left\{ \left\langle x, \bigcup_{\langle \hbar_x, \wp_x \rangle \in {}^{\wp}\hbar_x} \{\langle \hbar_x, \wp_x \rangle\} \right\rangle / x \in X \right\}$$

where $\langle \hbar_x, \wp_x \rangle$ is a subset of $[0,1]$.$\hbar_x$ denotes the possible membership degrees of the element $x \in X$ to the set H, and $\wp_x$ denotes the possibilities of $\hbar_x$ satisfying $\sum \wp_x = 1$.

Definition 2 (*[33]*)**.** For a PHFE $^{\wp}\hbar_x$, its score function is defined by:

$$S(^{\wp}\hbar_x) = \left(\sum_{k=1}^{|\hbar(\wp)|} \hbar^k \wp^k \right) / \sum_{k=1}^{|\hbar(\wp)|} \wp^k$$

For two PHFEs $\hbar_1(\wp)$ and $\hbar_2(\wp)$, if $S\left(\hbar_1(\wp)\right) > S\left(\hbar_2(\wp)\right)$, then we consider that $\hbar_1(\wp)$ is superior to $\hbar_2(\wp)$, denoted as $\hbar_1(\wp) > \hbar_2(\wp)$ or $\hbar_2(\wp) < \hbar_1(\wp)$.

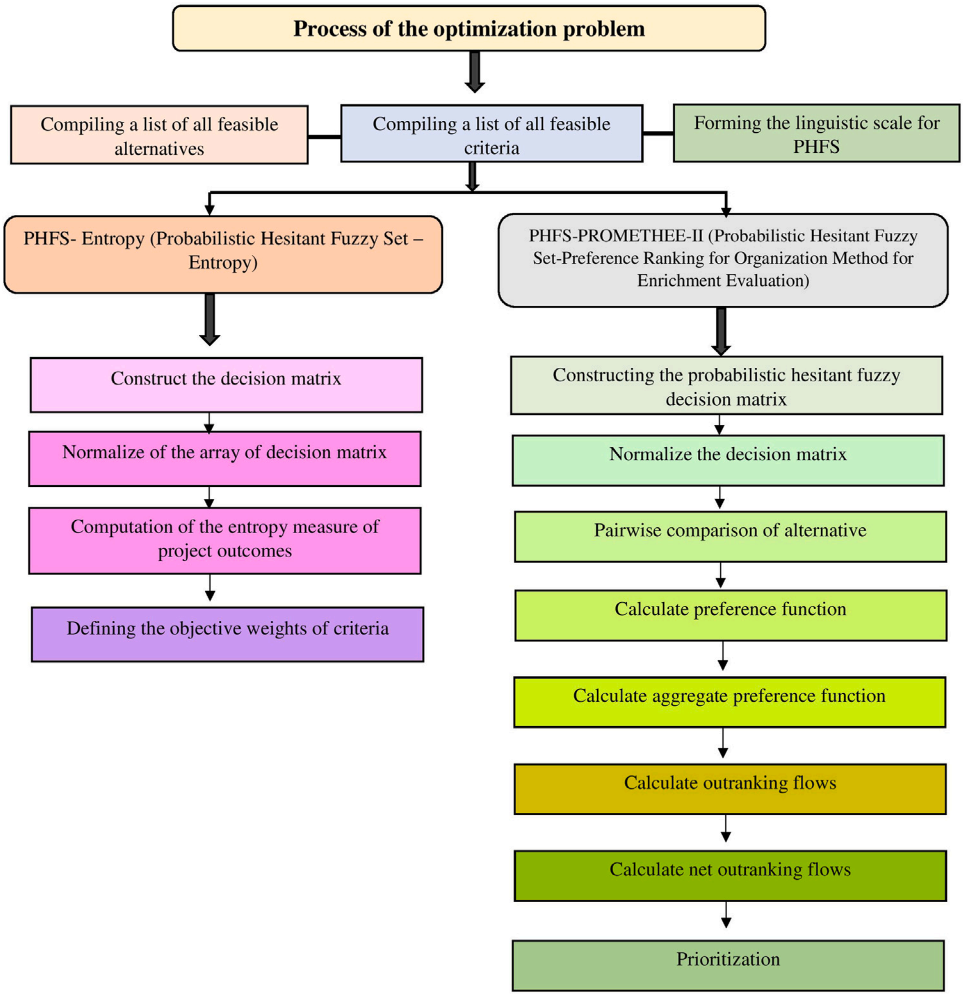

Fig. 1. The framework of the optimization problem.

(b) Algorithm of the proposed methods

The first stage of data collection was conducting a thorough literature study to identify the necessary set of 11 government policies that were shortlisted and chosen for further consideration.

The process of weighting the list of five criteria involves collecting data from experts in the medical field. After the assessment of the priority governmental measures for responding to the COVID-19 disease with the help of medical experts, the results were then analyzed using a novel MCDM technique. To estimate the weights of the criteria for use in the entropy approach in PROMETHEE-II. PROMETHEE I and II allow partial and absolute ranking of alternatives, respectively. The architecture of the proposed method is shown in Fig. 1.

Entropy weight method

Initiate the decision matrix $\tilde{D}_{ij}$. If ${}^{\wp}\hbar_{ij} = \{\langle \hbar_{ij}, \wp \rangle\}$, denotes the ith alternatives and jth criteria score that, according to the linguistic conversion scale.

$$[D_{ij}]_{m\times n} = \begin{bmatrix} & U_1 & U_2 & \cdots U_n \\ H_1 & {}^{\wp}\hbar_{11} & {}^{\wp}\hbar_{12} & {}^{\wp}\hbar_{1n} \\ H_2 & {}^{\wp}\hbar_{21} & {}^{\wp}\hbar_{22} & {}^{\wp}\hbar_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ H_m & {}^{\wp}\hbar_{m1} & {}^{\wp}\hbar_{m2} & {}^{\wp}\hbar_{mn} \end{bmatrix}$$

Step 1: The normalization of the values obtained is the first stage, and it is calculated based on:

$$\tilde{D}_{ij} = \frac{{}^{\wp}\hbar_{ij}}{\sum_{j=1}^{n} {}^{\wp}\hbar_{ij}} \tag{1}$$

Step 2: The entropy value F_i is defined as,

$$F_i = -\frac{\sum_{j=1}^{n} \tilde{D}_{ij} \cdot \ln \tilde{D}_{ij}}{\ln n} \tag{2}$$

$\tilde{D}_{ij} \cdot \ln \tilde{D}_{ij} = 0$, when $\tilde{D}_{ij} = 0$ in the actual evaluation utilizing the entropy weight for calculation.

Step 3: The higher the differentiation degree of the index (i), the greater the amount of information that may be extracted [46]. As a result, the entropy weight w_i is calculated.

$$w_i = \frac{1 - F_i}{\sum_{i=1}^{m} (1 - F_i)} \tag{3}$$

PROMETHEE-II method

The PROMETHEE-II advanced approach was introduced [47] in a conference held in [48]. After that, Brans and other researchers developed PROMETHEE-II in various forms for more than a decade [49].

Step 1: Eqs. (4) and (5) are used to normalize the PHF score decision matrix by the type of established criteria.

For beneficial criteria

$$S_{ij} = \frac{D_{ij} - \min(D_{ij})}{\max(D_{ij}) - \min(D_{ij})} \tag{4}$$

For non-beneficial criteria

$$S_{ij} = \frac{\max\left(D_{ij}\right) - D_{ij}}{\max\left(D_{ij}\right) - \min\left(D_{ij}\right)} \quad (5)$$

where $i = 1, 2, 3 \ldots m$; $j = 1, 2, 3 \ldots n$.

Step 2: Determine the ith alternative's evaluation differences from the other alternatives.

$$D(H_a - H_b) = \left(U_{(ij)_a} - U_{(ij)_b}\right) \quad (6)$$

Step 3: P_j's preference function should be calculated (H_a, H_b). Eqs. (7) and (8) provide the following two conditions, which are used to determine the preference function:

$$P_j(H_a, H_b) = 0 \qquad \text{if } U_{(ij)_a} \le U_{(ij)_b} \rightarrow D(H_a - H_b) \le 0 \quad (7)$$

$$P_j(H_a, H_b) = \left(U_{(ij)_a} - U_{(ij)_b}\right) \qquad \text{if } U_{(ij)_a} > U_{(ij)_b} \rightarrow D(H_a - H_b) > 0 \quad (8)$$

Step 4: Apply Eq. (9) to determine the combined preference, $\pi(H_a, H_b)$, as shown below.

$$\pi(H_a, H_b) = \frac{\sum_{j=1}^{n} w_j P_j(H_a, H_b)}{\sum_{j=1}^{n} w_j} \quad (9)$$

Step 5: Make a matrix of the aggregate preference functions. Depending on how many alternatives there are, an m x m-sized matrix is produced.

Step 6: Eqs. (10) and (11) from the list below are used to compute the leaving and entering outranking flows in the case of PROMETHEE-II.

Leaving (positive) flow for ath alternative, φ^+,

$$\frac{1}{n-1} \sum_{b=1}^{m} \pi(a, b) \quad (10)$$

Entering (negative) flow for ath alternative, φ^-,

$$\frac{1}{n-1} \sum_{b=1}^{m} \pi(a, b) \quad (11)$$

For example, $a \neq b$ and n is the number of alternatives.

Step 7: The net outranking flow was calculated for each option using Eq. (12). In case of PROMETHEE-II net outranking flow is determined only for total ranking of alternatives.

$$\text{Net Flow}\{\varphi(a)\} = \text{Leaving Flow}\left\{\varphi^+(a)\right\} - \text{Entering Flow}\left\{\varphi^-(a)\right\} \quad (12)$$

4. Case study

There is not much research that has assessed the intervention in the context of an infectious COVID-19 pandemic. Following a review of relevant research, a list of 11 strategies adopted in India's countries summarizes potential intervention strategies:

Limit of unnecessarily business (H_1): Limiting person-to-person contact is one of the pharmacological measures taken to reduce the severity of infection. While the WHO does not explicitly state that non-essential establishments are banned, shops, gas stations, restaurants, post offices, banks and other businesses must close at 6 p.m. or earlier to comply with the curfew. Retail centers, cafes and restaurants are all closed. However food delivery is allowed.

Curfew imposed (H_2): Although curfews were effective, they must be strictly enforced across the country to successfully prevent the spread of the disease. Government regulations restrict domestic movement to certain hours of the day. The curfew greatly reduced the spread of the epidemic.

Social isolation (H_3): This is thought to reduce personal contact, thereby reducing the chance of transmission from undiagnosed cases to others. Government rules limiting physical contact between people to 1.5 m or 6 ft are the foundation for this intervention. This is based on the assumption that individuals will become infected if they come into contact with someone who has been infected with Covid-19.

College and school closures (H_4): School closures were implemented during previous epidemics to prevent the virus from spreading widely. Treatment for severe influenza outbreaks and infections may include postponing the start of classes to prevent the virus from spreading.

Keeping infected individuals and patients under observation (H_5): When antiviral drugs and vaccines were ineffective in the early stages of the epidemic, governments recommended quarantine as one of the non-drug approaches to reduce the epidemic. Although this usage is based on historical and contemporary observations, few studies and investigations have found sufficient data to back it up. **Monitoring of health** (H_6): WHO has published several guidelines and research studies to monitor public health during pandemics. To prevent the spread of COVID-19 and reduce the mortality rate, WHO placed high priority on community health surveillance. When people are infected with the coronavirus or are at high risk of getting it, the government steps in to monitor their health.

Camping for public awareness (H_7): For example, on March 22, 2020, a provincial youth council in Namibia announced that it had conducted extensive public outreach on techniques for disseminating accurate information about COVID-19, including methods to prevent or reduce its health impacts. Prevents infection. The youth distributed leaflets containing reports on the epidemic and preventive measures.

Development of an emergence (H_8): This method is defined as restructuring part of the government's administrative infrastructure or establishing new task forces. The previous study reviewed several government strategies, including public investment and mobilization. For example, novel and adaptive solutions, turnkey manufacturing, restricted individual freedom, infrastructure, and corporate strategy create solutions for new purposes in new contexts.

Vaccination (H_9): Due to the widespread shortage of vaccines, the Government of India is using various strategies to mobilize countries and international organizations to provide residents with access to vaccines. In addition to actively negotiating the purchase of vaccines, the government also oversees vaccine development and production in the country. And also, the government is establishing a vaccine policy that focuses on urgent importation, analysis, technology transfer and domestic vaccine production.

Improved administration of the nation's health infrastructure (H_{10}): Intensive care beds are being redistributed and new hospitals are being built rapidly. In other, less severe areas an extensive medical staff is one of the most immediate medical resources. Previous research has recommended making the most of limited resources, treating everyone equally, and prioritizing the most disadvantaged.

The limitation of internal and external borders (H_{11}): Examples of internal border controls include government programs that restrict internal travel. The aim of this intervention is to separate diagnosed cases from others in the local community. 211 countries have established multiple internal border controls, including the United States, Malaysia and Schengen members. Due to border restrictions, flu epidemics were reduced. International travel restrictions that ranged from a few days to five months delayed growth and peaking.

Based on the applicable options and expert reviews, this research provides five prospective criteria, including "high acceptance among the populace (U_1)", "effectiveness in halting the COVID-19 epidemic (U_2)", "compatibility by any other standard (U_3)", "estimated total cost (U_4)", and "simple to implement (U_5)", where "(U_4)" is a non-beneficial criteria. The hierarchical decision of the five proposed criteria and 11 possible intervention strategies is described in Fig. 2 as follows: First, the primary objective was to determine the best government intervention. Second, evaluation criteria were developed and selected

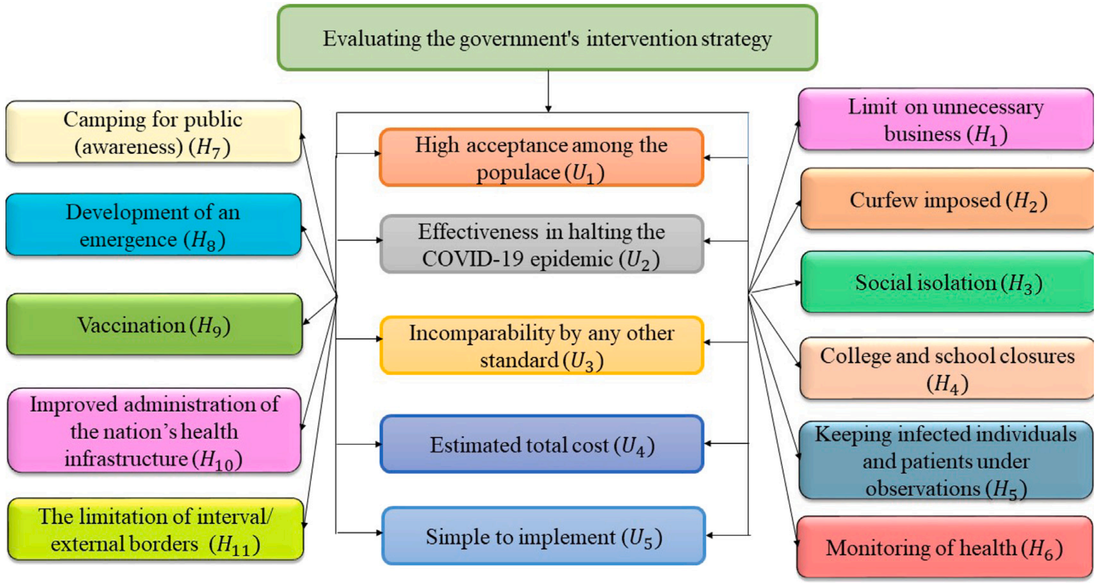

Fig. 2. Hierarchical structure for selecting criteria.

Table 2
Linguistic conversion scale and their corresponding PHFEs.

Linguistic term	Numerical values with PHFEs
Exceptional	$\{\langle 0.8, 0.5\rangle$ - $\langle 1.0, 0.5\rangle\}$
Very Good	$\{\langle 0.7, 0.6\rangle$ - $\langle 0.8, 0.4\rangle\}$
Satisfactory	$\{\langle 0.5, 0.4\rangle$ - $\langle 0.7, 0.6\rangle\}$
Average	$\{\langle 0.3, 0.7\rangle$ - $\langle 0.5, 0.3\rangle\}$
Insufficient	$\{\langle 0.1, 0.8\rangle$ - $\langle 0.3, 0.2\rangle\}$

based on a literature review and opinions of experts on the issue. Third, 11 potential intervention strategies were used against COVID-19 in several countries that were considered alternatives to India. Finally, a decision-making hierarchy is developed.

(a) Results analysis

Results of the PHF-Entropy

Construct a decision matrix with dimensions m *x* n, where m is the number of alternatives and n is the number of criteria. According to Definition 1 and using Table 2 linguistic change measure, we finally obtain Table 3, which shows the PHF-result matrix.

The probabilistic hesitation fuzzy score matrix is calculated using Definition 2, and the results are shown in Table 4. After that, the normalized PHF score matrix was calculated using step 1.

According to F_i, the entropy value is calculated using step 2.

F_i = {0.935292208, 0.951614383, 0.95887995, 0.962095867, 0.966438695}. The weight of each condition was calculated using step 3, and the resulting values of the evaluation criteria are shown in Fig. 3.

The PHF-entropy weights for the primary criterion include the set of all members of element x in the range [0, 1]. Specifications for the five key criteria were established using the above calculations. The most important factor for selecting intervention strategies is "high acceptance among the people (U_1)" value of 0.2867, followed by "effectiveness in halting the COVID-19 pandemic (U_2)" value of 0.2144. However, "compatibility by any other standard (U_3)" ranked third with a score of 0.1822. "simple to implement (U_5)" is the least important criterion with a value of 0.1487.

Results of the PHF-PROMETHEE-II

Step 1 the PHF score from Table 4 is used to normalize the result matrix, and the results are shown in Table 5. Then step 2 determines the valuation differences between the ith alternative and other alternatives. It is clear from step 3 that the value of the preference function is equal to zero, followed by the quotient of step 4, which becomes 1 because the sum of the criterion weights always equals 1. Find all combined priority values $\pi(H_a, H_b)$ using step 4 to multiply each criterion weight by the corresponding column element in the priority value.

In the analysis conducted in step 5 here, the total priority value for $\pi(H_1, H_2)$ is 0.2095, which indicates that H_1 has a total priority of 0.2095 over H_2. Therefore, as specified in this value (ie, 0.21095), it is assigned to cells 1, 2. For $\pi(H_1, H_3)$ the total priority value of H_1 for H_3 is 0.0511 from step 4, this value (0.0511) is assigned to cells 1 and 3. Therefore, a value is generated by assigning the accumulated preference function value from step 5 to each column in the above matrix in this manner. Step 6 is used to calculate the outgoing and incoming outranking flows in case of PROMETHEE II. Step 7 was used to determine the net outranking flow for each of the strategies. Only in the case of PROMETHEE-II is the net outranking flow of alternatives calculated for the entire ranking of alternatives. Table 6 shows the net excess flow of alternatives, and Fig. 4 shows a graphical representation of the alternative values.

Consequently, "(H_9) vaccination" is the optimal strategy, followed by "(H_3) social isolation", "(H_8) development of an emergence", "(H_{10}) improved administration of the nation's health infrastructure", and "(H_5) keeping infected individuals and patients under observation". Our findings are in agreement with those of those proposing a successful immunization program targeting regional elimination in the short to medium term [50] . As a result, the dynamics of the Covid-19 pandemic and immunization rates have significantly reduced the capacity of the health system.

In addition, governments had substantial infrastructure and resources to address the challenges of vaccine program implementation. Management of the vaccine supply chain, development and deployment of vaccine delivery sites, assessment of target sub population eligibility, training of front line staff and community mobilization pose barriers to implementation of vaccination campaigns. Also, important strategies to prevent the SARS-CoV-2 outbreak in Europe were identified by previous research [51], which was in line with our findings. Their study led to the development of an action plan for European protection against future SARS-CoV-2 strains. This includes procedures to detect the spread of the virus and individual strains, and efforts to contain the virus across borders. Interventions to increase the effective speed

Table 3
The PHF decision matrix.

	U_1	U_2	U_3	U_4	U_5
H_1	{(0.6,0.4),(0.7,0.6)}	{(0.1,0.5),(0.2,0.5)}	{(0.3,0.3),(0.4,0.7)}	{(0.3,0.8),(0.4,0.2)}	{(0.7,0.3),(0.8,0.7)}
H_2	{(0.2,0.5),(0.3,0.5)}	{(0.4,0.4),(0.5,0.6)}	{(0.5,0.3),(0.6,0.7)}	{(0.1,0.5),(0.2,0.5)}	{(0.3,0.8),(0.4,0.2)}
H_3	{(0.5,0.4),(0.6,0.6)}	{(0.4,0.3),(0.5,0.7)}	{(0.5,0.6),(0.6,0.4)}	{(0.1,0.4),(0.2,0.6)}	{(0.4,0.7),(0.5,0.3)}
H_4	{(0.1,0.4),(0.2,0.6)}	{(0.1,0.5),(0.2,0.5)}	{(0.5,0.2),(0.6,0.8)}	{(0.3,0.8),(0.4,0.2)}	{(0.2,0.6),(0.3,0.4)}
H_5	{(0.1,0.7),(0.2,0.3)}	{(0.7,0.2),(0.8,0.8)}	{(0.8,0.8),(0.9,0.2)}	{(0.2,0.2),(0.3,0.8)}	{(0.2,0.3),(0.3,0.7)}
H_6	{(0.6,0.2),(0.7,0.8)}	{(0.2,0.3),(0.3,0.7)}	{(0.1,0.2),(0.2,0.8)}	{(0.4,0.4),(0.5,0.6)}	{(0.3,0.7),(0.4,0.3)}
H_7	{(0.1,0.8),(0.2,0.2)}	{(0.3,0.4),(0.4,0.6)}	{(0.1,0.3),(0.2,0.7)}	{(0.2,0.6),(0.3,0.4)}	{(0.3,0.4),(0.4,0.6)}
H_8	{(0.2,0.3),(0.3,0.7)}	{(0.7,0.5),(0.8,0.5)}	{(0.8,0.3),(0.9,0.7)}	{(0.1,0.5),(0.2,0.5)}	{(0.5,0.7),(0.6,0.3)}
H_9	{(0.5,0.5),(0.6,0.5)}	{(0.6,0.5),(0.7,0.5)}	{(0.7,0.2),(0.8,0.8)}	{(0.1,0.6),(0.2,0.4)}	{(0.7,0.6),(0.8,0.4)}
H_{10}	{(0.6,0.6),(0.7,0.4)}	{(0.7,0.7),(0.8,0.3)}	{(0.8,0.3),(0.9,0.7)}	{(0.4,0.5),(0.6,0.5)}	{(0.7,0.2),(0.8,0.8)}
H_{11}	{(0.3,0.5),(0.4,0.5)}	{(0.4,0.2),(0.5,0.8)}	{(0.6,0.4),(0.7,0.6)}	{(0.2,0.3),(0.3,0.7)}	{(0.4,0.5),(0.5,0.5)}

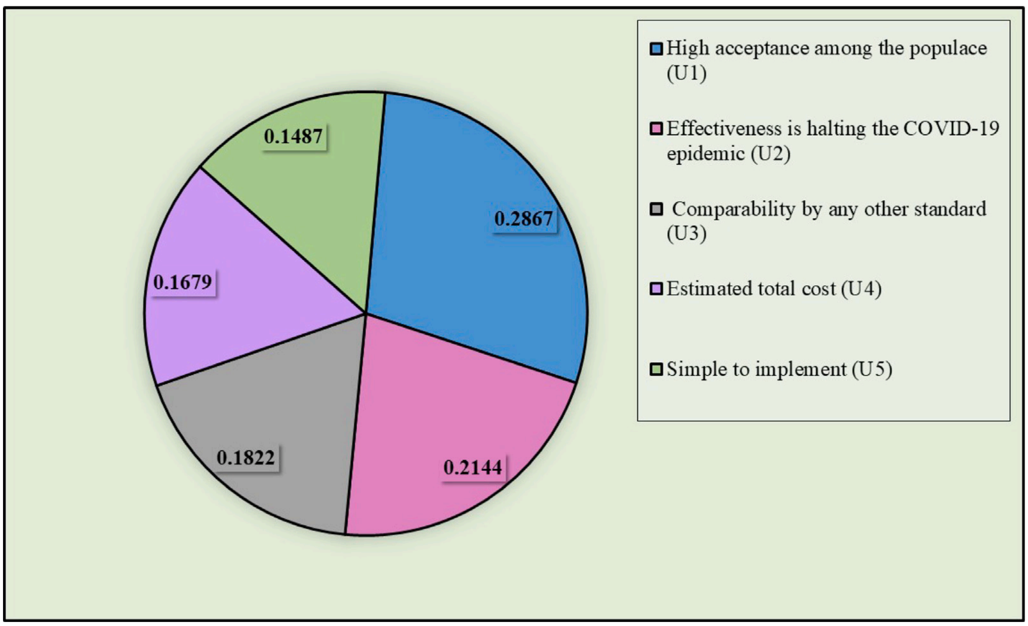

Fig. 3. Weights of the criteria.

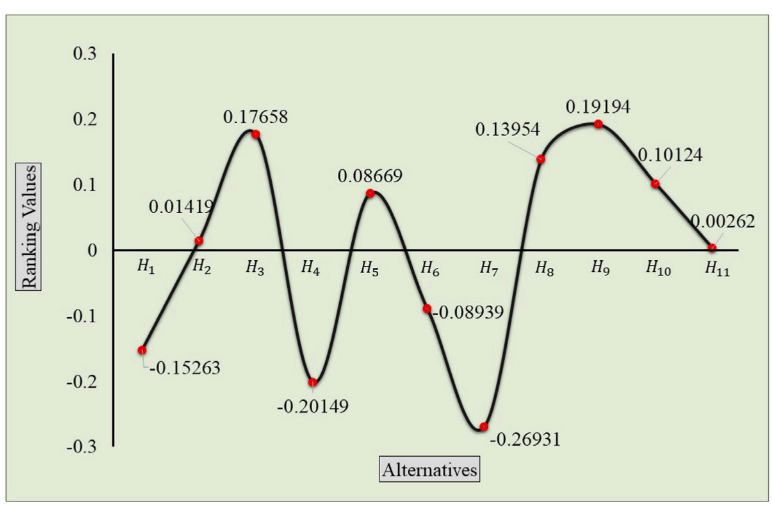

Fig. 4. The proposed PHF-PROMETHEE-II method.

of vaccination efforts were intended to spare the most vulnerable populations.

To show the applicability of our proposed MCDM method, we compared it with other existing methods based on different techniques. Analysis is done by comparing the change in weight of useful and ineffective criteria. Also, a sensitivity analysis is performed to show the applicability and reliability of the proposed hybrid decision-making system due to changes in criterion weights.

Comparison analysis

A comparative analysis was conducted to demonstrate the validity and applicability of the proposed method. A comparison was made

Table 4
The PHF score decision matrix.

	U_1	U_2	U_3	U_4	U_5
H_1	0.66	0.15	0.37	0.32	0.77
H_2	0.25	0.46	0.57	0.15	0.32
H_3	0.56	0.47	0.65	0.16	0.43
H_4	0.16	0.15	0.58	0.32	0.24
H_5	0.13	0.78	0.82	0.28	0.27
H_6	0.68	0.27	0.18	0.46	0.33
H_7	0.12	0.36	0.17	0.24	0.36
H_8	0.27	0.75	0.87	0.15	0.53
H_9	0.55	0.65	0.78	0.14	0.74
H_{10}	0.64	0.73	0.87	0.5	0.78
H_{11}	0.35	0.48	0.66	0.27	0.45

Table 5
The normalized PHF score decision matrix.

	U_1	U_2	U_3	U_4	U_5
H_1	0.964286	0	0.285714	0.5	0.018519
H_2	0.232143	0.492063	0.571429	0.972222	0.851852
H_3	0.785714	0.507937	0.685714	0.944444	0.648148
H_4	0.071429	0	0.585714	0.5	1
H_5	0.017857	1	0.928571	0.611111	0.944444
H_6	1	0.190476	0.014286	0.111111	0.833333
H_7	0	0.333333	0	0.722222	0.777778
H_8	0.267857	0.952381	1	0.972222	0.462963
H_9	0.767857	0.793651	0.871429	1	0.074074
H_{10}	0.928571	0.920635	1	0	0
H_{11}	0.410714	0.52381	0.7	0.638889	0.611111

Table 6
The alternatives' net outranking flow.

Alternatives	Leaving flow ϕ^+	Entering flow ϕ^-	Net flow ϕ	Rank
H_1	0.174549814	0.327188498	−0.15264	9
H_2	0.187130343	0.172931263	0.014199	6
H_3	0.266109992	0.089523842	0.176586	2
H_4	0.118512678	0.320002896	−0.20149	10
H_5	0.266937645	0.180241613	0.086696	5
H_6	0.21792863	0.307318615	−0.08939	8
H_7	0.092975442	0.362288443	−0.26931	11
H_8	0.279821258	0.14028053	0.139541	3
H_9	0.308022723	0.11607735	0.191945	1
H_{10}	0.316514874	0.215273918	0.101241	4
H_{11}	0.167526009	0.164902442	0.002624	7

by comparing PROMETHEE-II results with VIKOR, TOPSIS and COPRAS techniques. The results show the viability of any intervention techniques the Indian government could have used to prevent the spread of Covid-19. Table 7 and Fig. 5 show the final rankings of the options based on the comparative analysis. As predicted, the comparison demonstrates that different methods can produce slightly different ranking results. It is clear that the three proposed models work best to prioritize 11 potential treatments to prevent the COVID-19 pandemic in India.

Sensitivity analysis

It is necessary to evaluate the change of weight value because the weight of the criteria has a significant impact on the ranking. To demonstrate how the weights of various criteria affect how alternatives are ranked, sensitivity analysis cases were performed in two phases as part of this study.

Phase I: Using the proposed method, we consider equal weights for criteria, H_9 is obtained as the optimal solution.

Phase II: When assigning weights to beneficial criteria, 0.25 is the weight, and for ineffective criteria, 0 is the weight.

To perform a sensitivity analysis on the available options, a set of criteria is developed and the results are compared. As shown in Table 8 and Fig. 6, both scenarios significantly affect the potential scores for the evaluation criteria. The sensitivity analysis of PHF-PROMETHEE-II gave an incredibly reliable judgment. Even if the performance review ranking is modified, the replacement will remain unchanged.

5. Discussion

This study aims to provide a fuzzy MCDM approach for evaluating India's intervention strategies against Covid-19. Among India's intervention strategies against Covid-19, the processes identified in the case study included five criteria and 11 strategies: greater acceptance among the population (U_1); effectiveness in preventing the COVID-19 pandemic (U_2); comparison by any other constant (U_3); Estimated total cost (U_4); and ease of implementation (U_5) - these are five criteria. In addition, the level of satisfaction for each strategy is integrated in assigning priority weights to each strategy, along with the concept of uncertainty in making decisions.

Prioritization strategies consider decision complexity and uncertainty for effective public sector resource allocation, policy design and strategy development. Overall, the proposed approach provides complex and uncertain information across public sector intervention strategies for vaccination against public health (H_9). The choice of vaccination strategy is based on minimizing overall health and social costs during an epidemic. Although the approach takes longer to complete, it may be preferable if there are fewer deaths and greater morbidity during this time. Table 9 shows the dose of vaccine. Cost–benefit analysis evaluates the ethical, scientific, and implementation costs of potential techniques, taking into account healthcare costs and resources. Fig. 6 indicates the best strategy for reducing severe Covid-19 disease in people aged 65 years and older (see Fig. 7).

As a result of the 2019 coronavirus disease outbreak (COVID-19), people had to face an unsettled and unpredictable situation. Social isolation restricts people's actions under (H_3), daily routines, social interactions- elements of human well-being. It is intended to reduce contact between members of a large group as infectious individuals are identified and isolated.

This development of emergency (H_8) and curfew imposed (H_2) strategies aims to assist governments and organizations in formulating strategies for breakout outbreaks of COVID-19. Implementing preventive measures such as good hand hygiene, wearing high-quality masks, improving ventilation and maintaining a safe distance from sick or positive people.

A country's ability to produce goods and services with a strong and healthy labor force is ensured by an improved health infrastructure (H_{10}). Skilled doctors, nurses, and other healthcare workers, as well as a thriving pharmaceutical industry, are all part of the healthcare infrastructure.

Keeping infected persons and patients under observation (H_5) is a device for personal protection. The Indian economy was hit hard by unemployment and a sharp drop in growth following the nationwide shutdown. The early lockdown deployment initially slowed the pace of doubling of cases and gave time to upgrade critical medical infrastructure. The rest of the strategies are ranked as follows: limitation of internal and external borders (H_{11}), health monitoring (H_6), control of unnecessary business (H_1), college and school closure (H_4), and general awareness camp (H_7). The vaccination program helped reduce the burden of other activities.

6. Public implications

The COVID-19 pandemic has created major problems and unprecedented disruptions for many parts of the world. In recent years governments have taken urgent measures to control the spread of the COVID-19 virus. Social distancing measures include isolating infected people, isolating their contacts, giving people options to work from home, closing schools and canceling large gatherings. Such measures allow our healthcare system to gradually handle the additional burden. For example, a good case study was conducted at a European level,

Table 7
Alternatives are ranked, and preferences are ranked, regarding the fuzzy MCDM approaches being explored.

Alternatives	VIKOR	TOPSIS	COPRAS	PROMETHEE-II	Preference ranking
H_1	0.673156	0.558531	0.0788738	−0.152638684	9
H_2	0.509292	0.325403	0.0945828	0.01419908	6
H_3	0.016603	0.558429	0.1100034	0.176574642	2
H_4	0.882183	0.252088	0.0635618	−0.202569472	10
H_5	0.600581	0.449628	0.0958552	0.086635042	5
H_6	0.508664	0.561263	0.0823091	−0.089389985	8
H_7	1	0.183734	0.0594474	−0.269375142	11
H_8	0.327113	0.503405	0.1050681	0.141028423	3
H_9	0.088835	0.641998	0.1107706	0.191932714	1
H_{10}	0.270306	0.941083	0.1112727	0.101238655	4
H_{11}	0.380365	0.466948	0.0882552	0.002587894	7

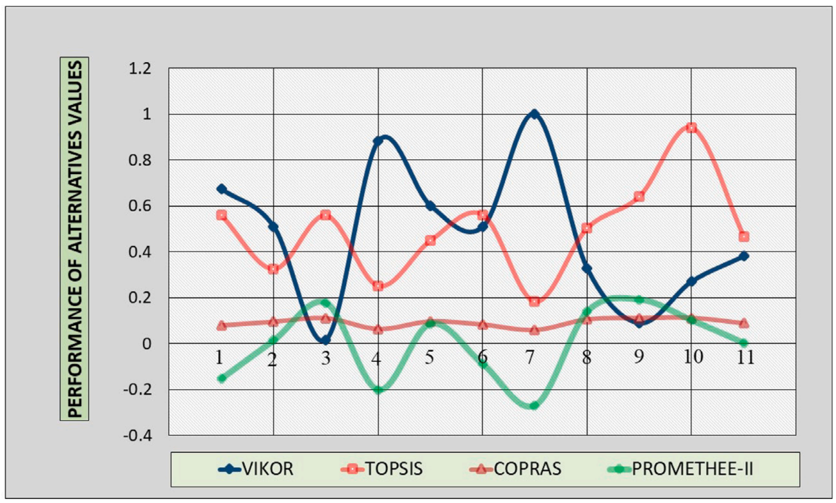

Fig. 5. Comparison analysis with existing MCDM methods.

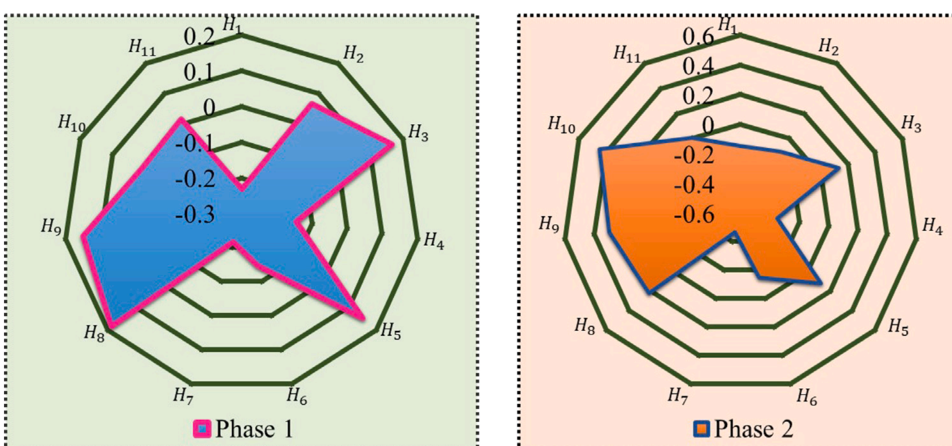

Fig. 6. Sensitivity analysis on two phases.

Table 8
Sensitivity analysis and preference ranking.

Method	Preference ranking values	Ranking order
PROMETHEE-II (Phase 1)	−0.23088, 0.06637, 0.165587, −0.14538, 0.15047, −0.14713, −0.21663, 0.184233, 0.15158, 0. 00686, 0.01463	$H8 > H3 > H9 > H5 > H2 > H11 > H10 > H4 > H6 > H7 > H1$
PROMETHEE-II (Phase 2)	−0.14421, −0.10675, 0.13099, −0.34897, 0.11903, −0.15018, −0.46652, 0.21842, 0.29564, 0.44674, 0.00582	$H9 > H3 > H8 > H10 > H5 > H2 > H11 > H6 > H1 > H4 > H7$

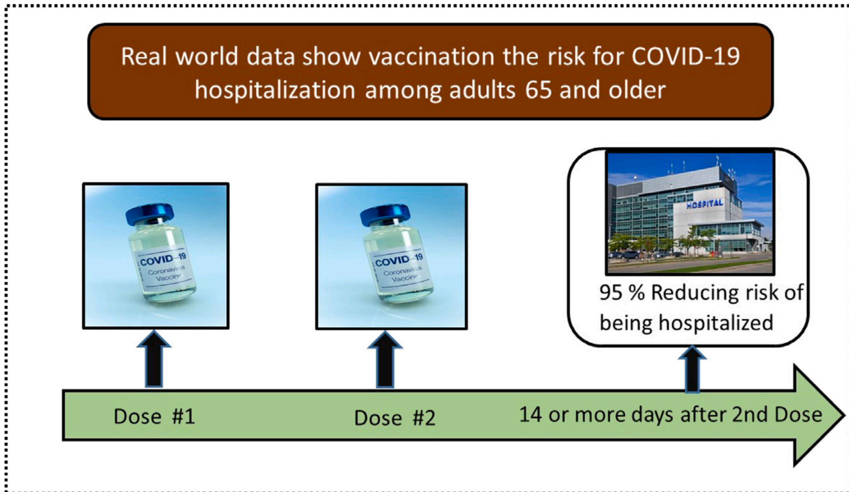

Fig. 7. Vaccination is essential to reduce COVID-19 in older adults.

Table 9
The depiction of vaccination levels.

Vaccination	Vaccination levels
Vaccination location	Local pharmacy Health service Local pop-up vaccination service (e.g., school and workplace) Large vaccination site supported by national guard
Waiting time at vaccination site	Immediately service 1 h 2 h
Vaccination appointment scheduling	Phone call Online website No scheduling required
Number of doses required per apart vaccinations episode	1 dose only 2 doses one month
Vaccination enforcement	Lifelong protection from server COVID-19 infection just requires one vaccine. Immunizations must be renewed annually to ensure protection against COVID-19 infection.
Vaccine frequency	Lifelong protection from server COVID-19 infection just requires one vaccine. Immunizations must be renewed annually to ensure protection against COVID-19 infection.

and several steps were defined, such as the need for rapid and effective immunization to prevent the spread [51].

In the context of India's fight against the pandemic in both the health and economic sectors, it is essential to have sound policies to improve resilience and prepare adequately. The ability to respond during a pandemic increases the likelihood of rapid economic recovery once the disease is under control, preventing the economy from entering a recession. The research assesses government responses to Covid-19 to make policy recommendations. In the proposed case study, a practical procedure for combining PHF-Entropy and PROMETHEE-II is established. One of the major advantages of the study is the selection of criteria through expert opinions and literature. Company officials can evaluate the situation and decide the best course of action to solve the problem using the framework provided. The obtained results can be considered as an important guide for companies that do not allow them to consider any ineffective and expensive measures in the face of the epidemic. Applied comparative analysis assists decision makers in assessing observational consistency.

7. Conclusions

The COVID-19 pandemic has spread rapidly across the globe. Governments are faced with various problems as a result of the exponentially increasing severity of the disease. Indian governments had well-implemented strategies to contain the spread of the Covid-19 pandemic. This is one of several investigations into the COVID-19 pandemic intervention choices in emergency preparedness as well as an in-depth assessment of their interdependencies and priority actions. This paper provides insights into the hybrid fuzzy MCDM technique and evaluates India's intervention strategies against the Covid-19 pandemic. Lists key goals that policy makers and decision makers should prioritize for emergency preparedness efforts.

An evaluation of response activities to the COVID-19 pandemic included an analysis of a specific situation that provided management and policy insights on socio-economics. First, the literature search revealed a total of 11 intervention options. Second, the PHF-PROMETHEE-II application demonstrated that most of the methods were recognized as receivers. Based on applicable preferences and expert interviews, this research presents five prospective criteria, including "higher acceptance among the public", "effectiveness in preventing the COVID-19 pandemic", "comparison with any other standard", "estimated total cost", and "ease of implementation". Although some countries have experienced great economic effects, many have experienced adverse environmental and social impacts. Therefore, it is necessary to implement government strategies. Further analysis with PHF-entropy allows measuring the systematic impact of social intervention strategies on emergency preparedness measures. "vaccination", "social isolation", and "development of an emergence" are the top three strategies.

The study aims to compare the prevention and control strategies adopted by other countries and India in the outbreak of the Covid-19 pandemic and analyze the effectiveness of their strategies. Once the peak of the second wave is over, all future moves should be planned in anticipation of the third wave. Monitoring for new cases, Covid-related deaths and virus variants should continue long enough after the second wave has leveled off. Issues surrounding vaccine hesitancy must be addressed and resources developed to mitigate them. We need to strengthen our health infrastructure. Also, improve laboratory capacity in the country to detect epidemics, predict upcoming outbreaks, and increase the number of beds with oxygen supply, ICU beds, ventilators, and infection control practices in general. A continuous dialogue with the people of India about the current and emerging situations will help us to face future challenges more efficiently and effectively.

The suggested approaches can be used to assess how other countries plan to intervene in the current global crisis and possible future epidemics. The evaluation of solutions resulting from the results of this work will serve as a starting point for further research as a follow-up study. This work can be extended for future research using fuzzy MCDM techniques. Uncertainties in the form of fuzzy, spherical fuzzy, or neutrosophic fuzziness can be combined and used to extend something further. It can get more information by comparing it with this article.

Declaration of competing interest

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

Data availability

No data was used for the research described in the article.

Acknowledgments

This work was supported by a National Research Foundation (NRF) of Korea grant funded by the Korean Government (MSIT) [Grant No. 2019R1A2C1090655] and also Noreen Izza Arshad would like to acknowledge the grant funder Yayasan Universiti Teknologi Patronas (YUTP)015LCO-483.

References

[1] Bartsch, et al. Vaccine efficacy needed for a COVID-19 coronavirus vaccine to prevent or stop an epidemic as the sole intervention. Am J Prev Med 2020;59(4):493–503.
[2] Farsaeivahid, et al. A rapid label-free disposable electrochemical salivary point-of-care sensor for SARS-CoV-2 detection and quantification. Sensors 2022;23(1):433.
[3] Ragab, et al. The COVID-19 cytokine storm and what we know so far. Front Immunol 2020;11:1446.
[4] Asadi, et al. Evaluation of factors to respond to the COVID-19 pandemic using DEMATEL and fuzzy rule-based techniques. Int J Fuzzy Syst Appl 2021;19:925–41.
[5] Samanlioglu, Kaya. Evaluation of the COVID-19 pandemic intervention strategies with hesitant F-AHP. J Healthc Eng 2020.
[6] Zhang. Weighted hesitant fuzzy sets and their application to multi-criteria decision making. J Math Comput Sci 2014;8:1091–123.
[7] Ana Borges, et al. Predicting and explaining absenteeism risk in hospital patients before and during COVID-19. Soc-Econ Plan Sci 2023;101549.
[8] Pandey, et al. Transforming a general hospital to an infectious disease hospital for COVID-19 over 2 weeks. Front Public Health 2020;8:1–8.
[9] Lanndon Ocampo, et al. Synthesis of strategies in post-COVID-19 public sector supply chains under an intuitionistic fuzzy environment. Soc-Econ Plan Sci 2023;85:101340.
[10] Wang, et al. A compromised decision-making approach to third-party logistics selection in sustainable supply chain using fuzzy AHP and Fuzzy-VIKOR methods. Mathematics 2021;9:886.
[11] Mohammed kasem sayadi, et al. Extension of VIKOR method for decision making problem with interval numbers. Appl Math Model 2009;33(5):2257–62.
[12] Guo, et al. Business risk evaluation of electricity retail company in China using a hybrid MCDM method. Sustainability 2020;12:2040.
[13] Zadeh. Fuzzy sets. Inf Control 1965;8(3):338–53.
[14] Zhang, et al. Operations and integration of probabilistic hesitant fuzzy information in decision making. Inf Fusion 2017;38:1–11.
[15] Wang, et al. Fuzzy hierarchical TOPSIS for supplier selection. Appl Soft Comput 2009;9:377–86.
[16] Taheriyoun, et al. Development of an entropy-based fuzzy eutrophication index for reservoir water quality evaluation. Iran J Environ Health Sci Eng 2010;7:1–14.
[17] Yunna Wu, et al. Investment monitoring key points identification model of big science research infrastructures – Fuzzy BWM-entropy-PROMETHEE II method. Soc-Econ Plan Sci 2023;86:101461.
[18] Ahmad, et al. Identification and prioritization of strategies to tackle COVID-19 outbreak: A group-BWM based MCDM approach. Appl Soft Comput 2021;111:107642.
[19] Tsai, et al. Analysis of key factors for supplier selection in taiwan's thin-film transistor liquid-crystal displays industry. Mathematics 2021;9:396.
[20] Alkan, Kahraman. Evaluation of government strategies against COVID-19 pandemic using q-rung orthopair fuzzy TOPSIS method. Appl Soft Comput 2021;110:107653.
[21] Jafar pourmahmound, Narges Bagheri. Uncertain Malmquist productivity index: An application to evaluate healthcare systems during COVID-19 pandemic. Soc-Econ Plan Sci 2023;3:101522.
[22] Mehregan. Designing a sustainable development model with a dynamic system approach. NeuroQuantology 2022;20(6):8143–64.
[23] Wu, et al. Assessing and comparing covid-19 intervention strategies using a varying partial consensus fuzzy collaborative intelligence approach. Mathematics 2020;8:1725.
[24] Meisami Sajad, et al. Using blockchain to achieve decentralized privacy in IoT healthcare. 2021, p. 14812, arXiv preprint arXiv, 2109.
[25] Chen. A Fuzzy-AHP and Fuzzy-TOPSIS approach for choosing mid-term occupational healthcare measures amid the COVID-19 pandemic. Health Policy Technol 2021;10:100517.
[26] Roy. The outranking approach and the foundation of ELECTRE methods. Theory and Decision 1991;31:49–73.
[27] Brauers, Zavadskas. Project management by MULTI-MOORA as an instrument for transition economies. Technol Econ Dev Econ 2010;16:5–24.
[28] Stanujkic. An extension of the MOORA method for solving fuzzy decision making problems. Technol Econ Dev Econ 2014;19:S228–55.
[29] Nurul muizzah Johari, et al. Features requirement elicitation process for designing a chabot application. IET - Institution of Engineering and Technology; 2022.
[30] Zavadskas, et al. The new method of multi-criteria complex proportional assessment of projects. Technol Econ Dev Econ 1994;1:131–9.
[31] Alimohammadirokni, et al. The strategic resources of a gastronomy creative city: The case of San Antonio, Texas. J Gastron Tour 2021;5:237–52.
[32] Saaty. How to make a decision — The analytic hierarchy process. European J Oper Res 1990;48(1):9–26.
[33] Jiang, Ma. Multi-attribute group decision making under a probabilistic hesitant fuzzy environment with an application to evaluate the transformation efficiency. Appl Intell 2018;48:953–65.
[34] Tarifa Almulhim, Igor Barahona. An extended picture fuzzy multi-criteria group decision analysis with different weights: A case study of COVID-19 vaccine allocation. Soc-Econ Plan Sci 2022;85:101435.
[35] Lauer, et al. The incubation period of corona virus disease 2019 (COVID-19) from publicly reported confirmed cases: Estimation and application. Ann Int Med 2020;172:577–82.
[36] Mumena. Impact of COVID-19 curfew on eating habits, food intake, and weight according to food security status in Saudi Arabia: A retrospective study. Program Nutr 2020;22.
[37] Wilder-Smith, Freedman. Isolation, quarantine, social distancing and community containment: Pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak. J Travel Med 2020;27:1–4.
[38] Ryu, et al. Non-pharmaceutical measures for pandemic influenza in non-healthcare settings-international travel-related measures. Emerg Infect Diseases 2020;26:2298–9.

[39] WHO. World Health Organization Writing Group Non-pharmaceutical interventions for pandemic influenza, national and community measures. Emerg Infect Diseases 2006;12:88–94.
[40] Huynh, et al. Development and psychometric properties of the health belief scales toward covid-19 vaccine in Ho Chi Minh City, Vietnam. Risk, Manag Healthc Policy 2021;14:2517.
[41] Kahanec, et al. The impact of repeated mass antigen testing for COVID-19 on the prevalence of the disease. J Popul Econ 2021;34:1105–40.
[42] Hamed farahani, et al. Finding the inverse of a fuzzy matrix using Eigen value method. Int J Innov Technol Explor Eng 2019;9:3030–7.
[43] Henriques, Gouveia. Assessing the impact of COVID-19 on the efficiency of Portuguese state-owned enterprise hospitals. Soc-Econ Plan Sci 2022;84:101387.
[44] Zhang, et al. COVID-19 mortality analysis reveals the critical role of timely supply of medical resources. J Infect 2020;81:147–78.
[45] Adeeth Cariappa, et al. COVID-19 induced lockdown effect on wheat supply chain and prices in India – Insights from state interventions led to resilience. Soc-Econ Plan Sci 2022;84:101366.
[46] Zhi-Hong, et al. Entropy method for determination of weight of evaluating indicators in fuzzy synthetic evaluation for water quality assessment. J Environ Sci 2006;18:1020–3.
[47] Richard Alex da Cunha, et al. A decision support approach employing the PROMETHEE method and risk factors for critical supply assessment in large-scale projects. Oper Res Perspect 2022;4:100238.
[48] Ahmad, et al. Analysis and classification of companies on the Tehran stock exchange with incomplete information. RAIRO - Oper Res 2021;55:2707–26.
[49] Thiago, et al. Improving decision-making and management of hospital resources: An application of the PROMETHEE II method in an Emergency Department. Oper Res Health Care 2014;3(1):1–6.
[50] Mahendra Piraveenan, et al. Optimal governance and implementation of vaccination programmes to contain the COVID-19 pandemic. R Soc Open Sci 2021;8:210429.
[51] Viola Priesemann, et al. An action plan for pan-European defence against new SARS-CoV-2 variants. Lancet 2021;397:469–70.

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