A Multi-Criteria Decision-Making Analysis for COVID-19 in Public Health under Neutrosophic Set: Case Study

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Abstract

This paper proposed a framework for assessing the COVID-19 response in Egypt. COVID-19 plays a vital role in public health, and selecting the best response can decrease the impact of the disease. This study used the type 2 neutrosophic set as a framework for dealing with uncertainty. The assessment of the COVID-19 response has various conflicting criteria, so the concept of multi-criteria decision-making (MCDM) is used to deal with COVID-19 criteria. The MCDM methods are adopted with the type-2neutrosophic set—the typ-2 neutrosophic AHP-COPRAS-VIKOR methodology framework. The AHP is used to compute the criteria weights. The COPRAS and VIKOR methods are used to rank the alternatives. The case study in Egypt is conducted to show the best response to COVID-19. Five main criteria and nineteen sub-criteria are used in this paper. The methodologies employed in this paper aid as examples for future research endeavors, inspiring a continued dialogue on refining and advancing MCDM methodologies in public health disasters.

Keywords: Neutrosophic Set; Covid-19; Intervention Strategies; AHP,;VIKOR; Public Health

1. Introduction

Widespread vaccination and immunization are the most efficient methods of eradicating COVID-19. All populations should have equal access to COVID-19 vaccinations; thus, governments and health authorities should prioritize their distribution and administration. Public awareness efforts to reduce vaccine reluctance and increase vaccination rates are also quite important. Reliable testing and contact tracking techniques are required to identify and isolate affected persons and stop the spread of the virus. Governments should invest in extensive testing capability, including fast diagnostic tests, and develop effective contact tracing programs to identify and alert close contacts of infected persons quickly.

To reduce the spread of COVID-19, public health interventions should be widely disseminated and strictly enforced. Avoiding big gatherings, washing one's hands often, keeping a clean environment, and using a face mask or other covering are all excellent examples of these precautions. The people must be educated on the necessity of following government rules and clear instructions, which the government should offer.

To successfully react to the pandemic, it is essential to strengthen the capability and preparation of healthcare systems. This involves expanding access to healthcare through boosting access to hospitals, intensive care units, and medical professionals. It is also crucial to ensure enough medication, safety gear, and medical tools are on hand.

The key to successfully managing the COVID-19 situation is effective risk communication and public awareness. Governments are responsible for promptly disseminating accurate information on the virus, preventative strategies, and vaccination campaign

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updates. It is essential to confront rumors and false information immediately via mechanisms that are open and grounded in science. The importation and dissemination of COVID-19 cases from high-risk locations may be averted by implementing travel restrictions and border control measures. Governments must monitor the issue and adjust travel limits and criteria as the epidemiological landscape changes.

Older adults, those with preexisting health concerns, and members of marginalized groups are all vulnerable and deserving of our support. During the pandemic, governments should secure their safety, give access to healthcare, and provide social services.

Investment in Research and Development Understanding the virus, creating effective medicines, and enhancing diagnostics all need continued investment in research and development. Governments should invest in scientific research, foster partnerships with other governments and international organizations, and streamline the process of disseminating research results to the public. The worldwide community must work together to stop the spread of the COVID-19 pandemic. The distribution of vaccines, the sharing of resources and knowledge, and the assistance of low-income nations with inadequate healthcare facilities are all areas where governments, international organizations, and pharmaceutical corporations might work together. Bouncing back from setbacks and adjusting to new conditions is crucial during a pandemic. To prioritize public health throughout the economic recovery, governments and companies must find novel ways to provide essential services, facilitate telecommuting and distance learning, and boost the global workforce. Table one shows the related studies of MCDM methods. The main contributions of this study are:

I. The type-2 neutrosophic set used in this paper is the first study for evaluating COVID-19 public health under uncertainty due to the framework dealing with uncertain information.
II. The type-2 neutrosophic set is the first study extended with the VIKOR and COPRAS methods.
III. It is the first study to use the hybrid AHP-COPRAS-COPRAS method.

2. Materials and Equipment

2.1 Preliminaries

Definition 1 [1]

Denote $Ǩ$ as the defined conversational domain and let $Ƒ[0,1]$ represent the complete collection of triangular neutrosophic numbers within the range $Ƒ[0,1]$. In the realm of type 2 neutrosophic number sets (T2NNS) embedded in the set of real numbers, the symbol $Ʋ$ is employed to signify it. $Ʋ = \{< ǩ, Ŧ_{Ʋ}(ǩ), Ɨ_{Ʋ}(ǩ), Ƒ_{Ʋ}(ǩ), ǩ \in Ǩ >\}$ Where $Ŧ_{Ʋ}(ǩ): Ǩ \rightarrow Ƒ[0,1], Ɨ_{Ʋ}(ǩ): Ǩ \rightarrow Ƒ[0,1], Ƒ_{Ʋ}(ǩ): Ǩ \rightarrow Ƒ[0,1]$. T2NNS $Ŧ_q(ǩ) = \left(Ŧ_{Ŧ_{Ʋ}}(ǩ), Ŧ_{Ɨ_{Ʋ}}(ǩ), Ŧ_{Ƒ_{Ʋ}}(ǩ)\right)$, $Ɨ_q(ǩ) = \left(Ɨ_{Ŧ_{Ʋ}}(ǩ), Ɨ_{Ɨ_{Ʋ}}(ǩ), Ɨ_{Ƒ_{Ʋ}}(ǩ)\right)$, $Ƒ_q(ǩ) = \left(Ƒ_{Ŧ_{Ʋ}}(ǩ), Ƒ_{Ɨ_{Ʋ}}(ǩ), Ƒ_{Ƒ_{Ʋ}}(ǩ)\right)$ are the memberships of truth, indeterminacy, and falsity within the set R for K. for all $ǩ \in Ǩ: 0 \leq Ŧ_{Ʋ}(ǩ)^3 + Ɨ_{Ʋ}(ǩ)^3 + Ƒ_{Ʋ}(ǩ)^3 \leq 3$, let $Ʋ =< \left(\left(Ŧ_{Ŧ_{Ʋ}}(ǩ), Ŧ_{Ɨ_{Ʋ}}(ǩ), Ŧ_{Ƒ_{Ʋ}}(ǩ)\right), \left(Ɨ_{Ŧ_{Ʋ}}(ǩ), Ɨ_{Ɨ_{Ʋ}}(ǩ), Ɨ_{Ƒ_{Ʋ}}(ǩ)\right), \left(Ƒ_{Ŧ_{Ʋ}}(ǩ), Ƒ_{Ɨ_{Ʋ}}(ǩ), Ƒ_{Ƒ_{Ʋ}}(ǩ)\right)\right) >$ refers to type 2 neutrosophic number.

Definition 2 [1]

Consider $Ʋ_1 =< (\left(Ŧ_{Ŧ_{Ʋ_1}}(ǩ), Ŧ_{Ɨ_{Ʋ_1}}(ǩ), Ŧ_{Ƒ_{Ʋ_1}}(ǩ)\right), \left(Ɨ_{Ŧ_{Ʋ_1}}(ǩ), Ɨ_{Ɨ_{Ʋ_1}}(ǩ), Ɨ_{Ƒ_{Ʋ_1}}(ǩ)\right), \left(Ƒ_{Ŧ_{Ʋ_1}}(ǩ), Ƒ'_{Ɨ_{Ʋ_1}}(ǩ), Ƒ_{Ƒ_{Ʋ_1}}(ǩ)\right)) >$ and $Ʋ_2 =< (\left(Ŧ_{Ŧ_{Ʋ_2}}(ǩ), Ŧ_{Ɨ_{Ʋ_2}}(ǩ), Ŧ_{Ƒ_{Ʋ_2}}(ǩ)\right), \left(Ɨ_{Ŧ_{Ʋ_2}}(ǩ), Ɨ_{Ɨ_{Ʋ_2}}(ǩ), Ɨ_{Ƒ_{Ʋ_2}}(ǩ)\right), \left(Ƒ_{Ŧ_{Ʋ_2}}(ǩ), Ƒ'_{Ɨ_{Ʋ_2}}(ǩ), Ƒ_{Ƒ_{Ʋ_2}}(ǩ)\right)) >$ are two T2NNS, then there are various operations applicable to these numbers.

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$$Ʊ_1 \oplus Ʊ_2 = \begin{pmatrix} \begin{pmatrix} \left(T_{TƱ_1}(ǩ)+T_{TƱ_2}(ǩ)-T_{TƱ_1}(ǩ)*T_{TƱ_2}(ǩ)\right), \\ \left(T_{ƗƱ_1}(ǩ)+T_{ƗƱ_2}(ǩ)-T_{ƗƱ_1}(ǩ)*T_{ƗƱ_2}(ǩ)\right), \\ \left(T_{ƑƱ_1}(ǩ)+T_{ƑƱ_2}(ǩ)-T_{ƑƱ_1}(ǩ)*T_{ƑƱ_2}(ǩ)\right) \end{pmatrix}, \\ \left(Ɨ_{TƱ_1}(ǩ)*Ɨ_{TƱ_2}(ǩ), Ɨ_{ƗƱ_1}(ǩ)*Ɨ_{ƗƱ_2}(ǩ), Ɨ_{ƑƱ_1}(ǩ)*Ɨ_{ƑƱ_2}(ǩ)\right), \\ \left(Ƒ_{TƱ_1}(ǩ)*Ƒ_{TƱ_2}(ǩ), Ƒ_{ƗƱ_1}(ǩ)*Ƒ_{ƗƱ_2}(ǩ), Ƒ_{ƑƱ_1}(ǩ)*Ƒ_{ƑƱ_2}(ǩ)\right) \end{pmatrix} \tag{1}$$

$$Ʊ_1 \otimes Ʊ_2 = \begin{pmatrix} \left(T_{TƱ_1}(ǩ)*T_{TƱ_2}(ǩ), T_{ƗƱ_1}(ǩ)*T_{ƗƱ_2}(ǩ), T_{ƑƱ_1}(ǩ)*T_{ƑƱ_2}(ǩ)\right), \\ \begin{pmatrix} \left(Ɨ_{TƱ_1}(ǩ)+Ɨ_{TƱ_2}(ǩ)-Ɨ_{TƱ_1}(ǩ)*Ɨ_{TƱ_2}(ǩ)\right), \\ \left(Ɨ_{ƗƱ_1}(ǩ)+Ɨ_{ƗƱ_2}(ǩ)-Ɨ_{ƗƱ_1}(ǩ)*Ɨ_{ƗƱ_2}(ǩ)\right), \\ \left(Ɨ_{ƑƱ_1}(ǩ)+Ɨ_{ƑƱ_2}(ǩ)-Ɨ_{ƑƱ_1}(ǩ)*Ɨ_{ƑƱ_2}(ǩ)\right) \end{pmatrix}, \\ \begin{pmatrix} \left(Ƒ_{TƱ_1}(ǩ)+Ƒ_{TƱ_2}(ǩ)-Ƒ_{TƱ_1}(ǩ)*Ƒ_{TƱ_2}(ǩ)\right), \\ \left(Ƒ_{ƗƱ_1}(ǩ)+Ƒ_{ƗƱ_2}(ǩ)-Ƒ_{ƗƱ_1}(ǩ)*Ƒ_{ƗƱ_2}(ǩ)\right), \\ \left(Ƒ_{ƑƱ_1}(ǩ)+Ƒ_{ƑƱ_2}(ǩ)-Ƒ_{ƑƱ_1}(ǩ)*Ƒ_{ƑƱ_2}(ǩ)\right) \end{pmatrix} \end{pmatrix} \tag{2}$$

$$ϐƱ_1 = \begin{pmatrix} \left(1-\left(1-T_{TƱ_1}(ǩ)\right)^{ϐ}, 1-\left(1-T_{ƗƱ_1}(ǩ)\right)^{ϐ}, 1-\left(1-T_{ƑƱ_1}(ǩ)\right)^{ϐ}\right), \\ \left(\left(Ɨ_{TƱ_1}(ǩ)\right)^{ϐ}, \left(Ɨ_{ƗƱ_1}(ǩ)\right)^{ϐ}, \left(Ɨ_{ƑƱ_1}(ǩ)\right)^{ϐ}\right), \\ \left(\left(Ƒ_{TƱ_1}(ǩ)\right)^{ϐ}, \left(Ƒ_{ƗƱ_1}(ǩ)\right)^{ϐ}, \left(Ƒ_{ƑƱ_1}(ǩ)\right)^{ϐ}\right) \end{pmatrix} \tag{3}$$

$$Ʊ_1^{ϐ} = \begin{pmatrix} \left(\left(T_{TƱ_1}(ǩ)\right)^{ϐ}, \left(T_{ƗƱ_1}(ǩ)\right)^{ϐ}, \left(T_{ƑƱ_1}(ǩ)\right)^{ϐ}\right) \\ \left(1-\left(1-Ɨ_{TƱ_1}(ǩ)\right)^{ϐ}, 1-\left(1-Ɨ_{ƗƱ_1}(ǩ)\right)^{ϐ}, 1-\left(1-Ɨ_{ƗƱ_1}(ǩ)\right)^{ϐ}\right) \\ \left(1-\left(1-Ƒ_{TƱ_1}(ǩ)\right)^{ϐ}, 1-\left(1-Ƒ_{TƱ_1}(ǩ)\right)^{ϐ}, 1-\left(1-Ƒ_{TƱ_1}(ǩ)\right)^{ϐ}\right) \end{pmatrix} \quad for\ ϐ > 0 \tag{4}$$

Definition 3 [1]

$$Ʊ_1 \oplus Ʊ_2 = Ʊ_2 \oplus Ʊ_1, Ʊ_1 \otimes Ʊ_2 = Ʊ_2 \otimes Ʊ_1 \tag{5}$$

$$ϐ(Ʊ_1 \oplus Ʊ_2) = (ϐƱ_1 \oplus ϐƱ_2), (Ʊ_1 \otimes Ʊ_2)^{ϐ} = Ʊ_1^{ϐ} \otimes Ʊ_2^{ϐ} \tag{6}$$

$$ϐ_1 Ʊ_1 \oplus ϐ_2 Ʊ_1 = (ϐ_1 + ϐ_2)Ʊ_1, Ʊ_1^{ϐ_1} \otimes Ʊ_1^{ϐ_2} = Ʊ_1^{(ϐ_1+ϐ_2)} \tag{7}$$

Definition 4 [1]

The score function is calculated as:

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$$ş(\text{Ʋ}_1) = \frac{1}{12}\begin{pmatrix} 8 + \left(\text{Ƭ}_{\text{Ƭ}_{\text{Ʋ}_1}}(\check{k})\right) + 2\left(\text{Ƭ}_{\text{Ɨ}_{\text{Ʋ}_1}}(\check{k})\right) + \text{Ƭ}_{\text{Ƒ}_{\text{Ʋ}_1}}(\check{k}) - \\ \left(\text{Ɨ}_{\text{Ƭ}_{\text{Ʋ}_1}}(\check{k}) + 2\left(\text{Ɨ}_{\text{Ɨ}_{\text{Ʋ}_1}}(\check{k})\right) + \text{Ɨ}_{\text{Ƒ}_{\text{Ʋ}_1}}(\check{k})\right) - \\ (\text{Ƒ}_{\text{Ƭ}_{\text{Ʋ}_1}}(\check{k}) + 2\left(\text{Ƒ}_{\text{Ɨ}_{\text{Ʋ}_1}}(\check{k})\right) + \text{Ƒ}_{\text{Ƒ}_{\text{Ʋ}_1}}(\check{k})) \end{pmatrix} \quad (8)$$

$$\text{ɓ}(\text{Ʋ}_1) = \frac{1}{4}\left(\left(\left(\text{Ƭ}_{\text{Ƭ}_{\text{Ʋ}_1}}(\check{k})\right) + 2\left(\text{Ƭ}_{\text{Ɨ}_{\text{Ʋ}_1}}(\check{k})\right) + \text{Ƭ}_{\text{Ƒ}_{\text{Ʋ}_1}}(\check{k})\right) - \left(\text{Ƒ}_{\text{Ƭ}_{\text{Ʋ}_1}}(\check{k}) + 2\left(\text{Ƒ}_{\text{Ɨ}_{\text{Ʋ}_1}}(\check{k})\right) + \text{Ƒ}_{\text{Ƒ}_{\text{Ʋ}_1}}(\check{k})\right)\right) \quad (9)$$

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Table 1: Overview of related studies using different MCDM methods.

No.	Authors	Year	Multi-Criteria Decision-Making Method											Sensitivity analysis	Comparative Analysis
			BWM	Entropy	TODIM	DEMATEL	AHP/ANP	PROMETHEE -II	TOPSIS	MERE C	FUCOM	CoCoSo	Multi-facility layout		
1	Sunit and Satish [2]	**2022**		✓	✓										
2	Ortíz-Barrios and Miguel [3]	**2023**				✓	✓								
3	Jeon and Suvitha [4]	**2023**		✓				✓						✓	
4	Salehi and Moradi [5]	**2023**		✓											
5	Ahmad and Masood [6]	**2023**	✓						✓					✓	
6	Magableh and Mistarihi [7]	**2022**					✓		✓						
7	Cakir and Tas [8]	**2021**											✓		
8	Paul and Pervez [9]	**2023**							✓						
9	Khan and Ali [10]	**2021**									✓				
10	Ghosh and Bhattacharya [11]	**2022**								✓		✓			

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2.2 Selected Criteria

The COVID-19 pandemic, an unparalleled global health crisis, has necessitated the implementation of multifaceted intervention strategies by nations around the world. In Egypt, the response to this crisis has been marked by a combination of public health measures, economic policies, and social initiatives aimed at mitigating the impact of the virus on various facets of society. To comprehensively assess the effectiveness of Egypt's intervention strategies, a set of criteria and sub-criteria from experts has been selected, and the criteria that span the critical dimensions of this response have been chosen. Experts carefully select these criteria to provide a rigorous and well-rounded evaluation, considering the intricacies of a nation's response to a pandemic of this magnitude. These criteria and sub-criteria establish a holistic framework for evaluating Egypt's response to the COVID-19 pandemic. Through a systematic analysis of these dimensions, a comprehensive assessment will be provided that informs policy decisions and contributes to a deeper understanding of the complex interplay between public health, economics, and society during times of crisis. The criteria are:

1. **Public Health Impact:**
    - 1.1. **Case and Mortality Rates:** Assesses the effectiveness of Egypt's measures in reducing the number of COVID-19 cases and deaths. It involves analyzing trends in infection rates, recoveries, and fatalities.
    - 1.2. **Hospitalization Rates:** Hospitalization rates help measure the weight of healthcare facilities. Lower hospitalization rates indicate successful management of COVID-19 patients and adequate healthcare resources.
    - 1.3. **Vaccination Coverage:** Evaluate the progress of Egypt's vaccination campaign, including the percentage of the population vaccinated and the distribution of vaccine doses.
    - 1.4. **Testing and Contact Tracing Efficiency:** The efficiency of testing and contact tracing measures can impact the timely identification and isolation of infected individuals, preventing further spread of the virus.
2. **Economic Impact:**
    - 2.1. **GDP (Gross domestic product) Growth/Contraction:** Gauges the pandemic's impact on Egypt's economic growth, examining whether the country experienced a recession or managed to maintain stability.
    - 2.2. **Unemployment Rate:** The unemployment rate reflects the economic consequences of lockdowns and restrictions. High unemployment can lead to social and economic instability.
    - 2.3. **Support for Affected Businesses:** Evaluating the extent of government support for businesses affected by the pandemic, such as financial assistance or tax relief.
3. **Social Impact:**
    - 3.1. **Education Disruptions:** Examines the extent to which the pandemic disrupted education, including school closures and remote learning challenges.
    - 3.2. **Mental Health Concerns:** Evaluating the impact of the pandemic on mental health, including rising stress, anxiety, and depression rates.
    - 3.3. **Social Cohesion and Compliance:** Measuring the level of public cooperation with preventive measures and the degree of social unity during the crisis.
    - 3.4. **Food Security:** Assessing the ability of the population to access and afford essential food items during the pandemic.
4. **Healthcare System Resilience:**
    - 4.1. **Healthcare Infrastructure Capacity**: Evaluating the capacity of hospitals, ICU beds, and medical equipment to manage COVID-19 cases.
    - 4.2. **Availability of Medical Supplies**: Examining the adequacy of personal protective equipment (PPE) and essential medical supplies.
    - 4.3. **Healthcare Workforce Capacity**: Assessing the ability of the healthcare system to maintain staffing levels and provide adequate care.
    - 4.4. **Emergency Response Readiness**: Evaluating the readiness of healthcare facilities to respond to surges in COVID-19 cases.
5. **Community Engagement and Compliance:**
    - 5.1. **Public Awareness Campaigns**: Assessing the effectiveness of public health campaigns and information dissemination.

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5.2. **Adherence to Preventive Measures**: Evaluating how well the population complied with mask-wearing, physical distancing, and other preventive guidelines.
5.3. **Trust in Government Guidance:** Measuring the level of trust the public has in government recommendations and mandates.
5.4. **Compliance with Vaccination Programs:** Assessing the willingness of the population to get vaccinated and the success of vaccination campaigns.

The benefit criteria are those that have a positive impact on the decision objective, while the cost criteria are those that have a negative impact. Based on this definition, I have divided the criteria as follows:

- Benefit criteria: These are the criteria that aim to be maximized, as they indicate a better performance than the alternatives. They are:
    - Č1.3. Vaccination Coverage
    - Č1.4. Testing and Contact Tracing Efficiency
    - Č2.1. GDP Growth/Contraction
    - Č2.3. Support for Affected Businesses
    - Č3.3. Social Cohesion and Compliance
    - Č3.4. Food Security
    - Č4.1. Healthcare Infrastructure Capacity
    - Č4.2. Availability of Medical Supplies
    - Č4.3. Healthcare Workforce Capacity
    - Č4.4. Emergency Response Readiness
    - Č5.1. Public Awareness Campaigns
    - Č5.2. Adherence to Preventive Measures
    - Č5.3. Trust in Government Guidance
    - Č5.4. Compliance with Vaccination Programs
- Cost criteria: These are the criteria that aim to be minimized, as they indicate a worse performance than the alternatives. They are:
    - Č1.1. Case and Mortality Rates
    - Č1.2. Hospitalization Rates
    - Č2.2. Unemployment Rate
    - Č3.1. Education Disruptions
    - Č3.2. Mental Health Concerns

3. Methodology

This section outlines the methodology employed in this research to assess and select the most effective alternative among Egypt's COVID-19 intervention strategies. The research employs a combination of three decision-making techniques: Analytic Hierarchy Process (AHP), Complex Proportional Assessment (COPRAS), and VIKOR (VlseKriterijumska Optimizacija I

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Kompromisno Resenje). This approach facilitates a robust and comprehensive evaluation of the strategies, considering multiple criteria.

Data for each criterion is collected from a variety of sources, including government reports, academic studies, official statistics, and expert opinions. The data covers the period corresponding to Egypt's response to the COVID-19 pandemic, allowing for a longitudinal analysis of the strategies.

Then, AHP (Analytic Hierarchy Process) is employed to establish the relative importance of each criterion in the decision-making process. AHP is a multi-criteria decision-making method that was developed by Thomas L. Saaty in the 1970s. AHP is based on the principle of pairwise comparisons, which allows decision-makers to compare the relative importance of criteria and the relative preference of alternatives concerning each criterion.

Then, Complex Proportional Assessment (COPRAS) is used to evaluate and rank the alternatives, COPRAS is an MCDM technique designed to evaluate and rank alternatives based on a set of criteria while accounting for both positive and negative aspects of each criterion. Developed as an extension of the classic Proportional Assessment (PROMETHEE) method, COPRAS is chosen because it takes into consideration the interdependencies and potential conflicts among criteria, offering a more comprehensive assessment of alternatives.

Then VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) is used to rank the alternatives and compare its result with COPRAS to compare its result with COPRAS and ensure that the selected methodology is valid, VIKOR is chosen because it considers both the maximum group utility and the minimum individual regret when selecting the most favorable alternative.

The proposed methodology is in detail in *Figure 1*.

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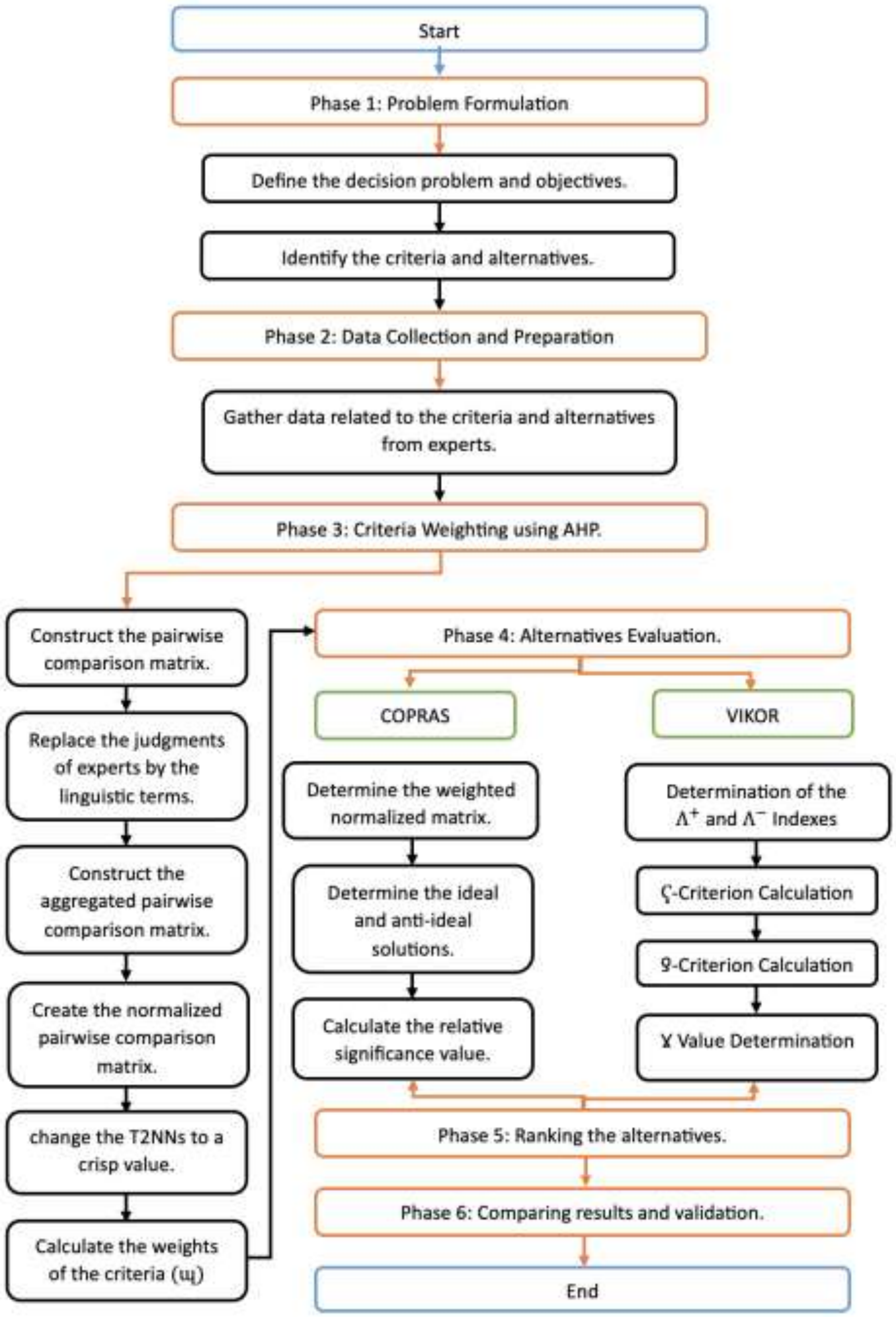

Figure 1: the proposed methodology along with its constituent steps.

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3.1 AHP:

AHP is one of the most widely used methods in MCDM in numerous areas. The MCDM methods were used to deal with various criteria [17-19]. The neutrosophic set used to deal with uncertainty [20-21]. The method has been extended with hesitant fuzzy sets, intuitionistic fuzzy sets, neutrosophic sets, and type -2 fuzzy sets. In this paper, the AHP method has been used with type-2 neutrosophic sets (T2NNs-AHP). This method combines the advantages of type-2 neutrosophic sets and AHP to provide a more realistic and robust approach to MCDM problems.

T2NNs-AHP used to apply the methodology, the following are the key steps involved in the process[1]:

A. At first, AHP has been used to get the weight of the main criteria:

1. **Step 1:** Construct the pairwise comparison matrix (Đ) by the expert's judgments.

$$
Đ = \begin{pmatrix}
\begin{pmatrix} \left(T_{T_{\upsilon_1^{(1)}}}(\check{k}), T_{Ɨ_{\upsilon_1^{(1)}}}(\check{k}), T_{F_{\upsilon_1^{(1)}}}(\check{k})\right), \\ \left(Ɨ_{T_{\upsilon_1^{(1)}}}(\check{k}), Ɨ_{Ɨ_{\upsilon_1^{(1)}}}(\check{k}), Ɨ_{F_{\upsilon_1^{(1)}}}(\check{k})\right), \\ \left(F_{T_{\upsilon_1^{(1)}}}(\check{k}), F_{Ɨ_{\upsilon_1^{(1)}}}(\check{k}), F_{F_{\upsilon_1^{(1)}}}(\check{k})\right) \end{pmatrix} & \cdots & \begin{pmatrix} \left(T_{T_{\upsilon_1^{(1)}}}(\check{k}), T_{Ɨ_{\upsilon_1^{(1)}}}(\check{k}), T_{F_{\upsilon_1^{(1)}}}(\check{k})\right), \\ \left(Ɨ_{T_{\upsilon_1^{(1)}}}(\check{k}), Ɨ_{Ɨ_{\upsilon_1^{(1)}}}(\check{k}), Ɨ_{F_{\upsilon_1^{(1)}}}(\check{k})\right), \\ \left(F_{T_{\upsilon_1^{(1)}}}(\check{k}), F_{Ɨ_{\upsilon_1^{(1)}}}(\check{k}), F_{F_{\upsilon_1^{(1)}}}(\check{k})\right) \end{pmatrix} \\
\vdots & \ddots & \vdots \\
\begin{pmatrix} \left(T_{T_{\upsilon_1^{(2)}}}(\check{k}), T_{Ɨ_{\upsilon_1^{(2)}}}(\check{k}), T_{F_{\upsilon_1^{(2)}}}(\check{k})\right), \\ \left(Ɨ_{T_{\upsilon_1^{(2)}}}(\check{k}), Ɨ_{Ɨ_{\upsilon_1^{(2)}}}(\check{k}), Ɨ_{F_{\upsilon_1^{(2)}}}(\check{k})\right), \\ \left(F_{T_{\upsilon_1^{(2)}}}(\check{k}), F_{Ɨ_{\upsilon_1^{(2)}}}(\check{k}), F_{F_{\upsilon_1^{(2)}}}(\check{k})\right) \end{pmatrix} & \cdots & \begin{pmatrix} \left(T_{T_{\upsilon_1^{(2)}}}(\check{k}), T_{Ɨ_{\upsilon_1^{(2)}}}(\check{k}), T_{F_{\upsilon_1^{(2)}}}(\check{k})\right), \\ \left(Ɨ_{T_{\upsilon_1^{(2)}}}(\check{k}), Ɨ_{Ɨ_{\upsilon_1^{(2)}}}(\check{k}), Ɨ_{F_{\upsilon_1^{(2)}}}(\check{k})\right), \\ \left(F_{T_{\upsilon_1^{(2)}}}(\check{k}), F_{Ɨ_{\upsilon_1^{(2)}}}(\check{k}), F_{F_{\upsilon_1^{(2)}}}(\check{k})\right) \end{pmatrix}
\end{pmatrix}
$$

2. **Step 2:** Replace the judgments of experts with the semantic terms type-2 scale [12].

3. **Step 3:** Construct the aggregated pairwise comparison matrix ƌ using Equation (4) where (ɞ) refers to each expert's weights.

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$$Ƌ = \begin{pmatrix} \begin{pmatrix} \left(Ͳ_{Ͳ_{Ʋ_1}}(\check{k}), Ͳ_{Ɨ_{Ʋ_1}}(\check{k}), Ͳ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ɨ_{Ͳ_{Ʋ_1}}(\check{k}), Ɨ_{Ɨ_{Ʋ_1}}(\check{k}), Ɨ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ƒ_{Ͳ_{Ʋ_1}}(\check{k}), Ƒ_{Ɨ_{Ʋ_1}}(\check{k}), Ƒ_{Ƒ_{Ʋ_1}}(\check{k})\right) \end{pmatrix} & \cdots & \begin{pmatrix} \left(Ͳ_{Ͳ_{Ʋ_1}}(\check{k}), Ͳ_{Ɨ_{Ʋ_1}}(\check{k}), Ͳ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ɨ_{Ͳ_{Ʋ_1}}(\check{k}), Ɨ_{Ɨ_{Ʋ_1}}(\check{k}), Ɨ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ƒ_{Ͳ_{Ʋ_1}}(\check{k}), Ƒ_{Ɨ_{Ʋ_1}}(\check{k}), Ƒ_{Ƒ_{Ʋ_1}}(\check{k})\right) \end{pmatrix} \\ \vdots & \ddots & \vdots \\ \begin{pmatrix} \left(Ͳ_{Ͳ_{Ʋ_1}}(\check{k}), Ͳ_{Ɨ_{Ʋ_1}}(\check{k}), Ͳ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ɨ_{Ͳ_{Ʋ_1}}(\check{k}), Ɨ_{Ɨ_{Ʋ_1}}(\check{k}), Ɨ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ƒ_{Ͳ_{Ʋ_1}}(\check{k}), Ƒ_{Ɨ_{Ʋ_1}}(\check{k}), Ƒ_{Ƒ_{Ʋ_1}}(\check{k})\right) \end{pmatrix} & \cdots & \begin{pmatrix} \left(Ͳ_{Ͳ_{Ʋ_1}}(\check{k}), Ͳ_{Ɨ_{Ʋ_1}}(\check{k}), Ͳ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ɨ_{Ͳ_{Ʋ_1}}(\check{k}), Ɨ_{Ɨ_{Ʋ_1}}(\check{k}), Ɨ_{Ƒ_{Ʋ_1}}(\check{k})\right), \\ \left(Ƒ_{Ͳ_{Ʋ_1}}(\check{k}), Ƒ_{Ɨ_{Ʋ_1}}(\check{k}), Ƒ_{Ƒ_{Ʋ_1}}(\check{k})\right) \end{pmatrix} \end{pmatrix}$$

4. **Step 4:** Convert the Type-2 neutrosophic matrix (Ƌ) to Crisp matrix (ժ) using the score function [12] Eq (8).
5. **Step 5:** Create the crisp normalized pairwise comparison matrix ɮ using Equation (10).

$$ɮ_{ij} = \frac{ժ_{ij}}{\sum_{i=1}^{m} ժ_{i}} , j = 1, 2, 3 \ldots . n \qquad (10)$$

6. **Step 6:** Calculate the weights of the criteria (ῳ) based on the pairwise comparison results.
7. **Step 7:** Calculate the Consistency index CI using Equation (11) and verify the consistency ratio CR using Equation (12).

$$CI = \frac{lambda - n}{n-1} \qquad (11)$$

$$CR = \frac{CI}{RI} \qquad (12)$$

In this context, CI represents the consistency index [1], while RI stands for the random index and n number of criteria.

B. After calculating the weight of the main criteria (ῳ), the same steps have been applied for each sub-criteria to calculate the weight of each (ϖ), and then Equation (13) is used to calculate the final weight of each sub-criteria ($ɰ_{ij}$).

$$ɰ_{ij} = ῳ_{i} * \varpi_{ij}, i = 1,2,3, \ldots m , j = 1,2,3 \ldots . n \qquad (13)$$

3.2 COPRAS:

COPRAS is an MCDM method that can be used to rank different alternatives based on various criteria and their weights. COPRAS was developed in 1996 by Zavadskas and Kaklauskas from Vilnius Gediminas Technical University[13]. It is based on the idea of normalizing the criteria values and combining them into a single quantitative measure, called the method criterion. COPRAS can manage both benefit and cost criteria, as well as crisp and interval data. COPRAS has several advantages over other MCDM methods, such as simplicity, transparency, efficiency, and less bias[14]. COPRAS has been widely applied to various decision problems in different fields, such as engineering, management, economics, environment, education, and social sciences. Some examples of COPRAS applications are cloud vendor selection[14] and sustainable building assessment[13]. The COPRAS method assesses the maximizing and minimizing index values, and the effect of maximizing and minimizing indexes of attributes on the results assessment is considered separately [13].

The integration between T2NNS-AHP and T2NNS-COPRAS is applied, this integration allows for harnessing of the strengths of both techniques, leveraging AHP's ability to establish criteria weights and the structured hierarchy of decision factors, while benefiting from COPRAS's capacity to evaluate alternatives in the presence of complex, interrelated criteria, and conflicting objectives. By combining these methodologies, my research aimed to provide a more nuanced and informed perspective on the

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decision problem at hand, offering a holistic and balanced framework that considers both the relative importance of criteria and the intricate relationships between them, leading to more robust and defensible decision outcomes.

The steps of the COPRAS method applied as follows [15]:

1. **Step 1:** Obtain experts' judgment of each alternative against the criterion based on their previous knowledge in the field then replace the linguistic variable given by the experts by the linguistic variables scale.
2. **Step 2:** Construct the aggregated Decision matrix (Ɋ) by the expert's judgments using Equation (4) where ɘ refers to each expert's weights.
3. **Step 3:** Convert the Type-2 neutrosophic pairwise matrix to a Crisp pairwise matrix using the score function [12] Equation (8).
4. **Step 4:** use Equation (14) to get the crisp normalized decision matrix (Ɋ^*).

$$\text{Ɋ}_{ij}^* = \frac{\text{Ɋ}_{ij}}{\sum_{i=1}^{m} \text{Ɋ}_{ij}}, j = 1, 2, 3 \ldots . n \qquad (14)$$

5. **Step 5:** Use Equation (15) and the weights resulting from T2NNS-AHP (ɰ) to Determine the Crisp-weighted normalized decision matrix (Ɋ^+).

$$\text{Ɋ}_{ij}^+ = \text{ɋ}_{ij} * \text{ɰ}_j; i = 1,2,3, \ldots, m, \; j = 1,2,3, \ldots, n \qquad (15)$$

Where ɰ_j is the weight of each sub-criteria $[\text{ɰ}_1, \text{ɰ}_2, \ldots, \text{ɰ}_n]$

6. **Step 6:** Determine the ideal and anti-ideal solutions based on the maximum and minimum values of each criterion. Using Equations. (16) and (17), the maximizing and minimizing indexes for each attribute are derived based on whether the attributes are of a negative or positive type.

$$\varsigma_{+i} = \sum_{j=1}^{\text{ꝑ}} \text{Ɋ}_{ij}; \; i = 1,2, \ldots, m \qquad (16)$$

$$\varsigma_{-i} = \sum_{j=\text{ꝑ}+1}^{\text{й}} \text{Ɋ}_{ij}; \; i = 1,2, \ldots, m \qquad (17)$$

Where ꝑ represents the count of positive attributes and $\text{й} - \text{ꝑ}$ denotes the number of negative attributes, Additionally, ς_i means the maximizing and minimizing indexes of the ith attribute, depending on its type.

7. **Step 7:** Calculate the relative significance value (Φ) for each alternative using Equations. (18) and (19).

$$\Phi_i = \varsigma_{+i} + \frac{\min_i \varsigma_{-i} \sum_{i=1}^{m} \varsigma_{-i}}{\varsigma_{-i} \sum_{i=1}^{m} \frac{min_i \varsigma_{-i}}{\varsigma_{-i}}} \qquad (18)$$

$$\Phi_i = \varsigma_{+i} + \frac{\sum_{i=1}^{m} \varsigma_{-i}}{\varsigma_{-i} \sum_{i=1}^{m} \frac{1}{\varsigma_{-i}}} \qquad (19)$$

8. **Step 8:** Rank the Alternatives based on their relative significance values, rank the alternatives from best to worst, with the high relative significance value being the high rank.

3.3 VIKOR:

VIKOR is an MCDM method used for ranking and selecting the best compromise or compromise solution from a set of alternatives in the presence of conflicting criteria. In this research, the VIKOR method is employed to facilitate the ranking and selection of the most suitable compromise solution from a pool of alternatives. VIKOR is particularly beneficial when confronted with decision scenarios characterized by competing criteria, where different alternatives excel in distinct aspects, making it challenging to pinpoint a single optimal solution.

In this research, the VIKOR method is applied as a pivotal component of the MCDM framework for evaluating Egypt's intervention strategies in response to the COVID-19 pandemic. This method was strategically employed following the determination of criteria weights through the AHP and the ranking of alternatives utilizing the COPRAS method. The primary purpose of incorporating VIKOR was to validate the rankings obtained from COPRAS and provide an additional layer of robustness to the decision-making process.

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The incorporation of the VIKOR method into this research not only bolstered the credibility of the decision outcomes but also ensured the alignment of results obtained from two distinct MCDM approaches, COPRAS and VIKOR. This rigorous approach aims to provide a well-rounded evaluation of Egypt's COVID-19 intervention strategies and offers valuable insights for policymakers and stakeholders in navigating complex, multi-criteria decision scenarios.

The weights of each sub-criterion used in the VIKOR steps are the weights resulting from T2NNS-AHP, the utilization of the VIKOR method encompasses the following steps [16]:

1. **Step 1:** Using the same Crisp aggregated Decision matrix (Ƣ) that resulted from step 3 in the COPRAS method to determine the Λ^+ and Λ^- Indexes for each criterion using Equations. (20) and (21).
For each criterion $j = 1,2, \dots .n$, the best Λ denoted as Λ^+ and the worst represented as Λ^-.

1.1. For the positive criteria:

$$\begin{cases} \Lambda_j^+ = \max_i \Lambda_{ij} \\ \Lambda_j^- = \min_i \Lambda_{ij} \end{cases}; i = 1,2, \dots, m, j = 1,2, \dots, n \quad (20)$$

1.2. For the negative criteria:

$$\begin{cases} \Lambda_j^+ = \min_i \Lambda_{ij} \\ \Lambda_j^- = \max_i \Lambda_{ij} \end{cases}; i = 1,2, \dots, m, j = 1,2, \dots, n \quad (21)$$

2. **Step 2:** Ϛ-Criterion Calculation
The Ϛ-criterion assesses how closely each alternative aligns with the ideal solution, considering the best and worst values for each criterion. It quantifies the performance of each alternative concerning the criteria.
The Ϛ-Criterion Calculation for each alternative is obtained using Equation. (22).

$$Ϛ_i = \sum_{j=1}^{n} ɰ_j \frac{(\Lambda_j^+ - \Lambda_{ij})}{(\Lambda_j^+ - \Lambda_j^-)}; i = 1,2, \dots, m \quad (22)$$

3. **Step 3:** ϱ-Criterion Calculation
Parallel to the Ϛ-criterion, the ϱ-criterion assesses the closeness of each alternative to the worst solution. It quantifies the deviation of each alternative from the worst possible values for each criterion while considering the criteria weights.
The ϱ-Criterion Calculation for each alternative is obtained using Equation. (23).

$$ϱ = \max_i \left[ɰ_j \frac{(\Lambda_j^+ - \Lambda_{ij})}{(\Lambda_j^+ - \Lambda_j^-)} \right]; i = 1,2, \dots, m, j = 1,2, \dots, n \quad (23)$$

4. **Step 4:** Ɣ Value Determination:
The Ɣ value, a key output of the VIKOR methodology, was computed for each alternative. This value serves as a comprehensive indicator of compromise. It considers the distances between each alternative and the ideal solution (Ϛ-criterion) and the worst solution (ϱ-criterion), encompassing the criteria weights.
For each alternative, the Ɣ value is calculated using Equation. (24).

$$\begin{cases} Ɣ = ɣ * \left[\frac{Ϛ_i - Ϛ^*}{Ϛ^- - Ϛ^*}\right] + (1 - ɣ) * \left[\frac{ϱ_i - ϱ^*}{ϱ^- - ϱ^*}\right] \\ Ϛ^* = \min_i Ϛ_i, \quad Ϛ^- = \max_i Ϛ_i, \quad ϱ^* = \min_i ϱ_i, \quad ϱ^- = \max_i ϱ_i \end{cases} \quad (24)$$

where ɣ indicates the strategic weight, it is assumed to be equal to 0.5.

5. **Step 5:** Ranking and Comparison
In this step, alternatives are arranged in descending order based on their values for (Ϛ), (ϱ), and (Ɣ). The alternative with the least cumulative attribute values emerges as the top-ranked or superior choice. This ranking, which identifies the best compromise solution, complements the rankings obtained from the COPRAS method. The comparison between the two sets of rankings served to validate the robustness of the decision-making process.

4. Results

In this paper, MCDM has been applied to evaluate the intervention strategies of Egypt against the COVID-19 pandemic. In 2020, Egypt stood out among emerging market nations as it managed to achieve a growth rate. This accomplishment can be

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attributed to the government's prompt actions, a brief lockdown period, and the diverse nature of Egypt's economy. However, Egypt also faced significant challenges, such as a sudden stop in tourism, capital outflows, fiscal pressures, and social vulnerabilities. To assess how well Egypt’s intervention strategies balanced the health, economic, and social aspects of the pandemic. Therefore, Egypt needs to adopt effective and efficient strategies to prevent, control, and mitigate the impact of the pandemic. In this research, a few alternative strategies have been explored that Egypt could have employed in its battle against the COVID-19 pandemic.

The multifaceted nature of the pandemic requires a dynamic approach that encompasses a wide array of interventions, from public health measures to economic policies and community engagement initiatives. While Egypt's response has encompassed a range of strategies, information from three experts has been gathered, the experts present herein eleven distinct alternatives, each targeting specific aspects of the pandemic management based on global evidence and best practices. *Table 2* summarizes the eleven alternative strategies that have been explored in this paper:

Table 2: Alternative strategies against the COVID-19 pandemic

Code	Strategy	Explanation
Á1	**Lockdown**	Implement a partial or full lockdown in areas with high or rising levels of transmission, such as curfews, closures of non-essential businesses and services, and bans on public events.
Á2	**Economic support**	Provide economic support to individuals, households, businesses, and sectors that are affected by the pandemic, such as cash transfers, subsidies, tax relief, loans, grants, etc.
Á3	**Mass Testing and Contact Tracing**	An accurate approach involving widespread testing and efficient contact tracing to identify and isolate cases immediately.
Á4	**Public Awareness Campaigns**	Extensive public awareness campaigns to educate the populace about preventive measures.
Á5	**Mask wearing**	Mandate and enforce the use of face masks in public places, especially where physical distancing is not possible.
Á6	**Healthcare Capacity Expansion**	Investing in the expansion of healthcare infrastructure and resources to accommodate surges in cases.
Á7	**Social distancing**	Limit and regulate the gatherings of people in indoor and outdoor settings, such as schools, workplaces, markets, restaurants, mosques, and churches.
Á8	**International Collaboration**	Collaborating with international organizations and neighboring countries to share resources and information.
Á9	**Travel restriction**	Impose and monitor travel restrictions on domestic and international flights, trains, and buses.
Á10	**Vaccination Campaign Acceleration**	Accelerate the vaccination campaign to cover as many people as possible, especially vulnerable groups.
Á11	**Social protection**	Enhance social protection measures to protect or improve social welfare, equity, inclusion, education, and human rights for vulnerable groups living in Egypt.

After collecting the pairwise comparison matrixes and the decision matrixes from the Experts and replacing the judgments of experts with the semantic terms, the proposed methodology has been applied to select the best strategy Egypt could follow against the COVID-19 pandemic.

AHP:
At first, the AHP has been applied for the pairwise comparison matrixes of the main criteria to get the weight for the main criteria as follows:

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1. **Step 1**: Constructing the aggregated pairwise comparison matrix ƌ using Equation (4) where all experts' weights ϐ $= \left(\frac{1}{3}\right)$.

2. **Step 2**: converting the T2NN aggregated pairwise comparison matrix (ƌ) to the crisp matrix (ɗ) using the score function [12] Equation (8). as shown in *Table 3*.

Table 3: the aggregated pairwise comparison crisp matrix

	Č 1	**Č 2**	**Č 3**	**Č 4**	**Č 5**
Č 1	0.333333	0.447862	0.749839	0.811939	0.696442
Č 2	2.402645	0.333333	0.341617	0.57638	0.804167
Č 3	1.356615	3.181539	0.333333	0.579167	0.717521
Č 4	1.313353	1.972557	1.744043	0.333333	0.291667
Č 5	1.587567	1.25212	1.480114	3.72096	0.333333

3. **Step 3:** Using *Table 3* and Equation (10) to get the normalized crisp matrix *Table 4*.

Table 4: The normalized crisp matrix (ɗ)

	Č 1	**Č 2**	**Č 3**	**Č 4**	**Č 5**	**Weight (ῳ)**
Č 1	0.047663	0.062312	0.161292	0.134834	0.244956	0.130211
Č 2	0.343553	0.046377	0.073483	0.095716	0.282846	0.168395
Č 3	0.193982	0.442654	0.071701	0.096179	0.25237	0.211377
Č 4	0.187796	0.274446	0.375148	0.055355	0.102586	0.199066
Č 5	0.227006	0.17421	0.318376	0.617917	0.117242	0.29095

4. Step 4: Calculate the weights of each main criterion (ῳ) as shown in Table four based on the pairwise comparison results, then verify that $\sum ῳ_j = 1 \, , j = 1,2,3 \ldots m$.

5. **Step 5:** Determination of the consistency $\mathcal{C}$ matrix using Equation (25), and the weighted sum value using Equation (26).

$$\mathcal{C}_{ij} = ῳ_j * ɗ_{ji}, i = 1,2,3 \ldots .m, j = 1,2,3, \ldots n \qquad (25)$$

$$WSV = \sum \mathcal{C}_i, i = 1,2,3 \ldots ., m \qquad (26)$$

6. **Step 6:** Determining the $lambda$ using Equation (27)

$$lambda = \sum \frac{WSV_j}{ῳ_j}, j = 1,2,3, \ldots n \qquad (27)$$

$$lambda = 5.07672$$

7. Step 7: Calculate the Consistency index CI using Equation (11) and verify the consistency ratio CR using Equation (12).

$$CI = 0.01918111$$

$$CR = 0.017125991$$

The main criteria weights are calculated, and their consistency is verified, the same steps are applied for each sub-criterion. The sub-criteria weights, consistency indexes (CI), and consistency ratios (CR) are presented in Table 5.

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Table 5: AHP calculations for all sub-criterion

Sub Criteria	Main Criteria $\omega_{Č1}$	$\omega_{Č2}$	$\omega_{Č2}$	$\omega_{Č3}$	$\omega_{Č4}$
Č 1	0.183929	0.244457	0.160767	0.157783	0.174693
Č 2	0.238828	0.317637	0.222362	0.215903	0.231882
Č 3	0.267684	0.437906	0.274056	0.287417	0.235269
Č 4	0.309558	-	0.342815	0.338897	0.358157
Sum	1	1	1	1	1
$lambda$	4.049723	3.068057	4.057126	4.124603	4.005395
CI	0.016574	0.034029	0.019042	0.041534	0.001798
CR	0.018416	0.05867	0.021158	0.046149	0.001998

When $\omega_{Č1}$ means the weights of the sub-criterion of the first main criteria

Then, use Equation (13) to calculate the final weight (ɰ) of each criterion after finishing the sub-criterion calculations and verification. The final weights of each criterion are shown in *Figure 2*.

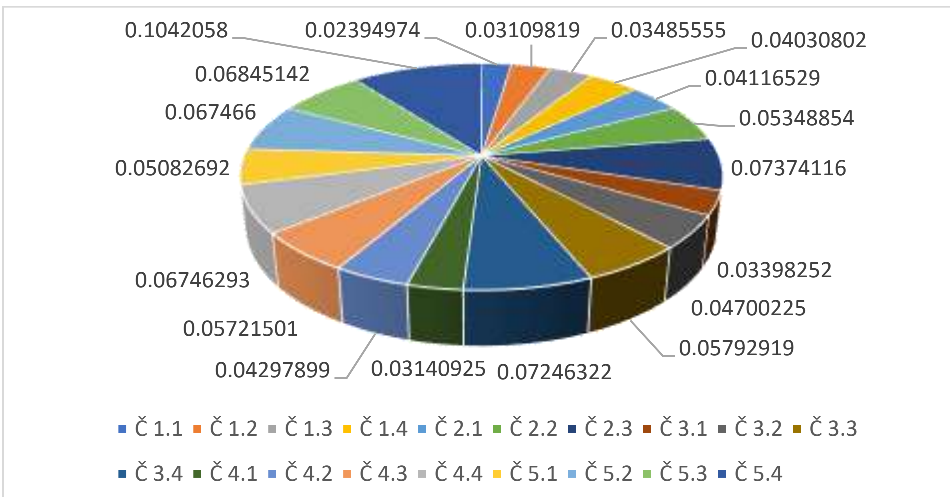

Figure 2: The final weights of each criterion.

COPRAS:

Using the decision matrixes that had been gathered from the experts, the COPRAS methodology has been applied to the alternatives of the strategies from **Error! Reference source not found.** five and the final weights of each criterion from F 2. The steps are as follows:

1. **Step 1:** Gather the experts' judgment of each alternative against the criterion based on their previous knowledge in the field and replace the linguistic variable given by the experts with the linguistic variables scale.

2. **Step 2:** Construct the aggregated Decision matrix (ŋ) by the expert's judgments using Equation (4) where the weights (ɘ) of all experts are equal. ɘ = $(\frac{1}{3})$.

3. **Step 3:** Converting the Type-2 neutrosophic aggregated matrix to aggregated decision Crisp matrix using the score function Equation (8), the aggregated crisp matrix that had been gotten is shown in *Table 6*.

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Table 6: The aggregated Decision matrix with crisp values

	Č 1.1	Č 1.2	Č 1.3	Č 1.4	Č 2.1	Č 2.2	Č 2.3	Č 3.1	Č 3.2	Č 3.3	Č 3.4	Č 4.1	Č 4.2	Č 4.3	Č 4.4	Č 5.1	Č 5.2	Č 5.3	Č 5.4
Á1	0.24	0.31	0.47	0.53	0.31	0.24	0.47	0.53	0.71	0.56	0.47	0.53	0.67	0.53	0.93	0.71	0.31	0.53	0.26
Á2	0.53	0.67	0.54	0.67	0.87	0.8	0.66	0.24	0.53	0.7	0.36	0.8	0.61	0.7	0.24	0.8	0.8	0.53	0.4
Á3	0.5	0.61	0.82	0.61	0.4	0.93	0.53	0.93	0.71	0.82	0.62	0.93	0.53	0.87	0.93	0.24	0.93	0.74	0.67
Á4	0.53	0.65	0.85	0.8	0.89	0.74	0.83	0.53	0.93	0.79	0.74	0.71	0.82	0.67	0.53	0.93	0.31	0.61	0.46
Á5	0.79	0.86	0.93	0.75	0.24	0.89	0.51	0.78	0.24	0.8	0.35	0.8	0.47	0.89	0.56	0.8	0.72	0.79	0.74
Á6	0.35	0.93	0.93	0.85	0.8	0.7	0.66	0.8	0.62	0.72	0.89	0.26	0.66	0.93	0.61	0.8	0.66	0.82	0.5
Á7	0.5	0.53	0.71	0.36	0.93	0.71	0.53	0.85	0.53	0.54	0.26	0.4	0.8	0.24	0.6	0.93	0.6	0.67	0.65
Á8	0.71	0.71	0.93	0.65	0.71	0.87	0.46	0.59	0.35	0.59	0.4	0.35	0.93	0.31	0.76	0.8	0.89	0.61	0.83
Á9	0.24	0.8	0.71	0.71	0.93	0.46	0.51	0.71	0.71	0.85	0.35	0.71	0.8	0.93	0.24	0.93	0.24	0.8	0.31
Á10	0.53	0.71	0.93	0.65	0.93	0.93	0.86	0.61	0.24	0.93	0.89	0.24	0.53	0.24	0.93	0.24	0.8	0.71	0.8
Á11	0.24	0.31	0.8	0.68	0.8	0.31	0.93	0.53	0.71	0.24	0.31	0.71	0.24	0.53	0.71	0.8	0.53	0.24	0.24

4. **Step 4:** Determining the Crisp normalized decision matrix ($Ɋ^{*}$) using Equation (14) and *Table 6*.
5. **Step 5:** Using Equation (15) and the weights resulting from T2NNS-AHP (ɰ) to get the Crisp-weighted normalized decision matrix ($Ɋ^{+}$).

Table 7: The Crisp weighted normalized decision matrix ($Ɋ^{+}$)

	Č 1.1	Č 1.2	Č 1.3	Č 1.4	Č 2.1	Č 2.2	Č 2.3	Č 3.1	Č 3.2	Č 3.3	Č 3.4	Č 4.1	Č 4.2	Č 4.3	Č 4.4	Č 5.1	Č 5.2	Č 5.3	Č 5.4
Á1	0.0011	0.0014	0.0019	0.0029	0.0016	0.0017	0.005	0.0025	0.0053	0.0043	0.006	0.0026	0.0041	0.0044	0.0089	0.0045	0.0031	0.0051	0.0047
Á2	0.0025	0.0029	0.0022	0.0037	0.0046	0.0057	0.007	0.0011	0.004	0.0054	0.0046	0.0039	0.0037	0.0059	0.0023	0.0051	0.0079	0.0052	0.0071
Á3	0.0023	0.0027	0.0033	0.0034	0.0021	0.0066	0.0056	0.0045	0.0053	0.0063	0.008	0.0045	0.0032	0.0073	0.0089	0.0015	0.0092	0.0072	0.0119
Á4	0.0025	0.0028	0.0034	0.0044	0.0047	0.0052	0.0087	0.0025	0.007	0.0061	0.0094	0.0035	0.005	0.0056	0.005	0.0059	0.0031	0.0059	0.0082
Á5	0.0037	0.0038	0.0038	0.0042	0.0013	0.0063	0.0054	0.0037	0.0018	0.0062	0.0045	0.0039	0.0029	0.0075	0.0054	0.0051	0.0072	0.0077	0.0131
Á6	0.0016	0.0041	0.0038	0.0047	0.0042	0.0049	0.007	0.0038	0.0047	0.0055	0.0114	0.0013	0.004	0.0078	0.0058	0.0051	0.0066	0.0079	0.0089
Á7	0.0023	0.0023	0.0029	0.002	0.0049	0.005	0.0056	0.0041	0.0039	0.0042	0.0034	0.0019	0.0049	0.002	0.0058	0.0059	0.006	0.0065	0.0116
Á8	0.0033	0.0031	0.0038	0.0036	0.0037	0.0061	0.0049	0.0028	0.0027	0.0045	0.0051	0.0017	0.0057	0.0026	0.0073	0.0051	0.0088	0.0059	0.0147
Á9	0.0011	0.0035	0.0029	0.0039	0.0049	0.0032	0.0054	0.0034	0.0053	0.0065	0.0045	0.0035	0.0049	0.0078	0.0023	0.0059	0.0024	0.0078	0.0055
Á10	0.0025	0.0031	0.0038	0.0036	0.0049	0.0066	0.0091	0.0029	0.0018	0.0071	0.0114	0.0012	0.0032	0.002	0.0089	0.0015	0.0079	0.0069	0.0143
Á11	0.0011	0.0014	0.0032	0.0038	0.0042	0.0022	0.0098	0.0025	0.0053	0.0018	0.004	0.0035	0.0014	0.0045	0.0068	0.0051	0.0053	0.0023	0.0042

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6. **Step 6:** Using Equations. (16) and (17) to Determine the ideal and anti-ideal solutions based on the maximum and minimum values of each criterion. as shown in *Table 8*.

Table 8: The ideal and anti-ideal solutions

	Ấ1	**Ấ2**	**Ấ3**	**Ấ4**	**Ấ5**	**Ấ6**	**Ấ7**	**Ấ8**	**Ấ9**	**Ấ10**	**Ấ11**
ς_{+i}	0.059	0.069	0.082	0.079	0.078	0.084	0.067	0.077	0.068	0.086	0.060
ς_{-i}	0.012	0.016	0.021	0.020	0.019	0.019	0.018	0.018	0.017	0.017	0.012

7. **Step 7:** Get the relative significance value for each alternative using Equations. (18) and (19).
8. **Step 8:** Ranking the Alternatives: Based on their relative significance values as shown in *Table 9*.

Table 9: The Rank of the alternatives

	Ấ1	**Ấ2**	**Ấ3**	**Ấ4**	**Ấ5**	**Ấ6**	**Ấ7**	**Ấ8**	**Ấ9**	**Ấ10**	**Ấ11**
Φ	0.083	0.086	0.096	0.093	0.093	0.099	0.084	0.093	0.086	0.103	0.083
Rank	10	7	3	5	6	2	9	4	8	1	11

VIKOR:

By Applying the VIKOR method in this research, the reliability of the decision outcomes has been enhanced, and the consistency of the results from two different MCDM approaches. the VIKOR method has been applied as follows:

1. **Step 1:** Determining the values of the Λ^{+} and Λ^{-} Indexes for each criterion and it is shown in *Table 10*, The values are calculated using the same crisp aggregated Decision matrix (ꟷ) resulting from step 3 in the COPRAS method in *Table 6* using Equations. (20) and (21).

Table 10: The values of the $\Lambda^{+}$and Λ^{-} Indexes for each criterion

	Č 1.1	**Č 1.2**	**Č 1.3**	**Č 1.4**	**Č 2.1**	**Č 2.2**	**Č 2.3**	**Č 3.1**	**Č 3.2**	**Č 3.3**	**Č 3.4**	**Č 4.1**	**Č 4.2**	**Č 4.3**	**Č 4.4**	**Č 5.1**	**Č 5.2**	**Č 5.3**	**Č 5.4**
Λ^{+}	0.24	0.31	0.93	0.85	0.93	0.24	0.93	0.24	0.24	0.93	0.89	0.93	0.93	0.93	0.93	0.93	0.93	0.82	0.83
Λ^{-}	0.79	0.93	0.47	0.36	0.24	0.93	0.46	0.93	0.93	0.24	0.26	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24

2. **Step 2:** The values of the Ç-Criterion for each alternative shown in *Table 11* are determined using *Table 10* and Equation (22). The Ç-criterion evaluates how each alternative approximates the ideal solution, using the best and worst values of each criterion.

Table 11: the Ç-Criterion and ϱ-Criterion values for each alternative and the rank of alternatives

Alternatives	**Ấ1**	**Ấ2**	**Ấ3**	**Ấ4**	**Ấ5**	**Ấ6**	**Ấ7**	**Ấ8**	**Ấ9**	**Ấ10**	**Ấ11**
Ç-Criterion	0.575	0.508	0.427	0.416	0.438	0.365	0.536	0.435	0.506	0.325	0.536
ϱ-Criterion	0.1	0.076	0.062	0.065	0.065	0.058	0.072	0.074	0.092	0.057	0.104
Ɣ	0.953	0.56	0.256	0.263	0.311	0.09	0.583	0.396	0.728	0	0.922
Rank	11	7	3	4	5	2	8	6	9	1	10

3. **Step 3:** Like the Ç-criterion, the ϱ-Criterion is shown in **Error! Reference source not found.**. It evaluates the difference of each alternative from the worst possible values for each criterion, considering the criteria weights. is calculated using **Error! Reference source not found.** and Equation (23).
4. **Step 4:** Using Equation (24) and the Ç-criterion and the ϱ-Criterion in *Table 10*, the VIKOR (Ɣ) index is determined for each alternative, where ƴ indicates the strategic weight, it is assumed that [ƴ = 0.5].

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5. **Step 5:** In this step, alternatives are ranked from highest to lowest based on their values for (Ϛ), (ϱ), and (Ɣ). The alternative with the smallest cumulative attribute values is the best or optimal choice. The rank of the alternatives is shown in *Table 13*.

5. Discussion

This section is an illustration of the results of the analysis using the methodology shown in Figure 1 to rank and choose the best strategies against the COVID-19 pandemic for Egypt. The results are based on the data collected from three experts.

At first, a presentation of the results resulting from the application of T2NN-AHP, offering a nuanced understanding of the criteria and sub-criteria based on their importance and impact. As shown in Table 12 by ranking the criteria based on their weights to see which criteria had the most impact on our decision. The top three criteria that have the most impact on our decision are Support for Affected Businesses, Food Security, and Compliance with Vaccination Programs.

Table 12: Ranking of the criteria.

Criteria	Weight (ɰ)	Rank
Č 1.1	0.02394974	19
Č 1.2	0.03109819	18
Č 1.3	0.03485555	15
Č 1.4	0.04030802	14
Č 2.1	0.04116529	13
Č 2.2	0.05348854	9
Č 2.3	0.07374116	2
Č 3.1	0.03398252	16
Č 3.2	0.04700225	11
Č 3.3	0.05792919	7
Č 3.4	0.07246322	3
Č 4.1	0.03140925	17
Č 4.2	0.04297899	12
Č 4.3	0.05721501	8
Č 4.4	0.06746293	6
Č 5.1	0.05082692	10
Č 5.2	0.067466	5
Č 5.3	0.06845142	4
Č 5.4	0.1042058	1

Let us demonstrate why "Support for Affected Businesses," "Food Security," and "Compliance with Vaccination Programs" are considered high-priority criteria:

- **Compliance with Vaccination Programs**: This criterion measures the impact of the intervention strategies on increasing the willingness and ability of the people to receive the COVID-19 vaccines. Achieving elevated levels of vaccination coverage is critical for achieving herd immunity, as it reduces the overall spread of the virus within the population, as well as prevents the emergence and spread of new variants or strains of the virus. And as it is seen that this criterion is not too high, because the vaccination campaign in Egypt faces many challenges, such as limited vaccine supply, low vaccine coverage, vaccine hesitancy, misinformation, and mistrust. Therefore, increasing compliance with vaccination programs can improve the immunity and protection of the population, as well as prevent the emergence and spread of new variants or strains of the virus.

- **Support for Affected Businesses:** This criterion measures the impact of the intervention strategies on maintaining or reestablishing economic activity, employment, income, and investment. This criterion is important because businesses play a crucial role in a nation's economic stability. Providing support to affected businesses helps mitigate economic downturns, preserves jobs, and supports the overall economic recovery. These businesses and sectors provide

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livelihoods and incomes for millions of people, as well as contribute to the GDP and tax revenues of the country. Supporting affected businesses during the pandemic is an investment in the long-term economic health of the nation.

- **Food Security**: This criterion measures the impact of the intervention strategies on protecting or enhancing food availability, access, utilization, and stability for the population. This criterion is important because food security is a critical component of a comprehensive pandemic response, ensuring that individuals and communities are resilient against both health and economic challenges. The pandemic has disrupted the food supply chains, increased food prices, reduced purchasing power, and affected the nutrition and health status of the people. Therefore, ensuring food security can prevent hunger, malnutrition, and disease, as well as it is intricately linked to social stability. When individuals have reliable access to food, it contributes to social cohesion, reduces stress, and helps maintain order within communities.

Subsequently, the COPRAS method contributes to the identification of the best strategy, conceding the trade-offs and synergies among different strategies. Then the VIKOR methodology adds depth to our analysis, considering the interrelationships and complex dynamics among the criteria. Through a systematic assessment, the strategies will be shown that exhibit the highest levels of efficiency and effectiveness in the context of Egypt's response to the pandemic.

The ranks of VIKOR and COPRAS methods are summarized and interpreted as shown in Table 13:

Table 13: Comparison between COPRAS and VIKOR rank

	Á1	**Á2**	**Á3**	**Á4**	**Á5**	**Á6**	**Á7**	**Á8**	**Á9**	**Á10**	**Á11**
COPRAS Rank	10	7	3	5	6	2	9	4	8	1	11
VIKOR Rank	11	7	3	4	5	2	8	6	9	1	10

According to the results of our Methodology using VIKOR and COPRAS, the best three strategies against the COVID-19 pandemic for Egypt are "Vaccination Campaign Acceleration," "Healthcare Capacity Expansion," and "Mass Testing and Contact Tracing", let's explore why "Vaccination Campaign Acceleration," "Healthcare Capacity Expansion," and "Mass Testing and Contact Tracing" are identified as the top three strategies for Egypt's response to the COVID-19 pandemic:

- **Vaccination Campaign Acceleration:** The result of this strategy when applying VIKOR method has the smallest cumulative attribute values of (Ϛ), (ϱ), and (Ɣ), and when applying the COPRAS method it has a high relative significance value (*Φ*), which means that this directly addresses the root cause of the pandemic by reducing the risk of infection, spread, and death from COVID-19, as well as increase the immunity and protection of the population. This strategy can also help restore the normal operation of the society and economy, as well as prevent the emergence and spread of new variants or strains of the virus.

- **Healthcare Capacity Expansion**: The result of this strategy when applying the VIKOR method has the second lowest cumulative attribute values of (Ϛ), (ϱ), and (Ɣ), and when applying the COPRAS method it has the second highest relative significance value (*Φ*), which indicate that this strategy can improve the quality and accessibility of healthcare services for the people, as well as increase the resilience and preparedness of the health system. This is vital for maintaining treatment availability, reducing mortality rates, and ensuring that the healthcare system can effectively respond to the evolving dynamics of the pandemic. Healthcare capacity expansion is essential for ensuring that the system remains robust and capable of addressing unforeseen challenges.

- **Mass Testing and Contact Tracing**: The result of this strategy when applying the VIKOR method has the third lowest cumulative attribute values of (Ϛ), (ϱ), and (Ɣ), and when applying the COPRAS method it has the third highest relative significance value (*Φ*), This strategy can notice and isolate the cases early and prevent further spread of the virus. This strategy can also help monitor the epidemiologic situation and evaluate the effectiveness of the intervention strategies. That strategy of gathering public support is more likely to succeed. Mass testing and contact tracing contribute to community cohesion by demonstrating a commitment to early intervention and containment.

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These three strategies are the best options for Egypt to choose when facing the COVID-19 pandemic, as they can achieve the best performance in terms of the criteria. These top three strategies are also consistent with the global evidence and best practices, as they have been recommended and implemented by many countries and organizations, such as the World Health Organization, the United Nations, and the European Union.

6. Conclusion

In navigating the complex landscape of Egypt's response to the COVID-19 pandemic, eleven different strategies have been evaluated, this paper journey has uncovered crucial insights into some MCDM methodologies such as AHP, VIKOR, and COPRAS combined with Type-2 neutrosophic sets. As we conclude this investigation, several key findings and overarching themes come to the fore, illuminating the path forward for effective pandemic management. The systematic application of the proposed methodology has highlighted the domination of three pivotal strategies: "Vaccination Campaign Acceleration," "Healthcare Capacity Expansion," and "Mass Testing and Contact Tracing." These strategies, identified as the most impactful through a scrupulous estimation of multiple criteria, form the base of a comprehensive and adaptive response to the challenges posed by the pandemic. It becomes apparent that the success of Egypt's response hinges on the cooperative deployment of these strategies or at least one of these strategies. Their interplay, as translated through the MCDM methodologies, reflects the need for an adaptable and multifaceted approach that matches public health imperatives, economic resilience, and societal cohesion. The insights assembled from this research offer not only a reflective analysis of Egypt's response but also a prospective roadmap for refining and fortifying strategies in the face of emerging challenges.

The methodologies employed in this paper aid as examples for future research endeavors, inspiring a continued dialogue on refining and advancing MCDM methodologies in the field of public health disasters. Therefore, the results of our methodology may not reflect the current or future situation of the pandemic in Egypt. The criteria and weights used in our analysis may not capture all the relevant and important characteristics of the pandemic, as they are based on our experts' judgment and preference and may not reflect the preferences or values of other stakeholders or decision-makers.

Future research can address these limitations by using more dependable or updated data sources or applying the same methodology with different criteria based on other experts' judgments, including more diverse and objective criteria and weights, and comparing different MCDM methods and techniques. Future research can also extend our analysis by considering other factors or scenarios, such as the environmental impact, political stability, or the uncertainty and risk of the pandemic. Also, can apply our analysis to other countries or regions.

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