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Assessment the Health Sustainability using Neutrosophic MCDM Methodology: Case Study COVID-19

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Abstract: As a result of the severe difficulties presented by the COVID-19 pandemic, a holistic response is required, one that takes into account both the urgent needs of patients and the long-term viability of healthcare institutions. This study aims to give a complete knowledge of the tactics and techniques necessary to maintain the continuing well-being of people and communities by examining the idea of health sustainability in the context of the COVID-19 pandemic. This study conducts a literature review to investigate the many facets of health sustainability, such as emergency preparedness, mental health care, health workforce support, health education and communication, research and innovation, international cooperation, and resilience in the face of pandemics. This study's results call attention to the necessity for universal healthcare access, mental health services, the upkeep of critical services, and international coordination as part of the COVID-19 response strategy. Societies may construct robust healthcare systems that can deal with the short- and long-term effects of the pandemic if they use a comprehensive strategy that takes into account social, economic, and environmental aspects. So, we used the concept of multi-criteria decision-making (MCDM) to deal with various criteria of health sustainability. The AHP MCDM method is used to deal with various criteria and give the weights of these criteria. The AHP used a comparison between various criteria, so we used the neutrosophic environment to deal with the vague data in the comparison process. The proposed framework is applied in the application of COVID-19.

Keywords: Neutrosophic Set, MCDM, Sustainability, Health, COVID-19

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1. Introduction

Worldwide, healthcare facilities, economies, and communities are all being tested by the COVID-19 epidemic. As the globe struggles to cope with the immediate effects of the pandemic, it is crucial to take a holistic and future-oriented strategy that not only solves the current health crisis but also guarantees the long-term viability of health institutions. This calls for health sustainability concepts to be included in COVID-19 response methods and policies [1], [2].

Promoting and maintaining health and well-being is at the heart of the notion of health sustainability, which recognizes the complex relationship between social, economic, and environmental issues and how they affect the health of people and communities. Health sustainability in the context of the COVID-19 pandemic requires a careful balancing act between responding to the virus's immediate effects and planning for the pandemic's longer-term effects on public health, healthcare systems, and the well-being of communities [3], [4].

The purpose of this article is to examine the many facets of health sustainability about the current COVID-19 outbreak. The goal of this study is to shed light on the most important factors to consider and steps to take to guarantee the long-term viability of healthcare systems and the continuous health of people and communities in the face of this ongoing problem [5]–[7].

This study intends to inform policymakers, healthcare providers, and academics on incorporating health sustainability principles into COVID-19 response plans by synthesizing current knowledge, data, and best practices. Despite the current epidemic, the results will help shape the creation of healthcare systems that can weather future storms without compromising the health of people or communities[8]–[10]. The characteristics of health sustainability, and the feasibility of using Multi Criteria Decision Making (MCDM) techniques were investigated in this research[11], [12]. Neutrosophic MCDM approaches have been proved to be useful in the decision-making process, and the outcomes of this application demonstrate the potential for considerable improvements in defect count and time to solution [13], [14].

2. Background

The COVID-19 has had a significant effect on world health. First discovered late in 2019, the virus has already caused a global pandemic that has impacted millions of people and put a burden on healthcare systems everywhere. The development of efficient response and mitigation methods requires an understanding of the health-related consequences of COVID-19 [15], [16]. Important health-related features of COVID-19 include:

COVID-19 is disseminated most often when an infected person coughs, sneezes, speaks, or breathes loudly, dispersing infectious virus particles into the air. The virus may also be transmitted from person to person by contacting infected surfaces and then touching one's own face. Fever, coughing, shortness of breath, exhaustion, muscular pains, loss of taste or smell, sore throat, and headache are all fairly typical symptoms. Controlling the spread of the virus might be difficult if some people show no symptoms but can still pass it to others [17], [18]. COVID-19 may cause moderate to severe sickness, with certain populations being at increased risk of severe disease. Hospitalization and mortality are more likely to occur in older persons and those with preexisting disorders such as cardiovascular disease, diabetes, chronic respiratory diseases, and weakened immune systems. However, even in healthy young people, serious sickness and problems may occur [19], [20].

The fast global spread of COVID-19 has put pressure on healthcare systems in all regions. Hospitals have been unable to cope with the influx of patients, which has resulted in a lack of essentials including beds, ventilators, and PPE. Workloads have grown, hours have become longer, and mental health issues have become more prevalent among healthcare employees.

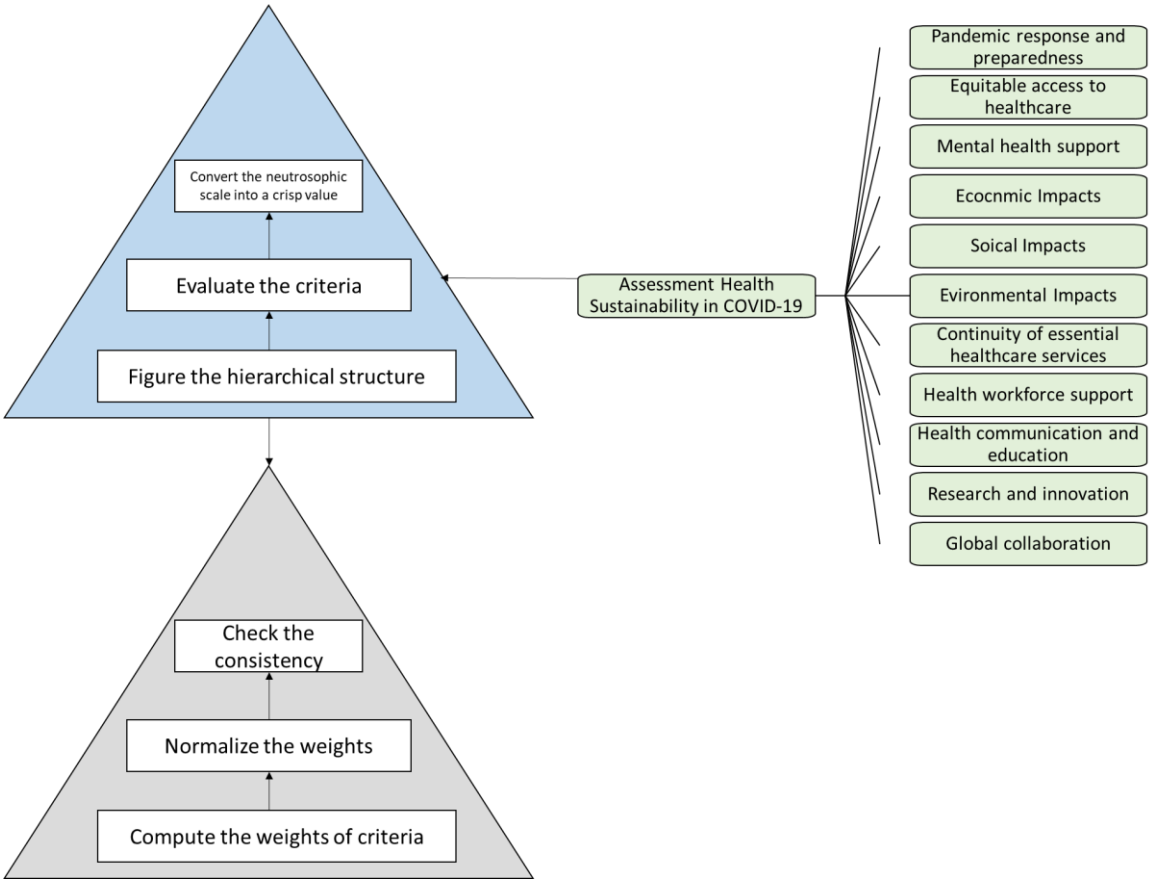

Figure 1. The relationsship between criteria and goal

Overall health outcomes have been negatively affected due to the interruption of normal healthcare services and the delay in diagnosing and treating various diseases.

Even in those with just a mild or moderate disease, COVID-19 may have lasting consequences. Long COVID occurs in some people after they have recovered from the acute phase of the virus. Chronic symptoms include sleepiness, shortness of breath, mental cloudiness, aches and pains in the muscles, joints, and chest, and heart. The chance of acquiring cardiovascular issues and mental health difficulties, for example, may be higher in COVID-19 survivors [21], [22]. The COVID-19 epidemic has had profound effects on people's mental health. Stress, anxiety, depression, and other mental health issues have grown in prevalence as a result of social isolation, fear of infection, economic insecurity, and the death of loved ones. Reducing the emotional toll of the epidemic has made it imperative that people have ready access to mental health care and support [23], [24]. The prevention of severe disease, hospitalization, and mortality due to COVID-19 may be greatly aided by vaccination. Many nations have produced and approved the use of vaccines for urgent situations, and there are continuous attempts to expand access to these vaccines in developing nations. In addition to vaccination, it is still important to take preventative measures against the transmission of the virus, including using masks, washing hands often, keeping a safe distance from others, and staying away from big gatherings [25], [26].

COVID-19 has shed attention to the inequities and disparities in health care that already exist in our countries. Higher infection rates, more severe sicknesses, and worse health outcomes have disproportionately affected marginalized groups, low-income people, racial and ethnic minorities, and persons with restricted access to healthcare facilities. For a thorough and successful

response to COVID-19, it is essential to address these inequalities and guarantee everyone has access to healthcare and resources [27], [28].

3. Material and Method

In this section we integrated the neutrosophic set with MCDM method such as AHP method to compute the weights of criteria. Among the several methods available for addressing MCDM issues, AHP is by far the most common. AHP is a methodical process for evaluating and prioritizing issues of great complexity. Hierarchical components such as goals, criteria, and alternatives are used to break down more complicated issues using this technique[29], [30].

Phase 1. Figure the hierarchical structure.

We draw the relationship between criteria and goal from this study as shown in Figure 1.

Phase 2. Evaluate the criteria. The criteria are evaluated by the experts by using linguistic scale of neutrosophic set.

$$A_{ij} = \begin{pmatrix} u_{11}^{k} & \cdots & u_{1n}^{k} \\ \vdots & \ddots & \vdots \\ u_{n1}^{k} & \cdots & u_{nn}^{k} \end{pmatrix} \quad (1)$$

Phase 3. Convert the neutrosophic scale into a crisp value.

Phase 4. Compute the weights of criteria.

$$w_i = \frac{\sum_{j=1}^{n}(u_{ij})}{n} \quad (2)$$

Phase 5. Normalize the weights.

$$w_i^m = \frac{w_i}{\sum_{i=1}^{m} w_i} \quad (3)$$

Phase 6 Check the consistency.

Verify that the comparison matrix used to make judgements is consistent. This is a function of the consistency rate (CR) and the total number of criteria (n) being compared. The CR ratio ensures that the pair-wise comparison matrix has been correctly evaluated.

$$Cosist = \frac{CI}{RI} \quad (4)$$

Where $CI\ and\ RI$ refer to the consistency index and random index

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

$$\lambda_{max} = \sum_{j=1}^{n}\left(w_j^m * \sum_{i=1}^{n} A_{ij}\right) \quad (6)$$

The pair-wise comparison matrix may be used without modification if CR is less than 0.1. If the neutrosophic AHP scheme's pair-wise comparison matrix lacks neutrosophic consistency, we

will use similar techniques to isolate the offending components and raise the level of consistency to an acceptable level.

4. Results and Analysis

This section applied the proposed method into eleven criteria in health sustainability in COVID-19.

When discussing COVID-19 and health sustainability, it is important to think about both the short- and long-term effects on public health and healthcare systems. Maintaining health and well-being, ensuring that everyone has access to healthcare, and reducing the strain on healthcare systems are all part of striking this balance as the pandemic response unfolds. Key factors in ensuring the long-term viability of health systems during the COVID-19 pandemic include:

Health sustainability in the face of a pandemic calls for tried-and-true methods of preventing the spread of COVID-19. To detect and control outbreaks, it is necessary to conduct extensive testing, contact tracing, and isolation procedures. Healthcare system capacity building and maintenance, medical supply security, and crisis response workforce preparation should all be prioritized in any emergency preparedness plan.

Access to Healthcare for All People: Ensuring that everyone can get the medical treatment they need during a pandemic is crucial to keeping the population healthy in the long run. Efforts should be made to provide healthcare services and information to underserved communities, low-income populations, and other vulnerable groups to reduce access inequities. Language, transportation, and technology divide in access to healthcare must all be overcome.

Support for Mental Health: The COVID-19 Pandemic Has Had a Serious Impact on People's Psyches. To ensure long-term health, it is essential to identify and manage mental health issues caused by the epidemic. Mental health services should be easily available, public awareness should be raised, and mental health aid should be included in pandemic response plans.

The provision of critical healthcare services must be maintained with COVID-19 response measures to ensure the long-term viability of the healthcare system. This includes making sure people can go to the hospital in an emergency and receiving treatment for chronic conditions. Care continuity may be achieved with fewer in-person visits by using methods like telemedicine and virtual consultations.

Sustaining health services during a pandemic depends critically on the health and morale of the healthcare workforce. Personal protective equipment (PPE), training, and mental health services should all be made available to healthcare providers to guarantee their safety on the job. The sustainability of the healthcare workforce must recognize and address the issues experienced by healthcare professionals, such as burnout and exhaustion.

Maintaining health during the COVID-19 epidemic requires constant and clear health communication. The public needs accurate and up-to-date information about the virus, preventative measures, testing, and vaccines. To stop the spread of the virus, health education initiatives may help people make better choices and adopt healthier habits. Supporting research and innovation for better diagnoses, treatments, and vaccinations is essential to ensuring long-term health in the context of COVID-19. The long-term health effects of COVID-19 should be studied, along with

the efficacy of various treatments and methods to prevent future pandemics. International Cooperation and Solidarity Are Necessary to Maintain Global Health During the COVID-19 Pandemic. An efficient international response may be achieved by the exchange of information, resources, and best practices across nations. Global health sustainability requires cooperation in the distribution of vaccines, the exchange of scientific data, and the aid of low-income nations with inadequate healthcare facilities.

Health sustainability concepts may be included in the response to the COVID-19 pandemic to lessen the severity of the pandemic's immediate health effects, safeguard vulnerable people, and construct healthcare systems that can better withstand future threats.

Phase 1. We draw the relationships between the assessment the health sustainability in the COVID-19 as shown in Figure 1. We collected 11 criteria to be evaluated by the neutrosophic AHP method.

Phase 2. We build the pairwise comparison matrix between criteria by using valued neutrosophic set by using Eq. (1).

Phase 3. We convert the neutrosophic number into one number, then we build the normalized pairwise comparison matrix as shown in Table 1.

Table 1. The normalized pairwise comparison matrix

	$HSCO_1$	$HSCO_2$	$HSCO_3$	$HSCO_4$	$HSCO_5$	$HSCO_6$	$HSCO_7$	$HSCO_8$	$HSCO_9$	$HSCO_{10}$	$HSCO_{11}$
$HSCO_1$	0.051626	0.020065	0.022589	0.045571	0.065108	0.065692	0.048289	0.059698	0.062203	0.042855	0.056067
$HSCO_2$	0.139907	0.054377	0.022499	0.045571	0.043963	0.06776	0.031134	0.040346	0.062096	0.081021	0.04861
$HSCO_3$	0.097591	0.103202	0.042701	0.045581	0.009401	0.018841	0.064755	0.105926	0.062203	0.042832	0.109288
$HSCO_4$	0.053609	0.056466	0.044333	0.047322	0.030386	0.018845	0.0266	0.057544	0.043562	0.061056	0.112884
$HSCO_5$	0.06031	0.094078	0.345481	0.118453	0.076061	0.054479	0.030152	0.076318	0.053939	0.074172	0.126937
$HSCO_6$	0.062501	0.063823	0.180251	0.199714	0.111038	0.079531	0.039817	0.05761	0.062203	0.061056	0.115347
$HSCO_7$	0.080791	0.131983	0.049832	0.134438	0.19063	0.150941	0.075569	0.04286	0.062203	0.042832	0.069767
$HSCO_8$	0.094553	0.147363	0.044077	0.089915	0.10897	0.150941	0.192778	0.109338	0.112859	0.061404	0.111395
$HSCO_9$	0.09798	0.103378	0.081043	0.128244	0.166473	0.150941	0.143422	0.11437	0.118054	0.099465	0.069767
$HSCO_{10}$	0.139831	0.077904	0.115722	0.089966	0.119032	0.151199	0.204794	0.206688	0.137768	0.116075	0.048202
$HSCO_{11}$	0.121301	0.147363	0.051472	0.055225	0.078936	0.09083	0.142691	0.129302	0.222911	0.317233	0.131735

Phase 4. We compute the weights of criteria by using Eq. (2) as shown in Figure 2.

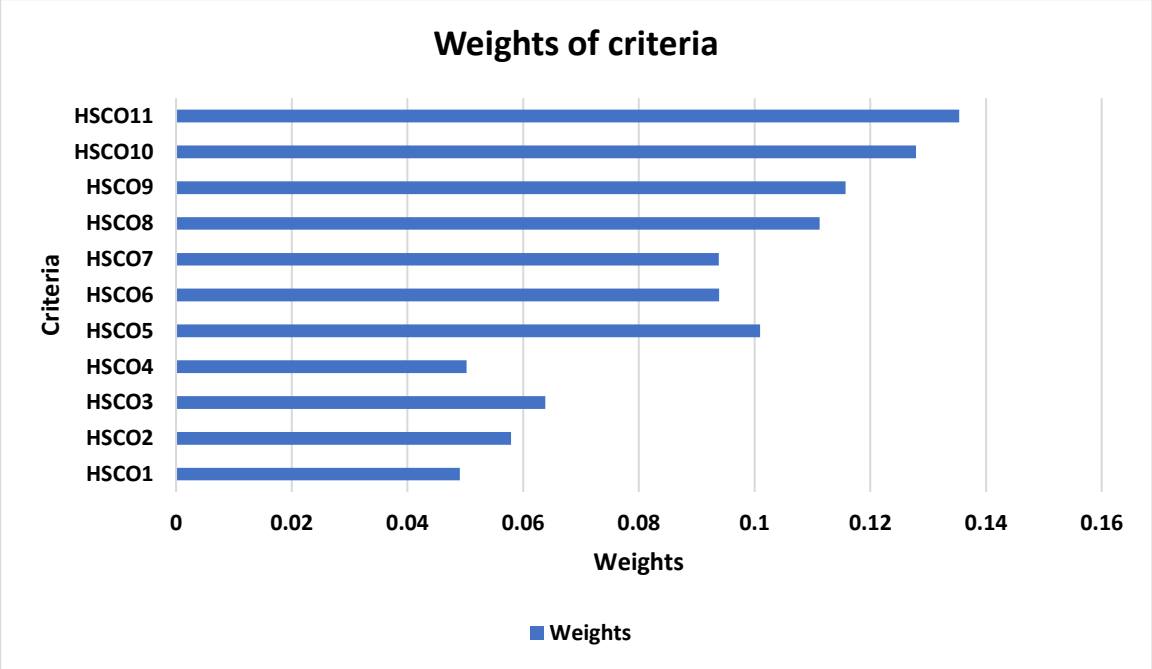

Figure 2. The weights of criteria in health sustainability in COVID-19.

Phase 5. Then we normalize the weights by using Eq. (3)

Phase 6. Then we check the consistency by using Eqs. (4-6). The consistency is less than 0.1. Health communication and support is the best.

5. Conclusions

The pandemic of COVID-19 has highlighted the significance of health sustainability in dealing with global health emergencies. This study provides insights and suggestions for policymakers, healthcare providers, and academics by examining the many elements of health sustainability in the context of the pandemic. The results indicate the need for an all-encompassing and coordinated strategy for health sustainability in reducing the effects of COVID-19. Pandemic planning, extensive testing, contact tracing, and isolation procedures have all been successful in stopping the spread of the virus. Protecting vulnerable populations and underserved areas requires prioritizing healthcare access for everyone. To combat the increasing mental health problems in people and communities, mental health care should be included in the response to the pandemic.

Maintaining the health of the community as a whole during a pandemic depends critically on the availability of basic healthcare services. Maintaining access to primary care, chronic disease management, and emergency medical services should be a top priority. Maintaining the health and resiliency of healthcare workers requires investment in areas such as personal protection equipment, training, and mental health services. Accurate information, encouragement of preventative action, and the development of sound judgment all stem from effective health communication and education. Establishing open and honest lines of communication is crucial for combating disinformation and giving

people access to fact-checked data. This research integrated the heath sustainability in COVID-19. This paper used the neutrosophic AHP method to compute the weights of criteria. The neutrosophic set is used to deal with inconsistent data in the evaluation process. Communication and support are the best.

Supplementary Materials

Not applicable.

Author Contributions

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, A.A. and A.S.; methodology, A.A.; software, A.A.; validation, S.L., A.S. and A.A.; formal analysis, S.L.; investigation, A.A.; resources, A.S.; data curation, A.A.; writing—original draft preparation, S.L.; writing—review and editing, A.A.; visualization, A.S. All authors have read and agreed to the published version of the manuscript.

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This article does not contain any studies with human participants or animals performed by any of the authors.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

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Data Availability Statement

All data generated and analyzed during this study are included in this manuscript.

References

[1] N. Ritmak, W. Rattanawong, and V. Vongmanee, "The dynamic evaluation model of health sustainability under MCDM benchmarking health indicator standards," *Int. J. Environ. Res. Public Health*, vol. 20, no. 1, p. 259, 2022.

[2] A. Abdelhafeez, H. K. Mohamed, and N. A. Khalil, "Rank and Analysis Several Solutions of Healthcare Waste to Achieve Cost Effectiveness and Sustainability Using Neutrosophic MCDM Model," *Neutrosophic Syst. with Appl.*, vol. 2, pp. 25–37, 2023.

[3] N. Ritmak, W. Rattanawong, and V. Vongmanee, "A New Dimension of Health Sustainability Model after Pandemic Crisis Using Structural Equation Model," *Sustainability*, vol. 15, no. 2, p. 1616, 2023.

[4] M. A. Taş and E. Çakir, "A hybrid fuzzy MCDM approach for sustainable health tourism sites evaluation," in *Handbook of Research on Advances and Applications of Fuzzy Sets and Logic*, IGI Global, 2022, pp. 77–104.

[5] T.-L. Nguyen *et al.*, "A novel integrating data envelopment analysis and spherical fuzzy MCDM approach for sustainable supplier selection in steel industry," *Mathematics*, vol. 10, no. 11, p. 1897, 2022.

[6] S. Salimian, S. M. Mousavi, and J. Antucheviciene, "An interval-valued intuitionistic fuzzy model based on extended VIKOR and MARCOS for sustainable supplier selection in organ transplantation networks for healthcare devices," *Sustainability*, vol. 14, no. 7, p. 3795, 2022.

[7] S. Seker, "IoT based sustainable smart waste management system evaluation using MCDM model under interval-valued q-rung orthopair fuzzy environment," *Technol. Soc.*, vol. 71, p. 102100, 2022.

[8] S. Moradi, G. Sierpiński, and H. Masoumi, "System dynamics modeling and fuzzy MCDM approach as support for assessment of sustainability management on the example of transport sector company," *Energies*, vol. 15, no. 13, p. 4917, 2022.

[9] M. Lowe *et al.*, "City planning policies to support health and sustainability: an international comparison of policy indicators for 25 cities," *Lancet Glob. Heal.*, vol. 10, no. 6, pp. e882–e894, 2022.

[10] W. Zhong, T. Schröder, and J. Bekkering, "Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review," *Front. Archit. Res.*, vol. 11, no. 1, pp. 114–141, 2022.

[11] R. Atassi and K. Yang, "An Integrated Neutrosophic AHP and TOPSIS Methods for Assessment Renewable Energy Barriers for Sustainable Developmen.," *Int. J. Neutrosophic Sci.*, vol. 18, no. 2, 2022.

[12] S. Karadayi-Usta, "A new servicizing business model of transportation: Comparing the new and existing alternatives via neutrosophic Analytic Hierarchy Process," *Neutrosophic Sets Syst.*, vol. 48, no. 1, p. 5, 2022.

[13] H. Yilmaz, S. Karadayi-Usta, and S. Yanık, "A novel neutrosophic AHP-Copeland approach for distance education: towards sustainability," *Interact. Learn. Environ.*, pp. 1–23, 2022.

[14] J. Reig-Mullor, A. Garcia-Bernabeu, D. Pla-Santamaria, and M. Vercher-Ferrandiz, "Evaluating ESG corporate performance using a new neutrosophic AHP-TOPSIS based approach," *Technol. Econ. Dev. Econ.*, vol. 28, no. 5, pp. 1242–1266, 2022.

[15] A. Sotoudeh-Anvari, "The applications of MCDM methods in COVID-19 pandemic: A state of the art review," *Appl. Soft Comput.*, p. 109238, 2022.

[16] A. H. Alamoodi *et al.*, "Systematic review of MCDM approach applied to the medical case studies of COVID-19: trends, bibliographic analysis, challenges, motivations, recommendations, and future directions," *Complex Intell. Syst.*, pp. 1–27, 2023.

[17] A. Puška, Ž. Stević, and D. Pamučar, "Evaluation and selection of healthcare waste incinerators using extended sustainability criteria and multi-criteria analysis methods," *Environ. Dev. Sustain.*, pp. 1–31, 2022.

[18] K. S. Poutanen *et al.*, "Grains–a major source of sustainable protein for health," *Nutr. Rev.*, vol. 80, no. 6, pp. 1648–1663, 2022.

[19] S. M. U. Islam, S. Khan, H. Ahmad, M. A. U. Rahman, S. Tomar, and M. Z. Khan, "Assessment of challenges and problems in supply chain among retailers during COVID-19 epidemic through AHP-TOPSIS hybrid MCDM technique," *Internet Things Cyber-Physical Syst.*, vol. 2, pp. 180–193, 2022.

[20] S. Ahmad *et al.*, "Analysing the impact of COVID-19 pandemic on the psychological health of people using fuzzy MCDM methods," *Oper. Res. Perspect.*, vol. 10, p. 100263, 2023.

[21] A. Memarpour Ghiaci, H. Garg, and S. Jafarzadeh Ghoushchi, "Improving emergency departments during COVID-19 pandemic: a simulation and MCDM approach with MARCOS methodology in an uncertain environment," *Comput. Appl. Math.*, vol. 41, no. 8, p. 368, 2022.

[22] T. Ali, K. Aghaloo, Y.-R. Chiu, and M. Ahmad, "Lessons learned from the COVID-19 pandemic in planning the future energy systems of developing countries using an integrated MCDM approach in the off-grid areas of Bangladesh," *Renew. Energy*, vol. 189, pp. 25–38, 2022.

[23] S. Ghosh and M. Bhattacharya, "Analyzing the impact of COVID-19 on the financial performance of the hospitality and tourism industries: an ensemble MCDM approach in the Indian context," *Int. J. Contemp. Hosp. Manag.*, vol. 34, no. 8, pp. 3113–3142, 2022.

[24] L. H. de Andrade, J. J. M. Antunes, A. M. A. de Medeiros, P. Wanke, and B. P. Nunes, "The impact of social welfare and COVID-19 stringency on the perceived utility of food apps: A hybrid MCDM approach," *Socioecon. Plann. Sci.*, vol. 82, p.

101299, 2022.

[25] A. Siddiqua, J. N. Hahladakis, and W. A. K. A. Al-Attiya, "An overview of the environmental pollution and health effects associated with waste landfilling and open dumping," *Environ. Sci. Pollut. Res.*, vol. 29, no. 39, pp. 58514–58536, 2022.

[26] I. W. Suryasa, M. Rodríguez-Gámez, and T. Koldoris, "Post-pandemic health and its sustainability: Educational situation," *Int. J. Health Sci. (Qassim).*, vol. 6, no. 1, 2022.

[27] G. M. Magableh and M. Z. Mistarihi, "Applications of MCDM approach (ANP-TOPSIS) to evaluate supply chain solutions in the context of COVID-19," *Heliyon*, vol. 8, no. 3, 2022.

[28] T.-C. T. Chen and C.-W. Lin, "An FGM decomposition-based fuzzy MCDM method for selecting smart technology applications to support mobile health care during and after the COVID-19 pandemic," *Appl. Soft Comput.*, vol. 121, p. 108758, 2022.

[29] A. Karasan, E. Ilbahar, S. Cebi, and C. Kahraman, "Customer-oriented product design using an integrated neutrosophic AHP & DEMATEL & QFD methodology," *Appl. Soft Comput.*, vol. 118, p. 108445, 2022.

[30] B. Y. Kavus, P. G. Tas, E. Ayyildiz, and A. Taskin, "A three-level framework to evaluate airline service quality based on interval valued neutrosophic AHP considering the new dimensions," *J. Air Transp. Manag.*, vol. 99, p. 102179, 2022.