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Fuzzy Multi-Criteria Decision-Making for Sustainable Risk Management

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Abstract

Economic, environmental, and social sustainability challenges are critical to managing sovereign credit risk in the MENA region. This paper proposes a framework for selecting comprehensive strategies using a Fuzzy Multi-Criteria Decision-Making (MCDM) approach. A hybrid Best-Worst Method (BWM) and Fuzzy TOPSIS model are applied to rank sustainability strategies related to sovereign credit risk, addressing the vagueness and uncertainty in stakeholder data. Ten strategies are evaluated across three sustainability dimensions: economic, environmental, and social. The findings highlight that Developing Human Capital and Regional Cooperation and Trade Integration are top priorities for economic sustainability, emphasizing skill development and trade relations. Public-private partnerships and renewable energy investments are most viable for environmental sustainability, leveraging private capital for large-scale projects. Social sustainability is best achieved through public-private partnerships and renewable energy investments, which create jobs and improve energy access, promoting socio-economic stability. Political stability and governance reforms are identified as enabling factors for sustainability initiatives. This research contributes to the systematic body of knowledge on sovereign risk management in developing economies, offering a consistent framework for decision-makers in the MENA region to prioritize sustainable growth and creditworthiness amid uncertainty.

Keywords: *Sustainable Risk Management, Fuzzy Multi-Criteria Decision-Making, MENA Region, Sovereign Credit Risk, Sustainability Strategies.*

Introduction

Sustainable risk management (SRM) is slowly becoming the order of the day as countries and organizations face the world's sustainability challenges. SRM has grown to become a broad discipline that assesses the ESG (environmental, social, and governance) 1. factors towards risk evaluation and decision-making. Concerning the MENA region, SRM is especially necessary, as the material covers the economic, environmental, and social aspects of sustainability that are important for its stability and development. The purpose of this paper is to identify the criteria for the selection of the complex approaches to the management of sovereign credit risks via Fuzzy Multi-Criteria Decision-Making (MCDM). By leveraging a hybrid methodology combining the BWM and Fuzzy TOPSIS, the paper identifies and ranks ten key strategies for sustainability across the three dimensions: three types of sustainability: economic, environmental, and social.

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For a comprehensive comparison and assessment of the sustainability strategies based on the three dimensions of sustainability, this paper uses a Fuzzy Multi-Criteria Decision-Making (MCDM) framework. Since the data regarding stakeholders is vague and uncertain, the BWM in combination with the Fuzzy TOPSIS should be applied. This unique combination of quantitative and qualitative data enables one to compare the costs and benefits and the efficiency of measures aimed at attaining sustainable development goals. The BWM is used to determine the weight of challenges and the Fuzzy TOPSIS is used to rank the strategy according to the performance of the multiple criteria against the challenges. This approach offers a sound and stable decision methodology that is useful, especially to the decision-makers in the MENA ranging in the field of sustainable development given the fact that the goals are numerous and yet uncertain.

It gives directions to the policymakers and stakeholders in the MENA region about what types of sustainability efforts should be given priority for enhancing sustainable economic prospects, environmental safety, and social well-being. The areas such as human capital development, regional integration in trade, partnerships with PPPs, and renewable energy investments are highlighted as relevant for sustainable development in the region. Furthermore, the paper suggests political stability and governance reforms as two key antecedents that underlie sustainable risk management and enhancing sovereign credit ratings.

Thus, this paper fills the gap in the literature on sustainable sovereign credit risk management and presents a feasible and customizable decision-making approach for the MENA region. Finally, this research has demonstrated how the Fuzzy MCDM method underlines the need to incorporate sustainability into risk management and highlights critical practical implications of sustainable growth and creditworthiness in the region's multifaceted environment.

Literature Review

Sustainable risk management (SRM) has, therefore, evolved into one of the most important subjects of research under sustainable development and corporate management. It can be seen that SRM extends the environmental, social, and governance (ESG) factors into risk management to preserve sustainability (Dikau and Volz, (2021), Korkmaz, (2022)). Regarding the critical issues facing the global environment such as climate change, depletion of natural resources, and inequality, several scholars have pointed out that SRM should encompass (Becker, (2023), Jabareen, (2013)). Mainly, sustainability is applied to risk management strategies to reduce adverse consequences and unlock opportunities connected with the shift to a sustainable economy (Gleißner, et al., (2022)). Thus, when speaking about sovereign decision-making, SRM can be considered appropriate as governments aim to achieve SDGs or sustainable development (Yazo-Cabuya et al., (2024), Moyer and Hedden (2020)).

Sustainable Risk Management

As one of the branches of SRM, ESG is compared to the traditional risk management approaches to enhance sustainable development (BenHamida et al., (2024)) and protect organizations. It is used by people indicating finial threats and risks to mention that modern tasks are connected and can't be solved separated from climate change, resource scarcity, and social injustice (Hurlbert, et al., (2019)).

Concept and Importance of SRM: SRM is linked to the risk assessment phase and the mitigation of the potential risks related to an organization's sustainability strategy. Such items refer to both the company's related and financial and operative items as well as the environmental and social

ones. Some of the conventional tools and methods concerning the measurement of risks are computed primarily for the financial risks and the variability of operations while excluding the ecological and social consequences. On the other hand, it has been mentioned that the ESG factor integrated into SRM; therefore, enables organizations to reduce risks effectively (Shah et al., (2024)). Below are the reasons that notify why ESG factors' integration into risk management is significant. Thus, it will be possible to determine which areas relate to practice concerning the applicability of this theory in the context of the organization's creativity to foster its competitiveness in the marketplace. For example, buying renewable power or adopting a green supply chain is said to involve a reduction in expenditure and the company's stature (Fontes and Freires, (2018)). Second, integration gives a chance to foresee the changes in the legislation and trends in society which may result in legal and reputational consequences (Karwowski and Raulinajtys-Grzybek, (2021)). Furthermore, it is also a problem for SRM to ensure that the organization can sustain and extend the organizational business operations in the long run by creating key instruments for carrying out business activities that may alter over time and environmental context (Bacciu, et al., (2012)).

Applications of SRM: The trend of the use of SRM has been discussed in many fields in the recent literature, and the effectiveness of the concept is evident (BenHamida et al., (2024)). For this particular reason, the deliberate use of SRM practices in the field of finance complements the positive established financial performance in terms of volatility reduction and enhancing risk-adjusted returns (Zhang and Ortiz, (2021), Ching et al. (2021)). For instance, the companies that take under consideration the ESG factors with the risk management frameworks include banks and investment firms to are capable of addressing types of the more profound monetary impacts resulting from environmental and social disturbances. In the case of the manufacturing industry, SRM helps the various firms manage different risks linked to the supply chain and the ability to meet the set environmental standards. Sustainable activities are incorporated in a manner that guaranty manufacturers not to be a source of hazard to the environment and at the same time facilitate cost savings of cost which come with wastage (Kt and Sarmah, (2021), Korkmaz, (2022), Razak et al. (2024)). The presented SRM frameworks are crucial to attaining sovereign decisions in public administration. Therefore, SRM is used by governments because it enables the achievement of the SDGs and adopts and sustainable economy. For instance, Ferri and Acosta,(2019) explain how sustainability incorporation in risk management allows governments to dodge risks that they are unable to foresee such as climate change and instability in societies. In this way, policy development becomes easier as a way of promoting resilience and development since one does not wait to be adverse before counteracting these outcomes. Similarly, Alhejaili, Mohammad Omar writes about Saudi Arabia's consideration of climate risk and sustainability goals within the country's financial legislation to enhance green finance, about Vision 2030 through a qualitative research method including literature analysis, interviews of professionals, and analysis of green finance documents (Alhejaili, (2024)). There is a list of the particular cases that prove the efficiency of SRM: For instance, the Norwegian Government Pension Fund Global (GPFG) has incorporated ESG factors in selecting its investments because the long-term risks must be managed to assure the returns' sustainability (Angell-Hansen, and Meling, (2021)). Because of such an investment approach, GPFG is economically stable, and in addition, it is actively helping to eliminate negative trends in businesses, withdrawing from non-eco-friendly companies, and investing in green energy. Another good example is Unilever which has aligned the SRM to the firm's strategic plan through the Unilever Sustainable Living Plan. This is a strategy that seeks to reduce the negative effects of the firm's actions and decisions on the natural environment, as well as enhance the number of upbeat influences in the lives of the

parties that show an interest in the firm, individuals' well-being, and their health. The incorporation of ESG criteria for risk management at Unilever has helped to realize a lot of cost savings, innovations, and growth (PLC, (2021)). In contrast with the latter, Nkwo et Al.(2024) examine the impact of ESG reporting on Unilever, and thus, notice a positive impact. These findings indicate that higher levels of sustainability lead to improved financial and dynamic performance besides enhancing stakeholders' trust and core corporate values (Nkwo et al. (2024)).

Economic Sustainability Challenges in MENA region

One of the key factors that have a direct impact on any region's development is its economic sustainability. The following are the economic pull factors that need to be discussed to determine how the economic challenges affect the outcome (Figure 1). This is a measure that is used to define; the extent to which high public debt (HPD) affects the capacity to finance sustainable development investments. The improvement of political stability, governance reforms, and transparency in, especially, public financial management can boost investor confidence and make room for development investments (Bousnina and Gabsi, (2023)). So-called oil-exporting economies and Dependence on Oil Revenues (DOR) are sensitive to price fluctuation. Venturing into new industries like communication, tourism, and manufacturing industries can help increase the economy and thus come out of this sort of predicament (Matallah, (2022), Matallah,(2020)). This indicates that high YUN is due to an excessive supply of youth with a certain level of education about the demand or the market requirements (Farzanegan and Gholipour, (2021)). It is suggested that commitment to spending on education and vocational training especially in STEMS, entrepreneurship, and integration of regions into trade markets will generate more employment opportunities (Arayssi et al. (2023)). Small and Medium Enterprises (SMEs) suffer from major challenges regarding the ability to get access to the required finance also known as ATF (Yoshino and Taghizadeh-Hesary, (2018)). The interventions involve the development of economic empowerment activities and the utilization of Public Private Partnership which act as a source of financial support since they enhance innovation and employment opportunities (Harvie, et al., (2023)). Tariff and non-tariff barriers (TRB) pose a barrier and regulator to trade and economic liberalizations (Vakulchuk and Knobel, (2018)). These factors can be overcome through countermeasures that strengthen regional cooperation in the sphere of the economy (Agarwal, V (2024)) and increase the integration of trade (Feng et al., (2024), Pomerlyan and Belitski, (2024), Dhingra et al., (2023)).

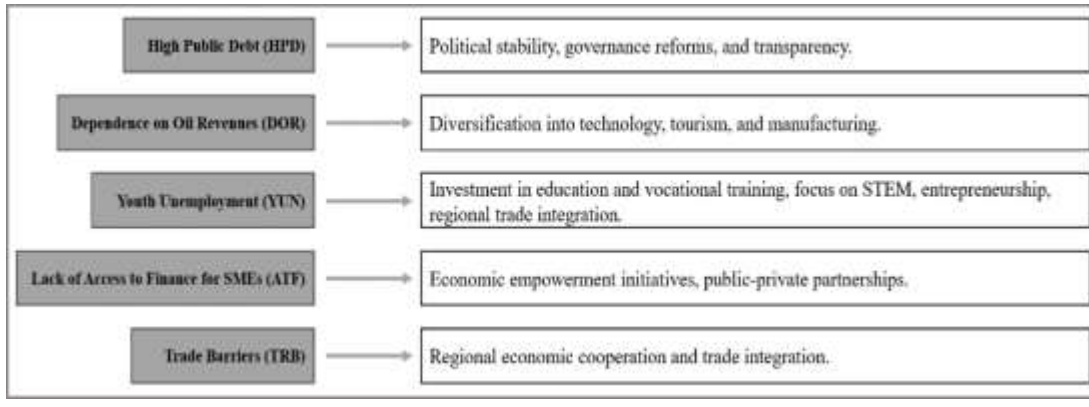

Figure 1. Economic sustainability challenges and solutions.

Green Finance and Sustainable Development

Green finance is underlined for its important role in steering development toward sustainability by directing funds to ecological projects (Lee, (2020)). It incorporates a broad category of green bonds, sustainable investments, and climate finance that attempt to finance projects that can promote sustainability (Gilchrist et al. (2021)). Environmental finance is crucial in the attainment of economic and social coherencies, especially where the 17 planned objectives have an association with the environment (UNEP, 2016) (Lee et al., (2022)).

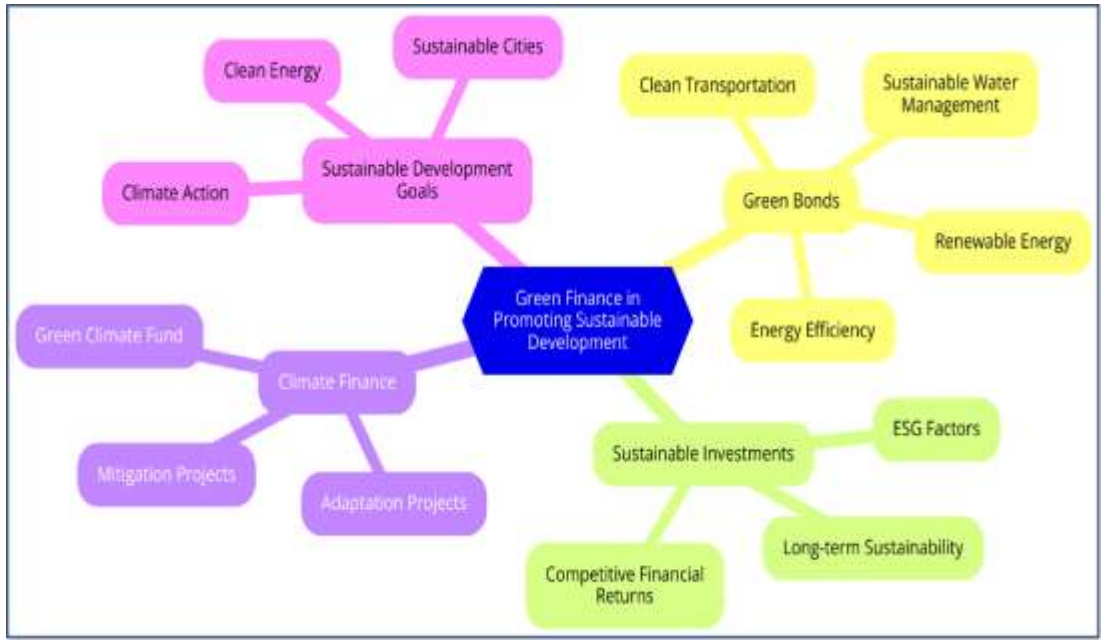

Figure 2. The relationship between green finance and sustainable development.

Green Bonds: Green bonds therefore are medium and long-term funding scheme instruments that are used to source funds for other environmental undertakings. Such bonds are employed as sources of financing activities such as renewable energy, efficient energy, green transport, and sustainable water management. Green bonds have lately emerged into the market and have only slightly developed mainly due to the investors' interest in green bonds as well as the support of the authorities. According to the findings of Flammer (2021), green bond helps in achieving environmental targets and green bonds do not harm the financiers' financial performance as lower cost of financing is paid and a higher enhancement of reputation can be received from green bonds.

Sustainable Investments: The elements of ESG are used by sustainable investments to make decisions concerning investment for sustainability. This investment strategy operates under the premise that the business corporations with higher ESG scores are more qualified for the future since this is fit for the future. In line with the conversation started by Friede et al. (2015) here, the authors extended the use of this assumption noting that sustainable investment can deliver on investment performance and sustainability goals. Sustainable investments appear as the new trend indicative of the readiness of investors to make sure that the recovery of their financial investment corresponds to sustainability.

Climate Finance: Climate finance therefore is focused on how to source and provide funds for mitigation and outcomes of climate change and the processes being undertaken to avert the impacts. Some of them are; funding of acquisition in renewable power, energy-efficient technologies, and climate proofing. Climate financing is crucial for developing nations chiefly because very few of them can afford climate change's effects. In the international systems, there are institutions like the GCF that have been established to pledge to climate finance and its realization in the more affected regions.

Consequently, green finances emerge as the preparation of the main instrument to combat climate change and is an effective mechanism for development. Still, green finance fosters funding for green initiatives, supports organizations to function sustainably, sparks creation, and applies SDG which supports the building block for the development of a sustainable global economy. Equally, green finance contributes to combating climate change through financing of renewable energy and energy efficiency, climate change initiatives, encouraging companies' accountability, and stating the shift to low-carbon finance. Thus, in connection with what has been shown in Figure 2, the place and importance of green finance in sustainable development is proved.

Social Sustainability Challenges in MENA region

Social sustainability focuses on improving the quality of life and ensuring equitable access to resources. Key social challenges include:

Political Instability (PIN): Uncertainty in political leadership kills any possibility of economic progress and disrupts the daily exercise of people's capabilities. Therefore, using political stability and governance, reforms, and raising the degree of openness, can lead to an increase in sovereign credit ratings and, respectively, stability (Kaplan and Akçoraoğlu, (2017)).

Gender Inequality (GIN): This outlines that gender inequality negates the possibilities of women's employment and future (Akhtar et al., (2023)). Such economic efficiency enhancement schemes that are associated with this site on gender equity can aid in helping to realize this difference.

Education Quality (EDQ): It also disqualified implying that many nations are in a capacity not to offer quality education. That is, access to modern technology and learning instruments and capital investment of people can promote sustainable human capital development and lifelong learning (Li and Xue, (2022)).

Healthcare Access and Quality (HAQ): Concerning the quality of the healthcare delivery system, it gets weakened, thus negatively affecting people and their productivity. In the writers' view, each country should align its healthcare policy with a suitable public-private partnership to enhance physical structure as well as services to the people to enhance overall health (Abbas et al., (2023)).

Social Inequality (SOI): Income and wealth disparity is arguably true in Fortson-Harwell and Marlotte, (2023) affecting the process of social integration and employment. A regard to maintaining and reducing the social disparity could be realized through funding in the education systems and vocational training for everyone.

Environmental Sustainability Challenges in MENA region

One can learn that the element of environmental sustainability plays a significant role in reducing

climate change and conserving the resources' stability. Other works, devoted to this subject, reveal several key questions that must be solved to achieve sustainability Jaheer et al., (2024). Climate Change Resilience (CCR) is important, particularly for the regions that are sensitive to the impacts of climate change and for which funds spent for resilience projects can significantly reduce the risk of getting exposed (Mehryar et al. (2022). Another key concern is Renewable Energy Development (RED) as a shift from fossil to clean sources such as Solar and Wind will reduce GHG emissions and also help to increase energy security as concluded in the research (Haqqi et al., (2023)). Concerning WRM (Water Resource Management), there is much discussion since the demand increases continuously, and water usage needs improved methods, techniques, and technology. Sustainable Urban Development (SUD) which includes environmentally sensitive infrastructure in a city through public transportation and solutions to the effects of sprawl on the environment is recommended in the urban planning literature (Montwiłł et al., (2021)). Lastly, Pollution Control and Management (PCM) is also a considerable area, because the analysis indicates that increasing the Environmental and Public Health Standards it is essential to apply strict regulatory measures and Pollution Control Technologies (Aridi and Yehya, (2022)). Together, these areas explain the interdisciplinarity as essential for environmental sustainability in the society of the 21st century and the large problem space that characterizes the challenge of climate change.

Methodology

To understand the strategies that must be adopted to overcome the challenges associated with it, the current study adopts a mixed-method approach, wherein the best-worst method is used to calculate the weights of the challenges. These weights are then used in the calculation of Fuzzy TOPSIS, which is utilized to evaluate strategies in sustainable sovereign credit. It was challenging to obtain precise and deterministic data from the stakeholders, instead, the data obtained was vague, incomplete, or subject to ambiguity. The Fuzzy TOPSIS is used to manage this uncertainty by allowing authors to work with fuzzy or imprecise information. In the current situation, there is a need to make decisions with multiple criteria or alternatives, hence, Fuzzy TOPSIS is applied. This approach considers both the benefits and drawbacks of each alternative about multiple criteria, making it suitable for ranking or selecting the best option when there's uncertainty or vagueness in the criteria or data.

Challenges for Sustainable Sovereign Credit

Initially, challenges are identified from the extant literature review as listed in Table 1. We have three main categories of challenges: economic, environmental and social, each of these have sub-challenges. .

Table1: Challenges for Sustainable Sovereign Credit

Challenge	Sub-Challenge	Notation	Description	Reference
Economic Sustainability Challenges	High Public Debt	HPD	High levels of public debt limit the ability to invest in sustainable development projects. Enhancing political stability, governance reforms, and transparency in public	Bousnina and Gabsi (2023). Hamida, H. B (2023)

			financial management can improve investor confidence and create fiscal space for development investments.	
	Dependence on Oil Revenues	DOR	Economies heavily reliant on oil exports are vulnerable to oil price volatility. Diversifying into other sectors such as technology, tourism, and manufacturing can stabilize economies and reduce this dependency.	Matallah (2020), Matallah (2022b).
	Youth Unemployment	YUN	High youth unemployment rates are caused by a mismatch between educational outcomes and job market needs. Investing in education and vocational training, particularly in STEM fields, entrepreneurship, and regional trade integration, can create more job opportunities.	Fakih et al. (2020)
	Lack of Access to Finance for SMEs	ATF	Small and Medium Enterprises (SMEs) face significant barriers to accessing finance. Creating economic empowerment initiatives and leveraging public-private partnerships can provide necessary financial support, fostering innovation and job creation.	Bakhouche, (2022).
	Trade Barriers	TRB	Tariff and non-tariff barriers restrict trade flows and economic integration. Enhancing regional economic	Aboushady et al. (2022)

			cooperation and trade integration can remove these barriers, fostering economic growth and stability.	
Social Sustainability Challenges	Political Instability	PIN	Political instability undermines economic growth and disrupts everyday life. Implementing political stability and governance reforms, along with enhancing transparency, can improve sovereign credit ratings and overall stability.	Sofuoğlu and Ay, (2020).
	Gender Inequality	GIN	Gender inequality affects women's participation in the workforce and access to opportunities. Economic empowerment initiatives that provide economic incentives for gender equity can help bridge this gap.	Ryan (2022)
	Education Quality	EDQ	The quality of education varies significantly, with many countries struggling to provide high-quality education. Providing access to modern technology and digital learning tools, along with investing in human capital, can promote lifelong learning and workforce development.	Saud et al. (2023), Awad (2021), Thorpe et al. (2010)
	Healthcare Access and Quality	HAQ	Inadequate healthcare systems affect public health and productivity. Leveraging public-private partnerships can improve healthcare infrastructure and	Hamidi and Akinci, (2016).

			service delivery, enhancing overall health outcomes.	
	Social Inequality	SOI	Income and wealth disparities hinder social cohesion and economic mobility. Investing in education and vocational training can help reduce social inequality by providing equal opportunities for economic advancement.	Boutayeb and Helmert, (2011)
Environmental Sustainability Challenges	Climate Change Resilience	CCR	The MENA region is highly susceptible to the impacts of climate change, including extreme heat, sea-level rise, and desertification. Investing in climate resilience projects, such as flood defenses, sustainable agriculture practices, and urban green spaces, can mitigate these risks and enhance long-term economic stability and sovereign credit ratings.	Namdar et al., (2021), Waha et al., (2017)
	Renewable Energy Development	RED	The region's reliance on fossil fuels for energy production contributes to economic vulnerability and environmental degradation. Expanding investments in renewable energy sources like solar and wind can reduce energy costs, lower carbon emissions, and increase energy security, thereby positively influencing sovereign credit	Razi and Dincer, (2022).

			assessments.	
	Water Resource Management	WRM	Water scarcity is a pressing issue in the MENA region, exacerbated by inefficient water use and infrastructure. Implementing advanced water management technologies and regional infrastructure initiatives, as well as public-private partnerships for desalination and water recycling projects, can improve water security and economic resilience.	Al-Gamal, (2021)
	Sustainable Urban Development	SUD	Rapid urbanization in the MENA region often leads to environmental degradation and infrastructure strain. Sustainable urban planning, including the development of eco-friendly housing, efficient public transport systems, and green infrastructure, can enhance livability and attract investment, thereby improving sovereign credit profiles.	Ben Hassen, and EI Bilali, (2024).

	Pollution Control and Management	PCM	Air and water pollution significantly affect public health and economic productivity in the MENA region. Strengthening regulations and investing in pollution control technologies through public-private partnerships can improve environmental quality, public health, and ultimately, economic performance, supporting stronger sovereign credit ratings.	Alharthi et al. (2022)

Data Collection

For this research, we selected a sample of respondents who work within the industry and possess substantial working experience with the relevant technologies. We conducted face-to-face and telephonic interviews to gather in-depth insights. Our questionnaire was thoughtfully formulated to comprehensively depict the risks we aimed to explore. The respondents were briefed on the objective of the study. After receiving their consent to participate we approached the participants for interviews. Overall, eight decision makers agreed to participate in the research; the list of the same is given in Table 2. The interviews helped us to understand and validate the challenges identified in the literature.

Table 2: List of Decision-Makers

S.No.	Decision Maker (DM)	Designation	Years of Experience	Industry
1	DM1	Chief Economist	15	Banking and Finance
2	DM2	Head of Risk Management	12	Sovereign Wealth Fund
3	DM3	Senior Credit Analyst	10	Investment Management
4	DM4	Director of Economic Research	18	Government Economic Agency
5	DM5	Sustainability Consultant	9	Environmental Consulting
6	DM6	Policy Advisor	11	Public Policy and Governance

7	DM7	Senior Portfolio Manager	14	Private Equity
8	DM8	Head of Sovereign Credit Strategy	13	Credit Rating Agency

Best Worst Method Implementation

- In the first step, the criteria for informed decision-making {c1, c2, …, cn} are determined by the authors and accepted by the decision-makers.
- The second step is to determine the best and worst-case scenarios from the specified parameters.
- Then, a vector of Best-to-Others (BO) is defined, which prefers the best criteria decision maker over others on a scale from 1 to 9.
- In the next step, a vector of Others-to-Worst is defined (OW), where decision-makers use the same segments
- Lastly, in Step Five, optimal weights are calculated, ensuring that the maximum absolute differences between the weights' ratios and the preferences are minimised. The consistency of these weights is then checked.

The weights of the challenges obtained in this step are used for prioritizing the strategies in the next step.

Fuzzy TOPSIS

In this step, Fuzzy TOPSIS methodology is used to prioritize the strategies utilized to evaluate strategies in cloud system implementation. The AHP deals with pairwise judgments; since the number of challenges and strategies at the alternative level are 8 and 10, the process will be more cumbersome. To overcome this difficulty, TOPSIS is a better choice, as it evaluates alternatives concerning each criterion. The views of the experts on the challenges and strategies for cloud computing are vague and subjective. It is prudent to integrate fuzzy set theory in decision-making as it can overcome the ambiguity in the opinions. The Fuzzy TOPSIS methodology is explained in the below steps, with more detailed steps provided in the appendix 1:

Step 1: Identification of the decision matrix

In this step, the views of various stakeholders are collected to assess the importance of the challenges over the strategies. Linguistic variables given in Table 3 are used to capture the opinions of the decision-makers.

Table 3: Linguistic ratings for strategy ranking

Linguistic term	Strategy (for pairwise comparison)
Not Important (NI)	(1,1,3)
Least Important (LI)	(1,3,5)
Moderately Important (MI)	(3,5,7)

Important (I)	(5,7,9)
Extremely Important (EI)	(7,9,9)

Step 2: Determination of consolidated fuzzy weights of challenges

Once the challenges were listed, we interviewed our targeted industrial experts. To quantify their opinions, we have used linguistic variables to measure their ratings in Table 3.

Step 3: Fuzzy scores of the pairwise comparisons

The impact of each indicator on each agile strategy is different. Hence, the inputs from the decision-makers aid in identifying this comparison. The five decision-makers express the rating of each challenge on each strategy as listed in Tables A1 to A5 (given in the appendix 1).

Step 4: Determination of fuzzy positive and fuzzy negative ideal solution

The fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) show the ideal solutions.

Step 5: Evaluation of the separation distances

The separation distance of the strategies is calculated using the FPIS and FNIS.

Step 6: Determination of the closeness coefficient and ranking of the strategies

The closeness coefficients of the strategies are calculated, and subsequently, the rankings of the strategies are identified.

Table 4: Strategies for Sustainable Sovereign Credit implementation in MENA region.

S.No	Notation	Strategies	Description	References
1	PSG	Political Stability and Governance Reforms	Enhancing political stability and governance is crucial for improving sovereign credit ratings. This can involve implementing democratic reforms, strengthening the rule of law, and ensuring transparency in government operations	Schomaker, and Bauer, (2020), Matallah, (2020).
2	EEI	Economic Empowerment Initiatives	Creating initiatives to make businesses more inclusive. Promoting gender equity by providing economic incentives	Nabut, (2014), Khalaf and Saqfalhait, (2020).
3	ATT	Access to Technology	Provide access to modern technology and digital learning tools to promote education and life long learning.	Cusolito et. al., (2022)

4	PPP	Public-Private Partnerships	Leveraging PPPs for infrastructure development can reduce the fiscal burden on governments and enhance the quality and efficiency of public services.	Ismail, (2020).
5	RII	Regional Infrastructure Initiatives	Promoting regional infrastructure projects to improve connectivity and economic integration.	El-Anis, I. (2021).
6	DoE	Diversification of Economies	Reducing dependence on oil by diversifying into other sectors such as technology, tourism, and manufacturing to stabilize economies.	Matallah (2020).
7	ERE	Enhancing Renewable Energy Investment	Investing in renewable energy sources like solar and wind can reduce reliance on fossil fuels and contribute to energy security. MENA countries have significant potential for solar energy, which can be harnessed through supportive policies and investment incentives.	Awijen et. al., (2022)
8	SGT	Strengthening Governance and Transparency	Enhancing transperency in public financial management can improve investor confidence. This includes adopting international standards for fiscal transparency and anti-corruption measures.	Schomaker, and Bauer, (2020)
9	DHC	Developing Human Capital	Investing in education and vocational training can boost human capital, leading to higher productivity and economic growth. Focus areas include STEM education, entrepreneurship, and skills development aligned with market needs.	Ibrahim, (2023)
10	RCT	Regional Cooperation and Trade Integration	Enhancing regional economic cooperation and trade integration can foster economic growth and stability.	Oumazzane, (2021)

Data Analysis

We categorize the challenges in the research process into three major sets: economic, environmental, and social. Although the risk management strategies are consistent across these categories, each set of challenges is evaluated independently. We apply the Best-Worst Method (BWM) for ranking the challenges within each category, thus obtaining specific weights for each. These are then used as weights in the TOPSIS ranking of the strategies in their effectiveness for any set of challenges. This will ensure that the peculiarities of economic, environmental, and social challenges are captured and reflected in strategy selection.

To ensure the integrity of the ratings, eight decision-makers were asked to assess the challenges multiple times, providing separate evaluations for each category. It is important to maintain the consistency and accuracy of the sets across all the challenge sets. The ensuing computations, done separately for each category, shall enable a nuanced understanding of how the strategies fare under different contexts so that the chosen risk management approaches will be apt for these various specific challenges in the economic, environmental, and social domains.

In case of the economic challenge, data has been collected through Best-Worst Method (BWM), for the eight decision-makers in this regard. Each decision-maker is asked to select the most and least important economic challenge as given in Table 5.

Table 5: Opinion of the decision makers for economic sustainability challenges

Economic Sustainability Challenges	DM1		DM2		DM3		DM4		DM5		DM6		DM7		DM8	
	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW
HPD	2	8	5	5	3	7	9	1	5	5	3	7	5	4	1	9
DOR	3	7	1	9	4	6	3	7	9	1	9	1	4	5	3	7
YUN	1	9	9	1	1	9	4	5	3	7	5	6	1	9	4	5
ATF	7	3	3	7	8	2	1	9	8	2	1	9	3	7	9	1
TRB	9	1	6	4	9	1	6	4	1	9	6	4	9	1	2	8

Based on these evaluations made by the decision-maker, a set of weights related to each economic challenge can be made through a pairwise comparison between the most and least important challenge. These weights reflect the relative importance of each challenge within the economic category as given in Table 6.

Table 6: Optimal weights for economic sustainability challenges

Economic Sustainability Challenges	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8
HPD	0.267	0.125	0.208	0.044	0.128	0.213	0.119	0.417

DOR	0.178	0.517	0.156	0.202	0.047	0.043	0.149	0.168
YUN	0.441	0.045	0.513	0.152	0.214	0.128	0.491	0.126
ATF	0.076	0.209	0.078	0.501	0.080	0.511	0.198	0.037
TRB	0.039	0.104	0.045	0.101	0.531	0.106	0.043	0.252

The same process was followed for the social and environmental challenges; this means unique characteristics from each set of challenges were considered in an independent manner, while keeping the methodology as consistent as possible across categories. Tables A1 and A2 provides the input of the decision makers. Figure 4 and Figure 5 shows the optimal weights of the environmental and social challenges respectively.

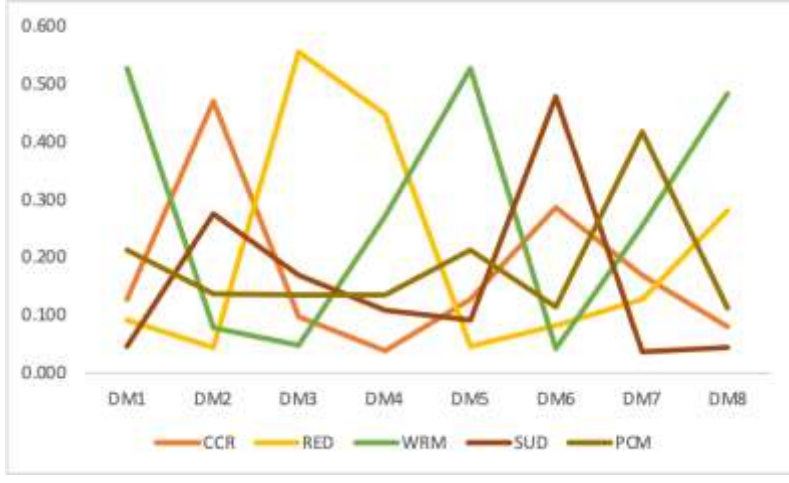

Figure 4: Optimal weights of the environmental challenges.

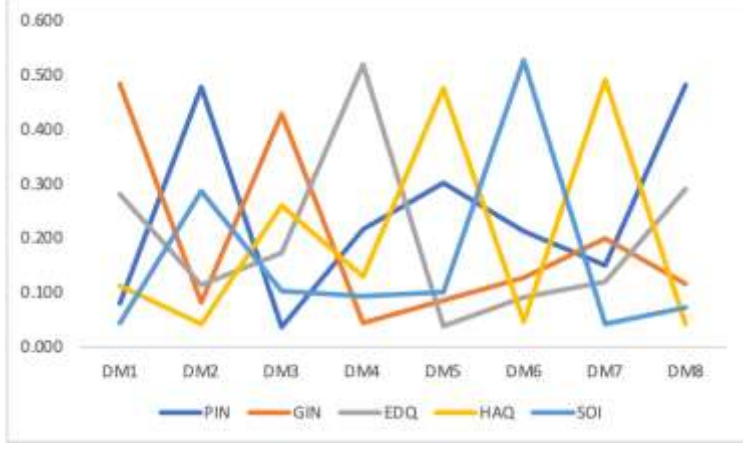

Figure 5: Optimal weights of the social challenges.

Further, Fuzzy TOPSIS is applied to rank strategies in terms of their ability to effectively respond to challenges associated with economic sustainability. The weights for challenges were established based on the Best-Worst Method (BWM). These weights are subsequently used within the Fuzzy TOPSIS to weigh various strategies. Below is a detailed explanation of each step, followed by the tables containing the necessary data and calculations.

The first step comprises the generation of a fuzzy decision matrix, in which we evaluate all strategies concerning economic challenges in sustainability. Each challenge is rated as to how important or effective it is, and is then translated through linguistic terms as Very Low, Low, Medium, High, and Very High fuzzy numbers. In the first step, the answers that the strategies offer are to the economic challenges. Each cell of the decision matrix in Table 7 represents a fuzzy rating assigned to a strategy by the first decision maker, in a similar manner data is collected from all the decision makers.

Table 7: Fuzzy rating assigned to a strategy by the first decision maker.

Notation	HPD	DOR	YUN	ATF	TRB
PSG	EI	I	I	I	MI
EEI	I	EI	I	I	EI
ATT	I	I	I	MI	MI
PPP	MI	I	EI	LI	LI
RII	I	EI	I	I	EI
DoE	MI	MI	EI	I	I
ERE	LI	MI	EI	MI	I
SGT	LI	I	EI	I	I
DHC	EI	EI	EI	EI	MI
RCT	LI	EI	I	I	MI

After constructing the fuzzy decision matrix, normalization is done in order to make values dimensionless. This gives a valid criteria comparison across different criteria. Normalization transforms the fuzzy number to comparable scales. Conventional normalization is done based on whether the criterion is beneficial or non-beneficial. After normalizing the decision matrix, the weights obtained from BWM are applied. These weights have been assigned based on the relative importance of each challenge belonging to economic sustainability. The greater the weight, the more significant the problem in the overall strategy appraisal. The weighted

normalized decision matrix is obtained by multiplying these weights with the normalized fuzzy decision matrix. We then calculate the Fuzzy Positive Ideal Solution and the Fuzzy Negative Ideal Solution. In words, FPIS stands for the best possible value for each challenge-the 'best' solution-and FNIS stands for the worst-for the worst case. For every criterion, in every strategy, the FPIS will be the maximum and the FNIS, the minimum. We then measure the distance from the FPIS and FNIS for each strategy using a technique called the distance measurement technique, Euclidean distance. The distance of each strategy from the FPIS indicates the closeness of that strategy to an optimal solution. Similarly, its distance from the FNIS measures the farthest distance it is from the worst possible outcome. Once the distances from FPIS and FNIS are calculated, we calculate the relative closeness of each strategy to the FPIS given in table A3-A5. The relative closeness score for each strategy will lie between 0 and 1, with a higher score indicating better strategy.

Tables 8: Optimal weights of the strategies for sustainability challenges

	Economic Sustainability Challenges		**Environmental Sustainability Challenges**		**Social Sustainability Challenges**	
Strategies	cci	Rank	cci	Rank	cci	Rank
PSG	0.247	10	0.579	2	0.352	8
EEI	0.285	9	0.578	3	0.347	9
ATT	0.402	6	0.573	4	0.327	10
PPP	0.383	7	0.594	1	0.472	1
RII	0.403	5	0.524	9	0.437	3
DoE	0.407	4	0.538	7	0.391	7
ERE	0.421	3	0.572	5	0.443	2
SGT	0.317	8	0.534	8	0.402	5
DHC	0.446	1	0.555	6	0.406	4
RCT	0.442	2	0.493	10	0.396	6

Discussions

With a robust risk management approach, the multifaceted challenges of sustainability for the credit management of sovereign states within the MENA region can be effectively placed on the horizon of analysis. Using the Best-Worst Method and combining it with Fuzzy TOPSIS, this study examines these challenges at economic, environmental, and social dimensions. This

mixed-method approach enables better decision-making under uncertainty, given that the data from stakeholders is very vague and ambiguous. In particular, this helps the authors to handle imprecision with the Fuzzy TOPSIS method, which offers a mechanism to rank strategies, considering both benefits and drawbacks.

Economic Sustainability Challenges

Economic sustainability is critical for the long-term stability of sovereign credit in the MENA region. The development of human capital (DHC) emerges as the strongest strategy to overcome the challenges facing economic sustainability with a cci of 0.446. Investment in education, skills development, and employment will thus help create a more resilient and diverse economy. Second is the Regional Cooperation and Trade Integration (RCT). That too shows the imperative of the MENA countries to seek much more intensive economic integration and cooperation that will yield better access to more significant markets while reducing the danger of economic isolationism. Following that are the Enhancing Renewable Energy Investments (ERE) and Diversification of Economies (DoE)** both of which have a cci value of 0.421 and 0.407, respectively.

These strategies align with the global focus on shifting towards renewable energy and the increasing trend of economic diversification away from oil reliance. Investments in renewables will reduce vulnerability to the price of oil shocks, whereas economic diversification can reduce systemic economic risks. Political Stability and Governance Reforms (PSG) is ranked lowest since it forms part of overall stability with a cci of 0.247 under economic sustainability. This may reflect complex political dynamics in the region that pose long-term economic risks but are harder to resolve in the short term.

Environmental Sustainability Challenges

The leading strategy from the point of view of environmental sustainability is ranked to be Public-Private Partnerships (PPP), with a cci of 0.594. This means both governments and the private sectors have to collaborate in assuaging some of these issues since it expedite resource mobilization, innovation, and the implementation of sustainable practices. The second strategy close behind is ranked with a cci of 0.579 as being Political Stability and Governance Reforms (PSG), which justifies the fact that there needs to be stable governance structures to enforce good environmental regulations and policies.

The second strategy is based on Economic Empowerment Initiatives (EEI) with a cci of 0.578. Therefore, in this regard, inclusive growth will directly relate to environmental sustainability if marginalized communities are empowered to be environmentally friendly. Regional Cooperation and Trade Integration (RCT) has the worst score at 0.493 for environmental challenges. It implies that even though regional cooperation is vital, perhaps it is not the most pragmatic solution immediately aimed at mitigating environmental risks.

Social Sustainability Challenges

In analyzing social sustainability, Public-Private Partnerships (PPP) top the ranking list with a cci score of 0.472 as a result of the role played by such cooperation mechanisms in improving welfare in society through enhancing jobs, infrastructures, and better service delivery. Renewable Energy Investments Enhancements (ERE) comes second with a cci score of 0.443; the social impacts of green energy investment include job creation in the renewable sector, reduced pollution with improved public health among others.

Although technology access is often trumpeted as an effective means for promoting social integration and development, its score for the cci is the lowest at 0.327. This sub-index indicates that while important, more urgent social imperatives in the region already supersede this one, which include governance reform and economic empowerment since there are pressing issues affecting social stability which have a direct impact on this aspect.

Cross-Cutting Themes and Strategic Implications

Some of the critical insights being gleaned from the cross-comparison of strategies across the three dimensions of sustainability point to the fact that across both environmental and social sustainability, strategies, such as PPPs, are at a premium, which means that using the resources and competencies of the private sector is considered essential in dealing with the problems facing the region. While DHC and RCT are catalysts for economic sustainability in this region, they also underscore labor demand in the region and stronger economic linkages as growth pathways to longer-term resilience.

One implication of the Fuzzy TOPSIS is that some strategies-maybe PPP and ERE-thrive in all directions, whereas others may be ranked in more focused attention in certain contexts. For instance, in the case of the PSG, a higher score in environmental sustainability but lagging behind in the economic and social fronts is evident. This therefore means that while governance reforms are important for ensuring sustainable environmental protection, economic and social benefits may come later.

Implications

Policy Implications

The results of this research have important policy implications for governments, financial institutions, and international organizations that intend to enhance sovereign credit risk management in the MENA region by sustainability strategies:

- Human Capital Development Governments should employ policies that can improve education systems, vocational training, as well as other forms of skill development. Improvement in human capital will not only enhance resilience within the economy but also be able to promote long-run growth through innovation and diversification. This is very coherent with worldwide trends on human capital investment since it increases productivity and competitiveness.
- Promote regional cooperation and trade integration. Regional organizations and trade bodies may strengthen economic cooperation within the MENA region. Policies promoting regional trade agreements, removing trade barriers, and encouraging crossborder investments will improve economic sustainability while reducing reliance on external markets, especially during an economic slowdown in other parts of the world.
- Public Private Partnerships for Environmental and Social Development. The law and incentives should be set up for PPP in critical sectors, such as infrastructure, renewable energy, and social services, to mobilize private sector funds, technologies, and expertise. It may facilitate gaining big funds, technologies, and capabilities relevant to huge investments in large-scale environmental and social projects.
- Motivate Renewable Energy Investment: The financial incentives, subsidies, regulatory,

and policy framework should be adopted by policymakers for the encouragement of renewable energy investment. Since environmental sustainability emerges to be one of the more critical factors in sovereign credit ratings, investment in renewable energies can be able to push these countries toward abandoning fossil fuel-based dependence and lessen associated environmental risks to the benefit of creditworthiness.

- Governance and transparency strengthening: Governance reform supporting better, more transparent governance approaches, anti-corruption, and institutional integrity will build a stable environment conducive to sustainable investments. Political stability and governance will be the critical enablers of all other sustainability strategies and must remain a high policy priority.

Theoretical implications

The theoretical contributions from this study are of paramount significance in the fields of sustainable risk management, decision science, and sovereign credit analysis:

- This research develops the application of decision-making frameworks by integrating Best-Worst Method to Fuzzy TOPSIS for establishing strategies that determine such strategies that evaluate themselves under uncertainty conditions. It overcomes past weaknesses of most traditional models since determinism was the primary source of data, thus making it more complex as a decision-making approach in terms of complexity and ambiguity surrounding the condition. This theoretical framework can also be developed further beyond sovereign credit about any domain of risk assessment.
- Sustainability as a multi-dimensional factor of sovereign credit risk The paper contributes to the literature with sustainability economic, environmental, and social turning into an essential factor behind sovereign credit risk. While much emphasis is given to macroeconomic variables in credit risk models, this research study develops the notion that sustainability's relative contribution to country-level creditworthiness is on an increase. This will eventually result in a change in the sovereign credit theory that gains its pace with regard to trends in sustainable finance and responsible investment.
- Cross-Cutting Role of Governance in Risk Management Frameworks: The paper draws the theoretical relevance of governance and political stability as foundational cornerstones for launching effective sustainability policies. By illustrating how reforms in governance allow economic, environmental, and social initiatives, this research contributes to a wider theoretical comprehension of institutional quality as a cross-cutting determinant in sovereign risk models.
- Context-Specific Strategy Prioritization in Emerging Economies: The paper extends previous studies by giving more detailed insight into how sustainability challenges and strategies vary by region. It helps open up the existing literature on the overall conditions of emerging economies, which are political, social, and environmental in nature - quite different from those experienced in developed markets. It reflects the importance of context-specific strategies and approaches to risk management when drawing on the conditions of developing regions.

Altogether, this research work presents a comprehensive theoretical and methodological framework with which to inter-weave sustainability into sovereign credit risk management, laying down the ground for future research in this very dynamically changing area of finance

and decision science.

Conclusion

The analysis of the findings of BWM-Fuzzy TOPSIS reveals that sustainable sovereign credit is unachievable in the MENA region only if this end is prepared for through a multi-pillared strategy. DHC, PPP, and ERE are crucial pillars in addressing economic, environmental, and social challenges in sustainability. This notwithstanding, such strategies should become high priorities for policymakers in the region to promote resilience and adaptability in a hyper-complex global environment. On the flip side of this coin, political instability and governance issues cannot be skipped over as they will have a direct bearing on the effectiveness of other strategies. Balanced short-term wins, combined with long-term reforms, will therefore be the key to sustainable risk management in the MENA region.

Limitations and future scope

This study provides significant insights in sustainable risk management strategy of the MENA region. However, there are some limitations to this study. First and foremost, the availability and accuracy of the data formed a considerable challenge. Stakeholder inputs on which this study depends are prone to be subjective, vague, or incomplete. Although the Fuzzy TOPSIS approach has been applied to deal with such uncertainties, inexact and detailed data might still influence results and final rankings. Thus, further studies should strengthen and standardize data collection mechanisms to enhance the level of precision. Geographical also, the conclusion and recommendation of the strategy are particular only for a region with specific political, economic, and social dynamics in MENA. Thus, the conclusions reached might not be applicable elsewhere in the world to regions or countries with different socio-political or economic contexts. Strategies can only be applied as a guideline or reference for other regions or areas in the world with similar contexts. Finally, the mixed-method approach of BWM and Fuzzy TOPSIS provides insight, but these methods are highly complex such that policymakers and practitioners who may not have a higher qualification in decision-making techniques would find them difficult to access. Simplification in such approaches or providing more practical tools for the stakeholders will enhance the implications of findings.

There is considerable scope for further extensions of results by this study in future research work. An important extension which would be much desirable relates to the extension of the geographical scope of analysis. Such studies can also be undertaken in other developing regions such as Sub-Saharan Africa or Southeast Asia where problems of sovereign credit risk and sustainability challenges are similar to those existing in the MENA region. Such comparisons would further enrich the understanding of how various regions go about managing sustainability risks in terms of sovereign credit. Sector-specific analysis could also be applied in further studies. While macro-level strategies are all management-driven, research that explores how specific sectors, such as the energy, agricultural, or technology sector, address the economic, environmental, and social sustainability challenges would bring better working insights. A more detailed approach, particularly sectoral, will enable the tailoring of risk management into the dynamics of the specific sector thus better guiding the practitioners in their domains.

Appendix 1

Fuzzy TOPSIS aims to identify the most suitable strategies (alternatives) based on the concept of the compromise solution. In this scenario, the compromise solution can be viewed as selecting the strategy with the minimum distance from the ideal solution and the maximum distance from

the negative ideal solution. The linguistic judgments of these experts were converted into triangular fuzzy numbers. We assume that there are *K* decision-makers $D=\{D_1, D_2, \ldots, D_k\}$, the agility indicators (criteria) be n, given as $I=\{I_1, I_2, \ldots, I_m\}$ and agile strategies (alternatives) be n given as $S=\{S_1, S_2, \ldots, S_n\}$. The opinions of the decision-makers are taken at an equal level, without giving preference to any. The weights of the criteria are denoted by decision-makers $\widetilde{w}_{jk}= \{e_j, f_j, g_n\}$, where $e_j=\min(e_{jk})$, $f_j=\frac{1}{K}\sum_{k=1}^{K} f_{jk}$ and $g_j=\max(g_{jk})$.

Similarly, we calculate the rating of the priority of the alternatives concerning each criterion for each decision-maker $\tilde{X}_{ij}= \{p_{ij}, q_{ij}, r_{ij}\}$, where $p_{ij}=\min(p_{ijk})$, $q_{ij}=\frac{1}{K}\sum_{k=1}^{K} q_{ijk}$ and $r_{ij}=\max(r_{ijk})$. Therefore, the fuzzy decision matrix is given as:

$$\widetilde{D} =.A_1\ A_2\ \vdots\ A_m\ |C_1\ \ C_2\ \ C_n\ \tilde{x}_{11}\ \tilde{x}_{21}\ \vdots\ \tilde{x}_{m1}\ \ \tilde{x}_{12}\ \ \tilde{x}_{22}\ \ \vdots\ \ \tilde{x}_{m2}\ \ \tilde{x}_{1n}\ \tilde{x}_{2n}\ \vdots\ \tilde{x}_{mn}$$

where *i=1,2,…,m ;j=1,2,…,n*

The linear transformation scale for comparison of the criteria can be helpful and less complex to use. Hence, we use the following formula for normalization in lieu of the complex normalization used in TOPSIS:

$$\tilde{A} = \left[\tilde{a}_{ij}\right]_{mxn} \quad i=1,2,\ldots,m\ ;j=1,2,\ldots,n$$

Where

$$\tilde{a}_{ij} = \left(\frac{p_{ij}}{r_j^*}, \frac{q_{ij}}{r_j^*}, \frac{r_{ij}}{r_j^*}\right) \text{ and } r_j^* = max\ r_{ij}\ (J \in benefit\ criteria)$$

$$\tilde{a}_{ij} = \left(\frac{p_j^-}{r_{ij}}, \frac{p_j^-}{q_{ij}}, \frac{p_j^-}{p_{ij}}\right) \text{ and } p_j^- = min\ p_{ij}\ (J \in cost\ criteria)$$

Construct the weighted normalized decision matrix $\tilde{V}$ by multiplying criteria weights $\widetilde{W}_j$with $\tilde{R}_{ij}$ as shown below:

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{mxn} \quad i=1,2,\ldots,m\ ;j=1,2,\ldots,n$$

Where $\tilde{v}_{ij} = \tilde{a}_{ij}(.)\widetilde{w}_j$

Determine fuzzy positive ideal solution (FPIS or B^*) and fuzzy negative ideal solution (FNIS or B^-) as follows:

$$B^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*)$$

Where $\tilde{v}_j^* = max(v_{ij})$ *i=1,2,…,m ;j=1,2,…,n* for benefit criteria

Where $\tilde{v}_j^- = min\ (v_{ij})$ *i=1,2,…,m ;j=1,2,…,n* for cost criteria

Calculate the separation measures for each alternative. The separation measures from FPIS and FNIS alternatives are calculated as follows:

$$d_i^+ = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_{ij}^+\right), \ i=1,2,\ldots,m$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_{ij}^-\right), \ i=1,2,\ldots,m$$

Where $d(\tilde{m}, \tilde{n})$ is the distance between two fuzzy numbers, calculated as:

$$d(\tilde{m},\tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

Calculating the relative closeness to the ideal solution for each alternative, the relative closeness of j[th] alternative with respect to PIS is calculated as follows:

$$C_i = \frac{d_i^-}{d_i^- + d_i^+}, \; i=1,2,\ldots,m$$

The index value C_i lies between 0 and 1. Rank the preference order of alternatives according to their relative closeness to the ideal solution.

Appendix 2

Table A1: Opinion of the decision makers for environmental sustainability challenges

	DM1		DM2		DM3		DM4		DM5		DM6		DM7		DM8	
Environmental Sustainability Challenges	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW
CCR	5	4	1	9	7	3	9	1	5	5	2	8	3	7	7	3
RED	7	3	9	1	1	9	1	9	9	1	7	3	4	6	2	8
WRM	1	9	7	3	9	1	2	8	1	9	9	1	2	8	1	9
SUD	9	1	2	8	4	6	5	5	7	3	1	9	9	1	9	1
PCM	3	7	4	5	5	5	4	6	3	7	5	4	1	9	5	4

Table A2: Opinion of the decision makers for social sustainability challenges

	DM1		DM2		DM3		DM4		DM5		DM6		DM7		DM8	
Social Sustainability Challenges	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW	BO	OW
PIN	7	3	1	9	9	1	3	7	2	8	3	7	4	6	1	9
GIN	1	9	7	3	1	9	9	1	7	3	5	4	3	7	5	5
EDQ	2	8	5	5	3	7	1	9	9	1	7	3	5	4	2	8
HAQ	5	4	9	1	2	8	5	6	1	9	9	1	1	9	9	1

SOI	9	1	2	8	5	4	7	3	6	5	1	9	9	1	8	2

Table A3: Rank of the Strategies for economic sustainability challenge

Strategies	d*	d-	cci	Rank
PSG	0.728	0.238	0.247	10
EEI	0.718	0.287	0.285	9
ATT	0.693	0.466	0.402	6
PPP	0.705	0.437	0.383	7
RII	0.687	0.463	0.403	5
DoE	0.688	0.473	0.407	4
ERE	0.664	0.484	0.421	3
SGT	0.737	0.343	0.317	8
DHC	0.667	0.537	0.446	1
RCT	0.669	0.529	0.442	2

Table A4: Rank of the Strategies for environmental sustainability challenge

	d*	d-	cci	Rank
PSG	0.458	0.631	0.579	2
EEI	0.461	0.631	0.578	3
ATT	0.482	0.647	0.573	4
PPP	0.437	0.640	0.594	1
RII	0.531	0.584	0.524	9
DoE	0.514	0.599	0.538	7
ERE	0.487	0.650	0.572	5

SGT	0.543	0.622	0.534	8
DHC	0.511	0.639	0.555	6
RCT	0.582	0.567	0.493	10

Table A5: Rank of the Strategies for social sustainability challenge

	d*	d-	cci	Rank
PSG	0.645	0.350	0.352	8
EEI	0.648	0.344	0.347	9
ATT	0.679	0.330	0.327	10
PPP	0.636	0.569	0.472	1
RII	0.636	0.494	0.437	3
DoE	0.655	0.421	0.391	7
ERE	0.632	0.502	0.443	2
SGT	0.635	0.427	0.402	5
DHC	0.625	0.427	0.406	4
RCT	0.649	0.426	0.396	6

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