Spectrum of Operational Research

Journal homepage: www.sor-journal.org
ISSN: 3042-1470

An Integrated Fuzzy Multi-Criteria Framework for Evaluation of Sustainable Communication Technologies

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ARTICLE INFO

Article history:
Received 23 November 2024
Received in revised form 9 January 2025
Accepted 17 February 2025
Available online 21 February 2025

Keywords:
Communication technologies; Fuzzy set; Multi criteria decision making; WENSLO; RAWEC.

ABSTRACT

Communication technologies are increasingly recognized as essential tools for advancing sustainability, offering solutions that support ecological responsibility, economic stability, and inclusive social progress. Recognizing their transformative potential, this study explores how such technologies contribute to sustainable development goals (SDGs) and presents a systematic approach for prioritizing them. To address the complexity and ambiguity involved in such complex evaluations, this study employs a fuzzy decision-making model, integrating the Fuzzy Weight by Envelope and Slope (F-WENSLO) method to derive the importance of evaluation criteria, followed by the Fuzzy Ranking Alternatives with Weights of Criterion (F-RAWEC) method to rank various communication technologies. The proposed model is applied to five communication technologies, including 5G Wireless Networks, Fiber Optic Communication Systems, Low Power Wide Area Networks, Wi-Fi 6, and Satellite Internet. Wi-Fi 6 emerged as the most sustainable, followed by Low Power Wide Area Networks, while Satellite Internet ranked lower. A high average correlation of 0.95 with other FMCDM methods confirms the reliability of the proposed model, making it a practical tool for sustainable technology selection. The robustness of the results is further supported by a sensitivity analysis. This research offers not only a rigorous evaluation framework but also valuable insights to inform investment decisions and policy development.

1. Introduction

Sustainable communication technologies hold significant potential to address the growing environmental challenges and resource scarcities in today's world. These technologies not only contribute to the preservation of natural resources but also support economic development and societal well-being, laying a solid foundation for a more livable future. However, evaluating sustainable communication technologies is a complex process that requires careful analysis of numerous factors. Key criteria in this evaluation include environmental impact, cost-effectiveness,

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https://doi.org/10.31181/sor21202529

societal benefits, user satisfaction, technological compatibility, and innovation. This study proposes a comprehensive analysis using a fuzzy multi-criteria decision-making (FMCDM) approach to select and prioritize sustainable communication technologies. FMCDM is an effective tool for managing uncertainty and complexities among different criteria, enabling a better understanding of the multidimensional nature of sustainable communication technologies [1,2]. In this context, the study aims to identify the most suitable technologies by detailing their strengths and weaknesses from a strategic perspective. This study offers a structured methodology for evaluating sustainable communication technologies using the proposed FMCDM framework, helping stakeholders make informed decisions. The findings enhance the understanding of how these technologies can be integrated into sustainable development strategies, ensuring a balanced focus on environmental, economic, and social goals. Weights by ENvelope and SLOpe (WENSLO) method has emerged as a significant approach in the field of MCDM. This method enhances decision-making accuracy by dynamically determining weight values, taking into account both envelope and slope properties. Recent studies have shown that WENSLO has a wide range of applications across various fields and is a robust method.

Peng *et al.,* [3] developed an integrated decision-making framework that combines q-rung orthopair fuzzy set theory with the WENSLO method to evaluate Internet of Things (IoT) platforms. In their study, subjective and objective weight assessment methods were combined to provide a rational and intuitive evaluation process. The importance of decision-makers' weight information, especially in uncertain environments, was emphasized. Pamučar *et al.,* [4] introduced WENSLO-alternative ranking technique based on adaptive standardized intervals (ARTASI) framework to assess airport efficiency. WENSLO was used to determine different weight sets for various airport categories. This method, integrated with ARTASI and Monte Carlo simulations, enabled a reliable and consistent evaluation of airport performance. Keleş [5] used WENSLO alongside other weighting methods to analyze trade facilitation indicators among E7 countries. The rankings obtained using multi-attributive border approximation area comparison (MABAC) and ARTASI methods demonstrated that WENSLO provides strong and differentiated weight allocations, enabling precise trade performance evaluations. Kara *et al.,* [6] developed an artificial intelligence-supported PF-WENSLO-alternative ranking using two-step logarithmic normalization (ARLON) hybrid method for sustainable brand logo selection. Similarly, Kara *et al.,* [7] applied an extended WENSLO-ARLON model with fuzzy set theory to measure sustainable brand value performance. Both studies confirmed the effectiveness of WENSLO in criterion weighting processes and demonstrated that the method is a reliable tool for sustainable brand evaluations. Demir *et al.,* [8] used fuzzy WENSLO (F-WENSLO) to evaluate occupational safety risks in the industrial sector. Their study showed how WENSLO, integrated with the fuzzy Bonferroni mean aggregation operator, can adapt to decision-making environments involving uncertainty, proving it to be a valuable tool in structuring occupational safety risk mitigation strategies. Trung *et al.,* [9] investigated the impact of different weighting methods, including WENSLO, on material selection in engineering design. The sensitivity analysis conducted in the study confirmed the stability and effectiveness of WENSLO in material ranking processes. Pamučar *et al.,* [10] proposed WENSLO- Aczel-Alsina Weighted ASsessment (ALWAS) method to evaluate green growth performance in G7 countries. This study highlighted ability of WENSLO method to objectively determine criterion weights and demonstrated that environmental factors are the most significant determinants of green growth.

Ranking of alternatives with weights of criterion (RAWEC) is a recently developed MCDM method to rank alternatives. RAWEC has been successfully applied in various fields and provides reliable results. Alrashdi *et al.,* [11] developed an MCDM model by integrating Neutrosophic Entropy and the RAWEC method to assess renewable energy risks. In their study, technical, environmental, safety, policy, and technological risks were identified and ranked using RAWEC method. Additionally, the potential of technologies such as artificial intelligence, blockchain, and IoT in mitigating these risks was examined. Trung *et al.,* [12] compared RAWEC method with simple additive weighting (SAW) and technique for order of preference by similarity to ideal solution (TOPSIS) to optimize the quality parameters of epoxy paints. The study determined the best component ratios for the paint in terms of criteria such as brightness, hardness, and impact resistance, demonstrating that the RAWEC method successfully ranked the alternatives. Trung *et al.,* [13] conducted an analysis on material selection in production and maintenance processes by comparing RAWEC and alternative ranking order method accounting for two-step normalization (AROMAN) methods. In the comparison using four different scenarios, the RAWEC method produced more stable results and was found to be more successful, particularly in the selection of cutting tool materials. Sandra *et al.,* [14] developed a new MCDM model to determine the most suitable drilling technique for heat extraction from geothermal reservoirs. In the study, RAWEC method identified the directional drilling method as the best alternative, and the impacts of this method on energy efficiency were analyzed. Nedeljković *et al.,* [15] combined RAWEC and MEREC methods to determine the optimal sales channel for agricultural products. In the study, environmental compatibility and consumer habits were identified as the most important criteria, and online sales were ranked as the most suitable method. Trung Do [16] examined how the rankings of the top ten universities in Vietnam changed with different criterion weighting methods. The study used methods like RAWEC, proximity index value (PIV), and root assessment method (RAM), and it was found that the results were largely similar regardless of the weighting method used. Puška *et al.,* [17] investigated the use of renewable energy sources to enhance agricultural sustainability in Bosnia and Herzegovina. In the analyses conducted using RAWEC method, solar energy was identified as the most suitable renewable energy source for agricultural sustainability. Puška *et al.,* [18] developed a new RAWEC model for selecting the location of agricultural distribution centers in Bosnia and Herzegovina. In the study, criteria weights were calculated using logarithm methodology of additive weights (LMAW) method, and the most suitable location was determined using RAWEC method. The validation of the results through sensitivity analyses demonstrated that RAWEC is a reliable and consistent method.

In the study, F-WENSLO method is used to determine the criteria weights, and F-RAWEC method is employed to rank the alternatives. This research provides significant contributions to the evaluation of sustainable communication technologies. The key contributions of the study are as follows:

i. Integration of fuzzy logic and MCDM: By combining fuzzy logic with multi-criteria decision-making, the study addresses the inherent uncertainties and complexities in evaluating sustainable communication technologies, offering a more robust and flexible framework.
ii. Objective weight determination: The use of F-WENSLO ensures that the criteria weights are determined objectively, taking into account both envelope and slope properties, which enhances the accuracy and reliability of the evaluation process.
iii. Comprehensive ranking of alternatives: The application of F-RAWEC provides a systematic and transparent ranking of sustainable communication technologies, enabling stakeholders to prioritize the most suitable options based on multiple criteria.
iv. Strategic insights for decision-makers: The study offers actionable insights for policymakers, industry leaders, and investors, helping them make informed decisions that align with sustainability goals.
v. Validation through sensitivity analysis: The robustness of the proposed methodology is validated through sensitivity analyses, demonstrating its reliability and consistency under varying conditions.

vi. Holistic evaluation framework: The study considers a wide range of criteria, including environmental impact, cost-effectiveness, societal benefits, and technological innovation, ensuring a holistic evaluation of sustainable communication technologies.

vii. Support for sustainable development goals (SDGs): By identifying and prioritizing technologies that contribute to sustainable development, the study supports the achievement of global sustainability objectives.

These contributions not only advance the understanding of sustainable communication technologies but also provide a practical and reliable decision-making tool for stakeholders aiming to integrate these technologies into their strategies.

2. Methodology

Sustainable communication technologies are a critical factor in supporting environmental, economic, and social sustainability. The effective development and implementation of these technologies not only enhance efficiency but also contribute to a more sustainable future by reducing environmental impacts. This study aims to systematically evaluate the potential risks and opportunities of sustainable communication technologies and establish a structured ranking approach based on relevant criteria. In this context, F-WENSLO method is applied to determine the weights of sustainable communication technology criteria, incorporating expert opinions and various sustainability factors. To ensure a balanced and integrated evaluation of each criterion by synthesizing expert assessments, fuzzy Bonferroni mean aggregation operator are used. In the final stage, F-RAWEC method is employed to compare the identified risks associated with sustainable communication technologies and prioritize the most effective strategic interventions.

The proposed integrated framework combines information synthesis, criteria prioritization, and strategic option ranking processes to offer a systematic approach for optimizing sustainable communication technologies. This structured methodology provides a comprehensive basis for evaluating and addressing all critical criteria related to sustainable communication technologies effectively.

2.1. Fuzzy Sets

Zadeh [19] proposed the concept of fuzzy sets to address uncertainty in variables and parameters. Triangular fuzzy number (TFN) is used in various studies to turn qualitative assertions into quantitative ones [20]. A TFN represents each figure with three numerals. The first, second, and third integers that define an FN reflect the lowest, most, and highest potential values, respectively $\tilde{A}(l,m,u)$. Eq. (1) defines the triangle type membership function for FNs.

$$\mu_A(x) = \begin{cases} 0, & x < l \\ \dfrac{x-l}{m-l}, l \le x \le m \\ \dfrac{u-x}{u-m}, m \le x \le u \\ 0, & x > u \end{cases} \tag{1}$$

TFNs can be transformed into crisp values by applying the center of gravity defuzzification technique represented by Eq. 2:

$$A = \frac{l + 4m + u}{6} \tag{2}$$

2.2. Fuzzy Bonferroni Aggregation Operator

Aggregation operators are mathematical tools used to combine individual preferences, evaluations, or judgments into a unified outcome, facilitating consensus in group decision-making processes.

Bonferroni Aggregation (BA) operator is shown by Eq. (3) [21].

$$BA^{p,q}(a_1, a_2, \ldots, a_n) = \left(\frac{1}{n(n-1)} \sum_{i,j=1\ (i \neq j)}^{n} a_i^p a_j^q \right)^{\frac{1}{p+q}} \tag{3}$$

where *n* is the number of experts, $p, q \geq 0$.

2.3. F- WENSLO Method for Prioritization of Criterion

Pamučar et al., [10] presented WENSLO method for determining weight coefficients of criterion (crisp version). In this study, WENSLO method is extended through fuzzification by incorporating TFNs to handle uncertainty in the evaluation process.

Step 1. Construction of the initial decision matrix

The selected experts evaluated the criteria by assigning linguistic terms from the fuzzy scale presented in Table 1.

Table 1
Fuzzy scale, linguistic expressions and triangular numbers

Fuzzy Linguistic Descriptive	Abbreviation	FN
Absolutely low	AL	(1,1,1)
Very low	VL	(1,1.5,2)
Low	L	(1.5,2,2.5)
Medium	M	(2,2.5,3)
Equal	E	(2.5,3,3.5)
Medium-high	MH	(3,3.5,4)
High	H	(3.5,4,4.5)
Very high	VH	(4,4.5,5)
Absolutely high	AH	(4.5,5,5)

Source: Božanić *et al.,* [22]

The combined decision matrix ($\tilde{Z}$) is obtained using Eq. (4).

$$\tilde{Z} = \left[\tilde{z}_{ij}\right]_{kxn} = \begin{bmatrix} \tilde{z}_{11} & \cdots & \tilde{z}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{k1} & \cdots & \tilde{z}_{kn} \end{bmatrix} \tag{4}$$

$\tilde{z}_{ij} = \left(z_{ij}^l, z_{ij}^m, z_{ij}^u\right)$ represents fuzzy value of criterion j. in alternative i.

Step 2. Normalizing the decision matrix $\left(\tilde{T}\right)$.

Eq. (5) is used to normalise the combined decision matrix.

$$\tilde{t}_{ij} = \left(t_{ij}^l, t_{ij}^m, t_{ij}^u\right) = \frac{\tilde{z}_j}{\sum_{j=1}^{n} \tilde{z}_j} = \left(\frac{z_j^l}{\sum_{j=1}^{n} z_j^u}, \frac{z_j^m}{\sum_{j=1}^{n} z_j^m}, \frac{z_j^u}{\sum_{j=1}^{n} z_j^l} \right) \tag{5}$$

Step 3. Calculation of criterion class interval ($\tilde{\rho}_j$).

The size of the j-th criteria class interval is determined using Sturges' rule, Eq. (6):

$$\tilde{\rho}_j = \left(\rho_j^l, \rho_j^m, \rho_j^u\right) = \left(\frac{max(z_j^l) - min(z_j^l)}{1 + 3.322 * log(k)}, \frac{max(z_j^m) - min(z_j^m)}{1 + 3.322 * log(k)}, \frac{max(z_j^u) - min(z_j^u)}{1 + 3.322 * log(k)} \right) \tag{6}$$

Step 4. Determination of the criterion slope ($\tan\tilde{\varphi}_j$).

The slope of the criterion is calculated by Eq. (7).

$$tan\tilde{\varphi}_j = \frac{\sum_{i=1}^{k} \tilde{z}_j}{(k-1)\tilde{\rho}_j} = \left(\frac{\sum_{i=1}^{k} z_j^l}{(k-1)\rho_j^u}, \frac{\sum_{i=1}^{k} z_j^m}{(k-1)\rho_j^m}, \frac{\sum_{i=1}^{k} z_j^u}{(k-1)\rho_j^l}\right) \quad (7)$$

Step 5. Determination of the criterion envelope ($\tilde{\varepsilon}_j$)

Eq. (8) calculates the total of the partial Euclidean distances between two consecutive criteria.

$$\tilde{\varepsilon}_j = \left(\sum_{i=1}^{k-1} \sqrt{\left(z_{i+1,j}^l - z_{ij}^l\right)^2 + \left(\rho_j^l\right)^2}, \sum_{i=1}^{k-1} \sqrt{\left(z_{i+1,j}^m - z_{ij}^m\right)^2 + \left(\rho_j^m\right)^2}, \sum_{i=1}^{k-1} \sqrt{\left(z_{i+1,j}^u - z_{ij}^u\right)^2 + \left(\rho_j^u\right)^2}\right) \quad (8)$$

Step 6. Determine the envelope slope ratio ($\tilde{\delta}_j$)

The ratio of the total Euclidean distance to the criteria slope is calculated using Eq. (9).

$$\tilde{\delta}_j = \frac{\tilde{\varepsilon}_j}{tan\tilde{\varphi}_j} = \left(\frac{\varepsilon_j^l}{tan\varphi_j^u}, \frac{\varepsilon_j^m}{tan\varphi_j^m}, \frac{\varepsilon_j^u}{tan\varphi_j^l}\right) \quad (9)$$

Step 7. Obtaining fuzzy weights $\left(\tilde{w}_j\right)$ of each of the criterion

Weights are determined using Eq. (10) depending on the criteria's significance coefficients.

$$\tilde{w}_j = \left(w_j^l, w_j^m, w_j^u\right) = \frac{\tilde{\delta}_j}{\sum_{j=1}^{n} \tilde{\delta}_j} = \left(\frac{\delta_j^l}{\sum_{j=1}^{n} \delta_j^u}, \frac{\delta_j^m}{\sum_{j=1}^{n} \delta_j^m}, \frac{\delta_j^u}{\sum_{j=1}^{n} \delta_j^l}\right) \quad (10)$$

2.4 F-RAWEC Method for Ranking Alternatives

Puška *et al.,* [18] presented RAWEC method for ranking alternatives (crisp version). RAWEC is fuzzified in this paper through the application of TFNs.

Step 1. Construction of the initial decision matrix

The selected experts prioritized the criteria using linguistic phrases from the fuzzy scale in Table 1. The combined decision matrix ($\tilde{X}$) is obtained using Eq. (11).

$$\tilde{X} = \left[\tilde{x}_{ij}\right]_{kxn} = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{k1} & \cdots & \tilde{x}_{kn} \end{bmatrix} \quad (11)$$

$\tilde{x}_{ij} = \left(x_{ij}^l, x_{ij}^m, x_{ij}^u\right)$ represents fuzzy value of criterion j. in alternative i.

Step 2. Developing the normalized matrix $\left(\tilde{N}\right)$.

When normalizing the initial decision matrix, double normalization is performed with Eq. (12) for the benefit normalization ($\tilde{n}_{ij}$) and Eq. (13) for the cost normalization$\left(\tilde{n}_{ij}\right)'$.

$$\tilde{n}_{ij} = \left(n_{ij}^l, n_{ij}^m, n_{ij}^u\right) = \frac{\tilde{x}_j}{max(\tilde{x}_{ij})} = \left(\frac{x_{ij}^l}{max(x_{ij}^u)}, \frac{x_{ij}^m}{max(x_{ij}^u)}, \frac{x_{ij}^u}{max(x_{ij}^u)}\right) \quad (12)$$

and

$$\left(\tilde{n}_{ij}\right)' = \left(n_{ij}^l, n_{ij}^m, n_{ij}^u\right) = \frac{min(\tilde{x}_{ij})}{\tilde{x}_{ij}} = \left(\frac{min(x_{ij}^l)}{x_{ij}^u}, \frac{min(x_{ij}^l)}{x_{ij}^m}, \frac{min(x_{ij}^l)}{x_{ij}^l}\right) \quad (12)$$

$$\tilde{n}_{ij} = \left(n_{ij}^l, n_{ij}^m, n_{ij}^u\right) = \frac{min(\tilde{x}_{ij})}{\tilde{x}_{ij}} = \left(\frac{min(x_{ij}^l)}{x_{ij}^u}, \frac{min(x_{ij}^l)}{x_{ij}^m}, \frac{min(x_{ij}^l)}{x_{ij}^l}\right) \quad (13)$$

and

$$\left(\tilde{n}_{ij}\right)' = \left(n_{ij}^l, n_{ij}^m, n_{ij}^u\right) = \frac{\tilde{x}_j}{max(\tilde{x}_{ij})} = \left(\frac{x_{ij}^l}{max(x_{ij}^u)}, \frac{x_{ij}^m}{max(x_{ij}^u)}, \frac{x_{ij}^u}{max(x_{ij}^u)}\right) \quad (13)$$

Step 3. Calculating deviation from the criteria weights

Eqs. (14) and (15) yield the total deviation from the weight of the criterion after first calculating the deviations of the normalized data from the maximum values denoted by the number 1. The deviation is then multiplied by the weights of the criteria.

$$\tilde{\vartheta}_{ij} = \left(\sum_{i=1}^{n}\left[\left(1 - n_{ij}^{u}\right) * w_{j}^{l}\right], \sum_{i=1}^{n}\left[\left(1 - n_{ij}^{m}\right) * w_{j}^{m}\right], \sum_{i=1}^{n}\left[\left(1 - n_{ij}^{l}\right) * w_{j}^{u}\right]\right) \tag{14}$$

$$\left(\tilde{\vartheta}_{ij}\right)' = \left(\sum_{i=1}^{n}\left[\left(1 - \left(n_{ij}^{u}\right)'\right) * w_{j}^{l}\right], \sum_{i=1}^{n}\left[\left(1 - \left(n_{ij}^{m}\right)'\right) * w_{j}^{m}\right], \sum_{i=1}^{n}\left[\left(1 - \left(n_{ij}^{l}\right)'\right) * w_{j}^{u}\right]\right) \tag{15}$$

Step 4. Calculation of the value of RAWEC method

The value of RAWEC method, as calculated using Eq. (16), falls within the range of (−1, 1).

$$\tilde{Q}_{i} = \frac{\left(\tilde{\vartheta}_{ij}\right)' - \tilde{\vartheta}_{ij}}{\left(\tilde{\vartheta}_{ij}\right)' + \tilde{\vartheta}_{ij}} = \left(\frac{\left(\vartheta_{ij}^{l}\right)' - \vartheta_{ij}^{u}}{\left(\vartheta_{ij}^{u}\right)' + \left(\vartheta_{ij}^{u}\right)}, \frac{\left(\vartheta_{ij}^{m}\right)' - \vartheta_{ij}^{m}}{\left(\vartheta_{ij}^{m}\right)' + \left(\vartheta_{ij}^{m}\right)}, \frac{\left(\vartheta_{ij}^{u}\right)' - \vartheta_{ij}^{l}}{\left(\vartheta_{ij}^{l}\right)' + \left(\vartheta_{ij}^{l}\right)}\right) \tag{16}$$

The superiority of an alternative is determined by the magnitude of its value, the higher the value, the better the alternative. The optimal alternative is identified as the one with the highest value.

3. Case Study

In recent years, the surge in digital connectivity and data transmission needs has accelerated the deployment of communication technologies worldwide. However, concerns about environmental degradation, energy use, and the social and economic implications of such technologies have brought sustainability into sharp focus. In this paper, a case study has been considered which aims to evaluate sustainability performance of five communication technologies like 5G Wireless Networks (A1), Fiber Optic Communication (A2), Low Power Wide Area Networks (A3), Wi-Fi 6 (A4), and Satellite Internet (A5). These technologies are widely considered for infrastructural upgrades, smart cities, and rural connectivity initiatives. Decision-makers face challenges in selecting the most sustainable technology due to complex trade-offs among environmental impact, financial feasibility, societal contribution, technological maturity, and practical implementation. For this evaluation, a team of four experts was formed. Information about the experts involved in the evaluation processes is presented in Table 2.

Table 2
Profiles of the Experts

Expert	Field of Expertise	Key Attributes
E1	Environmental Engineer	Energy, carbon footprint calculation, natural resource conservation
E2	Economics Expert	Economic sustainability, cost analysis, efficiency optimization
E3	Sociologist	Social accessibility, user satisfaction, societal impacts of technology
E4	Software and Technology Expert	Technological innovation, digital solutions, communication infrastructure

The insights provided by the experts significantly contributed to the evaluation of both sustainable communication technologies and the criteria, aiding in identifying potential solutions.

3.1. Criteria for Evaluating Sustainable Communication Technologies

The five main criteria and their sub-criteria determined for the evaluation of sustainable communication technologies are comprehensively presented in Table 3. These main criteria are grouped as Environmental Footprint (C1), Financial Impact (C2), Societal Contribution (C3), Technology Advancement (C4), and Practicality of Implementation (C5). The main and sub-criteria for the evaluation of sustainable communication technologies are shown in Table 3.

Table 3
Main and Sub-Criteria for Evaluating Sustainable Communication Technologies

Main Criteria	Sub-criteria	Definition of Sub-criteria
Environmental Footprint (C1)	Power Consumption (C11)	Measures the amount of energy consumed by a system or process during operation.
	Carbon Emissions (C12)	Refers to the release of carbon dioxide (CO2) and other greenhouse gases into the atmosphere.
	Resource Optimization (C13)	Efficient use and management of resources to minimize waste and reduce consumption.
	Biodiversity Impact (C14)	Measures the effect of an activity or technology on the variety and health of ecosystems.
Financial Impact (C2)	Economic Efficiency (C21)	Cost-effectiveness of a technology or project in relation to its output.
	Investment Yield (RoI) (C22)	Evaluates the return generated from an investment relative to its cost.
	Impact on Regional Economies (C23)	Economic benefits or challenges a technology brings to local communities.
	Sustainability Over Time (C24)	Long-term viability and continued performance of a system or technology.
Societal Contribution (C3)	Ease of Access (C31)	Level of convenience and availability for users to access a system or service.
	Community Engagement (C32)	Involvement of local communities in the development and use of a technology or solution.
	Customer Experience (C33)	Overall satisfaction and perception of users interacting with a product or service.
	Learning and Information Exchange (C34)	Ability to share knowledge and foster learning between individuals or organizations.
Technology Advancement (C4)	Research and Development Efforts (C41)	Investment for designing and improving technologies.
	Technology Integration (C42)	Seamless incorporation of new technologies into existing systems or infrastructures.
	Sustainability for the Future (C43)	Ability of technologies to maintain environmental, economic, and social viability over time.
	Innovation Potential (C44)	Capacity of technologies or system to introduce novel ideas or advancements.
Practicality of Implementation (C5)	User Accessibility (C51)	Ease with which users can interact with and navigate a system, especially for those with disabilities.
	Support and Training Requirements (C52)	Level of assistance and educational resources needed for users to effectively use a system.
	Scalability and Adoption Potential (C53)	Ability of technologies to grow or expand to meet increased demand and be widely accepted.
	Infrastructure for Support (C54)	Necessary physical and organizational systems in place to provide ongoing maintenance and assistance.

Table 3 outlines main criteria and their supporting sub-criteria for a comprehensive evaluation of sustainable communication technologies, offering an analytical framework to address practical challenges.

3.2. Sustainable Communication Technologies

The primary advantage of sustainable communication technologies lies in their ability to provide innovative solutions that minimize environmental impacts while maximizing societal benefits. Key alternatives within the domain of sustainable communication technologies are outlined in Table 4.

Table 4
Sustainable Communication Technologies

Alternative	Importance	Contribution
A1	Critical for enabling high-speed, low-latency applications.	High energy use but strong in technology & access.
A2	Backbone of modern digital infrastructure.	Low environmental footprint, scalable & efficient.
A3	Ideal for IoT and smart city applications.	Energy efficient, affordable, easy deployment.
A4	Enhances local area connectivity in dense environments.	Balanced sustainability with good access.
A5	Crucial for remote and underserved regions.	High carbon footprint and costly infrastructure.

Table 4 summarizes the significance of the considered communication technologies and their contributions to sustainability.

3.3. Data Collection and Analysis

The experts evaluated sustainable communication technologies using the main and sub-criteria outlined in Table 1. The results are presented in Table 5 for the main criteria and Appendix A (Table A1) for the sub-criteria.

Table 5
Expert Evaluation of Main-Criteria

Expert	C1	C2	C3	C4	C5
E1	VH	MH	VH	MH	E
E2	AH	VH	MH	H	M
E3	H	MH	H	AH	E
E4	MH	VH	H	VH	MH

This assessment in Table 5 reflects expert priorities and perceptions about the sustainable communication technologies. It also helps to identify which criteria have higher priority.

3.4. Determining the subjective weights with F-WENSLO method

The initial decision matrix, obtained as a result of the evaluation of the experts and presented in Table 5, is normalized using Eq. (5). The obtained normalized matrix is given in Table 6.

Table 6
Normalized decision matrix

	C1			C2			C3			C4			C5		
E1	0.2162	0.2647	0.3333	0.1667	0.2188	0.2857	0.2222	0.2813	0.3571	0.1622	0.2059	0.2667	0.1724	0.2400	0.3333
E2	0.2432	0.2941	0.3333	0.2222	0.2813	0.3571	0.1667	0.2188	0.2857	0.1892	0.2353	0.3000	0.1724	0.2400	0.3333
E3	0.1892	0.2353	0.3000	0.1667	0.2188	0.2857	0.1944	0.2500	0.3214	0.2432	0.2941	0.3333	0.1724	0.2400	0.3333
E4	0.1622	0.2059	0.2667	0.2222	0.2813	0.3571	0.1944	0.2500	0.3214	0.2162	0.2647	0.3333	0.2069	0.2800	0.3810
max	0.2432	0.2941	0.3333	0.2222	0.2813	0.3571	0.2222	0.2813	0.3571	0.2432	0.2941	0.3333	0.2069	0.2800	0.3810
Min	0.1622	0.2059	0.2667	0.1667	0.2188	0.2857	0.1667	0.2188	0.2857	0.1622	0.2059	0.2667	0.1724	0.2400	0.3333

The normalized values of the evaluation of the criterion C1 in Table 1 by E1 are obtained as follows.

$$\tilde{t}_{11} = \left(\frac{4}{5+5+4.5+4}, \frac{4.5}{4.5+5+4+3.5}, \frac{5}{4+4.5+3.5+3}\right) = (0.2162 \quad 0.2647 \quad 0.3333)$$

All elements of the matrix are calculated similarly. Subsequently, the criterion class range was calculated using Eq.(6), the criterion slope Eq.(7), the criterion envelope Eq. (8), the envelope slope ratio Eq.(9), and the fuzzy weight of each criterion Eq.(10) and presented in Table 7.

Table 7
Calculations according to F-WENSLO method for criteria

	C1			C2			C3		
$\tilde{\rho}_j$	0.0244	0.0266	0.0201	0.0167	0.0188	0.0215	0.0167	0.0188	0.0215
$tan\tilde{\varphi}_j$	0.8108	1.1333	1.6901	0.7259	1.1852	1.9286	0.7259	1.1852	1.9286
$\tilde{\varepsilon}_j$	0.4485	0.4592	0.4488	0.5011	0.5176	0.5373	0.3697	0.3824	0.3975
$\tilde{\delta}_j$	0.2654	0.4052	0.5536	0.2598	0.4368	0.7402	0.1917	0.3226	0.5476
$\tilde{w}_j$	0.0866	0.2078	0.4698	0.0848	0.2240	0.6282	0.0626	0.1654	0.4647

	C4			C5		
$\tilde{\rho}_j$	0.0244	0.0266	0.0201	0.0104	0.0120	0.0143
$tan\tilde{\varphi}_j$	0.8108	1.1333	1.6901	0.6336	1.1905	2.2249
$\tilde{\varepsilon}_j$	0.4485	0.4592	0.3853	0.4361	0.4526	0.4729
$\tilde{\delta}_j$	0.2654	0.4052	0.4751	0.1960	0.3802	0.7464
$\tilde{w}_j$	0.0866	0.2078	0.4033	0.0640	0.1950	0.6335

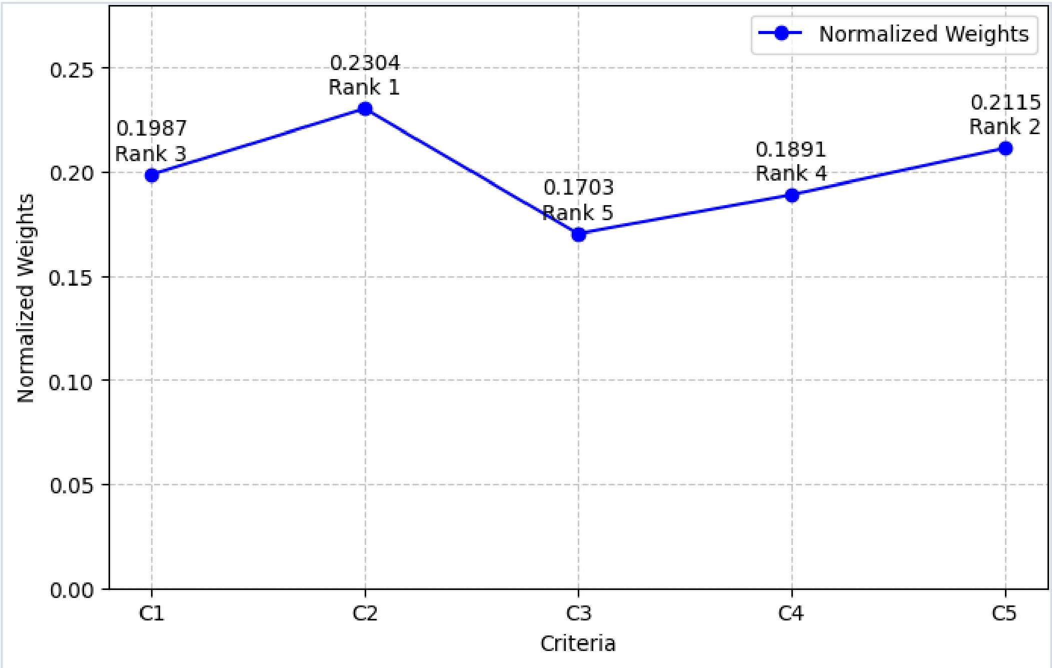

Fig. 1. Criteria normalized weights and ranking

Figure 1 shows the final values of criteria weights obtained using F-WENSLO method. It also presents the key criteria identified for the evaluation of sustainable communication technologies. The weightings and rankings indicate the relative importance of each criterion.

i. Financial Impact (C2) (0.2304 - Rank 1): This is the criterion with the highest weight value, indicating that economic benefit is considered the most critical factor in sustainable communication technologies.
ii. Practicality of Implementation (C5) (0.2115 - Rank 2): The high importance of ease of application suggests that the rapid and seamless adoption of technologies is crucial.
iii. Environmental Footprint (C1) (0.1987 - Rank 3): The fact that environmental impact ranks third suggests that while the ecological effects of sustainable technologies are considered, economic and applicability factors carry more weight.
iv. Technology Advancement (C4) (0.1891 - Rank 4): The relatively lower ranking of technological innovation may indicate that compatibility with existing technologies and

practical implementation are prioritized. However, considering the long-term effects of innovation, the importance of this factor may increase over time.

v. Societal Contribution (C3) (0.1703 - Rank 5): The lowest weight assigned to social impact suggests that decision-makers prioritize economic and environmental factors. However, the societal effects of sustainable communication technologies may become more influential in the long run.

Economic benefit and applicability are prioritized, while environmental and technological factors are also considered. The relatively low score of social impact may suggest that greater social policy support is needed for the widespread adoption of sustainable communication technologies. The weights for the sub-criteria were determined using the same procedure applied to the main criteria. The global weights, calculated by multiplying the main criteria weights with the sub-criteria weights, are presented in Table 8.

Table 8
Weights and rankings of sub-criteria

Criteria	Fuzzy weight	Local weight (normalized)
C1	(0.0866, 0.2078, 0.4698)	0.1987
C11	(0.0229, 0.0522, 0.1139)	0.0492
C12	(0.0022, 0.0028, 0.0035)	0.0484
C13	(0.0021, 0.0027, 0.0034)	0.0492
C14	(0.0020, 0.0025, 0.0033)	0.0462
C2	(0.0848, 0.02240, 0.6282)	0.2304
C21	(0.0270, 0.0615, 0.1283)	0.0572
C22	(0.0207, 0.0468, 0.1025)	0.0442
C23	(0.0237, 0.0496, 0.0917)	0.0447
C24	(0.0223, 0.0506, 0.0969)	0.0458
C3	(0.0626, 0.1654, 0.4647)	0.1703
C31	(0.0181, 0.0537, 0.1751)	0.0581
C32	(0.0206, 0.0546, 0.1577)	0.0565
C33	(0.0224, 0.0511, 0.1008)	0.0750
C34	(0.0182, 0.0449, 0.1207)	0.0454
C4	(0.0866, 0.2078, 0.4033)	0.1891
C41	(0.0208, 0.0436, 0.0702)	0.0378
C42	(0.0183, 0.0454, 0.1221)	0.0459
C43	(0.0204, 0.0456, 0.0984)	0.0429
C44	(0.0222, 0.0564, 0.1560)	0.0576
C5	(0.0640, 0.1950, 0.6335)	0.2115
C51	(0.0181, 0.0537, 0.1751)	0.0581
C52	(0.0183, 0.0493, 0.1447)	0.0513
C53	(0.0166, 0.0433, 0.1227)	0.0445
C54	(0.0170, 0.0416, 0.1103)	0.0419

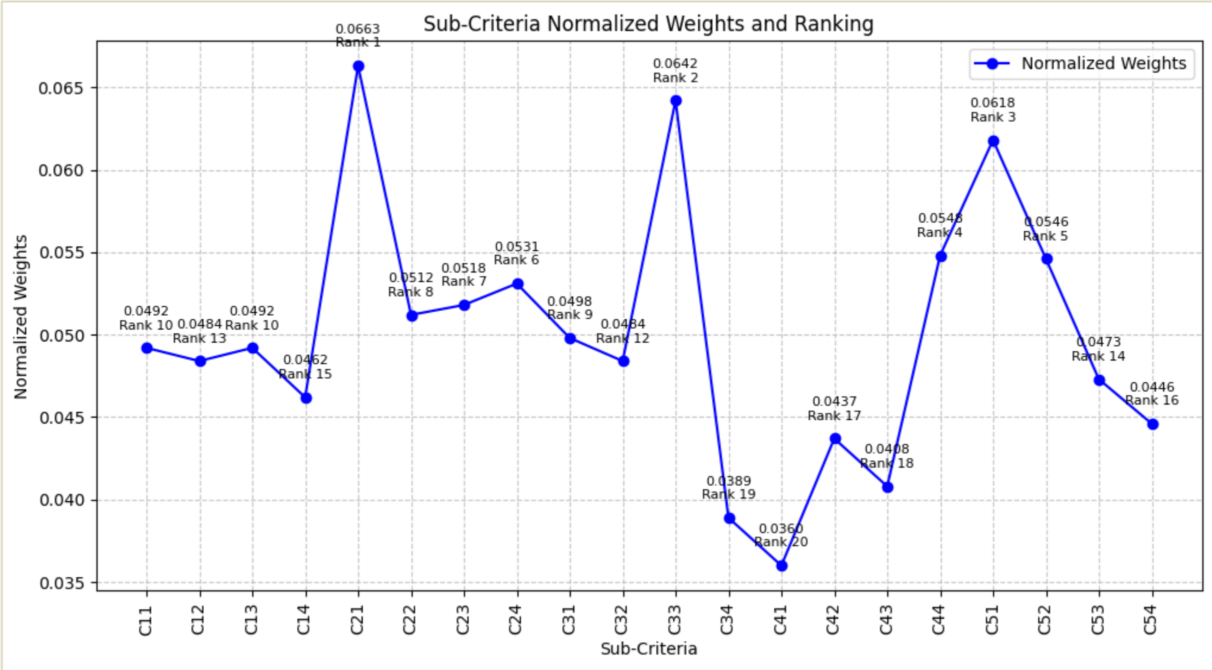

Fig. 2. Global Weights (Normalized) and Rankings of Sub-Criteria

Figure 2 presents the weights and rankings assigned to the sub-criteria of sustainable communication technologies. The following observations can be made:

✓ Most Important Criteria

Economic Efficiency (C21) (0.0663 - Rank 1): Economic efficiency holds the highest importance, indicating that cost-effective solutions are prioritized in sustainable technologies. Customer Experience (C33) (0.0642 - Rank 2): User satisfaction has received a high weight, meaning that user adoption and experience are critical criteria. User Accessibility (C51) (0.0618 - Rank 3): The user-friendliness of technologies is a significant factor in terms of widespread acceptance and feasibility.

✓ Moderately Important Criteria

Innovation Potential (C44) (0.0548 - Rank 4): Innovation is an important criterion, although it is not as prominent as feasibility and economic factors. Support and Training Requirements (C52) (0.0546 - Rank 5): Training and support requirements are considered crucial for the implementation of technology.

✓ Less Important Criteria

Research and Development Efforts (C41) (0.0360 - Rank 20): Research and development activities hold the lowest importance, which may indicate that existing technologies are more deployment-ready or that short-term results are prioritized. Learning and Information Exchange (C34) (0.0389 - Rank 19): Education and knowledge sharing have relatively low priority, but their importance may increase for long-term technology adoption.

✓ Environmental and Social Factors

Power Consumption (C11) and Resource Optimization (C13) (0.0492 - Rank 10): Energy consumption and resource utilization are of moderate importance. Carbon Emissions (C12) (0.0484 - Rank 13) and

Biodiversity Impact (C14) (0.0462 - Rank 15): Environmental factors such as carbon footprint and ecosystem impact have lower priority.
Based on these rankings, economic efficiency (C21), customer experience (C33) and user accessibility (C51) emerged as the most important criteria. While environmental and social factors are considered, they are prioritized lower compared to financial impact and technical advancement.

3.5. Fuzzy Bonferroni aggregation operator application

The decision makers interpreted the performance of the alternatives according to Table 1. In order to bring these individual evaluations together, a combined fuzzy decision matrix was obtained using Eq. (3) and given in Appendix B (Table B1).

3.6. Application of F-RAWEC method

The combined fuzzy decision matrix given in Appendix B (Table B1) is used as the initial decision matrix mentioned in the first step of the method. Then, Eq. (12) and Eq. (13) were used to obtain the benefit and cost normalized decision matrices. Then, Eq. (14) and Eq. (15) were used for deviations from the criterion weights. Finally, the RAWEC method value was obtained with Eq. (16) and is given in Table 9.

Table 9
Ranking of sustainable communication technologies

	$\tilde{\vartheta}_{ij}$			$(\tilde{\vartheta}_{ij})'$			$\tilde{Q}_i$			Q_i	Rank
A1	0.1658	0.3325	0.5948	0.1196	0.1798	0.2047	-0.5945	-0.2982	0.1362	-0.2751	5
A2	0.1518	0.2806	0.4151	0.1311	0.2098	0.2714	-0.4137	-0.1444	0.4230	-0.0947	3
A3	0.1546	0.2880	0.3774	0.1352	0.2233	0.3342	-0.3404	-0.1266	0.6196	-0.0379	2
A4	0.1437	0.2522	0.2898	0.1551	0.2703	0.4279	-0.1877	0.0348	0.9509	0.1504	1
A5	0.1623	0.3258	0.5148	0.1182	0.1787	0.2533	-0.5163	-0.2917	0.3244	-0.2265	4

This ranking in Table 9 shows the importance of different alternatives in terms of sustainable communication technologies. The integrated F-WENSLO and F-RAWEC model ranked Wi-Fi 6 (A4) as the most sustainable communication technology, followed by Low Power Wide Area Networks (A3) and Fiber Optic Communication (A2). Satellite Internet (A5) was placed fourth, while 5G Wireless Networks (A1) ranked lowest.

4. Sensitivity analysis and validation of the results

Sensitivity analysis and validation of the results obtained using F-RAWEC method were performed. The sensitivity analysis takes into account the variation of the Bonferroni means aggregation operator parameters (and). The comparison of F-WENSLO and F-RAWEC model with other models in the literature is presented as part of the validation results. For the comparison of the results of the considered MCDM models, a statistical correlation with the initial results was performed.

4.1. Sensitivity analysis - variation of p and q parameters

The overall effect of the parameters p and q presented in the Bonferroni mean aggregation operator on the ranking of the presented alternatives in the proposed optimal intervention strategies selection management approach is analyzed using a sensitivity analysis. Firstly, it can be observed that when the values of p and q are varied from 1 to 5, the ranking of all alternatives remains the same. Then, if we fix any of the parameters between 0 and 1, the difference in the ranking of the alternatives was also analyzed. Again, the ranking of all alternatives remained the same. The results of the sensitivity analysis by changing the parameters are shown in Figure 3.

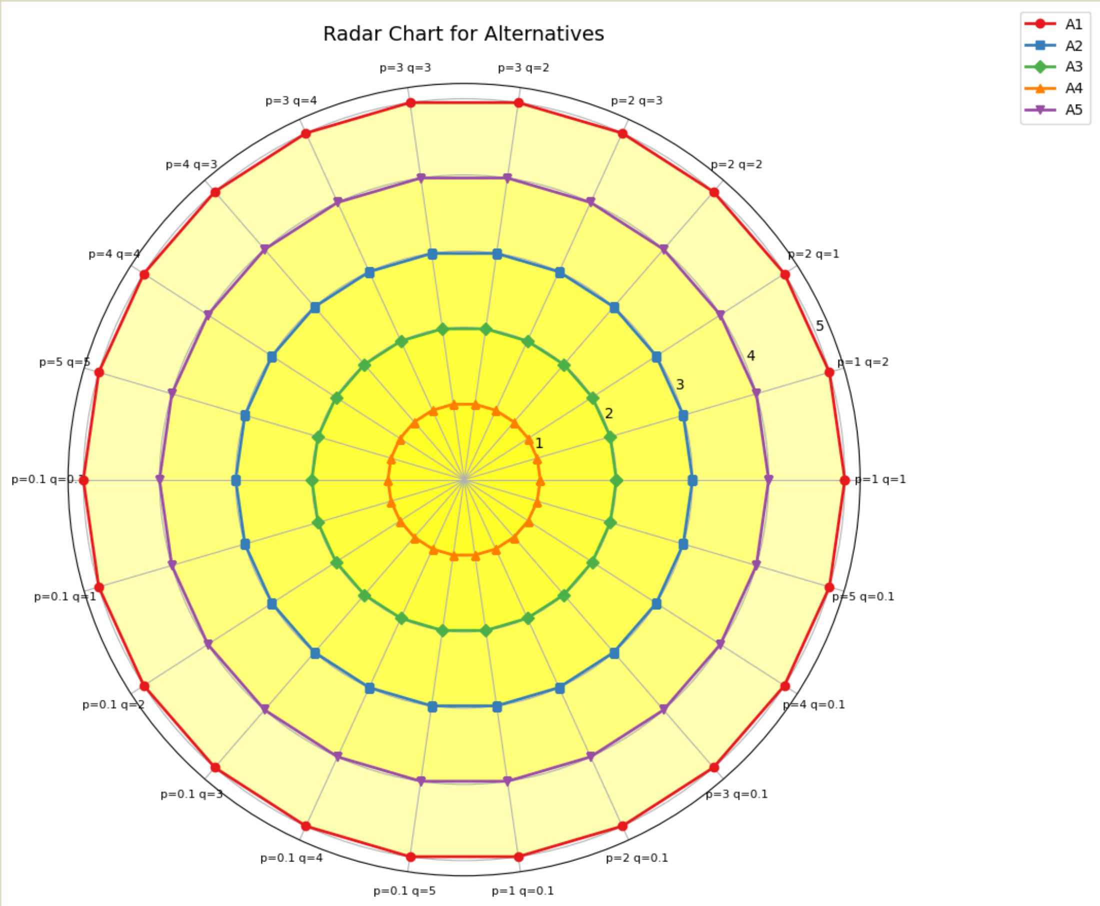

Fig. 3. Sensitivity analysis by varying the parameters p and q

The fact that the alternatives are ranked in the same order in all combinations in Figure 3 is remarkable in terms of the consistency and reliability of the approach adopted in the evaluation of sustainable communication technologies. In the evaluation of sustainable communication technologies, the final results are presented in Table 10. These findings demonstrate that the applied methodology yields a consistent and reliable ranking of alternatives, offering effective decision support for selecting the most appropriate technology. Table 10 also shows the effectiveness of the criteria used in the evaluation of sustainable communication technologies, the precision of the decision-making process, the strength of the systematic approach and the consistency achieved in the strategic planning processes.

Table 10
Parameter-based sensitivity analysis results

Evaluation	Explanation
Impact of Criteria	The consistent ranking of alternatives across all combinations indicates that the criteria used have a significant and effective influence on the evaluation process. This demonstrates the critical role of the defined criteria in assessing sustainable communication technologies and proves the reliability of the rankings.
Certainty in the Decision-Making Process	The identical rankings of alternatives in every scenario reflect clear perceptions and opinions of decision-makers regarding these alternatives. This allows for more confident and definitive decisions in the evaluation of sustainable communication technologies.

Table 10
Continued

Strength of the Systematic Approach	The emergence of identical rankings across all combinations highlights that the methods employed are based on a systematic and analytical approach. This validates the robustness of the decision-making processes applied in the evaluation of sustainable communication technologies.
Strategic Planning and Implementation	Consistent rankings across all combinations can ensure alignment in planning and implementing sustainable communication strategies. Decision-makers can effectively implement the identified alternatives by considering this consistency.
Likelihood of Achieving Objectives	The identical rankings of alternatives in every combination reduce uncertainty in achieving the goals of sustainable communication technologies. This provides a solid foundation for optimizing communication management processes and enhancing the contributions of sustainable communication technologies.

4.2. Validation of results- Comparison with other FMCDM techniques

The results of F-RAWEC method are compared with traditional multi-criteria models in the literature. CODAS method Ghorabaee *et al.,* [23], COPRAS method Zavadskas *et al.,* [24], MABAC method Pamučar and Ćirović [25] and TODIM method Gomes and Rangel [26] fuzzy versions were preferred. Figure 4 shows the results of the comparison of the mentioned FMCDM methods.

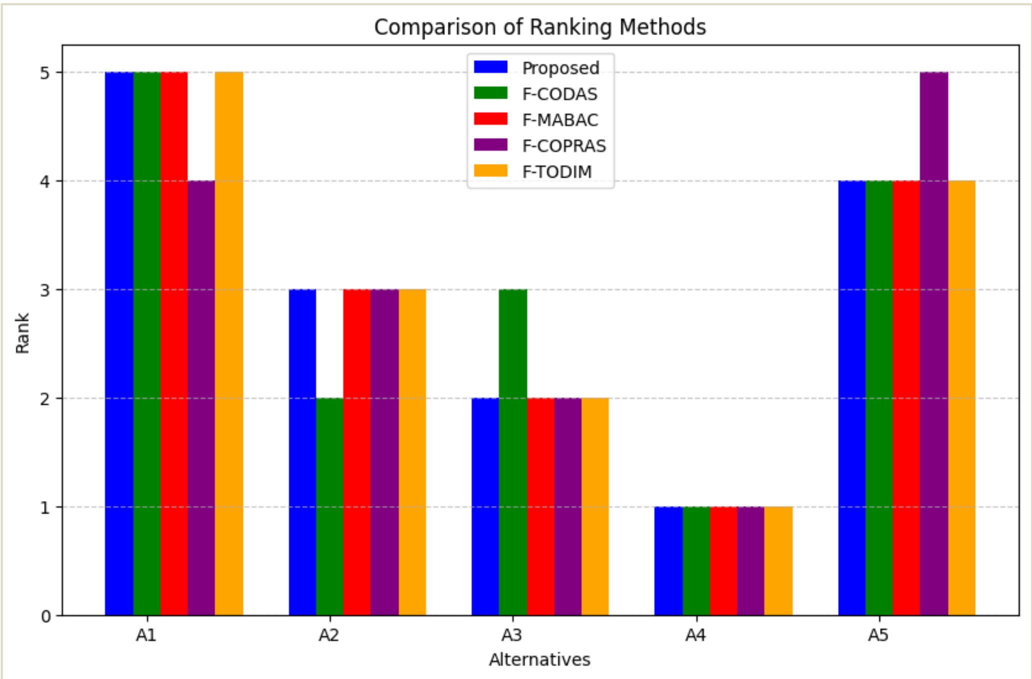

Fig. 4. Ranking stability of alternatives using various MCDM techniques

Figure 4 presents a comparison of rankings derived from various fuzzy decision-making methods, revealing a high level of consistency. The proposed method aligns exactly with F-MABAC and F-TODIM, indicating reliable and coherent evaluation results. Although slight variations are observed in the rankings from F-CODAS and F-COPRAS, the overall consistency supports the robustness of the proposed approach. This demonstrates that decision-makers can confidently apply the method to select sustainable communication technologies, knowing it produces stable and dependable outcomes.

The rankings obtained through F-RAWEC procedure and other methods were statistically correlated using Spearman Correlation Coefficient (SCC) [27]. The findings from SCC-based comparison of rankings are presented in Table 11.

Table 11
Rank correlations of the tested models

	F-CODAS	F-MABAC	F-COPRAS	F-TODIM
F-RAWEC	0.9	1	0.9	1

The results in Table 11 show a strong correlation (average 0.95) between F-RAWEC and the other four FMCDM methods. This high correlation indicates that the ranking derived from the proposed procedure is both valid and reliable.

5. Discussion, Practical, and Managerial Implications

In this study, the main criteria, sub-criteria, and alternatives established for evaluating sustainable communication technologies provide a multidimensional approach to sustainability. In our study, in addition to main criteria such as environmental footprint, financial impact, societal contribution, technology advancement, and practicality of implementation, sub-criteria supporting these main criteria have also been used. 5G Wireless Networks, Fiber Optic Communication, Low Power Wide Area Networks, Wi-Fi 6, and Satellite Internet. The ranking of each alternative has been examined within the framework of the established criteria and ranked according to their strategic importance. The evaluation of sustainable communication technologies using an MCDM approach, as outlined in this study, provides valuable insights for both practitioners and policymakers. The findings highlight the importance of economic benefits, ease of application, and environmental impact as the most critical criteria for evaluating sustainable communication technologies. These results align with the growing emphasis on cost-effective, user-friendly, and environmentally conscious solutions in the technology sector.

5.1. Key Findings and Their Implications

Financial Impact (C2) as the Top Priority: The highest weight assigned to economic benefit (0.2304) underscores the importance of cost-effectiveness and return on investment in sustainable communication technologies. This suggests that decision-makers prioritize technologies that offer clear economic advantages, such as long-term cost savings and contributions to local economies. For managers, this implies a need to focus on technologies that not only reduce operational costs but also provide measurable financial returns. Practicality of implementation (C5) as a Close Second: The high ranking of practicality of implementation (0.2115) indicates that the adoption and implementation of sustainable technologies are critical. User accessibility, minimal training requirements, and robust support infrastructure are essential for ensuring widespread adoption. This finding is particularly relevant for technology developers and managers, who must prioritize usability and accessibility to drive adoption. Environmental footprint (C1) and technology advancement (C4): While environmental footprint (0.1987) and technology advancement (0.1891) are important, they are ranked lower than economic and implementation criteria. This suggests that while sustainability and innovation are valued, they are often secondary to economic and practical considerations. However, as environmental regulations tighten and consumer demand for green technologies grows, the importance of these criteria may increase. Societal contribution (C3) as the Lowest Priority: The relatively low weight assigned to societal contribution (0.1703) indicates that societal benefits, such as ease of access and level of convenience, are often overlooked in favor of economic and technical factors. This highlights a potential gap in current decision-making processes, as social inclusivity and equity are critical for the long-term success of sustainable technologies.

5.2. Practical Implications for Stakeholders

i. For Technology Developers: Developers should focus on creating solutions that are not only innovative but also cost-effective and easy to implement. Emphasizing user-friendly designs and minimizing training requirements can enhance adoption rates.
ii. For Policymakers: Policymakers should consider incentivizing technologies that balance economic, environmental, and social benefits.
iii. For Managers: Managers should prioritize technologies that offer clear economic benefits and are easy to integrate into existing systems. Additionally, they should consider the long-term environmental and social impacts of their technology choices.

5.3. Managerial Implications

i. Strategic Planning: The findings suggest that economic and applicability factors should be at the forefront of strategic planning for sustainable communication technologies. Managers should conduct thorough cost-benefit analyses and prioritize technologies with high adoption potential.
ii. Stakeholder Engagement: Engaging stakeholders, including users, policymakers, and technology developers, is crucial for ensuring that sustainable technologies meet the needs of all parties. This can help address the relatively low priority given to social impact.
iii. Long-Term Vision: While economic and practical criteria are prioritized, managers should also consider the long-term environmental and societal impacts of their technology choices. Investing in innovative and socially inclusive technologies can yield significant benefits in the future.

6. Conclusions, Limitations, and Future Directions

6.1. Conclusions

This study proposed an integrated fuzzy decision-making framework combining F-WENSLO and F-RAWEC methods to evaluate sustainable communication technologies. The approach effectively captured expert judgments under uncertainty and assessed five alternatives based on a comprehensive set of environmental, financial, societal, technological, and practical criteria. The results demonstrated that Wi-Fi 6 and low power wide area networks emerged as the most sustainable technologies, supported by strong performance across highly weighted criteria. Comparative analysis with other FMCDM methods revealed a high level of consistency, with an average correlation of 0.95, validating the robustness and reliability of the proposed method. The evaluation was based on five main criteria including environmental footprint, financial impact, societal contribution, technology advancement, and practicality of implementation. Each criterion included detailed sub-criteria to ensure a comprehensive assessment of sustainability aspects. Among these, environmental footprint and practicality of implementation were found to have the highest influence on decision-making, reflecting the growing emphasis on eco-efficiency and ease of deployment in sustainable technology adoption. In contrast, criteria such as technology advancement and societal contribution were given relatively lower priority in the weighting process. While still important, these aspects were considered secondary to the immediate environmental and practical concerns associated with implementing sustainable communication technologies. As the world continues to grapple with the challenges of sustainability, the insights provided by this study offer valuable guidance for policymakers, managers, and technology developers. By adopting a holistic and systematic approach to evaluating sustainable communication technologies, stakeholders are better equipped to drive innovation, minimize environmental impact, and promote a more inclusive and equitable future.

6.2. Limitations

Despite its contributions, this study has several limitations:

i. The evaluation relies on the subjective judgments of experts, which may introduce bias. Future studies could incorporate a larger and more diverse group of experts to mitigate this issue.
ii. The study focuses on five alternatives. Expanding the scope to include more technologies could provide a more comprehensive evaluation.
iii. The study provides a snapshot of the current priorities and perceptions of sustainable communication technologies. However, these priorities may evolve over time as new technologies emerge and societal values shift.

6.3. Future Directions

i. Future research could develop dynamic evaluation models that account for changes in technology, regulations, and societal values over time. This would provide a more nuanced understanding of the long-term viability of sustainable communication technologies.
ii. Given the relatively low priority assigned to social impact, future studies could explore ways to better integrate social criteria into decision-making processes. This could involve developing new metrics or frameworks for assessing social inclusivity and equity.
iii. Conducting case studies and real-world applications of the proposed evaluation framework could provide valuable insights into its practical utility. This would also help identify potential challenges and areas for improvement.
iv. Expanding the scope of the study to include other industries, such as healthcare, transportation, and manufacturing, could provide a broader perspective on the applicability of the proposed framework.
v. Future research could explore the integration of machine learning and artificial intelligence techniques to enhance the decision-making process. These technologies could help automate data collection, analysis, and ranking, making the evaluation process more efficient and accurate.

Appendix A
Table A1
Evaluation of sub-criteria for experts

Experts	C11	C12	C13	C14	C21	C22	C23	C24
E1	VH	H	AH	MH	VH	H	AH	VH
E2	AH	VH	MH	H	H	AH	VH	MH
E3	MH	H	VH	AH	AH	VH	H	AH
E4	H	AH	H	VH	MH	VH	AH	VH
Experts	C31	C32	C33	C34	C41	C42	C43	C44
E1	E	MH	H	VH	AH	MH	VH	H
E2	M	H	MH	VH	H	VH	AH	MH
E3	MH	E	VH	H	VH	H	H	VH
E4	E	H	AH	MH	AH	VH	VH	MH
Experts	C51	C52	C53	C54				
E1	E	MH	H	VH				
E2	M	E	MH	H				
E3	MH	MH	MH	H				
E4	E	H	H	VH				

Appendix B
Table B1
Combined fuzzy decision matrix

	C11			C12			…			C54		
A1	4.2475	4.7478	5.0000	3.9948	4.4954	4.8734	…	…	…	3.4940	3.9948	4.4954
A2	2.9930	3.4940	3.9948	2.5981	3.1024	3.6056	…	…	…	3.1225	3.6228	4.1231
A3	4.1180	4.6188	4.8734	3.1225	3.6228	4.1231	…	…	…	3.4821	3.9843	4.4861
A4	2.9930	3.4940	3.9948	3.2210	3.7249	4.2279	…	…	…	2.5000	3.0000	3.5000
A5	3.8730	4.3732	4.8734	4.1180	4.6188	4.8734	…	…	…	3.5000	4.0000	4.5000

Acknowledgement
This research was not funded by any grant.

Conflicts of Interest
The authors declare no conflicts of interest.

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