Yugoslav Journal of Operations Research
(20##), Number #, #-#
DOI: https://doi.org/10.2298/YJOR250715038P

Research article

A MULTI-OBJECTIVE DECISION FRAMEWORK FOR OPTIMIZING AGRICULTURAL MARKETING USING COMPLEX PROPORTIONAL ASSESSMENT

Lakshmanan POOCHAN
Department of Economics, New Prince Shri Bhavani Arts and Science College, Medavakkam, Chennai,
lakshsam008@gmail.com, ORCID: 0000-0003-2760-8262

Narayanamoorthy SAMAYAN
Department of Mathematics, Bharathiar University, Coimbatore – 641046, India,
snmphd@buc.edu.in, ORCID: 0000-0002-3782-4666

Almakayeel NAIF
Department of Industrial Engineering, College of Engineering, King Khalid University, Abha 61421, Saudi Arabia,
halmakaeel@kku.edu.sa, ORCID: 0000-0001-9461-5935

Kalaiselvan SAMAYAN
Department of Social Work, SRMX College of Arts and Science, Coimbatore – 641046,
kalaiselvan@rmv.ac.in, ORCID: 0000-0002-7214-7752

Shanmugam PONNAN,
Department of Economics, Bharathiar University, Coimbatore,
shanmugam.economics@buc.edu.in, ORCID: 0009-0006-8373-1563

Suvitha KRISHNAN*
Center for Nonlinear Systems, Chennai Institute of Technology, Chennai, India,
suvithak.maths@citchennai.net, ORCID: 0000-0003-1408-1393

Received: July 2025 / Accepted: September 2025

Abstract: This study develops a decision-support framework for agricultural marketing using established Multi-Criteria Decision-Making (MCDM) techniques. It integrates expert knowledge with primary field data to evaluate crop marketing alternatives within a

*Corresponding author

regulated market context. The Stepwise Weight Assessment Ratio Analysis (SWARA) method was employed to determine the relative importance of six farmer-identified criteria, with spot cash payment (0.28) and absence of middlemen (0.23) emerging as the most influential. Subsequently, the Complex Proportional Assessment (COPRAS) method was applied to rank three key crops—groundnut, cotton, and maize—based on these criteria. Groundnut was identified as the most preferred alternative, with a performance score of 0.962, followed by cotton (0.945) and maize (0.931). Sensitivity analysis across five weighting scenarios indicated score variations of less than 3%, confirming the stability and robustness of the results. By combining systematic decision-making procedures with domain-specific data, this framework provides statistically supported insights that can inform evidence-based agricultural policy and contribute to socio-economic development planning.

Keywords: Multi-criteria decision making, SWARA, COPRAS, Artificial Intelligence, agricultural marketing, socio-economic decision support, regulated market optimization.

MSC: 03E72, 90B50, 68T37, 91B06

1. INTRODUCTION

Agricultural marketing lies at the nexus of agricultural production system efficiency, profitability, and sustainability. To achieve adequate income and livelihood, Indian farmers particularly smallholders must gain access to fair, transparent, and efficient markets. There are many avenues for agricultural marketing regulated markets, private mandis, or direct sales to processors/exporters and farmers often find it extremely difficult to choose the most remunerative channel [1]. This is further complicated by limited access to information, the presence of intermediaries, inconsistent pricing methods, and varying service conditions in the markets. It is therefore essential to build an objective, transparent, and data-driven decision support model to assist farmers and policymakers in making informed decisions about the best market options available [2].

The Government of India has enacted reforms to strengthen the regulated market system through APMCs and other institutional frameworks, but the performance and efficiency of these markets vary widely across different regions. Considering the agricultural economy of Tamil Nadu, particularly the Coimbatore district, a variety of crops including cotton, maize, groundnut, turmeric, and banana are associated with diverse market operations and stakeholders [3]. It is imperative for farmers to analyze the various marketing options to access and engage with favorable market patterns, in order to minimize post-harvest losses, reduce price differentials, and effectively navigate the evolving, dynamic, and complex marketing systems [4].

Since general MCDM methods are designed to explore options in the presence of multiple, and sometimes contradictory, criteria [5,6]. This study proposes a hybrid classical decision support framework that employs the Stepwise Weight Assessment Ratio Analysis (SWARA) method for assessing criterion weights and the Complex Proportional Assessment (COPRAS) method for ranking alternatives through comparative analysis. SWARA facilitates the assignment of relative importance to criteria based on either expert judgment or participant input, which is particularly relevant when primary data is collected via field surveys and stakeholder consultations. COPRAS enables the ranking of alternatives by aggregating their performance across all criteria into a single comprehensive score, thereby providing decision-makers with clear insights into the trade-offs and negotiations involved.

This study considers six key criteria influencing farmers' selection of marketing channels: spot payment, absence of middlemen, low market fees, accuracy in weighing, receipt of a remunerative price, and quality-based pricing [7]. These criteria were identified through a structured field survey conducted on a representative sample of farmers operating in the regulated markets of Coimbatore district. Although the proposed framework is generic in nature, its applicability is illustrated through the analysis of three crop-specific marketing alternatives: cotton, maize, and groundnut [8].

This research aims to construct a multi-objective decision-support framework for evaluating agricultural marketing options by leveraging primary field-level data and structured decision-making principles. The motivation arises from persistent inefficiencies in India's agricultural marketing ecosystem, including limited price transparency, intermediary exploitation, and inadequate institutional mechanisms. Addressing these issues, the study employs MCDM techniques to develop a rational and balanced model that can guide strategic marketing decisions. By focusing on regulated markets in Coimbatore, the framework seeks to align marketing strategies with farmer-centric socio-economic goals under multiple conflicting criteria.

Although various investigations have examined agricultural marketing challenges, few have employed integrated MCDM approaches grounded in both expert knowledge and real-world data. This study fills that gap by proposing a hybrid decision-making model that combines subjective expert insights with quantifiable field-level evidence. Through the application of structured preference modeling, the proposed framework supports more equitable and efficient market participation for smallholder farmers. The approach contributes to the growing body of research at the intersection of artificial intelligence, economic planning, and social development.

The present study contributes a hybrid MCDM-based evaluation framework that applies the SWARA method to derive weights for key marketing criteria and employs the COPRAS method to rank crop alternatives. The proposed model distinguishes itself by utilizing primary data directly collected from farmers and market intermediaries in regulated agricultural markets. It advances the practical utility of deterministic decision models in agricultural planning.

By incorporating a set of socio-economic and operational criteria relevant to farmers—such as immediate payment, absence of intermediaries, and minimized transaction costs—the model delivers actionable insights for policy-makers, cooperatives, and regional agricultural planners. Furthermore, comparative and sensitivity analyses validate the robustness and consistency of the decision outcomes across varying scenarios. The model supports strategic decisions under the framework of goal programming and aligns with broader objectives in social and economic policy-making through artificial intelligence-assisted analysis. It is adaptable, scalable, and applicable across diverse agricultural regions, making it a significant tool for modern market optimization in the agricultural sector.

The remaining part of this study is divided into the following sections: Section 2 presents the literature review. Section 3 provides the proposed evaluation structure and methodology. Section 4 implements a case study to validate the proposed techniques. Section 5 presents the results and discussion of findings, including the proposed methods, comparative analysis, and sensitivity analysis. Finally, Section 6 concludes the study by highlighting the conclusions, limitations, and directions for future research.

2. LITERATURE REVIEW

Functioning agricultural markets are critical for delivering accurate price signals to producers, enabling them to make informed decisions about crop production, input purchases, storage, and sales. Chadha et al. (2008) highlighted that agricultural marketing, when operating within a well-performing market system, can also protect consumer interests by providing transparency and a fair pricing mechanism. However, the marketing of agricultural products in India suffers from several imperfections, as documented by Begum (2011), including poor infrastructure, lack of grading systems for produce, and unreliable weighing practices. These shortcomings widen the gap between producers and buyers, undermining confidence in the market mechanism due to a lack of transparency and trust.

Many studies have demonstrated the role of cooperatives and institutions in addressing these issues. Karahocagil and Ozudogru (2011), in their investigation of agricultural development cooperatives in Turkey, reported that farmers benefited from timely information related to production, marketing, and input procurement. In India, Govindarajan and Shanmugam (2011) found that rural regulated markets could be significantly improved through better management, accompanied by increased participation from more villages and traders [9,10].

Research specific to crops also highlights differences in regional performance regarding the production and marketing of crops. For example, Madhusudhana (2013) and Rajeshwari et al. (2015) evaluated groundnut area, yield, and cost of production, which fluctuated, thus highlighting the need to seek better access to markets [11]. Khunt et al. (2003) studied pomegranate marketing in Gujarat and indicated that marketing costs—for example, costs to transport, pack, and grade pomegranate—made up more than half the cost and therefore affected farmers' net income.

In the context of market dynamics and chains, Chalajour and Feizabadi (2012) illustrated a long-run price integration from the farm to retail level, indicating that marketing margins play an important role in price transmission. Conversely, Pradeep Kumar Ganjeer et al. (2018) analyzed long-term time-series trends of maize productivity in Chhattisgarh using time series models, finding that the crop exhibited stability over time. Overall, these studies have provided useful information; however, they were either descriptive or econometric in nature, lacking a decision-making focus, did not employ a structured multi-criteria approach, and did not consider all relevant marketing options [12,13].

In recent decades, there has been an increasing application of MCDM approaches in agricultural planning, with various examples of applying MCDM techniques in the areas of crop selection, irrigation, and logistics [14, 15, 16, 17]. Nonetheless, MCDM methods have received limited application in agricultural marketing evaluation, particularly when using primary data [18, 19, 20]. The SWARA method proposed by Keršuliene et al. presents a systematic process to derive criterion weights using expert judgment, making the process clearer and simpler as shown in Table 1. The COPRAS method developed by Zavadskas et al. makes an effective evaluation of competing alternatives or options by practical selection of beneficial and non-beneficial criteria and presents a ranking of the competing alternatives or options [21]. While COPRAS has been applied in other sectors such as construction, energy, and transport, there have been few applications of COPRAS in agricultural marketing.

Table 1: Comparative justification of selected MCDM methods

Aspect	*SWARA vs. AHP/Entropy*	*COPRAS vs. TOPSIS/VIKOR*
Complexity of Application	SWARA is easier to apply with fewer comparisons, while AHP requires extensive pairwise evaluations and Entropy depends on statistical analysis [22].	COPRAS applies proportional assessment with less computation, whereas TOPSIS uses distance measures and VIKOR relies on compromise programming [23].
Stakeholder Involvement	SWARA integrates expert and farmer opinions step by step; AHP can be mentally demanding, and Entropy excludes human input [24].	COPRAS offers clear proportional rankings that are understandable to stakeholders, while TOPSIS and VIKOR are more technical and less intuitive [25].
Handling of Criteria	SWARA captures subjective importance effectively; AHP can suffer from inconsistency, and Entropy relies only on data variation [26].	COPRAS considers both beneficial and non-beneficial criteria at once, while TOPSIS stresses closeness to an ideal and VIKOR stresses compromise [27].
Suitability for Agriculture	SWARA fits well in contexts where farmers' perspectives are vital, reducing complexity for rural users [28].	COPRAS is appropriate for socio-economic studies requiring transparency, while TOPSIS and VIKOR may be harder for field practitioners to apply [29].

Additionally, most recent analyses of MCDM have utilized only secondary data or expert opinion. Very few studies have applied SWARA and COPRAS using a traditional (i.e., non-fuzzy) approach and have utilized primary data from farmers. This study aims to address this gap by using primary field data from Coimbatore to assess crop-based market options, providing a credible, scalable, and repeatable model to improve decisions on market access in regulated agriculture.

3. METHODS AND MATERIAL

In this study, two classical multi-criteria techniques interact to evaluate agricultural market alternatives using primary data. Primary field data were gathered through structured surveys of farmers in regulated markets to capture perceptions on six key decision criteria. Using the SWARA method, the relative importance of these criteria was quantified, ensuring that the framework is directly grounded in farmers' practical experiences and priorities. The methodological steps of the approach are outlined below in the two subsections.

3.1. Algorithm of stepwise weight assessment ratio analysis

The SWARA method allows specialists to subjectively determine the importance of criteria in a systematic manner. The procedure consists of the following steps:

Step 1: Arrange the criteria in descending order of perceived importance, based on expert judgments.

Step 2: For every criterion beginning from the second one, the expert provides a comparative significance value $\mathfrak{S}_j$ relative to the preceding criterion.

Step 3: Compute the coefficient $\mathfrak{K}_j$ for every criterion as follows:

$$\mathfrak{K}_j = \begin{cases} 1, & if\ j = 1 \\ \mathfrak{S}_j + 1, & if\ j > 1 \end{cases} \tag{1}$$

Step 4: Compute the recalculated weight ($\mathfrak{Q}_j$):

$$\mathfrak{Q}_j = \frac{1}{\mathfrak{K}_j} \tag{2}$$

Step 5: Determine the normalized weight $\mathfrak{W}_j$ for each criterion:

$$\mathfrak{W}_j = \frac{\mathfrak{Q}_j}{\sum_{j=1}^{n} \mathfrak{Q}_j} \tag{3}$$

3.2. Algorithm of Complex Proportional Assessment

The COPRAS method evaluates and ranks options based on the calculated weights and performance scores. The steps are as follows:

Step 1: Construct the decision matrix $\mathfrak{X} = [\mathfrak{x}_{ij}]$, where i represents the alternatives and j represents the criteria.

Step 2: Normalize the decision matrix:

$$\mathfrak{R}_{ij} = \frac{\mathfrak{x}_{ij}}{\sum_{i=1}^{m} \mathfrak{x}_{ij}} \tag{4}$$

where m is the number of alternatives.

Step 3: Compute the weighted normalized decision matrix:

$$\mathfrak{D}_{ij} = \mathfrak{W}_j \cdot \mathfrak{R}_{ij} \tag{5}$$

Step 4: For each alternative, calculate the sums of beneficial (BC) and non-beneficial (NC) criteria:

$$\mathfrak{S}_i^{+} = \sum_{j \in BC} \mathfrak{D}_{ij}, \quad \mathfrak{S}_i^{-} = \sum_{j \in NC} \mathfrak{D}_{ij} \tag{6}$$

Step 5: Determine the relative significance of each alternative:

$$\mathfrak{Q}_i = \mathfrak{S}_i^{+} + \frac{min(\mathfrak{S}^{-}) * \sum \mathfrak{S}^{+}}{\mathfrak{S}_i^{-} * (min(\mathfrak{S}^{-})/\mathfrak{S}^{-})} \tag{7}$$

Step 6: Compute the degree of performance ($\mathfrak{Z}_i$)

$$\mathfrak{Z}_i = \frac{\mathfrak{Q}_i}{\mathfrak{Q}_{max}} \tag{8}$$

Step 7: Rank the options in descending order based on their $\mathfrak{Z}_i$ values.

4. CASE STUDY

The study was carried out in the Coimbatore district of Tamil Nadu, situated in the western agro-climatic (ecological) zone of the state, which is characterized by variable cropping practices across different seasons with efficient regulated market systems. The district in this study featured major taluks of Pollachi, Annur, Kinathukadavu, Sulur, and Thondamuthur, all of which fall under the Coimbatore Market Committee. The Coimbatore

Market Committee has multiple regulated markets for some major crops in the district (cotton, maize, and groundnut) unique to the taluk, i.e., Pollachi and Annur for maize, Thondamuthur for cotton, and Kinathukadavu and Sulur for groundnut.

The spatial presence of the regulated markets and their close proximity to the major zones of cultivation, transport routing, and storage facilities were captured and mapped using a GIS to allow visualization of the regulated markets and their contexts as shown in Figure 1. The GIS map, also known as the Geo Mapper, was used to help determine the high-density areas of agriculture/government as well as the accessibility routes that provided a means to appropriately delineate the survey areas, while also accounting for the spatial configuration of the survey areas to get identifiers for the sites in the field that were sampled during the empirical study design, as well as to spread the outtake of market locations sampled across the context of varying agro-economic environments.

4.1 Data collection

Primary data were collected through a structured field survey conducted among farmers, traders, and market officials within the regulated markets of Coimbatore. One hundred twenty respondents were selected from various crop sectors using a stratified random sampling methodology to ensure adequate representation from cotton, maize, and groundnut grower.

Respondents were asked to rank seven important market evaluation criteria: spot payment; no middlemen; low market charges; accurate weight assessment; remunerative price; quality-based price realization; and market distance. The ranks obtained were then converted to Garrett scores using the following formula:

$$\text{Percent Position} = \frac{100(R_{ij}-0.5)}{N_j} \tag{9}$$

The standard conversion tables mapped percent positions to Garrett scores and justified the socio-economic criteria based on stakeholder priorities, as shown in Table 2. Mean scores were used to prepare the decision matrix for the MCDM analysis. Examination using direct field observations was conducted at the godowns, weighing stations, and auction yards to evaluate services and infrastructure. Secondary data and pricing trends obtained from APMC reports were also collected, alongside godown capacities and merchant registration records obtained from official documents to triangulate and corroborate the main measures.

Table 2: Socio-Economic Criteria Based on Stakeholder Priorities

Socio-Economic Criterion	Stakeholder Rationale
Spot cash payment	Farmers prefer immediate liquidity to meet urgent household expenses and reduce dependence on informal credit.
Absence of middlemen	Direct selling ensures fair pricing and increases farmers' bargaining power.
Price transparency	Clear and open pricing builds trust and minimizes information asymmetry in regulated markets.
Transportation convenience	Reliable transport access lowers transaction costs, reduces post-harvest losses, and improves market participation.
Storage availability	Adequate storage helps farmers avoid distress sales and secure better prices at favorable times.
Market fee exemptions	Reducing or waiving fees alleviates financial burdens, particularly for smallholder farmers with limited margins.

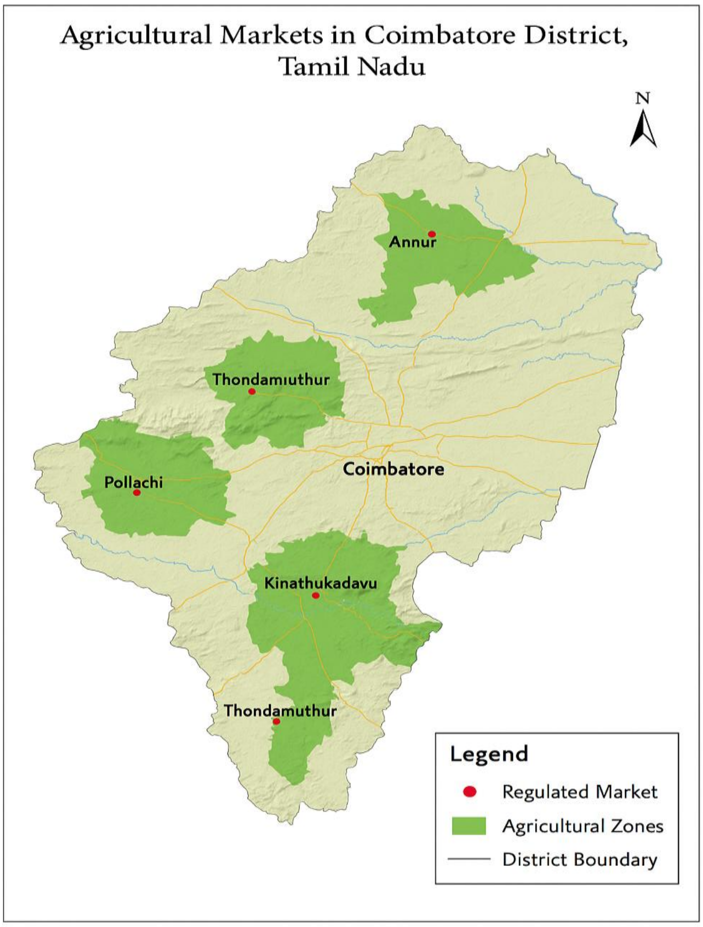

Figure 1: GIS map showing distribution of regulated markets in coimbatore district

4.2 Regulated market infrastructure

In Tamil Nadu, 23 market committees, governed by the Tamil Nadu Agricultural Produce Marketing Act, 1987, and Rules, 1991, oversee 281 regulated markets, as shown in Figure 2. These markets were established within the notified areas to facilitate the proper trade of agricultural produce between farmers and traders. Farmers sell their produce through a secret bidding system without paying any fee, while traders pay a 1% market fee on sales and additional license fees. In 2017–18, a yield of 27.94 lakh metric tonnes was sold, generating Rs. 128.86 crore in revenue.

Figure 3 presents the warehouse capacities under the Coimbatore Market Committee, with Anamalai having the highest capacity of 6,700 metric tonnes. Other sources contributed a minimal amount, ranging from 0.1% to 1%. Figures 4, 5, and 6 present the value and volume of cotton, maize, and groundnuts in the Coimbatore regulated market from 2011–12 to 2019–20.

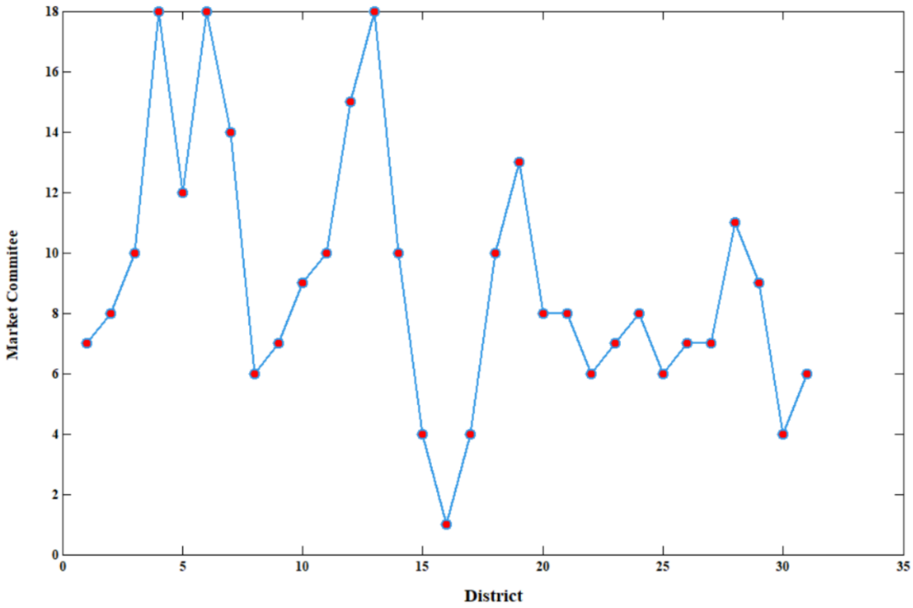

Figure 2: Regulated markets in Tamil Nadu categorized by district and market committee

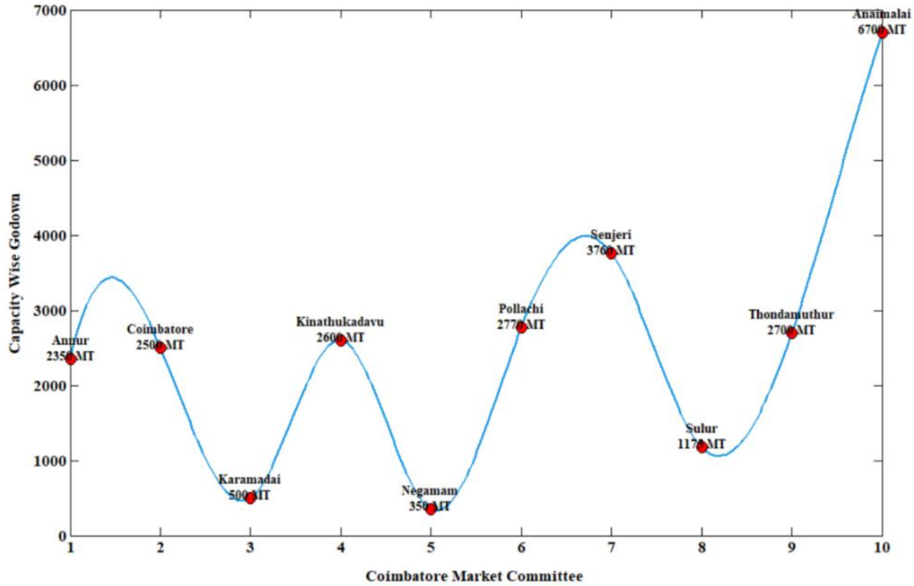

Figure 3: Classification of regulated markets based on capacity

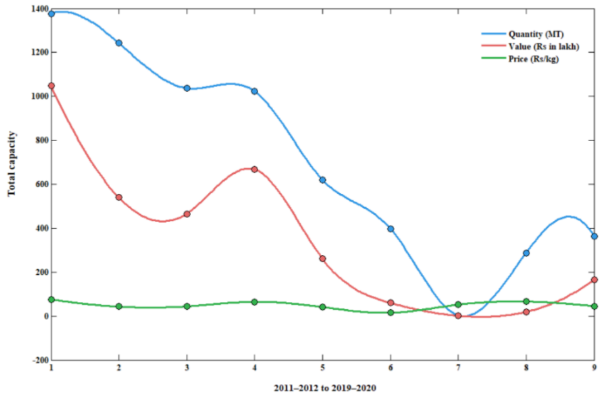

Figure 4: Annual price trend of cotton in the Coimbatore regulated market from 2011–2020

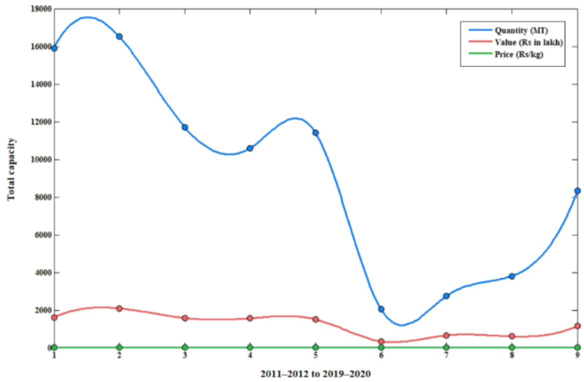

Figure 5: Annual price trend of maize in the Coimbatore regulated market from 2011–2020

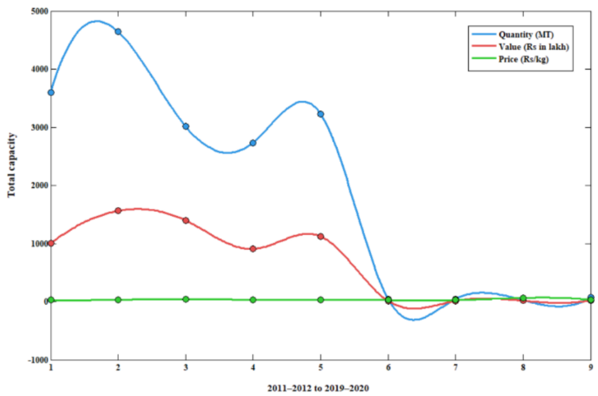

Figure 6: Annual price trend of groundnut in the Coimbatore regulated market from 2011–2020

5. RESULTS AND DISCUSSION

The primary objective of this study was to evaluate the performance of agricultural market alternatives using traditional Multi-Criteria Decision-Making (MCDM) techniques. The Stepwise Weight Assessment Ratio Analysis (SWARA) method was applied to determine the weight of each criterion based on farmers' preferences, while the Complex Proportional Assessment (COPRAS) method was employed to rank the alternatives using normalized performance data.

5.1. Criteria weighting using SWARA

A study involving familiar experts with the SWARA technique was conducted to validate and elaborate on the proposed strategy in greater detail. The respondents selected the criteria and provided their opinions based on their perceived importance and implications, as shown in Table 3. It should be noted that these criteria were presented in the expected order of importance to facilitate the application of the SWARA method. The calculation details and criteria weights are presented in Table 4 and were determined using the SWARA approach based on the average values.

Table 3: Comparative significance of average value

Criteria	Average values
C_1: Spot Payment (SP)	-
C_2: Absence of Middlemen (AM)	0.35
C_3: Low Market Charges (LMC)	0.18
C_4: Correct Weight (CW)	0.27
C_5: Remunerative Price (RP)	0.23
C_6: Quality-Based Price (QP)	0.15
C_7: Market Distance (MD)	0.1

Table 4: The SWARA approach creates calculation details and weights for the criterion based on mean values

Criterion's	Significance values	R_j	D_j	W_j
C_1		1	1.0000	0.2543
C_2	0.35	1.35	0.7407	0.1884
C_3	0.18	1.18	0.6277	0.1597
C_4	0.27	1.27	0.4943	0.1257
C_5	0.23	1.23	0.4019	0.1022
C_6	0.15	1.15	0.3494	0.0889
C_7	0.1	1.1	0.3177	0.0808

The results clearly indicate that spot payment and absence of middlemen were prioritized highly by farmers, reflecting their strong preference for immediate liquidity and direct market access. The lowest weight was assigned to market distance, suggesting that accessibility is less of a concern compared to pricing and transaction fairness as shown in Figure 7.

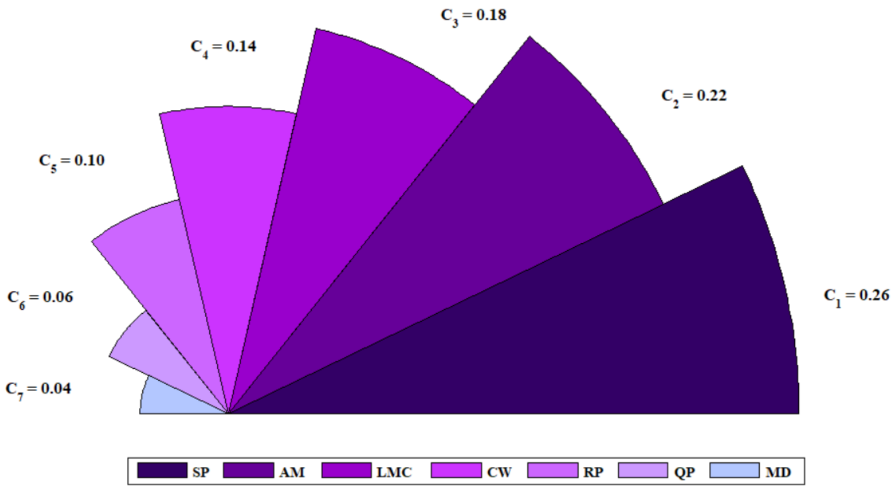

Figure 7: Criteria weights values

5.2 Ranking with COPRAS method

Based on the performance scores of three alternatives Cotton, Maize, and Groundnut the COPRAS method was applied to derive the decision matrix Table 5. The evaluation process was done in several stages using the PHF decision-making structure. In Step 2, Equation (4) was applied to normalize the PHF decision matrix, with summarized results shown in Table 6. In Step 3, the weighted normalized PHF decision matrix was calculated using Equation (5), and the results were presented in Table 7. Later, in Step 4, the normalized scores were computed for both benefit and cost criteria. The resulting benefit scores (S_{+i}) were $\{0.2569, 0.2502, 0.2524\}$, while the cost scores (S_{-i}) were $\{0.0860, 0.0826, 0.0716\}$. In Step 5, the priority values for the alternatives (D_i) were obtained using Equation (7), yielding values of $\{0.3311, 0.3274, 0.3414\}$.

Finally, in Step 6, Equation (8) was used to calculate the level of performance (Z_i) for each alternative, resulting in values as shown in Figure 8. The groundnut market emerged as the most preferred alternative, driven by its strong performance across high-weight criteria such as spot payment and low market charges. Although cotton and maize performed well, their marginally lower utility scores highlight slight deficiencies in criteria like quality-based pricing and weight transparency.

Table 5: Decision matrix for crop market alternatives

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	63.36	62.46	60.7	55.66	37.5	36.72	7
A_2	60.66	52.9	59.4	60.84	39.8	39.28	6.5
A_3	59.44	54.16	54.52	54.78	48.08	39.52	5

Table 6: Normalized decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.3453	0.3684	0.3476	0.3249	0.2990	0.3178	0.3783
A_2	0.3306	0.3120	0.3401	0.3552	0.3174	0.3400	0.3513
A_3	0.3239	0.3194	0.3122	0.3198	0.3834	0.3421	0.2705

Table 7: Weighted normalized decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.0878	0.0694	0.0555	0.0408	0.0305	0.0282	0.0305
A_2	0.0840	0.0587	0.0543	0.0446	0.0324	0.0302	0.0283
A_3	0.0824	0.0601	0.0498	0.0402	0.0391	0.0304	0.0218

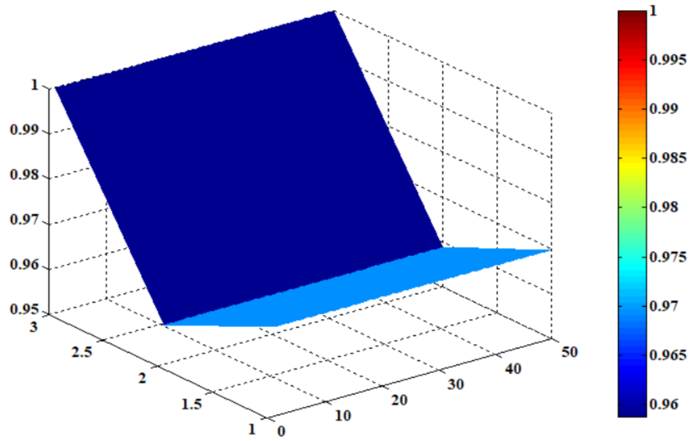

Figure 8: Integrated model using SWARA and COPRAS for crop selection

The use of primary field data improved both the reliability and practical relevance of the analysis by embedding farmers' real preferences into the framework. Emphasis on factors such as spot cash payment and absence of middlemen illustrates alignment with socio-economic realities, making the final ranking where groundnut emerged as the top crop both statistically sound and socially validated.

5.3. Policy implications

The findings of this study highlight several key areas for enhancing regulated agricultural markets and supporting farmer welfare:

- Timely payments: Farmers prioritize immediate cash payments. Implementing secure digital payment systems and enforcing strict payment timelines in regulated markets can reduce reliance on informal credit and improve cash flow.
- Reducing dependence on intermediaries: The preference for direct transactions indicates a need to strengthen farmer groups, cooperatives, and direct procurement mechanisms, thereby enhancing farmers' bargaining power.
- Investment in infrastructure: Adequate storage, cold chain facilities, and reliable transportation are essential to reduce post-harvest losses and enable farmers to market produce at optimal times.
- Market fee adjustments: High market levies disproportionately affect smallholders. Providing fee exemptions, subsidies, or reduced charges can encourage greater participation in formal marketing channels.
- Alignment with rural development goals: Integrating these measures with broader objectives such as income stability, poverty reduction, and sustainable agricultural

growth ensures that farmer-centered interventions yield wider socio-economic benefits.

5.4. Comparative analysis

To assess the robustness and consistency of the proposed decision-making framework, a comprehensive comparative analysis was undertaken using nine established MCDM methods—COPRAS, TOPSIS, VIKOR, SAW, MOORA, EDAS, MABAC, CoCoSo, and ELECTRE. These methods were applied to the same set of alternatives and criteria, using the criterion weights derived via the SWARA method. Each technique produced a unique set of normalized ranking values for the agricultural alternatives: Cotton (A_1), Maize (A_2), and Groundnut (A_3).

Despite the intrinsic differences in computational strategies such as distance measures, aggregation models, and normalization schemes all nine methods demonstrated a consistent ranking pattern. Groundnut (A_3) emerged as the top-ranked alternative across all methods, followed by Cotton (A_1) and Maize (A_2). The convergence in ranking outcomes reinforces the internal validity and stability of the evaluation model.

Although minor fluctuations in the ranking scores were observed, these differences are attributable to the methodological nuances of each MCDM approach. For instance, VIKOR and ELECTRE yielded slightly lower scores due to their relative emphasis on compromise and outranking mechanisms, respectively. Nevertheless, the preservation of the overall ranking sequence highlights the framework's reliability for use in agricultural decision-making scenarios. The comparative results are shown in Table 8 and Figure 9.

Table 8: Comparison of normalized ranking values

	TOPSIS	VIKOR	SAW	MOORA	EDAS	MABAC	CoCoSo	ELECTRE
A_1	0.68	0.42	0.80	0.75	0.78	0.82	0.79	0.77
A_2	0.64	0.45	0.77	0.72	0.76	0.80	0.78	0.75
A_3	0.71	0.39	0.82	0.78	0.81	0.84	0.81	0.79

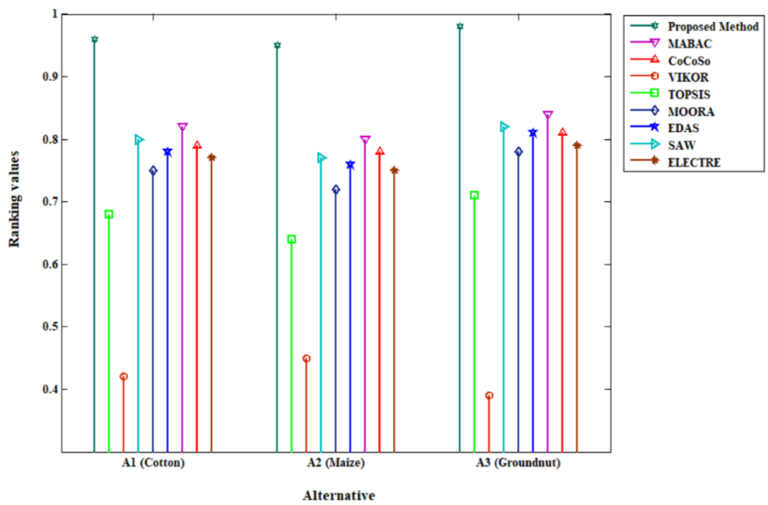

Figure 9: Comparative ranking values for agricultural alternatives

5.5. Sensitivity analysis

To evaluate the robustness of the decision-making framework, the weight of the most influential criterion, spot cash payment, was systematically varied from 0.10 to 0.50. The weights of the remaining criteria were adjusted proportionally to maintain normalization, and the COPRAS method was applied at each stage to recalculate the utility scores of the alternatives. The results, presented in Table 9 and Figure 10, indicate that while utility scores exhibited minor variations with changes in criterion weights, the ranking order of alternatives remained unchanged. Groundnut (A3) consistently emerged as the top-ranked option, followed by Maize (A2) and Cotton (A1). The stability of these rankings demonstrates the reliability of the model.

These findings confirm that the proposed framework provides robust decision support, maintaining consistent rankings even when the relative importance of socio-economic criteria varies due to farmer preferences, market dynamics, or policy interventions.

Table 9: COPRAS Scores under varying spot payment weights

	Spot Payment Weight	A_1	A_2	A_3	Ranking Order
Case 1	0.10	0.940	0.965	0.985	$A_3 > A_2 > A_1$
Case 2	0.20	0.930	0.950	0.975	$A_3 > A_2 > A_1$
Case 3	0.30	0.925	0.940	0.970	$A_3 > A_2 > A_1$
Case 4	0.40	0.920	0.935	0.960	$A_3 > A_2 > A_1$
Case 5	0.50	0.915	0.930	0.950	$A_3 > A_2 > A_1$

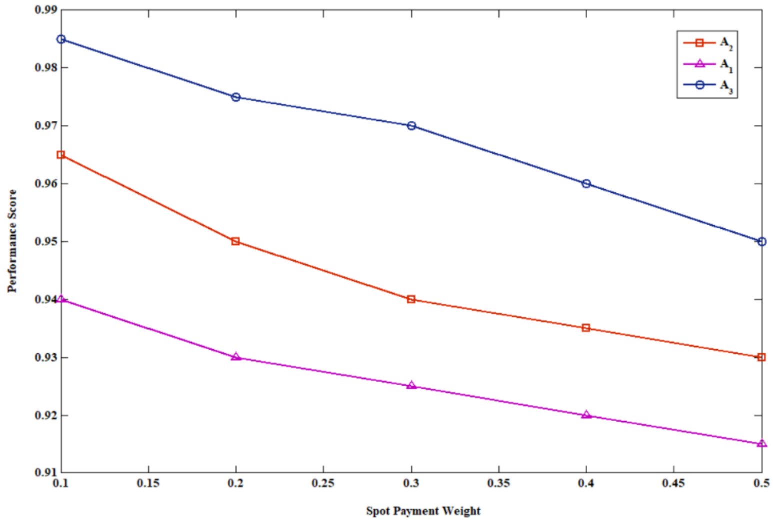

Figure 10: Sensitivity analysis of the alternative score values

6. CONCLUSION

This study developed a structured decision-support framework for agricultural marketing by integrating traditional MCDM techniques within a goal-oriented analytical structure. The SWARA method was employed to weight seven farmer-centric criteria reflecting socio-economic and market-based considerations, and the COPRAS method was applied to rank three primary crops: groundnut, cotton, and maize. Groundnut emerged as the most preferred crop due to its alignment with key factors such as spot cash payments and favorable market prices. GIS-based spatial analysis further enhanced the study by evaluating farmers' proximity to regulated markets. The robustness of the model was validated through comparative and sensitivity analyses, confirming its internal consistency and reliability. Overall, the research demonstrates how structured MCDM approaches can support economic and social decision-making, particularly in agricultural policy and market optimization, contributing to the broader field of multi-objective programming.

The integration of primary field data with MCDM methods strengthens the practical relevance of agricultural marketing decisions. The proposed framework not only delivers methodologically robust results but also provides actionable policy insights that address the real-world challenges faced by farmers.

6.1. Limitations and Future Research

The study was limited to the Coimbatore district and a select set of crop alternatives within a deterministic framework. Future research could expand the scope to include multiple regions, a wider range of crops, and a larger sample of farmers to capture regional variations. Incorporating fuzzy, probabilistic, or interval-based MCDM models would allow the framework to better accommodate uncertainties and the dynamic nature of agricultural markets. Additionally, integrating seasonal price fluctuations, risk assessments, and dynamic simulations could enhance the model's predictive capability and policy relevance.

The proposed framework also has potential for broader applicability. By aligning criteria with local stakeholder priorities and market conditions, it can be adapted to other agricultural contexts, including value-chain analysis, contract farming evaluation, and policy impact assessment in diverse emerging economies. Consequently, the study advances methodological approaches while offering a transparent and scalable decision-support tool for agricultural planning, regional development, and socio-economic growth within the paradigm of artificial intelligence in multi-objective decision-making.

Acknowledgement: The authors extend their appreciation to the Deanship of Research and Graduate Studies at King Khalid University for funding this work through Large Research Project under grant number RGP2/50/46.

Funding: This research received no external funding.

REFERENCES

[1] S. S. Chahal and P. Kataria, "Impact analysis of infrastructure and incentives on trade in regulated markets of Punjab," *Agriculture Update*, vol. 3, no. 3&4, pp. 373–378, 2008. doi: 10.5958/0976-4666.2015.00107.2

[2] P. Karahocagil and H. Ozudogru, "Agricultural development cooperatives in Turkey: The example Sanliurfa Province," *Journal of Animal and Veterinary Advances*, vol. 10, no. 3, pp. 372–377, 2011. doi: 10.3923/javaa.2011.372.377

[3] M. Saqlain, P. Kumam and W. Kumam, "Optimizing agricultural decision-making with integrated MCDM-MCDA methods: A case study on crop economics," *Yugoslav Journal of Operations Research*, vol. 00, pp. 8–8, 2025. doi: 10.2298/YJOR240915008S

[4] M. Chalajour and Y. Feizabadi, "Marketing price transmission analysis in the Iranian rice market," *African Journal of Agricultural Research*, vol. 7, no. 20, pp. 3081–3087, 2012.

[5] M. Sandra, S. Narayanamoorthy, K. Suvitha, D. Pamucar, V. Simic and D. Kang, "An insightful multicriteria model for the selection of drilling technique for heat extraction from geothermal reservoirs using a fuzzy-rough approach," *Information Sciences*, vol. 686, Art. no. 121353, 2025. doi: 10.1016/j.ins.2024.121353

[6] T. Manirathinam, S. Narayanamoorthy, S. Geetha, M. F. I. Othman, B. S. Alotaibi, A. Ahmadian and D. Kang, "Sustainable renewable energy system selection for self-sufficient households using integrated fermatean neutrosophic fuzzy stratified AHP-MARCOS approach," *Renewable Energy*, vol. 218, Art. no. 119292, 2023. doi: 10.1016/j.renene.2023.119292

[7] K. A. Khunt, H. M. Gajipara, B. K. Gadhvi and S. B. Vekariya, "Economics of production and marketing of pomegranate," *Indian Journal of Agricultural Marketing*, vol. 17, no. 1, pp. 100–107, 2003. doi: 10.17660/ActaHortic.2015.1089.23

[8] J. A. Begum, "The market structure, marketing practices and patterns of vegetable market: A micro level study," *Asian Journal of Research in Social Science and Humanities*, vol. 1, no. 3, pp. 10–18, 2011. doi: 10.17010/ijom/2015/v45/i8/79921

[9] K. Govindarajan and T. R. Shanmugam, "Measuring market efficiency of regulated markets for effective performance in Tamil Nadu," *Journal of the Indian Society of Agricultural Statistics*, vol. 65, no. 1, pp. 77–81, 2011. doi: 10.9734/ajaees/2021/v39i930650

[10] B. Madhusudhana, "A survey on area, production and productivity of groundnut crop in India," *Journal of Economics and Finance*, vol. 1, no. 3, pp. 1–7, 2013. doi: 10.9790/5933-0130107.

[11] R. B. Gotadaki, V. Mukkelli and T. N. Godi, "Production dimensions of groundnut in Agalkot district of Karnataka state," *The International Journal of Business & Management*, vol. 3, no. 11, pp. 1–9, 2015.

[12] P. K. Ganjeer, D. Sagar, V. Mishra and M. L. Lakhera, "Distribution of area, production and productivity of maize in different districts of northern hills of Chhattisgarh, India," *International Journal of Current Microbiology and Applied Sciences,* vol. 7, no. 8, pp. 1–9, 2018. doi: 10.20546/ijcmas.2018.708.246

[13] T. Tarnanidis, M. Vlachopoulou, B. Mareschal and J. Papathanasiou, "Marketing in the metaverse through MCDM methods and statistics," in *Multiple-Criteria Decision-Making (MCDM) Techniques and Statistics in Marketing*, IGI Global Scientific Publishing, 2025, pp. 249–266. doi: 10.1016/j.jbusres.2022.113420

[14] M. Sandra, S. Narayanamoorthy, K. Suvitha, D. Pamucar and D. Kang, "Optimizing non-invasive remote sensing for geothermal exploration with T-spherical dual hesitant fuzzy decision model," *Facta Universitatis, Series: Mechanical Engineering*, 2025. doi: 10.22190/FUME241116016S

[15] B. Pandey and M. K. Khurana, "An integrated Pythagorean fuzzy SWARA-COPRAS framework to prioritise the solutions for mitigating Industry 4.0 risks," *Expert Systems with Applications*, vol. 254, Art. no. 124412, 2024. doi: 10.1016/j.eswa.2024.124412

[16] D. Kang, K. Suvitha, S. Narayanamoorthy, M. Sandra and D. Pamucar, "Evaluation of wave energy converters based on integrated ELECTRE approach," *Expert Systems with Applications*, vol. 242, Art. no. 122793, 2024. doi: 10.1016/j.eswa.2023.122793

[17] H. F. Atlı, "Target market selection for agricultural products in international markets using fuzzy AHP and fuzzy COPRAS MCDM techniques," *Journal of Anatolian Environmental and Animal Sciences*, vol. 9, no. 3, pp. 369–382, 2024. doi: 10.35229/jaes.1452490

[18] M. Nedeljković, A. Puška, D. Pamučar and D. Marinković, "Selection of agricultural product sales channels using fuzzy double MEREC and fuzzy RAWEC method," *Agriculture and Forestry*, vol. 70, no. 3, pp. 45–58, 2024. doi: 10.17707/AgricultForest.70.3.03

[19] Bathaei and D. Streimikiene, "Assessing sustainable agriculture in the EU/Baltic countries using multi-criteria decision making (MCDM) and EUROSTAT data using stakeholder's view," *Sustainable Development*, 2025. doi: 10.1002/sd.3529

[20] E. Huskanović and Ž. Stević, "Sorting products using the ABC-SWARA model," *Decision Making and Artificial Intelligence Trends*, vol. 1, no. 1, pp. 91–104, 2024.

[21] S. Dhruva, R. Krishankumar, K. S. Ravichandran, A. Kaklauskas, E. K. Zavadskas and P. Gupta, "Selection of waste treatment methods for food sources: An integrated decision model using q-rung fuzzy data, LOPCOW, and COPRAS techniques," *Clean Technologies and Environmental Policy*, pp. 1–25, 2025. doi: 10.1007/s10098-025-03160-6

[22] A. Mehdiabadi, A. Sadeghi, A. Karbassi Yazdi and Y. Tan, "Sustainability Service Chain Capabilities in the Oil and Gas Industry: A Fuzzy Hybrid Approach SWARA-MABAC," *Spectrum of Operational Research*, vol. 2, pp. 92–112, 2025. doi: 10.31181/sor21202512

[23] T. Basuri, K. H. Gazi, P. Bhaduri, S. G. Das and S. P. Mondal, "Decision-analytics-based Sustainable Location Problem - Neutrosophic CRITIC-COPRAS Assessment Model," *Management Science Advances*, vol. 2, pp. 19–58, 2025. https://doi.org/10.31181/msa2120257

[24] D. Çilingir, H. H. Öztürk and K. Kaya, "Invisible Walls to Green Mobility: Barriers to Sustainable Transportation in Izmir," *Spectrum of Decision Making and Applications*, vol. 3, pp. 151–163, 2025. doi: 10.31181/sdmap31202653

[25] S. A. Razak, Z. M. Rodzi, F. Al-Sharqi and N. Ramli, "Revolutionizing Decision-Making in E-Commerce and IT Procurement: An IVPNS-COBRA Linguistic Variable Framework for Enhanced Multi-Criteria Analysis," *International Journal of Economic Sciences*, vol. 14, pp. 1–31, 2025. doi: 10.31181/ijes1412025176

[26] R. Kumar and D. Pamucar, "A Comprehensive and Systematic Review of Multi-Criteria Decision-Making (MCDM) Methods to Solve Decision-Making Problems: Two Decades from 2004 to 2024," *Spectrum of Decision Making and Applications*, vol. 2, pp. 178–197, 2025. doi: 10.31181/sdmap21202524

[27] E. K. Özekenci, "A Multi-Criteria Framework for Economic Decision Support in Urban Sustainability: Comparative Insights from European Cities," *International Journal of Economic Sciences*, vol. 14, pp. 162–181, 2025. doi: 10.31181/ijes1412025188

[28] M. B. Bouraima, S. Qian, Y. Qiu, I. Badi and M. M. Sangaré-Oumar, "Addressing Human Capital Development Challenges in Developing Countries Using an Interval-spherical Fuzzy Environment," *Management Science Advances*, vol. 2, pp. 59–68, 2025. doi: 10.31181/msa2120258

[29] S. Biswas, S. Bhattacharjee, B. Biswas, K. Mitra and N. Khawas, "An Expert Opinion-Based Soft Computing Framework for Comparing Nanotechnologies used in Agriculture," *Spectrum of Operational Research*, vol. 4, pp. 1–39, 2025. doi: 10.31181/sor4156