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Prioritizing MSMEs based on Technology Adoption Capabilities: A Fuzzy SAW-COPRAS Approach

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ABSTRACT

Emerging economies have started focusing on micro, small, and medium enterprises (MSMEs) as they see a lot of potential in these businesses. Quite often, these sectors are unorganized, but there is a significant contribution to the economy from them. Industry 4.0 has emphasized automation and encouraged the use of technologies. In this context, upskilling and reskilling are required. At the ground level, such technological adoptions are not direct, and the implementation of such technologies incurs challenges that affect the process of adoption. This paper presents a combined decision approach for the prioritization of MSMEs based on technology adoption capabilities. It must be noted that the presented framework attempts to prioritize MSMEs based on their ability to handle technology adoption issues. Notably, every MSME undergoes a transition in social, economic, and environmental contexts when shifting to technology-driven solutions. To facilitate the process and aid in better understanding, this paper puts forward a combined decision approach. First, the technology adoption factors are presented based on a literature review and discussions with MSME stakeholders. Later, Fuzzy SAW is used to determine the weights of tech-adoption criteria. These weights signify the relative importance of each criterion. Likewise, Fuzzy COPRAS is used to assign priority values to MSMEs. We consider the simple and straightforward procedure along with its ability to understand the criteria type before making a decision. Implications are discussed to support policymakers. A case example from India is considered to determine the usefulness of the proposed model. The results indicate that the top three criteria are lack of skillset (T5), infrastructure mismatch (T6), and high initial cost (T7), which are used to prioritize MSMEs.

1. Introduction

Industry 4.0 strongly encourages the intervention of technologies into day-to-day industrial activities not only to uplift profit but also to support micro, small, and medium enterprises (MSMEs) in achieving their sustainability targets, which play a crucial role in facilitating countries to achieve their Sustainable Development Goals (SDGs). By 2030, global leaders have agreed on significant

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control of carbon emissions, and each country has declared its targets and plans toward the common urgent goal—carbon footprint reduction [1,2].

At the ground level, the implementation of tech-driven solutions to diverse MSME problems is not direct and incurs a considerable number of challenges [3], which must be carefully addressed to support MSMEs in the smooth adoption of technologies for handling their day-to-day activities. Wielgórka [4] studied MSMEs in Poland and emphasized the need for environmental management systems that encourage MSMEs to participate in CSR activities related to sustainability and eco-friendly practices. Agyapong and Arthur [5] examined the role of MSMEs in eco-pollution and urged the promotion of sustainable businesses to combat the critical planetary challenge—climate change. Vásquez et al. [6] believe that the right technology can significantly reduce ecological impact by promoting circularity within MSMEs. However, as mentioned above, the adoption of such technologies is not direct, and certain research questions emanate from the study:

(RQ 1): What are the factors/criteria that affect the technology adoption within MSMEs?

(RQ 2): What is the relative importance of such criteria?

(RQ 3): How are MSMEs prioritized in terms of these adoption criteria?

Some contributions towards addressing these RQs are:

- The criteria for the study are chosen based on a review of the literature and suggestions from experts in the field.
- The fuzzy Simple Additive Weights (SAW) method is used for determining the weights of the criteria.
- The fuzzy Complex Proportional Assessment (COPRAS) method is used for ranking MSMEs based on these tech-adoption criteria.

The rest of the paper is organized as follows: Section 2 presents the literature review, Section 3 describes the methodology, Section 4 provides the case example, Section 5 discusses the findings, and Section 6 offers the concluding remarks.

2. Literature review on tech-adoption criteria

Bakare *et al.,* [7] inferred that technology adoption within enterprises improve efficacy of administration. But arguably its adoption by administrators is not direct and needs some level of adaptability strategy for smooth incorporation [8]. Nugroho [9] applied PLS approach to note that competitors pressure does not influence technology adoption of enterprises. To its contrary, Das *et al.,* [10] inferred that technology within enterprises keep them relevant and competitive in the worldwide market. Likewise, Putra and Darmawan [11] also inferred positive influence of technology on competitive advantage in the market. Ikhwana and Dianti [12] further support the line of thought that enterprises adopt technology to handle competition and gain advantage in the market. These arguments drive authors to consider the importance of competition and competitors in tech-adoption.

Purnamasari *et al.,* [13] clarified that enterprises must be informed about the perceived benefit that they get via tech-adoption and they must be encouraged to transition to technology. Lestari *et al.,* [14] applied PLS-SEM to understand the positive impact of perceived usefulness of technology to business of MSMEs indicating that technology supports MSME business with perceived benefits from its adoption. Hendrawan *et al.,* [15] inferred that resistance to change is a key challenge hindering MSMEs in tech-adoption. Mondal *et al.,* [16] considered BWM-ISM to understand the impact of resistace to change on tech-adoption in MSMEs.

Hendrawan *et al.,* [15] claimed that skillset is also crucial and lack of skillset is a potential challenge with MSMEs towards tech-adoption. Hendrawan *et al.,* [15] also pointed out that infrastructure scope and cost are crucial challenges that slows the tech-adoption within MSMEs.

Khatri [17] presented diverse challenges that hinder MSMEs and in this lack of sufficient skill to consider technology within the business is considered as a crucial issue.

3. Methodology – SAW and COPRAS combination

This section provides a stepwise procedure for determining the weights and ranks of criteria and MSMEs, respectively. For this purpose, a detailed formulation is presented. Specifically, tech-adoption criteria (TAC) are compared pairwise, which serves as input for the SAW method. Later, with the data on MSMEs and the weight vector, COPRAS is used for ranking. It must be noted that the weights are calculated from the pairwise rating data, and ranks are determined from the decision matrix.

The SAW method [18] follows a simple formulation, but it is practical and can be easily incorporated into the decision study by stakeholders. Moreover, COPRAS [19] is a ranking approach that considers criteria type during priority calculation and follows a simple, practically viable procedure that stakeholders can effectively incorporate into their decision model. The steps are given below:

Step 1: Collect pairwise ratings on TAC to form a matrix of order c×c. Fuzzy ratings are obtained from the qualitative terms.

Step 2: Apply the fuzzy SAW procedure for determining the weights of TAC, which results in a vector of order 1×c.

Step 2.1: Normalize the data in the pairwise matrix by using Eq. (1).

$$f_{j_1 j_2} = \begin{cases} apply\ singleton\ MF\ if\ a_{j_1 j_2} \neq 0 \\ 0 \quad\quad\quad\quad\quad\quad othewise \end{cases} \tag{1}$$

where $a_{j_1 j_2}$ is the rating and $f_{j_1 j_2}$ is the fuzzy value.

Step 2.2: Apply Eq. (2) for determining the sum vector.

$$n_j = \sum_{\substack{j_2=1 \\ j_1, j_2 \in j}}^{c} r_{j_1 j_2} \tag{2}$$

where j_1 and j_2 are any two criteria

Step 2.3: Normalize the vector for determining the weights of criteria.

$$w_j = \frac{n_j}{\sum_j (n_j)} \tag{3}$$

where w_j is the weight.

Step 3: Apply fuzzy COPRAS for determining the priority of MSMEs that yields a vector of $1 \times a$.

Step 3.1: Determine $Q1$, which is a vector of order $1 \times a$ obtained from the benefit type. It is calculated by Eq. (4).

$$Q1 = \sum_{j=1}^{B} w_j . n_{ij} \tag{4}$$

where B is benefit type.

Step 3.2: Determine $Q2$, which is a vector of order $1 \times a$ obtained from the cost type. It is calculated by Eq. (5).

$$Q2 = \sum_{j=1}^{C} w_j . n_{ij} \tag{5}$$

where C is the cost type.

Step 3.3: Determine $Q3$, which is a combination of $Q1$ and $Q2$ – calculated via Eq. (6).

$$Q3 = \delta \cdot Q1 + (1 - \delta) \cdot \frac{\sum_i Q2}{Q2 . \sum_i \left(\frac{1}{Q2}\right)} \tag{6}$$

where δ is the strategy value that can take values in the range 0 to 1.

Step 3.5: Arrange the vector $Q3$ is the descending order for determining the ranks of MSMEs.

4. Case example

Let us consider three MSMEs and seven TACs, namely: administrative support (T1), pressure from competitors/customers (T2), perceived benefits (T3), resistance to change (T4), lack of skillset (T5), infrastructure mismatch (T6), and high initial cost (T7). The first three TACs are of benefit type, and the remaining are of cost type. The three MSMEs are from India and are involved in product development using iron, with household products being the focus of these enterprises.

A detailed stepwise procedure is presented for determining the values of the key decision parameters. The ratings are provided on a 9-point Likert scale, with terms ranging from 1 to 9 and semantics as extremely low, very low, moderately low, low, normal, high, moderately high, very high, and extremely high. Their corresponding fuzzy values are 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9, respectively.

Step 1: Consider a 7×7 pairwise comparison matrix for determining the weights or relative importance of the TACs. A qualitative rating is used.

Table 1 provides pairwise comparison data for TACs, which are ratings on the 9-point Likert scale that are converted to their respective fuzzy values and used as input for the next step.

Table 1
Pairwise comparison data

PCM	T1	T2	T3	T4	T5	T6	T7
T1	0	5	5	6	7	6	8
T2	5	0	7	6	6	8	5
T3	5	7	0	4	6	5	5
T4	6	6	4	0	6	8	6
T5	7	6	6	6	0	7	7
T6	6	8	5	8	7	0	6
T7	8	5	5	6	7	8	0

Step 2: Apply the procedure in Section 3 to determine the weights, which yields a 1×7 vector. By applying Eqs. (1)–(3), a net information vector is obtained, which is then normalized to calculate the weights of TACs. Data is fuzzified by applying Eq. (1). Using Eq. (2), the net information vector is obtained, and by Eq. (3), the weights are determined as follows: T1 = 0.1423, T2 = 0.1423, T3 = 0.1231, T4 = 0.1385, T5 = 0.1500, T6 = 0.1538, and T7 = 0.1500. TAC 'T6' is considered the most important, followed by 'T7' and 'T5'. Likewise, the other TACs are sorted based on their relative importance.

Step 3: Consider a decision matrix of order 3×7 for ranking MSMEs. A qualitative rating is used.

Table 2 gives the fuzzy values that are used for determining the ranks of MSMEs. The initial rating data, in the form of qualitative terms, are fuzzified using Eq. (1).

Table 2
Rating MSMEs over TAC

CW	0.142308	0.142308	0.123077	0.138462	0.15	0.153846	0.15
Type	Benefit	Benefit	Benefit	Cost	Cost	Cost	Cost
DM	c1	c2	c3	c4	c5	c6	c7
M1	0.5	0.5	0.6	0.8	0.7	0.6	0.7
M2	0.6	0.6	0.7	0.5	0.8	0.5	0.8
M3	0.7	0.6	0.6	0.8	0.7	0.5	0.5

Step 4: Apply the procedure in Section 3 to determine the ranks of MSMEs.

Table 3 provides the results from COPRAS for ranking MSMEs based on the TACs. It can be observed that the rank order is M3 > M2 > M1, indicating that 'M3' is the most feasible MSME that could effectively manage the TACs.

Table 3
Results from SAW-COPRAS

Result	B	C	1/C	C_Part	Rank	Order
M1	0.216154	0.413077	2.420857	0.365446	0.2908	Rank 3
M2	0.256923	0.386154	2.589641	0.390925	0.323924	Rank 2
M3	0.258846	0.367692	2.719665	0.410553	0.334699	Rank 1

5. Sensitivity analysis and discussion

This section presents the sensitivity analysis of strategy values, with the key focus on understanding the effect of strategy values on the ordering of MSMEs. For this purpose, the strategy values are altered with a step size of 0.10 within the unit range, resulting in nine instances: 0.10, 0.20, …, 0.90. Specifically, these values are given as input to δ in Eq. (6), and the rank orders are determined for each alteration of the strategy value (Figure 1).

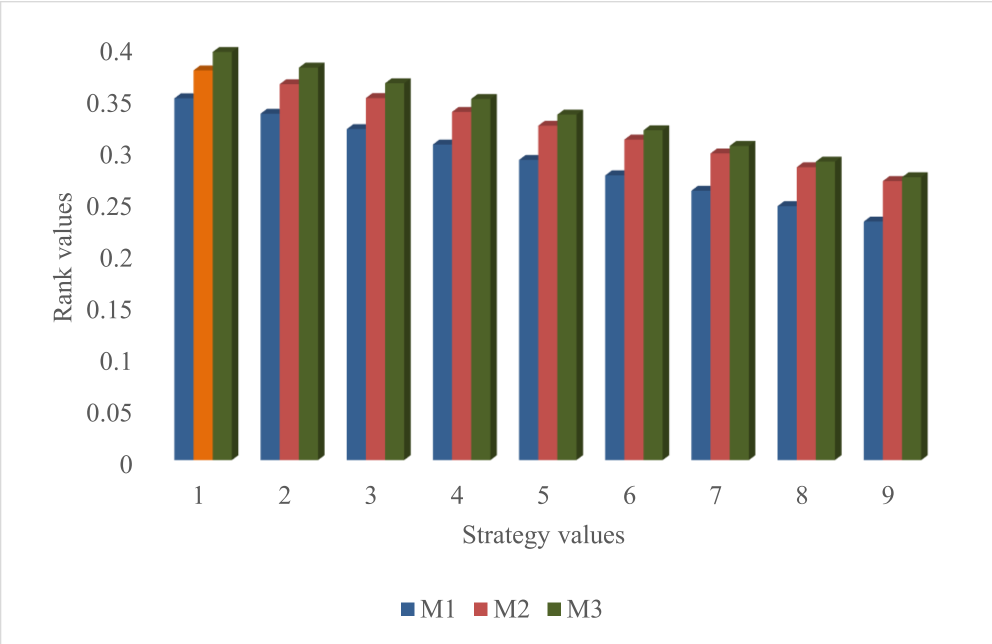

Fig. 1. Strategy value wise sensitivity analysis

From Figure 1, despite changes in strategy values, the rank order remains unchanged (rank values change). The change in rank values is expected, as there are changes in strategy values. However, the intact ordering of MSMEs indicates that the results are stable, and M3 > M2 > M1 is the resulting rank order of MSMEs.

Based on the importance (weights), the TACs lack of skillset (T5), infrastructure mismatch (T6), and high initial cost (T7) contribute close to 45%, with infrastructure mismatch having the highest relative importance, followed by lack of skillset and high initial cost. This is in line with the practice within a typical MSME construct, where there is little or no adequate infrastructure to support technology adoption. These issues typically occur due to space, financial, and mindset constraints, which are key catalysts for the mismatches observed in MSMEs.

6. Conclusion

This paper provides a decision tool that considers ratings from stakeholders and determines the key decision parameters, namely, the relative importance (weights) of TACs and the ranks of MSMEs based on performance over each TAC. Specifically, an integrated model is presented that considers data in the form of ratings via a Likert scale, which are further fuzzified and fed as input to the method section, where the weights are determined along with the ranks by using a SAW and COPRAS combination within the fuzzy context.

Some key benefits of the presented decision tool are: (i) it is simple and practically viable; (ii) it methodically determines weights of TACs and ranks of MSMEs; (iii) scalability in terms of scale-up and scale-out is feasible. Despite these benefits, there are some limitations, such as: (i) partial information on TACs cannot be accommodated; (ii) group decision activities involve multiple experts, whose weights are not determined or considered; and (iii) the orthopair construct is not considered or interpreted from the rating data.

Some key implications that can be noted are:

i. The tool is ready for use by stakeholders, and its simplicity facilitates use of this tool to support the decision process with minimal levels of training.
ii. Stakeholders can also interpret results easily, as the combination is simple and straightforward. This enables better experimentation for further detailed decisions.
iii. MSMEs are slowly drifting towards technology, but understanding the ground reality will help policymakers better plan and strategize ideas for promoting technology within MSMEs to achieve business sustainability.
iv. Considering both enablers and barriers within the criteria set provides a holistic perception for MSMEs, allowing policymakers to plan different measures for promoting enablers and mitigating barriers so that adoption becomes seamless.
v. During the transition from Industry 4.0 to Industry 5.0, MSMEs must not be left behind; stakeholders must actively focus on the betterment of MSMEs as they contribute significantly to the economy of countries.

In the future, the limitations are planned to be addressed. Furthermore, there are plans to consider data from social media to obtain a holistic perception from diverse entities and later use machine learning and decision systems for enhanced, informed decisions, which would help stakeholders effectively. As discussed above, the presented tool can be extended to other decision areas by considering appropriate data, and we also plan to explore different combinations with diverse orthopair and linguistic forms to present ready-to-use decision systems for complex decision problems.

Conflict of interest

Authors declare that there is no conflict of interest.

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References

[1] Streck, C., Keenlyside, P., & Von Unger, M. (2016). The Paris Agreement: a new beginning. *Journal for European Environmental & Planning Law, 13*(1), 3-29. https://doi.org/10.1163/18760104-01301002

[2] Klein, D., Carazo, M. P., Doelle, M., Bulmer, J., & Higham, A. (Eds.). (2017). *The Paris Agreement on climate change: Analysis and commentary*. Oxford University Press. https://doi.org/10.1017/cyl.2018.14

[3] Aggarwal, A., & Joshi, N. (2024). MSMEs' innovation: A barrier approach. *Journal of Small Business and Enterprise Development, 31*(3), 552-573. https://doi.org/10.1108/JSBED-07-2023-0304

[4] Wielgórka, D. (2016). Environmental management in the aspect of sustainable development in micro-, small-, and medium-sized enterprises. *Desalination and Water Treatment, 57*(3), 982-992. https://doi.org/10.1080/19443994.2015.1017322

[5] Agyapong, D., & Arthur, K. N. A. (2018, September). Sustainable business practices among MSMEs: Evidence from four metropolitan areas in Ghana. In *ECIE 2018 13th European Conference on Innovation and Entrepreneurship* (Vol. 25). Academic Conferences and publishing limited.

[6] Vásquez, P., Gallego, V., & Soto, J. D. (2024). Transforming MSMEs towards circularity: an attainable challenge with the appropriate technologies and approaches. *Environment Systems and Decisions, 44*(3), 624-644. https://doi.org/10.1007/s10669-023-09961-8

[7] Bakare, O. A., Achumie, G. O., & Okeke, N. I. (2024). The impact of administrative efficiency on SME Growth and Sustainability. https://doi.org/10.53022/oarjms.2024.8.1.0054

[8] Awwal, M. A. F., Utami, E. Y., & Purwoko, B. (2023). Technology Adaptation and CEO Characteristics: Enhancing Competitive Advantage in Indonesia's MSME of F&B in the Jabodetabek Region. *International Journal of Business, Law, and Education, 4*(2), 1228-1241. https://doi.org/10.56442/ijble.v4i2.322

[9] Nugroho, M. A. (2015). Impact of government support and competitor pressure on the readiness of SMEs in Indonesia in adopting the information technology. *Procedia Computer Science, 72*, 102-111. https://doi.org/10.1016/j.procs.2015.12.110

[10] Das, S., Kundu, A., & Bhattacharya, A. (2020). Technology adaptation and survival of SMEs: A longitudinal study of developing countries. *Technology Innovation Management Review, 10*(6). https://doi.org/10.22215/timreview/1369

[11] Putra, A. R., & Darmawan, D. (2022). Competitive Advantage of MSMEs in Terms of Technology Orientation and Entrepreneurship Competence. *International Journal of Service Science, Management, Engineering, and Technology, 2*(1), 15-20.

[12] Ikhwana, A., & Dianti, S. (2022). The Influence of Information Technology and SCM on Competitive Advantage to Improve MSMEs Performance. *International Journal of Computer and Information System, 3*(1), 6-11. https://doi.org/10.29040/ijcis.v3i1.54

[13] Purnamasari, P., Pramono, I. P., Haryatingsih, R., Ismail, S. A., & Shafie, R. (2020). Technology acceptance model of financial technology in micro, small, and medium enterprises (MSME) in Indonesia. *The Journal of Asian Finance, Economics and Business, 7*(10), 981-988. https://doi.org/10.13106/jafeb.2020.vol7.no10.981

[14] Lestari, E. D., Hamid, N. A., Rizkalla, N., Purnamaningsih, P., & Urus, S. B. T. (2022). The Effect of Financial Literacy, Cost of Technology Adoption, Technology Perceived Usefulness, and Government Support on MSMEs' Business Resilience. Global Journal of Business Social Sciences Review (GATR-GJBSSR), 10(3). https://doi.org/10.35609/gjbssr.2022.10.3(3)

[15] Hendrawan, S. A., Chatra, A., Iman, N., Hidayatullah, S., & Suprayitno, D. (2024). Digital transformation in MSMEs: Challenges and opportunities in technology management. *Jurnal Informasi dan Teknologi*, 141-149. https://doi.org/10.60083/jidt.v6i2.551

[16] Mondal, S., Singh, S., & Gupta, H. (2025). Exploring barriers to innovative marketing in MSMES: an analysis using a BWM-ISM multi-criteria decision-making framework. *Journal of Multi-Criteria Decision Analysis, 32*(1), e70005. https://doi.org/10.1002/mcda.70005?urlappend=%3Futm_source%3Dresearchgate

[17] Khatri, P. (2019). A Study of the Challenges of the Indian MSME Sector. *IOSR Journal of Business and Management, 21*(2), 05-13.

[18] Zavadskas, E. K., Turskis, Z., Dejus, T., & Viteikiene, M. (2007). Sensitivity analysis of a simple additive weight method. *International Journal of Management and Decision Making, 8*(5-6), 555-574. https://doi.org/10.1504/IJMDM.2007.013418

[19] Zavadskas, E. K., Kaklauskas, A., Peldschus, F., & Turskis, Z. (2007). Multi-attribute assessment of road design solutions by using the COPRAS method. *The Baltic journal of Road and Bridge engineering, 2*(4), 195-203.