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ORIGINAL ARTICLE

A Comprehensive framework for prioritizing alternative strategies in information management for micro, small, and medium enterprises (MSMEs) supply chain: a hybrid AHP-FUZZY TOPSIS approach

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Abstract

This empirical study systematically identifies and prioritizes alternative strategies for mitigating barriers to information management within the supply chain (SC) of micro, small, and medium enterprises (MSMEs). Integrating the Analytical Hierarchy Process (AHP) and fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), the research provides a comprehensive framework to discern, rank, and address barriers in SC information management for MSMEs. Through an empirical case study of an Indian MSME manufacturing organization, the framework is demonstrated as a systematic decision support tool for enhancing SC performance. The study highlights a targeted methodology for overcoming information management challenges, aiming to increase success rates within the MSME sector by offering a more accurate and systematic approach to SC information management.

Keywords Information management · AHP · Fuzzy TOPSIS · Supply chain

1 Introduction

Micro, small, and medium enterprises (MSMEs) play a significant role in global economies, contributing to employment, innovation, and economic growth. Within this context, effective information management within the supply chain (SC) is paramount for enhancing overall performance and competitiveness [1, 3]. However, MSMEs often face unique challenges, including limited resources, expertise, and infrastructure, which can hinder their ability to effectively manage information within the SC [4].To address these challenges, this empirical study systematically identifies and prioritizes alternative strategies for overcoming barriers to information management in the SC of MSMEs. Drawing upon established methodologies, the research presents a comprehensive framework that integrates the Analytical Hierarchy Process (AHP) and the fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS). By leveraging these methodologies, the framework provides MSMEs with a systematic approach to discern, rank, and address barriers hindering information management in the SC [2, 5].

The proposed framework serves as a nuanced decision support tool, enabling organizations to concentrate on high-priority strategies and develop stepwise implementation

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plans to enhance SC performance [1]. Specifically, the AHP is utilized to assign weights to identified barriers, establishing criteria for evaluation, while the fuzzy TOPSIS method is employed to derive a conclusive ranking of alternative strategies for information management within the SC. Through an empirical case study analysis of an Indian MSME manufacturing organization, the practical application of the proposed framework is demonstrated. This case study illustrates the framework's effectiveness in addressing information management challenges within the SC, highlighting its potential to increase success rates and improve overall performance within the MSME sector.

1.1 Purpose of study

Effective information management in MSMEs streamlines operations, optimizing resources [2], providing a competitive edge through informed decision-making [3], and fostering innovation for sustained growth [5]. This study recognizes the pivotal role of information management in enhancing efficiency, competitiveness, and innovation for the overall success of MSMEs. The identification of barriers to Information Management (IM) adoption within the Supply Chain (SC) is typically conducted through a comprehensive literature review and expert consultation. However, it is essential to acknowledge that these barriers, while significant, cannot feasibly be addressed simultaneously. Moreover, the relative importance of a particular barrier may vary among individual organizations due to their unique purposes, strategies, resource conditions, and capabilities. Therefore, to successfully enhance information management in the SC, it is imperative to propose and prioritize concrete and feasible solutions in a stepwise manner, tailored to the specific needs and priorities of each organization.

2 Research goal

This paper aims to systematically explore the challenges of Information Management (IM) in the Supply Chain (SC) and prioritize alternative strategies to overcome these hurdles. Prioritizing these strategies is crucial for organizations to develop implementation plans effectively, thereby gaining a competitive advantage. Addressing the challenges of IM in SC involves a multi-criteria decision-making (MCDM) process, where human judgment plays a pivotal role but is often characterized by vagueness and imprecision. Therefore, a hybrid framework combining Analytical Hierarchy Process (AHP) and fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) is proposed. AHP is utilized to determine the importance weights of the barriers, while fuzzy TOPSIS handles the performance ratings of feasible solutions using triangular fuzzy numbers (TFN). An empirical case study is presented to demonstrate the application of this framework. The paper is structured as follows: Sect. 2 provides a literature review on the challenges and alternative strategies of IM in SC. Section 3 introduces the AHP and fuzzy TOPSIS methods. Section 4 describes the proposed framework for prioritizing alternative strategies of IM in SC. Section 5 presents the empirical case study, and Sect. 6 concludes the paper.

3 Literature review

3.1 Barriers/challenges of information management in SC

The research paper systematically examines the multifaceted challenges hindering effective Information Management (IM) within the Supply Chain (SC). Through a comprehensive analysis of ten distinct criteria and corresponding sub-criteria, the paper delves into various dimensions of these challenges. These include limited financial resources, characterized by budget constraints and high initial costs, as highlighted by O'Leary [6] and Beynon-Davies [7] respectively. Additionally, the study explores the critical issue of a lack of skilled workforce, encompassing limited IT training programs and challenges in competitive talent acquisition, as discussed by Powell [8] and Heeks [9] respectively. Resistance to change emerges as another significant barrier, attributed to cultural resistance and the absence of structured change management processes, elucidated by Eason [10] and Cameron and Green [11] respectively. Moreover, the research investigates the constraints imposed by limited IT infrastructure, such as reliance on outdated hardware and inadequate network bandwidth, as outlined by Raj and Nair [12] and Comer [13] respectively. Data security concerns, lack of standardization, limited awareness and education, vendor lock-in, regulatory compliance challenges, and inadequate integration with existing systems are also scrutinized comprehensively. By synthesizing these findings, the paper aims to provide valuable insights for developing targeted strategies to address these challenges and enhance Information Management practices within the Supply Chain (Table 1).

3.2 Alternative strategies to overcome the barriers/challenges of information management in SC

This research paper presents a systematic exploration of alternative strategies aimed at overcoming the challenges of Information Management (IM) in the Supply Chain (SC). Drawing on scholarly references, twelve distinct alternative strategies are identified and categorized based on their potential to address specific barriers. These strategies encompass

Table 1 Hierarchy model of barriers in information management

Code	Criteria	Sub-criteria	Description	References
M1	Limited Financial Resources	Budget Constraints	Insufficient funds allocated specifically for Information Management projects	O'Leary [6]
		High Initial Costs	Upfront costs for implementing Information Management systems	Beynon-Davies [7]
M2	Lack of Skilled Workforce	Limited IT Training Programs	Lack of available training programs for employees to enhance IT skills	Powell [8]
		Competitive Talent Acquisition	Difficulty in attracting and retaining IT professionals	Heeks [9]
M3	Resistance to Change	Cultural Resistance	Organizational culture resistant to adopting new technologies	Eason [10]
		Lack of Change Management	Absence of structured change management processes	Cameron and Green [11]
M4	Limited IT Infrastructure	Outdated Hardware	Reliance on outdated hardware that may not support modern Information Management systems	Raj and Nair [12]
		Limited Bandwidth	Inadequate network bandwidth for handling data-intensive Information Management applications	Comer [13]
M5	Data Security Concerns	Lack of Encryption Measures	Failure to implement robust encryption measures for securing sensitive data	Schneier [14]
		Insufficient Cybersecurity Policies	Absence of comprehensive policies addressing cybersecurity issues	Campbell [15]
M6	Lack of Standardization	Vendor-specific Solutions	Reliance on vendor-specific Information Management solutions that may lack interoperability	Laudon and Laudon [16]
		Industry-wide Lack of Standards	Absence of standardized Information Management practices across the industry	Benbasat et al. [17]
M7	Limited Awareness and Education	Lack of Information Management Training Programs	Limited availability of educational programs focusing on Information Management	O'Brien and Marakas [18]
		Limited Access to Industry Information	Lack of access to relevant information about the benefits of Information Management	Grant [19]
M8	Vendor Lock-in	Inadequate Contractual Agreements	Contracts with vendors that limit flexibility and hinder switching	Swartz [20]
		Limited Vendor Options	Limited availability of alternative vendors offering compatible solutions	Ward and Peppard [21]
M9	Regulatory Compliance Challenges	Evolving Regulatory Landscape	Difficulty in keeping up with rapidly changing data protection regulations	Solove and Hartzog [22]
		Interpretation Complexity	Complexities in interpreting and implementing regulatory requirements	Kuner [23]
M10	Inadequate Integration with Existing Systems	Legacy System Incompatibility	Difficulty in integrating new Information Management systems with existing legacy systems	Sommerville [24]
		Data Migration Challenges	Complications in migrating data from old systems to new platforms	Rahm and Do [25]

Table 2 Alternative strategies of information management in SC

Code	Alternative strategies	Description	References
AS1	Leverage Open Source Solutions	Consider open-source Information Management systems to reduce licensing costs	Lerner and Tirole [26]
AS2	Invest in Employee Training	Develop training programs to enhance IT skills among the workforce	Noe [27]
AS3	Create a Change Management Plan	Develop a clear change management plan to address employee concerns	Kotter [28]
AS4	Adopt Cloud Solutions	Utilize cloud-based solutions to reduce on-premise infrastructure needs	Mell and Grance [29]
AS5	Implement Robust Encryption	Employ strong encryption methods to safeguard sensitive data	Schneier [14]
AS6	Align with Industry Standards	Adopt Information Management practices aligned with industry standards	Benbasat et al. [17]
AS7	Conduct Awareness Campaigns	Launch campaigns to educate employees on the benefits of Information Management	Kotler and Keller [30]
AS8	Evaluate Vendor Agreements	Carefully review and negotiate vendor contracts to minimize lock-in risks	Swartz [20]
AS9	Regular Compliance Audits	Conduct regular audits to ensure continuous compliance with changing regulations	Dhillon and Moores [31]
AS10	Implement Middleware Solutions	Use middleware solutions to facilitate seamless integration with existing systems	Turban et al. [32]
AS11	Internal Training Programs	Develop internal training programs to enhance awareness and understanding	Noe [27]
AS12	Strategic Budget Allocation	Gradually implement Information Management solutions in phases to manage costs	Roberts [33]

various approaches, including leveraging open-source solutions to reduce licensing costs [26], investing in employee training to enhance IT skills [27], and creating a change management plan to address employee concerns [28]. Additionally, adopting cloud solutions to reduce on-premise infrastructure needs [29], implementing robust encryption methods to safeguard sensitive data [14], and aligning with industry standards for best practices [17] are also considered. Other strategies include conducting awareness campaigns to educate employees on the benefits of IM [30], carefully evaluating vendor contracts to minimize lock-in risks [20], and regularly conducting compliance audits to ensure adherence to changing regulations [31]. Furthermore, implementing middleware solutions to facilitate seamless integration with existing systems [32], developing internal training programs for enhanced awareness and understanding [27], and strategically allocating budgets to implement IM solutions in phases [33] are explored. This comprehensive overview of alternative strategies provides a foundation for further examination and analysis to inform effective decision-making in SC IM (Table 2).

4 Research methods

4.1 AHP approach

T.L. Saaty created the multi-criteria method to decision making known as the AHP T.L. Saaty, [34]. It is a measuring theory that has been used in many fields, including decision theory and conflict resolution, in order to deal with both quantitative and qualitative criteria L.G. Vargas [35]. The AHP process is provided step-by-step as:

I. Create a pair-wise comparison matrix of the criteria using T.L. Saaty's scale of 1 to 9. on that scale, value 1 is applied when the two criteria are equally important. When criterion i and criterion j are compared pair-wise, assuming N criteria, the result is a square matrix A_{NXN}, where a_{ij} denotes the relative weight of criterion i relative to criterion j. When $i = j$ and $a_{ji} = 1/a_{ij}$, a_{ij} equals 1 in the matrix (Table 3).

II. Normalize the geometric mean of the rows in the comparison matrix to determine the relative normalized

Table 3 T.L. Saaty's Scale

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

Table 5 Linguistic variables for solutions ratings

Linguistic variables	Corresponding TFN		
Extremely low (EL)	0	0	0.1
Very low (VL)	0	0.1	0.3
Low (L)	0.1	0.3	0.5
Medium (M)	0.3	0.5	0.7
High (H)	0.5	0.7	0.9
Very high (VH)	0.7	0.9	1
Extremely high (EH)	0.9	1	1

weight (Wj) for each criterion.

$$\mathrm{GM}_j = \left[\prod_{j=1}^{n} = a_{ij}\right]^{\frac{1}{N}} \text{ and } \mathrm{W}_j = \frac{\mathrm{GM}j}{\sum_{j=1}^{N} \mathrm{GM}j} \quad (1)$$

III. Determine the matrices A3 and A4 so that

$$\mathrm{A4} = \mathrm{A3}/\mathrm{A2} \text{ and } \mathrm{A3} = \mathrm{A1} * \mathrm{A2}, \text{ where } \mathrm{A2} = [\mathrm{W1}, \mathrm{W2}, \ldots, \mathrm{W_j}]^{\mathrm{T}} \quad (2)$$

IV. Find out the average of matrix A4 to determine the largest eigen-value.

V. Calculate the consistency index (C.I.)

$$C.I = \frac{(\lambda max - N)}{(N - 1)} \quad (3)$$

Less variation from consistency is indicated by a lower C.I. number.

VI. Find out the consistency ratio using the formula

$$(\mathrm{C.R.}) = \mathrm{C.I.}/\mathrm{R.I} \quad (4)$$

Saaty states that for pair-wise comparisons, a value of C.R $\leq$ 0.1 has proven to be appropriate for maintaining consistency. Where R.I., which is based on the matrix size, is the random index (Table 4).

4.2 FUZZY TOPSIS approach

Fuzzy evaluations of TOPSIS criteria and alternatives are part of the fuzzy TOPSIS methodology Hwang and Yoon [36]. The alternative that is most distant from the negative ideal solution and most near to the positive ideal solution is selected using the TOPSIS method. The best performance values for each criterion make up the positive ideal solution, while the poorest performance values make up the negative ideal solution. The following is an outline of the fuzzy TOPSIS steps:

I. Collect the subjective evaluations of the decision maker on the importance of weights (Table 5).

II. Totalize the fuzzy ratings for the alternatives and the criteria. If every decision maker's fuzzy rating is represented by a triangle fuzzy number $R_k = (a_k, b_k, c_k)$, k = 1,2,…,k, subsequently, the total fuzzy rating is provided by $R = (a, b, c)$, k = 1,2., k where; $a = min_k\{a_k\}, b = \frac{1}{k}\sum_{k=1}^{k} b_k, c = max_k\{c_k\}$. If the decision maker's fuzzy rating and important weight for the kth is given by $X_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ and $W_{ijk} = (W_{ijk}, W_{ijk}, W_{ijk})$, i = 1,2..,m, j = 1,2..,n correspondingly, after which the fuzzy aggregated ratings (x_{ij}) of alternatives w.r.t each criteria

$$X_{ij} = (a_{ij}, b_{ij}, c_{ij}) \text{ where } a_{ij} = min_k\{a_{ijk}\},$$
$$b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ijk}, \ c_{ij} = max_k\{c_{ijk}\}, \quad (5)$$

Each criterion's total fuzzy weights (W_{ij}) are determined as

$$W_j = (W_{j1}, W_{j2}, W_{j3}), \text{ where}$$
$$W_{j1} = min_k\{W_{jk1}\},$$
$$W_{j2} = \frac{1}{k}\sum_{k=1}^{k} W_{jk2}, \ W_{j3} = max_k\{c_{j3}\} \quad (6)$$

III. Calculate the matrix of fuzzy decisions. The following is the construction of the fuzzy decision matrix for the criterion (W~) and alternatives (~D):

$$D = \begin{bmatrix} x_{11}x_{12}\ldots x_{1n} \\ x_{21}x_{22}\ldots x_{2n} \\ x_{31}x_{32}\ldots x_{3n} \\ \vdots \\ \vdots \\ \vdots \\ x_{m1}x_{m2}\ldots x_{m3} \end{bmatrix} \text{ where}$$

Table 4 The random consistency index (RI)

Size(n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

$$i = 1, 2, ..., m, \; j = 1, 2, ..., n \tag{7}$$

$$W = (W_1, W_2, ..W_n) \tag{8}$$

IV. Normalize the matrix of fuzzy decisions.
To normalize the raw data and put the different criterion scales into a comparable scale, linear scale transformation is used. The following gives the normalized fuzzy decision matrix ~ R:

$$R = \left[r_{ij}\right]_{m \times n}, \text{ where i} = 1, 2, \ldots, m, \; j = 1, 2, \ldots, n. \tag{9}$$

where

$$r_{ij} = \left(\frac{a_{ij}}{C*_j}, \frac{b_{ij}}{C*_j}, \frac{c_{ij}}{C*_j}\right) \text{ And } c*_j = max_i C_{ij} \text{ (benefit criteria)} \tag{10}$$

$$r_{ij} = \left(\frac{a_j}{C_{ij}}, \frac{a_j}{b_{ij}}, , \frac{a_j}{a_{ij}},\right) \text{ And } a_j = min_i a_{ij} \text{ (Cost criteria)} \tag{11}$$

V. Determine the normalized weighted matrix.
The normalized fuzzy decision matrix r_{ij} is multiplied by the weights (w_j) of the evaluation criteria to obtain the weighted normalized matrix V for criteria.

$$V = \left[v_{ij}\right]_{m \times n}, \; i = 1, \; 2, ..., m, \; j = 1, 2, ..., n, \text{ where } v_{ij} = r_{ij}(\cdot)\, w_j \tag{12}$$

VI. Determine both the fuzzy negative ideal solution (FNIS) and fuzzy positive ideal solution (FPIS). The following formula is used to calculate the alternatives' FPIS and FNIS:

$$A^* = (v*_1, v*_2, \ldots, v*_n) \text{ where } v*_j = ax_i\left\{v_{ij3}\right\}, i = 1, 2, \ldots, m, j = 1, 2, \ldots, n \tag{13}$$

$$A^- = (v_1, v_2, \ldots, v_n) \text{ where } v_j = min_i\left\{v_{ij1}\right\}, i = 1, 2, ..., m, j = 1, 2, ..., n \tag{14}$$

VII. Compute the each option's separation from the FPIS and FNIS.
The distance $(d*_i, \; d-_i,)of$ each weighted alternative i = 1, 2.., m, the following formula is calculated using the FPIS and FNIS:

$$d_i^* = \sum_{j=1}^{n} d_v\left(v_{ij}, v_j^*\right), \; i = 1, 2, ..., m, \tag{15}$$

$$d_i^- = \sum_{j=1}^{n} d_v\left(v_{ij}, v_j^-\right), \; i = 1, 2, \ldots, m \tag{16}$$

where $d_v(a, b)$ is the measurement of the separation between two fuzzy numbers, a and b.
Determine each option's closeness coefficient (CCi). The formula of closeness coefficient is

$$CC_i = \frac{d-_i}{d-_i + d*_i}, \; i = 1, 2, ..., \; m \tag{17}$$

VIII. Rank the alternatives.

5 Hybrid AHP-fuzzy TOPSIS framework for prioritizing information management strategies

The proposed hybrid fuzzy AHP-TOPSIS for prioritizing the alternative Strategies of information management in SC to overcome its barriers has following three phases (See Fig. 1).

Phase 1: Identification of the Barriers and Alternative Strategies of IM in SC.

In the initial phase, a decision-making group of experts is assembled, including senior managers, IT representatives, senior executives from supply chain (SC) members, and customers. Their task is to identify and assess barriers related to Information Management (IM) in the supply chain. This is achieved through a combination of literature review and the insights of these experts. Once the barriers are determined, a second expert panel, consisting of both IM and SC experts, is formed. This panel is responsible for evaluating strategies for Information Management in the supply chain. To ensure a structured approach, a hierarchical structure is established. Objectives are placed at the first level, main barriers at the second level, sub-barriers at the third level, and solutions at the fourth level. This systematic process helps in a comprehensive understanding of the challenges and effective planning for Information Management in the supply chain. (As shown in Fig. 1 below.)

Phase 2: Calculate weight of the barriers of Information Management in SC by AHP

Once a decision hierarchy has been established, the Analytic Hierarchy Process (AHP) will be employed to assess the relative importance of various barriers to Information Management within the supply chain (SC). This involves generating comparison tables based on expert evaluations, utilizing a predefined scale as outlined in Table 3. The comparison tables aid in discerning the significance of different factors. The geometric mean of expert assessments will be calculated to create a comprehensive evaluation chart. Subsequently, this chart will be utilized to quantify the importance of each barrier through the previously outlined methodology. This systematic approach ensures a precise and prioritized assessment of Information Management barriers within the supply chain.

Phase 3: Evaluation of the alternative strategies of IM in SC and determines final rank by fuzzy TOPSIS

To figure out the best strategies for overcoming barriers in Information Management within the supply chain (SC), we'll employ a method called fuzzy TOPSIS. This involves assessing different solutions using a linguistic scale, as illustrated in Table 4. Each solution gets a rating, and we use these ratings to calculate CCi values through fuzzy TOPSIS. The solutions are then ranked in descending order based on these CCi values.

6 Application of the proposed framework

The proposed framework is applied to rank the strategies of Information Management (IM) in the supply chain (SC) aimed at overcoming its barriers. This application follows the three phases outlined in the previous section, which are explained as follows:

6.1 Problem description

In contemporary times, an increasing number of Indian organizations recognize the pivotal role of information in the business success of Micro, Small, and Medium Enterprises (MSMEs). While some Indian organizations have ventured into implementing innovative practices integrated with their supply chains (SC), the overall success rate remains limited due to barriers in Information Management (IM) within the SC framework. Addressing this challenge requires a strategic approach involving the identification of these barriers and the formulation of effective strategies to overcome them.

Table 7 Pairwise comparison matrix of the barriers of limited financial resources

Criteria	C1	C2
C1	1	5
C2	0.2	1

Table 8 Pairwise comparison matrix of the barriers of lack of skilled workforce

Criteria	C3	C4
C3	1	6
C4	0.1667	1

Table 9 Pairwise comparison matrix of the barriers of resistance to change

Criteria	C5	C6
C5	1	7
C6	0.1428	1

Acknowledging the practical difficulty of implementing all solutions simultaneously, there is a critical need to prioritize these IM solutions within the SC. This prioritization enables MSME organizations to focus on high-ranking solutions, implementing them in a stepwise manner to enhance overall success rates. The case study of MSME Organization X, an Indian firm with a substantial turnover exceeding 35 crores, employing over 80 individuals, and maintaining relationships with 17 suppliers and vendors, exemplifies this imperative. Specializing in the manufacturing and sale of automotive parts and accessories, Organization X is keen on transforming and leveraging its knowledge into a competitive advantage through Information Management in the supply chain. The organization's proactive interest lies in identifying and systematically ranking IM strategies to overcome existing barriers, reflecting a strategic commitment to enhance operational efficiency and competitiveness within the dynamic business landscape (Fig. 2).

6.2 Case-Study

Phase 1: Identification of the Challenges/Barriers and Alternative Strategies of Information Management in SC

The decision group consists of ten experts, including three senior managers, two IT representatives, three senior executives from supply chain members, and two customers. Through literature review and discussions, 20 qualitative and quantitative barriers in Information Management within the

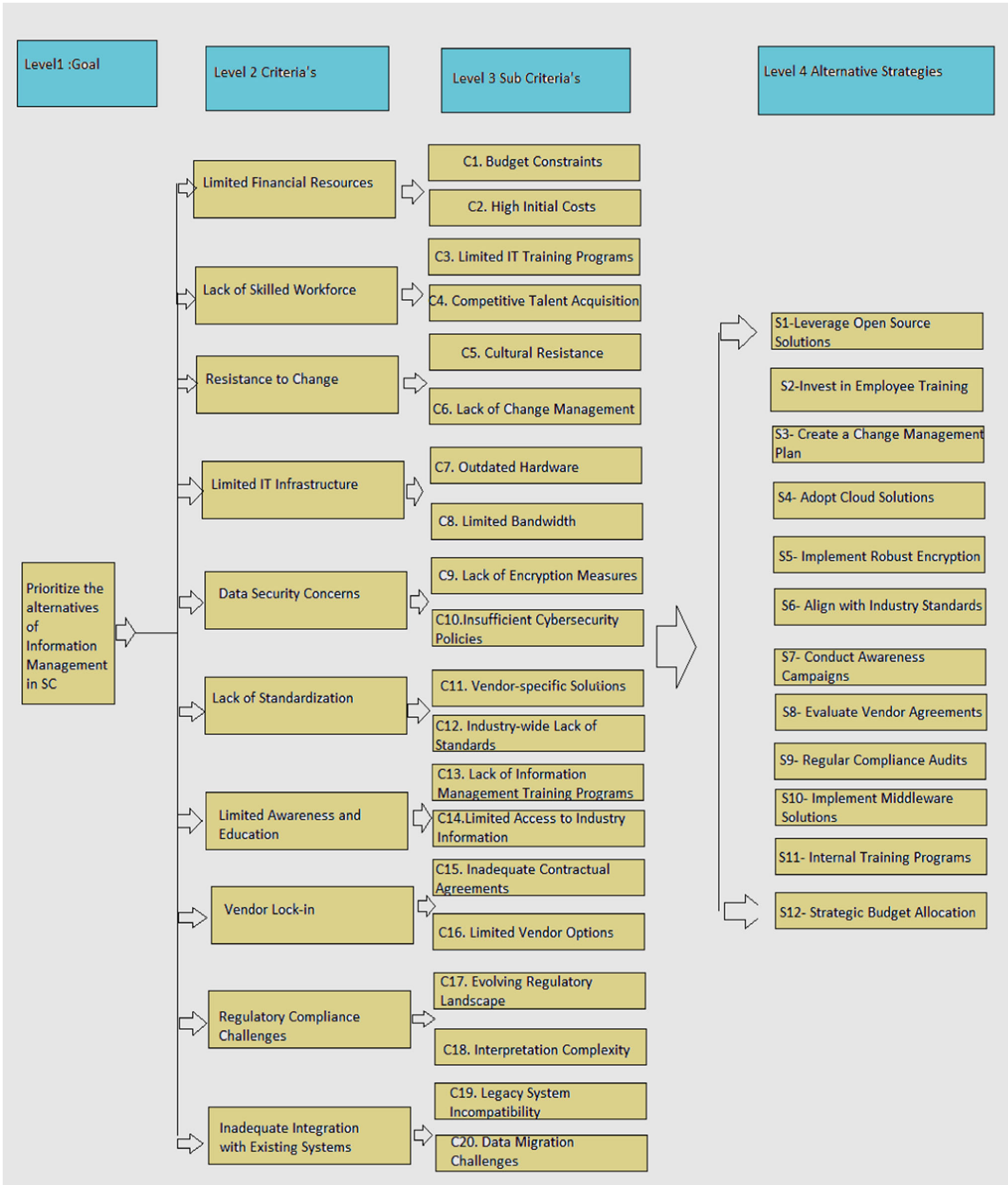

Fig. 1 Decision hierarchy model for prioritizing strategies of IM in SC

Fig. 2 Proposed hybrid fuzzy AHP-TOPSIS framework to prioritize the Alternative Strategies of Information Management in SC to overcome its barriers

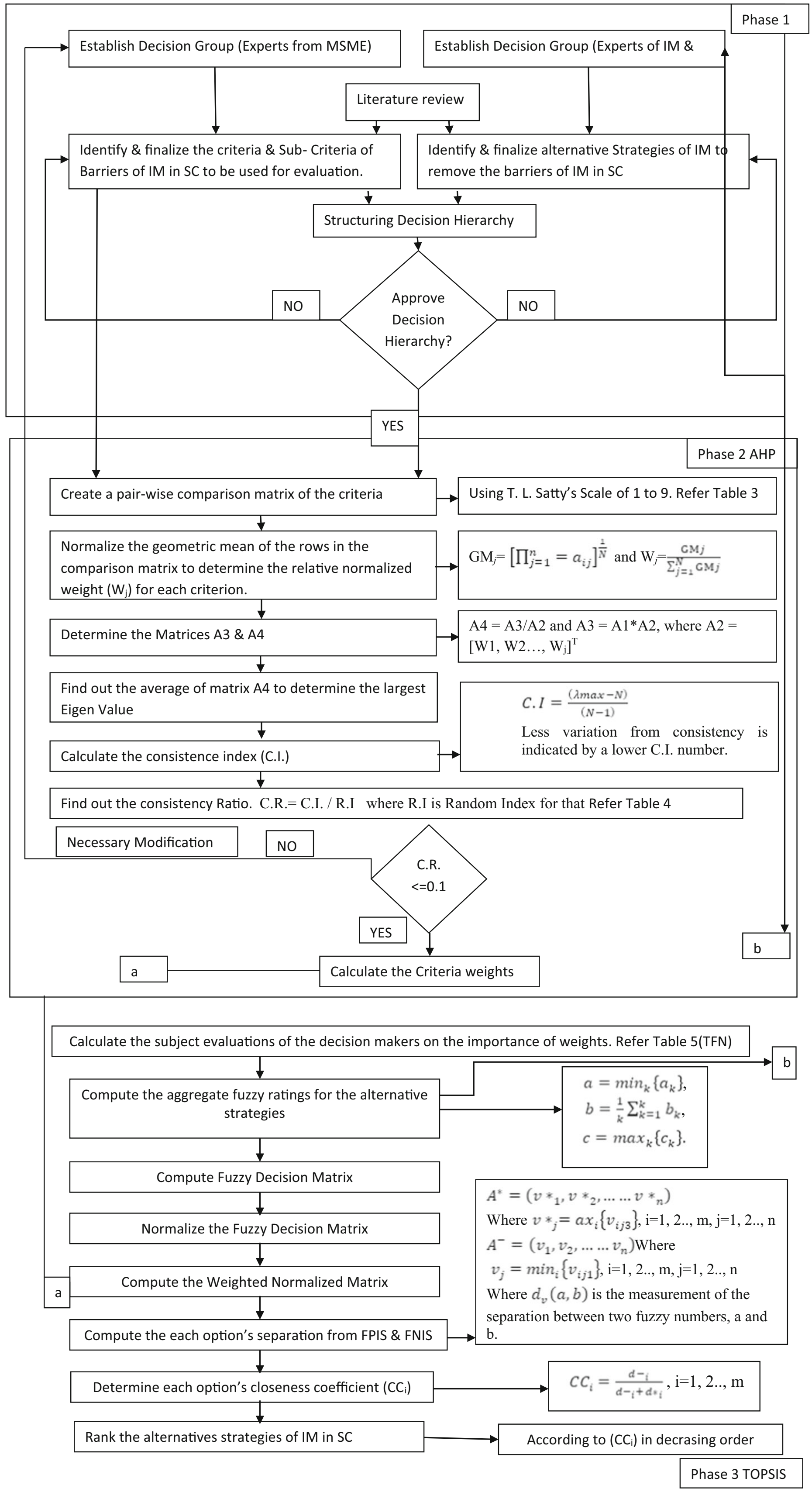

Table 6 Pairwise Comparison Matrix of the Main Criteria

Criteria	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
M1	1	2	2	3	4	5	4	3	4	3
M2	0.5000	1	2	2	3	5	5	4	3	4
M3	0.5000	0.5000	1	1	2	4	3	3	3	2
M4	0.3333	0.5000	1.0000	1	2	4	3	4	3	3
M5	0.2500	0.3333	0.5000	0.5000	1	3	3	4	4	3
M6	0.2000	0.2000	0.2500	0.2500	0.3333	1	3	2	2	3
M7	0.2500	0.2000	0.3333	0.3333	0.3333	0.3333	1	1	3	4
M8	0.3333	0.2500	0.3333	0.2500	0.2500	0.5000	1.0000	1	1	3
M9	0.2500	0.3333	0.3333	0.3333	0.2500	0.5000	0.3333	1.0000	1	3
M10	0.3333	0.2500	0.5000	0.3333	0.3333	0.3333	0.2500	0.3333	0.3333	1

Table 10 Pairwise comparison matrix of the barriers of limited IT infrastructure

Criteria	C7	C8
C7	1	4
C8	0.25	1

Table 11 Pairwise comparison matrix of the barriers of data security concerns

Criteria	C9	C10
C9	1	9
C10	0.1112	1

Table 12 Pairwise comparison matrix of the barriers of Lack of standardization

Criteria	C11	C12
C11	1	6
C12	0.1667	1

Table 13 Pairwise comparison matrix of the barriers of limited awareness and education

Criteria	C13	C14
C13	1	5
C14	0.2	1

Table 14 Pairwise comparison matrix of the barriers of vendor lock-in

Criteria	C15	C16
C15	1	7
C16	0.1428	1

Table 15 Pairwise comparison matrix of the barriers of regulatory compliance challenges

Criteria	C17	C18
C17	1	2
C18	0.5	1

Table 16 Pairwise comparison matrix of the barriers of inadequate integration with existing system

Criteria	C19	C20
C19	1	8
C20	0.125	1

supply chain are identified (see Table 1). This collaborative effort ensures a comprehensive understanding of the challenges and enriches the study's validity and relevance. Five expert panels, consisting of Decision-Making (DM) and Supply Chain (SC) experts, are formed to assess Information Management solutions against identified barriers in the supply chain. A total of 12 solutions, refined through literature review and discussions with the expert panels, are finalized (refer to Table 2). This collaborative process ensures comprehensive evaluation and selection of strategies tailored to address Information Management challenges in the supply chain. The decision hierarchy for this problem encompasses four levels. At the first level is the overarching goal of the decision process, specifically ranking Information Management (IM) solutions in the supply chain (SC) to overcome identified barriers. The second level involves the main barriers, the third level comprises sub-barriers, and the fourth level focuses on individual solutions (refer to Fig. 1). This hierarchical structure provides a systematic framework for prioritizing and addressing IM challenges within the SC context.

Phase 2: Calculate its weight of the barriers/ Challenges of Information Management in SC by AHP

During this phase, the decision group engaged in pairwise comparisons of the 10 primary barriers and 20 sub-barriers, referencing Table 3 for guidance. The geometric means of these comparison values were then computed, generating pairwise comparison matrices for both criteria and sub-criteria, as outlined in Tables 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16. The computed results, presented in Table 17, demonstrate consistency, as all consistency ratio (CR) values are below 0.1. This consistency affirms the reliability of the matrices used in the pairwise comparisons.

Phase 3: Evaluation of the Alternative strategies of Information Management in SC and find out the final rank by fuzzy TOPSIS approach

The expert panel members were tasked with constructing a fuzzy evaluation matrix utilizing linguistic variables outlined in Table 4. This matrix was developed by assessing solutions under each barrier individually, as detailed in Table 18. Subsequently, the linguistic terms were converted into their corresponding Triangular Fuzzy Numbers (TFN), resulting in the construction of the fuzzy evaluation matrix, as presented in Table 19. Due to space constraints, only the linguistic evaluation matrix and fuzzy evaluation matrix for expert 1 are provided here. Aggregate fuzzy weights for the alternatives were computed using Eq. (6) and are displayed in Table 20. It is important to note that, in this study, all criteria are considered barriers to Information Management in the Supply Chain (SC). The goal is to minimize these barriers, making them synonymous with cost criteria. Weighted normalization was then performed according to Eq. (12), and the results are presented in Table 21.

In this investigation, all identified barriers are characterized as cost criteria. Consequently, the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) were computed for each barrier using Eqs. (13) and (14) respectively. The distances were then calculated employing Eqs. (15) and (16). Subsequently, the Closeness Coefficient (CCi) was determined using Eq. (17). The summarized results are presented in Table 22. The alternatives were ranked in descending order based on their CCi values.

6.3 Result and discussions

The determination of the most crucial solution for overcoming barriers in Information Management (IM) within the Supply Chain (SC) context remains challenging. However, the application of a hybrid Analytic Hierarchy Process (AHP) and fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approach enhances comprehensiveness and systematicity. This hybrid methodology was employed in an Indian organization with the aim of enhancing SC performance in Micro, Small, and Medium Enterprises (MSMEs). The strategy involved a stepwise implementation of IM solutions to address identified barriers. A comprehensive assessment, based on literature reviews and expert opinions, led to the identification of 20 barriers and 12 alternative strategies. AHP was utilized to calculate the weights of these barriers, and subsequently, the alternative strategies were ranked using the fuzzy TOPSIS method. The results of the fuzzy TOPSIS evaluation for the organization under study are presented in Table 22. The evaluation focused on alternative strategies for the barriers of IM in the SC, and the ranking of alternative strategies was determined by their Closeness Coefficient index (CCi). The prioritized order of alternative strategies is AS1–AS2–AS9–AS5–AS7–AS11–AS3–AS6–AS10–AS4–AS12–AS8, indicating their importance from most to least critical. The highest-ranked strategy involves leveraging Open Source Solutions in IM adoption in SC. Following closely is the strategy of Investing in Employee Training to enhance employee skills within the SC, ranked second. The third-ranked strategy is to Conduct Regular Audits to ensure continuous compliance with changing regulations in SC. Consequently, it is recommended that the Indian case organization should prioritize the implementation of these solutions, with the remaining strategies to be addressed in a stepwise manner based on their respective rankings.

6.3.1 Sensitivity analysis

We conducted a sensitivity analysis to check how stable the rankings of solutions are when we change the weights of barriers. We performed 16 experiments, and the details are in Table 23. In the first experiment, we followed our initial study's approach. For the next 10 experiments (2 to 11), we increased the weight of each barrier one by one, while keeping the others low and equal. For example, in experiment 2, we set the weight of barrier M1 to 0.60, and the remaining nine barriers (M2–M10) were considered equally important with weights of 0.044 each. In experiments 12 to 16, we tried different scenarios, such as setting all barrier weights to 0.5 (experiment 12), making all weights equal at 0.05 (experiment 13), and setting barrier weights to 90%, 80%, and 70% in experiments 14, 15, and 16 respectively. Looking at Table 23 and Fig. 3, we observed that solutions S1 and S2 consistently had the highest scores in all experiments. However, the ranking of other alternatives changed frequently in different experiments. This indicates that determining the best Information Management strategies in the Supply Chain is quite sensitive to how we assign weights to the barriers.

Table 17 Final ranking of barriers of information management in SC

Major criteria code	Weights of major criteria	Sub-criteria code	Weights of sub-criteria	Final weight	Rank
M1	0.2262	C1	0.8333	0.1885	1
		C2	0.1667	0.0377	9
M2	0.1849	C3	0.8571	0.1585	2
		C4	0.1429	0.0264	12
M3	0.1214	C5	0.8750	0.1062	3
		C6	0.1250	0.0152	14
M4	0.1249	C7	0.8000	0.0999	4
		C8	0.2000	0.0250	13
M5	0.1007	C9	0.9000	0.0906	5
		C10	0.1000	0.0101	16
M6	0.0610	C11	0.8571	0.0523	6
		C12	0.1429	0.0087	18
M7	0.0562	C13	0.8333	0.0468	7
		C14	0.1667	0.0094	17
M8	0.0467	C15	0.8750	0.0408	8
		C16	0.1250	0.0058	19
M9	0.0442	C17	0.6667	0.0295	11
		C18	0.3333	0.0147	15
M10	0.0339	C19	0.8889	0.0301	10
		C20	0.1111	0.0038	20

Table 18 Linguistic decision matrix for the alternative strategies (expert 1)

	C1	C2	C3	C4	C5	…	…	…	…	C18	C19	C20
AS1	VH	M	VH	EH	M	…	…	…	…	VH	VH	VH
AS2	H	VH	M	EH	H	…	…	…	…	H	H	M
AS3	H	M	VH	H	L	…	…	…	…	H	H	VH
AS4	M	L	H	VH	VL	…	…	…	…	M	M	H
AS5	M	M	H	L	H	…	…	…	…	M	M	H
AS6	L	H	M	L	VL	…	…	…	…	L	L	M
AS7	M	H	M	M	EH	…	…	…	…	M	M	M
AS8	H	M	M	L	H	…	…	…	…	H	H	M
AS9	L	VL	H	VL	H	…	…	…	…	L	L	H
AS10	M	VH	M	H	M	…	…	…	…	M	M	M
AS11	VH	M	H	VH	EH	…	…	…	…	VH	VH	H
AS12	M	L	M	VL	H	…	…	…	…	M	M	M

7 Conclusions and future works

The effectiveness of Information Management (IM) in Supply Chain (SC) operations is often hindered by various barriers, leading to a relatively low success rate. Addressing these barriers through alternative strategies is imperative, yet simultaneous implementation of all solutions may be impractical due to constraints. Therefore, a systematic ranking of alternative strategies is essential for stepwise implementation. This study addresses this issue by proposing alternative strategies to overcome these barriers and emphasizes the significance of ranking these strategies for a systematic and phased implementation. Recognizing the complexities involved in simultaneous implementation, the study introduces a scientific framework that employs a hybrid multi-criteria technique, integrating Analytic Hierarchy Process (AHP) and fuzzy Technique for Order of Preference by

Table 19 Fuzzy decision matrix for the alternative strategies (Expert 1)

	C1			C2			…			…			…			C20		
AS1	0.7	0.9	1	0.3	0.5	0.7	0.7	…	…	…	…	…	…	…	…	0.7	0.9	1
AS2	0.5	0.7	0.9	0.7	0.9	1	0.3	…	…	…	…	…	…	…	…	0.3	0.5	0.7
AS3	0.5	0.7	0.9	0.3	0.5	0.7	0.7	…	…	…	…	…	…	…	…	0.7	0.9	1
AS4	0.3	0.5	0.7	0.1	0.3	0.5	0.5	…	…	…	…	…	…	…	…	0.5	0.7	0.9
AS5	0.3	0.5	0.7	0.3	0.5	0.7	0.5	…	…	…	…	…	…	…	…	0.5	0.7	0.9
AS6	0.1	0.3	0.5	0.5	0.7	0.9	0.3	…	…	…	…	…	…	…	…	0.3	0.5	0.7
AS7	0.3	0.5	0.7	0.5	0.7	0.9	0.3	…	…	…	…	…	…	…	…	0.3	0.5	0.7
AS8	0.5	0.7	0.9	0.3	0.5	0.7	0.3	…	…	…	…	…	…	…	…	0.3	0.5	0.7
AS9	0.1	0.3	0.5	0	0.1	0.3	0.5	…	…	…	…	…	…	…	…	0.5	0.7	0.9
AS10	0.3	0.5	0.7	0.7	0.9	1	0.3	…	…	…	…	…	…	…	…	0.3	0.5	0.7
AS11	0.7	0.9	1	0.3	0.5	0.7	0.5	…	…	…	…	…	…	…	…	0.5	0.7	0.9
AS12	0.3	0.5	0.7	0.1	0.3	0.5	0.3	…	…	…	…	…	…	…	…	0.3	0.5	0.7

Table 20 Aggregated fuzzy decision matrix for the alternative strategies

	C1			C2			…			…			C20		
	L-FW	M-FW	H-FW	L-FW	M-FW	H-FW	…	…	…	…	…	…	L-FW	M-FW	H-FW
AS1	0.7	0.9	1	0.3	0.5	0.7	…	…	…	…	…	…	0.46	0.66	0.82
AS2	0.5	0.7	0.9	0.7	0.9	1	…	…	…	…	…	…	0.54	0.74	0.88
AS3	0.5	0.7	0.9	0.3	0.5	0.7	…	…	…	…	…	…	0.46	0.66	0.82
AS4	0.3	0.5	0.7	0.1	0.3	0.5	…	…	…	…	…	…	0.26	0.46	0.66
AS5	0.3	0.5	0.7	0.3	0.5	0.7	…	…	…	…	…	…	0.38	0.58	0.78
AS6	0.1	0.3	0.5	0.5	0.7	0.9	…	…	…	…	…	…	0.42	0.62	0.82
AS7	0.3	0.5	0.7	0.5	0.7	0.9	…	…	…	…	…	…	0.42	0.62	0.82
AS8	0.5	0.7	0.9	0.3	0.5	0.7	…	…	…	…	…	…	0.3	0.5	0.7
AS9	0.1	0.3	0.5	0	0.1	0.3	…	…	…	…	…	…	0.2	0.34	0.54
AS10	0.3	0.5	0.7	0.7	0.9	1	…	…	…	…	…	…	0.54	0.74	0.88
AS11	0.7	0.9	1	0.3	0.5	0.7	…	…	…	…	…	…	0.38	0.58	0.78
AS12	0.3	0.5	0.7	0.1	0.3	0.5	…	…	…	…	…	…	0.18	0.38	0.58

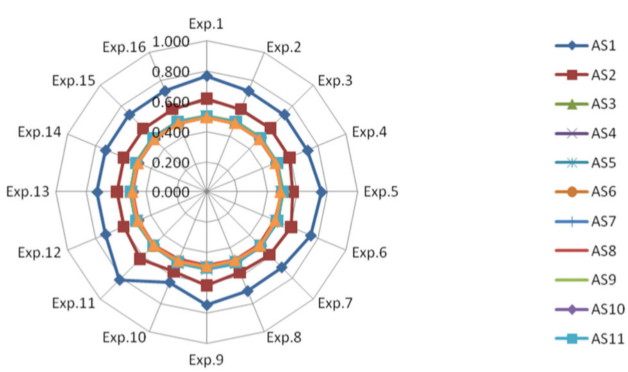

Fig. 3 Result of sensitivity analysis (CCi scores)

Similarity to Ideal Solution (TOPSIS). Acknowledging the inherent uncertainty in human judgment, the application of AHP and TOPSIS in a fuzzy environment is deemed essential.

The AHP method is employed to derive weights for the identified barriers to IM in SC, while fuzzy TOPSIS is utilized to rank the alternative strategies. The incorporation of weights obtained from AHP into fuzzy TOPSIS computations allows for the determination of solution priorities. Through a comprehensive empirical case study, the proposed framework's applicability is demonstrated. Furthermore, sensitivity analysis is conducted to scrutinize and elucidate the results. From a synthesis of literature review and expert opinions, a total of 20 barriers and 12 alternative strategies for IM in SC are identified. The hybrid fuzzy AHP-TOPSIS framework is then applied to rank these alternative strategies, revealing that leveraging Open Source Strategy in

Table 21 Weighted normalized fuzzy decision matrix for the alternative strategies

	C1			C2			…			…			C20		
AS1	0.583	0.750	0.833	0.050	0.083	0.117	…	…	…	…	…	…	0.051	0.073	0.091
AS2	0.417	0.583	0.750	0.117	0.150	0.167	…	…	…	…	…	…	0.060	0.082	0.098
AS3	0.417	0.583	0.750	0.050	0.083	0.117	…	…	…	…	…	…	0.051	0.073	0.091
AS4	0.250	0.417	0.583	0.017	0.050	0.083	…	…	…	…	…	…	0.029	0.051	0.073
AS5	0.250	0.417	0.583	0.050	0.083	0.117	…	…	…	…	…	…	0.042	0.064	0.087
AS6	0.083	0.250	0.417	0.083	0.117	0.150	…	…	…	…	…	…	0.047	0.069	0.091
AS7	0.250	0.417	0.583	0.083	0.117	0.150	…	…	…	…	…	…	0.047	0.069	0.091
AS8	0.417	0.583	0.750	0.050	0.083	0.117	…	…	…	…	…	…	0.033	0.056	0.078
AS9	0.083	0.250	0.417	0.000	0.017	0.050	…	…	…	…	…	…	0.022	0.038	0.060
AS10	0.250	0.417	0.583	0.117	0.150	0.167	…	…	…	…	…	…	0.060	0.082	0.098
AS11	0.583	0.750	0.833	0.050	0.083	0.117	…	…	…	…	…	…	0.042	0.064	0.087
AS12	0.250	0.417	0.583	0.017	0.050	0.083	…	…	…	…	…	…	0.020	0.042	0.064

Table 22 Closeness coefficient (CCi) and final ranking of the alternative strategies

Code	Alternative strategies	Description	di*	di-	CCi	Rank
AS1	Leverage open source solutions	Consider open-source Information Management systems to reduce licensing costs	0.830	2.767	0.769	1
AS2	Invest in employee training	Develop training programs to enhance IT skills among the workforce	2.633	4.297	0.620	2
AS3	Create a change management plan	Develop a clear change management plan to address employee concerns	4.016	4.016	0.500	7
AS4	Adopt cloud solutions	Utilize cloud-based solutions to reduce on-premise infrastructure needs	3.488	3.464	0.498	10
AS5	Implement robust encryption	Employ strong encryption methods to safeguard sensitive data	3.144	3.165	0.502	4
AS6	Align with industry standards	Adopt Information Management practices aligned with industry standards	2.331	2.323	0.499	8
AS7	Conduct awareness campaigns	Launch campaigns to educate employees on the benefits of Information Management	3.282	3.299	0.501	5
AS8	Evaluate vendor agreements	Carefully review and negotiate vendor contracts to minimize lock-in risks	3.150	3.053	0.492	12
AS9	Regular compliance audits	Conduct regular audits to ensure continuous compliance with changing regulations	2.498	2.525	0.503	3
AS10	Implement middleware solutions	Use middleware solutions to facilitate seamless integration with existing systems	3.246	3.232	0.499	9
AS11	Internal training programs	Develop internal training programs to enhance awareness and understanding	4.401	4.411	0.501	6
AS12	Strategic budget allocation	Gradually implement Information Management solutions in phases to manage costs	2.526	2.482	0.496	11

SC holds the highest rank among the strategies to overcome IM barriers. The empirical case study affirms the practicality of the proposed method for ranking IM strategies in SC. The outcomes highlight the relevance of this approach in aiding organizations to prioritize the implementation of solutions, thereby increasing the likelihood of overcoming IM barriers and enhancing overall success.

In conclusion, this study contributes a novel and reliable approach for prioritizing IM strategies in SC to overcome barriers. The proposed framework offers valuable insights for organizations seeking to optimize their decision-making processes in IM implementation. As avenues for future research, comparative analyses with alternative hybrid approaches,

Table 23 Experiments conducted to check sensitivity analysis

Exp	Conditions	AS1	AS2	AS3	AS4	AS5	AS6	AS7	AS8	AS9	AS10	AS11	AS12
1	Weights as actual	0.769	0.620	0.500	0.498	0.502	0.499	0.501	0.492	0.503	0.499	0.501	0.496
2	M1–0.6, M2–M10–0.4	0.725	0.595	0.500	0.497	0.503	0.499	0.503	0.490	0.505	0.499	0.501	0.494
3	M2–0.6, M1–M10–0.4	0.727	0.598	0.500	0.496	0.504	0.499	0.503	0.490	0.504	0.499	0.501	0.494
4	M3–0.6, M1–M10–0.4	0.722	0.596	0.500	0.497	0.503	0.499	0.503	0.490	0.504	0.499	0.501	0.494
5	M4–0.6, M1–M10–0.4	0.759	0.571	0.500	0.495	0.502	0.500	0.502	0.495	0.508	0.499	0.501	0.490
6	M5–0.6, M1–M10–0.4	0.744	0.607	0.500	0.494	0.508	0.498	0.502	0.486	0.506	0.499	0.501	0.491
7	M6–0.6, M1–M10–0.4	0.700	0.587	0.500	0.499	0.499	0.504	0.505	0.493	0.503	0.499	0.501	0.497
8	M7–0.6, M1–M10–0.4	0.705	0.576	0.500	0.492	0.510	0.498	0.503	0.486	0.503	0.498	0.501	0.490
9	M8–0.6, M1–M10–0.4	0.744	0.619	0.500	0.495	0.510	0.493	0.501	0.485	0.505	0.498	0.501	0.492
10	M9–0.6, M1–M10–0.4	0.642	0.569	0.500	0.495	0.509	0.491	0.505	0.483	0.507	0.499	0.502	0.492
11	M10–0.6, M1–M10–0.4	0.817	0.626	0.500	0.497	0.495	0.504	0.501	0.496	0.499	0.499	0.499	0.497
12	M1–M10–0.5, 50%	0.725	0.596	0.500	0.496	0.504	0.499	0.503	0.490	0.504	0.499	0.501	0.494
13	M1–M10–0.05, All Equal	0.725	0.596	0.500	0.496	0.504	0.499	0.503	0.490	0.504	0.499	0.501	0.494
14	M1–M10–0.045, 90%	0.725	0.596	0.500	0.496	0.504	0.499	0.503	0.490	0.504	0.499	0.501	0.494
15	M1–M10–0.04, 80%	0.725	0.596	0.500	0.496	0.504	0.499	0.503	0.490	0.504	0.499	0.501	0.494
16	M1–M10–0.035, 70%	0.725	0.596	0.500	0.496	0.504	0.499	0.503	0.490	0.504	0.499	0.501	0.494

such as the Best Worst Method with fuzzy multi-criteria techniques like fuzzy ELECTRE, fuzzy PROMETHEE, or fuzzy VIKOR, could provide further insights and contribute to the refinement of decision-making methodologies in the realm of IM in SC.

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