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ORIGINAL RESEARCH

Time inconsistency in sustainable partner selection for vertical collaborative network organizations

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Abstract

Collaborative Networked Organisations (CNOs) are increasingly recognised for their ability to harness cooperation and complementary competencies, outperforming individual efforts in pursuing business opportunities. However, the criticality of selecting the right long-term partner for a CNO has been understated, especially considering the evolving landscape of sustainability perceptions. This research addresses the issue of time inconsistency within the context of sustainable CNO partner selection by employing the Fuzzy Analytical Hierarchical Process with the Technique for Order of Preference by Similarity to Ideal Solution. Time inconsistency refers to a situation where preferences or decisions change over different points in time, leading to inconsistencies in choices or actions. Specifically, the study focuses on a Swiss Manufacturing CNO, examining how the evaluation of potential partners' environmental criteria changes over time. The findings reveal the presence of time inconsistency in environmental criterion evaluation between two time periods. This inconsistency stems from the evolving perception of environmental conditions and the increasing social and governmental pressures surrounding environmental standards. As a consequence, improper partner choices in CNOs can be made, potentially undermining the collaborative's overall sustainability goals. The study sheds light on the importance of considering dynamic sustainability factors in partner selection for CNOs, emphasising the need for a more comprehensive and adaptive approach to secure fruitful and lasting collaborations.

KEYWORDS

decision making, fuzzy reasoning, intelligent manufacturing systems

1 | INTRODUCTION

Collaborative Networked Organisations (CNOs) have emerged as a contemporary business model aimed at addressing the trend of mass customisation, where enterprises must consider the preferences, specificities, constraints, and assets of target markets [1]. Collaborative Design is an integral part of CNOs due to the nature of these complex business structures and plays a vital role as it facilitates the joint efforts of these interconnected entities to collectively innovate, create, and refine products or services. Through long-term collaboration, individual companies in CNOs can optimise their combined design and production offerings to customers while concurrently pursuing internal and shared sustainability objectives via sustainable partner selection. The concept of a CNO involves various interconnected networks of independent companies implying a shared distribution of responsibilities among them [2]. Therefore, when considering sustainability, it is essential to adopt a holistic perspective of the economic, social and environmental performances of each potential partner as they collectively contribute to determining the overall sustainability level achievable within the CNO [3]. Sustainability criteria serve as guiding principles within the context of collaborative design in CNOs as they ensure that the design efforts focus not only on innovation and efficiency but also on environmental, social, and economic sustainability.

The partner selection process is widely regarded as a pivotal component in forming various types of group collaborations between companies, receiving substantial attention in the literature. In recent years, sustainable partner selection has gained prominence, driven by companies' increased focus on environmental and social sustainability criteria, in addition to economic considerations. The prioritisation of sustainable partner selection has traditionally been confined to contexts such as supplier selection within supply chains and virtual enterprises (VEs), entities known for their comparatively shorter operational lifespans. In contrast, CNOs operate within a framework of extensive, semi-permanent collaborations between independent companies, usually SMEs. While sustainability in partner selection has received substantial attention in supply chains and VEs due to their shorter durations, its exploration within CNOs remains notably limited.

Furthermore, given the long-term nature of CNO partnerships, the focus on their environmental and social goals may vary over time due to individual CNO members' commitment to their company's internal sustainability objectives. In CNOs, the evolution of partner selection criteria over different time intervals reflects the dynamic nature of these collaborations. Initially, criteria might prioritise factors such as technical capabilities, financial stability, and cultural alignment. However, as CNOs progress, criteria importance could shift due to changes in market demands, technological advancements, or evolving sustainability goals similar to the political realm [4]. This variability introduces a time inconsistency problem, wherein the partner selected at one point in time may differ from the partner selected at a later stage, stemming from inherent time inconsistency in human decision-making. In various contexts, including economics, decision theory, and behavioural psychology, time inconsistency occurs when individuals or entities display preferences that vary when considering future outcomes or when assessing options at different points in time. This inconsistency in decision-making might result from changing circumstances, evolving priorities, or shifts in perspectives between present and future moments [5]. For instance, environmental considerations might gain prominence over time, influencing partner selection criteria to emphasise green practices, environmental management, or social responsibility. Moreover, economic uncertainties or shifts in industry trends might alter the emphasis on financial stability or technical expertise, necessitating flexibility in criteria evaluation. These changes could result from internal transformations within individual CNO members, external market shifts, or regulatory changes impacting the industry. Therefore, studying the evolution of these criteria across different time intervals provides insights into the adaptability and responsiveness of CNOs in aligning with evolving goals and challenges. Remarkably, this time inconsistency issue has not been explored in the context of the partner selection problem, thereby affecting the efficacy of partner selection methodologies in real-world scenarios characterised by dynamic and evolving decision-making environments. This discrepancy highlights a research gap concerning the critical element of time inconsistency in selecting partners aligned with sustainable practices within long-term collaborative frameworks, leading us to the question: How does time inconsistency in decision-making impact the sustainable selection of partners within CNOs?

This study aims to address a significant gap in research by exploring how time inconsistency influences the selection of long-term partners in CNOs. The central research question investigates the impact of time inconsistency on sustainable partner selection within CNOs. Consequently, this study addresses this fundamental issue and proposes a multi-criteria decision-making (MCDM) approach that can adapt to changing preferences and decision-makers' criteria over time and seeks to shed light on the temporal variability in partner selection criteria and the consequential impact on the overall sustainability outcomes within CNOs. This exploration holds importance for several reasons: it fills an underexplored area in understanding partner selection dynamics within complex collaborative networks such as CNOs, providing insights into decision-making processes. Moreover, it is crucial in aligning enduring collaborations with evolving sustainability goals, enabling decision-makers to navigate potential challenges and advantages effectively. Ultimately, this research contributes to refining decision-making strategies, fostering adaptive approaches for selecting sustainable partners within CNOs.

The primary objective of this paper is to gain insights into sustainable partner selection within CNOs and investigate how time inconsistency in decision-making could impact the final partner selection outcome. Understanding the temporal nature of decision-making concerning sustainability criteria is pivotal to refine and adapt partner selection methodologies used within these long-term collaborative networks. By addressing these critical knowledge gaps, this research aims to offer insights and strategic implications for decision-makers within CNOs, thus contributing to more effective and adaptive sustainable partner selection strategies. To accomplish this, the study proposes the combined utilisation of Fuzzy Analytical Hierarchical Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to select sustainable CNO partners. The paper's analysis involves evaluating a manufacturing CNO based in Switzerland under two distinct time period conditions, observing the evolution of founding members' perception of sustainability criteria over time and integrating experts into a historical context to coordinate the various phases of the partner selection process.

The structure of the paper is as follows: Section 2 reviews the existing literature on sustainable partner selection in collaborative organisations. Section 3 presents the comprehensive approach for sustainable partner CNO selection, followed by a case study implementation in Section 4, focusing on a Swiss CNO engaged in manufacturing parts for the watchmaking industry. Section 5 presents a sensitivity analysis and discussion of the results. Subsequently, managerial implications are developed and discussed in Section 5. Finally, Section 6 concludes the work and suggests potential directions for future research.

2 | LITERATURE REVIEW

2.1 | Partner selection

Fostering sustainability and resilience through collaboration requires common goals, effective planning, and risk sharing among partners [2]. Studies examining successful CNOs emphasise the importance of new members bringing technical complementarities, maintaining similar product and service quality levels, sharing a common business approach with suppliers, and being genuinely convinced of the mutual benefits of joining the CNO [6]. Parida et al. [7] argue that diversity among partners in a network benefits individual partner companies as long as the network's capability remains strong. Moreover, Vargas et al. [8] demonstrate that their proposed gain-sharing business model improved economic and environmental sustainability for the members of a logistics segment CNO in the UK. Various publications have proposed evaluation criteria specifically for the partner selection problem for CNOs including trust and transparency [9, 10], alignment of value systems [11], company integrity and reputation [12], as well as economic cost criteria [13]. O'Dwyer and Gilmore [14], based on a qualitative study of 5 manufacturing SMEs, identify 'customer orientation', 'partner capabilities', and 'value creation' as crucial factors for sustainable partner selection in strategic alliances among SMEs. Cheikhrouhou et al. [15] highlight the significance of human aspects, particularly trust, in vertical CNOs involving small and medium-sized enterprises. In a case study of a Swiss CNO from the machining industry, they employ an analytical hierarchy process (AHP) technique to identify various types of trust and assess their impact on knowledge and information exchange, finding that competence, relational trust, and contractual trust significantly influence relationship enhancement within the vertical CNO. Ayadi et al. [16] propose a fuzzy decision support system for evaluating the level of customer trust in suppliers based on the degree and quality of information sharing. They integrate various dimensions of information sharing to create a rule-based system that objectively assesses trust and aids in partner evaluation.

By incorporating sustainability criteria into collaborative design practices, CNOs can create products or services that are environmentally friendly, socially responsible, and economically viable [17]. This integration facilitates the development of designs that align with long-term sustainability goals, fostering innovation and fostering a positive impact on society and the environment. Moreover, it ensures that collaborative design efforts within CNOs are conscious of their broader impact and contribute to a more sustainable future [18].

The supplier selection problem has been treated in the literature to evaluate and select sustainable suppliers within a supply chain using various methods such as the balanced scorecard [19], best-worst method with VIKOR [20] and multi-objective mixed-integer programming (MILP) model [21]; however, supplier selection is distinctly different to CNO partner selection [22]. Supplier selection primarily involves the process of identifying and choosing suppliers to fulfil the needs of a single buyer. It is primarily transactional, aiming to ensure the timely provision of goods or services meeting specific quality, cost, and delivery requirements. This process typically emphasises short-term considerations such as price negotiation, quality standards, and efficiency in delivery [23]. On the other hand, CNO partner selection is a more complex and strategic process. In a CNO, the focus is not limited to fulfiling immediate requirements but is about forming a collaborative network or alliance of independent entities. Selecting partners for a CNO involves establishing long-term relationships with multiple firms that collectively contribute to achieving broader organisational goals, beyond just the exchange of goods or services. It involves factors like mutual trust, shared objectives, collaborative innovation, risk sharing, and a commitment to long-term success [24]. Thus, the decision-making criteria for CNO partner selection are inherently broader and encompass considerations related to compatibility, shared values, joint problem-solving capabilities, and the ability to adapt and evolve together within a networked environment. Ben Salah et al. [25] state that the lack of effective CNO design and management methodologies, coupled with gaps in horizontal CNO case studies and partner selection problem analysis, highlights the need for further research in a decision-making framework to guide sustainable partner selection for CNOs.

In response to the uncertainty inherently involved in judgement and evaluation processes, certain authors have addressed it in the partner selection problem. For instance, Huang et al. [26] tackle uncertainty in partner selection for VEs by proposing a simulation model based on the vague set theory, which considers project parameters such as due dates and costs. Vieira et al. [27] propose an integrated and quantitative risk analysis method to support the selection of logistic partners for a virtual organisation. Wu and Barnes [28] introduce an innovative multi-partner classification model that leverages ensemble learning technology and fuzzy set theory to classify prospective partners into four distinct categories. This classification allows for customised partner management strategies, thus enhancing the efficiency and efficacy of partner evaluation. Additionally, Wu et al. [29] present a multi-partner classification model for supply chain management partner qualification and classification, utilising ensemble learning and fuzzy set theory to categorise partners into four groups while factoring in uncertainty. Ye [30] presents an extended TOPSIS method for group decision-making with interval-valued intuitionistic fuzzy numbers, aiming to address the partner selection problem under incomplete and uncertain information environments. This approach is demonstrated using an example to showcase its feasibility and applicability under such conditions. Similarly, Rani et al. [31] combine Pythagorean fuzzy sets with TOPSIS to address sustainable recycling partner selection problems in the presence of unknown decision experts and weights, with results supporting the validity and efficacy of their proposed method. Polyantchikov et al. [32] suggest a combined fuzzy-AHP and TOPSIS approach to rapidly evaluate and select partners with the goal of mitigating project risks. Furthermore, Badulescu et al. [33] propose a combined AHP, Fuzzy-AHP, and TOPSIS approach that integrates the concept of risk in sustainable CNO partner selection amid future uncertainty.

Additionally, the literature predominantly focuses on partner selection in VEs, which are temporary collaborations for specific projects [3]. However, VEs differ from CNOs as they have limited lifespans, terminating after the completion of their designated tasks or projects. For instance, Xiao et al. [34] employ the improved gravitational search algorithm and particle swarm optimisation (PSO) to address the problem of green partner selection in VEs. Ye and Lin [35] suggest using an interval-valued fuzzy (IVF)-TOPSIS to select partners for VEs, taking into account the decision-maker's risk preference. Addressing sustainability aspects, Zhang et al. [36] utilise a Pareto genetic algorithm for green partner selection in VEs in the electronics industry, taking into account two green criteria: carbon emission and lead content. Similarly, Tiacci and Cardoni [37] propose a genetic algorithm which enables CNOs to effectively align their partner selection with their strategic goals, maximising the potential for success and value creation. Ishizaka and Nemery [38] propose the PROMETHEE group decision-making method for partner selection when sharing resources, and Yu et al. [39] develop an evaluation method for supplier selection using PSO and machine learning. Additionally, Ashayeri et al. [40] employ an intuitionistic fuzzy Choquet integral operator approach to select the best supply chain, and Yue [41] uses linguistic values and intuitionistic fuzzy information for partner selection in VE.

The literature highlights that the process of partner selection in collaborative networks is characterised by inherent uncertainty and complexity. To address this challenge, various techniques have been proposed to integrate fuzzy and ambiguous information into the selection process. However, the majority of existing research primarily focuses on partner selection for VEs, and very few consider the time inconsistency problem that arises when decision-making criteria and preferences change over time. As such, there is room for further research to develop models that account for anticipated changes in decision-making criteria over time for partner selection in collaborative organisations.

2.2 | Time inconsistency in decision-making

In behavioural economics, the concept of time inconsistency (or dynamic inconsistency) refers to the tendency of individuals to place greater value on present payoffs or immediate decision-making conditions over future potential conditions [42, 43]. In the field of political economics, policymakers often prioritise short-term conditions at the expense of long-term social welfare, leading to the selection of suboptimal policies [44]. Faccioli et al. [45] conducted a study on subjects' social preference for environmental policies with long-term or very long-term outcomes using the contingent valuation method. Surprisingly, subjects demonstrated no significant difference in their temporal decision-making, evaluating environmental policies similarly regardless of whether the outcome was closer or further into the future. On the contrary, Gabrielsen [46] demonstrated time inconsistency issues in governmental decision-making related to long-term environmental policies.

Barkan and Busemeyer [47] conducted experiments involving a 'sequential gambling paradigm' and found that subjects exhibited time inconsistency in their decisions, influenced by the reference point used to evaluate their choices. Augenblick et al. [48] performed a longitudinal experiment to model time inconsistency in the evaluation of 'work effort'. While subjects demonstrated awareness of their present bias and time inconsistency in their choices, their evaluation of work effort remained inconsistent between two time periods. However, a study on time inconsistency in food choices showed that individuals with less self-control were less aware of the time inconsistency of their choices, contradicting Augenblick et al. [48, 49]. Hardisty and Pfeffer [50] argued that an uncertain future leads individuals to exhibit more present bias, whereas a more uncertain present makes people value future gains and losses more. Imperfect or uncertain information has been identified as one of the main reasons for time-inconsistent decision-making, and it is suggested that big data and artificial intelligence can enhance the consistency of present decision-making by providing additional pertinent information [5].

2.3 | Gaps and research question

The research landscape has extensively explored time inconsistency across diverse domains, yet a notable gap persists concerning its influence on the selection of long-term strategic partners within CNOs. This study aims to fill this gap by investigating the research question emerging from the literature: How does time inconsistency in decision-making impact the sustainable selection of partners within CNOs? The investigation into this research questions is important for several reasons. Firstly, it delves into an underexplored area within the domain of partner selection dynamics, particularly in the context of CNOs, providing valuable insights into decision-making processes within these complex collaborative networks. Secondly, given the increasing emphasis on sustainability, understanding the interplay between time inconsistency and partner selection is crucial for fostering enduring collaborations aligned with evolving sustainability goals. Moreover, this research aims to uncover the potential challenges and advantages arising from time inconsistency, empowering decision-makers to anticipate and navigate these complexities effectively. Ultimately, this study aims to contribute not only to academic understanding but also to the refinement of decision-making approaches, thereby facilitating more adaptive and resilient strategies for selecting sustainable partners within CNOs.

3 | PROPOSED METHODOLOGY FOR SUSTAINABLE PARTNER SELECTION FOR CNOS AND INSIGHTS ON TIME INCONSISTENCY

The research problem revolves around the essential issue of time inconsistency in the selection of sustainable partners aligned with sustainable practices within the framework of long-term CNOs. Sustainability has emerged as a critical aspect for businesses in general, including the selection of partners. Moreover, the longevity and resilience of CNOs are contingent upon sustainability measures over time. Hence, a comprehensive analysis of all sustainability criteria considering dynamic inconsistency can assist CNOs in evaluating and sustaining long-term, resilient relationships that contribute to their collective objectives. To address this problem effectively, it necessitates the utilisation of multiple criteria for evaluating potential partners and the implementation of a robust approach to rank these partners seeking to join the CNO. The combined Fuzzy Analytical Hierarchy Process with Technique for Order of Preference by Similarity to Ideal Solution (F-AHP-TOPSIS) method serves as a structured mechanism for incorporating expert input regarding the perceived significance of each criterion in a systematic manner. The AHP-TOPSIS method holds several advantages over alternative approaches in partner selection for CNOs in its integration of qualitative and quantitative data. While methods such as Linear Programming or Data Envelopment Analysis focus solely on quantitative aspects, AHP-TOPSIS combines subjective expert opinions (AHP) with objective criteria-based rankings (TOPSIS), offering a more comprehensive assessment. Moreover, its ability to handle uncertainty, facilitated by F-AHP, provides adaptability to imprecise information, a feature which is absent in other methods such as Fuzzy Logic or Grey Relational Analysis. Unlike other MCDM methods such as ELECTRE or PROMETHEE, AHP-TOPSIS brings forth a structured approach with hierarchical structuring and pairwise comparisons, aiding in better prioritisation and decision clarity. Its robustness in handling diverse partner selection scenarios within CNOs, balanced evaluation of criteria importance and performance, and versatility make it a pragmatic choice for navigating the multifaceted landscape of CNOs.

This proposed methodology aims to assess and choose partners for sustainable CNOs while accounting for time inconsistency and expert judgement and effectively handles the uncertainties in input data by utilising fuzzy numbers. To achieve this, the F-AHP-TOPSIS approach must be conducted at various time points to accommodate the dynamic nature of sustainability criteria evaluation. Additionally, the TOPSIS method plays a pivotal role in ranking evaluated partners from the most favourable to the least, mitigating the risk of rank reversal that could potentially occur when using only the AHP method. The integration of these methodologies aims to yield a more resilient and dependable solution in the process of partner selection within CNOs.

The partner selection problem is addressed through a three-phase multicriteria decision-making process, which includes a preparation phase, prioritisation of sustainability criteria using the F-AHP method, TOPSIS for ranking alternative partners for CNO membership at time $= t$. The overall process entails several steps, as depicted in Figure 1.

3.1 | Phase 1: preparation phase to establish the sustainability criteria and the group of decision-makers

The initial stage involves the establishment of evaluation criteria, which are derived from a comprehensive literature review and subsequently narrowed down based on the specific internal requirements of the CNO. A total of nine sustainability criteria are identified, drawing upon concepts found in the literature. These criteria are organised into three distinct clusters, aligning with the three pillars of sustainability, each accompanied by a detailed explanation. The literature sources informing the selection of these criteria are appropriately referenced within their respective descriptions.

The selection of these specific metrics or criteria over others stems from their direct relevance and crucial impact on fostering successful and sustainable partnerships within CNOs. The chosen economic criteria, focusing on costs, technical capabilities, and financial stability, are pivotal in assessing a partner's commitment, compatibility, and capability to align with CNO strategies, resources, and goals. They ensure an optimal environment for efficient and sustainable collaborations. Similarly, the social criteria were selected due to their fundamental role in building cohesive and enduring partnerships. Assessing company culture, employee working conditions, and social trust allows for the establishment of strong values alignment, a positive work environment, and the cultivation of trust and collaboration essential for sustainable relationships within CNOs. Regarding the environmental criteria, their selection was driven by the critical importance of evaluating a company's dedication to sustainability. Factors such as pollution control strategies, environmental certifications, waste management practices, and broader green initiatives provide a comprehensive understanding of a potential partner's commitment to environmental sustainability, a crucial aspect in a CNO's business landscape and overall strategy. Other criteria may hold relevance in other partner selection contexts; however, the chosen criteria were deemed most critical for evaluating and fostering sustainable partnerships within CNOs due to their direct influence on financial alignment, cultural compatibility, and environmental dedication, which are essential for successful and resilient long-term collaborations.

Subsequently, Phase 1 in Figure 1 depicts the formation of a group of experts, comprising the CEOs of the member companies, responsible for identifying potential partners for the CNO. In Phase 2, these experts assess the alternative partners using the evaluation criteria delineated in Table 1, employing the Fuzzy AHP approach.

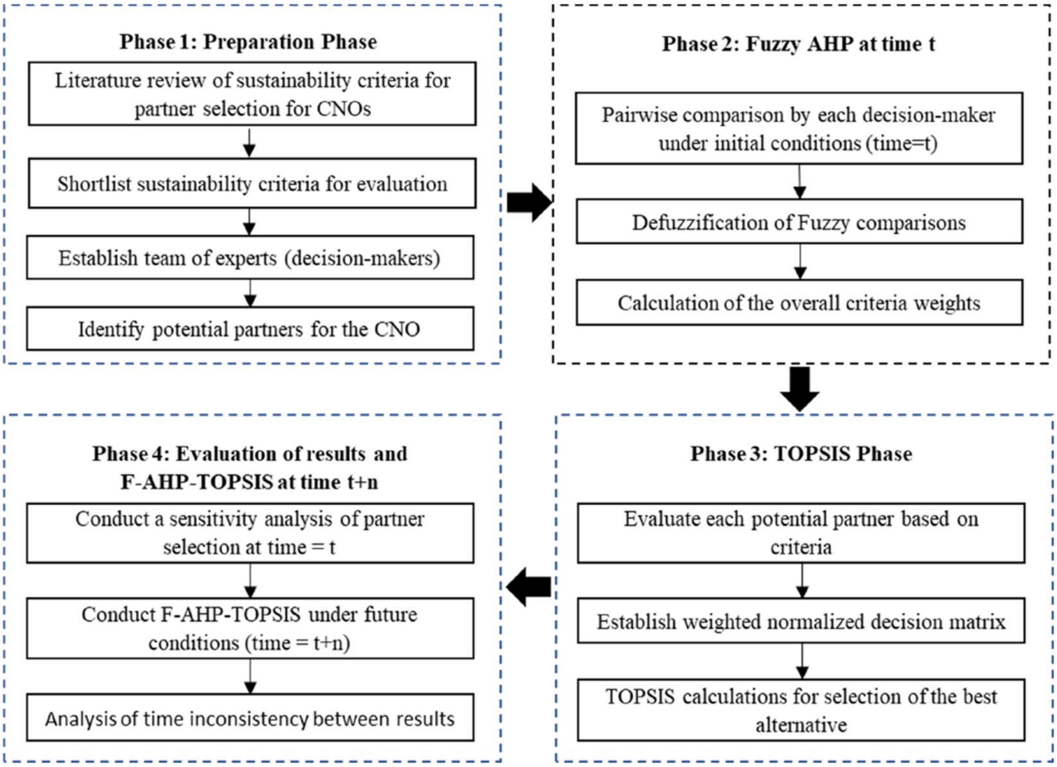

FIGURE 1 Methodology for sustainable partner selection for collaborative networked organisations at various time periods.

TABLE 1 Selected evaluation criteria divided into the three pillars of sustainability.

Criterion		Description	References
Economic			
Cost	C1	Refers to the monetary cost required for a candidate to become a member of the CNO, as well as the costs incurred to make the right adjustments to align their strategies and goals to act effectively as a team.	[13, 33]
Technical capabilities	C2	Takes into consideration the complementary capabilities of partners within the CNO, its technical experience, and its capability to innovate and develop new projects. It also considers the quality of its management system, its service and its information infrastructure.	[14, 51]
Financial trust	C3	Represents the financial stability of the potential partner, their transparency concerning financial transactions and profitability.	[10, 52, 53]
Social			
Culture	C4	Takes into consideration the compatibility of the candidates' goals, values and working culture with the other members of the CNO.	[10, 54]
Employment practices	C5	Refers to the work conditions of the company's employees, the health and safety measures taken and the career development strategy and operations.	[55]
Social trust	C6	Is determined by the reputation of the company and its willingness to share information, knowledge, and expertise with the other members of the CNO.	[10, 56]
Environment			
Pollution	C7	Considers the existence of an environmental budget and strategy, a system for pollution control and potential environmental certifications.	[20, 57]
Environmental management system	C8	Refers to the volume of waste, air and water pollution (per period) and their resource consumption including energy, water and raw materials.	[57, 58]
Green practices	C9	Includes the green Image of the company, its waste control system, and its recycling practices. It also takes into consideration the company's green production, marketing, transport and packaging.	[20, 59]

3.2 | Phase 2: F-AHP to determine the perception of importance of each criterion for a time = *t*

The method employed in this study utilises F-AHP for determining criteria weights and TOPSIS for ranking the alternatives, as described in a previous work by Kara et al. [60]. A significant advantage of AHP lies in its pairwise comparison approach, which, when combined with fuzzy sets theory, facilitates the weighting of both qualitative and quantitative criteria effectively. On the other hand, TOPSIS is favoured for its simplicity in decision-making and its adaptability, as pointed out by Joshi and Kumar [61]. Given that criteria weighting involves subjective assessment, employing the pairwise comparison is a suitable method for eliciting expert judgement, which is considered one of the key benefits of AHP. Moreover, considering the diverse nature of the criteria, which encompass both qualitative and quantitative aspects, fuzzy formulations appear to be more appropriate. Additionally, TOPSIS, a widely recognised MCDM technique, offers the advantage of considering both ideal and anti-ideal solutions, along with its ease of implementation [62].

The initial step involves requesting experts to provide qualitative ratings for each potential alternative partner seeking to join the network concerning each evaluation criterion, utilising a linguistic variable represented in Figure 2. The linguistic scale corresponds to Triangular Fuzzy Numbers (TFN) as shown in Figure 2, and these TFN are used to construct a decision matrix comprising the performance ratings of each potential partner concerning the evaluation criteria.

Experts collaboratively reach a consensus on the evaluations for each criterion by expressing them in a linguistic form to obtain the performance of the different alternatives. Subsequently, de-fuzzification is carried out using the formula presented in Eq. (1):

$$\overline{f}_{ij} = \frac{1}{3}\left[f_{ij}^{l} + f_{ij}^{m} + f_{ij}^{u}\right] \tag{1}$$

where f_{ij} is the fuzzy value of the ith criterion function for the alternative A_j, f_{ij}^{l} represents the lower value, f_{ij}^{m} the medium value and f_{ij}^{u} the upper value, and $\overline{f}_{ij}$ is the defuzzified value of f_{ij}.

By using TFN via pairwise comparisons, the fuzzy judgement matrix $\tilde{A}(a_{ij})$ can be expressed mathematically in Equation (2):

$$\tilde{A} = \left\{ \begin{array}{cccccc} 1 & \widetilde{a_{12}} & \widetilde{a_{13}} & K & \widetilde{a_{1(n-1)}} & \widetilde{a_{1n}} \\ \widetilde{a_{21}} & 1 & \widetilde{a_{23}} & K & \widetilde{a_{2(n-1)}} & \widetilde{a_{2n}} \\ M & M & M & M & M & M \\ M & M & M & K & M & M \\ \widetilde{a_{(n-1)1}} & \widetilde{a_{(n-1)2}} & \widetilde{a_{(n-1)3}} & K & 1 & \widetilde{a_{(n-1)n}} \\ \widetilde{a_{n1}} & \widetilde{a_{n2}} & \widetilde{a_{n3}} & K & \widetilde{a_{n(n-1)}} & 1 \end{array} \right. \tag{2}$$

The judgement matrix $\tilde{A}$ is an n x n fuzzy matrix containing fuzzy numbers $\tilde{a}_{ij}$ as shown in Equation (3):

$$a_{ij} = \left\{ \begin{array}{ll} 1, & i = j \\ \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9} \ or\ \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & i \neq j \end{array} \right. \tag{3}$$

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set, whereas $U = \{u_1, u_2, \ldots, u_n\}$ is a goal set. According to fuzzy extent analysis, the method can be performed with respect to each object for each corresponding goal, resulting in m extent analysis values for each object, given as $M_{gi}^{1}, M_{gi}^{2}, \ldots, M_{gi}^{m}, i = 1, 2, 3, \ldots, n$, where M_{gi}^{j} $(j = 1, 2, \ldots, m)$ are TFNs that repress the performance of the object x_i with regard to each goal u_j. The steps of the extent analysis can be detailed as follows:

Step 1 The fuzzy synthetic extent value with respect to the ith object is defined as follows:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{i} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} \tag{4}$$

where $\otimes$ is a fuzzy multiplication operator.

To obtain $\sum_{j=1}^{m} M_{g_i}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{g_i}^{i} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{5}$$

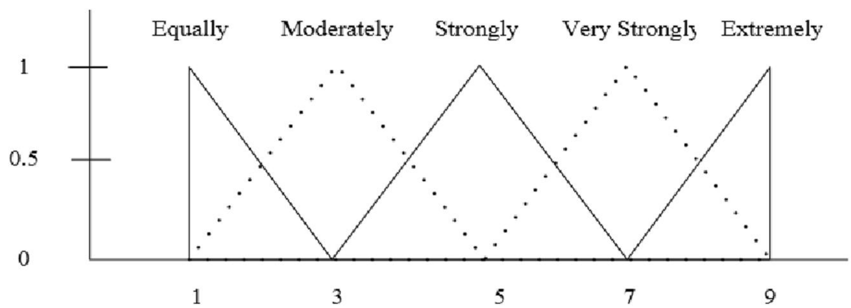

FIGURE 2 Linguistic variables describing the expert's opinion about every potential partner [52].

Also, obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^{j}\right]^{-1}$, perform the fuzzy addition operation of $M_{g_i}^{j}$ $(j=1,2,\ldots,m)$ values such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^{j}=\left(\sum_{i=1}^{n}l_i,\sum_{i=1}^{n}m_i,\sum_{i=1}^{n}u_i\right) \tag{6}$$

Then, compute the inverse of the vector in Equation (6) such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^{j}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}l_i},\frac{1}{\sum_{i=1}^{n}m_i},\frac{1}{\sum_{i=1}^{n}u_i}\right) \tag{7}$$

Step 2 The degree of possibility of $M_2 \geq M_1$ is defined as follows:

$$V\left(M_2 \geq M_1\right)=\sup_{y\geq x}\left[\min\left(\mu_{M_1}(x),\mu_{M_2}(y)\right)\right] \tag{8}$$

It can be equivalently expressed as follows:

$$V\left(M_2 \geq M_1\right)=\mathrm{hgt}(M_1\cap M_2)=\mu_{M_2}(d)=\begin{cases}1, & \text{if } m_2\geq m_1\\ 0, & \text{if } l_1\geq u_2\\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)}, & \text{Otherwise}\end{cases} \tag{9}$$

where hgt is the height of intersection of the two TFNs M_1 and M_2, and d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}.

To compare M_1 *and* M_2, both values of $V\left(M_1 \geq M_2\right)$ and $V\left(M_2 \geq M_1\right)$ are required.

Step 3 The degree possibility of a convex fuzzy number to be greater than k convex fuzzy numbers $M_i(i = 1,2, \ldots ,k)$ can be defined by Equation (10):

$$\begin{aligned}V\left(M\geq M_1,M_2,\ldots,M_k\right)&=V\left[\begin{array}{c}(M\geq M_1)\text{ and }(M\geq M_2)\text{ and}\ldots\\ \text{and }(M\geq M_k)\end{array}\right]\\&=\min V\left(M\geq M_i\right),i=1,2,3,\ldots,k\end{aligned} \tag{10}$$

Assuming that

$$d'(A_i)=\min V\left(S_i\geq S_k\right) \tag{11}$$

For $k = 1,2, \ldots,n$; $k \neq i$, then the weight vector is given by

$$W'=\left(d'(A_1),d'(A_2),\ldots,d'(A_n)\right)^T \tag{12}$$

where A_i $(i = 1, \ldots,n)$ has n elements.

Step 4 The normalised weight vectors are defined as follows:

$$W=\left(d(A_1),d(A_2),\ldots,d(A_n)\right)^T \tag{13}$$

where W is a non-fuzzy number.

The crisp values obtained from the qualitative and quantitative data allow it to be possible to evaluate the alternatives and criteria using TOPSIS.

3.3 | Phase 3: TOPSIS for ranking of partners based on the sustainability criteria

The TOPSIS approach is used to rank the alternatives based on their distance from the positive and negative ideal solutions. The number of alternatives (j) is denoted as $A_1, A_2, \ldots, A_j$. f_{ij} represents the value of the ith criterion function for the alternative A_j.

Assuming that n is the number of criteria, the TOPSIS procedure consists of the following steps:

Step 1 Determine the normalised decision matrix. Each normalised value r_{ij} is calculated as follows:

$$r_{ij}=\frac{f_{ij}}{\sqrt{\sum_{j=1}^{J}f_{ij}^{2}}},j=1,2,3\ldots n \tag{14}$$

Step 2 Determine the weighted normalised decision matrix. Each weighted normalised value v_{ij} is calculated as follows:

$$v_{ij}=w_i*r_{ij}\;\; j=1,2,3,\ldots,J \quad \textit{and} \quad i=1,2,3,\ldots,n \tag{15}$$

where w_i is the weight of the ith criterion and $\sum_{i=1}^{n}w_i=1$.

Step 3 Determine the ideal and negative ideal solutions, respectively A^* and A^-.

$$A^*=\left\{v_1^*,\ldots,v_i^*\right\}=\left\{\left(\max_i v_{ij}\middle|i\in I'\right),\left(\min_j v_{ij}\middle|i\in I''\right)\right\} \tag{16}$$

$$A^-=\left\{v_1^-,\ldots,v_i^-\right\}=\left\{\left(\min_j v_{ij}\middle|i\in I'\right),\left(\max_j v_{ij}\middle|i\in I''\right)\right\} \tag{17}$$

where I' is associated with the benefit criteria, and I'' is associated with the cost criteria.

Step 4 Calculate the distances from the positive and negative ideal solutions using the n-dimensional Euclidean distance. The distance of each alternative from the positive ideal solution is given as follows:

$$D_j^* = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_i^*\right)^2} \quad j = 1, 2, 3, \ldots, J \tag{18}$$

Similarly, the distance from the negative ideal solution is given as follows:

$$D_j^- = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_i^-\right)^2} \quad j = 1, 2, 3, \ldots, J \tag{19}$$

Step 5 *Calculate the relative closeness to the ideal solution.* The relative closeness of the alternative a_j is defined as follows:

$$CC_j^* = \frac{D_j^-}{D_j^* + D_j^-} \quad j = 1, 2, 3, \ldots, J \tag{20}$$

Step 6 Rank the preference order from closest to farthest from the ideal solution.

The F-AHP-TOPSIS approach was selected due to its unique capabilities in handling the multifaceted nature of the CNO partner selection process which has a complex decision-making landscape. CNOs involve diverse stakeholders with distinct objectives and expectations, necessitating alignment across varied interests to achieve collective goals. Evaluating potential partners involves assessing them against multiple heterogeneous criteria encompassing economic, technical, social, and environmental aspects, requiring a delicate balance and consideration of relative importance. Long-term collaboration within CNOs demands careful assessment of partners capable of maintaining sustained and meaningful relationships over extended periods. Additionally, the dynamic nature of decision-making within CNOs, coupled with information asymmetry among partners, contributes to the complexity of the selection process. Establishing trust, fostering relationships, ensuring compatibility, addressing risks, and integrating technological innovation further amplify the intricacies involved in CNO partner selection. F-AHP's ability to accommodate imprecision and subjective judgements proves advantageous, enabling decision-makers to express their preferences using linguistic variables, essential in managing the inherent ambiguity in their assessments. Moreover, F-AHP's hierarchical structure aids in evaluating diverse criteria and determining their relative importance, contributing to a comprehensive evaluation process. In conjunction, TOPSIS offers a systematic approach to MCDM, leveraging the priority weights derived from F-AHP to rank alternatives based on their proximity to the ideal solution. This combined methodology addresses the complexities inherent in CNO partner selection, particularly focussing on sustainability aspects. Previous success and applicability of these methods in similar contexts in the literature further validate their selection, promising a robust framework for CNO partner selection characterised by its adaptability and ease of use.

4 | IMPLEMENTATION OF SUSTAINABLE PARTNER SELECTION INTO A SWISS CNO

Swiss MicroTech (SMT) is a vertically integrated CNO located in Switzerland, encompassing businesses from the telecommunications, medical devices, precision machinery, and watchmaking sectors. Initially established by three founding entities, including a CNO network coach and two companies, SMT has experienced growth over time. The process of selecting new members to join the CNO is guided by specific criteria:

- Reducing costs of raw materials and tool machining through different suppliers.
- Generating synergy by enhancing the CNO's production capacity and capabilities.
- Expanding the technical and core competences of the CNO.

The decision-making regarding new member partnerships is reached through a consensus among the CEOs of the member companies. In this case study, a group of four experts, comprising the CNO network coach, the CEOs of the founding member companies, and an academic co-author of the paper, collaborates to identify and prioritise evaluation criteria obtained from a literature review. This approach uniquely incorporates both quantitative and qualitative judgements, particularly focusing on sustainability criteria, which is an innovative aspect. A pivotal condition for accepting new members lies in the complementarity of their capabilities with those of the existing CNO, as well as their relationship with current members. To prevent direct rivalry between members, each CNO member possesses distinct technical competencies. Moreover, an increasingly vital consideration for admitting new members is their commitment to environmental sustainability.

The research examines the historical process of choosing a new partner from six potential members, denoted as A1 to A6. The focus of the study is on the partner selection problem with particular attention given to incorporate sustainability criteria into the selection process. Moreover, the investigation centres on how the sustainability criteria evolve over a 15-year period and its subsequent impact on the selected partner. To analyse the influence of time inconsistency in criteria evaluations, two critical points in the CNO's lifecycle are considered: the CNO creation phase ($t = 0$) capturing the initial phase when founding members established the network's core principles and criteria for partner selection and serves as a baseline to understand the criteria's importance and perception at the CNO's outset; and a time instance 15 years later ($t + n = 15$) which reflects a significant duration allowing for considerable organisational growth and transformation. This interval allows insights into the evolution of partner selection criteria, aligning with potential changes in market demands, technological advancements, and evolving sustainability expectations within CNOs. By evaluating the criteria at these two distinct time points, the study aims to illuminate how perceptions of sustainability criteria for partner selection have potentially evolved over the CNO's lifecycle, capturing dynamic shifts in decision-making contexts and sustainability priorities across different phases of the CNO's existence. Experts were requested to evaluate the criteria at both these time points during the same session, considering their mindset and expectations at the CNO's inception ($t = 0$). Within this context, the selection of time periods ($t = 0$ and $t + n = 15$) for this study was strategically chosen to align with specific milestones within the CNO's evolution which allows to capture critical stages in its journey, enabling the analysis of how partner selection criteria evolve over time, considering different operational, economic, and market dynamics that could affect sustainability priorities within the network. Initially, the experts weighted the evaluation criteria based on their hypothetical partner selection process at the CNO's creation ($t = 0$). This involved utilising the F-AHP to derive the normalised weights of the criteria belonging to the fuzzy evaluation for each alternative, as presented in Table 2. The table illustrates the experts' weighting of the 9 sustainability criteria (C1 to C9) across the three sustainability pillars: economic, social, and environmental. A noteworthy finding is that the criterion C5, representing 'employment practice' within the social pillar of sustainability, was assigned a weight of zero in the pairwise comparison process. On the other hand, C4 and C6, encompassing 'culture' and 'social trust,' respectively, also belonging to the social sustainability pillar, obtained the second and fourth highest weights. This implies that although the experts consider the social pillar of sustainability as significant for partner selection, they do not view employment practices as important criteria in this context.

Upon examining Table 2, it can be observed that the economic criteria hold the highest significance, comprising 45% of the total weights. Following closely are the social criteria, accounting for 33% of the total weights, while the environmental criteria have the lowest relative importance at 21%. Interestingly, criterion C5, which assesses 'employment practices', holds a weight of 0, signifying its unique focus on how potential partners treat their employees internally concerning health and safety measures and career development. This might be attributed to the fact that all alternative partners operate in Switzerland, where strict laws governing health and safety at work are already enforced. Consequently, the experts may perceive that all potential partners adhere to federal regulations.

Subsequently, the evaluation of the six potential partners, denoted as A1–A6, is conducted by the experts based on the nine criteria using TFN. The defuzzified normalised evaluation results of A1–A6 are multiplied with the respective criteria weights to derive the decision matrix presented in Table 3. It is noteworthy that the cost (C1) of joining the CNO remains uniform across all partners.

The proximity measure, denoted as CC, is determined using the relative distances, D+ and D−, with respect to the positive and negative ideal solutions. The outcomes are presented in Table 4, showcasing the evaluation of alternative CNO partners A1–A6 and their corresponding rankings. A5 exhibits the highest relative closeness to the ideal solution and is ranked as the most favourable candidate for the CNO, closely followed by A1. On the other hand, A4 and A6 are ranked the lowest among the potential partners, which can be attributed to their relatively low scores in the environmental criteria, technical capabilities, and culture for A6, as well as low social trust for A4. Considering the partner rankings for the time = 0 scenario, A5 is chosen as the selected partner.

4.1 | Sensitivity analysis of the proposed sustainable partner selection approach

Once the final ranking results are obtained, a sensitivity analysis is performed at $t = 0$ to assess the robustness of the solution when the criteria weights undergo significant changes. For this analysis, each criterion is incrementally increased by

TABLE 2 Criteria Weights based scenario time = 0.

Sustainability pillar	Criterion	Label	Weight	Proportion
Economic	Cost	C1	0.057	45%
	Technical capabilities	C2	0.231	
	Financial trust	C3	0.165	
Social	Culture	C4	0.181	33%
	Employment practices	C5	0	
	Social trust	C6	0.152	
Environmental	Pollution	C7	0.109	21%
	Environmental management system	C8	0.018	
	Green practices	C9	0.087	

TABLE 3 Normalised decision matrix AHP-TOPSIS.

	Alternative potential partners					
Evaluation criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Cost (C1)	0.023	0.023	0.023	0.023	0.023	0.023
Technical capabilities (C2)	0.124	0.106	0.078	0.080	0.106	0.053
Financial trust (C3)	0.076	0.076	0.057	0.057	0.088	0.038
Culture (C4)	0.088	0.088	0.066	0.044	0.103	0.022
Employment practices (C5)	0.000	0.000	0.000	0.000	0.000	0.000
Social trust (C6)	0.079	0.067	0.050	0.034	0.079	0.050
Pollution (C7)	0.053	0.045	0.045	0.034	0.053	0.034
Environmental management system (C8)	0.009	0.007	0.007	0.005	0.011	0.005
Green practices (C9)	0.039	0.058	0.039	0.013	0.039	0.013

TABLE 4 Relative distances and final ranking of alternative collaborative networked organisation partners at $t = 0$.

Alternative partners:	A1	A2	A3	A4	A5	A6
D+	0.027	0.030	0.076	0.104	0.026	0.131
D−	0.118	0.109	0.063	0.039	0.122	0.053
Relative closeness (CC)	0.812	0.786	0.455	0.274	0.824	0.288
Final ranking	**2**	**3**	**4**	**6**	**1**	**5**

Note: Bold values indicate the final rankings per alternative.

50% and then 100%, while the remaining criteria are adjusted proportionally to maintain a total weight of 1 and can be represented mathematically as follows:

Let's assume you have n criteria, and you are incrementing the weight of criterion i by a factor k (e.g. 50% or 100%). The adjustment for the other criteria's weights can be calculated as follows:

$$\text{Original weight of criterion}: i = w_i$$

$$\text{New weight of criterion}: i = w_i' = w_i \times (1 + k)$$

To maintain the total weight at 1, the adjustment ratio (r_j) for each of the other criteria j can be calculated proportionately:

$$r_j = \frac{w_j}{\sum_{j=1}^{n} w_j - w_i} \tag{21}$$

Then, the adjusted weight of each other criterion j (w_j') is calculated as follows:

$$w_j' = r_j \times \left(1 + w_i'\right) \tag{22}$$

This ensures that when the weight of criterion i is increased by a certain factor, the weights of the other criteria are adjusted proportionately while maintaining the total weight of 1 in the overall evaluation.

Subsequently, the relative distance from the ideal solution is recalculated using the newly obtained data. The resulting rankings of the alternative partners at $t = 0$ are presented in Table 5.

The sensitivity analysis of the criteria weights at $t = 0$ reveals that A5 consistently emerges as the top-ranked alternative in most cases, except when the weights of C2 and C9 are increased, leading to A1 and A2 being ranked first, respectively. Furthermore, adjustments made to C4, denoted as 'Culture' in the social pillar, result in the lowest and highest relative closeness values for A6 and A5, namely 0.19 and 0.89, respectively.

4.2 | Sustainable partner selection at $t + n = 15$

Following a discussion with the CNO network coach, it was verified that the weights assigned to the criteria have undergone changes over the 15-year period since the establishment of the CNO. As part of the assessment process for partner selection at time $t + n = 15$ (15 years from the CNO's inception), the experts were asked to evaluate the criteria based on the latest partner selection requirements. According to the experts' feedback, environmental factors hold twice the significance at $t + n = 15$ compared to the time of CNO creation ($t = 0$). As a result, the weights of the environmental criteria were doubled, while those of the economic and social criteria were proportionally reduced. Table 6 displays the updated criteria weights, reflecting the revised perception of the environmental pillar's importance in partner selection for this CNO. This shift has made the environmental pillar the most crucial sustainability aspect for partner selection by Small and Medium-sized Technology (SMT) companies due to stringent recent regulations and environmental laws they must adhere to.

Based on the updated perception of the relative importance of the environmental pillars at $t + n = 15$, the rankings of the 6 alternatives are firstly A2, followed by A5, A1, A3, A6, and lastly A4 as seen in Table 7.

TABLE 5 Sensitivity analysis of criteria weights at $t = 0$.

Criteria	Weight change	A1		A2		A3		A4		A5		A6	
		CC	*rank*	CC	*rank*	CC	*rank*	CC	*rank*	CC	*rank*	CC	*rank*
C1	+50%	0.81	*2*	0.79	*3*	0.46	*4*	0.27	*6*	0.82	***1***	0.29	*5*
	+100%	0.81	*2*	0.79	*3*	0.46	*4*	0.27	*6*	0.82	***1***	0.29	*5*
C2	+50%	0.85	***1***	0.77	*3*	0.42	*4*	0.31	*5*	0.80	*2*	0.25	*6*
	+100%	0.88	***1***	0.76	*3*	0.39	*4*	0.33	*5*	0.78	*2*	0.20	*6*
C3	+50%	0.80	*2*	0.78	*3*	0.44	*4*	0.29	*6*	0.84	***1***	0.36	*5*
	+100%	0.79	*2*	0.77	*3*	0.42	*4*	0.31	*6*	0.86	***1***	0.42	*5*
C4	+50%	0.81	*2*	0.80	*3*	0.49	*4*	0.27	*5*	0.86	***1***	0.24	*6*
	+100%	0.82	*2*	0.81	*3*	0.51	*4*	0.27	*5*	**0.89**	***1***	**0.19**	*6*
C6	+50%	0.83	*2*	0.78	*3*	0.44	*4*	0.25	*5*	0.84	***1***	0.30	*6*
	+100%	0.85	*2*	0.77	*3*	0.43	*4*	0.22	*5*	0.86	***1***	0.31	*6*
C7	+50%	0.82	*2*	0.78	*3*	0.46	*4*	0.27	*6*	0.83	***1***	0.29	*5*
	+100%	0.82	*2*	0.77	*3*	0.47	*4*	0.26	*6*	0.83	***1***	0.28	*5*
C8	+50%	0.81	*2*	0.78	*3*	0.46	*4*	0.27	*6*	0.82	***1***	0.29	*5*
	+100%	0.81	*2*	0.78	*3*	0.45	*4*	0.27	*6*	0.83	***1***	0.29	*5*
C9	+50%	0.77	*3*	0.80	***1***	0.47	*4*	0.25	*6*	0.78	*2*	0.27	*5*
	+100%	0.74	*3*	0.82	***1***	0.49	*4*	0.22	*6*	0.74	*2*	0.25	*5*

Note: Bold-italic values indicate the 1st place ranking.

TABLE 6 Criteria weights based on scenario $t + n = 15$.

Sustainability pillar	Economic			Social			Environmental		
Label	C1	C2	C3	C4	C5	C6	C7	C8	C9
Weight ($t + n = 15$)	0.04	0.17	0.12	0.13	0	0.11	0.22	0.04	0.17
Proportion	33%			24%			43%		

TABLE 7 Relative distances and final ranking of alternative collaborative networked organisation partners at $t + n = 15$.

Alternative partners:	A1	A2	A3	A4	A5	A6
D+	0.040	0.027	0.067	0.117	0.040	0.131
D−	0.104	0.116	0.069	0.029	0.107	0.039
Relative closeness (CC)	0.723	0.811	0.508	0.196	0.730	0.228
Final ranking	**3**	**1**	**4**	**6**	**2**	**5**

Note: Bold values indicate final rankings per alternative.

When comparing the outcomes with Table 4, it is evident that only the top three ranked alternatives experienced a change in their ranking. Specifically, A3, A6, and A4 consistently maintained the fourth, fifth, and sixth positions despite the increase in criteria weights between $t = 0$ and $t + n = 15$. Notably, A2 emerged as the selected partner based on the criteria weights at $t + n = 15$, while it ranked third under the $t = 0$ conditions. The sensitivity analysis results generally aligned with the partner ranking in Table 4 at $t = 0$, but diverged at $t + n = 15$, with A2 being the highest ranked partner when the environmental criteria weights were modified, except for C9, 'Green Practices', where A2 obtained the top rank in the sensitivity analysis. This discrepancy can be attributed to the increased significance given to environmental sustainability criteria at $t + n = 15$, and the consequent relative impact on the social and economic criteria weights, illustrating the evolving perception of the importance of environmental factors in partner selection for a CNO.

The evaluation of potential partners occurred at two critical time points in the CNO's lifecycle: during its inception phase ($t = 0$) and after 15 years ($t + n = 15$). Experts assessed the criteria based on their mindset and expectations at the time of CNO establishment. The results revealed a notable rise in the importance of environmental criteria in the later time period. The weights of the environmental pillar became the most influential, followed by the economic and social pillars, signifying the shift in SMT's perception of environmental criteria over time. The evaluation of potential partners exhibited variation between the two time periods, highlighting the presence of time inconsistency in decision-making.

5 | DISCUSSION OF RESULTS AND MANAGERIAL IMPLICATIONS

The implementation case conducted in SMT provides valuable insights. Following the presentation of results to SMT's Network coach for review and feedback, experts confirmed that the selected partner for joining the CNO was A2, ranked as the best company according to the methodology under the criteria conditions of $t + n = 15$. The case study revealed a significant observation regarding the changing importance (weights) assigned to environmental criteria between $t + n = 15$ and $t = 0$, as indicated by a questionnaire filled out by experts. Notably, for C7, 'Pollution', the weight increased from 0.11 to 0.22, for C8, 'Environmental Management System', it increased from 0.02 to 0.04, and for C9, 'Green Practices', it increased from 0.09 to 0.17. Furthermore, the weights of the environmental pillar exhibited a remarkable shift, increasing from 21% to 43% of the total, surpassing the economic pillar which dropped from 45% to 33%, and the social pillar which decreased from 33% to 24%. This shift in weight distribution signifies SMT's changing perception of the importance of environmental criteria while selecting new partners between the two time periods. As demonstrated in Section 4, this evolution in the perception of the importance of environmental factors between $t = 0$ and $t + n = 15$ significantly influenced the ranking of the top three partners.

Our approach has identified a set of nine evaluation criteria, which falls within the optimal range recommended for AHP to ensure evaluation consistency [63]. These criteria also facilitate a comprehensive assessment of each potential CNO partner, as they are straightforward and easily understood by all experts involved. Further discussions with the network coach revealed that the most critical criterion for SMT is the complementarity of activities among different partners. However, the coach suggested that it should be treated as a distinct criterion rather than being integrated into the technical capabilities of individual partners. Complementarity in activities has been a significant challenge that the CNO has encountered throughout its 15-year existence. The primary objective of the SMT is to establish a group of enterprises that complement each other, fostering diversity and preventing conflicts among partners. Avoiding redundancy is crucial, as two partners offering the same activities within the CNO could potentially become direct competitors, undermining the collaborative purpose of the group. Hence, since its inception, the SMT has made concerted efforts to address this issue, holding meetings and reaching consensus decisions involving all partners to maintain a constructive and cooperative relationship among them.

In the existing literature, only one other study has conducted an evaluation of potential partners to join a CNO at two different time periods [33]. In this study, the weight of the environmental criteria doubled between the two time periods, similar to our findings. This demonstrates that even when experts are projecting for the future, they recognise that the environmental criteria will become more crucial in the future. This observation aligns with the hypothesis of Augenblick et al. [48], suggesting that individuals are aware of their present bias but still exhibit inconsistency in their evaluations over time. Therefore, this indicates that experts are conscious of their inclination to prioritise short-term rewards over long-term considerations. It emphasises the necessity of considering changes in the perception of sustainability criteria weights when employing MCDM approaches to assess sustainable partners for CNOs.

The extensive literature on partner selection in the contexts of VEs and supply chains cannot be directly applied to the context of sustainable partner selection for CNOs due to several reasons. Firstly, the duration of collaborations between partners in CNOs significantly differs from that of VEs [64]. CNO partnerships are characterised by long-term engagements spanning several years, and in some cases, even decades, making them semi-permanent in nature. On the other hand, collaborations in VEs are temporary, serving as provisional alliances with lifecycles limited to the duration of specific projects or business opportunities. Consequently, the evaluation criteria for sustainable partner selection in VEs differ from those applicable to CNOs, and factors such as change in perception and time inconsistency of the criteria are not as significant in the context of partner selection for VEs due to their relatively short-term lifespans.

Regarding the evaluation of potential sustainable partners, the findings from the implementation case indicate a shift in the perception of the significance of environmental criteria since the establishment of the CNO, consistent with the conclusions of previous studies [46]. Experts engaged in discussions attribute this change in relative weight for environmental criteria to the increasing pressure from governmental and societal entities to achieve specific environmental objectives. It is assumed that the experts are aware of their present bias [48], which may have led them to prioritise present gains and losses over future ones due to uncertainty regarding future environmental conditions [50]. The observed time inconsistency in the evaluation of environmental criteria could be attributed to a reluctance to commit to potential future constraints at an early stage, similar to the case of modular product design [65]. Alternatively, this inconsistency might arise from the absence of internal sustainability goals among the individual companies comprising the CNO and the experts group.

6 | CONCLUSION

The research centred on the process of sustainable partner selection within CNOs and investigated the potential impact of time inconsistency in decision-making on the final partner selection. To achieve this, the study proposed a combined approach of Fuzzy AHP and TOPSIS to identify sustainable partners for CNOs. The examination involved comparing the outcomes of a manufacturing CNO in Switzerland during two distinct time periods, enabling the observation of changes in the perception of sustainability criteria over time. The methodology encompassed a preparatory phase, during which evaluation criteria were identified and shortlisted based on the three pillars of sustainability: economic, social, and environmental. Subsequently, an MCDM approach was employed to prioritise the criteria and rank potential partners accordingly.

The partner evaluation and selection approach yielded results indicating time inconsistency in the decision-making process of the experts. Notably, the prioritisation of sustainability criteria varied between two time contexts, with the weight of environmental criteria doubling in importance at $t + n = 15$. This shift in the perception of the significance of environmental criteria is attributed to the enforcement of more stringent environmental regulations and increasing societal pressure. The study highlights the presence of time inconsistency in sustainable partner evaluation due to the constantly evolving sustainability paradigm. Consequently, it is recommended to consider present bias in sustainable partner selection for CNOs. However, current MCDM approaches are insufficient in addressing this issue, even though fuzzy techniques are designed to handle ambiguity and could potentially account for the future evolution of the network and partner selection decisions.

This research underscores the importance of acknowledging the time inconsistency of sustainability criteria during partner selection. The study illustrates that the significance of environmental criteria has increased over time, making it imperative to consider this evolution when choosing partners for CNOs. The paper contributes significantly to the existing literature on sustainable partner selection, providing a validated methodology that serves as a valuable tool for CNOs in their pursuit of long-term sustainable partners. Furthermore, the article highlights the necessity of accounting for the time inconsistency of sustainability criteria during the partner selection process. Additionally, the study identifies a comprehensive set of nine evaluation criteria, ensuring a holistic assessment of each potential CNO partner while maintaining evaluation consistency through the application of the AHP methodology.

Although this research makes valuable contributions, it is essential to acknowledge its limitations. The study's reliance on a single case study of a CNO restricts its generalisability to broader contexts. Additionally, it does not delve into potential trade-offs and conflicts that may arise among the evaluation criteria. Another aspect not explored is the possible impact of the partner selection approach on existing partner relationships and the dynamics within the CNO. While the study offers valuable insights into sustainable partner selection for CNOs, further research is needed to address these limitations and enhance the applicability and generalisability of the findings.

AUTHOR CONTRIBUTIONS

Yvonne Badulescu: Funding acquisition; methodology; writing—original draft. **Ezzeddine Soltan**: Conceptualisation; methodology. **Ari-Pekka Hameri**: Supervision; validation; writing—review and editing. **Naoufel Cheikhrouhou**: Conceptualisation; data curation; funding acquisition; methodology; supervision; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

No conflicts of interest to disclose.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available from the corresponding author upon request.

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