

Integrating Soft Systems Methodology and Value-Focused Thinking for multi-agent decision problems: The SSM–VFT Integrated Structuring Framework (SSM-VFT/ISF)

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Abstract

Complex decision problems in multi-agent networks often involve heterogeneous perceptions, values, objectives, and measurement perspectives among agents belonging to the same functional group. In such contexts, assuming a predefined and common set of criteria may obscure relevant divergences before multicriteria evaluation or optimization models are applied. This paper proposes the SSM–VFT Integrated Structuring Framework (SSM-VFT/ISF), a problem-structuring procedure that concomitantly integrates Soft Systems Methodology (SSM) and Value-Focused Thinking (VFT) to elicit, organize, and consolidate objectives and attributes in multi-agent decision problems. The framework preserves each agent’s individual perspective through the construction of Rich Pictures, Root Definitions, Conceptual Models, Fundamental Objectives, Means Objectives, and measurable attributes, and subsequently consolidates these individual structures into a common set of attributes representative of the group. The proposed framework is applied to the dairy Local Productive Arrangement of Venturosa, Pernambuco, Brazil, focusing on three supply-side agents with distinct decision profiles: traditional-relational, adaptive-collaborative, and technological-professional. The results show that the SSM-VFT/ISF can structure heterogeneous individual perspectives while producing a negotiated and traceable common measurement basis involving partnership stability, communication, milk technical quality, pricing, formalization, and planning capacity. The framework contributes to problem structuring and multi-agent decision problems by addressing heterogeneity not only in preferences or weights, but also in the formulation and operationalization of decision attributes.

Keywords: Problem structuring methods; Soft Systems Methodology; Value-Focused Thinking; Multi-agent decision-making.

1. Introduction

Complex organizational decisions are rarely made by a single agent with full control over the context, resources, and outcomes involved. In many cases, such decisions emerge from the interaction of multiple actors whose perspectives, interests, information, and levels of influence may differ substantially throughout the decision-making process (Dowling *et al.*, 2016; Gregory *et al.*, 2020). This configuration is particularly common in supply chains, procurement processes, supplier selection, and network order allocation problems, where different agents may assign varying degrees of importance to aspects such as cost, quality, lead time, reliability, flexibility, relationships, and benefit distribution. Moreover, these agents may pursue potentially conflicting objectives; for instance, cost reductions may entail quality losses, longer delivery times, or greater exposure to risk (Bodendorf *et al.*, 2022; Ghadimi *et al.*, 2018; Kelly and Chicksand, 2024).

In such contexts, the central difficulty lies not only in selecting the best alternative or mathematically solving the problem, but above all in formulating it appropriately. Prior structuring of the decision situation becomes a critical and important step for making values explicit, recognizing conflicts, delimiting objectives, and building a shared understanding among the agents involved, since applying analytical models to poorly formulated problems may lead to recommendations that are technically consistent but weakly aligned with the nature of the situation being addressed (Mitroff and Featheringham, 1974). This complexity increases when one recognizes that the relevant objectives are not fully defined a priori; rather, they must be elicited, organized, and translated into measurable attributes based on the values of each agent.

In the context of a production chain, a decision network may comprise different sets of agents organized according to their functional position within the decision system. Among these sets are the supply-side agents (SA), responsible for providing products, services, or production capacity, and the demand-side agents (DA), associated with the need for, acquisition of, or prioritization of such resources (Garcez *et al.*, 2025). However, the methodological problem addressed in this article does not necessarily concern joint decision-making between SA and DA. Instead, it concerns the structuring of situations in which multiple agents belonging to the same side of the network hold different perceptions, values, objectives, and interpretations of the decision problem. In these cases, an approach is needed that first preserves the individual perspectives of the agents and subsequently consolidates them into a common structure of objectives and attributes representative of the group under analysis.

To address situations of this nature, Problem Structuring Methods (PSMs) provide approaches aimed at structuring complex problematic situations by accommodating multiple perspectives, conflicting objectives, and uncertainties before analytical solution models are formulated (Mingers and Rosenhead, 2004; Rosenhead, 2006; Smith and Shaw, 2019). Owing to their participatory, interpretive, and interactive nature, PSMs are particularly useful in multi-agent contexts, where the legitimacy of problem formulation depends on the explicit recognition of the values, interests, and constraints of the decision-makers involved.

Among the approaches associated with problem structuring and decision support, Soft Systems Methodology (SSM) and Value-Focused Thinking (VFT) are particularly relevant. SSM supports the systemic understanding of complex problematic situations by emphasizing the representation of different perceptions, relationships, desirable transformations, and conceptual models of human activity systems (Checkland, 1981, 2000). VFT, in turn, structures decisions from the values of decision-makers, enabling their conversion into strategic objectives, Fundamental Objectives, Means Objectives, attributes, and courses of action (Keeney, 1996a, 1996b). Although grounded in distinct conceptual traditions, these approaches are potentially complementary: while SSM broadens the systemic and social understanding of the problematic situation, VFT provides greater rigor for eliciting, organizing, and operationalizing decision values and objectives.

The literature already reports studies that combine SSM and VFT in different decision contexts, highlighting the potential of this articulation to strengthen problem structuring (Abuabara *et al.*, 2018; Bernardo *et al.*, 2018; Bertotti Júnior and Costa, 2025; Françozo *et al.*, 2022; Kamari *et al.*, 2017; Neves *et al.*, 2009). As discussed in Section 3, however, these combinations tend to be predominantly sequential, with one methodology preparing the application of the other, or embedded within broader multimethodological arrangements. This pattern is particularly limiting in multi-agent decision problems. Structuring objectives in an aggregated manner from the outset may obscure divergences, asymmetries, and individual priorities, whereas structuring each perspective in isolation, without a subsequent consolidation mechanism, hinders the construction of a common basis for analysis. Thus, there remains a need for a framework that explicitly articulates the stages of SSM and the steps of VFT in a concomitant manner, structuring the individual perspectives of multiple agents belonging to the same side of the network and subsequently aggregating them into a common set of objectives and attributes.

Against this background, this article is guided by the following research question: how can SSM and VFT be integrated concomitantly to structure and aggregate objectives and attributes in decision problems involving multiple agents? To answer this question, the article proposes the SSM–VFT Integrated Structuring Framework (SSM-VFT/ISF), designed to structure objectives and attributes in multi-agent contexts. Rather than applying SSM and VFT as independent sequential stages, the framework explicitly articulates the stages of SSM and the steps of VFT, connecting the exploration of the Real World, the construction of Conceptual Models, the definition of Fundamental Objectives, the identification of Means Objectives, and the derivation of measurable attributes for each agent. Finally, the individual structures are consolidated into a common representation of the group under analysis.

The contributions of this article are organized into four dimensions. First, it proposes a concomitant integration between SSM and VFT, in which the stages of both approaches are articulated interdependently throughout the structuring process. Second, the framework explicitly addresses multi-agent decision problems by initially preserving the individual perspectives of the agents and subsequently aggregating them into a common structure of objectives and attributes. Third, it links the definition of Fundamental Objectives and attributes to the two central dimensions of SSM, namely the Real World and the Conceptual Model, thereby enhancing traceability among systemic perception, decision values, and measurement. Fourth, it provides a structured basis for supporting subsequent multicriteria decision models, especially in collaborative networks where different agents within the same group must have their perspectives considered in a legitimate and operationalizable manner.

The remainder of the article is organized as follows. Section 2 presents the theoretical background on Problem Structuring Methods, Soft Systems Methodology, and Value-Focused Thinking. Section 3 reviews the literature on combinations of SSM and VFT and delineates the methodological gap. Section 4 describes the SSM-VFT/ISF and its constituent stages. Section 5 demonstrates the application of the framework to a multi-agent decision problem and summarizes the findings. Finally, Section 6 presents the conclusions, limitations, and directions for future research.

2. Theoretical background

2.1. Soft Systems Methodology (SSM)

Soft Systems Methodology (SSM) is a problem-structuring approach developed to address complex, ill-defined organizational situations characterized by multiple interpretations of both the nature of the problem and the desirable changes to be pursued (Checkland, 1981, 2000). Unlike methods directly oriented toward finding an optimal solution to a previously formulated problem, SSM focuses on systemic learning about the problematic situation, seeking to make explicit the actors' perceptions, existing conflicts, relationships among human activities, and possible system transformations. Its central contribution, therefore, lies in supporting the construction of a structured and shared understanding of the problem before analytical decision models are formulated.

Although SSM was originally presented as a seven-stage process, contemporary applications allow greater flexibility and iteration across its phases. In general, the process involves (Checkland, 1981, 2000; Gupta and Shankar, 2024): i) identifying the unstructured problematic situation; ii) expressing the situation through representations such as Rich Pictures; iii) formulating Root Definitions of relevant systems; iv) building Conceptual Models of human activity systems; v) comparing the Conceptual Models with perceived reality; vi) identifying systemically desirable and culturally feasible changes; and vii) implementing improvement actions. Among these stages, CATWOE is particularly important, as it considers Customers, Actors, Transformation, Worldview, Owners, and Environmental constraints, thereby helping to clarify different dimensions of a relevant system and supporting the formulation of Root Definitions.

In the context of Multiple-Criteria Decision Making/Analysis (MCDM/A), SSM provides relevant support for the initial framing of the problem, the identification of stakeholders, and the representation of different perspectives on the decision situation (Bernardo *et al.*, 2018; Marttunen *et al.*, 2017; Neves *et al.*, 2009; Petkov *et al.*, 2007). Despite this strength in problem framing, SSM has limitations regarding the operationalization of objectives. Marttunen *et al.* (2017) observe that SSM offers strong support for defining the problem frame, moderate support for stakeholder identification and alternative development, and more limited support for identifying criteria, defining attributes, and explicitly addressing uncertainty. Moreover, its effective application requires specific facilitation skills, given its reliance on participatory interactions and collective learning processes. By incorporating stakeholders' perceptions into the construction of conceptually defensible and rational models, SSM enables a structured comparison between these models and the Real World, thereby supporting decision-

making and the formulation of recommendations in response to the problematic situation (Gupta and Shankar, 2024).

This capability is especially relevant in managerial and organizational contexts involving human activity systems, where problems are shaped not only by technical constraints but also by social, cultural, and ethical considerations. In this regard, prior studies emphasize that SSM is suitable for addressing soft problems because it explicitly incorporates the human factor, allowing participants to express their views independently and to clarify the issues they face, the reasons these issues arise, and their effects on the broader system (Sarkar *et al.*, 2023). Rather than seeking only a superficial consensus, SSM supports a reflective process through which different worldviews can be explored and compared, enabling the formulation of recommendations that are systemically meaningful and contextually grounded. This feature is particularly important in multi-agent problems, in which different decision-makers may interpret the same situation in distinct ways.

Thus, SSM provides an appropriate basis for exploring and representing the social and organizational complexity of a decision situation. However, it does not, by itself, offer a sufficiently detailed procedure for converting decision-makers' values and concerns into Fundamental Objectives, Means Objectives, and measurable attributes. This gap motivates its integration with value-oriented approaches such as VFT.

2.2. Value-Focused Thinking (VFT)

Value-Focused Thinking (VFT) is a decision-support approach oriented toward making decision-makers' values explicit and converting them into structured objectives (Keeney, 1996a, 1996b, 2012). The relationship between VFT and MCDM/A stems from a functional distinction between the problem-structuring and evaluation phases of decision analysis. MCDM/A methods are designed to evaluate, rank, classify, or select alternatives based on multiple conflicting criteria, either through additive value or utility functions (Keeney and Raiffa, 1976) or through outranking relations *sobreclassificação* (Belton and Stewart, 2002; Mareschal *et al.*, 1984; Roy, 1991). Historically, however, much of the MCDM/A literature has assumed that the problem is already well structured, devoting comparatively less attention to the definition of the criteria themselves. This perspective began to shift with the consolidation of VFT (Keeney, 1996a) and with applications that integrate problem structuring and multicriteria evaluation (Marttunen *et al.*, 2017; Poleto *et al.*, 2020; Silva *et al.*, 2019). In this arrangement, VFT plays a

structuring role: by making decision-makers' values explicit and organizing them into Fundamental Objectives, Means Objectives, and measurable attributes, it provides the criteria and measurement scales on which MCDM/A methods operate.

Unlike approaches that begin with the available alternatives, VFT assumes that higher-quality decisions should be guided by what decision-makers regard as essential in the decision context. Values, in this sense, are principles used to evaluate consequences, alternatives, actions, and omissions, serving as the basis for formulating objectives and subsequently constructing evaluation criteria. Although grounded in the tradition of decision analysis, VFT also draws on elements of cognitive psychology, policy analysis, and soft operational research by emphasizing value judgments, learning, and stakeholder engagement in complex situations (Gregory *et al.*, 2001).

The application of VFT generally involves identifying relevant values, converting them into objectives, distinguishing among strategic, fundamental, and means objectives, organizing these objectives into hierarchies and means–ends networks, and defining attributes capable of measuring the extent to which the objectives are achieved (Françoze and Belderrain, 2022; Keeney, 1996a). Values may be elicited through semi-structured interviews, wish lists, analysis of concerns, examination of existing alternatives, or directed questions such as “What is desirable?”, “Why is this important?”, and “What should be achieved?”. They are then converted into objective statements, preferably in a verb–object structure, to make the decision intention explicit (Martin-Moro *et al.*, 2025). In this study, the focus is on the stages related to structuring values, objectives, and attributes, since the SSM-VFT/ISF concentrates on problem formulation before the application of evaluation or optimization models.

A central contribution of VFT lies in distinguishing between Fundamental Objectives and Means Objectives. Fundamental Objectives represent what has intrinsic value for the decision-maker in each context, whereas Means Objectives indicate paths, actions, or mechanisms through which those fundamental ends can be achieved. This distinction is supported by the “Why is that important?” (WITI) test (Keeney, 1996a), in which each objective is repeatedly questioned regarding the reason for its importance. If the answer points to a higher-level objective, the objective is classified as a Means Objective; if it expresses an essential end of the decision, it is classified as a Fundamental Objective (Keeney, 1996a, 1996b). This logic enables objectives to be organized into hierarchies and means–ends networks, clarifying the relationships between desired ends and the means for achieving them.

In the context of this study, VFT is particularly relevant because it provides a systematic procedure for transforming agents' values and concerns into Fundamental Objectives, Means Objectives, and measurable attributes (Killemsetty *et al.*, 2022). This feature complements SSM: while the systemic methodology supports the understanding of the problematic situation and the identification of relevant systems, VFT strengthens the conceptual structuring of objectives and their operationalization into attributes. As a result, agents' individual perspectives can first be preserved and subsequently organized into comparable structures that can be aggregated.

3. Literature review

The combination of SSM and VFT has been explored in the literature as a strategy for strengthening the structuring of complex and ill-structured problems. In their review of methodological combinations in MCDM/A, Marttunen *et al.* (2017) highlight the frequent use of SSM to identify structuring elements and VFT to subsequently organize objectives, although their study does not propose a specific integrative approach between the two.

A recurring form of articulation between these approaches consists of using SSM as an initial stage for learning, framing, and representing the problematic situation, followed by VFT to organize and hierarchize the objectives identified. Neves *et al.* (2009), for example, used SSM to understand the decision context, identify relevant actors, and reveal objectives associated with the evaluation of energy efficiency initiatives; VFT was then applied to structure these objectives from the evaluators' perspective, enabling their conversion into criteria for multicriteria decision-support models. Similarly, Kamari *et al.* (2017) employed SSM and VFT in the development of a decision-support framework for sustainable building renovation, combining literature review, interviews, focus groups, and Delphi validation. In that study, SSM supported the representation of the problematic situation through tools such as Rich Pictures, CATWOE, Root Definitions, and Conceptual Models, whereas VFT supported the organization of sustainability objectives into categories, criteria, and indicators. Bernardo *et al.* (2018) also explored this combination to structure Fundamental Objectives and build a criteria tree for assessing the energy performance of school buildings.

Other studies extend this articulation through multimethodological arrangements. Abuabara *et al.* (2018), for instance, combined SSM, VFT, Strategic Options Development and Analysis (SODA), and Value-Focused Brainstorming (VFB) to support

the strategic formulation of work teams in an aerospace company. In that case, the sequential integration of methods facilitated the initial understanding of the context, the identification of objectives, and the formulation of strategic solutions. Françaço et al. (2022), in turn, incorporated VFT into a revised version of SSM, called Re-SSM, to address the excessive generation of possible transformations in systemic interventions. In their proposal, stakeholders' values are used to guide the selection of the most relevant and manageable transformations. More recently, Bertotti Júnior and Costa (2025) used VFT to identify strategic objectives and prioritization criteria for decarbonization actions, combining this structure with SSM to identify problematic situations, relevant systems, and implementation alternatives.

Taken together, these studies show that the articulation between SSM and VFT is promising for problem structuring because it combines two complementary rationalities. SSM contributes to broadening the systemic, participatory, and interpretive understanding of the problematic situation, whereas VFT provides greater conceptual rigor for translating values and concerns into Fundamental Objectives, Means Objectives, criteria, and attributes. However, the reviewed literature suggests that this combination tends to occur predominantly in a sequential manner or within broader multimethodological arrangements, in which one approach prepares for or complements the application of the other.

Thus, there remains room for the development of a methodological framework that articulates SSM and VFT concomitantly throughout the structuring process, explicitly connecting the Real World and Conceptual Model dimensions of SSM with the elicitation, organization, and measurement of objectives proposed by VFT. This gap is particularly relevant in multi-agent decision problems, in which different agents belonging to the same side of a decision network may hold distinct perceptions, values, and objectives. In such contexts, structuring individual perspectives in isolation may hinder the construction of a common basis for analysis, whereas premature aggregation may obscure relevant divergences among agents.

Accordingly, this study proposes the SSM–VFT Integrated Structuring Framework (SSM-VFT/ISF), designed to structure, in an integrated and concomitant manner, the values, Fundamental Objectives, Means Objectives, and attributes of multiple agents belonging to the same decision group. The framework seeks to first preserve the individual perspectives of the agents and subsequently consolidate them into a common

structure of objectives and attributes capable of supporting later stages of multicriteria decision support in collaborative networks.

4. Development of the SSM-VFT/ISF for Structuring Objectives and Attributes in Multi-agent Systems

This section presents the development of the SSM-VFT Integrated Structuring Framework (SSM-VFT/ISF), designed to support the structuring of objectives and attributes in multi-agent decision problems. Unlike applications that combine SSM and VFT predominantly in a sequential manner, the proposed framework articulates the stages of SSM and the steps of VFT concomitantly, progressively connecting the systemic understanding of the problematic situation with the elicitation of values, the definition of Fundamental Objectives, the identification of Means Objectives, and the construction of measurable attributes.

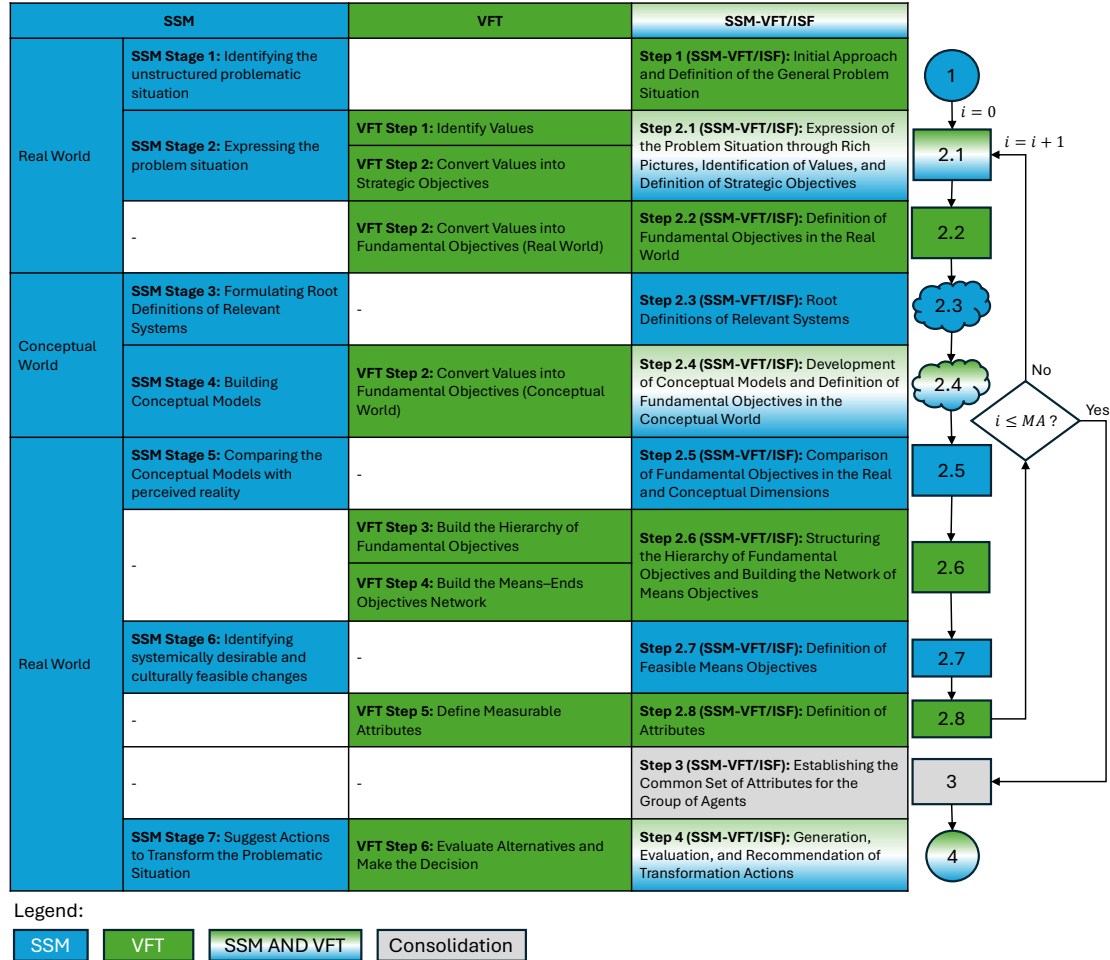
The framework is applied to a set of agents belonging to the same side of a decision network. Let $G = g_1, g_2, \dots, g_n$ denote the set of agents under analysis, where G may represent, for example, a group of *supply-side agents* SA or a group of *demand-side agents* DA . For each agent $g_i \in G$, the SSM-VFT/ISF first structures the agent's individual perception of the problematic situation, values, Fundamental Objectives, Means Objectives, and attributes. These individual structures are then compared and aggregated into a common structure representative of the group. This articulation is grounded in the complementarity between the two approaches: SSM broadens the systemic and social understanding of the problematic situation, whereas VFT provides rigor in converting that understanding into traceable objectives and attributes, avoiding both a purely qualitative analysis and a direct transition to criteria without clear traceability.

Formally, for each agent g_i , the framework considers a set of values (V_i), Fundamental Objectives (F_i), Means Objectives (M_i), and attributes (A_i). In the collective phase, these individual structures are consolidated into a common set of attributes (A_G), representative of the group G (Step 3). This logic ensures that individual perspectives are not replaced by a premature aggregated view but are instead preserved and made traceable until a common structure is constructed.

The stages of the SSM-VFT/ISF are presented in Figure 1 and detailed in the following subsections. The framework begins with the exploration of the problematic situation (Step 1), proceeds to the individual structuring of each agent's perceptions,

values, objectives, and attributes (Steps 2.1 to 2.8), and culminates in the consolidation of attributes into a common group structure and the generation of transformation actions (Steps 3 and 4).

Figure 1. Comparison between the steps of the SSM-VFT/ISF, the stages of SSM, and the steps of VFT.



4.1.1. Step 1 (SSM-VFT/ISF): Initial Approach and Definition of the General Problem Situation

Step 1 of the SSM-VFT/ISF is grounded in Stage 1 of SSM (Checkland, 1981) and aims to explore, in a holistic and participatory manner, the problematic situation associated with the decision network. This step seeks to understand the central elements, actors, relationships, perceived tensions, and contextual conditions involved, without anticipating solutions, criteria, or hypotheses. At this stage, the group of agents G to be analyzed is also delimited, such as a set of SA , DA , or another functional grouping within the network. This delimitation is necessary because the framework does not structure all

sides of the network simultaneously; rather, it supports the elicitation, organization, and subsequent aggregation of the individual perspectives of the agents belonging to G .

To support this exploratory process, interviews, participatory meetings, and document analysis may be conducted to identify preliminary perceptions, dissatisfaction, expectations, constraints, operational challenges, and potential sources of conflict. The purpose at this point is not yet to define objectives or attributes, but to build an initial understanding broad enough to guide the subsequent steps. As a complementary procedure, the general principles of SSM and VFT may be presented to the participants, providing conceptual alignment that facilitates engagement and prepares the group for the following stages.

As a result, this step produces an initial delimitation of the problem situation, the definition of the group G , and a preliminary shared understanding of the decision context. These outputs provide the basis on which the subsequent steps are applied individually to each agent ($g_i \in G$).

4.1.2. Step 2.1 to Step 2.8 (SSM-VFT/ISF)

4.1.2.1. Step 2.1 (SSM-VFT/ISF): Expression of the Problem Situation through Rich Pictures, Identification of Values, and Definition of Strategic Objectives

From this step onward, the SSM-VFT/ISF is applied individually to each agent ($g_i \in G$), to preserve the specificity of the agent's perceptions, values, and objectives before collective consolidation. Step 2.1 concomitantly articulates Stage 2 of SSM and the initial stages of VFT related to value identification and conversion into Strategic Objectives. In this step, the problem situation is expressed from the perspective of each agent (g_i) through an individual Rich Picture; based on this representation, the agent's values are elicited and converted into Strategic Objectives.

A Rich Picture is a graphical artifact used to represent structures, processes, roles, relationships, information flows, tensions, and perceived conflicts in a complex social situation (Checkland, 1981). For each agent (g_i), an individual Rich Picture (FR_i) is developed through a participatory and iterative process. This artifact mediates subsequent discussions by making explicit how the agent interprets the context, which elements are perceived as critical, and which relationships influence the agent's understanding of the problem.

In parallel, the agent's values are identified according to the principles of VFT (Keeney, 1996a). Values are understood as principles, priorities, and judgment standards

that express what the agent considers desirable, undesirable, critical, or worthy of priority. They may be elicited through semi-structured interviews, wish lists, analysis of concerns, examination of existing alternatives, identification of perceived deficiencies, and directed questions such as “What is important in this context?”, “What should be achieved?”, and “Why is this relevant?”. These values are then converted into Strategic Objectives, understood as broad statements of intent associated with the agent’s higher-level aspirations. This conversion is conducted through guided paraphrasing, semantic grouping, and iterative validation, ensuring consistency with the original values elicited from the agent.

Formally, for each agent ($g_i \in G$), this step produces a Rich Picture (FR_i), a set of values (V_i), and a set of Strategic Objectives (OE_i):

$$g_i \mapsto (FR_i, V_i, OE_i), \quad \forall g_i \in G. \quad (1)$$

This individualized representation preserves traceability among systemic perception, values, and decision intent, and provides the basis for unfolding the Strategic Objectives into Fundamental Objectives in the Real World in Step 2.2.

4.1.2.2. Step 2.2 (SSM-VFT/ISF): Definition of Fundamental Objectives in the Real World

Step 2.2 unfolds the logic of VFT in the definition of Fundamental Objectives within the Real World dimension of SSM. Its purpose is to translate the Strategic Objectives of each agent ($g_i \in G$) into Fundamental Objectives that are aligned with the decision context actually experienced by the agent, considering real operating conditions, operational constraints, available resources, current practices, and institutional relationships. Defining objectives from the conditions effectively present in the problem situation is a deliberate methodological choice, since these objectives will later be compared, in Step 2.5, with those derived from the Conceptual Models.

The distinction between Strategic Objectives and Fundamental Objectives follows Keeney (1996a): the former express broad aspirations, whereas the latter delimit what effectively matters in the specific decision context. Thus, the Strategic Objectives (OE_i) are analyzed and unfolded, together with the agent’s values (V_i), into a set of Fundamental Objectives in the Real World (F_i^R):

$$(OE_i, V_i) \mapsto F_i^R, \quad \forall g_i \in G, \quad (2)$$

where V_i denotes the set of values of agent (g_i).

The operationalization of this step is supported by the “Why Is That Important?” (WITI) test (Keeney, 1996a). For each objective derived from the agent’s values and Strategic Objectives, the reason for its importance is successively questioned. When the justification points to a higher-level objective, the objective is classified as a Means Objective; when it expresses an essential end in the decision context, it is classified as a Fundamental Objective. This procedure refines the initial structure by reducing ambiguities, overlaps, and excessively operational formulations. The resulting Fundamental Objectives should satisfy good structuring properties in VFT, such as essentiality, completeness, controllability, operationality, measurability in principle, decomposability, no redundancy, conciseness, and understandability (Keeney, 1996a), which are iteratively verified with the agent.

As a result, Step 2.2 produces, for each agent ($g_i \in G$), a preliminary set of Fundamental Objectives in the Real World (F_i^R), individually validated and traceable to V_i and OE_i . This set supports the formulation of Root Definitions of relevant systems in Step 2.3 and the subsequent comparison with the Conceptual World in Step 2.5.

4.1.2.3. Step 2.3 (SSM-VFT/ISF): Root Definitions of Relevant Systems

Step 2.3 corresponds to Stage 3 of SSM and marks the transition from the Real World to the Conceptual World. Its purpose is to formulate, for each agent ($g_i \in G$), Root Definitions of the relevant systems (RD_i), which concisely express the human activity systems considered relevant to understanding and transforming the problem situation. These definitions do not describe the observed reality; rather, they conceptually formulate what a system should be to perform a meaningful transformation from the perspective of the agent.

The construction of Root Definitions is guided by CATWOE, which comprises six elements: Customers (C), the beneficiaries or those affected by the transformation; Actors (A), those responsible for carrying out the activities; Transformation (T), the conversion of an input situation into an output situation; Worldview (W, Weltanschauung), which provides meaning and legitimacy to the transformation; Owners (O), those with the authority to allow or stop the system; and Environmental constraints (E), the external restrictions under which the system operates (Checkland, 1981).

Based on the Rich Picture, values, and previously structured objectives, the relevant transformations for each agent are identified. For each meaningful transformation, a Root Definition is formulated according to the following structure: a system operated by [A],

owned by [O], that performs [T], according to [W], benefiting or affecting [C], under the constraints [E]. The consistency of each definition is verified iteratively, with particular attention to the coherence between the Transformation (T) and the Worldview (W), as well as the compatibility among actors, owners, beneficiaries, and constraints.

Formally, for each agent ($g_i \in G$), Step 2.3 produces a validated set of Root Definitions (RD_i), derived from the previous artifacts:

$$(FR_i, V_i, OE_i, F_i^R) \mapsto RD_i, \quad \forall g_i \in G. \quad (3)$$

This set provides the basis for constructing the Conceptual Models in Step 2.4.

4.1.2.4. Step 2.4 (SSM-VFT/ISF): Development of Conceptual Models and Definition of Fundamental Objectives in the Conceptual World

Step 2.4 concomitantly integrates Stage 4 of SSM and the VFT logic related to Fundamental Objectives, now within the Conceptual World dimension. Its purpose is twofold: to develop, for each agent ($g_i \in G$), the Conceptual Models of the relevant systems based on the Root Definitions developed in Step 2.3, and to derive from these models the Fundamental Objectives that would be relevant if the system operated according to the idealized logic.

Following the guidelines of SSM, a Conceptual Model represents, in terms of operational verbs, the minimum necessary set of activities that the system defined by the corresponding Root Definition would need to perform to accomplish the proposed transformation (Checkland, 1981). Whereas the Root Definition specifies what the system is, the Conceptual Model expresses what the system does to produce the intended transformation. It is recommended that the model be structured as a network of logically related activities, with dependency, precedence, or feedback links, incorporating monitoring and control activities associated with the criteria of efficacy, efficiency, effectiveness, ethics, and elegance.

Based on the Conceptual Models, the Fundamental Objectives in the Conceptual World are identified by examining the activities, purposes, and systemic relationships embedded in each model. The WITI test, introduced in Step 2.2, is applied again to distinguish Fundamental Objectives from Means Objectives in the conceptual context (Keeney, 1996a), while preserving coherence with the proposed transformation and the worldview that gives it meaning.

Formally, for each agent ($g_i \in G$), Step 2.4 produces a set of Conceptual Models (MC_i) and a set of Fundamental Objectives in the Conceptual World (F_i^C):

$$RD_i \mapsto (MC_i, F_i^C), \quad \forall g_i \in G. \quad (4)$$

Once validated with the agent, these outputs support the comparison between F_i^R and F_i^C in Step 2.5, enabling the identification of convergences, divergences, gaps, and opportunities for improving the structure of objectives.

4.1.2.5. Step 2.5 (SSM-VFT/ISF): Comparison of Fundamental Objectives in the Real and Conceptual Dimensions

Step 2.5 corresponds to Stage 5 of SSM and marks the analytical return to the Real World after the conceptual immersion conducted in Steps 2.3 and 2.4. The traditional SSM comparison between Conceptual Models and perceived reality is adapted here to confront, for each agent ($g_i \in G$), the Fundamental Objectives in the Real World (F_i^R) with those in the Conceptual World (F_i^C). This adaptation preserves the reflective purpose of SSM while aligning it with the VFT focus on objective structuring.

The comparison identifies convergences, divergences, gaps, and partial overlaps between the two dimensions. Convergences indicate objectives recognized both in the experienced reality and in the idealized logic and can therefore be interpreted as stable elements of the structure. Divergences and gaps reveal objectives present in only one dimension, making it possible to discuss limitations of the current system or conceptual elements with limited practical adherence. The purpose is not to assign superiority to either dimension, but to integrate them: the Real World preserves the contextual adherence of the objectives, whereas the Conceptual World strengthens the critical capacity of the analysis by revealing objectives that might remain hidden in current practice.

Operationally, an analytical matrix is recommended to classify the objectives into four categories: objectives common to both dimensions; objectives exclusive to the Real World; objectives exclusive to the Conceptual World; and partially overlapping objectives requiring reformulation or conceptual alignment. For each correspondence, the analytical justification should be recorded. The analysis is conducted iteratively with the agent and supported by the Rich Picture (FR_i), the Root Definitions (RD_i), the Conceptual Models (MC_i), and the sets F_i^R and F_i^C , thereby fostering the reflective learning characteristic of SSM.

Formally, for each agent ($g_i \in G$), Step 2.5 produces a refined set of Fundamental Objectives (F_i), obtained from the comparison between F_i^R and F_i^C :

$$(F_i^R, F_i^C) \mapsto F_i, \quad \forall g_i \in G. \quad (5)$$

This refined and validated set provides the basis for structuring the hierarchy of Fundamental Objectives and the network of Means Objectives in Step 2.6.

4.1.2.6. Step 2.6 (SSM-VFT/ISF): Structuring the Hierarchy of Fundamental Objectives and Building the Network of Means Objectives

Step 2.6 corresponds to the VFT stages concerned with the formal structuring of the decision-maker's objectives (Keeney, 1996a). Based on the refined set of Fundamental Objectives (F_i) obtained in Step 2.5, two complementary structures are organized for each agent ($g_i \in G$): the hierarchy of Fundamental Objectives, which has a decompositional nature, and the network of Means Objectives, which has a relational nature.

The hierarchy follows the decomposition logic of VFT. For each Fundamental Objective, the question “What is meant by this objective?” is used to identify subobjectives that progressively clarify its meaning until a level of specificity compatible with the subsequent definition of attributes is reached. The more general objectives are placed at the top of the hierarchy, whereas the lower levels contain terminal subobjectives that will serve as the basis for operationalization into attributes.

The network of Means Objectives is built from questions such as “How can this objective be achieved?”, representing mechanisms, actions, or conditions that contribute to the achievement of the desired ends. Unlike the hierarchy, this network does not assume a strictly tree-like structure, since the same Means Objective may contribute to more than one Fundamental Objective, and a given objective may be achieved through different means. Both structures are developed iteratively with the agent, preferably with the support of diagrams, while the objectives are reexamined against the structuring properties previously introduced in Step 2.2 and reformulated when necessary.

Formally, for each agent ($g_i \in G$), Step 2.6 produces a hierarchy of Fundamental Objectives (H_i) and a network of Means Objectives (M_i):

$$F_i \mapsto (H_i, M_i), \quad \forall g_i \in G. \quad (6)$$

The hierarchy H_i supports the subsequent definition of measurable attributes, whereas the network (M_i) provides the basis for analyzing the feasibility of the Means Objectives in Step 2.7.

4.1.2.7. Step 2.7 (SSM-VFT/ISF): Definition of Feasible Means Objectives

Step 2.7 corresponds to Stage 6 of SSM and analyzes the feasibility of the Means Objectives contained in the network (M_i), identifying, for each agent ($g_i \in G$), which means are not only systemically desirable but also contextually feasible. Desirability derives from the connection between the means and the Fundamental Objectives; however, this connection alone does not ensure their viability. This step therefore introduces an explicit feasibility analysis, consistent with the SSM principle that relevant changes in social systems should be both systemically desirable and culturally feasible (Checkland, 2000). This prevents the framework from advancing toward the definition of attributes based on infeasible means.

The analysis considers different dimensions of feasibility: technical feasibility, related to the availability of resources, technologies, information, and competencies; economic feasibility, associated with the compatibility among costs, benefits, and financial constraints; organizational feasibility, related to the alignment with existing structures, processes, and capabilities; cultural feasibility, associated with actors' acceptance and compatibility with values and practices; and regulatory feasibility, related to compliance with rules, contracts, and legal requirements.

Operationally, a feasibility matrix is recommended, in which each Means Objective (M_i) is assessed according to the relevant dimensions, with its classification and justification recorded. The classification may be qualitative: feasible, partially feasible, or infeasible. Feasible means remain in the structure; partially feasible means are retained under specific conditions or reformulated; and infeasible means are documented as suspended elements, which may be reassessed if contextual conditions change. Rather than reducing the ambition of the structure, this step provides operational realism to the set of means and makes visible the agent's current limits of action.

Formally, for each agent ($g_i \in G$), Step 2.7 produces a subset of feasible Means Objectives (M_i^F):

$$M_i \mapsto M_i^F, \quad M_i^F \subseteq M_i, \quad \forall g_i \in G. \quad (7)$$

This subset, together with the justifications for retention, reformulation, or suspension, delimits the operationally viable means and provides the basis for defining attributes in Step 2.8.

4.1.2.8. Step 2.8 (SSM-VFT/ISF): Definition of Attributes

Step 2.8 corresponds to the VFT stage concerned with defining measurable attributes associated with the Fundamental Objectives. Based on the hierarchy (H_i) developed in Step 2.6 and the subset of feasible Means Objectives (M_i^F) identified in Step 2.7, the value and objective structure of each agent ($g_i \in G$) is operationalized through attributes capable of measuring the extent to which the objectives are achieved. This step therefore constitutes the transition from qualitative problem structuring to subsequent multicriteria evaluation.

Attributes are measurement scales associated with the terminal subobjectives in the hierarchy. According to Keeney (1996b), they can be classified into three types: natural attributes, which use scales directly related to the objective, such as monetary cost, time, distance, or production volume; constructed attributes, which are specifically developed for objectives without a natural scale, using ordered and described qualitative levels; and proxy attributes, which indirectly measure an objective through a correlated variable when direct measurement is infeasible or costly. Natural attributes should be prioritized because of their greater transparency and comparability. When they are not appropriate, constructed or proxy attributes may be used, provided that their use is explicitly justified and validated with the agent.

Each attribute should satisfy good measurement properties, such as clarity, comprehensiveness, direct adherence to the objective, operability, understandability, and non-ambiguity (Keeney and Gregory, 2005). These properties are verified iteratively with the agent. For each attribute, the unit of measurement, preference direction, admissible range, data collection procedure, and, when applicable, qualitative performance levels should be specified. For constructed attributes, a parsimonious number of mutually distinguishable and ordered levels is recommended. For proxy attributes, the conceptual link with the represented objective should be made explicit. The subset M_i^F helps verify the practical feasibility of the attributes, avoiding indicators that are disconnected from the agent's real possibilities for action.

Formally, for each agent ($g_i \in G$), Step 2.8 produces a set of individual attributes (A_i):

$$(H_i, M_i^F) \mapsto A_i, \quad \forall g_i \in G. \quad (8)$$

Once documented with scales, units, preference directions, and justifications, this set provides the basis for the collective phase, in which the individual attributes of the agents in (G) are compared, made compatible, and consolidated in Step 3.

4.1.3. Step 3 (SSM-VFT/ISF): Establishing the Common Set of Attributes for the Group of Agents

Step 3 marks the transition from the individual phase to the collective phase of the SSM-VFT/ISF. After Steps 2.1 to 2.8 have been applied to each agent ($g_i \in G$), a set of individual attributes (A_i) is available for each agent belonging to the group G under analysis. The purpose of this step is to compare, make compatible, and consolidate these individual sets into a common set of attributes (A_G), representative of the group G . This group may correspond, for example, to a set of supply-side agents SA , a set of demand-side agents DA , or another functional grouping previously delimited within the decision network.

The need for this step stems from both the internal logic of the framework and its positioning within the group decision-making literature. In many Multi-Criteria Group Decision Making (MCGDM) models, the set of criteria is assumed to be predefined and shared by all decision-makers, whose differences are then expressed mainly through criteria weights and alternative evaluations. However, Belton and Pictet (1997; Keeney and Raiffa, 1976) argue that the degree of commonality among the elements of a decision model, including the criteria themselves, should be understood as a methodological choice rather than an unavoidable assumption. This perspective opens room for more flexible ways of addressing heterogeneity among agents.

The SSM-VFT/ISF deliberately explores this flexibility: by individually structuring each agent's perceptions, values, objectives, and attributes in the previous steps, the framework allows heterogeneity to emerge not only in weights, but also in the composition, formulation, and granularity of the attribute sets. As a result, heterogeneous sets may emerge, reflecting differences in language, priorities, measurement scales, and ways of interpreting the decision problem. Before moving toward the evaluation of

alternatives, it is therefore necessary to decide, explicitly and traceably, which attributes should compose the analytical basis of the group G .

To guide this decision, the framework proposed by (Belton and Pictet, 1997) for group decision support using MCDM/A models is adopted as a conceptual reference. According to this formulation, a group decision procedure can be characterized by two aspects: the elements of the MCDM/A model, namely alternatives, criteria, evaluations, weights, and aggregation method, and the extent to which each of these elements is kept individual or made common to the group. The transition from individual to common information may be conducted through three elementary procedures: sharing, aggregating, and comparing. This perspective is particularly consistent with the SSM-VFT/ISF because the framework preserves, throughout Steps 2.1 to 2.8, the individual values, Fundamental Objectives, and attributes of each agent, while concentrating in Step 3 the decision regarding the extent to which attributes, specifically, should become common to the group. In the VFT logic adopted in this study, the attributes derived from Fundamental Objectives play the role assigned to criteria in a generic MCDM/A model.

The three procedures proposed by Belton and Pictet (1997) translate into distinct strategies for treating individual attributes. In sharing, the agents jointly construct a single common set of attributes, so that the group is treated, with respect to attributes, as a unified decision entity. This logic is consistent with participatory MCDM/A approaches, in which criteria are constructed through interviews, workshops, document analysis, and structured facilitation, with emphasis on clarity, legitimacy, and collective acceptance (Nordström *et al.*, 2010; Thokala and Madhavan, 2018). In comparing, each agent preserves their own set of attributes, and the analysis proceeds in parallel, comparing structures or results rather than imposing a single common set. This logic is close to Multi-Actor Multi-Criteria Analysis (MAMCA), in which different stakeholder groups may retain their own objectives, criteria, or weights, thereby preserving the plurality of perspectives before comparing results (de Almeida *et al.*, 2025; Belton and Pictet, 1997; Dean, 2022; Huang *et al.*, 2024; Macharis *et al.*, 2010). This approach is especially useful when relevant structural differences exist among agents. In aggregating, the individual structures are combined through an explicit operator. When later stages require the definition of weights or priorities, procedures such as the aggregation of individual judgments or the aggregation of individual priorities may be applied, depending on whether the group is interpreted as an integrated decision entity or as a set of individuals with their own preferences (Forman and Peniwati, 1998). These three procedures are not

mutually exclusive and may be combined throughout the process according to the degree of attribute heterogeneity and the intended level of consensus.

In the SSM-VFT/ISF, Step 3 operates predominantly according to the logic of aggregation, materialized through a consolidation operator. Formally, let A_i be the set of attributes defined for agent (g_i). The consolidation of the individual attribute sets can be represented as follows:

$$A_G = \mathcal{C}(A_1, A_2, \dots, A_n), \quad (9)$$

where A_G represents the common set of attributes of group G , and $\mathcal{C}(\cdot)$ denotes the methodological consolidation operator. This operator is not a closed mathematical function, but rather a structured procedure for conceptual and methodological compatibility, involving comparison, semantic grouping, scale harmonization, redundancy elimination, analysis of exclusive attributes, and collective validation. Operationally, an analytical comparison matrix is recommended, in which the agents (g_i) are arranged in one dimension and the attributes in the other, allowing correspondences, divergences, and gaps among the individual sets to be identified.

The matrix classifies attributes into three categories: common attributes, when different agents formulate equivalent or highly similar attributes; partially overlapping attributes, when they address the same decision dimension but differ in formulation, scale, or granularity; and exclusive attributes, when they appear only in the structure of one agent or a restricted subset of agents. Common attributes are directly consolidated through a harmonized formulation and compatible scale; partially overlapping attributes require conceptual compatibility while preserving the essential content of the individual formulations; and exclusive attributes are analyzed according to their relevance to the collective problem, adherence to the agents' Fundamental Objectives, measurement feasibility, and acceptance by the other participants.

The outcome of consolidation is not unique, but lies along a continuum delimited by two poles. At one pole, a parsimonious and negotiated set is obtained, in which partially overlapping attributes are merged and exclusive attributes of low collective relevance are suppressed, maximizing comparability among alternatives and cognitive economy in the evaluation. This solution is closer to sharing. At the other pole, an inclusive set is obtained, close to the union of the individual sets, retaining attributes that are relevant to only part of the agents and leaving the treatment of their nonrelevance to later stages, for example by assigning them zero importance in the evaluation of a specific agent. This solution maximizes the preservation of plurality and is closer to comparing

and aggregating. The position adopted along this continuum is a deliberate facilitation choice, conditioned by the degree of conflict among agents, the need for comparability among alternatives, and the level of consensus required for Step 4.

Regardless of the procedure and position adopted along the continuum, the treatment of partially overlapping and exclusive attributes requires interpretive negotiation. The literature on consensus in multi-agent (multiple decision-makers) decision-making suggests that this negotiation may be supported by iterative feedback processes, in which the level of agreement among participants is assessed, relevant divergences are identified, and successive adjustment rounds are conducted until an acceptable level of consensus is reached or, at least, disagreements are made explicit and transparent (Herrera-Viedma *et al.*, 2002; Matsatsinis *et al.*, 2005; Matsatsinis and Samaras, 2001). In the SSM-VFT/ISF, this logic may be incorporated into collective validation sessions, especially when deciding whether each attribute under discussion should be incorporated, merged, reformulated, maintained as specific to a subgroup, or documented as an unresolved divergence.

Consolidation should therefore be conducted through collective validation sessions supported by appropriate facilitation and explicit criteria for including, merging, reformulating, or excluding attributes. These criteria include adherence to the Fundamental Objectives legitimized by the agents, conceptual clarity, nonredundancy, measurement feasibility, comparability among alternatives, parsimony of the resulting set, and preservation of relevant diversity within the group. This step should not be understood as a mere reduction of individual attributes, but as the construction of a common analytical basis capable of representing the group without suppressing the specificities of its members. It is also important to emphasize that establishing a common set does not imply eliminating divergences: the individual structures remain documented and may be revisited in complementary analyses, especially when sensitive, conflicting, or difficult-to-consensually attributes are involved. Thus, A_G represents a negotiated measurement structure, built from individual contributions and collectively validated by the group G .

As a result of this step, a common set of attributes (A_G) is obtained, with harmonized formulations, compatible measurement scales, and traceability to the individual attributes (A_i). When full consolidation is not methodologically appropriate, the framework allows, consistently with the logic of comparison, the documentation of attributes specific to certain agents or subgroups, provided that their relationship with the

common set is explicitly stated. Accordingly, A_G constitutes the operational basis for subsequent stages of multicriteria evaluation, comparison of alternatives, or formulation of improvement actions, according to the decision scope defined in Step 4.

4.1.4. Step 4 (SSM-VFT/ISF): Generation, Evaluation, and Recommendation of Transformation Actions

Step 4 articulates Stage 7 of SSM with the VFT stage concerned with the identification of decision opportunities and the generation of courses of action. Based on the common set of attributes (A_G) established in Step 3, this step supports the formulation, evaluation, and recommendation of actions capable of transforming the problem situation analyzed by the group G . Consistent with SSM, which emphasizes systemically desirable and contextually feasible changes, and with VFT, which guides the generation of alternatives from decision-makers' values and objectives, actions are not treated as external alternatives. Rather, they are understood as transformation possibilities derived from the previously structured framework and should therefore be evaluated both in terms of technical performance and adherence to the collectively validated objectives and attributes.

The generation of actions may be conducted through collective sessions with the agents in G , using the hierarchy of Fundamental Objectives, the network of feasible Means Objectives, and the common set of attributes (A_G) as references. The aim is to identify incremental or transformative alternatives capable of improving the performance of the decision situation with respect to the attributes. These alternatives may include, for example, process changes, adjustments in selection criteria, redefinition of negotiation practices, coordination mechanisms, or forms of information sharing.

When the scope of the study includes formal evaluation, the actions may be assessed using a multicriteria method compatible with the nature of the attributes. This choice should consider whether the attributes are quantitative or qualitative, natural, constructed, or proxy; the acceptable degree of compensation among criteria (rationality); the availability of preference information; and the agents' ability to understand and validate the procedure (Keeney and Raiffa, 1976). This prevents the instrumental application of methods disconnected from the structure of objectives and attributes previously developed. The evaluation may also be complemented by sensitivity analysis to examine the stability of recommendations under variations in weights, value functions, or aggregation parameters. In the absence of a formal multicriteria model, at least a

structured qualitative analysis is recommended, based on the adherence of the actions to the Fundamental Objectives and their implementation feasibility.

Formally, let $X_G = x_1, x_2, \dots, x_m$ denote the set of actions generated for group G . Their evaluation, based on the common set of attributes A_G and on preference information or collective judgments (P_G) , can be represented as:

$$(X_G, A_G, P_G) \mapsto R_G, \quad (9)$$

where R_G is the resulting set of recommendations, which may take the form of a ranking, classification, selection, or justified description of actions. The recommended actions should be clearly described in terms of their purpose, agents involved, required resources, implementation conditions, expected impacts, and monitoring mechanisms, while preserving traceability with the refined Fundamental Objectives, the feasible Means Objectives, and A_G . This set R_G , validated by the group, constitutes the final output of the SSM-VFT/ISF, articulating the systemic learning promoted by SSM, the value orientation provided by VFT, and, when appropriate, multicriteria evaluation procedures.

5. Case Study in the Dairy Local Productive Arrangement of Pernambuco

5.1. Contextualization

The empirical application of the SSM-VFT/ISF was conducted in the dairy Local Productive Arrangement (LPA) of Venturosa, located in the Agreste region of Pernambuco, Brazil. This region is characterized by the socioeconomic relevance of dairy production and by the presence of commercial, logistical, technical, and relational interactions between small rural producers and small processing buyers. The immediate network investigated comprises raw milk suppliers and buyers involved in the production of cheese, a context in which decision-making is influenced by trust, geographic proximity, climatic seasonality, price fluctuations, milk quality, and the stability of commercial relationships.

The choice of this context is justified by its adherence to the methodological problem addressed in this article. In a previous study, Garcez et al. (2025) proposed, for the same application context, a decision-support model that integrates Multi-Attribute Utility Theory (MAUT) and Compromise Programming (CP) with an equity constraint for order allocation in a network with multiple suppliers and buyers. Although that model provides a prescriptive structure for multicriteria and multiobjective allocation, it assumes the prior existence of structured decision attributes that are representative of the multiple agents involved. The SSM-VFT/ISF operates precisely in this antecedent stage by

offering a systematic procedure for eliciting values, structuring objectives, defining individual attributes, and consolidating them into a common set suitable for supporting subsequent evaluation or optimization models.

For methodological delimitation, and without loss of generality, the application focused on the supply side of the network, that is, on the set of supply-side agents SA , defining the group under analysis as $G_{SA} = SA_1, SA_2, SA_3$. This delimitation makes it possible to examine in depth the heterogeneity among producers belonging to the same functional category and to demonstrate how the framework first preserves individual perspectives and subsequently makes them compatible within a common attribute structure. The extension of the procedure to demand-side agents DA and the subsequent integration of both sides of the network follow an analogous logic and are addressed in Garcez et al. (2025).

5.2. Multi-agent System Investigated

The group G_{SA} was composed of three dairy producers with distinct profiles within the LPA of Venturosa, Pernambuco. SA_1 has thirteen years of experience, an average weekly production of approximately 3,500 liters, and consolidated commercial relationships with low buyer turnover, characterizing a traditional-individual profile strongly oriented toward trust and relational stability. SA_2 , with three years of experience and an average weekly production of about 2,000 liters, presents a more adaptive profile, with interest in collaborative networks for the joint acquisition of inputs and greater sensitivity to market changes. SA_3 , with eight years of experience and an average weekly production of approximately 7,000 liters, has invested in mechanized milking, computerized herd management, and technical certification of milk quality, characterizing a technological-professional profile.

The diversity among these agents justifies the individual application of Steps 2.1 to 2.8 of the SSM-VFT/ISF. Rather than assuming a priori that the producers share the same objectives and attributes, the framework separately structures the perception, values, Fundamental Objectives, Means Objectives, and attributes of each SA_i , preserving the traceability of individual differences until collective consolidation in Step 3.

5.3. Data Collection Procedures and Framework Operationalization

The operationalization of the SSM-VFT/ISF was based on individual semi-structured interviews with each agent in G_{SA} , conducted using two complementary protocols. The first protocol, oriented toward the Real World, addressed current practices, difficulties, commercial relationships, seasonality, quality, costs, and expectations. The second, oriented toward the Conceptual World, explored improvement possibilities, idealized configurations, desirable transformations, and prospective views. Both protocols were organized into thematic blocks consistent with the structuring elements of the framework, such as long-term partnerships, information exchange, milk quality, productive sustainability, pricing, and planning.

Steps 2.1 to 2.8 were applied individually to each $SA_i \in G_{SA}$. To facilitate readability, the results are presented by framework step, comparing the outputs obtained for SA_1 , SA_2 , and SA_3 . Step 3 was conducted through a synchronous collaborative workshop with the three producers, mediated by facilitators, in which the individual attributes were compared, discussed, and consolidated into a common set A_G . Step 4 was limited to the formulation of suggested actions, without the formal application of a multicriteria method for evaluating alternatives.

5.4. Application of the SSM-VFT/ISF

5.4.1. Step 1: Exploration of the Problem Situation and Delimitation of the Group of Agents

Step 1 of the framework was conducted as described in Subsections 5.1 to 5.3, which characterize the LPA context, the multi-agent system investigated, and the data collection procedures. In addition, instructional sessions were held to disseminate knowledge among the agents regarding SSM, VFT, and the SSM-VFT/ISF itself.

5.4.2. Steps 2.1 to 2.8

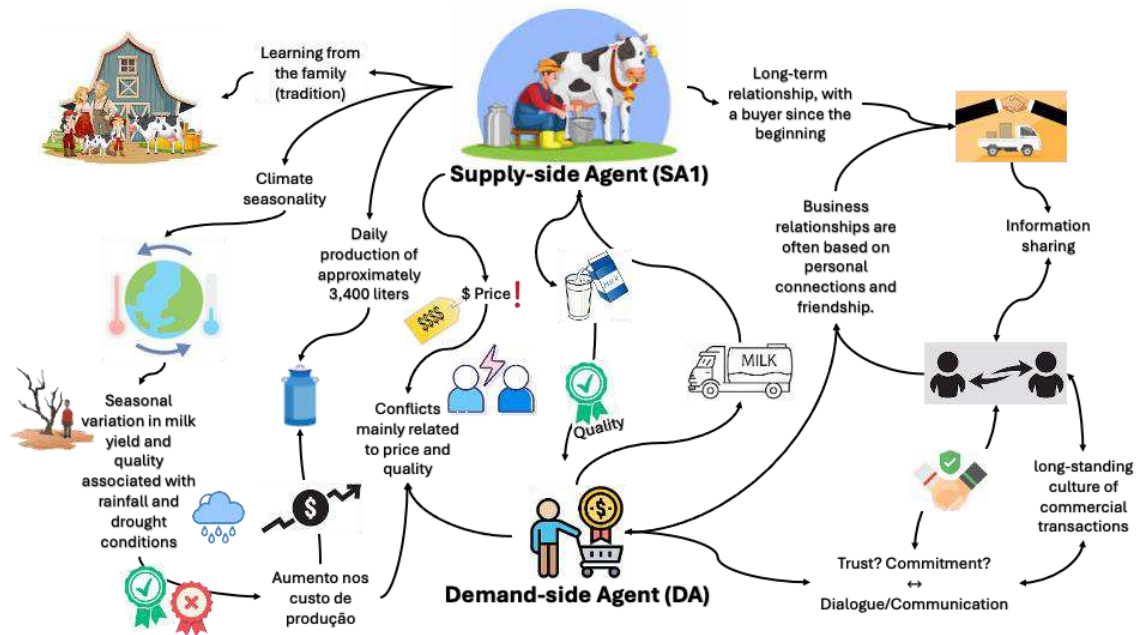
5.4.2.1. Step 2.1: Rich Pictures, Values, and Strategic Objectives

In Step 2.1, the individual Rich Pictures FR_i were developed, the values V_i were elicited, and the Strategic Objectives OE_i of each agent were defined based on the interviews and validated with the respective producers.

The Rich Picture of SA_1 (Figure 1) highlighted the centrality of trust-based relationships with buyers, long-term commercial commitments, and tensions associated with milk prices, in addition to exposure to climatic seasonality. Its values were concentrated in relational, economic, operational, and informational dimensions,

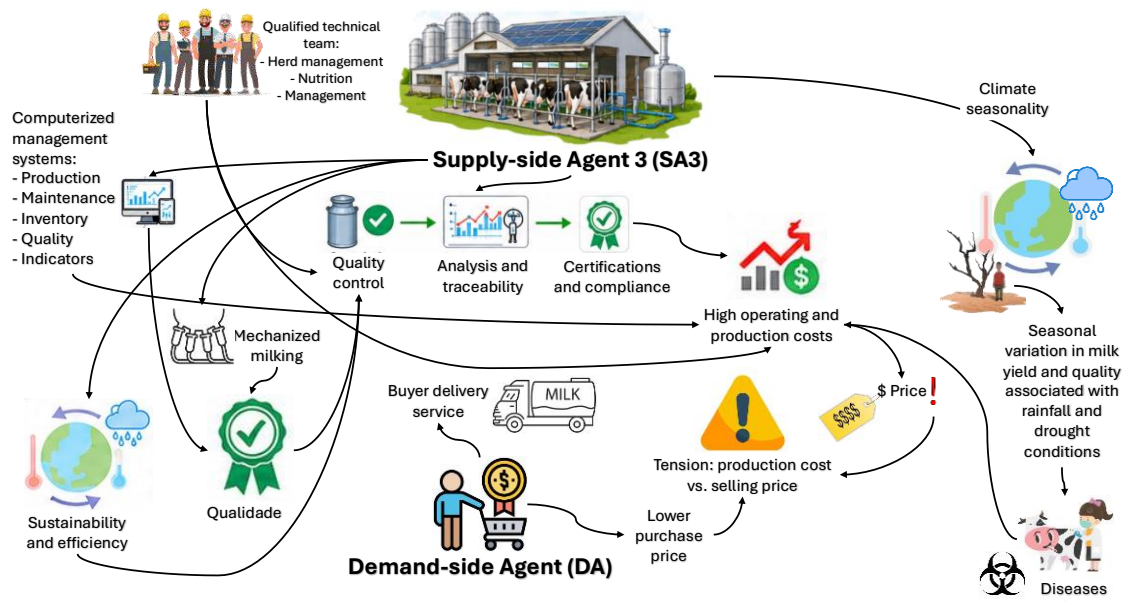
expressed through mutual trust, fair pricing, production continuity, and informational transparency. These values were converted into two Strategic Objectives: to maintain production with profit assurance and to foster long-term partnerships based on mutual trust with buyers.

Figure 1. Rich Picture of Supply-side agent 1 (SA_1)



The Rich Picture of SA_2 (Figure 2) represented a productive system under consolidation, sensitive to market fluctuations and oriented toward collaboration among producers. Its values, given by adaptability, business sustainability, trust in regular buyers, collaborative partnerships, competitiveness, payment predictability, and access to market information, resulted in Strategic Objectives aimed at ensuring production sustainability through reliable partnerships and maintaining competitiveness and adaptability in response to market changes.

Figure 2. Rich Picture of Supply-side agent 2 (SA_2)



The elicited values and the corresponding Strategic Objectives are presented in Tables 2 and 3, respectively.

Table 2. Values elicited individually from each supply-side agent

Values (V_i^n)	Category	Identified values
V_1^1	Relational	Mutual trust, commercial commitment, loyalty in long-term relationships
V_1^2	Economic	Fair price for milk, maintenance of production margin, revenue predictability
V_1^3	Operational	Production continuity, capacity to adapt to seasonality
V_1^4	Informational	Transparency in the exchange of information on quality and volume
V_2^1	Strategic	Adaptability to market transformations, business sustainability
V_2^2	Relational	Trust in regular suppliers, collaborative partnerships
V_2^3	Economic	Competitiveness, predictability of payments and deadlines
V_2^4	Informational	Access to market information and continuous exchange with partners
V_3^1	Technical-professional	Technical excellence, process standardization, laboratory control of quality
V_3^2	Strategic	Differentiation through certified quality, premium positioning in the regional market
V_3^3	Economic	Operational efficiency, return on technological investments
V_3^4	Informational	Generation and analysis of production data, technical traceability

Table 3. Strategic Objectives of each supply-side agent

Strategic Objective (OE_i^n)	Description
OE_1^1	Maintain milk production operations with profit assurance
OE_1^2	Foster long-term partnerships based on mutual trust with buyers
OE_2^1	Ensure production sustainability through reliable partnerships
OE_2^2	Maintain competitiveness and adaptability in response to market changes
OE_3^1	Consolidate the producer's position as a regional benchmark in certified milk quality
OE_3^2	Scale up production while maintaining technical standards and differentiation through added value

5.4.2.2. Step 2.2: Fundamental Objectives in the Real World

In Step 2.2, the values (V_i) and Strategic Objectives (OE_i) were unfolded into Fundamental Objectives in the Real World (F_i^R), considering the conditions actually experienced by each agent. The “*Why Is That Important?*” (WITI) test was applied to distinguish essential ends from means directed toward broader purposes.

For SA_1 , the Real-World objectives were concentrated on maintaining long-term commercial relationships, ensuring continuous information exchange on quality and volume, and obtaining a fair price. For SA_2 , the most relevant objectives were competitive pricing, trust-based relationships with regular buyers, predictability of payments and deliveries, and continuous information exchange. For SA_3 , the main objectives were technical certification and quality standards, differentiated pricing based on objective indicators, return on technological investments, and sharing performance indicators with selected buyers. The Fundamental Objectives in the Real World are presented in Table 4.

Table 4. Fundamental Objectives of each supply-side agent in the Real World

Fundamental Objective in the Real World ($F_i^{R,n}$)	Description
$F_1^{R,1}$	Maintain long-term commercial relationships with buyers
$F_1^{R,1}$	Promote continuous information exchange on quality and volume
$F_1^{R,3}$	Obtain a fair price for the milk sold
$F_2^{R,1}$	Obtain a competitive price for milk
$F_2^{R,2}$	Establish trust-based relationships with regular buyers
$F_2^{R,3}$	Ensure predictability in payments and delivery deadlines
$F_2^{R,4}$	Promote continuous information exchange with buyers
$F_3^{R,1}$	Maintain technical certification and quality standards for the milk produced

Fundamental Objective in the Real World ($F_i^{R,n}$)	Description
$F_3^{R,2}$	Obtain differentiated pricing based on objective quality indicators
$F_3^{R,3}$	Ensure consistent return on investments in production technology
$F_3^{R,4}$	Share technical indicators with selected buyers

5.4.2.3. Step 2.3: Root Definitions of Relevant Systems

In Step 2.3, the elements derived from the Rich Pictures, values, and Fundamental Objectives in the Real World supported the construction of the Root Definitions (RD_i), using the CATWOE structure as a guide. This structure considers Customers (C), Actors (A), Transformation (T), Weltanschauung (W), Owners (O), and Environmental constraints (E), as presented in Table 5.

Table 5. CATWOE elements of each supply-side agent

Root Definition (RD_i)	Element	Specification
RD_1	C	Buyers/processors involved in cheese production
	A	Supplier and direct collaborators
	T	Conversion of an informal and low-predictability system into a planned collaborative structure, supported by contracts and the use of production technologies
	W	Long-term partnerships, grounded in trust and technological investment, generate sustainable value for agents in the chain
	O	Supplier (SA_1)
	E	Seasonal variations in production, informal rules of the regional market, financial constraints
RD_2	C	Buyers/processors involved in cheese production
	A	Supplier and direct collaborators
	T	Transformation of isolated commercial relationships into collaborative network relationships, with efficient and competitive production
	W	Network collaboration and productive resilience support competitive permanence in the market
	O	Supplier (SA_2)
	E	Input price volatility, competitive pressures, production scale constraints
RD_3	C	Premium processing buyers and markets that value certified quality
	A	Supplier and qualified technical team
	T	Conversion of milk as a commodity into an input differentiated by certified quality and technical traceability
	W	Technical differentiation and certified quality constitute a sustainable competitive advantage in the market
	O	Supplier (SA_3)

Root Definition (RD_i)	Element	Specification
	E	Increasing regulatory standards, requirements of premium markets, costs of maintaining technology

The Root Definition of SA_1 emphasized the transformation of an informal and low-predictability commercial relationship into a planned collaborative structure, supported by production technology and more stable relationships. The Root Definition of SA_2 highlighted the transition from isolated commercial relationships to collaborative network-based relationships, with a focus on efficiency, competitiveness, and collective input purchasing. The Root Definition of SA_3 focused on converting a technologically advanced production system into one guided by continuous monitoring, quality certification, contracts linked to performance indicators, and differentiation in premium markets. These definitions provided the basis for constructing the Conceptual Models in Step 2.4.

5.4.2.4. Step 2.4: Conceptual Models and Fundamental Objectives in the Conceptual World

In Step 2.4, the Root Definitions (RD_i) were unfolded into Conceptual Models (MC_i), composed of the activities required to accomplish the proposed transformations and expressing the idealized logic of the relevant systems, without being limited to a description of the observed reality.

For SA_1 , the model emphasized production planning, investment in cooling and storage, contractual formalization, regular communication with buyers, quality monitoring, and seasonality management. For SA_2 , the main activities involved forming purchasing networks, consolidating regular buyers, organizing payments and deliveries, improving quality, and establishing systematic communication channels. For SA_3 , the model prioritized laboratory monitoring, technical training, sharing indicators, contracts with quality-based bonuses, evaluation of the return on investments, and prospecting premium buyers.

From these models, the Fundamental Objectives in the Conceptual World (F_i^C) were derived. For SA_1 , these objectives involved consolidating structured partnerships, investing in technology, formalizing relationships, and adapting production to future demand. For SA_2 , they emphasized milk quality, long-term partnerships, productive

autonomy, and integration into collaborative networks. For SA_3 , they focused on laboratory monitoring, research and development, contracts based on indicators, and diversification of premium buyers. The Conceptual Models and their respective objectives are presented in Tables 6 and 7.

Table 6. Activities of the Conceptual Model of each supply-side agent

Conceptual Model (MC_i^n)	Activity – Description
MC_1^1	Plan production according to seasonality and projected demand
MC_1^2	Invest in cooling and storage technologies to preserve quality
MC_1^3	Formalize contracts with buyers establishing prices, volumes, and deadlines
MC_1^4	Establish regular communication channels with buyers
MC_1^5	Monitor quality and production performance indicators
MC_1^6	Periodically evaluate system performance according to the 5E criteria (efficacy, efficiency, effectiveness, ethics, and elegance)
MC_2^1	Identify local producers to form collective input purchasing groups
MC_2^2	Establish long-term and exclusive partnerships with selected buyers
MC_2^3	Invest in milk quality through technology and animal welfare practices
MC_2^4	Fulfill agreed delivery deadlines and volumes
MC_2^5	Maintain systematic channels for information exchange with buyers
MC_2^6	Monitor and evaluate the performance of the collaborative network according to the 5E criteria
MC_3^1	Continuously monitor milk quality through systematic laboratory analyses
MC_3^2	Operate a computerized herd and production management system
MC_3^3	Maintain calibration and maintenance routines for mechanized milking equipment
MC_3^4	Continuously train the technical team in updated practices
MC_3^5	Share technical indicators with buyers and markets of interest
MC_3^6	Evaluate system performance according to the 5E criteria

Table 7. Fundamental Objectives of each supply-side agent in the Conceptual World

Fundamental Objectives in the Conceptual World ($F_i^{C,n}$)	Fundamental Objective in the Conceptual Model
$F_1^{C,1}$	Consolidate structured and long-term partnerships with buyers
$F_1^{C,2}$	Invest in technology and production process improvements to increase milk quality
$F_1^{C,3}$	Establish formal and standardized processes for commercial relationships
$F_1^{C,4}$	Adapt production to projected future demand

Fundamental Objectives in the Conceptual World ($F_i^{C,n}$)	Fundamental Objective in the Conceptual Model
$F_2^{C,1}$	Improve the quality of the milk produced
$F_2^{C,2}$	Consolidate long-term and exclusive partnerships with buyers
$F_2^{C,3}$	Increase productive autonomy
$F_2^{C,4}$	Integrate collaborative networks for collective input purchasing
$F_3^{C,1}$	Implement continuous systems for laboratory monitoring of quality
$F_3^{C,2}$	Invest in research, development, and continuous technical training
$F_3^{C,3}$	Establish contracts linked to objective quality indicators
$F_3^{C,4}$	Diversify the portfolio of premium-profile buyers

5.4.2.5. Step 2.5: Comparison between Fundamental Objectives in the Real World and the Conceptual World

In Step 2.5, the Fundamental Objectives in the Real World (F_i^R) were compared with those in the Conceptual World (F_i^C) through an analytical matrix, as shown in Table 8. This comparison enabled the identification of convergences, divergences, gaps, and partial correspondences between the purposes observed in practice and those derived from the idealized systems.

Table 8. Comparative matrix of the Fundamental Objectives of each supply-side agent

Fundamental Objective in the Real World ($F_i^{R,n}$)	Fundamental Objective in the Conceptual World ($F_i^{C,n}$)	Relationship	Observation
$F_1^{R,1}$	$F_1^{C,1}$	Partially overlapping	The Conceptual World broadens the notion of partnership by including formal structuring
$F_1^{R,2}$	$F_1^{C,3}$	Partially overlapping	Formalization in the Conceptual World supports information exchange in the Real World
$F_1^{R,3}$	-	Exclusive to the Real World	Fair pricing remains a central objective in the observed reality
-	$F_1^{C,2}$	Exclusive to the Conceptual World	Investment in technology emerges as an idealized aspiration
-	$F_1^{C,4}$	Exclusive to the Conceptual World	Planning based on projected demand is not fully realized in practice
$F_2^{R,1}$	-	Exclusive to the Real World	Competitive pricing remains an immediate concern
$F_2^{R,2}$	$F_2^{C,2}$	Partially overlapping	The Conceptual World reinforces the exclusivity of partnerships

Fundamental Objective in the Real World ($F_i^{R,n}$)	Fundamental Objective in the Conceptual World ($F_i^{C,n}$)	Relationship	Observation
$F_2^{R,3}$	-	Exclusive to the Real World	Temporal predictability remains an operational condition
$F_2^{R,4}$	-	Exclusive to the Real World	Information exchange in the Real World is broad and not specifically focused on network arrangements
-	$F_2^{C,1}$	Exclusive to the Conceptual World	Quality emerges as a central theme in the idealized perspective
-	$F_2^{C,3}$	Exclusive to the Conceptual World	Productive autonomy is an aspiration that is not fully realized
-	$F_2^{C,4}$	Exclusive to the Conceptual World	The collaborative input purchasing network is a distinctive idealized element
$F_3^{R,1}$	$F_3^{C,1}$	Partially overlapping	The Conceptual World systematizes continuous laboratory monitoring
$F_3^{R,2}$	$F_3^{C,3}$	Partially overlapping	The Conceptual World formally links pricing to objective indicators
$F_3^{R,3}$	-	Exclusive to the Real World	Return on investment remains an operational concern
$F_3^{R,4}$	-	Exclusive to the Real World	Current information exchange occurs informally
-	$F_3^{C,2}$	Exclusive to the Conceptual World	Investment in R&D and continuous training is an aspiration that is not fully realized
-	$F_3^{C,4}$	Exclusive to the Conceptual World	Diversification of the premium buyer portfolio constitutes an idealized goal

For SA_1 , long-term relationships and information exchange already present in practice could be expanded through formalization mechanisms, planning, and technology. For SA_2 , the pursuit of competitive pricing and predictability could be strengthened through collaborative networks, formalization of payments, and technical improvement. For SA_3 , a high degree of coherence was observed between the two dimensions, especially regarding certified quality, technical monitoring, and pricing linked to indicators, with opportunities to expand training and diversify buyers. The refined set of Fundamental Objectives is presented in Table 9.

Table 9. Refined Fundamental Objectives of each supply-side agent

Fundamental Objectives (F_i^n)	Description
F_1^1	Consolidate and expand long-term partnerships
F_1^2	Stimulate continuous information exchange

Fundamental Objectives (F_i^n)	Description
F_1^3	Ensure a fair price that supports competitiveness
F_1^4	Stimulate the use of technologies to improve quality and competitiveness
F_1^5	Formalize commercial relationships to provide security and transparency
F_1^6	Plan production with attention to seasonality and future requirements
F_2^1	Participate in collaborative networks to reduce costs and ensure competitive pricing
F_2^2	Establish stable and trust-based relationships with buyers
F_2^3	Ensure predictability in payments and deliveries to support productive investments
F_2^4	Stimulate continuous information exchange within the network
F_2^5	Improve milk quality through technology
F_3^1	Consolidate certification and continuous monitoring of technical quality
F_3^2	Link pricing to objective quality indicators
F_3^3	Ensure consistent return on technological investments
F_3^4	Establish formal channels for sharing technical indicators
F_3^5	Diversify the premium buyer base
F_3^6	Promote continuous technical training for the team

5.4.2.6. Step 2.6: Hierarchy of Fundamental Objectives and Network of Means Objectives

In Step 2.6, the refined set of Fundamental Objectives (F_i) was organized into two complementary structures: the hierarchy (H_i), which decomposes the objectives into more specific dimensions, and the network of Means Objectives (M_i), which makes explicit the mechanisms, actions, or conditions required for their achievement.

For SA_1 , the Means Objectives included negotiating conditions with regular buyers, maintaining regular communication, knowing the real production costs, investing in cooling technologies, establishing simple contracts, and monitoring seasonal patterns. For SA_2 , the main Means Objectives involved identifying local producers for group purchasing, selecting regular buyers, formalizing payments, creating communication channels, and investing in technical practices. For SA_3 , the means involved laboratory collection and analysis, indicator dashboards, technical training, contracts with quality-based bonuses, monitoring the return on investments, and prospecting premium buyers. The hierarchy and the network of Means Objectives are presented in Table 10.

Table 10. Structuring of the Means Objectives of each supply-side agent

Strategic Objective (OE_i^n)	Fundamental Objective (F_i^n)	Means Objective (M_i^n)	Description
OE_1^2	F_1^1	M_1^1	Negotiate advantageous conditions with regular buyers
OE_1^2	F_1^2	M_1^2	Maintain regular communication on quality and volume
OE_1^1	F_1^3	M_1^3	Know the real production costs and negotiate a minimum price floor
OE_1^1	F_1^4	M_1^4	Invest in cooling and storage tanks
OE_1^2	F_1^5	M_1^5	Establish simple and objective contracts with minimum clauses
OE_1^1	F_1^6	M_1^6	Monitor historical seasonal patterns and project demand
OE_2^1	F_2^1	M_2^1	Identify local producers and form purchasing groups
OE_2^1	F_2^2	M_2^2	Select regular buyers and establish contracts
OE_2^1	F_2^3	M_2^3	Formalize payment procedures and comply with the delivery schedule
OE_2^2	F_2^4	M_2^4	Create systematic communication channels
OE_2^2	F_2^5	M_2^5	Invest in cooling tanks and technical practices
OE_3^1	F_3^1	M_3^1	Maintain systematic routines for laboratory collection and analysis
OE_3^1	F_3^2	M_3^2	Implement indicator dashboards that can be shared with buyers
OE_3^1	F_3^3	M_3^3	Establish an annual technical training program for the team
OE_3^2	F_3^4	M_3^4	Negotiate contracts with quality-based bonus clauses
OE_3^2	F_3^5	M_3^5	Monitor the internal rate of return (IRR) and payback of technological investments
OE_3^2	F_3^6	M_3^6	Map and prospect premium buyers in the region

5.4.2.7. Step 2.7: Feasible Means Objectives

In Step 2.7, the Means Objectives (M_i) were submitted to a feasibility analysis based on five dimensions: technical, economic, organizational, cultural, and regulatory. Each means objective was classified as feasible, partially feasible, or infeasible, to distinguish those that could be implemented immediately from those conditioned by resources, acceptance, organizational capacity, or contextual adjustments.

Most means objectives were classified as feasible or partially feasible. For SA_1 , the main restrictions concerned the technical and economic feasibility of productive investments and the formalization of relationships traditionally based on informal trust. For SA_2 , the formation of collaborative networks proved promising, although dependent on organizational coordination and cultural acceptance among producers. For SA_3 , technical feasibility predominated, although some means were conditioned by the

economic feasibility of investments in monitoring, training, and expansion into premium markets. The feasibility matrix is presented in Table 11.

Table 11. Feasibility matrix of the Means Objectives of each supply-side agent

Means Objective (M_i^n)	Tech.	Econ.	Org.	Cult.	Reg.	Classification
M_1^1	Partial	Partial	Feasible	Feasible	Feasible	Partially feasible
M_1^2	Partial	Feasible	Feasible	Feasible	Feasible	Partially feasible
M_1^3	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
M_1^4	Feasible	Partial	Feasible	Feasible	Feasible	Partially feasible
M_1^5	Feasible	Feasible	Feasible	Partial	Feasible	Partially feasible
M_1^6	Partial	Feasible	Feasible	Feasible	Feasible	Partially feasible
M_2^1	Feasible	Feasible	Partial	Partial	Feasible	Partially feasible
M_2^2	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
M_2^3	Feasible	Feasible	Feasible	Partial	Feasible	Partially feasible
M_2^4	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
M_2^5	Feasible	Partial	Feasible	Feasible	Feasible	Partially feasible
M_3^1	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
M_3^2	Feasible	Partial	Feasible	Feasible	Feasible	Partially feasible
M_3^3	Feasible	Partial	Feasible	Feasible	Feasible	Partially feasible
M_3^4	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
M_3^5	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
M_3^6	Feasible	Partial	Feasible	Feasible	Feasible	Partially feasible

Tech. = Technical; *Econ.* = Economic; *Org.* = Organizational; *Cult.* = Cultural; *Reg.* = Regulatory.

5.4.2.8. Step 2.8: Definition of Individual Attributes

In Step 2.8, the terminal subobjectives of the hierarchy (H_i) and the feasible Means Objectives (M_i^F) guided the definition of the individual attributes (A_i). For each attribute, the type of attribute (natural, constructed, or proxy) the measurement scale, and its adherence to the corresponding objective were specified.

For SA_1 , the attributes included the average duration of partnerships, communication frequency, percentage difference between selling price and total cost, number of technologies used, existence of formal contracts, and existence of planning based on seasonality and demand. For SA_2 , the attributes included group purchasing, average duration of partnerships, percentage of deliveries and payments completed according to schedule, communication frequency, and total bacterial count. For SA_3 , the

attributes covered the compliance index with technical standards, percentage premium over the market price, internal rate of return on investments, frequency of indicator sharing, number of premium buyers, and annual hours of technical training. The individual attributes are presented in Table 12.

Table 12. Attributes defined individually for each supply-side agent

Attribute (A_i^n)	Attribute	Type	Measurement scale
A_1^1	Average duration of partnerships with buyers	Natural	Years
A_1^2	Frequency of communication with buyers	Constructed	Daily, weekly, biweekly, monthly
A_1^3	Percentage difference between selling price and total cost	Natural	%
A_1^4	Number of technologies used, such as tanks, tests, and management practices	Natural	Integer count
A_1^5	Existence of formal contracts with buyers	Proxy	Nonexistent, partial, formalized
A_1^6	Existence of planning based on seasonality and demand	Constructed	Nonexistent, informal, systematized
A_2^1	Percentage of purchases carried out in groups	Constructed	Nonexistent, partial, predominant
A_2^2	Average duration of partnerships with buyers	Natural	Years
A_2^3	Percentage of deliveries and payments completed according to schedule	Natural	%
A_2^4	Frequency of supplier–buyer communication	Constructed	Daily, weekly, biweekly, monthly
A_2^5	Total bacterial count (TBC)	Natural	UFC/mL
A_3^1	Compliance index with technical standards, based on Total Bacterial Count (TBC) and Somatic Cell Count (SCC)	Natural	CFU/mL and cells/mL
A_3^2	Percentage premium paid over the market price	Natural	%
A_3^3	Internal rate of return on technological investments	Natural	% per year
A_3^4	Frequency of sharing indicators with buyers	Constructed	Daily, weekly, monthly, absent
A_3^5	Number of active buyers with a premium profile	Natural	Integer count
A_3^6	Annual hours of technical training per employee	Natural	Hours per year

5.4.3. Step 3: Collective Consolidation of Attributes

Step 3 was conducted through a collaborative workshop with the three agents in (G_{SA}), with the purpose of comparing, making compatible, and consolidating the individual attributes (A_i) into a common set (A_G). The consolidation process, mediated

by facilitators, was supported by an analytical comparison matrix that grouped the attributes according to decision dimensions, as shown in Table 13.

Table 13. Comparative matrix of the individual attributes of the three supply-side agents

Decision dimension	SA_1	SA_2	SA_3
Partnership stability	Average duration of partnerships	Average duration of partnerships	Active premium buyers
Communication and information exchange	Communication frequency	Communication frequency	Frequency of technical indicator sharing
Milk quality	Technologies used	Total bacterial count	Compliance index (TBC, SCC)
Pricing	Price–cost difference	Group purchasing efficiency	Premium over market price
Formalization	Existence of contracts	Percentage of deliveries according to schedule	Contracts with quality-based bonuses
Planning and strategy	Seasonal planning	-	IRR and payback of investments

The matrix enabled the classification of attributes into three categories: convergent attributes, which were present in equivalent or highly similar forms among the agents, such as average duration of partnerships and communication frequency; partially overlapping attributes, associated with common dimensions but differing in scale or formulation, such as milk quality, pricing, and formalization; and exclusive attributes, linked to specific characteristics of the production profiles, such as premium buyers, internal rate of return, and participation in collective purchasing arrangements.

The deliberations resulted in six common attributes: average duration of partnerships with buyers; frequency of communication with buyers; technical quality of milk; price differential relative to the market reference; degree of formalization of commercial relationships; and planning and adaptation capacity. These attributes were formulated in a way that preserved the contributions of the three agents without imposing artificial homogenization. Milk technical quality, in particular, operated as an integrating dimension: for SA_1 , it was associated with the use of technologies; for SA_2 , with total bacterial count; and for SA_3 , with compliance with indicators such as Total Bacterial Count (TBC) and Somatic Cell Count (SCC).

The consolidation showed that, despite the heterogeneity of the profiles, there are decision dimensions that are sufficiently commensurable to support a common evaluation structure. Planning and adaptation capacity, for example, did not appear with the same

intensity across all agents, but it was collectively recognized as relevant for dealing with seasonality, market variations, and investment decisions. This reinforces the methodological role of Step 3, which is to build a common analytical basis without erasing the traceability of individual attributes.

The common set A_G , presented in Table 14, constitutes the main collective output of the SSM-VFT/ISF in this case study. The individual formulations remained documented as auxiliary material and may be retrieved in future analyses involving weighting, negotiation, multicriteria evaluation, or the definition of utility functions.

Table 14. Common set of attributes of the supply-side agents consolidated in the workshop

Common attribute of the group (A_G^n)	Common attribute	Origin: consolidated individual attributes	Type
A_G^1	Average duration of partnerships with buyers	SA_1, SA_2 directly; SA_3 through active premium buyers	Natural
A_G^2	Frequency of communication with buyers	SA_1, SA_2 directly; SA_3 through technical indicator sharing	Constructed
A_G^3	Technical quality of milk	SA_1 through technologies; SA_2 through TBC; SA_3 through TBC/SCC compliance index	Natural/Constructed
A_G^4	Price differential relative to the market reference	SA_1 through price–cost difference; SA_2 through group purchasing efficiency; SA_3 through premium price	Natural
A_G^5	Degree of formalization of commercial relationships	SA_1 through contracts; SA_2 through schedule compliance; SA_3 through quality-based bonuses	Constructed/Proxy
A_G^6	Planning and adaptation capacity	SA_1 through seasonal planning; SA_3 through IRR and payback	Constructed

5.4.4. Step 4: Formulation of Suggested Actions

Step 4 was limited to the formulation of suggested actions based on the common set of attributes A_G , without the formal application of a multicriteria method. This choice is consistent with the central objective of the article, which is to propose and demonstrate a procedure for structuring and consolidating objectives and attributes in a multi-agent context. The actions were organized according to axes corresponding to the common attributes.

For partnership stability, longer-term contracts and loyalty mechanisms based on performance and long-term relationships are suggested. For communication and information exchange, regular channels, periodic meetings, and routines for sharing

production and market indicators are recommended. For technical quality, common protocols for milk assessment, including Total Bacterial Count (TBC), Somatic Cell Count (SCC), and sanitary compliance, are proposed, along with continuous training and technical assistance. For pricing, transparent mechanisms linked to objective quality indicators and market conditions are recommended, making it possible to make cooperative or premium differentials explicit. For the formalization of relationships, the standardization of simple contractual templates is proposed, adaptable to different supplier profiles and subject to periodic review of commercial conditions. Finally, for planning and adaptation, collective planning spaces are suggested to address seasonality and market fluctuations, as well as coordination with public policies and sectoral financing sources.

If the framework is later integrated into a formal multicriteria evaluation stage, these actions may compose a set of alternatives (X_G), evaluated based on the common set of attributes (A_G) and collective preference information (P_G), producing a set of recommendations (R_G). In the present study, R_G takes the form of qualitatively structured recommendations derived from the analysis of the common attributes and consistent with the exploratory-applied scope of the research.

5.5. Discussions

The application of the SSM-VFT/ISF to the group G_{SA} demonstrated the operational feasibility of the framework in an empirical context marked by heterogeneity among agents belonging to the same functional category. The individual application of Steps 2.1 to 2.8 preserved relevant differences among the producers, whereas Step 3 demonstrated the possibility of consolidating a common set of attributes (A_G) without eliminating the traceability of the individual structures (A_i). This result is particularly relevant because it shows that heterogeneity among agents does not need to be treated only as variation in weights or preferences over previously defined criteria, but also as differences in the way decision attributes are perceived, formulated, and operationalized.

The comparative analysis revealed three distinct decision profiles. SA_1 presented a traditional-relational profile, guided by trust, partnership stability, and fair pricing. SA_2 presented an adaptive-collaborative profile, oriented toward economic sustainability, competitiveness, and participation in cooperative networks. SA_3 presented a technological-professional profile, centered on certification, technical monitoring,

operational efficiency, and differentiation through quality. These profiles reinforce the relevance of applying the framework individually, since premature consolidation could obscure substantive differences among agents who, although operating on the same side of the network, interpret the decision problem based on different trajectories, capabilities, and expectations.

The results also indicated that heterogeneity does not prevent the construction of a common analytical basis. The collaborative workshop made it possible to identify dimensions of commensurability among the agents, especially regarding milk technical quality, partnership stability, communication with buyers, formalization of commercial relationships, pricing, and planning and adaptation capacity. In this sense, the common set (A_G) should not be interpreted as a simple intersection of the individual attributes, but as a negotiated measurement structure built through semantic compatibility, scale harmonization, and collective validation. This finding reinforces the methodological contribution of Step 3 by showing that attributes initially formulated in different ways can be reorganized into common dimensions without losing traceability to their individual origins.

From a methodological perspective, the application also highlighted the integrative role of the Real World and Conceptual World dimensions of SSM within VFT. The comparison between F_i^R and F_i^C , conducted in Step 2.5, made it possible to distinguish objectives already present in current practice from those that emerged from conceptual reflection on idealized systems. This movement expanded the critical capacity of the structuring process, preventing objectives from being derived only from the constraints observed in the current context. At the same time, the feasibility analysis of the Means Objectives (M_i^F), conducted in Step 2.7, prevented the conceptual structure from advancing toward attributes disconnected from the agents' real implementation conditions.

Despite these findings, the application has limitations that must be explicitly acknowledged. The first limitation concerns the empirical scope. The study was conducted with three supply-side agents from a single dairy LPA, which restricts the empirical generalization of the results. The contribution of the case should therefore be understood primarily as an analytical demonstration of the applicability of the SSM-VFT/ISF, rather than as statistical validation of its effectiveness across different types of decision networks. Future studies should apply the framework to a larger number of

agents and to different LPAs, production chains, and organizational contexts to examine its robustness, adaptability, and sensitivity to different institutional configurations.

The second limitation is associated with the consolidation operator $\mathcal{C}(\cdot)$. In the present study, this operator was operationalized through a comparison matrix, semantic grouping, interpretive negotiation, and collective validation in a workshop. Although this procedure is consistent with the participatory nature of the framework, it still depends strongly on the quality of facilitation, the clarity of the criteria used for merging attributes, and the willingness of agents to negotiate meanings. Future studies may further formalize $\mathcal{C}(\cdot)$ by incorporating semantic similarity measures among attributes, consensus metrics, redundancy analysis, commensurability criteria, and structured procedures for deciding among sharing, aggregating, or comparing individual attributes.

The third limitation refers to the restriction of the application to the supply side of the network, without including demand-side agents (DA). In addition, Step 4 was limited to the formulation of suggested actions, without the application of a formal multicriteria or multiobjective method for evaluating, ranking, or selecting alternatives, as delimited in relation to Garcez et al. (2025). Future research may extend the application to both sides of the network and integrate the common attribute sets of supply-side and demand-side agents into subsequent decision-support models.

The fourth limitation concerns the temporal stability of the values, objectives, and attributes elicited. The application captured the agents' perceptions at a specific point in time, under particular market conditions, seasonal patterns, cost structures, and commercial relationships. In productive contexts subject to climatic variation, price fluctuations, and institutional changes, the sets V_i , F_i , M_i^F , A_i , and A_G may change over time. Longitudinal studies may investigate the stability of these elements by reapplying the framework across different production cycles or after relevant changes in the decision environment.

These directions indicate that the SSM-VFT/ISF should be understood not only as a procedure for structuring attributes, but also as a methodological platform for connecting participatory structuring, collective consolidation, and multicriteria decision support in multi-agent networks.

6. Conclusions

This article proposed the SSM-VFT Integrated Structuring Framework (SSM-VFT/ISF), a procedure that concomitantly integrates Soft Systems Methodology (SSM)

and Value-Focused Thinking (VFT) to structure objectives and attributes in multi-agent decision problems. The proposal is grounded in the recognition that, in decision networks, different agents belonging to the same functional group may present distinct perceptions, values, objectives, and measurement perspectives. Accordingly, the framework was designed to first preserve the individual structures of each agent and subsequently consolidate them into a common set of attributes representative of the group under analysis.

The main methodological contributions of the study lie in two dimensions. First, the framework provides a concomitant articulation between the systemic logic of SSM and the value orientation of VFT. Unlike predominantly sequential combinations, in which one approach prepares the application of the other, the SSM-VFT/ISF connects the stages of SSM and the steps of VFT throughout the same methodological flow. This integration makes it possible to relate the exploration of the problem situation, the construction of Rich Pictures, the formulation of Root Definitions, the development of Conceptual Models, the definition of Fundamental Objectives, the identification of feasible Means Objectives, and the construction of measurable attributes. As a result, the framework enhances traceability among systemic perception, decision values, objectives, and attributes. Second, the framework explicitly addresses a gap that remains underexplored in the literature on problem structuring and group decision-making: heterogeneity not only in weights, but also in the composition and formulation of criteria among decision-makers. By positioning the collective phase considering the typology proposed by Belton and Pictet (1997) (sharing, aggregating, and comparing) the framework offers a traceable path from individual structuring to the construction of a common set of attributes, avoiding both premature homogenization and excessive fragmentation that would hinder collective evaluation.

From a practical perspective, the SSM-VFT/ISF supports facilitators, analysts, and decision-makers who need to structure complex problems in multi-agent networks, such as collaborative networks, production chains, Local Productive Arrangements, and other multi-agent contexts. The framework can be used as an antecedent stage to multicriteria evaluation, negotiation, prioritization, or optimization models, especially when decision criteria are not yet clearly defined or when the premature adoption of a common set of criteria may obscure relevant divergences among agents.

The empirical application in the dairy LPA of Venturosa, Pernambuco, Brazil, demonstrated the operational feasibility of the SSM-VFT/ISF in a real context marked by

productive, relational, and technological heterogeneity. The analysis of the three supply-side agents made it possible to identify distinct decision profiles: traditional-relational, adaptive-collaborative, and technological-professional. Despite these differences, it was possible to consolidate a common set of attributes involving milk technical quality, partnership stability, communication, formalization of commercial relationships, pricing, and planning and adaptation capacity. This result illustrates the ability of the framework to build commensurability among distinct perspectives without suppressing their specificities.

Considering the limitations acknowledged in Subsection 5.5, a research agenda can be outlined in six directions. The first is the expansion of the empirical basis through the application of the framework to a larger number of supply-side agents and to other productive arrangements, strengthening external validation. The second is the extension of the procedure to demand-side agents (DA) and the investigation of protocols for integrating both sides of the network, including the treatment of conflicts of interest between supply-side agents (SA) and demand-side agents (DA). The third is the complete development of Step 4 through multicriteria and multiobjective methods, linking the common set of attributes (A_G) to approaches such as MAUT and Compromise Programming (Garcez *et al.*, 2025), as well as to preference elicitation procedures with partial information and to sensitivity and consensus analyses capable of assessing the stability of recommendations. The fourth is the further development of the consolidation operator $\mathcal{C}(\cdot)$, including the investigation of consensus measures, commensurability criteria, and negotiation-support instruments that make the transition from individual structures to the common set more systematic. The fifth consists of conducting longitudinal studies to examine the stability of values, objectives, and attributes over time. Finally, the sixth direction involves the development of facilitation tools and computational support for applying the framework in networks with a larger number of agents.

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