

USING VALUE-FOCUSED THINKING IN AN INTEGRATED PROCESS TO SUPPORT DECISIONS

Gustavo Barbi Vieira^{1*}, Ygor Logullo de Souza², Amanda Simões³,
Jônatas Araújo de Almeida⁴ and Mischel Carmen Neyra Belderrain⁵

Received June 30, 2023 / Accepted October 10, 2023

ABSTRACT. This work presents an integrated decision support process based on Value-Focused Thinking (VFT) applicable to personal and organizational decisions. There are three main goals of this research: (i) present a methodological discussion on Value-Focused Thinking (VFT) and depict how it can contribute to support decision processes; (ii) present an integrated guide for a decision-support process based on VFT to help analysts and decision-makers in conducting decision processes; (iii) present applications of the proposed approach in a personal and a public management problem. This work delivers two main contributions: (a) a unified process that integrates different approaches based on VFT with a consistent structure for sequencing the stages of the decision-making process; and (b) examples that demonstrate the use of the proposed process in real problems and different contexts, presenting insights not thoroughly explored in the literature.

Keywords: value-focused thinking, decision analysis, mcda, air traffic management (ATM).

1 INTRODUCTION

Decision-making is a significant part of our lives. Keeney (2020) argues that decisions are the only way to influence our lives purposefully. Nevertheless, despite the need to deal daily with

*Corresponding author

¹Instituto Tecnológico de Aeronáutica (ITA), Praça Marechal Eduardo Gomes, 50, Vila das Acacias, 12228-900, São José dos Campos-SP, Brasil / Universidade Federal de São Paulo, Av. Cesare Monsueto Giulio Lattes, 1201, Eugênio de Melo, 12247-014, São José dos Campos-SP, Brasil – E-mail: gustavogbv@ita.br <http://orcid.org/0000-0001-9799-4395>

²Instituto de Aplicações Operacionais, Praça Marechal Eduardo Gomes, 50, Vila das Acacias, 12228-970, São José dos Campos-SP, Brasil – E-mail: logulloyls@gmail.com <http://orcid.org/0000-0003-1622-6103>

³Instituto Tecnológico de Aeronáutica (ITA), Praça Marechal Eduardo Gomes, 50, Vila das Acacias, 12228-900, São José dos Campos-SP, Brasil – E-mail: amanda.acsimoes@gmail.com <http://orcid.org/0000-0002-4501-6562>

⁴Universidade Federal de Pernambuco, Av. Marielle Franco, s/n - Km 59, Nova, 55014-900, Caruaru-PE, Brasil – E-mail: jonatasaa@yahoo.com.br <http://orcid.org/0000-0001-8158-1342>

⁵Instituto Tecnológico de Aeronáutica (ITA), Praça Marechal Eduardo Gomes, 50, Vila das Acacias, 12228-900, São José dos Campos-SP, Brasil – E-mail: carmen@ita.br <http://orcid.org/0000-0002-5582-4977>

decisions, some people do not adopt a systematic approach to identify the values associated with the decision, for they identify values based on readily available alternatives, which tends to generate limited solutions in achieving the decision maker's objectives.

Hammond et al. (1999) claim that despite the importance of decisions, few people receive any training in decision-making throughout their lives. Therefore, individuals depend on their personal experiences to learn how to make decisions, which can yield bad decision-making habits and shallow thinking about decisions. Additionally, lessons learned from previous experiences are not always beneficial since decisions might vary significantly in different contexts and situations.

Hence, decision-makers need a consistent process to support personal and organizational decisions. Hammond et al. (1999) state that the only way to increase the chances of making a good decision is by applying a good decision-making process to reach the best solution possible while minimizing resource consumption (time, energy, money, etc.) and avoiding stress.

A decision process usually comprises two relevant stages: (i) define and structure the decision, and (ii) evaluate alternatives. Keeney (2020) names these steps as the "Front-End" and the "Back-End" of the decision-making process, respectively.

Therefore, this work has three main goals:

- Present a methodological discussion on Value-Focused Thinking (VFT) regarding its contribution to decision-making processes;
- Present a guide for an integrated decision support process based on VFT. We believe that this guide can be helpful for analysts conducting decision-making processes and to encourage decision-makers to adopt VFT in personal and organizational decisions;
- Present two cases to exemplify the VFT approach in real problems. We depict examples regarding a personal decision and a public management problem (see Appendix D).

This work is structured as follows: firstly, section 2 presents a brief literature review with some relevant concepts: definition of problem and problem situation, problem situation structuring, problem structuring methods, and VFT. Next, section 3 presents our proposal regarding an integrated process to help in value model generation with VFT. Finally, section 4 discusses the main results, the limitations of the approach, and some suggestions for future developments.

2 LITERATURE REVIEW

In this section, we present the definitions for problem, problematic situation, problematic situation structuring, problem structuring methods, and VFT.

2.1 Definitions for “Problem”

All individuals and organizations face many problems during their existence. According to Keeney (1992), decision problems are situations resulting from the actions of others and (or) circumstances beyond the control of the individual or organization. Hammond et al. (1999) emphasize that one must carefully define problems before solving them because *“a good solution to a well-described problem is almost always a smarter choice than an excellent solution to a poorly described problem”*.

Rittel & Webber (1973) mention that the problems faced by scientists and engineers are predominantly *“tame problems”* or *“benign problems”* (definition equivalent to “structured problems”), such as: solving a mathematical equation, analyzing physical or chemical structures, winning a chess game with a certain number of moves, among others. These problems usually have well-defined goals so one can state clearly whether the proposed solution achieved them.

In contrast to the previous definition, Ackoff (1962) argues that unstructured problems - called *“messes”* - comprise a system of interactions between interrelated problems. Strategic decisions commonly fit into this classification. Rittel & Webber (1973) uses the term *“wicked problems”* for unstructured problems and states that they usually do not have well-defined goals and, therefore, it is sometimes hard to propose a solution that satisfies the stakeholders. Some examples for *“wicked problems”* (Rittel & Webber, 1973): problems related to public policies for defining the location of a highway, adjusting a tax, and fighting crime, among others. We present other interesting definitions from Holt (2004) and Hector et al. (2009) in Appendix E.

Rittel & Webber (1973) highlight three relevant aspects that one must address to understand a problematic situation and propose actions to solve it:

- **Problem definition:** understand what distinguishes the current situation from the desired end state;
- **Location of the problem:** find the problem(s) amidst the complexity of the network of cause-effect relationships regarding the problematic situation;
- **Identification of actions to deal with the problem:** define which actions can reduce the distance between the current situation (*“what is”*) and the desired final state (*“what- ought-to-be”*). Hence, the greater the expansion of the system’s boundaries, the sophistication of the relationships of the social systems involved, and the desired effectiveness of the actions adopted to achieve the expected outputs, the harder it will be to operationalize the plan tailored to deal with the problematic situation.

Therefore, considering the previously-mentioned definitions, the proposal of a feasible solution requires a thorough understanding of the problematic situation and its particularities. The following section presents some methods that can be useful in this endeavor.

2.2 Structuring Problematic Situations

It is often difficult to define the decision problem (Rittel & Webber, 1973) due to the different worldviews of the stakeholders. Hence, decision-makers should depict the decision problem at the most fundamental level (from a philosophical perspective) to understand and accommodate the underlying beliefs and values of these different views (Hector et al., 2009).

There are several possibilities to approach a problematic situation from an organizational point of view:

- **Explicit problem situation:** during the execution of organizational activities, organizational staff personnel eventually realize that internal issues or external factors have caused an explicit problematic situation. In these situations, Problem Structuring Methods (PSM) can be helpful to clarify the problem and generate consensus among those involved. After this step of structuring the problem, decision-makers can agree on a set of actions (intervention) to deal with the problematic situation, according to the common understanding reached through the application of the PSM. The section 2.3 presents some additional details about PSM;
- **Problematic situation with hidden or unknown cause:** managers realize the existence of non-identified (hidden) internal difficulties that obstruct the organization from achieving its vision for the future and its strategic objectives. In these cases, one has to deal with the organizational and content complexity (Parnell et al., 2013a) to identify the root causes underlying the problematic situation. Approaches with a systemic focus can be helpful to deal with these situations, such as VSM (Beer, 1972), System Dynamics (Forrester, 1971), among others. Additionally, Manso (2022) proposes a method to identify the root causes of problems in the organizational processes at the strategic level that obstruct organizations or systems from achieving their respective strategic objectives. Then, the method allows decision-makers to identify opportunities to overcome those root causes and achieve the goals of their strategy.
- **Situations resulting from the strategic actions and initiatives defined for the organization:** the organization's vision of the future indicates strategic objectives that entail a set of initiatives to achieve it. Some of these initiatives may require choosing between two or more distinct courses of action. This choice is a decision opportunity (Keeney, 2020) to take the organization from a present condition to a better future defined by a strategic objective.

When a problematic situation requires a decision-making process to choose between two or more courses of action, there is a “decision problem” or a “decision opportunity”. Decision problems arise from internal difficulties or external factors. On the other hand, when an individual proactively seeks to improve his (or her) quality of life or when an organization adopts initiatives to evolve toward its strategic vision of the future, they create decision opportunities (Keeney, 1992, 2020).

Consequently, stakeholders should define decision objectives and viable alternatives to decide on the most appropriate course of action. Then, the individual (or organization) conducts a decision-making process with a careful choice of attributes for each objective and a decision-support method to choose the best option among the alternatives. Value-Focused Thinking - VFT is an approach that helps to create a value model with suitable objectives and attributes (Keeney, 1992, 2020). Sections 2.4 and 3 describe the VFT approach.

Figure 1 presents a conceptual diagram that summarizes the topics regarding problem structuring mentioned in this section. The upper part of the figure depicts the individual perspective (Keeney, 2020), and illustrates the steps described in the two previous paragraphs to deal with the problematic situation. The bottom part of the figure depicts the organizational point of view that integrates concepts from PSMs (Mingers & Rosenhead, 2011) and VFT (Keeney, 1992, 2020; Françaço & Belderrain, 2022). It illustrates the possibilities to approach a problematic situation presented in the second paragraph of this section and the steps described in the two previous paragraphs to deal with the problematic situation from an organizational perspective.

Section 2.3 briefly presents the PSMs, while Section 2.4 discusses the difference between “VFT as PSM” and VFT for decision analysis. Section 3 describes the proposed VFT steps for building a value model.

2.3 Problem Structuring Methods

Rosenhead & Mingers (2001) state that Problem Structuring Methods (*Problem Structuring Methods –PSMs*) emerged as a pragmatic approach to face “unstructured problems” and that, in general, were not addressed by Traditional Operations Research, whose focus was on problems described in terms of performance measures, constraints, and by cause-and-effect relationships. According to Rosenhead & Mingers (2001), unstructured problems imply the existence of (i) Multiple actors; (ii) Multiple perspectives; (iii) Conflicting interests; (iv) Relevant intangibles; and (v) Key uncertainties. PSMs provide models to clarify a problematic situation, converging to an agreed-upon definition regarding the problem and to agreements that allow it to be solved at least partially (Mingers & Rosenhead, 2004).

Keisler et al. (2014) highlight that PSMs typically have a greater focus on the interpretation of the problematic situation than the traditional methods of Operations Research (“Hard OR”) and, therefore, the process of structuring the problem has equal (or even greater) importance than the results obtained through its application.

The most referenced PSMs are (Mingers & Rosenhead, 2004):

- **Strategic Options Development and Analysis (SODA):** this method uses cognitive maps as a modeling device to record the perspectives of each participant in a problematic situation. Then, these maps are used as sources to generate an aggregated map that merges the individual views. The aggregated map supports group discussions toward a commitment to a set of actions (Ackermann & Eden, 2020; Mingers & Rosenhead, 2011);

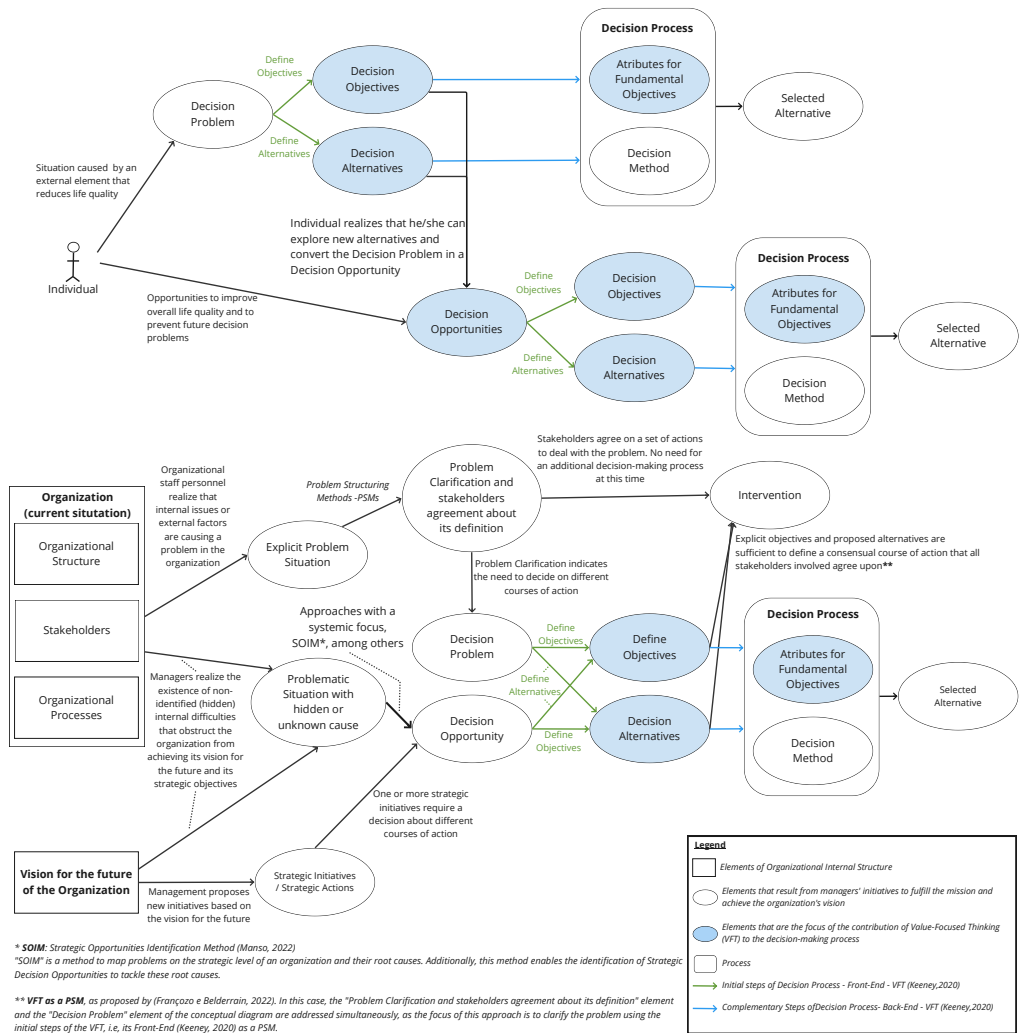


Figure 1 – Conceptual Diagram about “Problematic Situation”, “Problem Structuring” and Decision Process with VFT.

Source: The authors

- **Soft Systems Methodology (SSM):** the purpose of this method is system redesign. Participants build ideal conceptual models, one for each relevant worldview. They then compare these models to existing system perceptions to debate what changes are culturally feasible and systemically desirable (Wheeler & Checkland, 2000; Georgiou, 2015; Mingers & Rosenhead, 2011);
- **Strategic Choice Approach (SCA):** SCA focuses on managing uncertainty regarding issues at the strategic level of organizations. Facilitators help participants to model the connections between decision areas. Interactive comparisons of alternative decision schemes

emphasize relevant uncertainties in the decision context. The information collected in the previous stages of the method allows participants to define priority areas for partial commitment. They can also plan explorations and contingency plans to clarify relevant aspects of the uncertainties (Friend, 1989; Mingers & Rosenhead, 2011).

Keisler et al. (2014) mentions that VFT is considered consistent with the motivations of PSMs. Hence, we briefly describe the "VFT as PSM" approach and its difference from the traditional VFT approach in Section 2.4.

2.4 VFT as PSM and VFT to support the definition of value models

Value-Focused Thinking (VFT) (Keeney, 1992) is an approach that states that every decision should focus on identifying the fundamental objectives of the stakeholders involved. These objectives will guide decision-makers to identify better alternatives and better decision situations.

VFT's main steps are (Keeney, 2020):

- **Front-End: define and structure the decision you are facing**

1. Define the decision problem or decision opportunity you face;
2. Identify your values and define them as goals, to clarify what you want to achieve;
3. Create alternatives that contribute to achieving your goals;

- **Back-End: Evaluate your alternatives and make your decision**

1. Describe the possible consequences of each alternative to indicate your degree of achievement of the objectives;
2. Identify the pros and cons and weigh the importance of each alternative;
3. Select an alternative using the information and insight generated from your assessment;

Françoze & Belderrain (2022) present a systematic structure for VFT in four stages to support its application analogous to traditional PSMs. This approach focuses on the "VFT Front-End" approach (Keeney, 2020) to clarify the understanding of a problematic situation, generating an agreed-upon definition of the problem and consensual agreements for its resolution.

However, VFT is usually adopted with a broader focus than the other PSM, linking objectives to actions with measurable results (Keisler et al., 2014; Keeney, 1992, 2020). This approach is known as "*Decision analysis through value models generated with VFT*" (Keeney & von Winterfeld, 2008). Thus, the VFT proposed by Keeney (1992) helps to identify the objectives that the individual should attain to restore his (or her) original quality of life affected by the problem. Similarly, VFT helps the organization identify the objectives to overcome a decision problem and ensure the fulfillment of its mission. Additionally, VFT also enables the identification of

decision opportunities, i.e., when individuals proactively seek to improve their quality of life and organizations structure actions to achieve their strategic vision of the future.

Figure 1 depicted the main contribution of the VFT to the structuring of decision problems. The elements highlighted in blue are the main results of the application of the VFT, the green arrows indicate the actions of VFT's "Front-End" (Keeney, 2020), and the blue arrows represent the creation of criteria and attributes for the decision-making process, consolidating the value model as foreseen in the "Back-End" of VFT (Keeney, 2020).

Section 3 presents the process proposed for criteria and attribute generation based on the VFT approach focused on decision analysis.

3 PROPOSAL OF AN INTEGRATED DECISION PROCESS WITH VFT

VFT reflects stakeholders' subjective (sometimes conflicting) values in decision problems and decision opportunities for applying multi-attribute utility (Keeney, 1992). Therefore, since its initial conception, VFT supports multiattribute approaches well established from an axiomatic point of view. Due to these characteristics, the value models generated from VFT are also helpful for identifying criteria for other multicriteria approaches. Hence, several examples in the literature of applications combine VFT with different multicriteria methods (Parnell et al., 2013b; Françaço et al., 2019).

De Almeida (2013) presents a procedure for building a decision support model, with twelve steps grouped into three phases to guide the decision-making process. This procedure has been adopted often to address, in a structured way, the divergent and convergent phases of the decision-making process presented by (Marttunen et al., 2019). Figure 2 shows the procedure proposed by (De Almeida, 2013) - we highlight VFT's contribution to this procedure in grayscale.

Figure 2 shows that the focus of VFT is to support steps 2, 3, and 4 of the "Preliminary Phase" of the procedure. Nevertheless, step "1- Characterize the decision maker(s) and other authors" is essential to identify the stakeholders to interview to identify their values with VFT. Additionally, step "5- Identify state of nature" is relevant to adjust the means-ends objectives network and to evaluate the objectives included in the hierarchy of fundamental objectives.

The following sections depict our proposal for a VFT-based approach in the preliminary phase of the decision-making process. This proposal integrates several aspects of VFT presented in a scattered form in the literature.

3.1 Overview of the Proposed Process

Our proposal consists of a set of integrated steps organized into 3 phases:

1. **Define Initial Decision Frame and Decision Statement:** In this phase, the stages of mapping stakeholders, identifying the initial decision frame, and generating the decision statement are carried out;

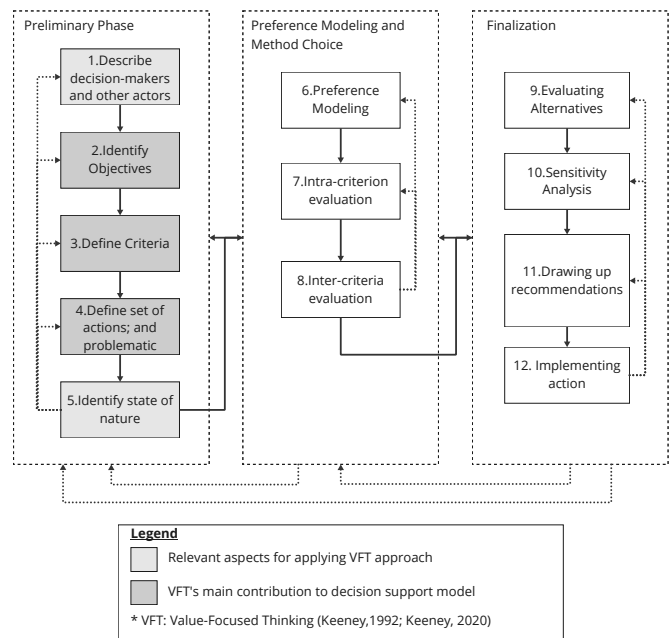


Figure 2 – Procedure for resolving an MCDM/A problem – highlighting relevant aspects regarding VFT approach.

Source: Adapted from De Almeida (2013); De Almeida et al. (2015).

- 2. Define Decision Objectives:** This is the most relevant phase of the proposed process. Firstly, the technique for qualitative value modeling is defined to enable the identification of the stakeholders' values. The *Value-Focused Brainstorming- VFB* (Keeney, 2012) approach enables the identification of these values when there is more than one stakeholder. Then, analysts help stakeholders to convert these values into objectives that serve as inputs for modeling a means-ends objectives network and a fundamental objectives hierarchy. In the last step, attributes to measure each lower-level "fundamental objective" should be defined;
- 3. Define Decision Alternatives:** In this phase, stakeholders identify and detail alternatives for the decision. *Value-Focused Brainstorming- VFB* (Keeney, 2012) enables new alternatives generation by considering the perspective of each stakeholder as well as the group collective perspective;

Appendix A presents a figure that comprises all phases and steps of our proposal. We emphasize that the proposed process is a guide to help analysts to apply VFT in an integrated way. We do not intend to exhaust all possible variations of the VFT approach with this proposal. Therefore, depending on the type of application, analysts may identify the need to adjust one or more of the proposed steps. We also highlight that this process is iterative, as results obtained throughout the

process might indicate the need for adjustments in previous steps, as depicted on the right side of the figure presented in Appendix A.

The following subsections describe each step of the proposed process.

3.2 Define Initial Decision Frame and Decision Statement

Phase 1 comprises steps to define the “Initial Decision Frame” (Keeney, 2008) and the “Decision Statement”. We clarify that sometimes the “Initial Decision Frame” is also referred to as “Decision Context”.

This process depends upon the correct identification and characterization of stakeholders, which complies with step “1-Describe decision-maker(s) and other actors” of the procedure proposed by (De Almeida, 2013) - Figure 2. Therefore, the quality of the initial decision frame and statement depends upon the proper identification of the participants.

This phase comprises seven steps: “1.1-Map Stakeholders”, “Identify Initial Decision Frame (with three variants: 1.2-Single Stakeholder; 1.3-Single Decision-Maker / Multiple Stakeholders; 1.5-Multiple Decision-Makers / Multiple Stakeholders”, “1.4 Plan a Workshop to identify Initial Decision Frame by promoting interaction between stakeholders”, “1.6 Document Initial Decision Frame” and ”1.7 Define Decision Statement”. Figure 3 presents an overview of the steps of this phase and sections 3.2.1 to 3.2.7 depict each one of them.

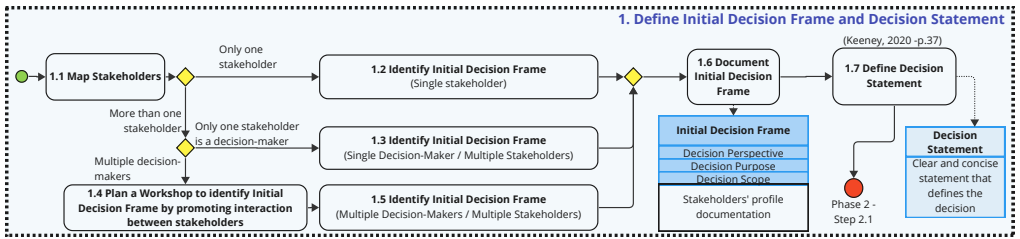


Figure 3 – Integrated decision support process based on VFT - Phase 1.

Source: The Authors.

3.2.1 Map Stakeholders (1.1)

Stakeholders are individuals, groups, or organizations interested in a decision or concerned about its implications. Therefore, leaders, managers, and other responsible parties should consider stakeholders’ opinions in the decision process (Bryson, 2004). Their importance is often associated with the plurality of their demands for the organization (Ackermann & Eden, 2011).

There are many definitions for types of stakeholders in the literature. We highlight the taxonomy presented by (Parnell et al., 2013a), with five types of stakeholders listed in order of relevance:

- **Decision authority:** an individual with authority and responsibility to accept and authorize the implementation of a solution to a problem or decision opportunity;
- **Customer:** Defines requirements and drives decision-making efforts. Additionally, this stakeholder is responsible for making the decision support request;
- **Owner:** responsible for operations related to the decision, ensuring its purpose and adequacy;
- **User:** responsible for conducting system operations related to the decision;
- **Consumer:** individuals or organizations with intentional dependencies on the outputs of the decision-making process;

Throughout this paper, we distinguish the type “Decision authority” (named as “decision-maker”) and other types of stakeholders. When we use the term “stakeholders”, we refer generically to all stakeholders (Decision authority, Client, Owner, User, and Consumer).

Hence, in this first step, analysts should map the personal information of each stakeholder and identify their role in the decision-making process. Then, they should store this information within the initial decision frame description to give credibility to the process and serve as a reference for future inquiries.

3.2.2 Identify Initial Decision Frame - Single Stakeholder (1.2)

The “initial decision frame” helps the decision maker to focus on the most relevant elements of the decision. Hence, its definition must comprise three fundamental aspects (Parnell et al., 2013a):

- **Purpose:** The decision frame should clarify why the decision is being made, when it must be made and which of its consequences are important, i.e., which value measures should be defined to compare the alternatives that will be considered in the decision process;
- **Perspective:** the decision frame should indicate how the decision is to be viewed. This helps to identify the issues that have to be addressed and the people that should be part of the decision-making process;
- **Scope:** the decision frame must define which actions may be considered as part of the problem and which may not. Therefore, the frame sets a boundary around the alternatives that are within the scope. Once agreement about the frame is reached, all alternatives that are outside the boundaries of the frame should not be considered. It is also important to make clear whether the “default” alternative (do nothing, i.e., maintain the current state) should be considered in the scope of the decision.

When there is only one decision-maker, he is responsible for providing all the information for the three elements of the initial decision frame.

Keeney (2008) states that the initial decision frame is typically a set of words that characterize the general context of the decision. Therefore, defining an initial version for the decision frame (in the terms proposed by Parnell et al. (2013a)) enables the definition of fundamental objectives and decision alternatives consistent regarding the proposed context. Once those involved execute the decision-making process, they can depict the decision frame thoroughly by describing the fundamental objectives and the decision alternatives (Keeney, 1992, 2020).

3.2.3 Identify Initial Decision Frame - Single Decision-Maker / Multiple Stakeholders (1.3)

As indicated in section 3.2.2, the decision-maker is responsible for providing information for the initial decision frame. Therefore, when there is a decision-maker and multiple stakeholders, the decision-maker should define the perspective, purpose, and scope of the decision. The decision-maker can ask for advice from other stakeholders about some specific aspect, but he (or she) should give the final word about the initial decision frame. If the decision-maker chooses to share the responsibility for defining the decision frame with other stakeholders, the analysts should use the script presented in Appendix B.

3.2.4 Plan a Workshop to identify Initial Decision Frame by promoting interaction between stakeholders (1.4)

When there are multiple decision-makers involved, the analyst(s) must promote an alignment of the individual perspectives of the decision-makers so that there is a consensus regarding the initial decision frame. The fundamental requirement in this process is “*communication*” (Parnell et al., 2013a).

Analysts must strive to foster this alignment through individual interviews to understand each decision-maker’s perspective, purpose, and scope regarding the decision. Later, after consolidating the information collected from the interviews, analysts can promote one or more workshops with the decision-makers to present the initial decision frame generated with the previously collected information and mitigate any divergences. To do so, analysts should use the script depicted in Appendix B.

3.2.5 Identify Initial Decision Frame - Multiple Decision-Makers / Multiple Stakeholders (1.5)

Following the workshop, the analysts should describe the initial decision frame aspects according to the agreement between decision-makers. This description must comprise the aspects “Purpose”, “Perspective (with the identification of decision makers)” and “Scope - with the timeframe

defined for the decision”. The details about the initial decision frame definition were already described in Section 3.2.2.

3.2.6 Document Initial Decision Frame (1.6)

The information defined for the “Initial Decision Frame” must be documented along with the profile of each stakeholder and their role in the decision-making process. This information has to be continually revisited throughout the process to ensure consistency and alignment with the purpose and scope defined by the decision-makers.

3.2.7 Define Decision Statement (1.7)

Keeney (2020) highlights that the “Decision Statement” is a clear and concise statement that defines the decision. This statement must adhere to the initial decision frame identified in the previous step and follow the pattern shown in Figure 4.

Decision Statement		
Clear and concise statement that defines the decision		
General Structure		
Decide	+	which + action
		what (related to the
		when overall objective
		whether or to the set of
		how alternatives)
		if
Examples:		
-Decide how I can have more enjoyable evenings		
-Decide which pair of new skis I should buy		
-Decide where to go on vacation		
-Decide which vehicle I should buy for my company next year		

Figure 4 – Decision Statement.

Source: Adapted from Keeney (2020).

3.3 Define Decision Objectives

Phase 2 contains the steps to identify the decision objectives and generate the means-ends objectives network and the fundamental objectives hierarchy. It comprises 18 steps that include some process variations for the identification of objectives. The following sections describe the steps of this Phase.

Hence, the steps of Phase 2 correspond to the stages “2-Identify Objectives” and “3-Establish Criteria” of the procedure proposed by De Almeida (2013) (Figure 2). Therefore, some stages of Phase 2 focus on the quality of the criteria establishment process to ensure that they meet the properties of: (i) being measurable; (ii) operational; and (iii) understandable. These are rele-

vant to enable objectives to be measured and to facilitate the comparison of alternatives by the stakeholders.

Figure 5 presents an overview of the steps of this phase and sections 3.3.1 to 3.3.18 depict each one of them.

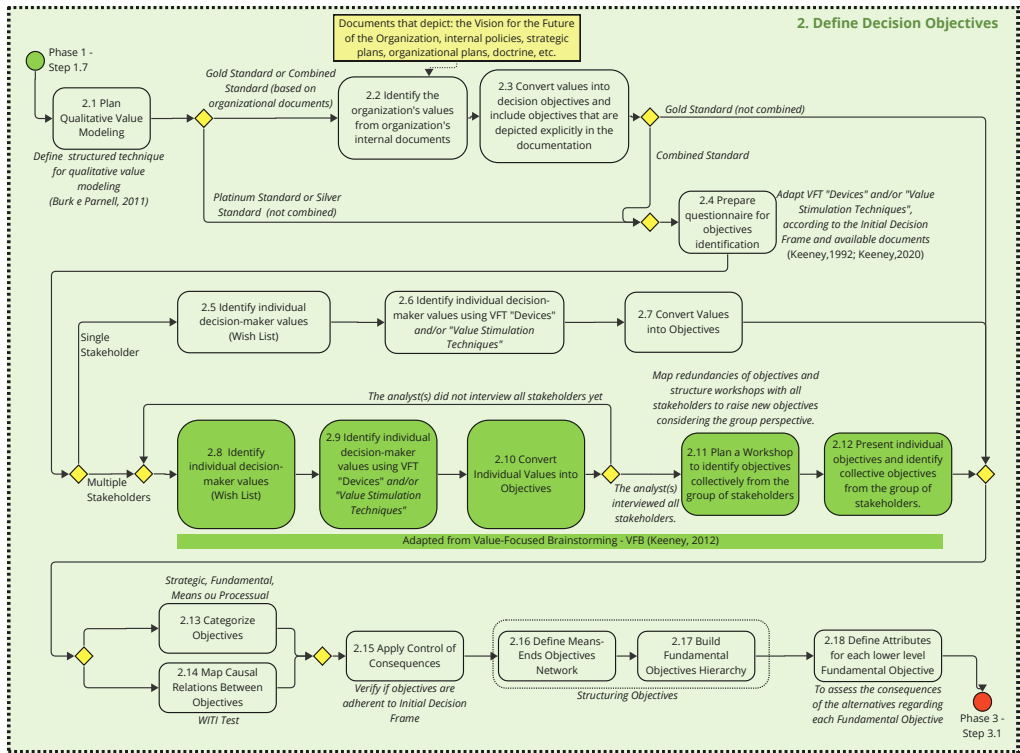


Figure 5 – Integrated decision support process based on VFT - Phase 2.

Source: The Authors.

3.3.1 Plan Qualitative Value Modeling (2.1)

Burk & Parnell (2011) mention four structured techniques to ensure the credibility of the qualitative value model:

- **Platinum Standard:** Decision analysts should focus on eliciting information directly from senior decision-makers and key stakeholders. Therefore, the Platinum Standard is based on information collected in interviews with those who are directly responsible to make (and influence) the decisions;
- **Gold Standard:** This technique proposes the collection of information directly from documents approved by senior decision-makers, with a special interest on these subjects: vision

of the future, policies adopted by the organization, doctrine, organizational architecture and capability planning. When examining these documents, decision analysts can capture information about value measures, functions and also organization's objectives. Additional information can be collected by interviewing key stakeholders, in order to complete the value measures gathered from the documents that were examined;

- **Silver Standard:** This value model uses data from *stakeholders' representatives*. It is useful when gold standard documents are not updated or not complete and when the analysts can't schedule interviews with the senior decision makers and key stakeholders;
- **Combined Standard:** in this technique, the decision analysts combine two or three of the previous techniques. Hence, gold standard documents are reviewed and combined with value measures and information gathered from interviews with senior decision makers, key stakeholders and also stakeholder representatives, according to their availability. It is the most common technique, since it can be adapted to many different situations within the organizations

Regardless of the chosen technique, analysts should be careful to ensure the traceability of the information in the decision model. Therefore, a formal process to collect the required data is of utmost importance for the credibility of the model and will help those involved to make adjustments in previous stages of the process whenever necessary.

3.3.2 Identify the organization's values from organization's internal documents (2.2)

If the technique adopted is the "Gold Standard" or "Combined Standard", analysts should examine the organization's documentation to identify values that may contribute to the decision-making process. As mentioned in Section 3.3.1, these documents should depict the vision for the future of the organization, internal policies, strategic plans, organizational plans, doctrine, organizational architecture, and capacity planning, among others.

We also highlight that the initial decision frame and the decision statement set the guidelines and context boundaries for identifying these objectives (see Section 3.2).

3.3.3 Convert values into decision objectives and include objectives that are depicted explicitly in the documentation (2.3)

Keeney (2020) presents the relationship between the concepts of "Value" and "Objective" according to the VFT. While "Value" expresses what is important to the decision-making context, "Objective" clearly expresses how the corresponding value influences the decision-making process. Therefore, the objective comprises three elements: (i) context (expressed by the initial decision frame); (ii) direction (usually expressed by a verb); and (iii) object (the essence of the value described by the decision maker/*stakeholder*).

To clarify the meaning of each value, one should define it as an objective, using a verb followed by an object. Therefore, an objective indicates what you want to achieve regarding that value when making the decision (Keeney, 2020). Table 1 presents a few examples of value-to-objective conversion.

Table 1 – Some examples of value-to-objective conversion.

Value	Stated as	Value restated as an Objective
Woodworking	Activity	Have access to a woodworking shop
Account for respiratory condition	Circunstance	Avoid aggravating the respiratory condition
Not need a car	Concern	Have necessary goods and services nearby
Affordable	Criterion	Minimize living costs
Near my daughter	Desire	Minimize travel time from daughter's home
Distance to major medical center	Metric	Have good access to medical care

Source: Adapted from Keeney (2020).

Furthermore, when identifying objectives from the documentation, analysts may perceive the need to include new stakeholders with the knowledge required to explore other topics. Therefore, analysts should update the results of Phase 1 to include these new stakeholders. This update is similar to the feedback described in the procedure presented by De Almeida (2013).

3.3.4 Prepare questionnaire for objectives identification (2.4)

Analysts can use the original VFT "Devices" and/or "Value Stimulation Techniques" or adapt them according to the Initial Decision Frame and available documents. Appendix C presents the original versions of these questionnaires and highlights the similarity between them.

Keeney (2020) proposes Value Stimulation Techniques to identify values considering personal decisions. On the other hand, VFT Devices help analysts to map values for both organizational and individual decisions. Nevertheless, analysts should choose the questionnaire based on his/her experience and also considering stakeholder's profile.

If the analyst identifies the need to adapt the questionnaire, the adjustments must consider the "Initial Decision Frame" and the "Decision Statement".

3.3.5 Identify individual decision-maker values (Wish List) - Single Stakeholder (2.5)

At this stage, the analyst should encourage stakeholders to comment on their wishes and desires regarding the decision (question 1 of VFT Devices - (Keeney, 1992)). The interview should be semi-structured to leave the stakeholder free to weave their considerations regarding the decision.

If appropriate, analysts can recall the “Decision Statement” and the elements of the “Initial Decision Frame” to prevent the values indicated by the stakeholder from deviating from the scope defined for the decision. However, at this point, it is of utmost importance that stakeholders feel free to express themselves. Moreover, there is plenty of opportunity to adjust the scope in later steps of the process (“Control of Consequences”).

3.3.6 Identify individual decision-maker values using VFT Devices and/or Value Stimulation Techniques (2.6)

At this stage, the analyst should use the VFT Devices (as presented in Section 3.3.3. It is noteworthy that questions 9 and 10 serve at this time only as a tool to encourage respondents to think more deeply about the values involved. The complete mapping of causal relations (question 9) and the attributes for measuring the level of achievement of objectives (question 10) will be detailed in the final steps of Phase 2: “Define Decision Objectives.”

3.3.7 Convert Values into Objectives (2.7)

In this step, the conversion of individual values into objectives must be done in the same way as presented in Section 3.3.3.

3.3.8 Identify individual decision-maker values (Wish List) - Multiple Stakeholders (2.8)

Keeney (2012) proposes an approach called “*Value-Focused Brainstorming (VFB)*” that incorporates two basic characteristics of VFT to a traditional process of brainstorming, namely: (i) describe the objectives of the decision problem before identifying/creating alternatives; (ii) individuals must create alternatives individually before participating in any group interaction. The VFB steps are (Keeney, 2012):

1. Define the problem to be solved;
2. Identify objectives of a solution for the problem;
3. Create alternative solutions individually;
4. Create alternative solutions collectively.

At this stage of the process, the definition of the problem has already been established (through the initial decision framing and statement). Hence, Keeney (2012) recommends that analysts

should use a process analogous to steps 3 and 4 of VFB to identify objectives, that is: first, the analysts conduct individual interviews with the stakeholders to elicit their objectives; subsequently, these objectives are combined and organized so that the stakeholder group can validate them collectively and add additional ones that might be missing.

Keeney (2020) also states that when a group is making a decision, the values of each member are relevant. Therefore, analysts should elicit them separately. Afterward, the group must evaluate all the values together to define an overall purpose for the decision.

Therefore, in a decision-making process with multiple stakeholders, the current step represents the individual interview with each stakeholder to identify their wish list as presented in Section 3.3.5.

3.3.9 Identify individual decision-maker values using VFT "Devices" and/or "Value Stimulation Techniques" - Multiple Stakeholders (2.9)

In a decision-making process with multiple *stakeholders*, this step comprises the individual interview with each stakeholder using the questionnaire already presented in Section 3.3.4.

3.3.10 Convert Individual Values into Objectives - Multiple Stakeholders (2.10)

In a decision-making process with multiple *stakeholders*, this step comprises the value-to-objective conversion from the information gathered in the individual interview with each stakeholder, in a similar way to that presented in Section 3.3.3.

3.3.11 Plan a Workshop to identify objectives collectively from the group of stakeholders (2.11)

After the individual stakeholder interviews, the objectives identified should be combined and organized. This step requires mapping possible redundancies and structuring workshops to raise new objectives by considering the group perspective. Therefore, analysts must carefully prepare the information collected in the interviews and schedule meetings according to the availability of the stakeholder group.

After eliminating redundancies between objectives, it may be beneficial to categorize them into groups ("*clusters*") that deal with the same type of concern regarding the decision problem (Keeney, 2013). The categories (or clusters) can also be stated as objectives (Keeney, 2013) or functions (Parnell et al., 2013a) in the hierarchy of fundamental objectives. This technique can stimulate the proposal of missing objectives and can make hierarchies more complete.

At this stage, the analyst(s) should be concerned about scheduling a sufficient number of workshops ("*Focus Group*" - (Parnell et al., 2013a)) and individual interviews to advance in the subsequent stages of the 'Define Decision Objectives', that is, steps 2.12 to 2.18 shown in figure 15.

The ideal number of participants in these workshops is between 6 and 12 individuals (Parnell et al., 2013a).

Additionally, the identification of objectives from the interviews can lead to a process of reflection on the problem that indicates the need to include other stakeholders to assist in the detailing of some specific objectives, in a similar way to that described in the Section 3.3.3 and according to aspects of feedback and return foreseen in the framework presented by De Almeida (2013).

3.3.12 Present individual objectives and identify collective objectives from the group of stakeholders (2.12)

In this stage, the analysts present the combined list of objectives in a workshop for validation and stimulate discussions to identify missing objectives. Analysts should emphasize the importance of considering the initial decision frame and statement to avoid discussing topics that are out of the scope of the decision.

Analysts should limit the time allocated to workshops to a maximum of two hours to enable the active engagement of participants without cognitive exhaustion (Kotiadis & Tako, 2018). This limit is also recommended for (Tako & Kotiadis, 2021) online meetings.

The following sections (3.3.13 to 3.3.18) describe the next steps for the process of generating criteria and attributes for a value model with VFT.

3.3.13 Categorize Objectives (2.13)

The categorization of objectives is defined in parallel with the mapping of causal relations between objectives (Seção 3.3.14). Throughout the process of mapping causal relations, objectives can be classified into one of the following categories:

- Strategic objectives: a general guide for the entire decision-making process. They are used by management to guide decisions made by many different individuals and groups throughout the organization
- Fundamental objectives: they are the basis for all interest in the decision to be considered. Fundamental objectives represent all the decision-makers' (and stakeholders') concerns in the context of the decision. They also are a source for the identification of attributes that can be used to measure the consequences of alternatives Keeney & Gregory (2005);
- Means objectives: they are important because of the implications for the degree of achievement of other (more fundamental) objectives in the decision context. They are means for achieving fundamental objectives and are also useful for stimulating thinking about alternatives.
- Others: objectives that do not fit into the previously-mentioned categories. They usually reflect the concerns of the stakeholders regarding the decision-making process's character-

istics, such as transparency, integration between steps, deadlines, among others (Keeney, 2008).

3.3.14 Map Causal Relations Between Objectives - *WITI Test* (2.14)

Analysts must interact with stakeholders to identify causal relations between objectives. These will enable the differentiation between means and fundamental objectives (Keeney, 1992).

For each identified objective, it is necessary to ask the question “*Why Is This objective Important in the decision context?*” - **WITI Test** (Keeney, 1992). This question allows one to identify the causal relations between the objectives (Keeney, 1992), also called decision relations influence (Keeney, 2020). There are two possible answers (Keeney, 1992):

- The objective is important because of its implications for some other objective. In this case, it is a means objective, and the answer to the question might identify another objective;
- The objective is one of the main reasons for interest in the decision problem. In this case, this objective is a **fundamental objective candidate**. The definition of whether this objective will be a “fundamental objective” depends upon the “Control of Consequences” step presented in Section 3.3.15.

Figure 6 presents an illustrative example referring to the definition of a new computational platform for the online sales service of a company. The initial decision frame and the decision statement are at the upper part of the figure. The list of objectives is at the bottom left, and the map of causal relations (generated after the WITI Test) is at the right.

Some objectives indicated by stakeholders eventually go beyond the scope of the decision and serve as strategic drivers of the decision. These objectives must be classified as “Strategic” and kept aside from the causal relations elicitation. Nevertheless, one can include the strategic objectives on the map as additional information in the decision-making process (as shown in the example highlighted in green in Figure 6).

There are also objectives elicited from the decision-makers that reflect concerns with the proper functioning of the decision-making process, such as: “Define the solution before the end of the month” or “Include a representative of the sales sector in the debate”, among other possibilities. Analysts should classify these objectives as procedural and not include them in the causal relationship map. Nevertheless, analysts must show stakeholders how these concerns are being addressed in the decision-making process to ensure transparency of the process and confidence in the results.

3.3.15 Apply Control of Consequences (2.15)

After mapping the causal relations, analysts and stakeholders should analyze fundamental objectives in light of the initial decision frame and statement. For one to consider an objective as

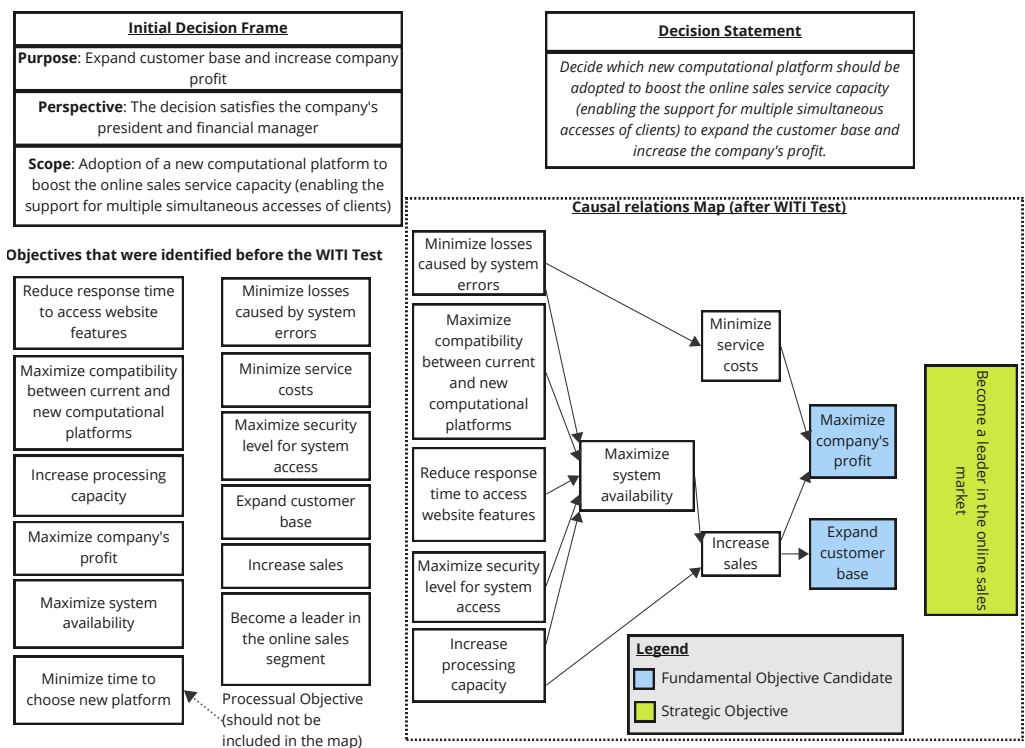


Figure 6 – Illustrative example - Decision about the adoption of a new computational platform for online sales service of a company.

Source: The Authors.

fundamental, all alternatives that can significantly influence its achievement must belong to the decision context (Keeney, 1992).

If a fundamental objective candidate is too broad, alternatives beyond those in the decision context may influence its attainment. Thus, since this objective is not controlled only by alternatives that pertain to the decision context, it is not a legitimate fundamental objective (Keeney, 1992).

“Control of Consequences” is an intrinsic concept to the process of structuring objectives and enables the complete definition of the decision frame, comprised of fundamental objectives fully integrated with the context and alternatives defined for the decision problem. Figure 7 presents the concept of “Decision Frame” proposed by (Keeney, 1992). The specific decision context includes all possible alternatives to the decision and adheres to the perspective, purpose, and scope defined in the initial decision frame and in the decision statement.

At this stage, analysts must evaluate the fundamental objective candidates identified in the causal relations mapping regarding their adherence to the decision-making context (initial decision frame + feasible alternatives). If the candidate definitions are too broad, it is necessary to refine them by undertaking the following two questions for each candidate:

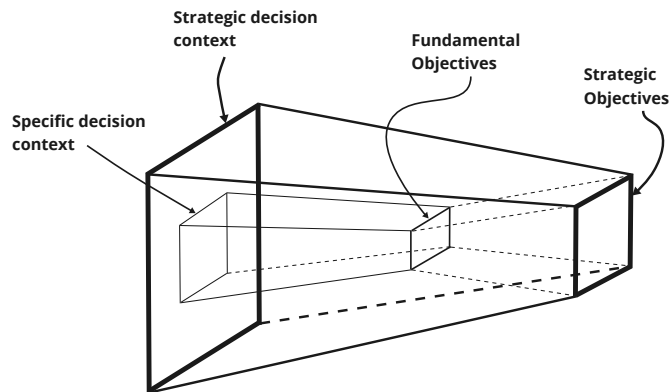


Figure 7 – Decision frame with fundamental objectives for a specific context.

Source: Keeney (1992).

1. *“Will this objective contribute to my strategic objective(s)?”* - verifies adherence to the perspective and purpose defined in the initial decision frame;
2. *“Is there any way to influence the achievement of this objective through alternatives from outside of my decision context?”* - verifies adherence to the scope defined in the initial decision frame;

Table 2 presents the “Control of Consequences” for two fundamental objectives candidates from the example in Figure 6.

We now present a variation of the example in Figure 6 in which the decision about the computational platform is an initiative of the organization’s IT sector, based on its internal budget and with scope restrained to this sector. In this case, the perspective of the initial decision frame is: “Decision satisfies the IT Manager”. Hence, the control of consequences needs to adjust the fundamental objectives of this decision according to this perspective. Fundamental objectives candidates in this context would be: “Maximize system availability” and Minimize service costs”, as shown in Figure 8.

3.3.16 Define Means-Ends Objectives Network (2.16)

The “Control of Consequences” results also help to refine the causal relations from the “WITI Test” to adjust them to the decision frame. The result of this step is the means-ends objective network proposed by (Keeney, 1992).

When “Control of Consequences” requires refining the definition of a fundamental objective, it might be necessary to refine related means-objectives accordingly. Figure 9 presents the Means-end Objectives Network generated from the map of causal relations Shown in Figure 6 by considering the results of the “Control of Consequences” step explained in Table 2.

Table 2 – Example for Control of Consequences.

Fundamental Objectives Candidates	Maximize company's profit	Expand customer base
1-Will this objective contribute to my strategic objective(s)?	Yes, because it contributes to increasing the company's profit (purpose) and satisfies the company's president and financial manager (perspective)	Yes, because the essential goal of this decision is to expand the customer base (purpose), and it satisfies the president and the financial manager of the company, who want to increase the number of customers.
2-Is there any way to influence the achievement of this objective through alternatives from outside of my decision context?	One can maximize the company's profit by reducing the cost of manufacturing products (without reducing sales revenue), reducing payroll expenses, investing exceeding capital in profitable financial operations, etc.	Yes. Other ways to influence achievement: Conduct marketing campaigns to attract new customers; expand services in physical stores, among others.
Control of Consequences:	Refinement of objective definition: <i>Maximize the company's profit by adopting a new computational platform for the online sales service.</i>	Refinement of objective definition: <i>Expand customer base by adopting a new computational platform for the online sales service.</i>

Source: The Authors.

We included an overall fundamental objective, defined as “*Increase company's sales by adopting a new computational platform for the online sales service*” in the network shown in Figure 9 as a synthesis of all other fundamental objectives. The overall fundamental objective is the starting point of the “Fundamental Objectives Hierarchy”. The other fundamental objectives serve as inputs for the “*Decomposition of fundamental objectives*” (Keeney, 1992) described in Section 3.3.17.

Figure 10 shows the Means-End Objectives Network for the illustrative example of Figure 8. The overall fundamental objective is: “*Maximize support for multiple simultaneous client accesses in the online sales computational platform*”.

3.3.17 Build Fundamental Objectives Hierarchy (2.17)

The “Fundamental Objectives Hierarchy” results from the decomposition of the fundamental objectives identified in the previous steps of the process. This step requires attention to some desirable properties of fundamental objectives(Keeney, 1992):

- 1. **Essential:** must indicate consequences directly associated with the fundamental reasons for interest in the decision problem;

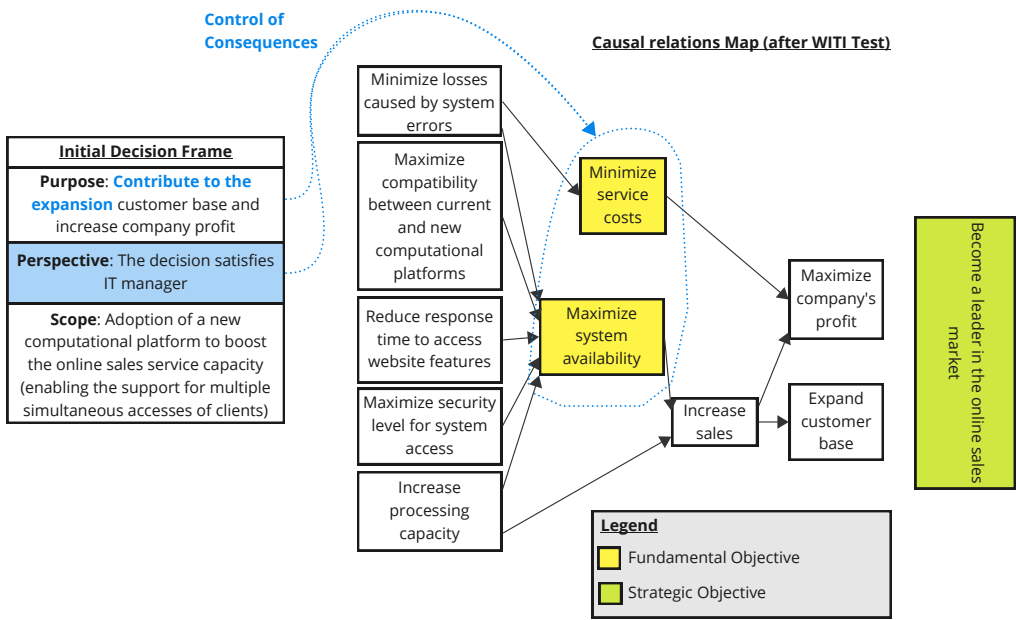


Figure 8 – Example for control of consequences with a different initial decision frame (IT Manager perspective).

Source: The authors.

2. **Controllable:** must represent consequences that are influenced only by the alternatives that belong to the decision context;
3. **Complete:** include all relevant aspects of the decision alternatives' consequences;
4. **Measurable:** define objectives precisely and specify the degrees for measuring their performance;
5. **Operational:** the information required for performance measurement must be available, and its collection must be feasible regarding time and resources available;
6. **Decomposable:** allows the individual analysis of the different objectives;
7. **Non-redundant:** required to avoid double counting of possible consequences;
8. **Concise:** reduce the number of objectives to the minimum indispensable for the analysis of the decision;
9. **Understandable:** must facilitate the generation and communication of insights to guide the decision-making process.

The “Control of Consequences” presented in Section 3.3.15 addresses the “Essential” and “Controllable” properties of fundamental objectives.

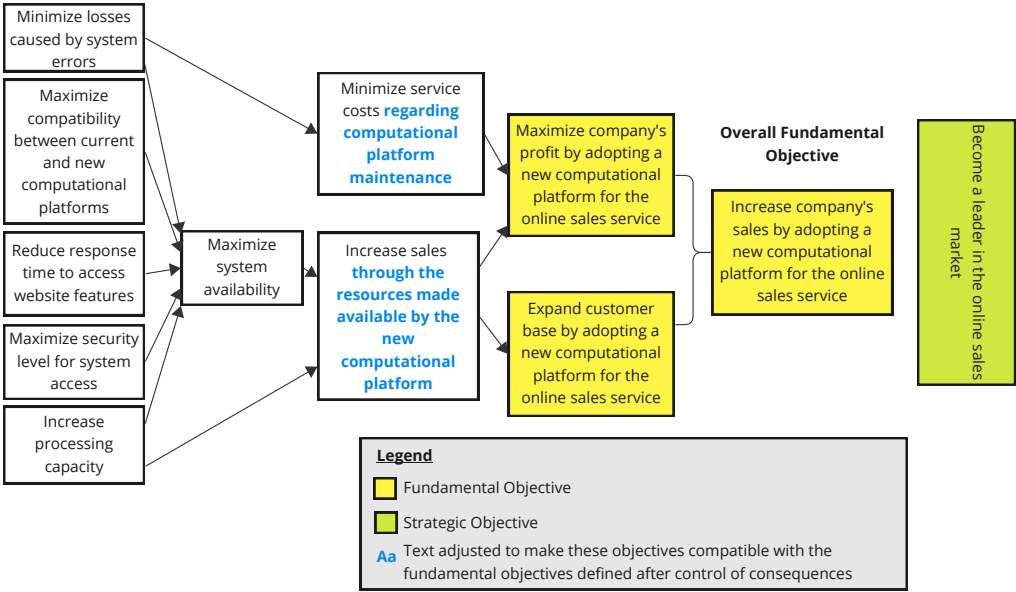


Figure 9 – Illustrative Example- Means-Ends Objectives Network.

Source: The authors.

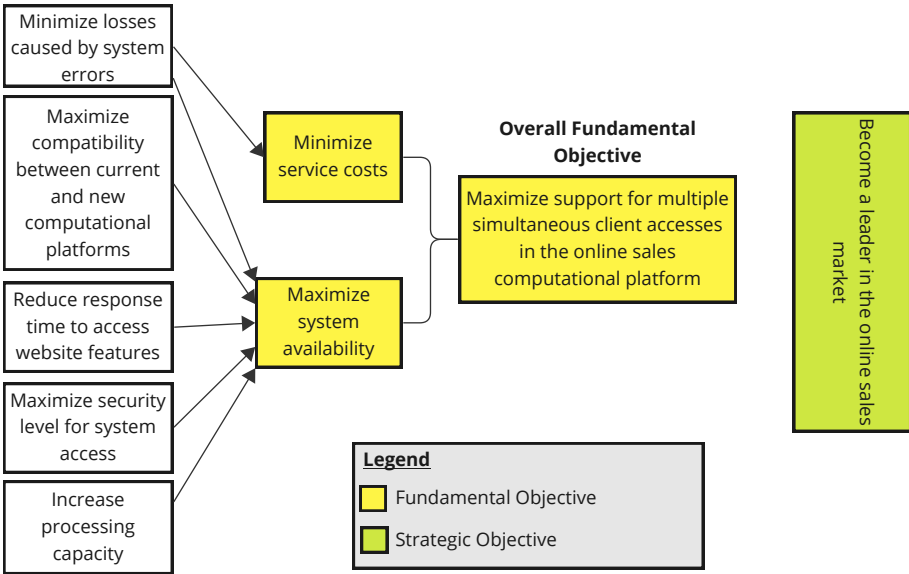


Figure 10 – Illustrative Example- Means-Ends Objectives Network from IT Manager Perspective.

Source: The authors.

The decomposition of the fundamental objectives must be exhaustive, which means that the hierarchy of objectives must contain all concerns of the stakeholders related to the consequences of the decision problem (this is also part of the previously-mentioned “Complete” property).

On the other hand, analysts should guide stakeholders to specify fundamental objectives only until reaching the required level. If one can measure an objective at the current level of decomposition (or even in its original form, without decomposing it), then he must create an attribute for it (named *natural* -see Section 3.3.18). Therefore, the decomposition of an objective should only proceed as long as we can identify concerns (related to that objective) that are still not measured by an attribute indicated in the hierarchy (Keeney, 1992).

Once the hierarchy is complete, the objectives at the last level correspond to the attributes of the value model to select a solution for the problem. These objectives can also be the criteria in a “MCDA model” for the decision problem. Figure 11 presents an example of the decomposition of fundamental objectives from Figure 9.

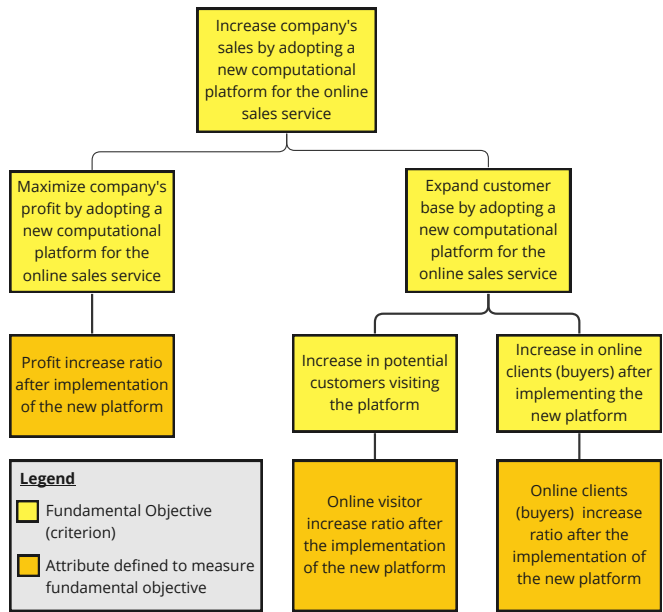


Figure 11 – Illustrative Example -Fundamental Objectives Hierarchy.

Source: The authors.

Figure 11 shows that it was not necessary to decompose the fundamental objective “*Maximize company’s profit by adopting a new computational platform for the online sales service,*” and the following attribute depicts its measurement: “*Profit increase ratio after implementation of the new platform.*” Regarding the objective “*Expand the customer base through a new computational platform for online sales,*” stakeholders indicated two concerns: “*Increase in potential customers visiting the platform*” (potential customers) and “*Increase in online clients (buyers)*

after implementing the new platform.” Consequently, the decomposition of this objective and the corresponding attributes defined to measure them reflect these two concerns.

Section 3.3.18 depicts in more detail the generation of attributes for fundamental objectives.

3.3.18 Define Attributes for Each Lower Level Fundamental Objective (2.18)

The definition of fundamental objectives always requires value judgments (Keeney, 1992). Consequently, the choice of attributes to measure these objectives must also reflect the value judgment of stakeholders regarding the achievement of those objectives in the alternatives’ evaluation.

There are three types of attributes to express the value judgment of stakeholders concerning fundamental objectives (Keeney, 1992):

- **Natural (direct):** attribute with common interpretation, i.e., with a universal understanding of its meaning. Examples: for the objective “Minimize Costs”, a likely natural attribute would be “Cost measured in dollars”; for the objective “Minimize fatalities”, an appropriate natural attribute could be “Number of fatalities”.
- **Constructed:** attributes that describe the objective thoroughly in a specific context. Example: for the objective “Maximize public responsiveness to the landfill site definition”, it might be challenging to define a natural attribute. Therefore, one can use “levels of support or opposition from organized groups in the community regarding the location of the landfill” to define a constructed attribute for this objective. “Gross Domestic Product - GDP” is another example of a constructed attribute that uses a combination of information (household consumption, business investment, government spending, and trade balance) to measure the objective “Economic health of a country”. There are several other examples mentioned in (Keeney, 1992) that may be useful for a better understanding of the topic;
- **Proxy:** when natural or constructed attributes are challenging to define, the model might require a proxy measure for a fundamental objective. A proxy attribute usually corresponds to a natural attribute for a means objective that influences the fundamental objective.

There are five desirable properties for good attributes (Keeney & Gregory, 2005):

- **Unambiguous:** there is a clear relationship between consequences and their description through the attribute. Requires an appropriate choice for the attribute scale and its corresponding levels of measurement;
- **Comprehensive:** The attribute’s levels cover the full range of possible consequences of the corresponding objective, and the value judgments implicit in the attribute are reasonable/sensible.

- **Direct:** Attribute levels should directly describe the consequences of the alternatives. One should avoid to use probability levels in attributes. When we deal with probabilities, we are likely concerned about uncertainties (not attributes). Therefore, whenever “uncertainty” is relevant in the attribute scale, the possible outcomes can be mapped to expected values (using a decision tree). Then the analyst must adjust the attribute scale to include the resulting range of expected values and use it to describe the alternatives;
- **Operational:** The information to describe the consequences is available, its collection must be feasible regarding time and resources available, and the value trade-offs can be made in a reasonable/sensible way. Therefore, there should be a proper balance between the effort required to define and measure the attribute and the expected measurement accuracy.
- **Understandable:** Consequences and value trade-offs made through the attribute can be easily understood and communicated. For instance, consider the objective “*Minimize patient weight*”: the attribute “*Weight reduction in pounds per month*” is easily understood by people in the US. However, the attribute “*Weight reduction in kilos per month*” might not be well understood by them.

Keeney & Gregory (2005) present a process for choosing attributes with the following steps:

1. Select a fundamental objective to generate the corresponding attribute;
2. Verify whether it is possible to identify one or more natural attributes that are comprehensive, direct, and operational. Choose the best among them (least ambiguous and most understandable);
3. If the objective is too broad, try to decompose it into component objectives. If this is possible, try to identify natural attributes for each component;
4. When no natural attribute for a objective is available, try to develop a constructed attribute;
5. When no natural or constructed attributes are available, identify a possible proxy attribute.

Figure 12 presents the aforementioned process.

3.4 Define Decision Alternatives

In Phase 3, the original decision alternatives are detailed and new ones can be identified by exploring possible decision opportunities. This phase comprises 8 steps that include some process variations for the identification of alternatives. This phase is directly related to the fourth stage of the framework proposed by de Almeida (2013) (see Figure 2). Figure 13 presents an overview of the steps of this phase.

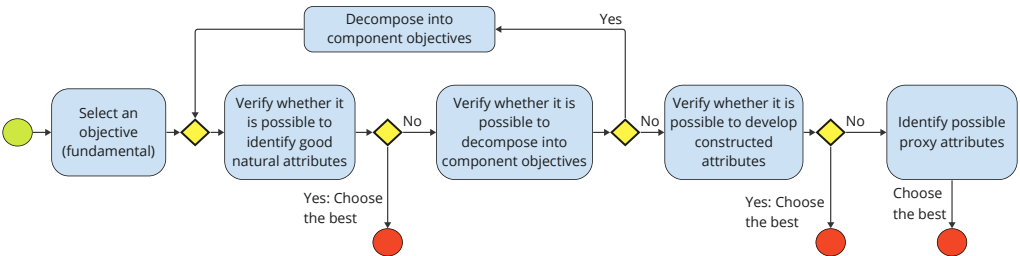


Figure 12 – Process to Select Attributes (in BPMN notation).

Source: Adapted from Keeney & Gregory (2005).

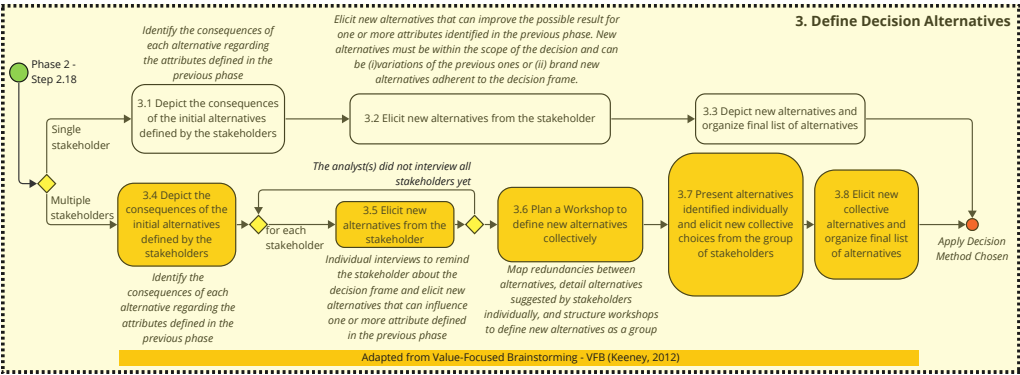


Figure 13 – Integrated decision support process based on VFT - Phase 3.

Source: The Authors.

The first three steps of this phase apply to situations where there is only one stakeholder involved:

1. **Depict the consequences of the initial alternatives defined by the stakeholders(3.1):** verify how each original alternative meets the fundamental objectives. These original alternatives normally emerge, in an incipient way, during the process of Initial Framing of the Problem (described in Section 3.2 and also in the answers to some questions of the questionnaire for identification of objectives (described in Section 3.3.6) In this step, analysts should elicit the values that these alternatives will receive for each attribute defined previously (according to Section 3.3.18);
2. **Elicit new alternatives from the stakeholder (3.2):** Elicit new alternatives that can improve the possible result for one or more attributes identified in the previous phase. New alternatives must be within the scope of the decision and can be (i) variations of the previous ones or (ii) brand new alternatives adherent to the decision frame. The Means-Ends Objectives Network mapped in the previous phase can be a source for possible ideas regarding the desirable characteristics of new solution alternatives. Keeney (1992) proposes a practical procedure at this stage: consider each fundamental objective individually and

check whether there are new alternatives that can improve the result regarding that objective. Subsequently, analysts should consider the objectives two by two and apply the same analysis. Then three by three, and so on, until analysts use all combinations of fundamental objectives to elicit possible new alternatives;

3. **Depict new alternatives and organize final list of alternatives (3.3):** For each new alternative identified in the previous step, analysts must elicit the values for their consequences regarding each attribute defined in Phase 2 (see Section 3.3.18).

The subsequent five steps apply to situations with two or more stakeholders:

1. **Depict the consequences of the initial alternatives defined by the stakeholders (3.4):** verify how each original alternative (indicated by the different stakeholders) meets the fundamental objectives. This step is analogous to step 3.1 described before;
2. **Elicit new alternatives from the stakeholder (3.5):** Conduct individual interviews to remind the stakeholder about the decision frame and elicit new potential alternatives to improve the result for one or more attributes identified in the previous phase. This step is analogous to step 3.2 described before and must be done for each stakeholder individually;
3. **Plan a Workshop to define new alternatives collectively(3.6):** Map possible redundancies between alternatives identified in the previous step, detail the alternatives suggested by stakeholders in the individual interviews, and structure workshop(s) to elicit new alternatives from the group perspective;
4. **Present alternatives identified individually and elicit new collective choices from the group of stakeholders(3.7):** Encourage the stakeholders to examine the previously defined fundamental objectives and propose new alternatives to improve the result for one or more attributes identified in the previous phase. New alternatives must be within the scope of the decision and can be (i) variations of the previous ones or (ii) brand new alternatives adherent to the decision frame. The Means-Ends Objectives Network mapped in the previous phase can be a source for possible ideas regarding the desirable characteristics of new solution alternatives. The practical procedure mentioned in step 3.2 can also be applied here (procedure proposed by Keeney (1992));
5. **Elicit new collective alternatives and organize final list of alternatives (3.8):** Analysts must describe new alternatives identified in the workshop in this step. For each new alternative, analysts must elicit the values for their consequences regarding each attribute defined in Phase 2 (see Section 3.3.18).

Although some steps of the previous phases briefly listed some alternatives, we emphasize that Phase 3 comprises the steps required to depict them thoroughly. Therefore, analysts now focus on previously identified alternatives and new ones to describe their consequences regarding the

attributes defined in Phase 2. Hence, Phase 3 enables analysts to elicit the complete set of actions regarding the desired outcomes for the decision.

We add a remark regarding the fifth step of the procedure proposed by (De Almeida, 2013) (see Figure 2): “5-Identify state of nature”. Despite not being part of the scope of this work, we highlight that the state of nature might influence some steps of the proposed process. For instance, the behavior of entities that are not under the control of the stakeholder group may result in actions that restrict desired alternatives.

Uncertainties might also affect the results of the process, such as (i) the degree of precision of the measurement scale and the data collected and (ii) objectives whose consequences behave according to a variation explained by a probability distribution.

3.5 Applications and Results

Appendix D presents two application examples and their results. The first depicts a personal (family) decision, and the latter describes an organizational decision. These examples explore each step of our proposal thoroughly. Hence, we believe that they are a valuable reference for VFT practice.

4 CONCLUSION

This work presented a guide for defining and structuring objectives and attributes (or criteria) for decision-making processes with VFT. The guide integrated different VFT nuances from several sources in the literature, providing analysts and decision-makers with a consistent structure for applying this approach.

The original contribution of this work is the structured VFT approach that enables practitioners to deal with decision problems from the beginning until the generation of attributes and alternatives. To achieve this goal, Section 2 presented the definitions for problematic situations and described how VFT helps with decision problems and opportunities. Then, Section 3 depicted our proposed process for generating criteria/attributes and describing alternatives.

This work has a limitation: since we did not explore the “Back-End” of the VFT approach, our discussion about decision opportunities did not include comparisons between alternatives regarding inter-criteria preference relations and sensitivity analysis. Nevertheless, our proposal explores decision opportunities in alternative definition stages and can help practitioners to benefit from them in the early stages of the decision process.

Finally, we highlight some opportunities for future work: (i) the execution of our proposal using other structured techniques for qualitative value modeling (Silver and Combined), (ii) the extension of the proposed process for the “VFT as PSM” approach (Françozo & Belderrain, 2022); (iii) use of different adaptations of “VFT devices” or “value stimulation techniques” in our proposed process; (iv) possible variations of the steps comprised in “Define Decision Objectives” and “Define Decision Alternatives” phases depending on the results of the preference modeling

or the decision method; and (v) use of multi-methodological approaches, combining other PSMs with the VFT application steps proposed in this paper.

Acknowledgements

The authors thank the Brazilian Coordination of Superior Level Staff Improvement (CAPES), the Brazilian National Counsel of Technological and Scientific Development (CNPq), the Foundation for Research in the State of Pernambuco (FACEPE) and the Brazilian Air Force (FAB) for the institutional support.

References

- ACKERMANN F & EDEN C. 2011. Strategic Management of Stakeholders: Theory and Practice. *Long Range Planning*, **44**(3): 179–196. Available at: <http://dx.doi.org/10.1016/j.lrp.2010.08.001>.
- ACKERMANN F & EDEN C. 2020. Strategic Options Development and Analysis. In: REYNOLDS M & HOLWELL S (Eds.), *Systems Approaches to Making Change: A Practical Guide*. chap. 4, pp. 139–198. Walton Hall, Milton Keynes: The Open University.
- ACKOFF RL. 1962. Some Unsolved Problems in Problem Solving. *Journal of the Operational Research Society*, **13**(1): 1–11. Available at: <https://doi.org/10.1057/jors.1962.1>.
- BEER S. 1972. *Brain of the Firm*. London: The Penguin Press.
- BRASIL. 2018. DCA 11-45: Concepção Estratégica Força Aérea 100. Tech. rep.. Força Aérea Brasileira.
- BRYSON JM. 2004. What to do when Stakeholders Matter: Stakeholder Identification and Analysis Techniques. *Public Management Review*, **6**(1): 21–53.
- BURK RC & PARNELL GS. 2011. Portfolio Decision Analysis – Lessons from Military Applications. In: SALO A, KEISLER J & MORTON A (Eds.), *Portfolio Decision Analysis: Improved Methods for Resource Allocation*. chap. 14, p. 333–358. New York: Springer.
- DE ALMEIDA AT. 2013. *Processo de decisão nas organizações: construindo modelos de decisão multicritério*. São Paulo, SP: Editora Atlas.
- DE ALMEIDA AT, CAVALCANTE CAV, ALENCAR MH, FERREIRA RJP, DE ALMEIDA-FILHO AT & GARCEZ TV. 2015. *Multicriteria and Multiobjective Models for Risk, Reliability and Maintenance Decision Analysis*. Switzerland: Springer International Publishing.
- FORRESTER JW. 1971. Counterintuitive Behavior of Social Systems. *Technology Review - Alumni Association of the Massachusetts Institute of Technology*, Available at: www.clexchange.org.
- FRANÇOZO RV & BELDERRAIN MCN. 2022. A problem structuring method framework for value-focused thinking. *EURO Journal on Decision Processes*, **10**(April).

FRANÇOZO RV, BELDERRAIN MCN, PACHECO BCS, PIRATELLI CL & BERGIANET NCR. 2019. Value-focused thinking na prática: análise do desenvolvimento e aplicações no período (2010-2018). In: *Anais do LI Simpósio Brasileiro de Pesquisa Operacional*. Limeira-SP: SOBRAPO.

FRIEND J. 1989. The strategic choice approach. In: ROSENHEAD J & MINGERS J (Eds.), *Rational Analysis for a Problematic World: Problem Structuring Methods for Complexity, Uncertainty and Conflict*. chap. 6, pp. 121–157. Chichester: Wiley.

GEORGIU I. 2015. Unravelling soft systems methodology. *International Journal of Economics and Business Research*, **9**(4): 415–436.

HAMMOND J, KEENEY RL & RAIFFA H. 1999. *Smart Choices: A Practical Guide to Making Better Decisions*. Boston: Harvard Business Review Press.

HECTOR D, CHRISTENSEN C & PETRIE J. 2009. A problem-structuring method for complex societal decisions: Its philosophical and psychological dimensions. *European Journal of Operational Research*, **193**(3): 693–708. Available at: <http://dx.doi.org/10.1016/j.ejor.2007.06.058>.

HOLT R. 2004. Risk Management: The Talking Cure. *Organization*, **11**(2): 251–270.

KEENEY R. 2012. Value-Focused Brainstorming. *Decision Analysis*, **9**: 303–313.

KEENEY RL. 1992. *Value-Focused Thinking: A Path to Creative Decision Making*. Cambridge: Harvard Business School Press.

KEENEY RL. 2008. Applying Value-Focused Thinking. In: DECKRO RF (Ed.), *Military Operations Research*. chap. 3, pp. 7–17. Alexandria, VA: Military Operations Research Society.

KEENEY RL. 2013. Identifying, prioritizing, and using multiple objectives. *EURO Journal on Decision Processes*, **1**(1-2): 45–67.

KEENEY RL. 2020. *Give Yourself a Nudge: Helping Smart People Make Smarter Personal and Business Decisions*. Cambridge: Cambridge University Press.

KEENEY RL & GREGORY RS. 2005. Selecting attributes to measure the achievement of objectives. *Operations Research*, **53**(1): 1–11.

KEENEY RL & VON WINTERFELD D. 2008. Practical value models. In: EDWARDS W, MILES RF & VON WINTERFELDT D (Eds.), *Advances in decision analysis: from foundations to applications*. chap. 13, p. 232–252. New York: Cambridge University Press.

KEISLER J, TURCOTTE DA, DREW R & JOHNSON MP. 2014. Value-focused thinking for community-based organizations: objectives and acceptance in local development. *EURO Journal on Decision Processes*, **2**(3-4): 221–256.

KOTIADIS K, TAKO A & VASILAKIS C. 2014. A participative and facilitative conceptual modelling framework for discrete event simulation studies in healthcare. *Journal of the Operational Research Society*, **65**: 197–213. Available at: <https://doi.org/10.1057/jors.2012.176>.

KOTIADIS K & TAKO AA. 2018. Facilitated post-model coding in discrete event simulation (DES): A case study in healthcare. *European Journal of Operational Research*, **266**(3): 1120–1133. Available at: <https://doi.org/10.1016/j.ejor.2017.10.047>.

MANSO DF. 2022. *Strategic Opportunities Identification Method*. Ph.D. thesis. Instituto Tecnológico de Aeronáutica. São José dos Campos.

MARTTUNEN M, HAAG F, BELTON V, MUSTAJOKI J & LIENERT J. 2019. Methods to inform the development of concise objectives hierarchies in multi-criteria decision analysis. *European Journal of Operational Research*, **277**(2): 604–620. Available at: <https://doi.org/10.1016/j.ejor.2019.02.039>.

MINGERS J & ROSENHEAD J. 2004. Problem structuring methods in action. *European Journal of Operational Research*, **152**(3): 530–554.

MINGERS J & ROSENHEAD J. 2011. Introduction to the Special Issue: Teaching Soft O.R., Problem Structuring Methods, and Multimethodology. *INFORMS Transactions on Education*, **12**(1): 1–3.

PARNELL GS, BRESNICK TA, TANI SN & JOHNSON ER. 2013a. *Handbook of Decision Analysis*. Hoboken: John Wiley & Sons, Inc.

PARNELL GS, HUGHES D, BURK RC, DRISCOLL PJ, KUCIK PD, MORALES BL & E NUNN LR. 2013b. Invited review—survey of value-focused thinking: Applications, research developments and areas for future research. *Journal of Multi-Criteria Decision Analysis*, **20**(1-2): 49–60. Available at: <https://onlinelibrary.wiley.com/doi/abs/10.1002/mcda.1483>.

PHILLIPS LD & PHILLIPS MC. 1993. Facilitated work groups: theory and practice. *Journal of the Operational Research Society*, **44**(6): 533–549.

REKHA V S & MUCCINI H. 2018. Group decision-making in software architecture: A study on industrial practices. *Information and Software Technology*, **101**(April): 51–63. Available at: <https://doi.org/10.1016/j.infsof.2018.04.009>.

RITTEL HWJ & WEBBER MM. 1973. Dilemmas in a General Theory of Planning. *Policy Sciences*, **4**(1): 155–169.

ROSENHEAD J & MINGERS J. 2001. *Rational Analysis for a Problematic World Revisited*. Chichester, England: John Wiley & Sons.

TAKO AA & KOTIADIS K. 2021. A Tutorial on Participative Discrete Event Simulation in The Virtual Workshop Environment. In: *2021 Winter Simulation Conference (WSC)*. pp. 1–12. Phoenix.

WHEELER FP & CHECKLAND P. 2000. Systems Thinking, Systems Practice: Includes a 30-Year Retrospective. *The Journal of the Operational Research Society*, **51**(5): 647.

How to cite

VIEIRA GB, SOUZA YL, SIMÕES A, DE ALMEIDA JA & BELDERRAIN MCN. 2024. Using value-focused thinking in an integrated process to support decisions. *Pesquisa Operacional*, **44**: e276110. doi: 10.1590/0101-7438.2023.043.00276110.

APPENDIX A INTEGRATED DECISION SUPPORT PROCESS

The starting point of any decision-making process is to understand the decision context and the characteristics of the problem, which requires the identification of stakeholders, their interests, concerns, and expectations (Marttunen et al., 2019). During this “opening” phase of the decision-making process, also called the “divergent” phase (Marttunen et al., 2019), participants develop a comprehensive representation of the problem. Regarding the VFT approach, this representation corresponds to the means-ends objectives network and the objectives hierarchy.

Figure 14 presents the divergent phase of the decision-making process and its contribution to the value model for the multi-attribute (*Multi-Attribute Utility Theory - MAUT* or *Multi-Attribute Value Theory - MAVT*) or multicriteria (*Multi-Criteria Decision Analysis -MCDA*) method chosen in the convergent phase. The intermediate steps shown in Figure 14 represent a transition between the divergent and convergent phases for simplifying large objective hierarchies in some scenarios where there is a large volume of data (“*data rich*”) such as public tenders, environmental decisions, among others (Marttunen et al., 2019).

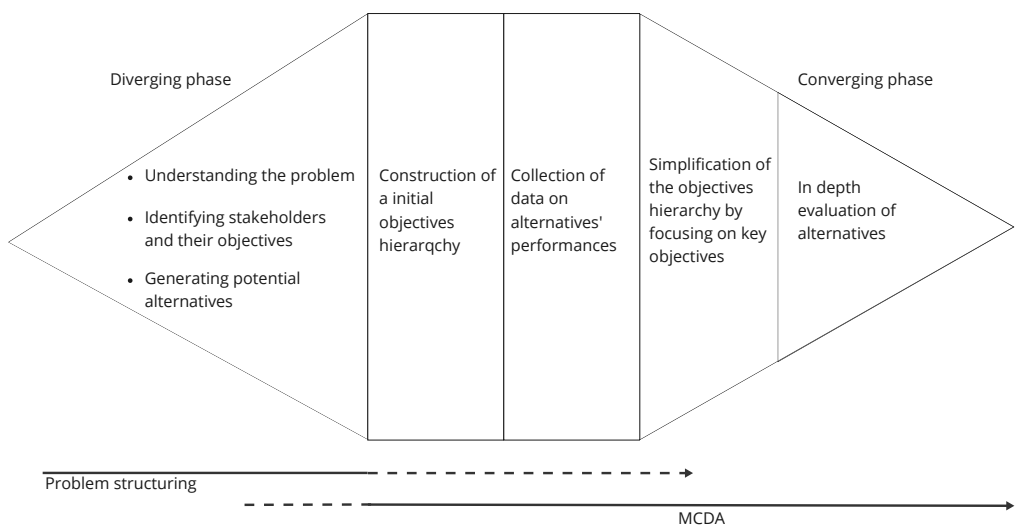


Figure 14 – Diverging and converging phases of decision process and steps to build objectives hierarchy.

Source: Adapted from (Marttunen et al., 2019)

Therefore, our proposal process comprises several steps to guide decision-making process through the diverging and converging phases. Figure 15 presents an overall view of the proposed process.

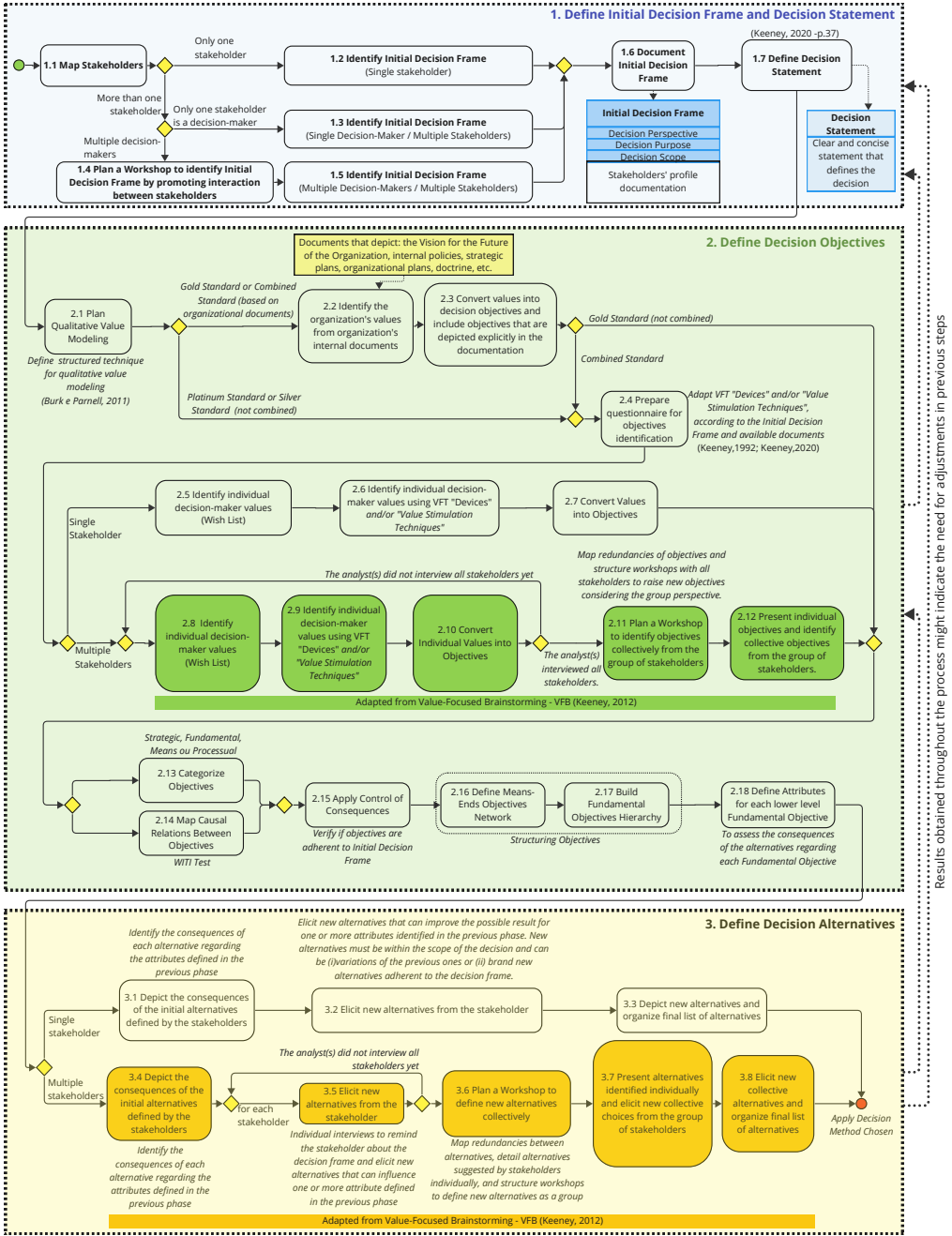


Figure 15 – Integrated decision support process based on VFT.

Source: The Authors

APPENDIX B DECISION FRAMING WORKSHOP - MULTIPLE DECISION-MAKERS

We will present some recommendations for a “Decision Framing Workshop” , with the aim of generating a consensual definition for the Initial Solution Framing mentioned in Section 3.2.4. This text was adapted from Chapter 6 (item 6.4) of (Parnell et al., 2013a).

Analysts must deal with three relevant issues before undertaking this workshop:

- **Duration:** The typical duration of a workshop is one working day. Analysts should avoid extending this activity further to ensure that all relevant decision-makers will be able to participate in the workshop;
- **Participants:** Decision makers, stakeholders and subject matter experts. The maximum number of participants should be 15 individuals (which may be extended to a maximum of 20 individuals in exceptional situations (Parnell et al., 2013a)). Other authors also discuss the subject: a facilitator must maintain the guidance of a group so that the objectives of the workshops and stages of the intervention process are achieved. For this, a relevant factor is the size of the group that will participate in each activity. A group of 7 to 15 people is considered sufficient such that individualities are preserved, multiple perspectives are represented and consensus is reached (Phillips & Phillips, 1993). Kotiadis et al. (2014) also suggest that a maximum of 12 people should participate in activities to enable the communication and sharing of the perspectives of all participants. However, when analysts need to deal with more complex tasks, they can divide the participants in smaller groups of 3 to 5 individuals (Rekha V & Muccini, 2018);
- **Simultaneous Participation:** If the decision-makers are unavailable for simultaneous participation in a workshop, the analysts can split it into two or more smaller sessions. Notwithstanding, analysts can also complement these sessions by interviewing decision-makers who didn’t attend the main workshop.

The roadmap suggested for the Decision Framing Workshop comprises 7 steps:

1. Vision Statement;
2. Issue raising;
3. Categorization of the issues;
4. Decision Hierarchy;
5. Values and trade-offs;
6. Initial influence diagram;
7. Decision schedule and logistics.

The following sections will present each of the aforementioned steps.

B.1 Vision Statement

The vision statement describes the purpose of the decision. In summary, analysts must obtain the answer to the following questions regarding the decision:

- What are we going to do?
- Why are we doing this?
- How will we know that we have succeeded?

An example of a vision statement is shown in Table 3:

Table 3 – Example questions and answers to generate a vision statement.

Questions	Answers
What are we going to do?	Manufacture product efficiently (minimizing cost)
Why are we doing this?	Ensure successful product launch in the market in the upcoming year
How will we know that we have succeeded?	All participants (decision makers, subject matter experts, and stakeholders) are satisfied with the solution
Vision Statement	We will decide how to manufacture the product in the most cost-efficient way. We need to do this to ensure a successful product launch next year. We'll know that we have succeeded if all participants are satisfied that we've chosen the best path forward

Source: Adapted from (Parnell et al., 2013a).

B.2 Issue raising

After understanding the purpose of the decision stated in the vision statement, it is important that all participants describe any concerns and issues related to the decision that come to their mind.

This step resembles traditional brainstorming, except that discussions should be guided by the vision statement identified in the previous workshop step (Section B.1).

Hence, it is imperative to state each relevant issue in a way that allows the understanding of its meaning. Parnell et al. (2013a) exemplify this concept: “Market share” is not an appropriate definition, as it does not fully express the meaning of the issue. Therefore, a better statement for this issue is: “Our Market share is diminishing.”

There are some good practices for eliciting relevant issues (Parnell et al., 2013a):

- Ensure that there are participants in the workshop representing as many diverse perspectives as possible;

- Ensure that issues raised by all are heard;
- Remind all participants that issue raising is just an initial step in the decision process (and not the search for a solution);
- Ensure plenty of time for this step (1 to 3 hours);
- Prohibit pre-judgments on the issues raised;
- The goal at this stage is “quantity” and not “quality”;

B.3 Categorization of the issues

After identifying the relevant issues, it is important to categorize them into four predefined types, as shown in Table 4.

Table 4 – Categorization of Issues.

Type	Description	Goal
Decisions	Issues suggesting choices that can be made as part of a decision	Scope (it is the raw material for creating alternatives)
Uncertainties	Issues suggesting uncertainties that should be considered during the decision-making process	Checklist to be used in the analytical framework for evaluating alternatives
Values	Issues that refer to the measures that will be used to compare alternatives.	Checklist for defining the measures (criteria) for evaluating the alternatives
Other	Issues that do not fit into the other categories, such as those related to the decision process itself	Adjustments in the decision process

Source: Adapted from Parnell et al. (2013a) - Chapter 6 - item 6.4.3.

B.4 Decision Hierarchy

In this step, participants should assign each issue identified by the type “Decision” to one of the three levels of the decision hierarchy, according to the model presented in Figure 16.

Parnell et al. (2013a) present an interesting example of a decision hierarchy for choosing a datacenter location for an organization (see Table 5).

B.5 Values and trade-offs

In this step, analysts can adopt VFT to refine the issues classified as “Values” in Step B.3 and to identify new values. We present further details in Sections 2, 3, and D.

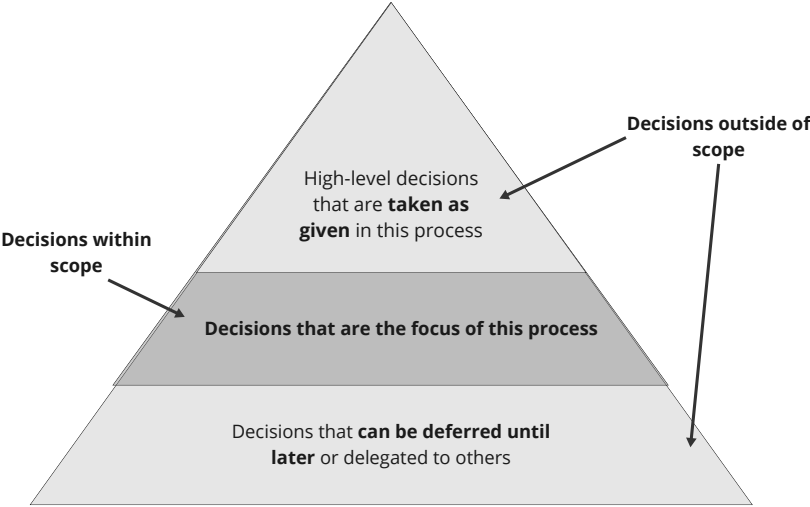


Figure 16 – Decision Hierarchy.

Source: Parnell et al. (2013a) - Figure 6.2.

Table 5 – Example of a decision hierarchy for choosing a datacenter location for an organization.

Level in the Hierarchy	Level Description	Allocation example
Upper Level	Done deals; predefined decisions and established policies.	Organization’s mission; Need to increase the capacity of data centers; Locate new datacenter outside the metropolitan area of the Capital; At least 50 MW of electrical power available.
Middle Level	Current Decision Focus; Strategic decisions to be made	Datacenter location, Datacenter facility security, floor space available (for operations and for administrative tasks), communications, power supply (primary and backup), and cooling (primary and backup).
Lower Level	Subsequent decisions. Tactical or implementation decisions postponed to the future.	Datacenter implementation, acquisition of land/facilities, missions assigned to the datacenter, acquisition of equipment, and continuity of operations.

Source: Adapted from Parnell et al. (2013a) - Figure 6.5.

B.6 Initial influence diagram

Parnell et al. (2013a) recommend the adoption of influence diagrams to clarify some aspects of the initial decision frame. For more details, see Appendix B of Parnell et al. (2013a).

B.7 Decision schedule and logistics

After defining the initial decision frame in the previous steps, the analysts should propose a schedule for the following meetings to identify stakeholders' values and execute the decision process. These latter arrangements should also define meeting locations, the composition of the teams, and all other required information.

APPENDIX C VFT DEVICES AND VALUE STIMULATION TECHNIQUES

<i>VFT Devices (Keeney, 1992)</i>	<i>Value Stimulation Techniques - (Keeney,2020)</i>
<div><ol style="list-style-type: none">1. A Wish list: What do you want? What do you value? What would be ideal? If you had no limitations at all, what would your objectives be?2. Alternatives: What is a perfect alternative, terrible alternative, some reasonable alternatives, the status quo? What is good or bad about each?3. Problems and Shortcomings: What major problems are you working on now, or what major problems are confronting you?4. Consequences: What has occurred that was good or bad? What might occur that you care about?5. Goals, constraints and guidelines: What are your aspirations to meet the stated goals and constraints? What limitations do these place on you?6. Different perspectives: What would your competitor or constituency or other stakeholders be concerned about? At some time in the future, what would concern you?7. Strategic objectives: What are your ultimate values that may be represented in a mission statement, a vision statement, or a strategic plan? What are you values that are absolutely fundamental?8. Generic Objectives: What values do you have for your customers, you employees, your shareholders, yourself? What environmental, social, economic, or health and safety values are important?9. Structuring objectives: For each stated value, ask why it is important. For each response, ask why it is important. & For each stated value, ask why it is important. For each response, ask why it is important.10. Quantifying objectives: For each stated value, specify its meaning more precisely. For broad values, identify major component parts?</div>	<div><ol style="list-style-type: none">1. Emotions and feelings: Articulate your emotions and feelings evoked by the decision situation. Ask yourself why you care about these and how your alternatives may influence them.2. Alternatives: Identify a perfect alternative, a terrible alternative, some reasonable alternatives and the status quo. What is good or bad about each?3. Consequences: Think about what might occur after you make your decision. What might occur that is good or bad?4. Goals and constraints: Review any goals or constraints you have. What are your reasons for setting these?5. Different perspectives: Suppose that a friend or a competitor you know faced your decision. What might their values be? If you faced this decision at some time in the future, what would concern you?6. Strategic values: Consider the strategic values that you have for guiding your life or your organization. Are any of these values, or aspects of them, relevant to this decision?7. Disappointment and regret: After you have experienced the consequences of your decision, what might disappoint you and what might you regret?8. Generic values: What values have you had in the past for the same or similar decisions that you have faced? Are these relevant now?</div>
<p>Note 1: Items highlighted in blue indicate elements that appear in only one of the lists. Items in black letters appear with similar definitions in both lists.</p> <p>Note 2: In Keeney(2020), the Wish List remains a previous step before value stimulation techniques.</p>	

Figure 17 – VFT Devices and Value Stimulation Techniques.

Source: Adapted from Keeney (1992) and Keeney (2020).

APPENDIX D APPLICATIONS AND RESULTS

This section presents two application examples and their results. The first depicts a personal (family) decision, and the latter describes an organizational decision.

D.1 Personal Decision - buying new notebooks during COVID-19 pandemic

Here we use the proposed process to define criteria and attributes regarding a decision about buying new notebooks during the COVID-19 pandemic. We describe a real case from 2020 of a family living in São José dos Campos, São Paulo. We modified some of the original information to preserve the identity and privacy of the family.

People commonly use intuition to simplify this kind of decision in families. Nevertheless, this case demonstrates how VFT concepts regarding criteria definition and value model generation can support problem-solving for different levels of complexity.

D.1.1 Context of the decision problem

In 2020, with the onset of the COVID-19 pandemic, family members had to migrate their professional and educational activities to the virtual environment via social networks and videoconferencing platforms.

This situation required an immediate adaptation of the family's equipment for virtual interaction, which had to be used primarily for videoconferences and access to virtual learning environments.

However, at that time, most families did not have enough equipment to enable access to virtual environments simultaneously and with the same level of quality for all members. Even in homes with equipment for everyone, there was often only one terminal with more resources for professional or educational collaboration tools (generally a more robust personal computer or laptop). The other members had to use smartphones designed primarily for entertainment or social interaction.

Therefore, families had to adapt quickly to online professional or academic collaboration tools with the resources that were immediately available. At first, the experience was adequate since it allowed the continuity of professional and educational activities without disrupting the previously-defined schedules.

However, after a few months of "improvisation" using the available tools, many families realized the importance of acquiring devices with better computational capacity for all family members. Among the desired features, these devices should enable **new possibilities for content production, more agility, larger screen size to improve reading comfort, and resources to enable enhanced display of the information available on professional and academic platforms.**

Thus, the context of this decision problem is: to decide which equipment should be bought for two family members so that they can use professional and academic platforms more effectively and efficiently.

D.1.2 Initial Decision Frame and Decision Statement - Personal Decision

From the information presented in Section D.1.1, we can define the purpose of this decision as: “*Purchase of new laptops for family members, to enable them to use online professional and academic platforms*” ’.

Regarding the perspective of the decision, Table 6 describes the stakeholders (entities) and their interests concerning the decision.

Table 6 – Stakeholders and their interests - Personal Decision.

Stakeholders	Interests regarding the decision
Father	The father is concerned about the difficulties faced by his wife and daughter regarding their access to online professional platforms (wife) and online educational platforms (wife and daughter); Also concerned about the family budget (cost of the solution);
Mother	The mother lacks an individual device to develop her professional activity (requires working with data sheets and presentations) and to use online educational platforms; On the other hand, she considers the acquisition of a new device as an investment (rather than an additional cost for the family);
Daughter	The daughter has been struggling to keep up with online school classes on her smartphone because the screen is too small and makes it difficult to view content and interact. In her opinion, the new device is an opportunity for better performance in virtual learning.

Source: The authors.

Although the daughter is a stakeholder directly affected by the decision, the decision-makers in this context are the father and the mother. Thus, the decision perspective is: “The decision must satisfy the father and mother, according to their preference criteria”.

Regarding the scope, there are some pre-established premises: the budget limit for acquisition is R\$4,000.00 (payment method that allows installments is preferred), there should be technical assistance in Brazil for the equipment, and the time interval for the final decision expires in 2 weeks. Details about the procurement process (after selection) are outside the scope.

Hence, considering the previously-mentioned information, we present the Initial Decision Frame in Figure 18.

The decision statement is: “*Decide which notebooks should be purchased so that two family members (mother and daughter) can use online professional and educational platforms considering the deadline expectation of the stakeholders (two weeks) and respecting the defined budget limit (R\$4,000.00).*”.

Initial Decision Frame	
Purpose	Purchase of new laptops for family members, to enable them to use online professional and educational platforms
Perspective	The decision must satisfy the father and mother of the family
Scope (must consider "timeframe" defined by decision-maker(s))	<div>-Meet the needs of two family members (mother and daughter)</div> <div>Assumptions: -budget limited to R\$4,000.00 (allowing installment payments); -equipment disposes of technical assistance in Brazil; -Decision must be taken within two weeks.</div> <div>Out of Scope: Details about the acquisition process (after selection) are not in scope.</div>
Stakeholders' profile documentation (decision-makers and other participants)	<div>Father: decision-maker</div> <div>Mother: decision-maker - will also receive one of the equipments</div> <div>Daughter: stakeholder that will receive one of the equipments</div>

Figure 18 – Initial Decision Frame - family decision example.

Source: The Authors.

D.1.3 Elicit Decision Objectives - Personal Decision

In this example, the qualitative value modeling technique was “Platinum Standard” - interviews with the main decision-makers and stakeholders.

The interviews enabled the analyst to identify the individual values of each participant with the “Wish List” (presented in Section 3.3.8) and through the use of value stimulation techniques (proposed by Keeney (2020) and described in Section 3.3.9). The analyst identified 25 objectives from the stakeholders, some of them redundant. Eliminating redundancies and obtaining consensus from the group of stakeholders (as presented in Sections 3.3.11 and 3.3.12), the analyst was able to refine a list of 18 objectives, as follows:

1. Promote family’s budget balance;
2. Provide conditions to promote good future opportunities for the mother ;
3. Provide conditions to promote good future opportunities for the daughter;
4. Promote a harmonious family environment;
5. Provide conditions to promote good health for all members of the family;
6. Provide conditions to a well-structured family in the present and future;
7. Ensure an excellent interaction with online professional environments for the mother;

8. Ensure an excellent interaction with virtual learning platforms for the mother;
9. Ensure an excellent interaction with virtual learning platforms for the daughter;
10. Provide conditions for a bearable social distancing to all members of the family;
11. Minimize ergonomic problems for the daughter caused by improper posture and habits when using equipment for online activities;
12. Minimize ergonomic problems for the mother caused by improper posture and habits when using equipment for online activities;
13. Ensure that the daughter has good school performance during the COVID-19 pandemic;
14. Avoid interrupting the mother's professional activities;
15. Provide conditions to prevent the mother from getting demotivated during the COVID-19 pandemic;
16. Provide conditions to prevent the daughter from getting demotivated during the COVID-19 pandemic;
17. Contribute to earning the income needed to support the family;
18. Promote the mother's personal fulfillment;

The analyst elicited the causal relations between the objectives (according to the procedure described in Section 3.3.14) and classified them according to the procedure described in Section 3.3.13. Figure 19 presents the map of causal relations for this example.

The next step was to execute the "Control of Consequences" (described in Section 3.3.15). Figure 20 presents the results of this step.

After the control of consequences step, the analyst elicited the means-ends objective network (according to the procedure described in Section 3.3.16). The analyst and the stakeholders also adjusted some means objectives presented in figure 19 to ensure that they fit into the initial decision frame. Figure 21 presents the means-ends objective network for this example.

Finally, the analyst elicited the information required to decompose the objectives, thus generating the "hierarchy of fundamental objectives" and the corresponding attributes, according to the procedures described in Sections 3.3.17 and 3.3.18. Figure 22 presents the hierarchy of fundamental objectives for the example and the attributes defined for each objective in the last level of the hierarchy.

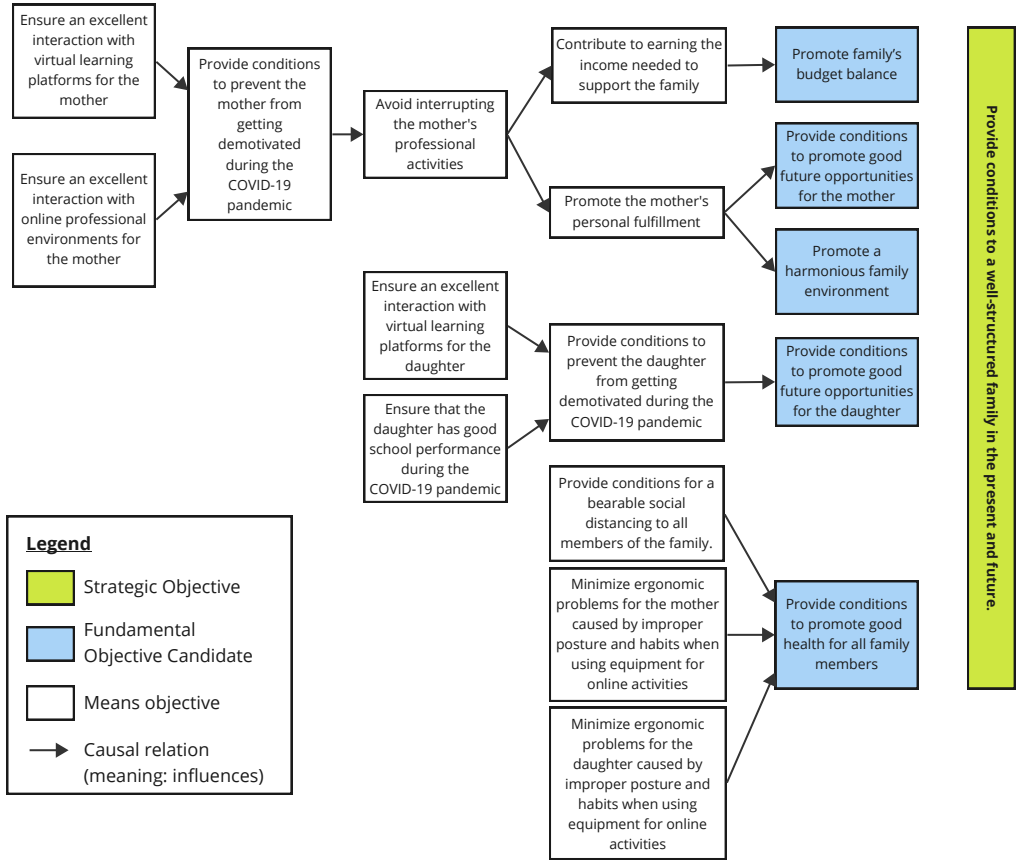


Figure 19 – Causal Relations Map - Personal Decision.

Source: The authors.

D.1.4 Define Decision Alternatives - Personal Decision

The list of decision alternatives for this example was simple: notebooks that were available on the market at the time of the decision (in 2020). After an online search in the internet, the family identified five notebooks with a value below the maximum limit (R\$4,000.00).

There were two sets of alternatives: (i) individual notebooks (five alternatives) and (ii) pairs of notebooks (20 possible alternatives). However, only one of the alternatives from the second set (with two notebooks) was feasible, i.e., below the limit of R\$4000.00. Therefore, there were six viable alternatives at the beginning of the decision: five with one notebook only and one with two notebooks. Then, following VFT's principle of identifying decision opportunities, one decision-maker (mother) proposed to violate the R\$4,000.00 limit to assess other combinations of notebooks. Thus, stakeholders agreed to exchange a slight increase in cost with the opportunity provided by a new set of alternatives that would become available. Hence, two new options

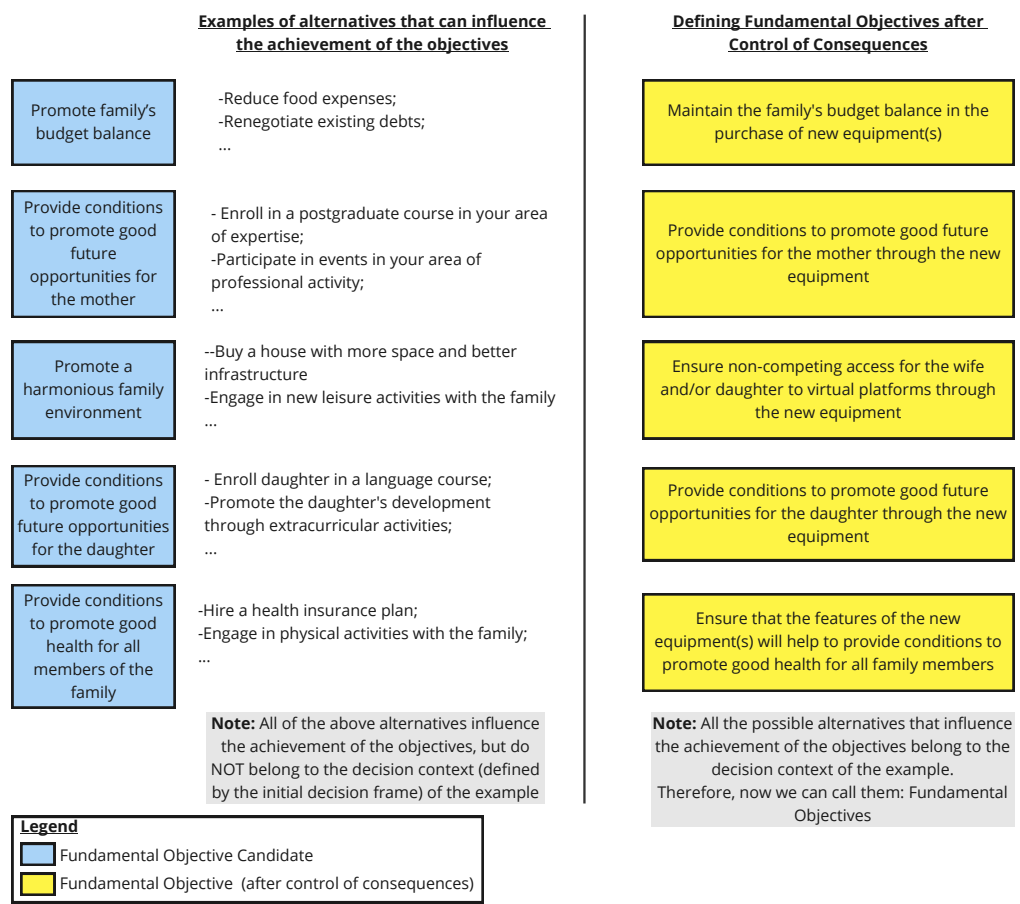


Figure 20 – Control of Consequences - Personal Decision.

Source: The authors.

with two notebooks became viable (this procedure corresponds to step “3.5-Identify alternatives proposed by stakeholder”, described in Section 3.4.

Afterward, the stakeholders (father, mother, and daughter) realized they could benefit from including tablets as an option for the decision problem. Thus, stakeholders considered two new alternatives that comprised one notebook and a tablet in the final set.

The focus of this paper is to present how VFT can help to identify objectives, attributes, and alternatives for decision problems. Therefore, this example doesn’t include preference modeling regarding intra-criteria evaluation, inter-criteria evaluation, and other steps regarding procedures to resolve decision problems (shown in Figure 2). Nevertheless, to illustrate the final result of this case, we highlight that the solution adopted and implemented was one of those generated as a decision opportunity, namely: one notebook and one tablet. This alternative fully met the prerequisites for the solution and was implemented successfully, benefiting the family as a whole.

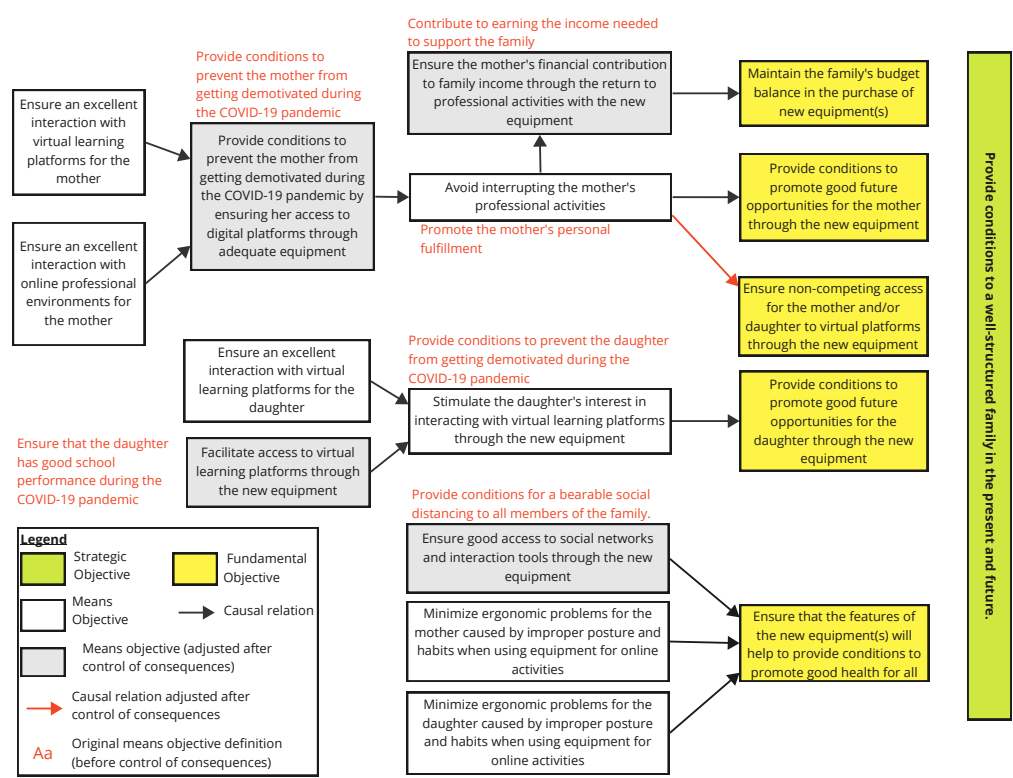


Figure 21 – Means-ends objective network - Personal Decision.

Source: The Authors.

At this point, a remark: in this example, the family explored decision opportunities before preference modeling and other steps of "VFT's Back-End" since the participants readily identified other options available.

Nevertheless, although it is not within the scope of this article, we must emphasize that the exploration of decision opportunities may be even more beneficial after evaluating the alternatives (step 9 of the procedure shown in Figure 2). At that point, analysts and decision-makers can explore other options by combining the original alternatives or creating new ones that allow more favorable results regarding the outcomes of the decision model. Furthermore, step "12-Implement Decision" of the procedure proposed by De Almeida (2013) (shown in figure 2) indicates that, whenever possible, one should procrastinate the decision to stimulate reflection about its outcomes and to enable a better analysis of the problem and identification of better decision opportunities.

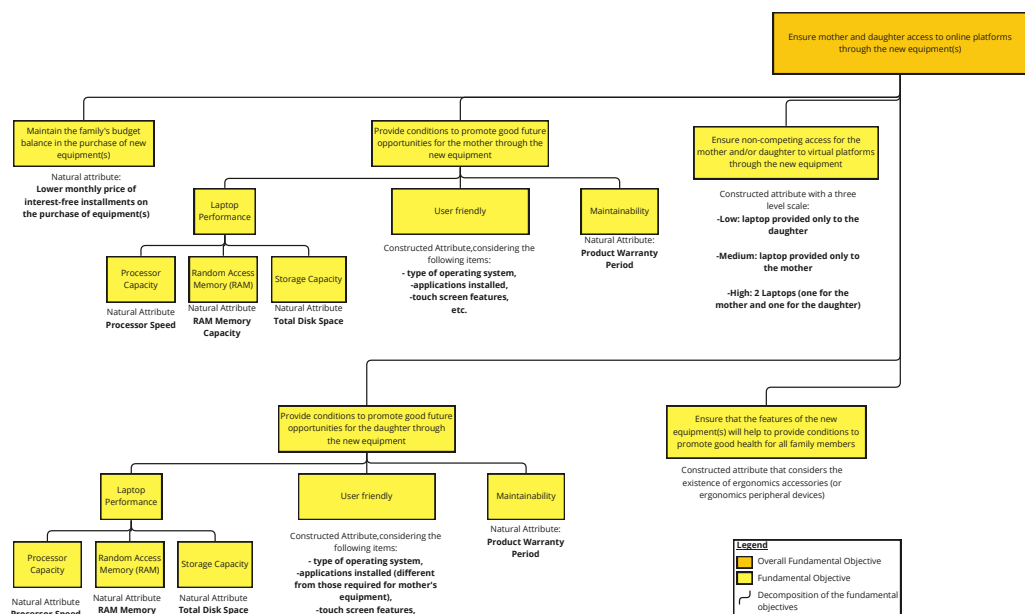


Figure 22 – Hierarchy of fundamental Objectives - family decision example.

Source: The Authors.

D.2 Organizational decision - Selection of a service provider to maintain the systems of an airport control tower

We depict this organizational example based on public information from a document named “Strategic Concept - Força Aérea 100”, which describes the strategic plan of the Brazilian Air Force (FAB) to adapt to the challenges it will have to face in 2041 (100th anniversary of the FAB). This document is public and available on the Internet (Brasil, 2018).

Although we did not interview the stakeholders that developed this plan (infeasible access due to their high seniority in BAF), we elicited the values and information for this example based on the publicly available documentation. This information enabled us to generate criteria and attributes considering a fictitious decision-making context.

D.2.1 Initial Decision Frame and Decision Statement - Organizational Decision

The purpose of the decision is “*Selection of a service provider to support and maintain the systems of a new airport control tower (TWR)*”. A TWR manages all aircraft traffic during take-off and landing. In other words, it is accountable for Air Traffic Control in Airports. TWRs are often also responsible for coordinating and controlling the movement of pedestrians, land vehicles, and aircraft on the ground (“*Ground Control (GND CTL)*”).

The perspective of the decision is: “*The decision must comply with the guidelines of the Brazilian Air Space Control Department (in Portuguese: Departamento de Controle do Espaço Aéreo Brasileiro - DECEA) and with the performance and safety criteria required by current legislation*”.

Regarding the scope of the decision, alternatives should include only service providers with a branch less than 50km from the new airport or those that ensure that they will meet this criterion before signing the contract. Additionally, the deadline for this decision is one year, which is the opening date of the new airport. Details regarding the profile of the company’s employees, service execution schedule, and other contractual elements are not part of this decision scope.

The initial decision frame for this example is shown in Figure 23.

Initial Decision Frame	
Purpose	Selection of a service provider to support and maintain the systems of a new airport control tower (TWR)
Perspective	The decision must comply with the guidelines of the Brazilian Air Space Control Department (in Portuguese: Departamento de Controle do Espaço Aéreo Brasileiro - DECEA) and with the performance and safety criteria required by current legislation
Scope (must consider "timeframe" defined by decision-maker(s))	<div>-Consider only service providers that have a branch less than 50km from the new airport or those that ensure that they will meet this criterion before signing the contract;</div> <div>-The deadline for this decision is one year, which is the opening date of the new airport;</div> <div>Out of Scope: Details regarding the profile of the company's employees, service execution schedule and other contractual elements are not part of this decision scope.</div>
Stakeholders' profile documentation (decision-makers and other participants)	<div>A representative of the Director of the Air Traffic Management Department (DECEA)</div> <div>Subject Matter Experts knowledgeable about the subsystems operated in a control tower (TWR)</div>

Figure 23 – Initial Decision Frame - Organizational Decision.

Source: The Authors.

The decision statement is: “*Decide which service provider to hire to support and maintain the systems of the new airport control tower (TWR) that complies with the guidelines of the Department of Airspace Control Brazilian (DECEA) and with the performance and safety criteria required by current legislation and respecting pre-defined criteria (up to one year for final decision and company branch less than 50 km from the new airport)*”.

D.2.2 Define Decision Objectives - Organizational Decision

We adopted the “Gold Standard” as the structured technique for qualitative value modeling. Therefore, we extracted objectives from FAB’s strategic documentation, i.e., from the “Strategic Concept - Air Force 100” (Brasil, 2018).

We did not intend to be exhaustive in the objectives elicitation for this example, as our goal was only to show an application example of the process proposed in Section 3 for an organizational decision.

Figure 24 presents the map of causal relations between objectives generated for this example. We adapted part of the original terminology usually applied by BAF and simplified some topics for a better understanding by the readers.

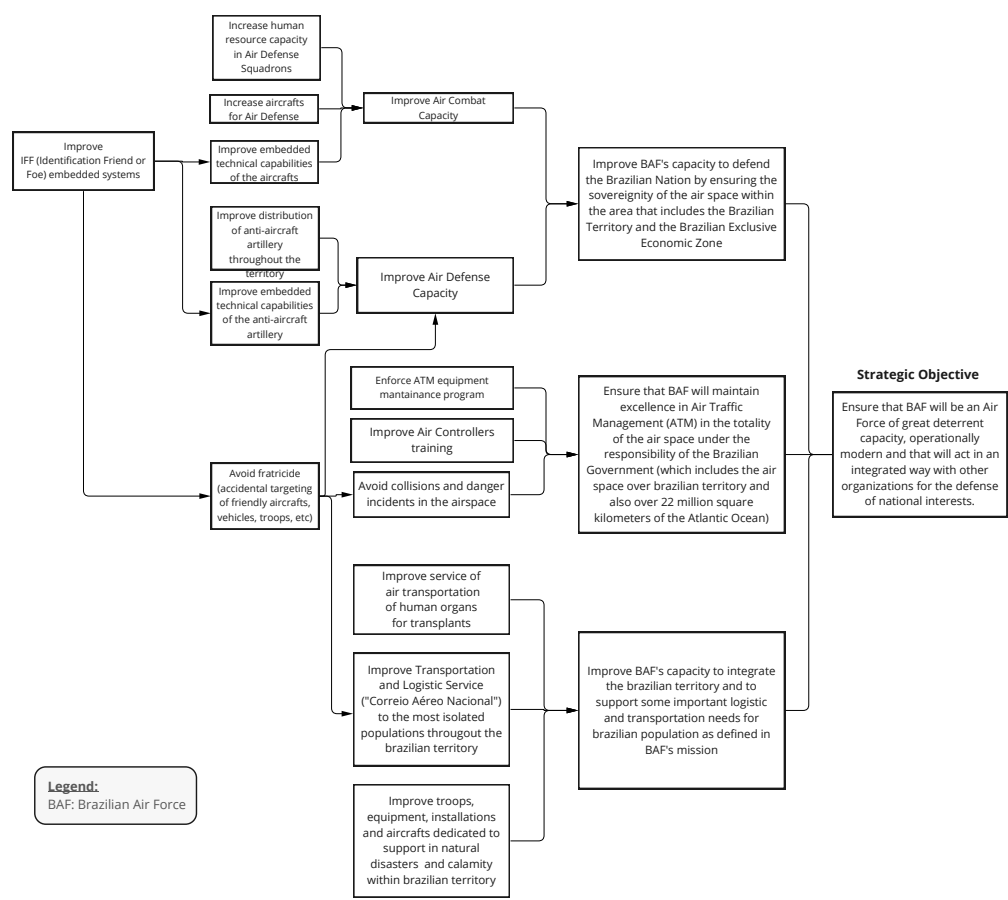


Figure 24 – Causal Relations Map - Organizational decision.

Source: The authors.

In the next step, we applied “Control of Consequences” (described in Section 3.3.15). Following the Control of Consequences step, we adjusted the means-ends objectives network according to the procedure described in Section 3.3.16. Therefore, we modified some means objectives in Figure 24 to ensure their adequacy to the initial decision frame. Figure 25 presents the results of these steps.

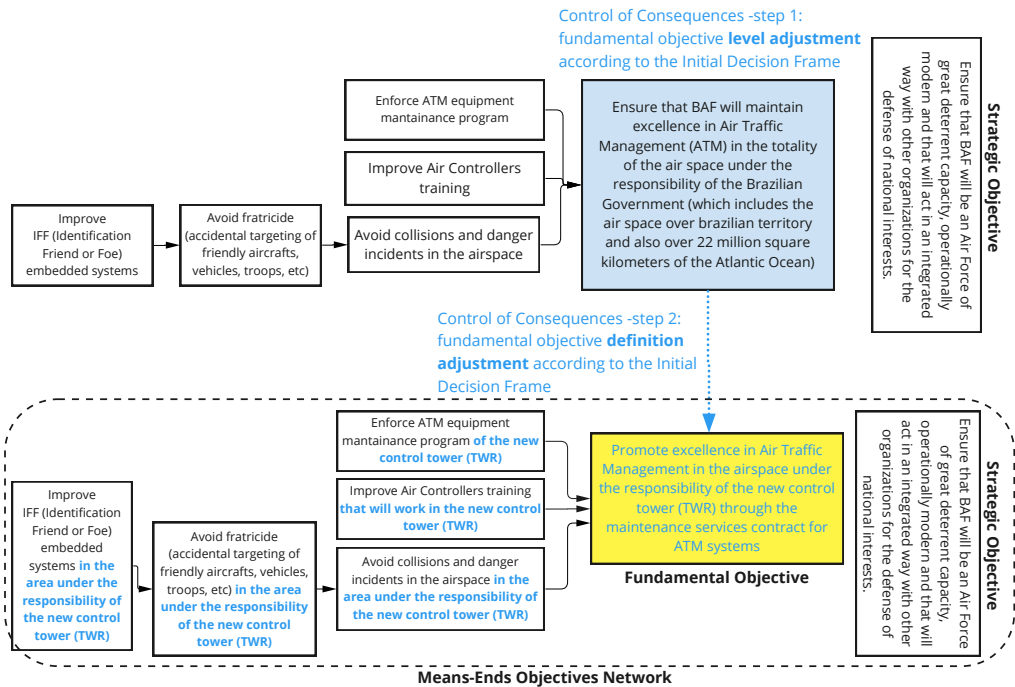


Figure 25 – Consequences' Control and means-end objective network - organization's decision example.

Source: The authors.

Finally, we decomposed the objectives to generate the fundamental objectives hierarchy and to identify the corresponding attributes according to the procedures described in Sections 3.3.17 and 3.3.18. Figure 26 presents the hierarchy of fundamental objectives for this example and the attributes defined for each objective in the last level of the hierarchy.

We highlight that the proposed attributes (indexes) do not have reference parameter values since the example depicts a decision regarding a new airport. Consequently, for this example, the analysis of a bid offer should compare the values for service parameters proposed by the company (reliability of its systems, training courses offered, among others) with the average performance for the same services in other equivalent airports already in operation.

Furthermore, Figure 26 presents a simplified hierarchy for this purpose. An actual bidding process for this type of service would possibly generate a more thorough structure with some other attributes. Nevertheless, the process described in Section 3 can guide analysts and decision-makers through all steps of those actual decisions.

D.2.3 Define Decision Alternatives Definition - Organizational Decision

The alternatives for this example are the companies that are candidates in the bidding to contract support and maintenance services for the TWR systems of the new airport.

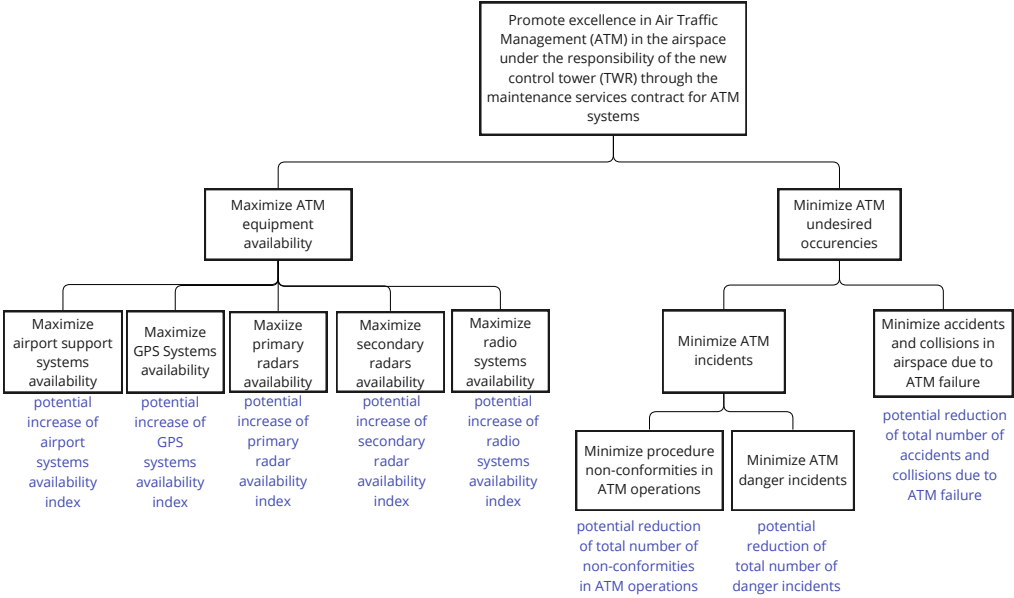


Figure 26 – Fundamental Objectives Hierarchy and Attributes - Organizational Decision.

Source: The authors.

The organization must generate a complete value model (which includes modeling intra and inter-criteria preferences) before executing the bid to contract the service. During the bidding, companies usually present their proposals to demonstrate that they satisfy minimum requirements. At this stage, it is worth considering whether there are decision opportunities. For instance: a company meets the defined criteria very well but eventually does not meet the prerequisite of having a branch 50km away (or less) from the new airport. In this case, analysts and decision-makers can evaluate whether it is feasible to modify this prerequisite to enable new alternatives to benefit the overall outcome of the decision process.

Therefore, in bidding processes of this type, the organization’s staff should define intermediate steps so that candidate companies can present their preliminary proposals. Hence, the organization’s personnel can explore decision opportunities before the final selection.

APPENDIX E CLASSIFICATION PROPOSED BY HOLT (2004) AND HECTOR ET AL. (2009) FOR NON-STRUCTURED PROBLEMS

Holt (2004) presents an approach focused on risk management and groups problems into four classes: “*tame problems*” (analogous to other authors), “*messes*”, “*wicked problems*” and “*wicked messes*”. Therefore, these authors differentiate “*messes*” from “*wicked problems*” and create a fourth class. Table 7 presents the main characteristics of the classification proposed by (Holt, 2004).

Table 7 – Classes of Problems: Disciplinary Involvement and Dialogue Characteristics.

Classes of Problems	Tame problems	Messes	Wicked Problems	Wicked Messes
Mission Characteristics	Ends or goals are prescribed or apparent	Ends and means are unknown at the outset, to a lesser or greater degree	End is never fixed, means always invoke qualitative judgements; variable methodology and epistemology	End is non-existent, variable epistemology and ontology. Plausible alternative solutions can always be found
Solution Features	Analytical or algorithmic solution	Iterative, pan-system and evolutionary	Trial and error; no final strategies; discipline from constant testing.	Holistic (structural and mental); revolutionary
Problem examples	Lexical ordering; Analytical geometry	Architecture; Epidemic control; Lean production; Migration patterns	Diversity policy; Psychometric testing	Urban design; Ecological management
Characteristics of the dialogue between stakeholders	Linear, self-referential	Explorative, non-linear, systems analysis	Explorative, non-linear, risk disposition analysis	Imaginative, often chaotic and rhetorical

Source: Adapted from Holt (2004).

Extending the original definition of “*wicked problem*” (Rittel & Webber, 1973), Hector et al. (2009) proposes a taxonomy to classify complex problems into three distinct types:

- **Type 1:** Problems solved by reductionist solution approaches or solutions based on systemic analysis. In these cases, one can apply well-known methods, such as mathematical modeling, computer simulation, and traditional engineering or scientific methods;
- **Type 2:** Problems that require a combination of reductionist, analytical, and different systemic approaches due to their systemic nature and complexity; and
- **Type 3:** Problems that limit the use of purely analytical techniques due to their uniqueness and complexity. These problems require the engagement of stakeholders with conflicting visions about the situation. Sometimes, there are irreconcilable differences in beliefs and values between stakeholders. Additionally, in these situations, stakeholders are eventually willing to impose their will coercively to achieve their own goals. The moral status of the

stakeholders can be hard to identify, and some may not be formally represented in the decision-making group (for instance, fauna affected in situations that require deforestation of a forest area).

According to Hector et al. (2009), sustainable development problems fall into the “Type 3” category. Much of the complexity of these problems derives from large amounts of information and conflicts of beliefs, values, interests, desires, worldviews, etc. Therefore, critical sense, ethics, and reasoning are necessary to deal with them.

Hector et al. (2009) also mentions that problem structuring approaches for “Type 3” must satisfy two requirements: (i) facilitate access to all information available; and (ii) structure the problem to consider the information coming from different dimensions (beliefs, interests, values, worldviews, etc.) in a critical approach toward its solution.