CHAPTER 1

INTEGRATED AND ADVANCED CORE FRAMEWORK FOR THE ANALYSIS AND EVALUATION OF TECHNOLOGICAL OBJECTS (FCIA-OT)

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ABSTRACT — This article presents the FCIA-OT Framework, developed as an advanced, systemic, and modular techno-scientific ontology, designed with formal grammar, projective language, and an architecture of analytical patterns to redefine the paradigms of analysis and evaluation of technological objects in high-complexity contexts. Structured around the Systemic Matrix of Integrated Vectorial Dimensions (MSDVI), composed of twelve functionally integrated dimensions and validated analytical vectors, the FCIA-OT operates as a third-order formalized system, in which each core functions as an interoperable, replicable, and actionable subsystem, capable of translating the techno-agential experience into auditable and normatively grounded evaluative constructs with epistemic rigor. Built upon the Agent-Technology Interaction (ATI) logic, the framework articulates functional, perceptual, affective, contextual, and operational variables through its continuous and transdisciplinary matrix, anchored in established foundations of usability engineering, cognitive modeling, and techno-epistemic interaction. Its structure enables a multivectorial reading of real usability, surpassing fragmentary or taxonomic approaches by integrating criticality, situated attributes, and normative criteria within a logic responsive to techno-functional transformations. The integration of the scalar and chromatic systems SPMI (Multidimensional Modular Integrated Scoring System) and SCDMIC (Modular Integrated System for Color Classification and Definition) into the dimensional matrix enhances its representational density, allowing for precise scalar evaluation and formal encoding of critical intensity and techno-functional adequacy of the vectors in each dimension. This analytical architecture, sustained by the MSDVI, positions the FCIA-OT as an epistemic device oriented toward technical action, capable of generating interoperable data applicable to processes of evaluation, auditing, regulation, certification, and project reconfiguration. Its modular logic ensures adaptability to distinct domains and granularities, structuring an integrated platform for the analysis, measurement, and representation of technological objects in emerging and high-complexity scenarios.

KEYWORDS — FCIA-OT; Ontology; Dimensional Matrix; Analytical Architecture; Evaluation; Usability; Interaction; Technological Objects; Auditing; Regulation; Certification.

1 INTRODUCTION

The growing sophistication of computational systems and the intensification of interactions between agents and technological objects have rendered obsolete the evaluative approaches based on simplified reductions of experience. The complexity of techno-agential interaction demands models capable of operating across multiple simultaneous dimensions, integrating analytical rigor, empirical validation, and real-world applicability. The agent's experience, as a dynamic field of both objective and subjective factors, requires frameworks that articulate observation and interpretation with methodological precision. Traditional models for usability and interaction evaluation reveal structural shortcomings by limiting themselves to isolated metrics or fragmented interface analysis.

Three principles formulated by Gould & Lewis (1985) anticipated part of these demands by emphasizing the centrality of a continuous focus on users and their tasks, the empirical measurement of interactions, and the adoption of iterative testing and adjustment cycles. However, much of today's approaches remain confined to simulations or experiments disconnected from real usage conditions. These limitations reinforce the urgency for an evaluative architecture capable of operating on situated data and multiple experiential vectors.

Smith & Mosier (1986), in systematizing fundamental parameters for interface design, highlight the importance of structural consistency, perceptible feedback to the user, and the prevention of operational errors. While essential, these elements prove insufficient in the face of contemporary technological density, which requires continuous operational adaptability and integration between the functional and contextual layers of interaction.

Methodological advancement in the analysis and evaluation of technological objects demands the formulation of hybrid, evidence-driven structures designed to enable an integrated reading of the agent's experience. Segmented approaches, by failing to capture the structural and situational complexity of usability in real environments, expose the need for a more comprehensive model. As a technical response to these limitations, this research proposes the Framework Core Integrado e Avançado para Análise e Avaliação de Objetos Tecnológicos (FCIA-OT) as a structured and advanced techno-scientific matrix, designed to redefine evaluative paradigms within the domain of usability and interaction. The framework is grounded in an iterative, articulated, and action-oriented methodological core, capable of integrating multiple dimensions of analysis with precision, applicability, and scientific consistency.

2 INTEGRATED AND ADVANCED CORE FRAMEWORK FOR THE ANALYSIS AND EVALUATION OF TECHNOLOGICAL OBJECTS (FCIA-OT)

The FCIA-OT constitutes a high-complexity analytical system, developed to structure the analysis and evaluation of technological objects through an integrated, technical, and systematic logic. It does not confine itself to point-based usability measurement but articulates an advanced model that combines objective and subjective variables, designed to interpret the agent's experience in a holistic and situated manner. Its architecture transcends approaches focused solely on the interface, offering an analytical matrix applicable to multiple contexts, phenomena, and complex constructs, from prototyping to real-world use.

The framework's architecture is grounded in a set of calibrated metrics, supported by principles of HCI and usability and interaction engineering, which together form a robust system for continuous evaluation. The model favors the structured identification of critical points without limiting itself to fault diagnosis, and it guides the development of evidence-based solutions. This dynamic ensures not only the traceability of collected data but also its operationalization within the design cycle, contributing directly to the functional and experiential evolution of the evaluated objects.

According to Wichansky (2000), the reliability of evaluative methods depends on the rigorous application of tasks, metrics, and scenarios defined by standardized protocols. The FCIA-OT incorporates this principle by establishing validated procedures aligned with methodological criteria that ensure the repeatability and precision of results. This structure eliminates common arbitrariness in exploratory evaluations, replacing empirical intuitions with traceable and replicable processes.

Expanding on this approach, Wixon (2003) observes that the impact of usability methods on development lies in their capacity to guide real improvements, not merely to identify flaws. This perspective is fully absorbed by the FCIA-OT, whose iterative approach allows empirical data to directly inform design decisions, sustaining a cycle of continuous and technically driven improvement.

In alignment with this, Dumas & Salzman (2006) argue that effective tests must isolate usability as a central variable, involve real users, employ critical tasks, capture multiple types of data, and translate them into practical recommendations. These foundations are integrated into the core of the FCIA-OT, whose methodological structure was designed to ensure adherence to these criteria across all phases, from task definition to the generation of technical reports.

In the domain of agent experience, Bargas-Avila & Hornbæk (2011) identify recurring limitations in studies that evaluate only one or two dimensions, thereby compromising analytical completeness. The FCIA-OT addresses this limitation by integrating cognitive, affective, operational, and contextual variables into its evaluation matrix, structuring a multiscalar reading of usability and interaction within complex systems.

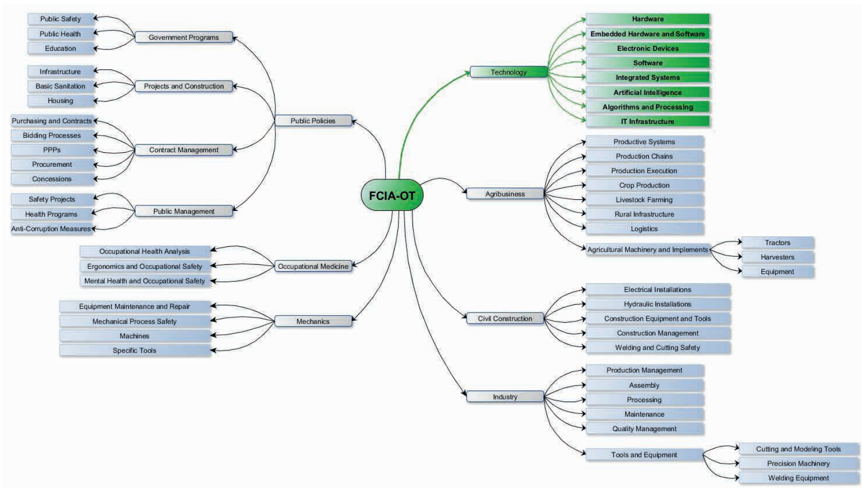
Wixon (2011) further observes that evaluations focused exclusively on objective measures fail to capture the essential subjective aspects of experience. The framework balances these two poles by articulating performance metrics with perceptual data, such as satisfaction and contextual appropriation, generating insights more attuned to the realities of use.

Methodological complexity is also addressed by Van Turnhout et al. (2014), who highlight the challenge of reconciling scientific rigor with practical relevance in HCI research. The FCIA-OT adopts a mixed, replicable, and iterative approach that bridges these two demands, operating as a model of translation between technical, scientific, and design domains.

Within this same scope, Weichbroth (2020) notes that the dispersion of evaluative attributes and the absence of consolidated models compromise the validity of results. The FCIA-OT presents itself as a structured response to this issue by systematizing a stable set of dimensions, theoretically grounded and designed for replicable applications without relying on arbitrary categories.

At its core, the FCIA-OT systematizes the process of analysis and evaluation based on rigorous techno-scientific criteria, integrating empirical observation, iterative validation, and practical application. By organizing actionable data, the framework enables teams to generate targeted solutions, surpassing prescriptive or disjointed approaches. Its methodology distances itself from experimental models centered on physiological measurements, prioritizing a situated, replicable analysis anchored in real-world use. Figure 1 presents a mind map summarizing some of the thematic areas encompassed by the FCIA-OT, highlighting the technology module employed in this study for presenting the integrated and advanced matrix with its core components.

FIGURE 1: SUMMARY MIND MAP OF THE FCIA-OT



Source: Author.

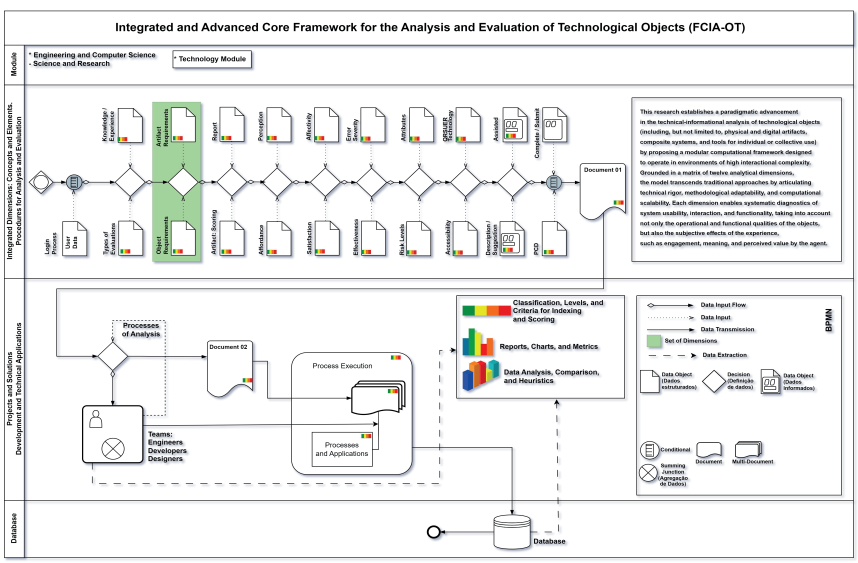
2.1 Guidelines: Technical Procedures in the FCIA-OT

The methodological formulation of the FCIA-OT responds critically to the limitations observed in traditional usability evaluation models, which are often reduced to isolated tasks, disconnected measurements, and scenarios detached from real-world usage conditions. As noted by Hornbæk (2006), evaluations focused solely on elementary metrics fail to capture the complexity of the cognitive and social interactions involved in the agent's experience. In contrast, the FCIA-OT integrates multiple contexts, scales, and levels of complexity, operating under a techno-scientific logic oriented toward real-world application.

Law et al. (2009a) emphasize that anticipating the user experience in the early stages of development is essential for producing artifacts that are more responsive and aligned with the agents' expectations. The FCIA-OT incorporates this guideline by enabling evaluations with or without fully functional systems, allowing for robust inferences based on advanced simulations and interactive prototypes. This approach strengthens technical decision-making prior to product consolidation, promoting resource efficiency and enhancing design quality.

Complementarily, Vermeeren et al. (2010) point out that in-depth experience evaluations require insertion into real environments and methodologies that respect the participants' routines. The FCIA-OT operationalizes this requirement by articulating laboratory and field procedures within a continuous, sensitive, and non-intrusive structure. This strategy balances analytical depth with practical feasibility, promoting greater data reliability and situational alignment. Figure 2 presents the FCIA-OT technical flowchart, which synthesizes the sequence of the applied methodological stages. This representation functions as a procedural reading tool, facilitating the visualization of the application logic and the unfolding of the framework's analytical activities.

FIGURE 2: FLOWCHART – INTEGRATED AND ADVANCED CORE FRAMEWORK FOR TECHNOLOGICAL OBJECTS ANALYSIS AND ASSESSMENT (FCIA-OT)



Source: Author.

The procedural sequence illustrated in Figure 2 is detailed in Table 1, which presents the technical-scientific procedures that constitute the operational core of the FCIA-OT. Each stage is described with methodological precision, indicating its specific functions, analytical objectives, and expected outcomes. This table serves as a reference tool for understanding the internal operations of the framework, organizing the process from data collection to the systematization of metrics and the issuance of assessment reports.

The stages are arranged sequentially and cumulatively, ensuring systematic execution and traceability of procedures. Each phase was designed to preserve methodological consistency and scientific validity, respecting the complexity of the integrated dimensions. The technical detailing reinforces the robustness of the matrix, demonstrating its capacity to generate applicable and replicable data for the evaluation of technological objects under real usage conditions.

TABLE 1: TECHNICAL PROCEDURES OF THE FCIA-OT

Stage	Scientific and Technical Description	Objectives	Expected Outcome
1. Agent Identification	**Collection of the agent's code, name, sex, disability status, and other personal data,** aiming to individualize both the agent and each analysis instance through the association with a unique identifier.	Ensure traceability and personalization of the analysis.	Agent identified for future reference and behavioral analyses.
2. Identification of the Type of Analysis and Assessment	**Definition of the type of Analysis and Assessment.** Analysis and Assessment (final agent); Assisted Analysis and Assessment (technical agent, specialist, engineer); Technical Report (engineer agent).	Accurately classify the scope, nature, and objective of the analytical and systemic investigation.	Analysis and Assessment qualified by level, nature, and comparative purpose.
3. Selection of the Agent's Knowledge Level	**Identification of the agent's level of knowledge and experience,** assigning a corresponding score. This classification directly influences the analysis and assessment.	Accurately classify the agent to align analyses and assessments with their competencies.	Score assigned based on the agent's knowledge level, accurately qualifying the scope and depth of the analysis and assessment of the technological object.
4. Identification of the Object Type	**Identification of the object to be analyzed,** using the Object Requirements. Identifies its core features, such as hardware, software, among others.	Define the object's fundamental properties to guide the subsequent analysis.	Object classified with its main properties defined.

5. Identification of the Object's Artifact and Artifact Scoring	**Identification and assessment of the artifacts associated with the object,** using the Object Artifact Requirements. Covers elements such as components, parts, interface, processes, among others.	Evaluate the object's critical components that impact the agent's experience.	Object artifacts identified, analyzed, and scored. Comparative analysis.
6. Description of the Report	**Concise record of the report** associated with the object's artifact, highlighting critical information from the analysis.	Characterize the object's artifact based on the information defined in the report.	Artifact identification described. Subsequent analysis.
7. Selection of the Affordance	**Identification of the affordance selected by the agent,** categorized by level, influencing the evaluation of interaction with the object.	Map how the agent perceives and interacts with the object's affordances, impacting the agent's experience.	Affordance identified, categorized, and scored. Subsequent analysis.
8. Selection of the Perception	**Assessment of the agent's perception and response,** considering how they interpret and react to the object's affordances. Impacts the analysis and assessment.	Understand the agent's emotional and cognitive responses to the affordances. Impacts the agent's experience.	Perception identified, categorized, and scored. Subsequent analysis.
9. Affective Selection	**Assessment of the agent's affectivity toward the object.** This stage evaluates the degree of pleasure or discomfort associated with the interaction. It impacts the analysis and evaluation process.	To quantify and understand the emotional impact of the interaction. It influences the agent's experience.	Affectivity identified, classified, and scored. Comparative analysis.
10. Agent Satisfaction Selection	**Identification of the agent's satisfaction with the object,** measuring the quality of the experience with the object's artifact. It affects the analysis and evaluation.	To quantify satisfaction and identify areas for improvement. It influences the agent's experience.	Agent satisfaction recorded for future reference. Scored. Subsequent analysis.
11. Effectiveness Selection	**Qualification of the effectiveness as perceived by the agent.** This evaluates the success of the object's artifact in fulfilling its intended purposes. It affects the analysis and evaluation.	To assess the success of the interaction between the agent and the object's artifact. It influences the agent's experience.	Effectiveness identified, categorized, and scored. Comparative analysis.
12. Error Severity Identification	**Evaluation and categorization of the severity of errors** identified during interaction with the object's artifact, using a predefined severity scale. It affects the analysis and evaluation.	To identify the magnitude of usability issues and their impacts. It influences the agent's experience.	Error severity identified and defined. Scored. Subsequent analysis.

13. Risk Level Identification	**Determination of risks** associated with the object's artifact, classifying them in terms of the potential impact and extent of each risk. It affects the analysis and evaluation.	To determine the magnitude and assess the criticality of risks in order to prioritize corrections and understand their impacts. It influences the agent's experience.	Risk levels identified and categorized. Scored. Subsequent analysis.
14. Identification of Attributes for the Object's Artifact and Scoring of Attributes	**Identification and evaluation of the attributes and descriptors associated with the object's artifact,** based on the Object Attributes framework. It determines the artifact's scope. It affects the analysis and evaluation.	To determine the scope of the artifact in relation to its attributes. It influences the agent's experience.	Attributes identified, analyzed, and scored. Comparative analysis.
15. Identification of Accessibility for the Object's Artifact and Scoring of Accessibility Criteria	**Identification and evaluation of Accessibility criteria applicable to the object's artifact,** using defined elements (criteria). It affects the analysis and evaluation.	To determine the scope of the artifact with respect to each Accessibility criterion. It influences the agent's experience.	Accessibility criteria identified, analyzed, and scored. Comparative analysis.
16. Identification of QRSUER Technology for the Object's Artifact and Scoring of QRSUER Criteria	**Identification and evaluation of QRSUER Technology criteria applicable to the object's artifact,** based on specific elements (criteria). It impacts the analysis and evaluation.	To determine the scope of the artifact in relation to each QRSUER Technology criterion. It influences the agent's experience.	QRSUER Technology criteria identified, analyzed, and scored. Comparative analysis.
17. Collection of Descriptions and Suggestions	**Recording of the agent's descriptions, suggestions, and feedback,** enabling qualitative insights into the interaction with the object.	To capture direct feedback to guide improvements.	Descriptions and suggestions documented for review and analysis. Comparative analysis.
18. Collection of Assisted Analysis	**Recording of descriptions and data from assisted analysis.** A professional observes end agents, whether with disabilities or not, in specific testing environments or real-use scenarios, registering additional observations on the object's use.	To ensure inclusion and precision in assisted analyses, and determine whether it qualifies as a Technical Report.	Additional data collected and documented. Comparative analysis or classified as a Technical Report.
19. Generation of Document 1	**Consolidation of all collected data into a structured document** (Document 1), containing all information from the analysis and evaluation.	To create a solid data foundation for subsequent analysis by developers and manufacturers.	Document 1 generated, containing complete and structured information.

20. Analysis by Developers	**Receipt and analysis of Document 1 by manufacturers, developers, designers, and engineers,** who discuss solutions for the identified issues.	To identify and define technical solutions to improve the object.	Document 1 analyzed and initial solutions proposed.
21. Discussion and Approval of Solutions	**Validation of the proposed solutions,** formalizing decisions in a new document **(Document 2).**	To formalize the solutions to be implemented.	Document 2 generated, containing structured and approved solutions.
22. Implementation of Solutions	**Execution of modifications and improvements to the technological object,** in accordance with the procedures defined in Document 2.	To update the object according to the agreed specifications.	Object updated and enhanced.
23. Data Storage	**Recording and storage of the implemented data** and solutions in a database.	To ensure the availability of information for future analyses.	Data stored and ready for continuous and evolutionary analysis.
24. Analysis and Reporting	**Generation of reports and charts** based on the stored data, enabling detailed analyses.	To provide structured information from the analyses and evaluations of technological objects.	Reports generated, supporting advanced analysis and decision-making.

Source: Author.

The analysis of technological objects from the FCIA-OT perspective requires the adoption of a systemic logic, grounded in strict scientific and technical criteria. The framework does not operate as a passive system for organizing data, but rather as an Advanced System for Structured Information Management, capable of processing, classifying, and redistributing data based on logical interconnections and methodological cores.

The central proposition of FCIA-OT is to structure an application-oriented scientific investigation, in which interdependent dimensions of usability and interaction are articulated with precision. The analytical model adopted enables the understanding of how cognitive, operational, and affective variables influence the adequacy of technological objects to the agents' demands and the context of use, providing concrete inputs for design decisions in complex environments.

Grounded in a consolidated theoretical-methodological foundation, FCIA-OT integrates scientific rigor and technical innovation. Its core unites theory, practice, and technique in a replicable, situated analysis system, applicable to diverse realities. This structure contributes to decoding the complexity of technological systems, fostering concrete advancements in evaluative and design practices within the field of usability and interaction.

Although originally designed for specific technological environments, FCIA-OT presents a high degree of flexibility. Its adaptable architecture allows application across multiple domains and systemic configurations, without compromising analytical precision. This adaptability makes the framework a strategic tool for fostering sustained improvements in design, analysis, and development processes across various fields.

2.2 Guidelines: Integrated Scientific-Technical Cores

The development of robust guidelines for evaluation in HCI remains a persistent challenge. Seffah et al. (2006) point out that available usability models lack consistent definitions, methodological integration, and adequate computational support. The absence of clear links between criteria and evaluative factors often leads to the adoption of ad hoc empirical practices, driven by familiarity rather than technical precision. This gap, marked by the lack of systemic rigor, highlights the urgency of a consolidated architecture capable of reducing operational costs, optimizing communication among experts, and establishing replicable guidelines grounded in technical principles and scientific validity.

In response to these deficiencies, FCIA-OT structures its functional core through the Integrated Scientific-Technical Cores: specialized units that operate as the analytical engines of the framework. In this context, the term Core refers to the central logic of the system, a modular, scalable core driven by scientific and technical criteria, designed to articulate data, contexts, and variables in high-precision evaluations. This advanced information-processing system transcends fragmented or merely descriptive models.

Each Core represents a functional unit within the Systemic Matrix of Integrated Vectorial Dimensions (MSDVI), which comprises twelve dimensions designed to analyze operational, affective, cognitive, technical, and contextual aspects. These units are organized into independent analytical modules that can be activated according to the nature of the object under evaluation. This modularity enables tailored configurations, fostering interoperability among the Cores and ensuring full adaptability to the demands of diverse and constantly evolving environments.

This structure extends beyond functional organization; it enhances the integration of analytical dimensions through a high-granularity computational logic capable of capturing cross-relations between criteria and enabling interdependent analyses. Each Core is grounded in its own scientific foundation, anchored in technical standards, specialized literature, and consolidated methodologies in usability engineering and computer science. This foundation ensures methodological validity, replicable reliability, and alignment with international standards.

Unlike rigid or static models, the Cores of the FCIA-OT are both structured and dynamic. They allow modular updates, the inclusion of new criteria, reconfigurations, and adaptations without compromising methodological consistency. This characteristic positions them as analytical engineering guidelines, with simultaneously calibrated scientific and practical applicability.

The operational logic of the Cores is supported by structured information management mechanisms, optimizing every stage from data collection to the generation of precise and actionable diagnostics. These mechanisms transform raw data into manageable analytical structures, fostering a clear, traceable informational base oriented toward technical decision-making.

As a set, the Cores are consolidated as strategic components of the FCIA-OT, articulating technical rigor with systemic flexibility. Their operational standardization enables not only the scalability of the framework but also its application across various domains, including laboratory settings, field environments, and complex digital ecosystems. Within this scope, the concept of the Core System encapsulates the idea of a nucleus designed to function as the logical and functional center of the framework, responsible for organizing and guiding the analytical processes under high, consistent methodological standards applicable to various types of technological objects.

3 GUIDELINES: INTEGRATED TECHNICAL-SCIENTIFIC DIMENSIONS

The integrated technical-scientific dimensions of the FCIA-OT constitute the operational foundations that support high-precision analyses, methodological rigor, and technical-informational adherence. They are elevated to specialized computational structures, surpassing disciplinary boundaries and forming a unified, adaptable, and replicable analytical systemic matrix. Each dimension was designed based on robust theoretical and practical foundations, drawn from a systematic review of the specialized literature and internationally recognized technical-normative guidelines. Their construction ensures that each dimensional core contributes synergistically to the framework's robustness, reliability, and interpretive reach.

Within the FCIA-OT scope, the dimensions operate as structuring axes that organize critical variables of the technical-scientific analysis of technological objects, whether physical, digital, or hybrid. Each one encapsulates specific sets of criteria, organized to respond to distinct evaluative constructs. Their modularity allows for selective activation according to analytical requirements, adapting to the evaluation's objectives without compromising the system's structural coherence.

Unlike aggregative arrangements or disjointed collections, these dimensions operate in a network, integrated by a computational logic that synchronizes their criteria and enables interdependent inferences. This structure reinforces the internal consistency of analyses and ensures methodological adaptability across different technical and operational contexts.

The dimensions cover central domains such as usability, interaction, accessibility, efficiency, security, and contextual impact. They were constructed under a technical-scientific rigor aimed at articulating specific criteria with systemic effects, enabling the FCIA-OT to function as a high-complexity, high-precision evaluative matrix. The twelve integrated dimensions are presented below in a methodical manner, with an exposition of their theoretical foundations, technical criteria, and structural roles within the framework system.

3.1 Knowledge/Experience Dimension (CEX)

The Knowledge/Experience Dimension (Dimensão Conhecimentos/Experiências – CEX) structures the levels of mastery mobilized by the agent when interacting with a technological object, translating operational, cognitive, and situational repertoires into classifiable technical gradients. This dimension goes beyond performance assessments, encompassing the historicity of the agent's relationship with the technology, the nature of appropriation, and the complexity of the perceptual, interpretive, and operative mechanisms involved in technical action.

By integrating variables such as sociotechnical repertoire, learning styles, accumulated exposure, contextual motivations, and cognitive structures, CEX enables a systematic reading of interaction that transcends reductions centered on mere functional competence. The agent's experience is interpreted as a dynamic and interdependent phenomenon, composed of sensorimotor states, pragmatic meanings, affective dispositions, and symbolic interpretations modulated over time through use.

The literature highlights the necessity of this expanded approach. Gould & Lewis (1985) point out that underestimating the cognitive diversity of users undermines the accuracy of design decisions, especially when based on unvalidated assumptions. Aykin (1989) reinforces that individual characteristics directly influence performance and operational preferences, while Kanis (1998) demonstrates that accumulated actions throughout interaction decisively affect the system's perceived functionality. Hassenzahl (2003) deepens this point by emphasizing the subjective, mutable, and psychologically dense nature of technological experience.

Forlizzi & Battarbee (2004) propose a distinction between fluent, cognitive, and narrative experiences, emphasizing that each operates in a specific manner in shaping interaction. This classification broadens the analytical scope, enabling the framework to identify how the agent engages with the system—whether automatically, reflectively, or symbolically. Dumas & Salzman (2006) reiterate that user experience results from a combination of functional and emotional factors, influenced by context, expectations, and feedback, which reinforces the complexity of the phenomenon to be assessed.

Naumann et al. (2007) contribute by elucidating the activation mechanisms of tacit and non-conscious knowledge, which often guide action without being verbalized. These mechanisms are essential to understanding agent behavior in operational situations where tacit knowledge prevails over conscious rationalization.

In this same domain of agent experience, Alshamari & Mayhew (2008) underscore the importance of accounting for user diversity during testing, showing that different repertoires directly influence the types of problems encountered and performance indicators. The CEX dimension internalizes this premise by expanding the analytical criteria to encompass heterogeneity, trajectories, and technological appropriation patterns. Janlert & Stolterman (2010) distinguish between the internal complexity of the artifact and its interface, allowing one to understand how the structural distribution of complexity affects perception and performance in action.

According to Wixon (2011), although measurements of subjective experiences are imperfect, they are essential for promoting meaningful evaluations. The objectification of subjective states, such as trust and fluency, is not only feasible but also enhances design quality, provided it is carried out using valid criteria and appropriate instruments.

Building upon this foundation, Burlamaqui & Dong (2015) systematize the role of knowledge as an accumulation of experiences, beliefs, and culture. In the human context, these cognitive layers are mobilized during interaction with artifacts, informing decisions, expectations, and interpretations. This approach is incorporated into CEX as a transversal axis, capable of qualifying all other dimensions of the FCIA-OT.

The Knowledge/Experience Dimension, therefore, does not merely describe the agent's level of familiarity with the technology but interprets their technical-cognitive trajectory, modes of appropriation, and engagement patterns that guide situated action. The coherence between the agent's mental models and the system's operational models constitutes a critical variable for action fluency. CEX enables the mapping of such dissonances by classifying the agent's degree of technical-operational mastery across ten hierarchical levels, organized into a scoring system (CEX10 to CEX01) using SPMI scoring and the SCDMIC chromatic and semantic codification. Table 2 presents the formatted knowledge/experience levels and the definitions related to the agent.

TABLE 2: DEFINITION OF KNOWLEDGE/EXPERIENCE (CEX) LEVELS

Code	Knowledge/ Experience Levels	Definition	SPMI
CEX10	Beginner	Introductory knowledge of technologies. Ability to recognize, power on/off, or operate elementary functions of a technological object with external guidance. (Beginner).	10
CEX09	Basic Operator	Ability to use routine operational functions in specific technologies (digital or physical), such as operating equipment, basic tools, or performing simple normative tasks. (Basic).	9
CEX08	Functional Agent	Ability to operate and configure standard functions of technological objects, understand modes of operation, and handle devices autonomously in predictable contexts. (Intermediate).	8
CEX07	Operational Technician	Competence in diagnosing failures, performing intermediate technical configurations, adapting usage across different contexts, and handling model or version variations. (Technical Intermediate).	7
CEX06	Advanced Technician I	Knowledge of technical fundamentals for operation, maintenance, and reconfiguration of technological objects. Skilled in parameterization, testing, and controlled interventions. (Advanced I).	6
CEX05	Advanced Technician II	Ability to integrate technologies, automate tasks, develop structured modifications, and adapt physical or digital components to contextual requirements. (Advanced II).	5
CEX04	Integration Specialist	Mastery over multiple converging technologies. Performs complex interventions, promotes systemic compatibility, and develops advanced solutions and adaptations. (Advanced III).	4
CEX03	Technological Architecture Specialist	Ability to design, develop, and maintain complex technological objects or systems, whether physical or computational, with full command of their life cycles and applications. (Advanced IV).	3
CEX02	Systemic Professional	Operates at a high level of complexity in advanced technologies, develops interdisciplinary solutions, and masters theoretical and operational foundations of various classes of objects. (Advanced V).	2
CEX01	Strategic/ Developer Level	Acts as designer, engineer, researcher, or creator of the technology. Critically evaluates their own objects and frameworks, validating properties and functionalities through structured heuristics. (Advanced VI).	1

The CEX dimension structures, in hierarchical order, the levels of mastery that an agent may demonstrate when facing any technological object, be it a product, service, interface, process, tool, or system. Each level (CEX10 to CEX01) describes the progression of the agent's capacity to recognize, operate, modify, integrate, or design technologies, incorporating cognitive, operational, and situational competencies. These levels are linked to a scoring system that associates codes and colors based on the degree of complexity and maturity of the object, through chromatic standardization. CEX is a transversal dimension of the FCIA-OT, directly qualifying the other 11 dimensions and enabling cross-analysis across different agent profiles and evaluated technologies.

Source: Author.

CEX formalizes a technical-scientific model for experience assessment, grounded in empirical evidence, replicable, and anchored in principles of interaction engineering, cognitive ergonomics, and behavioral science. Its transversality within the FCIA-OT makes it a qualifying axis of the integrated matrix, structuring the evaluation according to criteria of technological maturity, interpretive complexity, and functional adaptation.

3.2 Affordance Dimension (AFF)

Affordance Dimension (Dimensão Affordance – AFF) constitutes the invisible articulation between the materiality of the technological object and the interpretative capacity of the agent, whether human, artificial, or hybrid. It is not a static or intrinsic property, but rather an inferential circuit that emerges from the convergence of three vectors: the operational morphology of the object (what can be done), the historical repertoire of the agent (what has already been learned), and the contingent demand of the environment (what needs to be done).

From this relational structure, inferable patterns of action emerge, either evident or latent, which may be codified, induced, or interpreted, thereby influencing action directly or in mediated form. Affordance, therefore, is not an isolated attribute of the object, but an interrelational vector that regulates the intelligibility of action. When this vector stabilizes within the relationship between agent and artifact, through perceptual recurrence (as in the recognition of a button), consolidated training (such as the operation of a control system), or systematic decoding (such as algorithmic reading of visual patterns), an operational fluency is established in which the interface becomes invisible.

This research treats Affordance as a technical-informational dimension of analysis, structured upon principles of distributed cognition, semiotic engineering, and adaptive systems. The proposal advances by constructing a technical taxonomy grounded in formal inferences concerning clarity, risk, and required learning load, aiming not only at classification but also at enabling its measurement, simulation, and diagnostic application across multiple domains.

The original conception of affordance, formulated by Gibson (1979), is based on the notion of properties directly perceivable by the agent, environmental structures that reveal their action possibilities without the need for elaborated cognitive mediation. These configurations, described as relational invariants, are articulated through ecological perception, allowing the agent to identify opportunities for use solely based on the functional relation between their capacities and the characteristics of the object.

The scientific-technical understanding of Affordance thus requires recognizing that its manifestation is neither universal nor homogeneous. Perceptual variations, differences in expertise, cultural divergences, and inadequate codifications directly affect the clarity of interaction. Norman (1988) warns that when users are confronted with unfamiliar objects, they seek visual cues or external instructions to interpret their uses. When such cues are poorly designed, illusory affordances emerge, prone to error.

This vulnerability is also emphasized by Gaver (1991), who distinguishes between affordance itself and the information that renders it perceivable: there are cases in which the appropriate action is directly perceived, but also situations in which the object induces misguided attempts. He also introduces the notion of sequential affordance, wherein interaction reveals opportunities for action not initially perceptible. Action, therefore, becomes not only a consequence of perception but also its catalyst.

In the field of graphic and digital design, Norman (1999) reformulates the original notion by differentiating real affordances, tied to physical structures, from perceived affordances, which operate through user conventions and beliefs. In symbolic contexts, the challenge lies not in the physical existence of functionality, but in the ability to induce its correct reading. The failure to communicate this reading results in absent or false affordances, demanding greater design investment in cultural cues, visual feedback, and linguistic consistency.

The gradualist perspective proposed by McGrenere & Ho (2000) expands on this rationale by proposing that affordances should be treated as a continuum, varying in clarity and effectiveness. This continuum is affected by sensory codification, functional coherence, and the agent's degree of familiarity. At one end are consolidated affordances; at the other, latent, ambiguous, or unrecognized ones.

The theory of micro-affordances, introduced by Ellis & Tucker (2000), reinforces the role of automatic perception. Even without conscious intent, certain objects activate implicit motor dispositions. These activations are structured by neural patterns that integrate visual properties with associated action schemas, and they can either facilitate or distort interpretation.

Complementing this perceptual perspective, Hassenzahl (2003) introduces the concept of product character as a cognitive abstraction that synthesizes functional and emotional attributes, directly influencing the agent's initial interpretation. This construct unfolds in two stages: first, through the objective perception of pragmatic attributes related to operability; then, through a subjective elaboration of character, modulated by hedonic and contextual aspects. The clarity of these pragmatic attributes reinforces the alignment between structure and expected action, being decisive for the emergence of consolidated affordances, where the designed functionality coincides with the perceived and effectively executed function.

In an effort toward formalization, Hartson (2003) distinguishes four categories: cognitive, physical, sensory, and functional. Cognitive affordances operate by inference; physical ones by tangible structure; sensory affordances by perceptible evidence; and functional ones through direct relation between function and usability. This categorization reveals that an affordance is not limited to what can be done, but also to how that possibility is perceived and executed.

From an inferential standpoint, Brown & Blessing (2005) argue that affordances can be learned or analogically deduced from previous experiences. Turner (2005), in turn, suggests that although the concept is theoretically simple, its practical application requires distinctions between directly perceptible structures and more complex historical compositions shaped by conventions and patterns of use.

Zhang & Patel (2006) systematize this discussion by treating affordances as the result of interaction between external structures and internal representations, classifying them as biological, physical, cognitive, and mixed. This classification reinforces the idea that affordances are emergent properties, always conditioned by an ecosystem of relations.

In alignment with this view, Vyas, Chisalita, & van der Veer (2006) suggest that clear affordances provide unequivocal information, while unclear affordances lead to multiple interpretations. You & Chen (2007) advance the discussion by distinguishing between directly perceivable affordances and those dependent on symbols or conventions. The former are triggered by physical attributes; the latter rely on cognitive processes shaped by culture and conceptual repertoire.

For Maier & Fadel (2008), affordances are expressions of the complementarity between artifact and agent and cannot be assessed in binary terms. Their diagnosis requires gradated analysis, since an affordance is only actualized when the agent recognizes it as such within a given operational context.

This perceptual contingency is revisited by Still (2009), who reformulates the concept from a cognitive perspective, emphasizing the relationship between consistency, constraint, and predictability. He argues that effective affordances emerge from systems whose functional logic is transparent and coherent with the agent's mental model.

Kaptelinin & Nardi (2012) introduce the distinction between handling and effect affordances, emphasizing that integration between the two is essential for the technical operation of complex systems. Kannengiesser & Gero (2012) further develop this reasoning, proposing three levels of affordance, reflective, reactive, and reflexive, which correspond to different degrees of awareness and adaptation.

When addressing computational affordances, Burlamaqui & Dong (2015) argue that they are not absolute, but design-calibrated. An effective affordance requires that both the behavior and structure of the artifact be simultaneously recognizable; otherwise, misinterpretation may occur. A similar concern is raised by Abhari, Davidson, & Xiao (2016), who point out that collaborative affordances shape action within digital and sociotechnical environments, functioning as co-creation devices.

In the domain of mental actions, McClelland (2019) proposes that cognitive affordances also play a role in the selection of thoughts, intentions, or decision strategies. These affordances operate on abstract planes but follow the same logic: the interaction among stimulus, context, and possible action. Within these conceptual parameters, Scarlett & Zeilinger (2019) emphasize that multiple computational affordances may operate even without direct evidence, highlighting the need to reconceptualize the affordance concept in light of algorithmic enactment.

This rich and multifaceted theoretical foundation underpins the proposal presented in this Affordance Dimension. It not only systematizes these findings but translates them into a technically inferential structure. Table 3 presents the defined types of affordances, along with their respective descriptions, theoretical foundations, and impact levels for advanced technical-informational analysis.

TABLE 3: DEFINITION OF AFFORDANCE TYPES (AFF)

Adapted from Research	Code	Affordance Type	Definition	SPMI
Perceived (Gibson, 1979); Prior Knowledge (Norman, 1988); Real, Perceived (Norman, 1999); Clear (McGrenere & Ho, 2000); Pragmatic Attributes (Hassenzahl, 2003); Sensorial (Hartson, 2003); Cultural (Turner, 2005); Physical, Biological (Nutrition, Toxicity) (Zhang & Patel, 2006); Clear (Vyas, Chisalita, & van der Veer, 2006); Comprehended (You & Chen, 2007); Physical (Maier & Fadel, 2008); Perceived (Still, 2009); Clear (Burlamaqui & Dong, 2015)	AFF01	Consolidated	A consolidated affordance represents maximum alignment between designed intention and agent interpretation. It is explicitly codified in perceptual, logical, and functional terms, enabling action without error or ambiguity. The object manifests an affordance that is immediately recognizable and operable, validated by multiple agents from different contexts and with varying levels of expertise. It is widely stabilized through the collective history of use and perception.	**10**

Perceived (Norman, 1988); Perceived (Gaver, 1991); Perceived (Norman, 1999); Perception–Action Coupling (Ellis & Tucker, 2000); Sensorial (Hartson, 2003); Relation (Turner, 2005); Direct Perception (Zhang & Patel, 2006); Clear (Vyas, Chisalita, & van der Veer, 2006); Sensorial & Perceptible (You & Chen, 2007); Physical (Maier & Fadel, 2008); Perceptible (Still, 2009); Reflexive (Kannengiesser & Gero, 2012); Collaboration, Communication (Abhari, Davidson, & Xiao, 2016); Perceptible (Scarlett & Zeilinger, 2019); Perceived, Sensory Cues (McClelland, 2019)	AFF02	Perceptible	The object expresses physical and sensory properties that clearly suggest possible actions to the agent, even without extensive usage history. The perceptible affordance operates based on explicit visual and tactile evidence. Action is deduced from cues provided by the object itself, and the agent is able to correctly interpret them through direct sensory perception. Although contextual influence may still occur, the risk of error remains low.	**9**
Interpreted (Norman, 1988); Hedonic Attributes (Hassenzahl, 2003); Context (Turner, 2005); Cognitive (Hartson, 2003); Inferred (Brown & Blessing, 2005); Internal–External Interaction (Zhang & Patel, 2006); Clear (Vyas, Chisalita, & van der Veer, 2006); Cognitive (You & Chen, 2007); Comprehension (Maier & Fadel, 2008); Effective (Kaptelinin & Nardi, 2012); Reactive (Kannengiesser & Gero, 2012); Ideation, Collaboration (Abhari, Davidson, & Xiao, 2016); Interpreted (Scarlett & Zeilinger, 2019); Contextual Perception (McClelland, 2019)	AFF03	Interpreted	This affordance requires intermediate cognitive processing to be understood. It depends on the agent's interpretative context and conceptual repertoire. This category operates through inference: the action is not self-evident but is deducible. The agent must apply mental schemas, analogies, or prior knowledge. The risk of error is moderate and depends on the compatibility between the object's code and the agent's mental model.	**8**

Need for Instruction (Norman, 1988); Learned (Brown & Blessing, 2005); Mixed (Zhang & Patel, 2006); Unclear (Vyas, Chisalita, & van der Veer, 2006); Dependence on Symbols or Conventions (You & Chen, 2007); Instrumental, Learning-Driven (Kaptelinin & Nardi, 2012)	AFF04	Information-Dependent	The affordance cannot be understood unless the agent receives or constructs prior specific knowledge, through conventions, symbols, or training. The agent must undergo a learning process or seek instruction in order to interpret and operate the affordance. The action is not intuitive, and there is a potential risk of error due to a lack of prior information. The effectiveness of the affordance depends on the agent's technical or cultural domain.	**2**
False (Gaver, 1991); False (Hartson, 2003); Unclear (Vyas, Chisalita, & van der Veer, 2006); False Positive (You & Chen, 2007); Cultural and Social (Kaptelinin & Nardi, 2012)	AFF05	Positive Inductive	The object suggests more than one possible action, each interpretable differently by distinct agents, yet at least one of these interpretations may be functional. The affordance induces interpretive variations, often due to cultural differences, backgrounds, or usage contexts. There is a risk of error, but also the possibility of success. Operational success depends on correctly selecting among competing interpretations.	**-1**
False (Gaver, 1991); False (Hartson, 2003); Unclear (Vyas, Chisalita, & van der Veer, 2006)	AFF06	Dual Interpretation	The affordance is ambiguous and suggests multiple actions that may be mutually exclusive or hazardous. The object emits conflicting or generic signals, leading the agent to misinterpret or commit an operational error. Incorrect action may cause functional failure or risk. It requires design revision or contextual adaptation.	**-3**
False (Gaver, 1991); Unclear (Vyas, Chisalita, & van der Veer, 2006)	AFF07	Negative Inductive	The affordance leads the agent, even an experienced one, to incorrect interpretations. The object's structure is poorly calibrated with plausible mental models. This category functions as a cognitive trap: the cues provided by the object are misleading and structured in a way that induces incorrect action. It is difficult to learn, requires design reconceptualization, and carries a high risk of failure.	**-4**

Hidden (Gaver, 1991); Hidden (Hartson, 2003); Hidden (You & Chen, 2007); Unclear (Vyas, Chisalita, & van der Veer, 2006); Hidden, Invisible (Scarlett & Zeilinger, 2019)	AFF08	Non-Interpreted	The affordance is not perceived by the agent. There is no signal, no decoding, and no possible action. The object provides no cues sufficient to activate the agent's cognition. It remains invisible or unintelligible, regardless of the level of expertise. Extreme engagement is required for it to be explored, rendering it non-operational by default.	**-5**
Sequential (Gaver, 1991); Reflective (Kannengiesser & Gero, 2012); Reveal of Use, Continuous Experience, New Action Opportunities (McClelland, 2019); Emergent (This Research)	AFF09	Emergent	The emergent affordance is neither designed nor initially perceived, but manifests through exploration, repetition, or adaptation during use. It is identified when the agent recognizes an unplanned functionality or behavior that becomes operational. The emergent affordance reveals itself as a consequence of sustained interaction with the artifact, in which the agent becomes a co-author of its operable meaning. It may lead to useful discoveries or to unintended and inadequate uses. Its validation depends on evidence of observable functionality and is automatically attributed based on the Object Requirements Dimension. Classified as a systemic conditional (blue class), its scoring is generated from the combination of the Effectiveness, Error Severity, and Risk Degree dimensions, according to system parametrization (weighted or averaged). It requires cross-analysis between the artifact's actual behavior and the effects of interaction, and cannot be attributed solely through the agent's initial perceptual or cognitive intent.	

Functional (Hartson, 2003); Functional (This Research)	AFF10	Finalistic	The finalistic affordance represents the validation of achieved functionality: it manifests when the agent's action directly results in fulfilling a predefined functional purpose, even if such function is not explicitly perceived in the artifact. This category operates on the systemic functional plane, assessing whether the executed interaction effectively reaches the intended objective. Its existence depends on the compatibility between the action performed and the purpose achieved, regardless of the object's perceptual clarity. Scoring is automatically attributed through systemic inference based on the Effectiveness Dimension, combined with four specific elements from the Attributes Dimension: Utility, Efficiency, Functionality, and Stability. This multidimensional composition validates whether the action was effective, useful, stable, and efficiently executed, consolidating its status as a functional affordance of finalistic nature. It is classified as conditional (blue class), as it requires cross-validation between the functional outcome obtained and the intention declared by the agent.	

The AFF dimension structures, through a technical-scientific taxonomy, the different affordance vectors that may emerge from the interaction between agent and technological object. Each vector (AFF01 to AFF10) represents a distinct inferential configuration, ranging from the consolidated affordance, fully recognizable and operable, to non-interpreted or emergent forms. These types allow for classifying the degree of clarity, risk, ambiguity, and learning involved in the functional decoding of the object. AFF is a strategic dimension of the FCIA-OT, integrating perceptual, cognitive, and systemic analysis, with direct impact on the other dimensions of the framework.

Source: Author.

Each identified affordance vector constitutes a logical structure of operational inference, ranging from direct recognition to the emergence of unforeseen functions. This variability enables the reading of affordance as an indicator of compatibility or dysfunction, serving even as a vector for assessing failures or systemic errors. Three Laws were formulated in this research as the epistemic and computational foundations of the Affordance Dimension:

Law of Algorithmic Couplability ("Everything is Code"): Every system, whether physical or abstract, is configured as a mesh of codified states, whose coupling depends on interpretive protocols. The manifestation of an affordance occurs when there is operational isomorphism between the codes of the agent and those of the object, regardless of the medium (matter, energy, or information).

Law of Trajectory Dependence ("Nothing is Innate"): Every interpretive action results from historical processes, such as evolutionary algorithms, adaptive learning, or energy minimization. The perception of affordance reflects an accumulation of optimizations rather than spontaneous intuition.

Law of Necessary Reconfiguration ("Dynamic Reconvergence"): Changes in system parameters, whether environmental, physical, or computational, require constant recalibration of coupling protocols. The absence of such recalibration compromises the intelligibility of action and may lead to interpretive collapse.

The systematization of affordance types and the formulation of the three laws establish the inferential and computational basis for reading, simulating, and validating technological interactions. The AFF dimension thus transcends descriptive classifications and functions as a diagnostic and predictive tool, essential for assessing the stability, risk, and functional intelligibility of any technical object.

3.3 Perception Dimension (PRC)

The Perception Dimension (Dimensão Percepção – PRC) is structured as a formal core for assessing interpretative accuracy between sensory stimuli and the functional responses of agents, whether human, artificial, or hybrid. Within the scope of FCIA-OT, perception is understood as a high-level inferential operation, wherein environmental signals, whether physical, symbolic, or digital, are read, categorized, and projected onto preexisting interpretative repertoires. Its technical function is not limited to stimulus reception but involves the activation, modulation, and recalibration of cognitive and sensori-computational trajectories.

In this framework, perception is positioned as a computable vector for decoding, diagnostics, and functional anticipation. Shaw, Turvey, & Mace (1982) outline a seminal distinction between two perceptual modes: while propositional perception demands cognitive processing, judgment, and inferential analysis, non-propositional perception operates immediately, as a direct coupling between the organism and structural invariants in the environment. This distinction provides a theoretical foundation for differentiating perceptual vectors based on the level of interpretative effort required, supporting the modeling of PRC as a hierarchical system.

However, perception is not exhausted by the objective aspects of the object. Tractinsky (1997) demonstrates that the perceived aesthetics of an interface directly influence apparent usability, indicating that how something is perceived, even before functional use, can shape subjective acceptability and affect user attitudes. In line with this, Cutting (1998) expands this understanding by treating perception as an informational mediation process between the physical world and mental representation, showing that both objects and events are registered by sensory systems through codified and structurally differentiable signals. This introduces a critical connection with the FCIA-OT matrix: perception becomes a transcodification operation that transforms stimuli into operational maps, reconfiguring internal states.

Along this same line, Tucker & Ellis (1998) reinforce this functional link by demonstrating that merely visualizing objects can automatically activate associated motor representations, revealing a connection between perception and action that occurs even without deliberate intention. This principle strengthens the role of PRC as a sensori-pragmatic operator. Creem & Proffitt (2001) go further by showing that proper action requires not only visuomotor coordination but also the integration of semantic knowledge, demonstrating that technical perception is always also a functional reading of the object.

This dual character of perception, as a sensory filter and semantic projection, is explored by Hassenzahl (2003), who emphasizes that perceptions generate emotional and behavioral consequences, and that the functional valuation of an object depends on the context in which it is perceived. In alignment with the Law of Trajectory Dependence, he shows that the value attributed to a given artifact varies according to the agent's history, environment, and expectations, configuring a perception modulated by affective-cognitive trajectories.

Norman (2004) deepens this tripartite structure by proposing three levels of perceptual processing: the visceral, which is pre-reflective and immediate; the behavioral, oriented toward action and execution; and the reflective, linked to symbolic meaning. The PRC incorporates these levels as formal strata, each requiring distinct decoding and response patterns. Perception, therefore, is not a monolithic function but a distributed network of filters and translators operating in parallel.

This understanding is reinforced by Ciftcioglu, Bittermann, & Sariyildiz (2006), who propose a distinction between the act of seeing and the act of perceiving. While the former is a directed and objective process, the latter is probabilistic, interpretive, and subject to cognitive variability. This distinction technically supports the classification of PRC as a dimension with multiple levels of synchronicity and accuracy. Contrary to passive systems, perception is modeled here as an active inference structure, directly linked to the architecture of the agent.

The PRC core must address different forms of complexity. Janlert & Stolterman (2010) emphasize that perceptual complexity is not necessarily an obstacle; it may constitute benign complexity when shaped to enrich experience and facilitate progressive mastery. This conception underpins PRC as a technical operator of simulation and prediction: well-designed perception can enable learning and adaptation even in dense systems.

Perceptual reading is not limited to the isolated individual; it is sensitive to broader systemic architectures. Abhari, Davidson, & Xiao (2016) argue that technological affordances vary depending on business models, assigned tasks, and network configurations, reinforcing that the perception of action possibilities is not fixed but shaped by interpretative ecosystems and design strategies. This perspective, aligned with the Law of Necessary Reconfiguration, highlights that perception is subject to collective dynamics, making it a strategic element in collaborative co-innovation contexts.

At this point, PRC also functions as a metric of perceptual load, anchored in objective models. Zali (2016) defines cognitive load as the user's capacity to interact with systems with minimal mental effort, describing it as a psychomotor performance metric calibrated to usage strategies. Perception is not passive: it requires technical calibration between system structure, agent capabilities, and interactional strategies, an indispensable condition for adaptive functionality. McClelland (2019) complements this framework by addressing the perception of affordances under contextual and cognitive filters, showing that sensitivity to stimuli is dynamic and modulated by goals, mental states, and accumulated experience.

The contextual relevance of perception is further emphasized by Yang (2020), who highlights the importance of visual forms in perceptual decomposition, noting that elements such as inclination or deformation generate specific visual tensions that influence attentional focus. This evidence confirms that perception is always directed and modeled, and that any failure in its design directly compromises the functional activation of the system.

Thus, the PRC core is established as an operational basis for technical intelligibility and the reliability of action. Through the systematized reading of perceptual categories, FCIA-OT enables the detection of design flaws, simulation of interpretative effects, and projection of more responsive, safe, and operational systems. Table 4 presents the structured types of perception and their corresponding definitions, aligned with the vectors identified in the literature.

TABLE 4: DEFINITION OF PERCEPTION TYPES (PRC)

Adapted from Research	Code	Perception Type	Definition	SPMI
Direct Perception (Shaw, Turvey, & Mace, 1982); Perceived Clarity (Tractinsky, 1997); Automatic Potentiation (Tucker & Ellis, 1998); Direct Registration of Invariants (Cutting, 1998); Benign Complexity (Janlert & Stolterman, 2010); Low Cognitive Load (Zali, 2016); Visual Perception (Yang, 2020)	PRC01	Instructive	When facing objects, interfaces, symbols, equipment, and systems, there is synchrony, an immediate clarity, in the agent's perception of both the context and the object. Perception occurs directly and instantaneously, without the need for inference, analysis, or prior experience. The agent recognizes, understands, and responds to the object automatically, as the perceptual cues are explicitly organized, with low cognitive cost and high environmental predictability. This type of perception is linked to clear visual input, direct registration of invariants, and immediate semantic activation.	**10**
Sensory Cue Analysis (Cutting, 1998); Semantic Processing (Creem & Proffitt, 2001); Reflective (Norman, 2004); Analytical/ Interpretative Processing (Ciftcioglu, Bittermann, & Sariyildiz, 2006); Reflective Analysis (Janlert & Stolterman, 2010); Interpretation and Understanding (Abhari, Davidson, & Xiao, 2016); Adaptation (Zali, 2016); Reflective Analysis, Interpretation, and Required Reflection (McClelland, 2019)	PRC02	Argumentative (Analytical or Reflective)	When facing objects, interfaces, symbols, equipment, and systems, the synchrony between the agent's perception and the affordance of the object only occurs after analysis. Perception is not immediate, requiring the agent to activate analytical, interpretative, or reflective mechanisms to decode the perceptual situation. It is an intermediate process in which the agent must engage in a moderate cognitive effort—interpreting cues, constructing meaning, and validating understanding before perceiving the possible action. This type of perception involves dense semantic processing and demands a mental organization that precedes action.	**5**
Perceptual Adaptation Through Continuous Interaction (Cutting, 1998); Context (Hassenzahl, 2003); Continuous Experience, Interaction (Janlert & Stolterman, 2010); Direct Experience, Continuous Interaction (McClelland, 2019)	PRC03	Reactive	When facing objects, interfaces, symbols, equipment, and systems, the synchrony between the agent's perception and the affordance of the object occurs only when the agent's perception changes based on experience or continuous interaction. Perception depends on time and repeated exposure to the object or system. The agent does not immediately identify meaning or function but develops perception through successive interactions. It is a progressive form of perception, generated by continuous sensorimotor adaptation, which modifies perceptual interpretation as new information is incorporated.	**3**

Meaningful Learning (Janlert & Stolterman 2010)	PRC04	Inquisitive	When facing objects, interfaces, symbols, equipment, and systems, there is no synchrony between the agent's perception and the affordance of the object; either simple or complex learning is required. In this case, the agent must mobilize cognitive structures not only for interpretation but for acquiring knowledge. Perception is interrupted due to the absence of prior repertoire or clarity of cues. The agent becomes aware of the need to learn, to seek instructions or simulations in order to understand the object. This is common in situations involving innovative elements or unconventional symbolic structures.	**2**
Active Learning (Shaw, Turvey, & Mace, 1982); Analytical Process, Cognitive Effort (Ciftcioglu, Bittermann, & Sariyildiz, 2006); Considerable Effort, Discovery (Janlert & Stolterman, 2010)	PRC05	Exploratory	When facing objects, interfaces, symbols, equipment, and systems, there is no synchrony between the agent's perception and the affordance of the object; effort is required for discovery, following attempts and exploratory interaction with the system. Perception emerges only through practical attempts and experimentation. The agent lacks sufficient visual, semantic, or symbolic indicators and must explore the object physically or virtually, testing perceptual hypotheses to identify its function. This is the most demanding type in terms of cognitive and motor effort, frequently associated with flawed design, high ambiguity, or functional opacity.	**-5**

The PRC dimension is structured based on technical-functional criteria that define the actionable perceptual vectors in any interaction process between agents and technological objects. Each vector (PRC01 to PRC05) describes a specific form of sensori-informational decoding, ranging from direct and instructive perceptions to interrogative or exploratory forms. These types qualify the degree of clarity, inference, learning, or effort required for the functional reading of the object, allowing the identification of perceptual overloads, intelligibility failures, or demands for interpretative reconfiguration. PRC is a central dimension in the FCIA-OT matrix, operating as a vector for systemic analysis, perceptual simulation, and prediction of cognitive failures in natural, computational, or hybrid environments.

Source: Author.

This active reading of perceptual fields is grounded in three epistemic foundations of the FCIA-OT matrix. First, through the Law of Algorithmic Coupling, all perception is modeled as a process of decoding codified states, whose intelligibility depends on the isomorphism between the object's structures and the agent's protocols. Second, the Law of Trajectory Dependence establishes that no perception is innate: all perceptual capacity results from interactive histories, prior exposures, accumulated learning, and evolutionary processes of interpretative refinement. Third, the Law of Necessary Reconfiguration states that changes in system state, whether environmental or internal to the agent, require continuous recalibration of perceptual filters and protocols, under penalty of interpretative collapse, misreading, or misaligned actions.

Perception is thus no longer understood as a stage prior to action, but as a technical system of inferential input, operating in synergy with Affordance and qualifying the entire interactive chain. By formalizing its types, criteria, and constraints, the PRC core offers computable instruments for diagnosing perceptual opacities, adaptive simulation, interface engineering, and functional auditing of systems in operation, consolidating itself as a foundational dimension for the reliability, accessibility, and safety of usability and interaction.

3.4 Affective Dimension (AFV)

The Affective Dimension (Dimensão Afetividade – AFV) constitutes a strategic core in the evaluation of technological objects due to its modulatory role in the emotional, symbolic, and functional experience of agents when facing interactive phenomena or complex systems. Far from being restricted to immediate or superficial responses, affect operates as a dynamic valuation system, directly influencing the perception of trustworthiness, stability, subjective utility, familiarity, and rejection. In advanced analytical contexts, this dimension intersects cognitive, sensorimotor, social, and cultural domains, shaping a vector that structures affective bonding with the object, whether physical, digital, or hybrid.

The model proposed by Kleinginna & Kleinginna (1981) defines emotion as a multifactorial phenomenon, composed of affective, cognitive, physiological, and expressive-behavioral components that operate in an integrated manner. The emotional response articulates pleasure or displeasure, appraisal, expression, and neurophysiological correlates. This distinction from other affective states allows for precise identification of the emotional impact of technologies and their functional modulations.

From an experiential perspective, Csikszentmihalyi (1990) defines flow as a state of pleasurable immersion, where action and awareness merge under intense focus, control, and satisfaction. It emerges from the balance between challenge and competence, sustained by continuity, clear feedback, and minimal distraction. The occurrence of flow in interactive contexts reveals the role of affective engagement as a structuring condition for the functional appropriation of the object.

Molich & Nielsen (1990) emphasize the importance of structures that support natural dialogue, predictability, and the minimization of cognitive barriers. When there is coherence among language, structure, and feedback, the agent tends to build trust in the system, reducing mental load and preventing experiences of frustration. Conversely, design inconsistencies, ambiguities, and lack of clarity in responses compromise the affective bond and generate functional discontinuity, revealing the interdependence between communicative design and emotional stability in interaction.

In alignment with this, Fredrickson (2001) proposes that positive emotions temporarily broaden thought–action repertoires, creating upward spirals of well-being and fostering the development of enduring resources such as resilience, expanded coping, and subjective reorganization. These emotions promote flourishing and the emergence of positive meanings, even in the face of adversity. Positive affect operates as a vector of adaptation and subjective strengthening.

Russell (2003) highlights the complexity of affect by understanding it as a primary appraisal of stimuli, anchored in the axes of pleasure–displeasure and activation–deactivation. This framework constitutes a system of affective qualification essential to decision-making. Feelings such as pleasure, displeasure, or empathy derive from these initial evaluative responses, operating as judgments of subjective utility. Thus, empathy is defined as attributed affect, resulting from the mental simulation of experiences perceived in others.

In the same framework, Norman (2004) distinguishes between affect and emotion based on their functional dynamics: affect is a broad evaluative system operating at both conscious and unconscious levels, whereas emotion represents its conscious manifestation associated with causal identification. The relationship between affect and cognition shows that emotional judgments both shape and are shaped by cognitive and decision-making processes.

Decety & Jackson (2004) understand empathy as the affective perception of another agent's emotional state, without requiring a direct behavioral response or an attitude of solidarity. In this view, empathic experience demands only the sensitive recognition of the other's emotional state, whether real or inferred, sustained by perceptual simulation and a minimal emotional alignment between agents.

From Smith's (2006) perspective, empathy simultaneously articulates two distinct yet complementary competencies: the capacity to adopt another agent's mental perspective (cognitive empathy) and the ability to vicariously share their emotions (emotional empathy). These two dimensions structure the empathic phenomenon as a complex form of affective connection, fundamental in interpretative processes mediated by symbolic systems.

Khalid (2006) argues that affect is interwoven with rationality, functioning as an amplifier of objectivity in evaluative processes. When discussing the relationship between pleasure and functional appreciation, he maintains that positive emotions reinforce perceived value assessments, even in technical judgments. However, he acknowledges the methodological limitations of measuring such affects, as subjective reactions such as intellectual pleasure are not always accessible through physiological or expressive means.

Kouprie & Visser (2009) treat empathy in design as a process involving direct contact, projective imagination, and stimulation of symbolic co-experience. They observe that, although tools for fostering empathy are available, the absence of a consolidated language hinders generalization. The exploratory nature of these approaches demands interpretive sensitivity regarding the construction of affective bonds mediated by objects or systems.

Zhai et al. (2009) reinforce the functional role of affectivity by demonstrating that positive affects enhance perceptions of well-being and satisfaction in both everyday and professional contexts, while negative affects tend to diminish these indicators, compromising the subjective evaluation of experience. In this model, affectivity is positioned as a central variable in the valuation of technology, influencing acceptance, engagement, and continued use.

In line with the functionality of affectivity, Brave & Nass (2009) argue that more effective technologies are those capable of recognizing and expressing emotional states in a manner consistent with verbal and situational content. Interfaces that disregard the agent's affective state tend to trigger emotional dissonance. Proper articulation between function, form, and affective expression contributes to intuitive and psychologically sustainable interactions.

According to Tullis & Albert (2013), usability failures can trigger negative affective states such as frustration, anxiety, and rejection. These reactions may be tolerated when there is perceived value, showing that negative affect can be functional. In contrast, emotional neutrality often signals the absence of connection, which undermines engagement and the relevance of the object.

The FCIA-OT operationalizes the Affective Dimension based on technical criteria that consider the nature of the object, the affective profile of the interacting agent, and the expected response patterns. The analysis is grounded in principles from affective neuroscience, emotion psychology, and cognitive ergonomics, ensuring precision in identifying positive and negative patterns of affective bonding. Table 5 outlines the types of affectivity relevant for technical analysis, articulating manifestations ranging from emotional comfort, pleasure, and curiosity to states of rejection, frustration, and anxiety. These categories function as vectors that modulate acceptance, trust, and the value attributed to the object, enhancing the diagnostic sensitivity of the evaluation system.

TABLE 5: DEFINITION OF TYPES OF AFFECTIVITIES (AFV)

Adapted from Research	Code	Types of Affectivities	Definition	SPMI
Emotional Well-being (Kleinginna & Kleinginna, 1981); Cognitive Broadening, Psychological Resilience (Fredrickson, 2001); Positive Affectivity (Zhai et al., 2009); Pleasant Affects (Brave & Nass, 2009)	AFV01	Emotional Comfort	A sense of emotional stability and subjective safety in relation to the technological object. Refers to the extent to which a system, phenomenon, or technology provides the agent with a stable, welcoming, and predictable emotional experience, reducing internal tensions and generating a continuous state of affective tranquility throughout use, contact, or analysis.	**10**
Intense and Meaningful Satisfaction (Csikszentmihalyi, 1990); Flourishing, Discovery of Positive Meaning (Fredrickson, 2001); Pleasure (Russell, 2003); Pleasure (Khalid, 2006); Pleasant Affects (Brave & Nass, 2009)	AFV02	Pleasure/ Satisfaction	Subjective experience of contentment, pleasure, or gratification during interaction with the technological object. Expresses the perception of positive affective value resulting from the experience or use of the technological object, phenomenon, or system. It involves sensations of emotional gratification, attentional pleasure, and meaningful fulfillment that cognitively validate the choice and support the continuity of the experience.	**9**
Broadened Thought–Action Repertoire (Fredrickson, 2001)	AFV03	Curiosity	Affective impulse that motivates active exploration of functionalities, patterns, or logics of the technological object. Characterizes the affective state that induces spontaneous and sustained investigation in the face of perceived complexity, novelty, or interpretive openness of the object under analysis. It acts as a vector of discovery, contributing to cognitive broadening and exploratory engagement.	**8**
Action–Consciousness Fusion (Csikszentmihalyi, 1990); Enduring Resources, Upward Spiral of Well-being (Fredrickson, 2001)	AFV04	Emotional Engagement	Intensity of the affective connection between the agent and the elements of the technological object. Describes the degree to which the experience with the object triggers lasting emotional bonds and attentional affective investment. It results from the perception of the affective meaning of the phenomenon, activating prolonged interest and sustained emotional involvement.	**7**
Full Attentional Focus (Csikszentmihalyi, 1990)	AFV05	Immersion	Feeling of total attentional and affective involvement with the technological object. Indicates the agent's deep absorption in the experiential flow triggered by the system, technology, or construct. Immersion occurs when peripheral stimuli are suspended, generating a state of full affective presence and perceptual continuity.	**6**

Security (Kleinginna & Kleinginna, 1981)	AFV06	Trust	Perception of safety and predictability when interacting with or analyzing the technological object. Corresponds to the affective belief in the functional stability, integrity, and coherence of the observed system or phenomenon. It arises from the consistency in the object's responses, the fulfillment of tacit expectations, and the absence of abrupt interpretive ruptures.	**5**
Unexpected Elements (Kleinginna & Kleinginna, 1981)	AFV07	Surprise	Emotional reaction to unexpected elements that challenge but do not compromise the experience with the object. It manifests in response to unanticipated stimuli that disrupt expected behavior patterns of the technological object. It triggers a momentary reconfiguration of attention and may induce positive or neutral reinterpretations of the phenomenon.	**4**
Overcoming Difficulties (Kleinginna & Kleinginna, 1981); Undoing Effect (Fredrickson, 2001)	AFV08	Relief	Sudden reduction of emotional tension associated with the experience of the technological object. Refers to the restoration of affective balance after resolving discomforts, interpretative difficulties, or obstacles in the interaction with the object. It occurs when anticipated tensions subside or when the emotional expectation is favorably reconfigured.	**3**
Empathy (Russell, 2003); Empathy (Decety & Jackson, 2004); Empathy (Smith, 2006); Empathy (Kouprie & Visser, 2009)	AFV09	Empathy	Affective resonance evoked by the technological object in relation to others, oneself, or its content. Denotes the system's, phenomenon's, or interface's capacity to elicit intersubjective emotional connection or symbolic identification. It is activated by human representations, narratives, or sensitive dynamics that enhance the agent's emotional understanding.	**2**
Emotional Neutrality (Tullis & Albert, 2013)	AFV10	Neutrality	State of absence of significant affect or emotional activation toward the technological object. Defined by affective indifference triggered by stimuli that do not elicit relevant emotional involvement—neither positive nor negative. It may indicate dissonance with the agent's interest, failure of impact, or cognitive-emotional saturation.	**-1**

Negative Emotion–Driven Repertoire Restriction (Fredrickson, 2001); Apprehension or Concern (Tullis & Albert, 2013)	AFV11	Anxiety	Anticipatory tension generated by uncertainties or perceived instabilities in the technological object. It reflects the affective perception of threat, discomfort, or unpredictability that undermines the agent's emotional well-being. It results from interpretative gaps, stimulus overload, or communicative failures of the system, triggering a continuous state of alert.	**-3**
Extended Coping (Fredrickson, 2001); Displeasure (Russell, 2003); Tolerated Difficulties (Tullis & Albert, 2013)	AFV12	Tolerated Frustration	Feeling of partial discomfort that the agent accepts due to the perceived functional value. Represents a controlled form of negative affect that is rationally absorbed by the agent when the technological object presents failures, excessive demands, or interpretative challenges, but whose purpose or value outweighs the generated tension.	**-4**
Negative Emotions (Kleinginna & Kleinginna, 1981); Frustrations (Molich & Nielsen, 1990); Displeasure (Russell, 2003); Negative Affectivity (Zhai et al., 2009)	AFV13	Frustration	Negative affective state generated by persistent obstacles, incoherence, or critical failures of the object. Characterizes the rupture between expectations and the object's responses, resulting in emotional depletion, loss of interpretative control, and the agent's refusal to maintain the interaction. It is a critical marker of intense affective dissonance.	**-5**

The AFV dimension structures, based on psycho-emotional and functional principles, the vectors of affective response modulated during the interaction between agents and technological objects. Each vector (AFV01 to AFV13) represents a specific emotional state, positive, neutral, or negative, that emerges from the functional, symbolic, or interpretative experience with the object. These types qualify the degree of pleasure, engagement, discomfort, empathy, or frustration involved, allowing the identification of bonds, ruptures, tolerances, and subjective reorganizations. AFV is a transversal component of the FCIA-OT, operating as an axis for experiential analysis, emotional tracking, and the prediction of technological acceptance, appropriation, or rejection in any complex system.

Source: Author.

The integration of the AFV dimension into the FCIA-OT matrix is operationalized through technical-scientific criteria that consider the nature of the object, the affective profile of the interacting agent, and the expected or undesired patterns of emotional response. The analysis integrates principles from affective neuroscience, emotion psychology, situated cognition, and functional ergonomics, enabling the identification of positive, neutral, or negative emotional states with high interpretative precision. These vectors directly modulate reliability, perceived value, engagement, and resilience in the experience with the object, constituting a sensitive core for the functional, symbolic, and ethical assessment of technology.

3.5 Satisfaction Dimension (STSF)

The Satisfaction Dimension (Dimensão Satisfação – STSF), within the scope of the FCIA-OT, functions as a structuring vector of symbolic-functional adherence between agents and technological objects. More than a punctual reaction to the use experience, satisfaction is configured as a complex evaluative synthesis, derived from the congruence between subjective expectations, perceived performance, emotional response, and attributed value. This dimension is not restricted to the post-use stage, but articulates predictive factors, such as cognitive anticipations, prior experiences, and affective predispositions, with the hedonic, functional, and relational components of interaction. It stands as a critical variable for the analysis of acceptance, continued use, attributed reliability, and symbolic recommendation of the object.

Satisfaction results from the convergence of contextual, relational, technical-interactional, and perceptual-subjective factors, as framed by the interpretative structure proposed by Pearson & Bailey (1980), which defines the satisfaction experience as a multidimensional phenomenon grounded both in the system's qualities and in the agent's internal configurations.

From a cognitive and self-referential perspective, Diener et al. (1985) define satisfaction as a cognitive-subjective judgment arising from the comparison between experienced conditions and individual standards of adequacy. This evaluation does not follow universal objective criteria but emerges from the interplay between affective memory, personal goals, and internalized meanings. By detaching satisfaction from normative metrics, they reveal its interpretative and constructed nature.

In the context of inter-industrial satisfaction measurement, Fornell (1992) proposes the Customer Satisfaction Barometer (CSB), introducing an analytical model based on three interrelated dimensions: overall evaluation, expectation confirmation, and distance from the ideal. This framework isolates the influence of perceived quality on loyalty behavior, demonstrating that satisfaction functions as a mediator between perceived delivery and strategic value.

As a practical evaluation tool in usability studies, Brooke (1996) proposes the System Usability Scale (SUS) as a lightweight instrument applicable to various technologies, enabling rapid measurement of perceived experience. Its Likert-scale structure, oriented toward subjective judgment of functionality and ease of use, incorporates satisfaction as a variable associated with interactional efficiency, comprehensibility, and attributed system trust.

In alignment with the notion of satisfaction as a variable experience, Lindgaard & Dudek (2003) characterize it as a multidimensional phenomenon whose definition cannot be rigidly standardized. They argue that the satisfaction experience varies according to the agent's profile and the symbolic context of interaction, reinforcing the construct's complexity and the need for analytical approaches sensitive to experiential diversity.

In the context of projected loyalty, Reichheld (2003) broadens this scope by developing the Net Promoter Score (NPS), which links satisfaction to recommendation intention. Its categorization into promoters, passives, and detractors enables inferences about trust, attachment, and expectations of continuity, making satisfaction a variable of both functional and affective predictive value.

In line with the methodological challenges of subjective measurement, Griffiths, Johnson, & Hartley (2007) warn of the need for rigorous evaluative approaches, noting that the uncritical adoption of satisfaction as a success metric may obscure technical or symbolic flaws. If not controlled by multivariate criteria, the subjectivity of judgment tends to yield inconsistent or non-interpretable results.

Expanding this issue, Briggs, Reinig, & de Vreede (2008) further argue that initial dissatisfaction, even when not stemming from technical failures, negatively impacts continued use. They observe the effects of "confirmation" (when delivery exceeds expectations) and "dissonance" (when delivery does not meet expectations, even if technically adequate), indicating that satisfaction is mediated by subjective and emotional filters that extend beyond isolated performance.

Reinforcing the role of non-functional variables, Laugwitz, Held, & Schrepp (2008) emphasize the centrality of hedonic aspects and emotional responses in satisfaction evaluation. They argue that aesthetic, symbolic, and affective criteria operate jointly with functional factors, forming a hybrid and subjective judgment matrix regarding the technological object.

Expanding the relational architecture of satisfaction, Briggs & Sindhav (2015) propose that its judgment may emerge from multiple elements, hardware, software, services, policies, data, people, which interact systemically.

This systemic view requires an evaluative model capable of capturing the interweaving of these factors, as proposed by FCIA-OT. Within this architecture, satisfaction is understood as the result of perceived affordances, interactional fluency, projected symbolism, and alignment with both tacit and explicit expectations. Table 6 presents the levels of satisfaction technically structured, ranging from states of full adherence to extreme forms of functional rejection, and operationalized into a scale of affective and evaluative response. These types not only describe subjective judgments but also enable cross-analyses between technical, affective, and symbolic attributes of the object.

TABLE 6: DEFINITION OF TYPES OF SATISFACTION (STSF)

Adapted from Research	Code	Types of Satisfaction	Definition	SPMI
Pearson & Bailey (1980); Diener et al. (1985); Fornell (1992); Brooke (1996); Lindgaard & Dudek (2003); Reichheld (2003); Griffiths, Johnson, & Hartley (2007); Briggs, Reinig, & de Vreede (2008); Laugwitz, Held, & Schrepp (2008); Briggs & Sindhav (2015); Zarour (2020)	STF01	Extremely Satisfied	Maximum state of positive adherence, in which no dissonance exists between expectation and functional delivery. Corresponds to the highest degree of alignment between the object's attributes and the performance, usability, and symbolic value requirements. No perceived gaps or demands for optimization are present.	10
	STF02	Very Satisfied	High level of satisfaction with occasional recognition of minor, non-compromising inconsistencies. Indicates near-complete alignment between expectations and functional response, with only minor limitations that do not compromise the object's acceptability.	9
	STF03	Fairly Satisfied	Predominant satisfaction coexisting with the perception of aspects requiring revision. The object demonstrates satisfactory functional performance but exhibits perceptual or operational friction points that suggest adjustments for the consolidation of experiential excellence.	8
	STF04	Satisfied	State of functional acceptance with perceived value, even in the presence of discrete limitations. The experience is predominantly positive, although the object does not reach optimal levels across all evaluative parameters. Satisfaction is maintained but not consolidated.	7
	STF05	Moderately Satisfied	Partial satisfaction coexisting with evident limitations that reduce perceived value. The functional delivery meets minimum acceptability requirements, yet recurrent failures or technical shortcomings result in loss of affective and functional adherence.	6
	STF06	Neutral	Absence of decisive affective response; balance between positive and negative valences. No affective bond, either positive or negative, is formed. The experiential response is indifferent, marked by a balance between sufficient functional aspects and minor shortcomings that prevent a conclusive judgment.	0

Pearson & Bailey (1980); Diener et al. (1985); Fornell (1992); Brooke (1996); Lindgaard & Dudek (2003); Reichheld (2003); Griffiths, Johnson, & Hartley (2007); Briggs, Reinig, & de Vreede (2008); Laugwitz, Held, & Schrepp (2008); Briggs & Sindhav (2015); Zarour (2020)	STF07	Dissatisfied	Explicit dissatisfaction in response to perceived deficiencies in the object. Failures outweigh positive aspects, directly affecting the system's utility, clarity, or usability. Perceptible frustration and loss of functional trust emerge.	**-1**
	STF08	Fairly Dissatisfied	High level of rejection due to poor technical or symbolic adherence. The object presents serious performance gaps, incompatibility with expectations, or critical failures in essential dimensions, significantly impairing the experience.	**-3**
	STF09	Very Dissatisfied	Perception of generalized inefficiency and structural failure. There is a collapse in reliability, usability, or symbolic value structures. The object is assessed as dysfunctional or inadequate for its intended purpose.	**-4**
	STF10	Extremely Dissatisfied	Maximum state of functional, symbolic, and affective frustration. No satisfaction criterion is met. The experience is negative across all dimensions, resulting in a complete rupture of the bond, explicit rejection, and refusal of future use.	**-5**

The STSF dimension structures, based on subjective-functional parameters, the satisfaction vectors attributed to technological objects, interactive systems, or complex phenomena. Each vector (STF01 to STF10) represents a specific degree of adherence between expectations, perceived delivery, and symbolic value, ranging from states of full acceptance to extreme rejections. These types serve as interpretative indicators of trust, continued use, and affective valence, enabling the identification of approval, neutrality, or frustration patterns that directly impact the bond with the analyzed object.

Source: Author.

The integration of the STSF dimension into the FCIA-OT matrix enables the incorporation of subjective evaluation data into technical analyses, linking individual expectations to functional and affective attributes. By systematizing satisfaction levels as interpretative expressions of experience, STSF enhances the identification of symbolic incongruities, perceptual failures, and functional mismatches, supporting more accurate diagnoses and responsive interventions throughout the technology development or evaluation cycle.

3.6 Effectiveness Dimension (EFT)

The Effectiveness Dimension (Dimensão Efetividade – EFT), within the context of the FCIA-OT, is configured as a high-level systemic attribute that transcends mere task execution or isolated functional performance. It refers to the technical-operational capacity of a technological object or phenomenon to achieve, in an integral and accurate manner, the structural objectives that define it, while preserving its functional consistency even under adverse or prolonged usage conditions. This dimension requires critical observation of factors such as precision, completeness, robustness, and functional alignment, whose interdependence sustains the conformity between design intent and effective outcome.

Initial efforts to distinguish between efficiency and effectiveness are clearly found in Pearson & Bailey (1980), who observed that conventional evaluations are predominantly based on metrics such as throughput or intensive hardware use. While these indicators express raw performance, they do not ensure that the system is producing useful results. Effectiveness, in this sense, requires qualitatively distinct metrics aimed at verifying functional adherence between operation and intended purpose.

The relevance of this distinction becomes even more evident in the studies of Rouse (1981), who analyzed dynamic systems in which technical failures compromise not only performance but also operational integrity itself. This perspective reinforces that effectiveness is not limited to task completion, but is constituted as a guarantee of continuity, adaptability, and functional resilience, especially in high-complexity environments.

This understanding is further developed through a multifactorial perspective, as demonstrated by Bailey & Pearson (1983), who identified 39 critical variables for systemic quality evaluation. These factors range from structural reliability to clarity, security, informational timeliness, and normative adequacy, and do not operate in isolation. They form an interdependent network that sustains the effective operability of computational and hybrid systems. For FCIA-OT, these elements serve as structural axes of the EFT dimension, whose analysis requires the integrated reading of these variables as technical vectors of systemic effectiveness.

The critique of excessive complexity is strongly articulated by Goodwin (1987), who demonstrated that the accumulation of functionalities may compromise core performance, even when technically feasible. Under this condition, effectiveness depends on structural clarity and the rational organization of operations, reducing noise, redundancy, and cognitive interference.

This critical line is reinforced by Bevan (1995b), who argues that effectiveness does not reside in mere technical interaction capability, but in the coherence between system, task, and user, even under varied conditions. Although centered on cognitive engineering, this proposition contributes directly to the FCIA-OT's understanding of functional robustness and stability amid usage variations.

The discussion on functional degradation caused by the disordered accumulation of resources is expanded by Kaufman & Weed (1998) and McGrenere (2000). Both highlight phenomena such as "bloat" and "creeping featurism," which increase complexity without real performance gains. In FCIA-OT, these conditions are identified as vectors of effectiveness loss, as they affect system precision, fluency, and coherence.

Although stemming from a hedonic perspective, Hassenzahl (2003) offers a relevant reflection by emphasizing that effectiveness also manifests in durable states of adherence and appropriation. For FCIA-OT, although the subjective dimension is not central, it is acknowledged that operational rejection and usage fatigue compromise functional completeness, rendering sustained effectiveness unfeasible.

The model of Naumann et al. (2007) reinforces the importance of achieving exact, complete, and sustainable results with low cognitive demand. This conceptual synthesis aligns with the FCIA-OT's understanding that effectiveness should emerge from the interaction between structural stability, functional accuracy, and operational fluency, without ruptures or overload.

Kortum & Peres (2014) reiterate this position by emphasizing that the mere accomplishment of a task does not constitute full effectiveness. A system that forces the operator into continuous compensations or causes discomfort, even if technically functional, loses effective value. FCIA-OT incorporates this view by proposing that effectiveness be understood as technical-functional balance with minimal friction.

Zali (2016) concludes this trajectory by emphasizing that effectiveness is not exhausted in punctual success, but involves the sustainability of such performance with precision and reduced effort over time. This view precisely reflects FCIA-OT's distinctive criterion: functionally consistent systems that are technically efficient and ontologically aligned with their purposes.

The analysis of effectiveness requires the articulation of objective indicators, such as operational precision, functional success, and structural consistency, and technical-contextual parameters, such as adaptability, resilience, and performance persistence. Table 7 presents the types of effectiveness technically structured and their analytical definitions, in alignment with the FCIA-OT matrix.

TABLE 7: DEFINITION OF EFFECTIVENESS TYPES (EFT)

Adapted from Research	Code	Types of Effectiveness	Definition	SPMI
Effectiveness (Pearson & Bailey, 1980); Effectiveness (Bailey & Pearson, 1983); Effective (Goodwin, 1987); Completeness (Naumann et al., 2007); Usable (Kortum & Peres, 2014); Precise and Efficient (Zali, 2016)	EFT01	Effective	The technical-functional configuration demonstrates completeness, operational precision, and systemic stability, ensuring high performance, structural coherence, and full alignment with projected objectives.	10
Capacity, Clarity (Bailey & Pearson, 1983); Minimal Cognitive Effort (Naumann et al., 2007)	EFT02	Considerable	The functioning of the system or object displays satisfactory performance and intermediate functional alignment, but requires structural compensations or partial technical adjustments.	5
Complexity (Goodwin, 1987); Creeping Featurism, Functional Overload (McGrenere, 2000); Alterations (Feltovich et al., 2004)	EFT03	Moderate	The structure presents technical limitations, consistency deviations, and performance interference, partially compromising efficiency and requiring recurrent operational adaptations.	-3
Failures (Rouse, 1981); Excessive Complexity (Goodwin, 1987); Bloat (Kaufman & Weed, 1998); Bloat (McGrenere, 2000); Error, Changes (Feltovich et al., 2004)	EFT04	Insufficient	The operation reveals systematic failures, structural overload, and performance dysfunctions that render completeness unfeasible, reduce functional efficacy, and prevent compliance with technical-operational objectives.	-5

The EFT dimension systematizes, through technical-operational criteria, the degrees of effectiveness manifested in technological objects, functional systems, or complex configurations. Each vector (EFT01 to EFT04) represents a specific level of adherence between structure, operation, and purpose, ranging from fully effective configurations to those compromised by systemic failures or critical instabilities. The types express patterns of completeness, precision, robustness, and functional coherence, allowing the identification of the extent to which the analyzed phenomenon sustains its technical purpose without deviations, losses, or dysfunctional demands.

Source: Author.

The integration of the EFT dimension into the FCIA-OT matrix plays a critical role in distinguishing merely operational systems from technically consistent configurations. By evidencing the degree of convergence between design intent, functional behavior, and achieved outcome, this dimension enables the assessment of how well the analyzed structure is able to maintain its technical integrity under varying contextual demands. The classification of effectiveness types is not limited to the analysis of isolated performance but aims to identify sustainable patterns of accuracy, stability, and completeness, essential for maintaining systemic coherence. The articulation of these vectors with other evaluative dimensions strengthens an integrated understanding of the object's technical-functional performance, revealing its potential for reliable operation, structural adherence, and actual use value.

3.7 Object Requirements Dimension (RQO) and Artifact Requirements Dimension (RQA)

The Object Requirements Dimension (Dimensão Requisitos de Objetos – RQO), in conjunction with the Artifact Requirements Dimension (Dimensão Requisitos de Artefatos de Objetos – RQA), constitutes the structural foundation of the FCIA-OT technological assessment model. This epistemological architecture not only organizes the constituent elements of a technological object but also enables its technical and functional decomposition into parametrizable descriptive units. The RQO configures the analytical unit that defines the object as the central construct, while the RQA unfolds the attributes of its artifacts, parts, subsystems, processes, and technical properties. The convergence of these two structural layers provides a systemic, scalable, and multigranular approach for the analysis and evaluation of any object, phenomenon, or technological, physical, digital, hybrid, or biotechnological construct.

The conceptual solidity of the RQO rests on the premise that technological objects are not static entities but organized systems composed of design, functional, computational, and procedural interactions. This complexity demands formal modeling, as indicated by Finkelstein & Finkelstein (1983), who argue that system design can be structured through models organized according to formalizable procedural patterns. Such models function as regulatory schemas guiding object development, granting internal consistency and operational logic.

Molich & Nielsen (1990), addressing usability principles in interactive design, introduce essential criteria for failure prevention and informational clarity, which the RQA dimension absorbs as verifiable requirements in the functional and interactional attributes of artifacts. The presence of mechanisms that enhance efficiency for experienced agents, combined with error minimization and constructive guidance in case of failures, becomes a measurable parameter within the RQA operational descriptors.

From the perspective of Janlert & Stolterman (1997), the concept of an artifact's "character," defined as the integration of aesthetic, technical, and ethical attributes, broadens the understanding of the object's design dimension. The character is operationalized in the RQO taxonomy through categories such as hardware design, software design, interface, and aesthetic-functional elements, which capture both tangible and behavioral aspects of the technological system.

Norman (2004), structuring the user experience around function, performance, and usability, reinforces the analytical triad guiding object requirements: function as the purpose structure, performance as operational effectiveness, and usability as intelligibility of use. These parameters find direct representation in the RQA codes, enabling not only their description but also the assignment of analytical values to properties such as responsiveness, interface logic, and usage complexity.

The affective dimension of design, as described by Khalid (2006), is incorporated into the FCIA-OT framework by recognizing that beliefs, values, and judgments emerge from user-system interaction. The emotional response is technically modeled through descriptors such as aesthetics, texture, shape, and personalization, elements evaluable in the RQA and fundamental for mapping the user experience.

The historical separation between software engineering and usability, identified by Bygstad, Ghinea, & Brevik (2008), highlights the importance of models integrating both dimensions from the outset of the design cycle. FCIA-OT's proposal addresses this challenge by conceiving a unified structure wherein technical functionality and interaction experience are evaluated integrally, rather than residually, as in traditional methods.

Velmourougan et al. (2014) reinforce this point by demonstrating that usability failures cause critical damages. Within the FCIA-OT scope, such understanding transforms into a technical element through specific RQA requirements, such as error, instability, crashes, and failures, providing a robust basis for preventive and corrective diagnostics.

Pete & Balasubramaniam (2015) emphasize the importance of consistency in artifact evolution, highlighting that discrepancies between versions affect system trust and maintainability. The modeling proposed by FCIA-OT contemplates this aspect by including requirements aimed at compatibility, resilience, technical instructions, and maintenance, ensuring analytical traceability of artifacts over time.

Table 8 structures the Object Requirements (RQO) as first-order elements for description and categorization of the technological construct. This classification encompasses from design and prototype to integrated subsystems, computational resources, advanced materials, and emerging technologies such as artificial intelligence, biotechnology, and hybrid solutions. Each table entry represents a critical unit of analysis, allowing the conceptual and technical delimitation of the central object.

Table 9 organizes the Artifact Requirements (RQA) according to an extensive set of physical-functional, structural, perceptual, operational, and computational descriptors. These requirements enable detailed decomposition of each component of the evaluated object, with the application of parametric values supporting comparative, predictive, and diagnostic analyses.

TABLE 8: OBJECT REQUIREMENTS (RQO)

Code	Object Requirements	Description
RO01	Project	Initial conception or technical detailing of a technological object.
RO02	Prototype	Initial or experimental version of a technological object.
RO03	Object	Primary entity to be analyzed. Can be a device, system, or technological solution.
RO04	Parts and Components	Individual components that constitute the technological object.
RO05	Hardware	Physical technological elements.
RO06	Hardware: Equipment	General equipment, such as machines and devices.
RO07	Hardware: Server	Hardware intended for hosting systems and data.
RO08	Hardware: Computer (PC)	Personal computers used in various contexts.
RO09	Hardware: IoT Device	Sensors, actuators, and devices connected to the Internet.
RO10	Hardware: Mobile Devices	Smartphones, tablets, and other portable devices.
RO11	Hardware: Wearables	Technological devices worn on the body, such as smartwatches and smart glasses.
RO12	Advanced Materials	Materials with innovative or superior properties, used to enhance devices.
RO13	Hardware: Network	Equipment and devices for network infrastructure.
RO14	Equipment	Devices used for specific functions.
RO15	Equipment: Electro-electronics	Domestic or industrial devices powered by electricity.
RO16	System	Set of interconnected components working in synergy.
RO17	Software	Programs and applications performing specific functions.
RO18	Software: Operating System	Platform managing hardware and software.
RO19	Software: Application	Programs developed for specific tasks.
RO20	Integrated System	Combination of hardware, software, and networks for comprehensive solutions.
RO21	Software: Middleware	Intermediate software for system integration.
RO22	Digital Tool	Software or hardware used to facilitate tasks.

RO23	Biotechnology	Technological applications based on biological systems, living organisms, or derivatives.
RO24	Artificial Intelligence	Computational systems designed to simulate human capabilities such as learning and decision-making.
RO25	Hybrid Technologies	Combinations of different technologies to create innovative and multifunctional solutions.
RO26	Design	Planning and structuring of the technological object.
RO27	Design: Object	Aesthetic and functional aspects of the object as a whole.
RO28	Design: Hardware	Aesthetics and functionality of hardware.
RO29	Design: Software	Software interface and usability.
RO30	Design: Interface	Interaction between the agent and the system.
RO31	Design: Screen(s)/Forms	Visual structures presented to the agent.
RO32	Process	Set of actions producing results.
RO33	Procedure	Specific sequences for task execution.
RO34	Algorithm	Logic and sequence of computational steps.
RO35	API	Programming interface connecting systems and applications.

The RQO dimension organizes, based on structural and functional descriptors, the fundamental components that constitute a technological object as the central analytical unit. Each item (RO01 to RO35) corresponds to critical characterization elements such as design, hardware, software, and computational processes, enabling the mapping of the object's total configuration in technical-operational, design, and interactional terms. This taxonomy supports the delimitation of the primary construct, facilitating robust analyses of scope, composition, and systemic functionality.

Source: Author.

TABLE 9: ARTIFACT REQUIREMENTS OF OBJECTS (RQA)

Code	Object Artifact Requirements	Description	SPMI
RA01	Size	General measurements of the object or component.	**-5 a 10**
RA02	Dimension	Height, width, and depth of the artifact.	**-5 a 10**
RA03	Structure	Physical or functional organization of the artifact.	**-5 a 10**
RA04	Weight	Mass of the object, considering its transportability and usability.	**-5 a 10**
RA05	Height/Inner Space	Internal dimensions or usable internal height of the object.	**-5 a 10**
RA06	Mass	Amount of matter contained in the artifact.	**-5 a 10**
RA07	Surface	Texture and external finish of the object.	**-5 a 10**
RA08	Elasticity	Ability to return to the original shape after deformation.	**-5 a 10**
RA09	Stiffness	Resistance to deformation under stress.	**-5 a 10**

RA10	Durability	Capacity to retain functionality over time, resisting wear and continuous use.	**-5 a 10**
RA11	Shape	Geometric configuration or contours of the artifact.	**-5 a 10**
RA12	Quality	Overall assessment of the excellence and adequacy of the artifact's attributes.	**-5 a 10**
RA13	Strength	Ability to withstand physical or environmental stress without damage.	**-5 a 10**
RA14	Mobility	Capability of being moved or transported.	**-5 a 10**
RA15	Heating	Thermal behavior during operation.	**-5 a 10**
RA16	Consumption	Efficiency in the use of energy or resources.	**-5 a 10**
RA17	Texture	Tactile characteristics of the object's surface.	**-5 a 10**
RA18	Color(s)	Color palette employed in the design of the artifact.	**-5 a 10**
RA19	Luminosity	Intensity of light emitted or reflected by the artifact.	**-5 a 10**
RA20	Opacity	Degree of transparency or visibility of the object.	**-5 a 10**
RA21	Interface	Interaction point between the agent and the system.	**-5 a 10**
RA22	Pagination	Organization of content or visual elements.	**-5 a 10**
RA23	Movement	Ability to be repositioned or displaced.	**-5 a 10**
RA24	Position/Location	Spatial placement or orientation of the artifact.	**-5 a 10**
RA25	Visualization/ Visual	Quality and clarity of visual representations.	**-5 a 10**
RA26	Interface Controls	Devices or elements used to manipulate the system.	**-5 a 10**
RA27	Symbols/Icons/ Representation	Graphical elements used for visual communication.	**-5 a 10**
RA28	Configuration	Adjustable parameters and settings of the artifact.	**-5 a 10**
RA29	Installation	Ease of assembly or readiness for use.	**-5 a 10**
RA30	Uninstallation	Simplicity of removal or disassembly.	**-5 a 10**
RA31	Complexity	Degree of difficulty in using or understanding the artifact.	**-5 a 10**
RA32	Responsiveness	Ability to adapt to different usage conditions.	**-5 a 10**
RA33	Interface Logic	Organization and operation of the artifact's interface.	**-5 a 10**
RA34	Execution Logic	Functional execution flow of the artifact.	**-5 a 10**
RA35	Procedural Logic	Methods or steps followed by the artifact to perform tasks.	**-5 a 10**
RA36	Processing Output	Manner in which data are processed and transmitted.	**-5 a 10**
RA37	Processing Response	Response time and quality to user commands.	**-5 a 10**
RA38	Interaction	Capability of interacting with other systems or agents.	**-5 a 10**
RA39	Compatibility	Capacity to operate adequately with various systems, devices, or standards.	**-5 a 10**
RA40	Adaptability	Ability to adjust to different contexts or agents.	**-5 a 10**

RA41	Computational Intelligence	Integration of AI techniques to enhance functionalities.	**-5 a 10**
RA42	Biocompatibility	Compatibility of the artifact with biological systems.	**-5 a 10**
RA43	Hybridization	Combination of different technologies or concepts within the artifact.	**-5 a 10**
RA44	Customization	Ability of the artifact to adjust to user preferences or needs.	**-5 a 10**
RA45	Storage	Amount of data or information the artifact can store.	**-5 a 10**
RA46	Speed/Frequency	Operational performance related to execution time and processing cycles.	**-5 a 10**
RA47	Interconnection	Ability to connect and operate in an integrated manner among internal components, including both physical and digital communication.	**-5 a 10**
RA48	Error	Operational failures or unexpected behaviors that do not fully disrupt functionality.	**-5 a 10**
RA49	Instability/ Freezing	Conditions in which the artifact becomes temporarily nonfunctional or unresponsive, but recoverable without complete restart.	**-5 a 10**
RA50	Failure	Critical faults that render the artifact completely inoperative, requiring technical intervention, reboot, or replacement.	**-5 a 10**
RA51	Resilience	Ability to recover after a failure.	**-5 a 10**
RA52	Technical Instructions	Availability, clarity, completeness, and accessibility of manuals, user guides, technical documentation, and operational instructions.	**-5 a 10**
RA53	Maintainability	Ease, frequency, required time, and complexity of performing preventive, corrective, or evolutionary maintenance.	**-5 a 10**
RA54	Technical Support	Availability, quality, geographic coverage, response time, and customization of technical support services provided to the artifact, whether remote or in person.	**-5 a 10**

The RQA dimension unfolds, according to physical-functional, computational, and interactive parameters, the specific attributes of artifacts, parts, and properties constituting a technological object. Each requirement (RA01 to RA54) represents a granular unit of analysis, encompassing structural and perceptual aspects as well as computational logic, operational performance, and technical resilience. This systematic decomposition enables the quantification of critical attributes, supporting comparative, diagnostic, and predictive evaluations with high descriptive and analytical precision.

Source: Author.

The articulated structure between the requirements dimensions establishes a unique methodological platform capable of supporting transversal and multiscale evaluations, from microdevices to highly complex technological infrastructures. The core allows adaptive reconfiguration of analytical criteria, with the selection and combination of RQO and RQA requirements, technical, functional, structural, computational, perceptual, interactional, ergonomic, affective, social, environmental, regulatory, compliance, investigative, certification-related, and other specific axes, according to the system's logic, the application domain, and the objectives of analysis and evaluation. This flexibility ensures the systematic incorporation of disruptive technologies and the precise application across various scientific and industrial fields.

3.8 Error Severity Dimension (GVE)

The Error Severity Dimension (Dimensão Gravidade de Erros – GVE), within the scope of the FCIA-OT, establishes rigorous classificatory criteria for detecting, analyzing, and categorizing failures in technological objects, with an emphasis on functional, interactional, and cognitive impact. It is conceived as a systemic and non-reductionist core capable of affecting object performance, task continuity, and agent experience. Its modeling is not limited to the mere detection of operational failures, but incorporates factors such as tolerance, traceability, severity, persistence, recovery capability, and the risks associated with unmitigated failure. The dimension is structured in gradual levels of impact, enabling the mapping of states ranging from error-free conditions to critical failures, with support for decision-making in computational and hybrid environments under controlled risk.

A systemic understanding of failure severity can be traced back to the initial formulations of Hansen (1971), who interpreted errors as design deficiencies that could be mitigated through modularity and clear messaging. By shifting responsibility from the user to the system, he introduced an interaction engineering-centered approach. Bailey & Pearson (1983) expanded this perspective by emphasizing the diagnostic function of failures, associating their identification with the predictability of user rejection and the need for systematic measurements regarding the impact of technological updates.

Following this reasoning, the absence of well-structured feedback, as argued by Goodwin (1987), leads to redundant task cycles and directly compromises system efficiency. In this case, error transcends the technical domain, becoming a rupture in the agent's action flow. In the same direction, Nadin (1988) identifies semiotic failure as one of the main causes of persistent errors, highlighting the disconnection between icons, messages, and system functions in designs lacking symbolic integration. This approach broadens the concept of failure into the domain of interface languages and reinforces the idea of error as a communicational discontinuity.

Molich & Nielsen (1990) add to the model the requirement of continuous feedback during extended operations, linking the absence of clear signaling to the perception of systemic failure. Systems must be tolerant of input errors, offering immediate recovery mechanisms, and the severity of a failure is directly related to the clarity of the message and the possibility of resuming operation without frustration or intimidation.

From a different analytical perspective, Randell (1975) differentiates the structural nature of hardware and software failures. While physical defects are finite and traceable, software failures result from design inadequacies amplified by logical complexity, which makes exhaustive validation unfeasible and leads to recurrent and systemic errors.

Westland (2002) introduces the time variable into failure cost, demonstrating that the later a correction occurs, the greater its structural and financial impact. Severity, therefore, becomes a function not only of the type of error but also of the stage in the life cycle at which it occurs. Holzinger (2005) complements this approach by establishing a distinction between trivial and catastrophic errors, indicating that immediate rectifiability is a critical quality parameter in interactive systems. Severity analysis thus comes to include autonomous correction capacity and the extent of the failure's consequences.

In critical scenarios, Liljegren (2006) highlights the role of perceived severity in the selection of critical technologies, particularly in healthcare contexts, and systematizes criteria that allow estimation of the impact and persistence of failures. This methodology supports classification by severity levels, with the difficulty of committing errors being a primary usability marker. Pete & Balasubramaniam (2015) contribute the notion of failure traceability, showing that inconsistencies arising from the independent evolution of artifacts must be mapped and controlled based on precise technical criteria.

From the perspective of objective measurement, Zali (2016) establishes specific metrics for quantifying errors, evaluating both frequency and usage accuracy, and introduces an objective model for measuring severity. Heuwing, Mandl, & Womser-Hacker (2016) incorporate into the dimension the concept of reusing failure data across distinct design cycles, optimizing responses to recurring problems. Yusop, Grundy, & Vasa (2017) advocate for detailed descriptions in usability reports, including severity classifications and redesign proposals, as a way to ensure the technical intelligibility of failures for those responsible for resolving them.

Table 10 presents the coding system for the GVE dimension, composed of hierarchical severity levels anchored in technical-operational criteria extracted from the analyzed research. Each level expresses a specific degree of functional, perceptual, or structural impact on the evaluated object, serving as a technical basis for diagnostic, comparative, and predictive analyses.

TABLE 10: DEFINITION OF ERROR SEVERITY (GVE)

Adapted from Research	Code	Types of Error Severity	Definition	SPMI
Hansen (1971); Randell (1975); Bailey & Pearson (1983); Goodwin (1987); Nadin (1988); Molich & Nielsen (1990); Platt (1999); Westland (2002); Holzinger (2005); McRoberts (2005); Liljegren (2006); Alshamari & Mayhew (2008); Pete & Balasubramaniam (2015); Zali (2016); Heuwing, Mandl & Womser-Hacker (2016); Yusop, Grundy, & Vasa (2017); Albayram et al. (2018)	GVE01	No Errors	No errors identified. All functionalities operate as expected, without interruptions or failures. Error-Free State.	0
	GVE02	Negligible	The error has no perceptible impact on usability or functionality. No immediate correction is required.	1
	GVE03	Minor	The error has minimal impact on usability but does not prevent execution of core tasks. Attention required in future versions.	2
	GVE04	Moderate	The error affects usability and may cause agent frustration. Core functions can still be performed, though with limitations or difficulty.	3
	GVE05	Severe	The error significantly compromises usability, causing malfunctions in key features and degrading the agent's experience. Requires prioritized correction.	4
	GVE06	Critical	The error causes a system-wide failure, making the software unusable or resulting in data loss. Urgent correction is required.	5

The GVE dimension structures, through technical-operational criteria, the gradation of failure severity in technological objects, computational systems, and hybrid configurations. Each vector (GVE01 to GVE06) represents a specific level of functional, perceptual, or structural impact on the object, ranging from complete absence of errors to critical failures that render usage unfeasible. These types qualify the severity of failures based on their interference with task continuity, system recovery capacity, fault tolerance, and associated failures, providing parameters for diagnosis, corrective prioritization, and traceability in iterative design and evaluation cycles.

Source: Author.

The integration of the GVE dimension into the FCIA-OT matrix enables the technical qualification of failure as a critical and multiscalar variable, integrating operational, perceptual, and design aspects into reliability diagnostics. By structuring gradual severity levels based on fault tolerance, recovery capacity, and systemic impact, GVE supports precise analyses of the functional compromise of evaluated objects. This dimension enhances error traceability, guides corrective interventions, and expands the scope of reliability engineering within iterative cycles of technological development and evaluation.

3.9 Risk Degree Dimension (GSR)

The Risk Degree Dimension (Dimensão Graus de Risco – GSR), within the scope of FCIA-OT, functions as a structuring analytical vector for the assessment of reliability, safety, and functional sustainability of technological objects. Structured in increasing levels of criticality, GSR classifies risks based on objective criteria of severity, scope, and direct impact on the agent, the task, and the system. The proposed modeling transcends the traditional normative approach by incorporating contextual, cognitive, semiotic, and design variables into the analysis of vulnerability factors, supporting failure prediction, identification of critical omissions, and the outlining of preventive technical requirements.

Since Goodwin (1987), the relationship between design risks and neglect of usability has been observed, understood not merely as a functional flaw, but as a vector of progressive obsolescence. Poor usability, by imposing perceptual and operational barriers, increases cognitive load and weakens the system's persistence within its usage cycle. This fragility is amplified by inadequate ergonomic conditions, as noted by Bohnhoff, Brandt, & Henning (1992), who associate physical and mental risks with prolonged exposure, demanding evaluative models that incorporate protection of the worker's integrity as a core technical responsibility. Platt (1999) reinforces this approach by highlighting "usability risk" as a critical element for product trust and adoption, especially when the design fails to address users' real demands and expectations.

In the field of product engineering, Skelton & Thamhain (2005) propose a taxonomy of risks that includes both external and internal variables, warning that the absence of reliable data on usage contexts increases project complexity and weakens decision-making processes. McRoberts (2005) links the severity of risk to its probability, emphasizing the importance of anticipating misuse as an integral part of risk management. This perspective is expanded by Hirata et al. (2013), who show that everyday consumer products are often not evaluated according to rigorous technical criteria, leaving designers to make intuitive decisions, frequently resulting in avoidable accidents caused by design deficiencies.

In high-risk contexts, Albayram et al. (2018) argue that clear and emotionally balanced communication is essential for safe decision-making. Critical systems must be designed to reduce cognitive overload and reinforce trust bonds, particularly when interface failures or operational delays may escalate into harmful events.

The GSR dimension plays a transversal role in safe systems engineering, integrating technical, human, and operational variables into hierarchical classifications that are sensitive to context and functional criticality. Table 11 presents the defined risk degree types, systematized into technical-operational levels based on empirical evidence from the analyzed research. Each type corresponds to a specific level of risk, ranging from the absence of threats to critical vulnerabilities, allowing the mapping of impact severity on the object, its interfaces, and its usage agent.

TABLE 11: DEFINITION OF RISK DEGREES (GSR)

Adapted from Research	Code	Types of Risk Degrees	Definition	SPMI
Hansen (1971); Bailey & Pearson (1983); Goodwin (1987); Bohnhoff, Brandt, & Henning (1992); Platt (1999); Holzinger (2005); Skelton & Thamhain (2005); McRoberts (2005); Liljegren (2006); Alshamari & Mayhew (2008); Hirata et al. (2013); Yusop, Grundy, & Vasa (2017); Albayram et al. (2018)	GSR01	No Risk	The risk is nonexistent. No impact or inconvenience is expected in usage, operation, or interface. Risk-Free State.	**0**
	GSR02	Very Low	The risk is virtually nonexistent, with no significant impact expected. May include minor inconveniences in use or interface without serious consequences.	**1**
	GSR03	Low	The risk is low, with potential for minor issues such as mild physical discomfort, temporary loss of usability, or occasional hardware/software failures.	**2**
	GSR04	Moderate	The risk may affect both usage and user safety, including ergonomic errors, moderate data loss risks, or recurring failures that impair functionality.	**3**
	GSR05	High	The risk is significant, involving serious issues such as potential injury, critical hardware/software failures, or data security breaches.	**4**
	GSR06	Very High	The risk is extreme and may result in severe accidents such as fire, explosion, disability due to prolonged use, or complete system failure with irrecoverable data loss.	**5**

The GSR dimension formalizes, based on technical and situational criteria, the identifiable degrees of risk in technological objects, operating systems, or critical interactive configurations. Each vector (GSR01 to GSR06) represents a graduated level of potential threat, ranging from risk-free contexts to scenarios involving severe compromise of physical, cognitive, or informational integrity. These degrees express the scale of functional vulnerability, agent exposure, and design impact, allowing inference of the robustness, reliability, and safety level required for operation in controlled or adverse environments. This mapping becomes essential for decisions guided by mitigation, prevention, or redesign criteria.

Source: Author.

The integration of the GSR dimension into the FCIA-OT matrix enables the qualification of risk as a strategic variable in design, operational, and evaluative decisions. By structuring failure exposure into hierarchical levels sensitive to function, interface, and agent, this dimension makes it possible to anticipate vulnerabilities and define critical safety requirements. Its articulation with other dimensions of the model reinforces the diagnostic capacity of FCIA-OT in controlled-risk contexts, enhancing precision in managing reliability, usability, and functional robustness of the technological objects under analysis.

3.10 Attribute Dimension (ATB)

The Attribute Dimension (Dimensão Atributos – ATB), within the FCIA-OT framework, constitutes the technical core for encoding the quality of interaction between agent and technological object, allowing for the analytical decomposition of properties that define its functional, symbolic, and experiential adequacy. The identification and quantification of these attributes enable performance diagnostics based on operational, perceptual, and contextual criteria, aligning technical analysis with real-world use.

From this integrated perspective, Tractinsky (1997) argues that a system's acceptability depends not only on its functional usability, but also on the integration of aesthetic aspects. The aesthetic experience, historically neglected in the HCI field, represents a critical factor in system acceptance, requiring investigations that articulate these dimensions within interactive modeling. This conceptual movement is further developed by Frøkjær, Hertzum, & Hornbæk (2000), who highlight the inadequacy of assessments that disregard dimensions such as effectiveness, efficiency, and satisfaction in complex tasks. The fragmentation of metrics undermines the validity of results and the capacity for systemic diagnosis.

Continuing this development, Holzinger (2005) consolidates five core attributes for evaluating interactive software, learnability, efficiency, memorability, error tolerance, and satisfaction, structuring a coherent model between technical performance and the agent's experience. Complementarily, Laugwitz, Held, & Schrepp (2008) include attractiveness, clarity, efficiency, dependability, stimulation, and novelty as measurable expressions of user perception in broader contexts.

Despite this conceptual expansion, Ilmberger, Schrepp, & Held (2008) point out the limitations of treating aesthetics as an independent attribute, suggesting that its influence occurs indirectly and is mediated by semantic dimensions of the interface.

Reinforcing the role of context, Hartmann, Sutcliffe, & Angeli (2008) emphasize that the weight assigned to quality attributes depends directly on the nature of the task and the domain of use: in critical contexts, usability and functionality prevail; in playful environments, aesthetics and engagement gain centrality.

In a more comprehensive formulation, Zali (2016) proposes an expanded taxonomy of attributes, including effectiveness, efficiency, satisfaction, learnability, memorability, operability, attractiveness, cognitive load, safety, accessibility, compatibility, usefulness, and flexibility, linked to specific metrics that enable integrated interaction modeling. Aligned with this perspective, Weichbroth (2018) stresses the relevance of contextual encoding in interface construction, demonstrating that responsiveness and symbolic expectation constitute attributes that support the functional intelligibility of the object.

In the most contemporary formulation of the attributive model, Zarour (2020) concludes that system success depends on the articulation between technical requirements and experienced attributes, making the measurement and qualification of attributes a strategic activity in environments of innovation and competitiveness. Within FCIA-OT, this dimension also incorporates adaptive attributes such as flexibility, portability, and interoperability, enabling reconfigurations according to the type of object, the agents involved, and the operational ecosystem in which it is embedded.

The applied approach in the ATB dimension ensures not only the traceability of interaction quality criteria, but also their formalization as analytical types, subject to comparative measurement across different evaluation, diagnostic, or technological development cycles. Table 12 presents the defined types of attributes, organized into technical-operational levels and empirically derived from the analyzed studies, aligned with the FCIA-OT matrix.

TABLE 12: DEFINITION OF ATTRIBUTE TYPES (ATB)

Adapted from Research	Code	Attribute Types	Definition	SPMI
Tractinsky (1997); Frøkjær, Hertzum, & Hornbæk (2000); Han et al. (2001); Holzinger (2005); Laugwitz, Held, & Schrepp (2008); Ilmberger, Schrepp, & Held (2008); Hartmann, Sutcliffe, & Angeli (2008); Zali (2016); Weichbroth (2018); Zarour (2020)	ATB01	Usability	The ease with which the agent understands and uses the object, without excessive effort, to achieve their goals efficiently and effectively.	**-5 a 10**
	ATB02	Usefulness	Assesses whether the object provides the necessary functions and features to meet the agent's practical needs and expectations within their usage context.	**-5 a 10**
	ATB03	Efficiency	Evaluates the speed and resources consumed during the use of the object to complete a task, optimizing the agent's performance and time.	**-5 a 10**
	ATB04	Functionality	Verifies the object's ability to correctly perform all expected operations and actions, according to its specifications and intended purposes.	**-5 a 10**
	ATB05	Accessibility	Determines how well the object can be used by agents with different abilities and conditions, without compromising the quality of the experience.	**-5 a 10**

Tractinsky (1997); Frøkjær, Hertzum, & Hornbæk (2000); Han et al. (2001); Holzinger (2005); Laugwitz, Held, & Schrepp (2008); Ilmberger, Schrepp, & Held (2008); Hartmann, Sutcliffe, & Angeli (2008); Zali (2016); Weichbroth (2018); Zarour (2020)	ATB06	Flexibility	Refers to the object's capacity to adapt to different usage scenarios or customizations, offering alternatives to meet diverse needs.	**-5 a 10**
	ATB07	Controllability	Measures the agent's ability to adjust and manipulate the object according to their preferences, achieving the desired outcome with precision.	**-5 a 10**
	ATB08	Interoperability	Assesses the object's ability to operate correctly and in an integrated manner with other systems or devices, expanding its usefulness across contexts.	**-5 a 10**
	ATB09	Portability	Measures how easily the object can be transported or used across various environments and platforms without compromising its functionality.	**-5 a 10**
	ATB10	Compliance	The degree to which the technological object adheres to relevant regulations, technical standards, and industry norms, ensuring appropriate and safe use.	**-5 a 10**
	ATB11	Stability	Verifies the object's consistency and reliability over time, ensuring continuous operation without frequent failures.	**-5 a 10**
	ATB12	Aesthetics	Assesses the object's visual appeal, including its appearance, layout, and design, which influence the agent's acceptance and satisfaction.	**-5 a 10**
	ATB13	Acceptability	Refers to the agent's willingness to adopt the object, considering its functionality, ergonomics, and usage context.	**-5 a 10**
	ATB14	Innovation	Measures the extent to which the object incorporates new solutions or technologies to enhance the user experience or solve problems creatively.	**-5 a 10**
	ATB15	Simplicity	The clarity and straightforwardness in the object's presentation and operation, ensuring that the agent can interact with it without unnecessary complexity.	**-5 a 10**

The ATB dimension formalizes, based on technical-interactional criteria, the attributes that qualify the performance and acceptability of technological objects. Each vector (ATB01 to ATB15) represents a measurable property linked to the system's functionality, perception, or adaptability in response to the agent's demands and contextual conditions. The attributes range from pragmatic aspects, such as usability and efficiency, to hedonic and normative dimensions, such as aesthetics, acceptability, and compliance. The typological modeling enables precise inferences about design coherence, systemic responsiveness, and the degree of alignment between the object and its operational purpose, becoming decisive in processes of evaluation, development, or reconfiguration.

Source: Author.

The integration of the ATB dimension into the FCIA-OT matrix enables the systematization of critical properties in agent–object interaction, articulating both objective and subjective attributes under measurable and comparable criteria. By operationalizing variables such as usability, accessibility, flexibility, and aesthetics at technical-analytical levels, ATB enhances diagnostic capacity regarding the performance, adaptability, and acceptability of technological objects. This structure supports precise and sustainable design decisions, sustaining cross-sectional analyses in real-world application contexts and contributing to the continuous enhancement of systemic quality.

3.11 Accessibility Dimension (ACB)

The Accessibility Dimension (Dimensão Acessibilidade – ACB), within the technical-structural scope of the FCIA-OT framework, constitutes a multiscalar analytical axis aimed at identifying and qualifying barriers that hinder the full operationalization of technological objects by agents with diverse functional profiles. Its formalization goes beyond the application of isolated assistive technologies, encompassing an integrative architecture conceived from the early stages of the technological cycle. This architecture incorporates interoperability across platforms, interactive plasticity, and adaptive support for the agents' sensory, motor, cognitive, and situational conditions.

Cooper (1999), in describing what he terms the "software apartheid" phenomenon, highlights how poorly designed digital products generate operational exclusion, particularly affecting groups with limited familiarity with digital practices. Such segregation undermines agents' autonomy and restricts their participation in social and productive processes mediated by technology. Based on this premise of structural exclusion, Han et al. (2001) propose articulating accessibility, adaptability, controllability, and effectiveness as technical vectors that define the scope of use and functional accuracy in system interaction.

Within this same field, Abascal (2002) introduces the notion of Universal Design as a design methodology that anticipates accessibility requirements from the outset, avoiding reliance solely on compensatory resources. He warns of the ethical and legal risks emerging from neglecting privacy and the social exclusion of agents with disabilities. Wegge & Zimmermann (2007) broaden this understanding by emphasizing the importance of interoperability with assistive technologies, which ensures continuity of use through compatibility with devices already familiar to the user.

In analyzing cognitive relations within human–machine symbiosis, Griffith & Greitzer (2007) propose the concept of "neo-symbiosis," wherein the system must adapt to human cognitive limits. This approach demands the redesign of interfaces to include monitoring mechanisms and dynamic adjustments capable of mitigating information overload and reducing operational stress. Extending this analysis, Hochheiser & Lazar (2007) shift the focus of accessibility toward a critical dimension of design, revealing how subtle design decisions can redefine the role of the analyst or designer, imposing responsibilities that transcend the technical domain and involve social, political, and personal dimensions.

In the context of web interaction, Fogli, Parasiliti Provenza, & Bernareggi (2013) observe that widely adopted accessibility standards often focus on static criteria such as layout, color schemes, and link structures. However, these standards prove insufficient in the face of the dynamic complexity of contemporary applications, which rely on client-side scripts and real-time interaction. Based on this critique, they advocate expanding evaluation criteria to encompass richer dynamics that adapt to agent behavior.

According to Coughlan & Miele (2017), emerging technologies such as augmented reality (AR) can function as sensory mediators by offering visual annotations, tactile guidance, or auditory cues that enhance the accessibility of physical objects and environments. In parallel, Begnum (2020) analyzes the evolution of interactive design through the emergence of graphical interfaces and assistive devices, highlighting solutions such as screen readers and adaptive switches that expand the functional scope for agents with motor or visual impairments.

Considering this complexity of criteria, Lin Cheoh et al. (2020) advance this axis by demonstrating that, although compliance with technical accessibility standards is essential, interactive effectiveness depends on the integration of subjective preferences. Accurate evaluation of interfaces thus requires the systematic incorporation of feedback from users with disabilities to ensure alignment between normative guidelines and real usage demands.

The formalization of the ACB within the FCIA-OT is structured around technical-operational criteria organized into analytical groups that integrate elements such as informational redundancy, keyboard navigability, visual contrast, cognitive accessibility, multimodal responsiveness, and compatibility with assistive technologies. This dimension enables graduated measurement of accessibility in tangible, digital, hybrid, or cyber-physical objects, ensuring compliance with principles of full inclusion and technological equity. Table 13 presents the types of accessibility criteria and their technical definitions, aligned with the FCIA-OT matrix.

TABLE 13: DEFINITION OF ACCESSIBILITY CRITERIA TYPES (ACB)

Adapted from Research	Groups	Code	Accessibility Criteria Types	Definition	SPMI
Cooper (1999); Han et al. (2001); Abascal (2002); Wegge & Zimmermann (2007); Griffith & Greitzer (2007); Hochheiser & Lazar (2007); Fogli, Parasiliti Provenza, & Bernareggi (2013); Coughlan & Miele (2017); Begnum (2020); Lin Cheoh et al. (2020); Cecilio (2022)	**AC1: Texts, Images, and Media**	ACB01	Text Alternatives (Alt Text)	Provides alternative descriptions for non-text elements, ensuring accessibility for screen readers.	**-5 a 10**
		ACB02	Information Redundancy	Essential information is presented redundantly (text, audio, visual), addressing diverse user needs.	**-5 a 10**
		ACB03	Interaction with Multimedia	Offers accessible controls (e.g., captions, transcripts, volume control) for videos, audio, and multimedia content.	**-5 a 10**
		ACB04	Multilingual Content Support	Supports multiple languages, providing accessible translation for essential terms.	**-5 a 10**
	AC2: Navigation and Interaction	ACB05	Keyboard Navigation	Enables complete navigation via keyboard, including visible focus and logical traversal between elements.	**-5 a 10**
		ACB06	Navigation Consistency	Maintains a predictable and organized structure to reduce cognitive load.	**-5 a 10**
		ACB07	Category and Filter-Based Navigation	Provides efficient navigation through menus and filters accessible via keyboard and screen readers.	**-5 a 10**
		ACB08	Time and Interaction Control	Allows adjustment of interaction timing or pausing of activities based on the agent's needs.	**-5 a 10**

Cooper (1999); Han et al. (2001); Abascal (2002); Wegge & Zimmermann (2007); Griffith & Greitzer (2007); Hochheiser & Lazar (2007); Fogli, Parasiliti Provenza, & Bernareggi (2013); Coughlan & Miele (2017); Begnum (2020); Lin Cheoh et al. (2020); Cecilio (2022)	**AC3: Visual Design and Settings**	ACB09	Color Contrast	Ensures sufficient contrast between text and background to facilitate reading for users with visual impairments.	**-5 a 10**
		ACB10	Font Size and Adjustability	Allows text resizing without loss of content or functionality.	**-5 a 10**
		ACB11	Visibility and Legibility	Uses clear fonts, appropriate spacing, and adequate contrast to ensure universal legibility.	**-5 a 10**
		ACB12	Accessibility Adjustments	Enables configuration options such as text enlargement, contrast adjustment, and caption activation.	**-5 a 10**
		ACB13	Adaptation to Usage Contexts	Supports adjustments for different usage environments (e.g., noisy or poorly lit settings).	**-5 a 10**
	AC4: Forms and Feedback	ACB14	Accessible Forms	Ensures clear labels, instructions, and accessible validation in forms.	**-5 a 10**
		ACB15	Error and Success Feedback	Provides clear and accessible feedback for errors and confirmations.	**-5 a 10**
		ACB16	Clear Input Errors	Communicates input errors accessibly, with suggestions for correction.	**-5 a 10**
	AC5: Multimodality and Emerging Technologies	ACB17	Multimodality	Offers multiple modes of input and output (text, audio, video, gestures).	**-5 a 10**
		ACB18	AR/VR Accessibility	Ensures accessibility in augmented and virtual reality environments (e.g., adapted interfaces).	**-5 a 10**
		ACB19	IoT Accessibility	Ensures IoT devices are accessible via voice control and adapted applications.	**-5 a 10**
		ACB20	Mobile Application Accessibility	Provides optimized interfaces for mobile devices, including gesture and voice control.	**-5 a 10**

Cooper (1999); Han et al. (2001); Abascal (2002); Wegge & Zimmermann (2007); Griffith & Greitzer (2007); Hochheiser & Lazar (2007); Fogli, Parasiliti Provenza, & Bernareggi (2013); Coughlan & Miele (2017); Begnum (2020); Lin Cheoh et al. (2020); Cecilio (2022)	**AC6: Assistive Technologies and Privacy**	ACB21	Screen Reading Compatibility	Compatible with screen reading software, ensuring correct content interpretation.	**-5 a 10**
		ACB22	Compatibility with Assistive Technologies	Compatible with screen readers, magnifiers, voice control, and other assistive devices.	**-5 a 10**
		ACB23	Voice Interface Accessibility	Supports clear interaction via voice commands, with auditory feedback.	**-5 a 10**
		ACB24	Accessible Privacy and Security	Provides accessible privacy and security settings with clear explanations.	**-5 a 10**
		ACB25	Cognitive Accessibility	Facilitates use by agents with cognitive impairments, through clear navigation and simple instructions.	**-5 a 10**
	AC7: Experience and Temporary Adjustments	ACB26	Reaction Time and Interactivity	Allows adjustment of response times for agents with motor or cognitive impairments.	**-5 a 10**
		ACB27	Smooth Responses and Transitions	Utilizes smooth animations and transitions for users with cognitive or sensory disabilities.	**-5 a 10**
		ACB28	Accessibility in Temporary Situations	Provides accessibility for agents with temporary limitations (e.g., injuries).	**-5 a 10**
		ACB29	Multimodal Feedback	Offers visual, tactile, and auditory feedback for all interactions.	**-5 a 10**
		ACB30	Stress and Well-being	Designs aimed at reducing stress and promoting well-being, avoiding physical and mental overload.	**-5 a 10**

The ACB dimension formalizes, through technical-operational criteria, the elements that determine the degree of accessibility of technological objects in real usage contexts. Each vector (ACB01 to ACB30) represents a measurable vector of functional compatibility between the agent and the system, considering sensory, motor, cognitive, or situational limitations. The modeling of these types enables rigorous diagnostics of design adequacy, adaptive capacity, and the inclusive sustainability of the evaluated objects, consolidating the ACB dimension as a structuring core of inclusion engineering within the scope of the FCIA-OT framework.

Source: Author.

The integration of the ACB dimension into the FCIA-OT matrix establishes an evaluative architecture capable of formalizing, at technical and functional levels, the relationship between technological objects and the various accessibility profiles required by agents with sensory, motor, cognitive, or situational limitations. By systematizing multistructural criteria such as informational redundancy, interactive plasticity, and assistive compatibility, ACB expands the traditional scope of accessibility, linking it to principles of technological justice and design efficiency. This core ensures the integrated measurement of operational barriers and enablers, contributing to the elimination of inequalities in technology access and use, and enabling responsive adjustments in development, validation, and continuous improvement processes.

3.12 QRSUER Technology Dimension (Quality, Social Responsibility, Sustainability, Usefulness, Ethics, and Reason)

The QRSUER Technology Dimension (Dimensão Tecnologia QRSUER) constitutes a core and cross-cutting axis of the FCIA-OT, designed to establish rigorous technical-scientific criteria capable of measuring, qualifying, and classifying the systemic performance of technological objects through the lens of their commitments to structural quality, social responsibility, resource sustainability, pragmatic usefulness, ethical principles, and rational foundations. It is a technological approach of high analytical complexity, whose scope is not limited to functional performance, but incorporates, in both normative and evaluative terms, socio-environmental, energy, cognitive, and moral variables. The pillars of QRSUER are:

Quality: Products and systems that meet or exceed expected technical and functional standards, demonstrating excellence in design and performance.

Social Responsibility: Adoption of fair and equitable practices that positively impact communities and workers involved.

Sustainability: Reduction of emissions, rational use of resources, and waste minimization, with a focus on environmental preservation and the well-being of future generations.

Usefulness: Development aimed at solving practical problems and improving quality of life.

Ethics and Reason: A solid foundation in moral principles, ensuring that technology is used for positive, legal, and non-harmful purposes for human health or the environment.

This dimension operates through a set of technical criteria that analyze the impact of both tangible and intangible objects across all phases of their life cycle—from conception and resource extraction to planned obsolescence, disposal, and reintegration through circular economy practices. The QRSUER structure is grounded in technical-scientific guidelines and formal classifications that encompass attributes such as energy efficiency, emissions reduction, recyclability, adaptive modularity, regenerative impact, sociotechnological equity, carbon neutrality, water management, and biodiversity protection, among others, allowing for the assessment of risks, merits, deficiencies, and regenerative potential of evaluated technologies, in accordance with the modular structure of the FCIA-OT.

Since the late 1980s, Rauner, Rasmussen, & Corbett (1988) warned that computational environments designed solely for individual performance overlook the essential role of cooperative relationships in the workspace. Technological development requires that machines act as an extension of the human, not as a substitute, a premise that links technical design to principles of autonomy and continuous learning. Simultaneously, Cutler (1989) exposed the operational limits of the prevailing industrial model by highlighting the contradiction between the increasing use of plastics and the absence of viable solutions for their end-of-life management. The lack of effective policies for the reintegration of such waste into the production cycle generates a massive environmental liability, underscoring the urgency of integrating "Design for Recycling" strategies from the early stages of engineering.

In the early 1990s, Shneiderman (1990) broadened this discussion by proposing that accessible and ethically informed technologies must meet not only technical standards but also include traditionally marginalized populations. The organizational structure of systems must, in this regard, support both the functional diversity of agents and the strengthening of social structures that ensure equity.

This position converges with Bohnhoff, Brandt, & Henning (1992), for whom the anthropocentric model constitutes the key to an engineering approach that values life. By promoting systems that enhance human capabilities, it becomes possible to achieve productivity, safety, and sustainability simultaneously, linking technical responsibility with intergenerational justice.

In the following decade, the challenges associated with the end of the life cycle of computational systems became central. Jain & Wullert (2002) anticipated the structural risks of ubiquitous computing by demonstrating that its widespread distribution and rapid obsolescence transform devices into catalysts of invisible contamination. Non-biodegradable materials, heavy metals, and toxic gases generated during production or incineration turn everyday objects into agents of chronic environmental degradation. In line with this concern, Bhuie et al. (2004) showed that devices such as cell phones and computers contain toxic elements with high leaching potential, whose improper handling and disposal compromise groundwater, soil, and air, shifting the technical issue into the ethical-sanitary domain.

The scaling crisis of electronic waste is addressed with greater technical precision by Hilty (2005), who quantified the flow of obsolete equipment and identified both the potential for precious metal recovery and the health risks related to irregular disposal. Although economically attractive, global recycling of electronic equipment perpetuates inequalities, as it is mostly carried out in low-income countries without proper environmental controls or labor protections.

In response to this imbalance, Blevis (2007) proposed a classificatory framework of sustainable practices, ranging from conventional disposal to high sociocultural value solutions, such as durable design and symbolic reuse. The classification reinforces the need to articulate design decisions with regenerative, rather than merely compensatory, horizons.

The conceptual proposal of Green IT, developed by Murugesan (2008), offers a normative model that covers the entire life cycle of computational systems, linking technical performance to the mitigation of environmental impacts. Unlike isolated approaches, Green IT presupposes a systemic, integrated engineering aligned with principles of energy efficiency, social justice, and organizational ethics. Subsequently, Bose & Luo (2011) reinforced the business viability of this transition by demonstrating that sustainable practices promote not only resource savings but also operational and collaborative gains. Sustainability, therefore, ceases to be a burden and becomes a structuring competitive advantage.

Tang & Zhou (2012) emphasized that the adoption of sustainable production technologies is not merely a technical decision, but a strategic positioning vector. Reverse logistics operations not only reduce environmental impacts but also create new markets and strengthen public perception of corporate responsibility. At this point, technology is no longer treated as instrumentally neutral and enters the realm of ethical reputation and institutional coherence.

Pargman & Raghavan (2014) deepened this critique by showing that much of today's technological systems are developed without rigorous consideration of the intensive use of natural resources. The ecological footprint must be treated as a design variable, not as a remediable consequence. The critique is not aimed at the absence of solutions, but at the recurrent neglect of environmental variables that condition the systemic sustainability of technology. This shift is expanded by Remy et al. (2018), who pointed out the inadequacy of traditional evaluation methods at the interface between HCI and sustainability. Technological research, they argue, must consider not only the artifact's performance but also the side effects generated in social, environmental, and epistemological dimensions, demanding new methodological paradigms.

In industrial applications, Cecilio (2022) argued that the convergence between automation and Joint Cognitive Systems (JCS) requires the incorporation of assistive technologies and technical adaptation methodologies that prioritize operators. The absence of such structures compromises not only workers' health but also the performance of production processes themselves, revealing structural gaps that undermine both efficiency and equity. In the same analytical context, Sharma, Kumar, & Nardi (2023) denounced practices such as software-induced obsolescence and the deliberate limitation of repairability. Although justified under market logics, such strategies perpetuate forced replacement cycles and amplify waste generation. In response, they proposed a shift toward technological development models that incorporate economic literacy, planned redesign, and a break with the infinite growth paradigm.

Within this framework, QRSUER Technology emerges as a technical-scientific construct aimed at operationalizing critical, precise, and measurable criteria that qualify technologies from multiple perspectives: environmental, ethical, social, functional, and regenerative. Table 14 presents the formalization of the criteria of this dimension, organized by thematic groups.

TABLE 14: DEFINITION OF TECHNOLOGY CRITERIA TYPES (QRSUER)

Adapted from Research	Groups	Code	Criterion Types QRSUER	Definition	SPMI
Rauner, Rasmussen & Corbett (1988); Cutler (1989); Shneiderman (1990); Bohnhoff, Brandt, & Henning (1992); Jain & Wullert (2002); Bhuie et al. (2004); Hilty (2005); Blevis (2007); Murugesan (2008); Bose & Luo (2011); Tang & Zhou (2012); Pargman & Raghavan (2014); Remy et al. (2018); Cecilio (2022); Sharma, Kumar, & Nardi (2023)	**TQ1: Sustainability and Resources**	TQRS01	Resource Use and Efficiency	The product or system meets practical needs by promoting resource efficiency, including energy use, and contributing to environmentally sustainable and socially responsible solutions. It evaluates consumption during use, encourages input optimization, and minimizes negative impacts while maximizing overall benefits.	**-5 a 10**

Rauner, Rasmussen & Corbett (1988); Cutler (1989); Shneiderman (1990); Bohnhoff, Brandt, & Henning (1992); Jain & Wullert (2002); Bhuie et al. (2004); Hilty (2005); Blevis (2007); Murugesan (2008); Bose & Luo (2011); Tang & Zhou (2012); Pargman & Raghavan (2014); Remy et al. (2018); Cecilio (2022); Sharma, Kumar, & Nardi (2023)		TQRS02	Resource Sustainability	Emphasizes the use of renewable materials and efficient management of natural inputs, prioritizing practices that minimize waste and promote long-term resource sustainability throughout the product or system's life cycle.	**-5 a 10**
		TQRS03	Emission Reduction	Significant reduction of pollutant emissions throughout the product or system's life cycle, contributing to the mitigation of environmental impacts and aligning with global standards of environmental responsibility.	**-5 a 10**
		TQRS04	Solid Waste Management	The product or system's ability to minimize waste generation, as well as to reuse and properly dispose of it, promoting practices that comply with sustainability standards and responsible waste management.	**-5 a 10**
		TQRS05	Active Disposal	Strategic actions for appropriate end-of-life disposal, including initiatives that promote reuse, recycling, and practices that ensure the responsible management of materials.	**-5 a 10**
		TQRS06	Carbon Neutrality	The product or system's capacity to offset or eliminate its carbon emissions, aligning with global sustainability goals and contributing to the reduction of the carbon footprint.	**-5 a 10**
		TQRS07	Regenerative Impact	Practices that not only minimize environmental impacts but also contribute to the regeneration of affected ecosystems, expanding the environmental benefits generated by the product or system.	**-5 a 10**
		TQRS08	Water Efficiency	Evaluates water use optimization, from consumption reduction to efficient reuse and the implementation of technologies that minimize waste and encourage water conservation throughout the product or system's life cycle.	**-5 a 10**

Rauner, Rasmussen & Corbett (1988); Cutler (1989); Shneiderman (1990); Bohnhoff, Brandt, & Henning (1992); Jain & Wullert (2002); Bhuie et al. (2004); Hilty (2005); Blevis (2007); Murugesan (2008); Bose & Luo (2011); Tang & Zhou (2012); Pargman & Raghavan (2014); Remy et al. (2018); Cecilio (2022); Sharma, Kumar, & Nardi (2023)		TQRS09	Biodiversity Protection	Measures and practices that minimize impacts on local ecosystems, promote biodiversity conservation, and ensure responsible environmental management across the entire production chain, including actions to restore habitats and protect native species.	**-5 a 10**
	TQ2: Sustainable Design and Circular Economy	TQRS10	Recyclability	Capacity for component reuse or recycling at the end of their useful life, promoting a circular approach that reduces waste and environmental impact.	**-5 a 10**
		TQRS11	Facilitated Repairability	Ease of repairing or replacing components, extending the product's lifespan and reducing costs associated with disposal and the acquisition of new items.	**-5 a 10**
		TQRS12	Modular Adaptability	Encourages the modification, replacement, and upgrading of modular components, enabling greater flexibility in use and maintenance, reducing waste, and enhancing product or system durability.	**-5 a 10**
		TQRS13	Circular Design	Design practices that ensure durability, resource reuse, and waste reduction. Prioritizes solutions that minimize environmental impacts throughout the product or system's life cycle, supporting the circular economy.	**-5 a 10**
	TQ3: Social Impact and Inclusion	TQRS14	Social Impact and Equity	The product or system promotes accessibility, technological inclusion, and benefits for communities, ensuring fair, equitable practices that contribute to reducing social inequalities.	**-5 a 10**
		TQRS15	Technological Inclusion	Integration of different social groups into the product or system, promoting equitable access to technologies and the use of innovative solutions.	**-5 a 10**
		TQRS16	Positive Local Economic Impact	Strengthens local production chains by encouraging job creation, use of regional suppliers, and sustainable community development, reducing socioeconomic disparities.	**-5 a 10**

Rauner, Rasmussen & Corbett (1988); Cutler (1989); Shneiderman (1990); Bohnhoff, Brandt, & Henning (1992); Jain & Wullert (2002); Bhuie et al. (2004); Hilty (2005); Blevis (2007); Murugesan (2008); Bose & Luo (2011); Tang & Zhou (2012); Pargman & Raghavan (2014); Remy et al. (2018); Cecilio (2022); Sharma, Kumar, & Nardi (2023)	**TQ4: Compliance, Ethics, and Transparency**	TQRS17	Transparency and Privacy	Clarity and honesty in communicating environmental and social impacts, ensuring the ethical and responsible use of personal data and sensitive information related to the product or system.	**-5 a 10**
		TQRS18	Transparency and Traceability	Promotes clear, accessible, and verifiable disclosure of environmental and social information. Includes traceability, certifications, and reports that ensure ethical and environmental assessment across the production chain, reinforcing accountability to stakeholders.	**-5 a 10**
		TQRS19	Legal Compliance	Ensures that the product or system is in full compliance with applicable environmental laws and regulations, supporting an ethical and responsible market approach.	**-5 a 10**
		TQRS20	Ethics and Transparency in AI Systems	Ensures that AI systems, algorithms, and architectures are developed and applied based on ethical principles, bias mitigation, and regulatory compliance, ensuring transparency and accountability in data use.	**-5 a 10**
	TQ5: Innovation and Technological Impact	TQRS21	Material Safety	Use of non-toxic and health-safe materials. Evaluates both the benefits provided and the mitigation of risks associated with use and disposal, prioritizing materials that promote sustainability and well-being.	**-5 a 10**
		TQRS22	Sustainable Integration	The product or system's alignment with environmental and social practices in its context of use, promoting a balance between functional performance and positive environmental impact.	**-5 a 10**
		TQRS23	Responsible Innovation	Assesses the product or system's commitment to introducing technologies that benefit both the environment and society, promoting sustainable progress.	**-5 a 10**

Rauner, Rasmussen & Corbett (1988); Cutler (1989); Shneiderman (1990); Bohnhoff, Brandt, & Henning (1992); Jain & Wullert (2002); Bhuie et al. (2004); Hilty (2005); Blevis (2007); Murugesan (2008); Bose & Luo (2011); Tang & Zhou (2012); Pargman & Raghavan (2014); Remy et al. (2018); Cecilio (2022); Sharma, Kumar, & Nardi (2023)	**TQ6: Environmental Conservation and Preservation**	TQRS24	Efficient Use of Space	Evaluates how efficiently the product or system uses physical space, promoting solutions that minimize spatial occupation without compromising functionality or performance.	**-5 a 10**
		TQRS25	Environmental Preservation	Practices that ensure the conservation of ecosystems and biodiversity, reducing negative impacts associated with the production, use, and disposal of the product or system.	**-5 a 10**
		TQRS26	Preservation of Water and Subsurface Resources	Practices, systems, and technologies aimed at preserving bodies of water (rivers, seas, lakes) and subsurface resources (aquifers, groundwater), preventing contamination by pollutants, waste, or toxic substances. Includes water and soil purification and recovery technologies, proper waste disposal, and sustainable practices that ensure water quality and soil integrity, with an emphasis on protecting aquatic and underground ecosystems.	**-5 a 10**
		TQRS27	Air Pollution and Atmospheric Protection	Practices, products, or systems that prevent atmospheric pollution in its various forms, including the reduction of emissions of pollutants (such as CO_2, methane, nitrogen oxides) and the mitigation of impacts related to global warming. Addresses technologies and methods for capturing and neutralizing atmospheric pollutants, preventing the release of toxic substances into the air, and promoting sustainable practices that ensure air quality and protect the atmosphere.	**-5 a 10**
		TQRS28	Chemical, Radioactive, and Heavy Metal Contamination	Evaluates the impact of chemical, radioactive, and heavy metal contamination associated with the product or system's life cycle. Considers risks to human health, the environment, and society, promoting mitigation practices and technologies that reduce emissions, leaks, and harmful exposure.	**-5 a 10**

Rauner, Rasmussen & Corbett (1988); Cutler (1989); Shneiderman (1990); Bohnhoff, Brandt, & Henning (1992); Jain & Wullert (2002); Bhuie et al. (2004); Hilty (2005); Blevis (2007); Murugesan (2008); Bose & Luo (2011); Tang & Zhou (2012); Pargman & Raghavan (2014); Remy et al. (2018); Cecilio (2022); Sharma, Kumar, & Nardi (2023)		TQRS29	Space Pollution and Environmental Impact	Practices, products, or systems that prevent environmental pollution in all its forms, including solid, liquid, gaseous, and other material or immaterial by-products that negatively affect the space environment. Encompasses prevention of impacts caused by space debris, improper disposal of materials in space, and the generation of harmful by-products. Also includes the accumulation of waste that may compromise natural resources and space infrastructures.	**-5 a 10**

The QRSUER dimension articulates, through technical-operational vectors, the criteria used to assess the systemic performance of technological objects with regard to sustainability, social responsibility, circularity, usefulness, ethics, and design rationality. Vectors TQRS01 to TQRS29 classify measurable attributes organized into thematic groups, enabling formal inferences on merit, impact, and technological compliance according to the modular logic of the FCIA-OT framework.

Source: Author.

The modeling of QRSUER types enables normative and technical-scientific inferences regarding the degree of systemic adherence, environmental responsibility, and ethical maturity of technological objects. By integrating formal measurement parameters with guidelines for sustainability, equity, and transparency, this dimension becomes decisive in processes of evaluation, redesign, certification, and technological adaptation, contributing to the transformation of industrial, institutional, and interactional practices under the modular logic of the FCIA-OT framework.

4 INTEGRATION OF SPMI AND SCDMIC SYSTEMS INTO THE MODULAR STRUCTURE OF THE FCIA-OT

The FCIA-OT matrix incorporates two proprietary systems: the Integrated Modular Multidimensional Scoring System (SPMI) and the Integrated Modular Color Definition and Classification System (SCDMIC), both designed to systematically and jointly quantify and represent the analytical results derived from each technical vector within the framework's dimensions. These systems operate synchronously, assigning scalar values and chromatic categories to the criticality of each observed element, thereby maximizing technical precision and methodological scalability. The SPMI and SCDMIC systems (see Chapter 2) function as integrated mechanisms for quantitative and visual representation of the analysis, structuring scalar weightings and chromatic codifications associated with the FCIA-OT dimension vectors.

The SPMI is a continuous modular assessment system whose logic allows values to be represented on a primary scale ranging from -5 to 10. SPMI values are assigned per vector (or element) of each dimension. In advanced contexts, the system may also operate with decimal values, applicable to the evaluation of micro-scale structures such as lines of code, modular artifacts, or specific functions. However, when opting for this decimal-based scoring mode, it is essential to have the appropriate knowledge for its correct application, ensuring effective data collection across each integrated dimension and evaluated element.

Complementarily, the SCDMIC classifies, through integrated colors, the level of criticality or adequacy of each scored vector. The colors red, orange, yellow, green, and conditional blue (c), used in cases requiring systemic interpretation, represent technical stages and alert levels that support rapid and auditable visualization of the matrix, promoting a precise interpretative reading aligned with the technical-normative scope of the FCIA-OT. Table 15 presents the integration of dimension vectors with the SPMI/SCDMIC systems, evidencing the application logic and modular coding structure that underpin the framework's operationalization.

TABLE 15: NTEGRATION OF DIMENSION VECTORS WITH THE SPMI SCALE AND SCDMIC CHROMATIC CATEGORIZATION

Dimensions	Integrated Modular Multidimensional Scoring System (SPMI)																
	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	C
Knowledge/ Experience							○	○	○	○	○	○	○	○	○	○	○
Object Requirements	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
Affordance	○	○	○		○			○						○	○	○	○
Perception	○							○	○		○					○	
Affectivity	○	○	○		○			○	○	○	○	○	○	○	○	○	
Satisfaction	○	○	○		○	○						○	○	○	○	○	
Effectiveness	○		○								○					○	
Error Severity						○	○	○	○	○	○						
Risk Levels						○	○	○	○	○	○						
Attributes	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
Accessibility	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
QRSUER Technology	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	

Presents the modular integration of the technical vectors from the FCIA-OT dimensions with the SPMI (Integrated Modular Multidimensional Scoring System) and the SCDMIC (Integrated Modular Color Definition and Classification System). Each vector is represented by a marker "○", indicating its position on the SPMI scale, which ranges from -5 to 10, with a conditional value "c" reserved for specific systemic analyses. The chromatic codification assigned to each value corresponds to the critical levels defined by the SCDMIC: red, orange, yellow, green, and conditional blue (c). This structure enables accurate assessment of criticality, quality, and adequacy levels of the elements, in technical and normative alignment with the framework's criteria. The matrix also allows the use of decimal scoring for detailed analysis of micro-scale structures, ensuring metric coherence, traceability, and data auditability.

Source: Author.

The integration of the SPMI and SCDMIC systems into the modular matrix of the FCIA-OT enhances the level of precision, auditability, and intelligibility of the analyses, enabling the formal and visually interpretable representation of the multivectorial complexity of the evaluated technological objects. By combining scalar metrics and chromatic categories, these systems become essential for the continuous operationalization of the framework, ensuring normative coherence, technical responsiveness, and adaptive potential across evaluative, design, and reconfigurative applications.

5 DISCUSSION

The structuring of the FCIA-OT consolidates a high-density interpretative and normative platform, technically and ontologically grounded, whose architecture not only organizes dimensions, vectors, and evaluative attributes, but reconfigures them into a formally modeled matrix designed to address scenarios of sociotechnical complexity. Unlike fragmented or taxonomic approaches, the framework operates as a third-order modular system, in which each dimension constitutes an autonomous epistemic nucleus, yet remains interoperable, allowing for analytical granularity without compromising systemic cohesion.

The integrated proposition of the SPMI and SCDMIC systems introduces a methodological and representational leap, transforming the FCIA-OT matrix into an instance of technical-cognitive synthesis. The SPMI provides a continuous modular scale with microcomponent adaptability, while the SCDMIC operates as a normatively codified chromatic semiotic system, capable of expressing evaluative criticality within auditable visual environments. This integration is not merely symbolic, but operational, enabling multiple dimensions to be simultaneously analyzed, classified, and designed through a shared language of value and impact.

By articulating dimensions, the FCIA-OT formalizes criteria that were previously addressed in isolated, non-measurable, or subjectively interpreted ways. The framework's ontology, by its instrumental nature, enables the reconfiguration of analysis and evaluation practices, the design of interventions, and the structuring of development cycles based on auditable, normative, and scientifically justified classificatory structures.

The FCIA-OT's ability to absorb, combine, and evaluate technical-cognitive, sociopolitical, environmental, and epistemic variables within a single matrix represents a rupture with classical functionalist models as well as with low-resolution heuristic methodologies. The matrix does not merely measure performance, it determines design coherence, normative convergence, and systemic impact through interdependent vectors. It constitutes a new kind of scientific language applied to technology: one that structures meaning, codifies value, and infers technical-operational potential with analytical precision.

Within the context of interaction engineering, technical-social design, and the evaluation of hybrid artifacts, the FCIA-OT inaugurates a new category of frameworks: neither reactive nor merely descriptive, but active, synthetic, and normative. Its application is not limited to post-project evaluation, but extends to planning, impact simulation, risk auditing, and the very technical-scientific conception of systems. The modular integration of dimensions with the scoring and chromatic classification systems transforms the FCIA-OT into a cognitive and normative infrastructure capable of operating across academic, industrial, institutional, and regulatory contexts.

The scalable and expandable nature of the framework, combined with its foundation in formalized criteria and validated vectors, positions the FCIA-OT as a scientific platform capable of customization, interoperability, and replication. Its modular logic allows for the creation of domain-specific instances (educational, industrial, governmental, environmental, etc.) without compromising the epistemic integrity of its original architecture. In summary, the FCIA-OT not only offers a new methodology: it proposes a new ontological grammar for the evaluation, development, and systemic qualification of complex technological objects.

6 CONCLUSION

The FCIA-OT is presented in this work as a novel ontology of modular and scalar nature, which surpasses conventional approaches by formally and audibly integrating multiple essential dimensions for the analysis, evaluation, and development of complex technological objects. By structuring validated criteria and systems of combined, chromatic, and multidimensional scoring, the framework not only describes but operates as a high-precision instrumental platform, capable of guiding strategic decisions and technical interventions with epistemic foundation and normative consistency.

The incorporation of the SPMI and SCDMIC systems represents a significant methodological advancement, enabling the qualification and quantification of criticalities with scalar granularity and compositional flexibility, decisive aspects when addressing the complexity of contemporary systems. The convergence between metrics and visual representations ensures coherence among technical reading, symbolic coding, and design action, thus enhancing the analytical power of the framework and its applicability in decision-making processes.

The modular logic of the FCIA-OT enables its adaptation to different domains and analytical scales, while preserving the epistemic integrity of its architecture. From integrated sociotechnical systems to micro-scaled components, its structure responds with precision and transparency to the operational, scientific, and normative demands of complex environments. As an applied ontology, it establishes a solid foundation for the advancement of evaluative practices, sustainability, and ethical responsibility in hybrid technologies, with empirically justified and normatively articulated foundations.

By combining methodological rigor, ontological structuring, and transdisciplinary applicability, the FCIA-OT positions itself as a strategic resource for researchers, developers, and managers, offering a robust referential that consolidates innovation, auditability, and sustainability across the life cycle of complex constructs. More than a methodology, it proposes a new grammar for the engineering of analysis and evaluation: synthetic, normative, and scientific.

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