CHAPTER 4

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

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ABSTRACT — This study presents the rigorous application of the Integrated and Advanced Core Framework for Analysis and Evaluation of Technological Objects (FCIA-OT) across three representative case studies: an interactive software with a graphical client registration interface, an embedded climate control system with dedicated firmware, and a UAV featuring a multicomponent hardware and software architecture. The analytical and evaluative processes were conducted in real-world settings, with technical data collected in loco, subjected to robust metrics, and structured into quantitative and qualitative matrices. The FCIA-OT demonstrated a unique capacity to model and measure the complexity of heterogeneous technological objects, operating with high precision through its integrated systems: the Integrated Modular Multidimensional Scoring System (SPMI), the Integrated Modular System for Color Classification and Definition (SCDMIC), the Global Usability and Interaction Score (SGUI), and the Integrated Modular Critical Score (SCMI). The results reveal a framework structurally superior to traditional approaches, enabling not only evaluation, but also deep understanding, traceability, and investigation of complex constructs with scientific replicability. The framework enables a data-driven diagnostic engineering approach, scalable and validated across distinct technological domains, capable of supporting technical analyses, generating auditable scientific evidence, and guiding standardization processes with methodological rigor. The proposed methodology establishes a new level of technical analysis, with high disruptive potential for industry, applied research, and regulatory certification systems.

KEYWORDS — FCIA-OT; SPMI; SCDMIC; SGUI; SCMI; Technological Evaluation; Complex Constructs; Diagnostic Engineering; Usability; Interaction; Regulatory Certification.

1 INTRODUCTION

The consolidation of a robust framework for the analysis and evaluation of interactive technologies demands conceptual structures capable of meeting criteria of validity, precision, and applicability. In the face of highly complex phenomena and constructs, such structures cannot be limited to prescriptive artifacts or fragmented approaches: they require the integration of technical, cognitive, and contextual requirements in an iterative, dynamic, and operationalizable manner. The Integrated and Advanced Core Framework for the Analysis and Evaluation of Technological Objects (FCIA-OT) constitutes a structured technical response to this gap. Designed to operate across multiple levels of complexity, the framework articulates objective and subjective criteria, empirical-analytical techniques, and multiple layers of modular interpretation.

System evaluation, according to Hollnagel & Woods (1982), requires verifying the validity of the design, involving both the simulation of real-world conditions and the correspondence between experimental and operational outcomes. Finkelstein & Finkelstein (1983) emphasize that evaluation and decision-making constitute the core of the design methodology, grounded in the generation of concepts aimed at meeting specific requirements. Neal & Simons (1984) reinforce the iterative nature of evaluation, advocating for progressive adjustments to software and documentation based on quantitative and qualitative data obtained through successive testing cycles.

Aligned with the importance of evaluation, Landauer (1988) expands this perspective by highlighting that the increasing complexity of interfaces and their accelerated transformation demand full-task experiments and real environments. This perspective emphasizes the need for end-to-end performance measurement and the adoption of combinatorial methods capable of enabling unexpected results. In the field of usability, Karat (1997) proposes a distinction between subjective evaluations, derived from human experience, and objective ones, supported by measurable parameters, indicating that, in complex systems, the relationship between both is not always empirically ascertainable.

Based on this ambivalence, Hassenzahl et al. (2000) identify two autonomous perceptual dimensions: ergonomic quality (EQ), associated with simplicity and control, and hedonic quality (HQ), related to innovation and pleasure. Although both influence the appeal of interactive systems, they operate under potentially conflicting logics, which imposes limitations on the simultaneous maximization of these attributes. In addition, Hassenzahl (2001) links product evaluation to user cognition, whose effects include behavioral consequences, such as increased frequency of use and reduced learning curve, and emotional ones, such as satisfaction, frustration, or disappointment.

The FCIA-OT is grounded in these conceptual foundations. By integrating technical, analytical, and perceptual requirements, it enables a multiscalar approach with evaluative depth and methodological flexibility. The case studies presented below demonstrate the empirical application of the model across three distinct objects, revealing its capacity for adaptation and responsiveness to the functional, structural, and interactive diversity of the systems analyzed.

2 CASE STUDIES: APPLICABILITY OF FCIA-OT

The empirical validation of the FCIA-OT requires its application in real and varied contexts, in which system complexity, interface heterogeneity, and the diversity of performance criteria can be observed at an operational scale. The methodological choice of case studies allows for the in-depth examination of such variables, enabling the technical refinement of criteria, the validation of the framework's architecture, and the tracing of applicable patterns.

Accordingly, Wixon (2003) argues that case studies are more suitable for understanding the practical application of methods, offering a richer and more situated view of the real dynamics involved in the development and use of technologies. Liljegren (2006) classifies usability evaluation methods into empirical and analytical, emphasizing that both should be employed based on their capacity to identify concrete issues and generate relevant data for system safety and performance. These methods are fully compatible with the modular and iterative logic of the FCIA-OT.

Approaches must be rigorous and capable of identifying real problems. Rosenbaum (2008) observes that usability evaluation should be integrated into the product lifecycle, ensuring that design decisions are supported by continuously collected empirical evidence. This integration, as enabled by the FCIA-OT, ensures a systemic approach that is responsive to data, maximizing the technical value of the evaluation. In a complementary manner, Heuwing, Mandl, & Womser-Hacker (2016) indicate that the use of specific metadata facilitates the categorization and retrieval of usability data across diverse contexts, particularly when the analysis is conducted with modular depth.

While Yusop, Grundy, & Vasa (2017) reveal recurring deficiencies in traditional usability failure tracking systems, often failing to capture essential data such as problem severity or redesign proposals, these gaps are addressed by the FCIA-OT through explicitly documented requirements and criteria.

The application of the FCIA-OT in real-world contexts aims to validate the consistency of its technical-analytical architecture and the effectiveness of the embedded evaluation systems. The Systemic Matrix of Integrated Vectorial Dimensions (MSDVI), the framework's core structural component, organizes objective and subjective criteria into twelve dimensions grouped in interdependent blocks, enabling a multiscalar, iterative, and responsive analysis of technological objects (see Chapter 1). Among the integrated systems, the SPMI and SCDMIC function as quantitative and visual representation mechanisms, assigning weights and chromatic categories to the criticality of the observed elements (see Chapter 2). The SGUI and SCMI scores reflect, respectively, the relative frequency of recurrence and the critical intensity of the analyzed elements, contributing to more precise and comparable dimensional diagnoses across different evaluated objects (see Chapter 3).

The following studies explore the applicability of the framework across three distinct technological objects, each with varied compositions, purposes, and technical characteristics. The analyses are conducted based on parameters of ecological validity, methodological rigor, and sensitivity to both objective and subjective data, grounded in consolidated scientific references, with the aim of demonstrating the technical robustness and functional versatility of the proposed approach.

2.1 Case Study: Interactive Software – Graphical User Interface for Client Registration

The application of FCIA-OT in interactive software contexts enables a multiscalar analysis of the agent–technology relationship, simultaneously incorporating functional, perceptual, and affective aspects. Graphical interfaces designed for operational tasks, such as client registration, demand responsiveness, clarity, and contextual adherence, without disregarding subjective factors that influence the user experience, such as the sense of control, emotional appeal, and perceived value.

According to McGrenere (2000), one of the central challenges in system design lies in the variability of utility perception among different users. The phenomenon of subjective bloat, characterized by the discrepancy between the number of available features and their perceived usefulness, undermines simplicity and hinders interaction efficiency. The author proposes personalization strategies adapted to diverse user profiles, grounded in social roles, routines, or digital personae, in order to align functionalities with specific usage needs.

Forlizzi & Battarbee (2004) emphasize that interactive experience is shaped both by the architecture of the interface and by the user's subjective construction during interaction. A system cannot be evaluated solely based on its technical structure, but through the multiplicity of ways in which it is experienced. The construction of system value is, therefore, linked to its capacity to generate meaningful and emotionally coherent experiences.

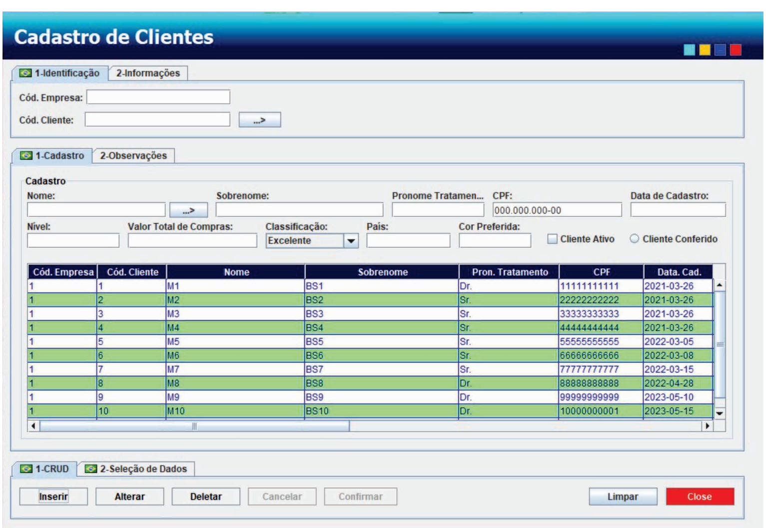
This interdependence between objective attributes and subjective perception is also underscored by Hassenzahl, Diefenbach, & Göritz (2010), who highlight the importance of integrating pragmatic criteria, such as functionality and usability, with hedonic aspects related to satisfaction and pleasure. The perceived quality of a system is not defined solely by its efficiency, but by its ability to balance instrumental functionality and emotional response. This balance directly affects the user's judgment and the acceptance of the technology.

Hassenzahl (2018) expands this approach by arguing that the momentary appeal of a product depends on the degree of correspondence between its apparent character and the usage situation. This correspondence is not static, but dynamic, requiring continuous adjustments between perceived attributes and situational demands. The adaptability of the system is a determining factor for users' emotional and behavioral responses, influencing everything from engagement to loyalty.

The operationalization of FCIA-OT in this case study aimed to map, based on these references, the critical points of usability, perception, and contextual adequacy of the client registration interface. By integrating technical, cognitive, and affective variables, the framework enables a thorough interpretation of the interactive experience, reinforcing its diagnostic robustness and its capacity to generate specific recommendations for system enhancement.

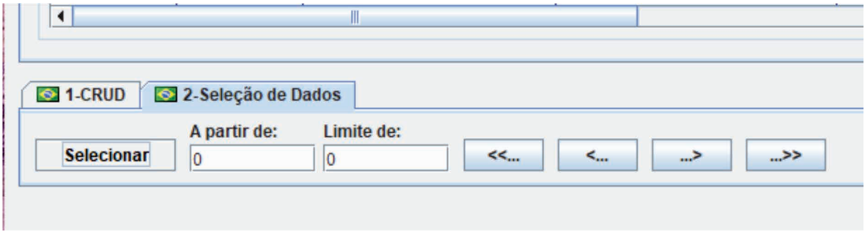
The analysis and evaluation of the client registration system interface, represented in Figures 1 and 1.1, was conducted based on the multidimensional structure of FCIA-OT. Tables 1, 1.1, 1.2, and 1.3 consolidate a technical analysis with multiple entries, each considering Object Requirements (RQO) and Artifact Requirements (RQA), descriptive accounts, and corresponding quantitative attributions within the qualitative dimensions of the framework.

FIGURE 1: CLIENT REGISTRATION SOFTWARE



Source: Author.

FIGURE 1.1: DATA SELECTION SOFTWARE



Source: Author.

Table 1 structures the direct observation of merit and failure points identified in the interface, with emphasis on the Artifact Requirements (RQA) dimension, which captures functional, perceptual, and structural attributes of the user experience. These records constitute the empirical starting point for subsequent analytical stages, conducted based on the twelve-dimension technical-analytical matrix of the FCIA-OT.

Each row in the table represents an individual technical entry, derived from the direct application of the RQA dimension's criteria. The "RO" column identifies the corresponding Object Requirement; "RA" refers to the involved Artifact Requirement. The "RA Desc." field synthesizes the observed technical category, such as interface logic, visual structure, layout, or controls, while "Report" and "Description" document the empirical occurrence of the failure or success, as recorded in the real usage environment. These data comprise the initial observational basis upon which interdimensional analyses will be superimposed, enabling modular, relational, and contextualized evaluation.

TABLE 1: SOFTWARE ANALYSIS AND EVALUATION

Technological Object: Software – Client Registration					
*****	**RO**	**RA**	**Desc. RA**	**Report**	**Description**
1	RO17	RA01	Size	The screen is not the correct size; it is too large	On smaller monitors, more than one system window must be opened
2	RO17	RA25	Visualization / Visual	The screen has a basic default layout	The system design could be improved
3	RO17	RA18	Color(s)	The default screen color is basic	The color scheme requires enhancement
4	RO17	RA26	Interface Controls	The form control buttons are small	The buttons are somewhat small and require focused attention during selection

5	RO17	RA24	Position / Location	The [red] close buttons on the form are correctly positioned	
6	RO17	RA26	Interface Controls	The Company Code field does not support [Enter] to search	Pressing [Enter] after input would facilitate search and eliminate the need to click the button
7	RO17	RA26	Interface Controls	The Client Code field does not support [Enter] to search	Pressing [Enter] after input would facilitate search and eliminate the need to click the button
8	RO17	RA26	Interface Controls	The Registration Date field lacks a calendar	A date mask alone is insufficient; a date picker would eliminate the need for manual input
9	RO17	RA25	Visualization / Visual	The alternating row colors in the data grid enhance visualization	
10	RO17	RA22	Pagination	The data grid does not include pagination buttons	Pagination is necessary to improve efficiency
11	RO17	RA33	Interface Logic	The data search highlights a range of values but does not alert for large intervals	No alert is issued when a large value range is entered
12	RO17	RA33	Interface Logic	When large value intervals are entered, the system becomes slow or unresponsive	The system is slow or fails when executing high-volume data queries
13	RO17	RA34	Execution Logic	The CRUD button sequence is functional but requires familiarity	
14	RO17	RA35	Procedural Logic	The CRUD operation sequence requires training	

Source: Author.

Table 1.1 systematizes the technical assessment of the analyzed set based on the following dimensions:

Knowledge/Experience (CEX): Level 7 across all records confirms that the evaluators have full command of the interface's concepts and interactions. This factor validates the legitimacy of the assessment, eliminating biases related to lack of familiarity.

Affordance (AFF) and Perception (PRC): Items 6, 7, 8, and 10 reveal affordance constraints (2, 2, 2, -5) combined with static perceptual responses (PRC = 3, 3, 3, 5), indicating low functional intelligibility, especially in search controls and in the absence of calendar features or pagination.

Affectivity (AFV) and Satisfaction (STSF): Dissatisfaction emerges systematically in items 6 to 12, where STSF ranges from -1 to -5. These values reflect negative emotional reactions triggered by operational limitations, highlighting the correlation between technical deficiencies and user frustration.

Effectiveness (EFT): Records 10, 12, and 13 display significant drops in effective performance (ranging from -3 to -5), particularly in cases involving delays or system failure during high-volume data queries.

Severity of Errors (GVE) and Risk Levels (GSR): Values range from 0 to 4, with record 12 standing out negatively in GVE. Severe slowness and the absence of alerts in searches involving extreme value ranges represent substantial operational risks that may compromise process continuity.

TABLE 1.1: SOFTWARE EVALUATION

*	CEX	RQA	AFF	PRC	AFV	STSF	EFT	GVE	GSR
1	7	3	2	3	-1	6	5	1	1
2	7	4	2	3	-1	6	5	1	0
3	7	4	2	3	-1	6	5	1	0
4	7	5	8	3	-1	0	5	1	1
5	7	10	10	10	3	7	10	0	0
6	7	2	2	3	-3	-1	5	2	0
7	7	2	2	3	-3	-1	5	2	0
8	7	-5	2	3	-3	-4	-3	2	1
9	7	7	9	10	3	7	10	0	0
10	7	-5	-5	5	-4	-4	-3	3	1
11	7	-3	-4	2	-3	-1	5	3	1
12	7	-5	-4	-5	-5	-5	-5	4	3
13	7	3	2	-5	-3	6	-3	3	0
14	7	1	2	-5	-3	0	5	2	0

Source: Author.

Table 1.2 presents the Attributes (ATB) under analysis, which offer concrete evidence of either the maturity or fragility of specific interface elements:

Record 1 (ATB01 = 6): Reflects basic conformity regarding screen size, although the report indicates inadequacy for smaller monitors.

Record 2 (ATB12 = 5): The default visual layout is perceived as acceptable, though not advanced.

Records 6 and 7 (ATB03 = 4): The absence of [Enter] functionality does not prevent operation but reduces both fluidity and productivity.

Record 12 (ATB02 = -4, ATB03 = -3, ATB04 = -5, ATB11 = -3): Represents the most structurally compromised point in the analysis. The overlap of failures related to response time, visual design, control behavior, and feedback mechanisms constitutes a critical scenario, seriously undermining the interface's functional integrity.

TABLE 1.2: SOFTWARE EVALUATION

*	ATB	SPMI
1	ATB01	6
2	ATB12	5
6	ATB03	4
7	ATB03	4
11	ATB04	3
12	ATB02	-4
12	ATB03	-3
12	ATB04	-5
12	ATB11	-3
13	ATB05	-4
14	ATB03	5
14	ATB04	6

TABLE 1.3: SOFTWARE EVALUATION

*	ACB	SPMI
1	ACB12	-5
1	ACB13	-3
2	ACB11	-3
3	ACB09	7
4	ACB10	-2
5	ACB06	7
6	ACB05	-3
6	ACB06	-2
7	ACB26	1
9	ACB11	8
11	ACB16	-5
12	ACB15	-5
13	ACB25	-4
14	ACB25	-4

Source: Author.

Table 1.3 presents a mixed overview of Accessibility (ACB), highlighting significant issues:

ACB12 (-5), ACB13 (-3) in Record 1: These values reveal difficulties in interface scaling across different screen resolutions, directly affecting visual accessibility.

ACB09 (7) in Record 3: The basic color scheme received a high score in this case, representing a rare positive factor within a predominantly negative context.

ACB05 (-3), ACB06 (-2), ACB26 (1) in Records 6 and 7: These indicate barriers in interaction controls, particularly regarding functional accessibility (e.g., keyboard usage).

ACB15 and ACB16 (-5) in Records 11 and 12: These penalize the system's failure to respond to agent interactions and the absence of appropriate feedback mechanisms.

ACB25 (-4) in Records 13 and 14: Although the procedural sequence is functional, it lacks clarity and does not offer intuitive operational accessibility.

This ACB dimension reinforces the technical critique: the more severe the failures in perception, feedback, and control, the more critical the accessibility penalty becomes.

Based on the four evaluation tables, the need for a complete redesign of the client registration interface becomes evident, particularly in three core areas of recurrent failure:

Interaction and Controls (RA26): Multiple records point to operational issues in basic controls. The absence of keyboard shortcuts, calendar elements, and pagination reflects a low-efficiency interactive environment.

System Responses (RA33, RA34, RA35): The system fails to properly handle high-volume data inputs, leading to critical malfunctions. These failures directly compromise the dimensions of Effectiveness (EFT), Satisfaction (STSF), Error Severity (GVE), and Risk Level (GSR).

Visual and Perceptual Consistency (RA25, RA18): The design exhibits low visual appeal, a lack of visual hierarchy, and an absence of functional color schemes, factors that negatively affect perception, affectivity, and user satisfaction.

The triangulation of PRC, AFF, and ATB confirms a systemic chain of perceptual and functional failures, compromising intelligibility, legibility, and operability. The presence of critical interface zones intensifies user frustration, reduces confidence, and undermines overall effectiveness.

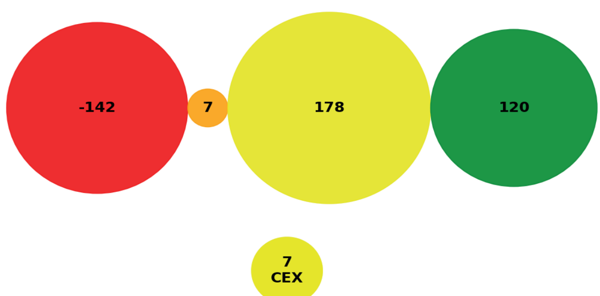
Although structurally functional, the interface contains substantial limitations that affect usability, accessibility, and perceived value. The FCIA-OT's multidimensional analysis reveals that these are not isolated issues but recurring patterns that significantly compromise the agent experience.

Figure 2 illustrates the modular distribution of score volume by color, according to SCDMIC criteria under the SPMI. It reflects the performance of the evaluated technology based on processed observational and technical data. Each circle proportionally represents the concentration of points assigned to clusters of correlated dimensions, highlighting levels of: Excellence (green), localized adjustments (yellow), instability (orange), and criticality (red).

In total, 120 points were identified in the systemic maturity range (green), 178 points as moderate (yellow), indicating localized technical demands; 7 points as problematic (orange), associated with relevant operational failures; and a substantial volume of -142 critical points (red), corresponding to severe failures that require immediate corrective action regarding the technological object's requirements. These dysfunctions compromise proper usage, generate operational risks, or prevent the execution of expected tasks, with direct impact on agent experience and safety.

The CEX score, isolated in yellow at the lower base, reinforces that the diagnostic judgment is not compromised by lack of expertise, even when the domain level is intermediate (CEX = 7). The figure provides a visual and accurate synthesis of the interface's performance configuration, reaffirming the diagnostic effectiveness of the FCIA-OT.

FIGURE 2: DISTRIBUTION OF SCORE VOLUME (SPMI) AND COLOR PATTERN (SCDMIC)



Segmented circular visualization of model dimensions, with color coding based on the SCDMIC. Each circle represents dimensions grouped within specific criticality ranges: Red (critical zone), Orange (functional instability), Yellow (intermediate level), and Green (high maturity). The visual structure aggregates dimensions by color volume and highlights CEX (Evaluator Knowledge/Experience Dimension) as an isolated axis. This configuration enables a synoptic reading of the functional state, operating as a high-precision pre-diagnostic mechanism for identifying priority areas for reengineering, structural adjustments, and interactive validation.

Source: Author.

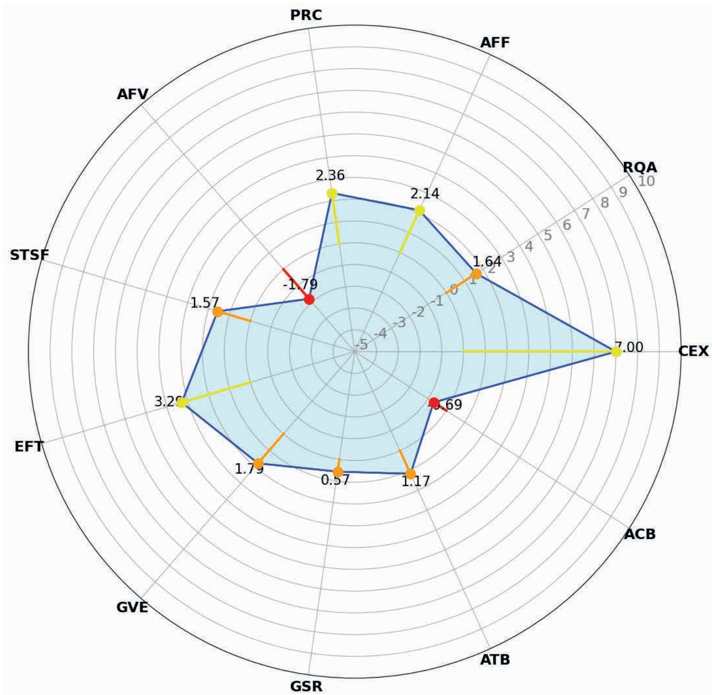
Figure 3 presents a hybrid polar visualization that integrates, within a single analytical plane (radar), two complementary levels of diagnostic reading: (i) the individualized representation of dimensions, plotted radially with color coding based on the criticality levels defined by the SCDMIC; and (ii) the continuous closed blue contour, which expresses the topological average profile of the evaluated technology.

The individualized radial lines, combined with their respective chromatic markers, blue (systemic conditional), red (critical), orange (problematic/unstable), yellow (moderate), and green (excellent/adequate), function as vectors of semantic gradation, facilitating the objective identification of points of vulnerability, intermediate stability, and relative excellence across each dimension. This chromatic distribution, anchored in the defined ranges within the scope of the SCDMIC, enhances interpretative precision and supports the application of rigorous technical criteria throughout analysis and reengineering cycles.

In parallel, the continuous blue line, which connects the average values of all dimensions, provides an aggregated and synoptic reading of the structural distribution of the technological object. The resulting geometry, marked by inflections, angular distortions, and asymmetries, acts as a diagnostic signature, enabling the identification of functional imbalances, critical dispersions, and concentrations of maturity across specific axes of evaluation.

The overlay of these two visualization regimes maximizes the technical intelligibility of the diagnosis, supports interdimensional comparative analyses, and guides evidence-based decision-making in stages of functional enhancement, validation, and systemic reengineering.

FIGURE 3: INTEGRATED RADAR DIAGNOSIS: CRITICAL CODING BY DIMENSION AND CONTINUOUS AVERAGE PROFILE (BLUE RADAR)



Hybrid polar visualization of the dimensions assessed according to the FCIA-OT model. The colored radial lines represent the average values of each dimension, coded according to the SCDMIC (red = critical; orange = unstable; yellow = moderate; green = adequate). The continuous blue contour indicates the aggregated topological average of the dimensions, enabling a synoptic reading of the structural distribution and identification of functional asymmetries.

Source: Author.

This scenario reinforces the FCIA-OT's analytical capacity to precisely map, with scientific and technical accuracy, rupture points that compromise both interaction engineering and the software's functional logic. By identifying these interrelationships, the framework not only supports a robust diagnostic process but also provides strategic input for reengineering efforts focused on advanced usability, functional accessibility, and qualified perception. In this way, it is consolidated as a systemic tool of high technical value for the evaluation and reconstruction of interactive technologies.

2.2 Case Study: Embedded Control System with Firmware – Conventional Air Conditioning Unit

The application of FCIA-OT to the analysis of embedded systems enables a technical-analytical approach guided by physical-digital interaction, taking into account the perceptual, operational, and semantic unfoldings mediated by the firmware. In this type of object, the assessment must encompass both the structural coherence of the hardware and the internal logic of digital control, with emphasis on how visual affordances, tactile responsiveness, and flow sequences communicate to the agent the possible states of action and feedback.

The air conditioning control examined in this study, characterized by its minimalist architecture and sequential internal logic, exemplifies an artifact whose performance depends on the alignment between perceptual clarity and functional predictability. By decomposing this object into the sets of Object Requirements and Artifact Requirements, FCIA-OT enables precise mapping of critical interaction zones, revealing hidden patterns of failure or merit in the relationships among agent, interface, and context.

Simplicity and clear functionalities are highlighted by McGrenere (2000), who identifies that an excess of features misaligned with the agent's profile, known as subjective bloat, compromises usability by cognitively overloading the interface. Personalization strategies and selective simplification, based on agent profiles and usage contexts, can restore system balance without sacrificing functional capability.

According to Forlizzi & Battarbee (2004), the user experience is co-determined by technical and contextual factors. The environment, social routines, and emotional states directly influence both the perception and meaning of the interaction, making it essential that the evaluation include environmental and situational variables.

In line with this understanding, Komine, Takanishi, & Aoyama (2006) demonstrate that simplified interfaces, with self-explanatory graphical elements and consistent feedback, reduce initial usage barriers and are particularly effective in contexts with low technological familiarity. According to the authors, response predictability is as essential as command clarity.

Hassenzahl, Diefenbach, & Göritz (2010) observe that pragmatic quality does not operate in isolation. Its effect on the experience depends on the affective mediation promoted by the system, that is, the sense of control, trust, and appropriateness experienced by the user influences how utility is perceived. In agreement, Hassenzahl (2018) systematizes that the appeal of an artifact is linked to its ability to meet the agent's situational aspirations. This includes both pragmatic goals, such as modifying the environment, and hedonic goals, such as reinforcing identity or evoking memories.

Figure 4 presents the control unit of the air conditioning system, which serves as the empirical basis for the decomposition of constituent elements and the application of the FCIA-OT's technical-analytical dimensions. The methodology employed in this study organizes the data based on the modular distinction between the physical hardware and the embedded system, allowing the identification of how failures in icon legibility, tactile inconsistencies, and lack of explicit feedback compromise the agents' ability to correctly interpret the interface states. The mapping reveals zones of vulnerability in which interaction becomes non-intuitive, dysfunctional, or ambiguous.

FIGURE 4: AIR CONDITIONING CONTROL

Air conditioning control. 12,000 BTUh unit, Split Wall type, 220V, noise level 29 dB(A). Firmware: specialized software embedded in non-volatile hardware (ROM, EPROM, flash) that controls and manages specific device operations. It functions as a critical interface between physical components and logical functionalities, regulating hardware behavior in embedded systems.

Source: Author.

The analysis and evaluation of the control, structured in Tables 2, 2.1, 2.2, 2.3, and 2.4, were conducted through the direct application of FCIA-OT's modules and submodules, considering multiple cycles of observation and real manipulation. The records were organized into technical entries, with qualitative and quantitative details on functional, perceptual, and symbolic failures, successes, and neutralities, mapping the maturity of use in everyday situations. Table 2 includes entries related to the Artifact Requirements (ARQ). Each occurrence was interpreted through the dimensions of the framework, revealing recurrent patterns of deviation from or adherence to the agents' expectations. The result is a technical-scientific radiograph of the quality of interaction promoted by the device.

TABLE 2: ANALYSIS AND EVALUATION OF THE AIR CONDITIONING CONTROL

Technological Object: Air Conditioning Control					
*	RO	RA	Desc. RA	Report	Description
1	RO06	RA02	Dimension	The artifact's dimensions are adequate	
2	RO06	RA04	Weight	The artifact's weight is suitable for handling	
3	RO06	RA16	Power Consumption	Battery consumption is moderate	
4	RO30	RA25	Display/ Visual	The screen displays many symbols	The system design could be improved
5	RO16	RA33	Interface Logic	Navigation is not clear or guided	The navigation logic is item-by-item and requires learning
6	RO16	RA27	Symbols/Icons/ Representation	Many symbols are ambiguous and require learning	Symbols must be clear, standardized, and explained in the agent manual
7	RO16	RA31	Complexity	The artifact presents logic that requires learning for nearly all features	
8	RO16	RA34	Execution Logic	All features follow sequential steps that are unclear	One must go through previous features to access the desired one
9	RO16	RA27	Interface Controls	The "+", "–", and power buttons are intuitive for increasing, decreasing temperature, and turning off	
10	RO16	RA26	Symbols/Icons/ Representation	The mode control displays unclear icons	It requires learning
11	RO16	RA26	Interface Controls	The "Menu w/ Conf." setting to remove the temperature display is unclear	It requires learning
12	RO16	RA26	Interface Controls	The "Menu w/ Conf." setting for automatic activation is not instructive	This option should always be disabled by default and clearly included in the agent manual
13	RO16	RA26	Interface Controls	The "Menu w/ Conf." setting to configure automatic on/off times is not instructive	The logic to set on/ off times is unclear and requires learning
14	RO16	RA26	Interface Controls	The "Menu w/ Conf." setting to set the clock is not instructive	It is necessary to go through multiple other options to reach this setting

15	RO16	RA26	Interface Controls	The "Menu w/ Conf." setting for sleep mode is unclear	Its logic, icon, and modes require learning
16	RO16	RA26	Interface Controls	The "Menu w/ Conf." setting for energy-saving mode is unclear	The logic of this option is unclear and requires learning and understanding of its functional outcome
17	RO03	RA12	Build Quality	Assembly and fit are of intermediate quality	
18	RO03	RA53	Maintainability	No preventive, corrective, or evolutionary maintenance options	
19	RO03	RA52	Technical Instructions	Documentation and instructions are incomplete	

Source: Author.

Table 2.1 systematically and technically structures the analytical judgment of the functional control module based on nine critical dimensions, allowing an in-depth diagnosis of the interface's intelligibility, efficiency, and safety.

Knowledge/Experience (CEX): The uniformity in values (CEX = 6) indicates that the evaluators possess intermediate-to-high technical experience in handling the controls assessed. This pattern minimizes the influence of noise stemming from inexperience, thus granting reliability to the sample and legitimacy to the triangulation with other dimensions.

Object Requirements (ARQ): The highest adherence indices appear in entries 1, 2, and 9 (ARQ ≥ 8), indicating that in these cases, the controls more fully meet the expected requirements for the functional context. In contrast, entries 5 through 8 and 10 through 19 show a sharp decline (ARQ ranging from -5 to 2), revealing critical dissonances between the designed behavior and the operational need.

Affordances (AFF) and Perception (PRC): Among entries 5 through 8 and 10 through 13, a recurring set of negative or ambiguous affordances is observed (AFF between -5 and -1), often accompanied by low cognitive construction perceptions (PRC between -5 and 2). This configuration characterizes a functional breakdown between action signaling and perceptual inference, pointing to informational design failures in components such as buttons, interactive fields, and filter functions, whose semantics do not foster effective cognitive engagement.

Affectivity (AFV) and Satisfaction (STSF): Emotional impacts become evident in the sequence of entries from 4 to 16, where STSF shows a recurrence of negative values. This instance reflects an affective state marked by frustration, uncertainty, and additional cognitive load in the use of controls, generally linked to unrecognized affordances and exploratory perceptions (PRC = -5), as observed in entries 5, 6, and 10. Positive STSF reappears only in entries 1, 2, 3, 9, and 17, where affordances are well signaled and performance remains stable.

Effectiveness (EFT): The operational effectiveness dimension reveals significant losses in entries such as 3, 8, 10, 12, 13, 14, 15, 16, 17, and 18, where values between -5 and -3 reflect delays, functional failures, and inconsistency in interface feedback, especially when operating filters, validating inputs, or reconfiguring displays. In contrast, entries 1, 2, 4, 5, 6, 7, 9, 11, and 19 return positive or neutral EFT values, suggesting partial stability under specific conditions.

Severity of Errors (GVE) and Risk Levels (GSR): The presence of severe errors and operational risks is concentrated in entries 3 through 8 and 10 through 19, where GVE and GSR values range from 1 to 3. These values indicate the potential exposure of agents to silent failures, information loss, or misuse of sensitive controls. The combined analysis of GVE and GSR dimensions demonstrates that the absence of clear affordances, together with imprecise perceptions and weak feedback, undermines the robustness of the control system and raises the level of risk in the continuous use of the technology.

TABLE 2.1: CONTROL EVALUATION

*	CEX	RQA	AFF	PRC	AFV	STSF	EFT	GVE	GSR
1	6	8	9	10	3	7	5	0	0
2	6	9	9	10	3	9	5	0	0
3	6	5	8	5	-3	6	-3	3	1
4	6	3	2	2	-3	-1	5	3	1
5	6	-1	-1	-5	-1	-1	5	3	2
6	6	-4	-4	-5	-3	-3	5	2	2
7	6	-5	-5	-5	-1	-3	5	3	2
8	6	-3	-3	2	-1	-1	-3	2	2
9	6	9	10	10	5	6	10	0	0
10	6	-4	-4	-5	-1	-1	-3	3	2
11	6	1	-4	-5	-3	-3	5	1	2
12	6	-3	-3	2	-1	-4	-3	2	3
13	6	1	-3	2	-1	-4	-3	2	2
14	6	1	2	2	-1	-1	-3	1	1
15	6	-2	2	2	-5	-3	-5	3	2
16	6	-2	2	2	-3	-4	-5	2	2
17	6	2	8	5	3	6	-3	1	3
18	6	-3	-3	2	-5	-1	-3	3	3
19	6	-4	-3	2	-3	-5	5	3	3

Source: Author.

Table 2.2 reveals, from the perspective of Technological Attributes (ATB), the distribution of maturity and failures of the evaluated control, highlighting the structural behavior of the artifact in relation to expected functional and ergonomic requirements:

Usability (ATB01) shows excellent performance in entries 1 and 2 (SPMI = 7), indicating that agents' quickly understand the essential commands and operate the control with reduced cognitive effort. This demonstrates compatibility between the visual structure and the agent's interaction expectations.

Efficiency (ATB03) undergoes progressive degradation, with a negative highlight in entry 12 (-3), suggesting operational delays or redundant processes during basic interactions. Although entry 3 still maintains a positive score (4), the subsequent decline indicates a lack of consistency in the system's responses over continued use.

Functionality (ATB04) reveals a localized functional collapse. While entry 4 maintains acceptable performance (4), entry 7 shows a severe breakdown (-4), and entry 16 reinforces the issue with an additional negative score (-3). The same attribute reappears in entry 13 with a score of (1), indicating unstable fluctuation in the operational architecture.

Accessibility (ATB05) reaches concerning levels, with two entries falling within critical ranges: entry 8 (-4) and 13 (-1). The partially positive score in entry 10 (2) does not offset the overall trend of inefficiency regarding the control's suitability for different agents' profiles or usage conditions, which compromises the universality of the solution.

Simplicity (ATB15) appears only in entry 9 with an excellent score (8), suggesting that although the visual presentation and navigation elements are well designed, their aesthetic quality and direct usability are not consistently replicated across the control's other functionalities.

Compliance (ATB10) is recorded only in entry 19, with a critical score (-5). This implies a direct failure to adhere to design or safety standards, representing a normative or technical risk, especially in regulated or sensitive environments.

The analyzed artifact, in its control form, demonstrates structural fragility in fundamental attributes such as functionality, accessibility, and compliance. The data indicate that, although the control is usable under ideal conditions, its performance is neither stable nor universal, with recurring failures in simple tasks and non-optimized contexts. The technical maturity of the control is therefore compromised, requiring corrective actions in the layers of functional architecture, operational response, and normative adherence.

TABLE 2.2:

CONTROL EVALUATION

*	ATB	SPMI
1	ATB01	7
2	ATB01	7
3	ATB03	4
4	ATB04	4
7	ATB04	-4
8	ATB05	-4
9	ATB15	8
10	ATB05	2
12	ATB03	-3
13	ATB04	1
13	ATB05	-1
16	ATB04	-3
19	ATB10	-5

TABLE 2.3:

CONTROL EVALUATION

*	ACB	SPMI
6	ACB06	-5
7	ACB06	-3
8	ACB06	-2
9	ACB06	7
9	ACB11	7
10	ACB11	-3
13	ACB06	-1
13	ACB12	-5
14	ACB06	-2
16	ACB06	-4
19	ACB04	1

TABLE 2.4:

CONTROL EVALUATION

*	QRSUER	SPMI
3	TQRS01	3
3	TQRS02	1
17	TQRS04	-5
17	TQRS05	-4
17	TQRS11	-4
17	TQRS12	-3
17	TQRS10	-3
18	TQRS10	-3
18	TQRS11	1

Source: Author.

The evaluation of accessibility criteria in Table 2.3 reveals critical gaps in attribute ACB06 (Navigation Consistency). The accumulation of negative scores in entries 6, 7, 8, 13, 14, and 16, with SPMIs ranging from -1 to -5, indicates structural fragmentation in the organization and predictability of navigation. This pattern highlights instability in the interaction architecture, compromising the agent's cognitive efficiency during continuous use of the control. Only entry 9 shows a satisfactory pattern (7), standing isolated in the dataset.

The analysis also points to significant shortcomings in ACB12 (Accessibility Adjustments), with entry 13 scoring -5, indicating the absence of fundamental interface personalization mechanisms such as contrast settings, captions, or resizing options that accommodate user diversity.

Regarding criterion ACB11 (Visibility and Legibility), there is a sharp contrast between entries 9 (7) and 10 (-3). While the former ensures visual clarity and perceptual comfort, the latter presents perceptual obstacles that impair legibility, indicating a lack of uniformity in visual implementation.

Finally, ACB04 (Support for Multilingual Content) shows a neutral-positive result (1), suggesting an initial stage of implementation, though without significant impact on the inclusive experience.

The evaluation of the QRSUER technology criteria in Table 2.4 reveals unstable performance of the control system with respect to the environmental and social standards defined by QRSUER, as evidenced by the recurrence of negative scores across several critical aspects.

Although there are moderately positive results in Resource Utility and Efficiency (TQRS01 = 3) and Resource Sustainability (TQRS02 = 1), indicating some alignment with operational efficiency practices and conscious resource usage, the sequence of severely negative outcomes in cases related to Solid Waste Management (TQRS04 = -5), Active Disposal (TQRS05 = -4), Facilitated Repair (TQRS11 = -4 and 1), Modular Adaptability (TQRS12 = -3), and Recyclability (TQRS10 = -3 and -3) exposes structural weaknesses in the product or system life cycle.

The absence of effective disposal and reuse mechanisms, combined with low modularity and repair difficulty, compromises durability, increases obsolescence, and intensifies environmental impact. This condition reflects non-compliance with circular economy principles and sustainable design, limiting the regenerative efficiency and socio-environmental responsibility of the technology.

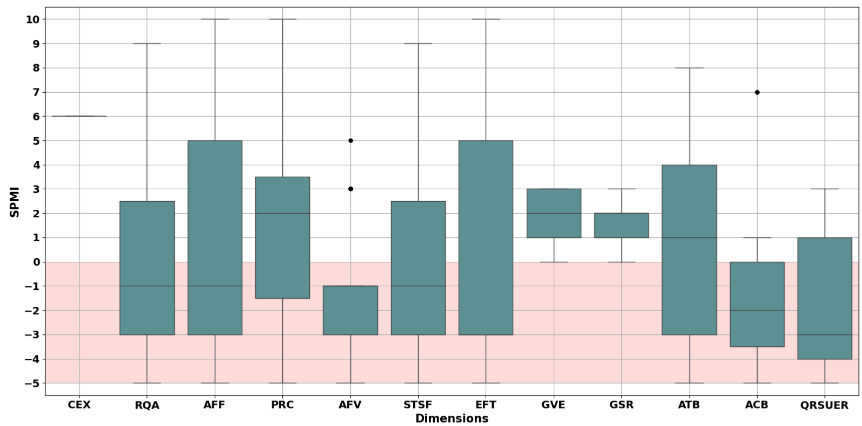
The repeated negative scoring in items evaluated by multiple controllers (such as TQRS10 and TQRS11) reinforces the consistency of these failures, indicating that they are not attributable to individual perception but rather to the materiality of the problems.

Therefore, the control analysis under QRSUER reveals that, although there are isolated efforts toward resource efficiency, the evaluated technology shows significant limitations in waste management, modularity, and circularity, requiring technical restructuring to meet essential sustainability and socio-environmental responsibility requirements.

Figure 5 synthesizes the statistical distribution of the control's performance across the main evaluative dimensions of FCIA-OT, based on the SPMI structure. The score ranges, codified and standardized, enable the precise positioning of the control along a continuous scale from -5 to 10, revealing dispersions, outliers, and central tendency measures associated with each modular axis.

Variations in the statistical configuration across dimensions indicate distinct patterns of adherence to the evaluative requirements. In modules such as AFV, EFT, GVE, and GSR, the absence of essential distribution components, such as the median or upper quartiles, suggests anomalous compressions, centrality bias, or score clustering in critical zones of the scale. These patterns, from the technical perspective of FCIA-OT, are interpreted as markers of structural instability, low functional consistency, or residual performance of the control in these dimensions.

FIGURE 5: MODULAR STATISTICAL DISTRIBUTION OF THE CONTROL IN THE EVALUATIVE DIMENSIONS OF FCIA-OT



Boxplot chart structured according to the SPMI, with a scale ranging from -5 to 10. It represents the distribution, dispersion, and positioning of the control across the 12 evaluative dimensions of FCIA-OT, highlighting medians, variations, and possible outliers on each modular axis.

Source: Author.

The graphical modeling based on SPMI functions as a high-precision analytical mechanism, enabling not only the visualization of the modular positioning of the control but also the identification of zones of compliance, distortion, or vulnerability. Emerging evidence from this modeling is essential to support rigorous technical inferences regarding the maturity, robustness, and suitability of the technology in relation to the set of requirements underpinning each evaluated dimension.

The presence of outliers, when identified, signals atypical performance deviations that, although isolated, may reveal critical failures or significant structural fluctuations in the technology's behavior. The occurrence of statistical compression, characterized by the clustering of scores within narrow segments of the scale, imposes interpretative limitations that require methodological attention, as such compressions may obscure functional asymmetries or conceal relevant patterns of non-compliance.

2.3 Case Study: Unmanned Aerial Vehicle (UAV) – Integrated Multicomponent Hardware and Software System

The analysis of high-complexity systems, such as Unmanned Aerial Vehicles (UAVs), requires a multiscalar evaluative approach, in which technical performance, agent–machine interaction, and operational responsiveness are observed in an integrated manner. The architecture of these systems, comprising hardware modules, firmware, and embedded software, imposes critical demands for reliability and precision, particularly in real-time operations under unpredictable environmental conditions.

Within the scope of FCIA-OT, the evaluation considers the relationships among perception, action, and response, examining the system's technical maturity based on the coherence between issued commands, received feedback, and resulting operational states. Elements such as status legibility, semantic compatibility between input and response, fault management, and the fluidity of functional chaining constitute core analytical axes, where localized failures can produce systemic compromises in usability and safety.

According to Woods & Roth (1988), complex systems must be assessed through systemic models capable of identifying vulnerabilities that emerge not only from the interface itself but from the interdependent relationships among operators, artifacts, and environment. The effectiveness of such systems depends on continuous validation in real operational contexts, where human behavior and system logic interact in real time under high cognitive load.

This logic of adaptation and balance between control and autonomy is also discussed by McGrenere (2000), who proposes light personalization mechanisms to mitigate the so-called subjective bloat, a condition in which the presence of functions misaligned with the user's profile compromises interface clarity and effectiveness. A system's ability to modulate its functionalities according to situational patterns and mission needs directly contributes to reducing cognitive overload and increasing operational fluidity.

From this perspective, Hassenzahl, Diefenbach, & Göritz (2010) demonstrate that user experience is deeply mediated by subjective dimensions such as the feeling of competence, autonomy, and belonging during use. In critical technologies, operational trust is not built solely through objective utility, but through the sense of control and predictability that the system is able to communicate to the operator in real time.

In the same line, Fernandez, Insfran, & Abrahão (2011) point out that the multiplicity of definitions and usability assessment methods undermines the comparability of results across systems. Unified approaches, capable of integrating different dimensions and contexts, enable more robust diagnoses and more reliable interpretations, especially in mission-critical systems such as those analyzed in this study.

Complementing this discussion, Hassenzahl (2018) proposes a distinction between products with a pragmatic emphasis (ACT mode) and those with hedonic value (SELF mode), indicating that the way the operator perceives the purpose of the technology directly influences their functional and emotional perception. In systems such as UAVs, the pragmatic appeal is dominant, but the value of subjective experience must not be overlooked, as safety and precision also depend on the sense of confidence and fluidity perceived during use.

Figures 6, 6.1, 6.2, and 6.3 document critical moments of the UAV's functional cycle, including phases of takeoff, task execution, and manual adjustments in the field. These empirical records support the technical evaluation by evidencing the system's real-time dynamics in operation, revealing consistent strengths and functional vulnerabilities. Direct observation allows verification of how feedback failures, response delays, or low command clarity can compromise interaction effectiveness and mission safety. The analysis conducted based on FCIA-OT highlights critical performance zones, linking visual data to the twelve-dimensional technical-analytical matrix, ensuring the ecological and methodological validity of the assessment performed.

FIGURE 6: UAV DURING REFUELING

FIGURE 6.2: APPLICATION IN PRE-PLANTING OF CORN

FIGURE 6.1: CONTROL IN OPERATION

FIGURE 6.3: APPLICATION FOR COTTON DEFOLIATION

UAV with a capacity of 40 L, four brushless motors, 29,000 mAh battery, maximum flow rate of 22 L/min, and flight speed up to 36 km/h.

Source: Author.

The analysis and evaluation of the UAV, detailed in Tables 3, 3.1, 3.2, 3.3, and 3.4, was conducted based on the systematic application of FCIA-OT modules and submodules under real operational conditions. Each recorded technical entry reflects targeted observations on functional, perceptual, and symbolic occurrences, highlighting both merits and limitations of the technology. Table 3 organizes records linked to Artifact Requirements (RQA), focusing on execution demands in critical timeframes. Each entry constitutes a diagnostic element, revealing patterns of adherence, deviation, or neutrality according to the framework's dimensional criteria. Based on this foundation, it becomes possible to map the system's degree of maturity and reliability, identifying cores of technical excellence and critical zones that impair interaction fluidity and operational effectiveness in practical contexts.

TABLE 3: ANALYSIS AND EVALUATION OF THE UAV

Technological Object: UAV					
*	RO	RA	Desc. RA	Report	Description
1	RO06	RA03	Structure	Chassis not designed for landing with payload.	Structure must support operations with payload; its absence compromises operational safety
2	RO04	RA03	Structure	Landing legs not designed for payload landing	Structural reinforcement is required to absorb impact with attached payload
3	RO04	RA03	Structure	Arms lack breakaway points in the event of a collision	Absence of breakaway points may compromise the entire equipment's structural integrity
4	RO04	RA03	Structure	Screw thread length is reduced	Fastening is compromised in several structural components
5	RO04	RA03	Structure	LED headlights are energy inefficient (Excessive Heat)	Lighting systems generate heat beyond acceptable levels
6	RO06	RA45	Storage	Viability of 1,000 mAh/kg of load capacity	Evaluation of energy density per unit mass is required
7	RO06	RA03	Structure	Remote control should feature a 7″ screen	Ergonomic and operational requirement for field visualization
8	RO06	RA45	Storage	Load capacity between 3 and 4 kg/hp	Proportionality between payload and engine power must be dimensioned
9	RO06	RA03	Structure	Optimization of blade angle × rotation × wingspan for silent operation	Aerodynamic design must consider noise generation in operating environments
10	RO04	RA03	Structure	Hoses are too narrow	Hoses with inadequate cross-sectional area must not be used

11	RO06	RA03	Structure	Equipment should be waterproof (IP68)	Essential for operation in outdoor and humid environments
12	RO04	RA03	Structure	Absence of LIDAR sensors	Integration of LIDAR sensors enhances flight safety and autonomy
13	RO04	RA03	Structure	No cabling provided for spectral cameras	Electrical infrastructure must be preconfigured for modular installation
14	RO05	RA03	Structure	Not predisposed to upgrade: Processor, ROM, RAM, Storage, Communication Board, Motor Control Board, Cameras, LIDAR Proximity Sensors	Closed architecture compromises the system's technical scalability
15	RO06	RA26	Interface Controls	No electrical predisposition (ISOBUS type) for 4 additional sensor buttons	Interfaces must support integration of standardized accessories
16	RO06	RA03	Structure	Mechanical space not standardized for couplings	Universal compatibility requires physical standardization, similar to tractor three-point hitches
17	RO06	RA03	Structure	Absence of fixation points for ground transport	Tie-down points are necessary to ensure safe logistics
18	RO05	RA03	Structure	Hardware not prepared for ground transport vibrations	Lack of impact absorption compromises durability in agricultural environments
19	RO04	RA03	Structure	Refueling system with threaded cap is inefficient	Quick coupling connection would be more efficient and secure
20	RO06	RA03	Structure	Lack of efficient thermal exchange system and aerodynamic optimization	Required for prolonged operation in tropical environments
21	RO06	RA03	Structure	No structural predisposition for cargo transport across all brands	Standardization of transport capability is essential for agricultural functionality
22	RO04	RA54	Technical Support	No specialized maintenance available outside the dealership	Related to technical availability of parts and maintenance services
23	RO04	RA03	Structure	Universal rubber chock to be attached to the landing gear	Support and landing element
24	RO04	RA03	Structure	Customizable propellers with at least 3 or 4 different pitch angles	Influences structural behavior and functional performance of the propellers
25	RO05	RA44	Customization	Standardize blade numbering (as with tires)	Facilitates functional identification, maintenance, and customization

26	RO06	RA44	Customization	Classify UAVs as tractors (agricultural/industrial)	Technical classification related to use and application (similar to the "Yellow Line" designation)
27	RO16	RA33	Interface Logic	Login via individual registration + sub-login for pilot account	The system login is unique, restricting multi-pilot usage
28	RO16	RA28	Configuration	Missing Task Configuration Instructions	E.g.: Free flight, demonstration, work [Mapping, spray details, routes, area, equipment]
29	RO16	RA33	Interface Logic	Larger buttons, more divisions in command tree	Functional and visual hierarchical organization
30	RO16	RA33	Interface Logic	Missing button to change landing location to current control location	Operator should be able to change the UAV's landing point during autonomous operation
31	RO16	RA33	Interface Logic	Missing on/off commands in the system for UAV auxiliary inputs	Subsystem integration via interface
32	RO16	RA28	Configuration	Missing configuration for auxiliary connectors: W/Ah to recalculate autonomy	Recalculation logic based on external energy inputs
33	RO16	RA39	Compatibility	No system log connection with local weather station via Bluetooth	Integration of weather data into the system
34	RO16	RA28	Configuration	No manual configuration of the spraying system for autonomous flight	Task-system integration through configuration
35	RO16	RA28	Configuration	Missing autonomous flight configuration without activating the spraying system	Separation between flight and application logic
36	RO06	RA49	Instability/ Crash	Any kind of failure: the equipment halts and returns to base	Failure of the automatic operational safety protocol
37	RO16	RA49	Instability/ Crash	The system attempts to regain control of the equipment upon detecting slight terrain tilt	Safety logic requires contextual refinement (100% flat terrain is uncommon in field operations)
38	RO16	RA35	Procedure Logic	Refueling call can only be activated manually by the pilot	Manual procedure required in specific contexts
39	RO16	RA34	Execution Logic	System does not generate curved paths/guidance lines for application (e.g., pivots)	Failure in curved georeferencing logic
40	RO16	RA34	Execution Logic	System does not report obstacles in 3D	Absence of three-dimensional spatial mapping

41	RO16	RA34	Execution Logic	System lacks the option to activate/deactivate parallel circuits without interrupting autonomous flight	Independent control of subsystems (e.g., weighing, flow rate, pressurization, atomization)
42	RO16	RA34	Execution Logic	System does not store/ display failure reports by date/time	Absence of detailed technical history
43	RO16	RA34	Execution Logic	System lacks harness mapping/diagnostic based on resistance (Ω) at each connection point	Preventive and precise technical diagnostics
44	RO06	RA28	Configuration	Equipment lacks a configured preventive maintenance plan	Similar to vehicular maintenance logic
45	RO06	RA39	Compatibility	Predisposition for ISOBUS port (UAV + compatible implement)	Critical point of agro-industrial integration
46	RO06	RA28	Configuration	Configuration branch for throttle power/response per installed propeller	Dynamic integration between hardware (propeller) and power software (customization)
47	RO16	RA34	Execution Logic	System does not link UAV prefix to ANAC RAB, nor bring flight plan to a button on the controller	The task itself should act as the flight plan, or the flight plan should be the task
48	RO03	RA12	Quality	Assembly, parts, components, and intermediate structures	

Source: Author.

Table 3.1 presents, in a technical, systematic, and methodologically rigorous manner, the evaluation of the technological object "UAV," encompassing the primary variables for critical analysis across multiple dimensions. The assessment aims to diagnose the structural robustness, functional coherence, systemic adaptability, and operational risks of the technological solution.

Knowledge/Experience (CEX): The convergence of CEX values at level 6 demonstrates advanced technical proficiency on the part of the evaluators regarding the UAV's architecture, subsystems, and integrated functionalities. The consistency observed in the judgments consolidates the epistemological robustness of the evaluations, substantially minimizing the incidence of biases associated with practical gaps in the context of remotely piloted aircraft operation and embedded systems analysis.

Object Requirements (RQA): Structural and functional requirements were recurrently violated in 42 of the 48 entries (RQA between -5 and 3), with emphasis on critical failures in fastening elements, lack of predisposition for upgrades (L14), and incompatibilities with industrial protocols such as ISOBUS (L15, L45). The sharp decline in RQA indicates a systemic misalignment between design, field operation, and the demands of the agro-industrial context.

Affordance (AFF) and Perception (PRC): The physical and logical interface of the UAV exhibits ambiguous or negative affordances (AFF between -5 and -2), associated with perceptions of weak cognitive construction (PRC between -5 and 2), particularly in entries 27 to 43. The absence of explicit signals and the fragmented logic of commands disrupt the operator's mental model, undermining both the predictability and intelligibility of actions, especially during flight control phases, task configuration, and subsystem activation.

Affectivity (AFV) and Satisfaction (STSF): Negative emotional load is accentuated in entries 7 to 26 and 27 to 47, with STSF ranging from -3 to -5, reflecting ongoing frustrations regarding the system's structural rigidity, the absence of critical features, and the limited possibilities for customization. Affective responses are strongly correlated with the perception of limited agent autonomy in adverse operational scenarios, reinforcing the need for ergonomic, configurational, and informational improvements.

Effectiveness (EFT): Functional performance shows significant degradation in entries 15, 18, 19, 34, 36, 39, 41, and 42, with EFT values ranging from 5 to -3. These losses occur mainly during operations under payload, imprecise landings, refueling logic, failures in three-dimensional mapping, and the absence of maintenance plans. Systemic instability compromises operational fluidity, reduces the predictability of automated actions, and increases exposure to failures in complex scenarios.

Error Severity (GVE) and Risk Level (GSR): The dimensions of severity and risk reveal a critical pattern in entries 11, 15, 18, 27, 36, 37, 39, and 41, with GVE values between 2 and 5. The lack of robust safety protocols, forced control attempts during sloped landings (L37), and the absence of predictive electrical diagnostics (L43) indicate structural and logical vulnerabilities with the potential for catastrophic failures. In this context, operational risk is increased not only by physical limitations but also by decision-making gaps within the agent–technology interface.

TABLE 3.1: UAV EVALUATION

*	CEX	RQA	AFF	PRC	AFV	STSF	EFT	GVE	GSR
1	2	-5	-5	-5	-3	-1	-3	3	5
2	2	-5	-3	-5	-3	-1	-3	3	4
3	2	-1	-1	5	-3	-1	-3	3	4
4	2	-3	2	2	-3	-1	5	2	3
5	2	1	2	5	-3	6	5	2	3
6	2	3	2	3	-3	6	5	2	2
7	2	4	-1	5	3	6	5	1	2
8	2	2	-3	2	3	-1	5	2	3
9	2	4	2	3	3	6	-3	1	2
10	2	-3	-3	2	-3	-1	5	3	2
11	2	1	-5	-5	-3	-1	5	4	3
12	2	-4	-4	-5	-3	-3	-3	4	5
13	2	3	-4	-5	3	6	5	1	2
14	2	5	2	3	-1	6	5	1	2
15	2	-5	2	-5	-3	-3	-3	2	4
16	2	5	2	3	-1	6	5	3	1
17	2	6	-3	2	-3	6	5	3	1
18	2	-4	-4	-5	-5	-3	-3	4	5
19	2	6	2	3	-1	6	5	2	1
20	2	-2	2	2	-3	-3	5	2	1
21	2	5	-4	-5	-1	-3	-3	2	2
22	2	2	2	5	-1	6	5	2	3
23	2	1	-4	-5	-3	-1	5	3	1
24	2	3	2	3	-3	-1	5	3	2
25	2	5	2	3	3	7	5	1	1
26	2	6	2	3	3	7	5	3	1
27	2	-2	-3	2	-3	-1	-3	4	3
28	2	-1	-5	-5	-1	6	5	2	3
29	2	4	-1	5	-1	6	5	2	1
30	2	-1	-5	-5	-1	-1	-3	3	2
31	2	-1	-5	-5	-1	-1	5	2	2
32	2	-1	2	5	-3	-1	5	2	3
33	2	4	2	3	-1	6	5	3	1
34	2	2	-5	-5	-3	6	5	3	2
35	2	2	-4	-5	-3	6	5	3	3

36	2	-1	-3	2	-3	-3	-3	4	4
37	2	-1	2	5	-1	-1	-3	4	3
38	2	2	-3	2	-1	6	-3	3	2
39	2	3	-4	-5	-3	-1	5	3	2
40	2	3	-3	2	-1	-1	5	1	2
41	2	-1	-1	5	-3	-1	5	2	3
42	2	4	2	3	-1	-1	5	2	1
43	2	-4	-4	-5	-1	-3	-3	5	4
44	2	2	2	5	-1	-1	5	1	2
45	2	-2	-3	2	-5	-3	-3	5	5
46	2	1	-5	-5	-5	-3	-3	4	3
47	2	3	2	3	-1	-1	5	2	3
48	2	-3	-3	2	3	6	5	1	3

Source: Author.

Table 3.2, interpreted through the lens of Attributes (ATB), translates the functional and structural collapse of the evaluated UAV, revealing a recurrent pattern of failures in critical operational, safety, and regulatory compliance requirements.

Attributes such as Usability (ATB01) exhibit severely compromised performance in launches 1, 2, and 3 (-4), indicating that the structural design and operational ergonomics fail to meet the minimum principles of reliable control and agent adaptability. This initial deficiency already compromises the entire chain of interaction with the system, regardless of the sophistication of its internal features.

The attribute Functionality (ATB04) is marked by multiple negative occurrences, including launches 1, 12, 27, 30, and 45, ranging from (-2 to -5), which demonstrates instability in the core of the artifact's executive tasks, particularly in processes that should occur in an automated, fluid, and predictable manner. The most critical case is found in launch 12 (-5), where the functional failure is directly associated with structural degradation in the control logic, indicating that the system not only fails, but fails critically in sensitive operational environments.

Operational Efficiency (ATB03) suffers a significant reduction in launches 11, 36, and 45 (-3), suggesting a loss of responsiveness in scenarios demanding speed and precision, such as automated agricultural tasks. The same applies to System Stability (ATB07) and Interface Control (ATB11), both scoring negatively (-2) in launches 36 and 37, revealing operational risks related to freezing, the absence of adaptive logic, and low tolerance to contextual environmental variations.

At the regulatory and structural levels, Compliance (ATB10) stands out negatively in launches 12, 18, and 48 (-5 and -3), indicating failures in the UAV's adherence to technical, safety, and industrial assembly standards. The recurrence of this failure compromises certification, commercial scalability, and the safe use of the system in regulated environments.

The data set reveals a pattern of systemic critical fragility, in which multiple attributes simultaneously exhibit low levels of maturity. The UAV's architecture, as it currently stands, lacks not only functional robustness, it demonstrates integrated inefficiency across hardware, control logic, and interface requirements, demanding complete reengineering of the affected subsystems.

TABLE 3.2:

UAV EVALUATION

*	ATB	SPMI
1	ATB01	-4
1	ATB04	-3
2	ATB01	-4
3	ATB01	-4
11	ATB03	-3
12	ATB04	-5
12	ATB10	-5
18	ATB10	-5
27	ATB04	-2
30	ATB04	-3
36	ATB03	-3
36	ATB07	-2
37	ATB11	-2
45	ATB03	-3
45	ATB04	-3
48	ATB10	-3

TABLE 3.3:

UAV EVALUATION

*	ACB	SPMI
7	ACB06	5
7	ACB09	4
12	ACB06	-5
12	ACB08	-3
14	ACB13	-2
27	ACB15	-4
27	ACB16	-3
27	ACB17	-2
28	ACB15	-3
32	ACB15	1
40	ACB13	-1
42	ACB15	-3
44	ACB13	-2
47	ACB17	1

TABLE 3.4:

UAV EVALUATION

*	QRSUER	SPMI
1	TQRS01	-3
1	TQRS02	-2
5	TQRS01	-1
5	TQRS19	2
36	TQRS01	-2
37	TQRS01	-1
48	TQRS05	-4
48	TQRS10	1
48	TQRS11	-1
48	TQRS19	3
48	TQRS22	1

Source: Author.

Table 3.3 reveals a critical overview within the Accessibility (ACB) dimension of the UAV's embedded and control system, with a significant incidence of negatively scored elements across multiple launches.

Navigation Consistency ACB06 (-5) in launch 12 indicates a severe disruption in navigation consistency, directly impacting interaction predictability and continuity of user experience. The level of severity correlates with previously identified structural failures in RA28 and RA33, related to the absence of stable functional patterns and insufficient task configuration capabilities.

Time and Interaction Control ACB08 (-3) in launch 12 points to the lack of resizing mechanisms and interface responsiveness, compromising usability in varied environments with fluctuating brightness or across different control platforms. This limitation directly affects operability in open-field conditions, where adaptability is essential.

Contextual Adaptation ACB13 (-2) in launch 14 reflects a lack of contrast adjustment and visual customization features, which compromises legibility under adverse operational conditions commonly found in agricultural environments.

Error and Success Feedback ACB15 (-4) in launch 27 highlights a significant failure in visual and auditory feedback for agent-performed actions. The absence of return signals for critical commands increases operational risk, especially in autonomous flight tasks involving real-time parameter changes.

On the other hand, Navigation Consistency ACB06 (5) in launch 7 and Color Contrast ACB09 (4) in launch 7 indicate partial efforts to stabilize the navigation and visualization experience. However, these advances remain insufficient when compared to the broader set of failures evidenced in the other launches.

The convergence between the critical points in this dimension and the requirements of RA03, RA28, RA33, and RA34 highlights a systemic pattern of technical non-compliance, in which the lack of integration between physical structure, logical interface, and operational feedback creates critical zones of interaction.

The ACB dimension does not operate in isolation; rather, it is directly impacted by failures in configuration (RA28), execution of operational logic (RA34), physical and logical compatibility (RA39), and interface structure (RA33). The convergence of these failures compromises system intelligibility, renders prolonged use by different agents unfeasible, and amplifies operational risks in the agricultural deployment of the UAV.

Table 3.4 shows that the evaluated UAV exhibits predominantly negative technical-environmental performance, with a concentration of scores falling within critical zones, particularly in the criteria of material sustainability, disposal, circularity, and resource management.

Criterion TQRS01, referring to Utility and Resource Efficiency, was assessed at multiple stages of the life cycle. In item 1, it received scores of (-2 and -3), indicating severe inefficiency in structural design, with technically irrational choices regarding material use. The score of (-2) in item 36 reinforces this trend, evidencing the absence of integrated strategies for optimizing mass, volume, and autonomy. In item 5, the occurrence of TQRS01 with (-1) suggests slight operational improvement, likely linked to incremental adjustments in the embedded software and flight architecture. In item 37, the same criterion reappears with (-1), denoting a repetition of performance still insufficient to reposition the system outside the critical zone. This set of results indicates that the project does not reach technical maturity in terms of rational use of by-products and inputs.

In item 5, TQRS19 (Legal Compliance) was rated (2), indicating the incipient presence of functionalities with transformative potential. In item 48, the same criterion obtained a score of (3), revealing an intermediate stage of development aimed at environmental technological integration, although still lacking a systematized structure to maximize positive impact. In item 48, this same criterion TQRS19 reappears again with a score of (3), indicating a development stage related to intermediate integration, but the UAV, within its evolutionary logic, still requires better technological structuring.

In item 48, the results for post-consumption management were technically critical. TQRS05 (Active Disposal) was scored (-4), indicating a total absence of guidelines, mechanisms, or technical solutions for safe disposal. TQRS10 (Recyclability), with a score of (1), suggests a minimal degree of material reuse, possibly limited to isolated metallic components, with no modular structure to facilitate disassembly or reprocessing.

Criterion TQRS11 (Facilitated Repair), also in item 48, was rated (-1), reflecting moderate obstacles to technical maintenance, such as rigid casings, permanent fixings, and lack of technical documentation. These factors directly compromise the extension of the useful life cycle and promote the intensification of early disposal.

TQRS22 (Sustainable Integration) was scored (1) in item 48. This indicates the presence of traces of adaptability in the design, though without systemic incorporation of functional sustainability principles, such as component interchangeability, expanded modularity, or backward compatibility.

The analysis shows that the evaluated UAV exhibits severe deficiencies in the structuring criteria of the QRSUER dimension. The predominance of critical scores (-3, -2, and -4) demonstrates that the project remains at an unsatisfactory stage in terms of environmental and sustainable performance, particularly in circularity, disposal, and efficient resource use. Although some signs of responsible innovation emerge in criterion TQRS19 (2 and 3), the imbalance between functional sophistication and ecological responsibility compromises the technological object's viability in light of the dimension's requirements.

The integrated technical-scientific systems and structures for analysis, assessment, and representation, as defined within the logical scope of FCIA-OT, operate as methodological cores for modular measurement of the technology from the perspective of Usability and Interaction Engineering. The SGUI is applied as an analytical and critical component of this process, in which the quantitative evidence obtained in the technical-analytical matrices, Tables 3.1, 3.2, 3.3, and 3.4, is converted into interpretive scores, allowing for the measurement of functional behavior and the relative impact of each identified element in the model.

Each column of the matrix corresponds to a specific functional dimension, composed of launches that reflect the scores associated with the evaluative elements. The recurrence of elements within the same column reveals patterns of repetition, indicating their systemic relevance. For each identified element, the total frequency across launches is calculated, followed by application of the following formula:

$$\mathbf{SGUI = (Frequency_{element} / \sum Frequencies_{all}) \times 100}$$

The interpretation of the values obtained follows the criteria defined in the matrix of the corresponding dimension, allowing for the identification of each element's relative presence within the evaluated system. The SGUI functions as a functional indicator of recurrence, highlighting frequency patterns that reflect the intensity of each element's manifestation across dimensions. In this regard, the SGUI can be interpreted as a marker of event frequency, reflecting the relative distribution of data within a constant analytical base, thereby ensuring proportionality and comparability across distinct dimensions.

As a subsequent stage in the measurement procedure, the SCMI is applied. It operates on the relative frequency of elements and incorporates the weights established in the SPMI, calculating the critical percentage contribution of each element to the technical maturity of the dimension. Its calculation formula is defined as:

$$\mathbf{SCMI = (SPMI_{element} / \sum SPMIs_{all}) \times 100}$$

The obtained value supports the stage of critical classification, signaling elements with outstanding performance, intermediate performance, or negative impact, according to their relative contribution to the technical maturity of the dimension. The SCMI functions as a metric of qualitative weight, integrating the modulated values of the SPMI to measure the effective impact of each component on the structural performance of the system. From this perspective, the SCMI can be interpreted as an indicator of the interaction energy of each element with the functional structure of the evaluated technological object, revealing the intensity and direction (positive or negative) of its technical contribution within the modular context.

The application of technical and systemic analysis through the SGUI and SPMI indices (Tables 4 and 4.1) enables the identification of critical patterns, recurrences, and technical expressiveness in the evaluated elements. The results express the quantitative and weighted distribution of the occurrences, providing an objective basis for data interpretation and for the construction of the dimensional diagnostics presented below.

TABLE 4: SYSTEMIC AND CRITICAL ANALYSIS OF THE UAV

Acronym	Element	SPMI	Launch	SCMI	SGUI %	Level	SCMI %
CEX	2	2x1 = 2	1	2	99%	2	99%
RQA	6	6x3 = 18	48	42	6,25%	2	42,86%
	5	5x4 = 20	48	42	8,33%	2	47,62%
	4	4x5 = 20	48	42	10,42%	2	47,62%
	3	3x6 = 18	48	42	12,50%	2	42,86%
	2	2x6 = 12	48	42	12,50%	2	28,57%
	1	1x4 = 4	48	42	8,33%	2	9,52%
	-1	-1x8 = -8	48	42	16,67%	2	-19,05%
	-2	-2x3 = -6	48	42	6,25%	2	-14,29%
	-3	-3x3 = -9	48	42	6,25%	2	-21,43%
	-4	-4x3 = -12	48	42	6,25%	2	-28,57%
	-5	-5x3 = -15	48	42	6,25%	2	-35,71%
AFF	2	2x19 = 38	48	-63	39,58%	5	-60,32
	-1	-1x4 = -4	48	-63	8,33%	7	6,35%
	-3	-3x10 = -30	48	-63	20,83%	6	47,62%
	-4	-4x8 = -32	48	-63	16,67	6	50,79%
	-5	-5x7 = -35	48	-63	14,58%	6	55,56%
PRC	5	5x9 = 45	48	15	18,75%	5	300,00%
	3	3x11 = 33	48	15	22,92%	5	220,00%
	2	2x11 = 22	48	15	22,92%	5	146,67%
	-5	-5x17 = -85	48	15	35,42%	4	-566,67%
AFV	3	3x7 = 21	48	-74	14,58%	13	-28,38%
	-1	-1x17 = -17	48	-74	35,42%	11	22,97%
	-3	-3x21 = -63	48	-74	43,75%	11	85,14%
	-5	-5x3 = -15	48	-74	6,25%	13	20,27%

STSF	7	7x2 = 14	48	69	4,17%	10	20,29%
	6	6x17 = 102	48	69	35,42%	8	147,83%
	-1	-1x20 = -20	48	69	41,67%	7	-28,99%
	-3	-3x9 = -27	48	69	18,75%	10	-39,13%
EFT	5	5x32 = 160	48	112	66,67%	3	142,86%
	-3	-3x16 = -48	48	112	33,33%	4	-42,86%
GVE	5	5x2 = 10	48	123	4,17%	2	8,13%
	4	4x7 = 28	48	123	14,58%	3	22,76%
	3	3x15 = 45	48	123	31,25%	5	36,59%
	2	2x16 = 32	48	123	33,33%	5	26,02%
	1	1x8 = 8	48	123	16,67%	4	6,50%
GSR	5	5x4 = 20	48	122	8,33%	3	16,39%
	4	4x5 = 20	48	122	10,42%	3	16,39%
	3	3x14 = 42	48	122	29,17%	4	34,43%
	2	2x15 = 30	48	122	31,25%	5	24,59%
	1	1x10 = 10	48	122	20,83%	4	8,20 %

SPMI Total – SGUI: Total number of occurrences recorded per element, expressing the raw frequency of presence within the dimension.

Launch: Refers to the launches performed in the analysis and evaluation.

SPMI Total – SCMI: Weighted sum of the technical scores assigned to the elements (severity, impact, or relevance).

SGUI (%): Relative Frequency Score, calculated in proportion to the total number of occurrences.

SGUI – Level: Indicates the relational position of the element within the dimension, based on its frequency and impact. It expresses the degree of recurrence and technical relevance in the analyzed set.

SCMI (%): Represents the proportional technical weight of the element within the functional dimension. It indicates how much the item impacts the system, positively or negatively, without qualifying it as good or bad, but rather showing how much it weighs technically in the functional balance.

CEX: When applicable, 99% represents the maximum achievable operational level; 100% applies only to the manufacturer or developer of the artifact itself, as an ideal reference.

Source: Author.

TABLE 4.1: SYSTEMIC AND CRITICAL ANALYSIS OF THE UAV

Acronym	Element	SPMI	Launch	SCMI	SGUI %	Level	SCMI %
ATB	-2	-2x3 = -6	48	-54	6,25%	2	11,11%
	-3	-3x7 = -21	48	-54	14,58%	2	38,89%
	-4	-4x3 = -12	48	-54	6,25%	2	22,22%
	-5	-5x3 = -15	48	-54	6,25%	2	27,78%
ACB	5	5x1 = 5	48	-17	2,08%	4	-29,41%
	4	4x1 = 4	48	-17	2,08%	4	-23,53%
	1	1x2 = 2	48	-17	4,17%	3	-11,76%
	-1	-1x1 = -1	48	-17	2,08%	2	5,88%
	-2	-2x3 = -6	48	-17	6,25%	2	35,29%
	-3	-3x4 = -12	48	-17	8,33%	2	70,59%
	-4	-4x1 = -4	48	-17	2,08%	2	23,53%
	-5	-5x1 = -5	48	-17	2,08%	2	29,41%
QRSUER	3	3x1 = 3	48	-5	2,08%	4	-60,00%
	2	2x1 = 2	48	-5	2,08%	3	-40,00%
	1	2x2 = 4	48	-5	4,17%	3	-80,00%
	-1	-1x3 = -3	48	-5	6,25%	2	60,00%
	-2	-2x2 = -4	48	-5	4,17%	2	80,00%
	-3	-3x1 = -3	48	-5	2,08%	2	60,00%
	-4	-4x1 = -4	48	-5	2,08%	2	80,00%

Source: Author.

The SCMI% index is a relative metric, specific to each dimension. Its denominator corresponds to the total sum of the weighted scores of the elements belonging to the dimension itself, so that the value assigned to each element reflects the functional context in which it is inserted. Therefore, the same type of artifact may present significant variations in SCMI% across different dimensions, even with opposite polarities, depending on the distribution of technical weights in the analysis.

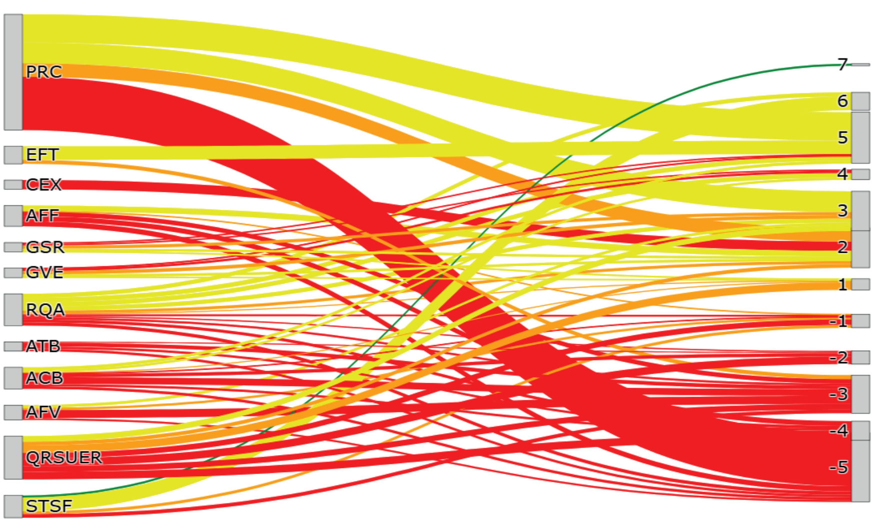
This behavior represents a fundamental property of the calculation, as it enables the FCIA-OT system to detect localized functional patterns and assess modular maturity with contextual precision. Elements with negative weights reduce the total sum of the dimension, allowing positively weighted elements to exceed 100% in absolute value. This effect arises from the relational structure of the metric itself, which does not operate based on a fixed reference, but on functional proportionality.

Figure 7 illustrates the relationship between the twelve analyzed functional dimensions and the evaluated elements according to the percentages derived from SPMI%. The visualization clearly reveals the relative weight of each element within the systemic context, highlighting the most critical, recurrent, or technically relevant flows based on the interaction density and computed impact within each dimension.

The SCMI% expresses the weighted technical proportion of an element in relation to the total of the dimension, functioning as a relational impact index. Its purpose is to characterize the technical relevance of the element within the analyzed set, respecting the specific operational dynamics of each dimension and revealing both critical potentialities and nuclei of technical maturity in the studied modules.

The Knowledge/Experience Dimension (CEX) reveals complete cognitive uniformity on the part of the agent throughout the entire evaluation. All recorded entries are exclusively concentrated on element (2), indicating an absolute absence of fluctuation in the levels of knowledge and experience applied during the process. This pattern expresses an evaluative operational regime sustained by consolidated technical mastery, in which the agent demonstrates full capacity to understand, interpret, and apply the system's requirements, both conceptual and operational, without incurring in interpretative deviations, methodological weaknesses, or cognitive inconsistencies.

FIGURE 7: SANKEY MAP OF WEIGHTED SYSTEMIC INTERACTIONS (SPMI%) BETWEEN FUNCTIONAL DIMENSIONS AND EVALUATED ELEMENTS



Sankey chart structured according to the proportional distribution of SPMI% values, connecting each functional dimension of the system to the corresponding elements, with relative weights represented by the width of the flows. The colors follow the technical typology of the SCDMIC, according to their nature and impac.

Source: Author.

From the standpoint of reliability, this consistency of level (2) constitutes a critical technical indicator, ensuring that the judgments issued across the dimensions, artifacts, and modules of the UAV stem from an agent positioned at an advanced level of proficiency, capable of operating the analytical instruments of the FCIA-OT with systemic accuracy. In summary, the CEX Dimension confirms a scenario of cognitive stability and interpretative precision, elements essential to the validity of the data produced and to the robustness of the inferences drawn about the UAV at this stage of systemic evaluation.

The Object Artifact Requirements Dimension (RQA) reveals a complex functional configuration among artifacts, components, and structural elements of the evaluated technological system. The data indicate an unstable balance between components with strong adherence to technical requirements (positive elements) and critical instances with severe structural deviations (negative elements), which imposes a scenario of strategic attention on the systemic architecture of the UAV.

The set of positive elements is led by artifacts (5 and 4), both with SCMI% of (20 = 47.62%), indicating functional maturity and intermediate technical compliance. These artifacts operate as anchors of stability in structured subdomains, suggesting an intermediate application of design and validation criteria. Artifact SCMI% (3 = 42.86%) reinforces this trend of intermediate technical performance, especially due to its increased recurrence (6 launches), which demonstrates intermediate functional reliability across multiple operational instances.

In parallel, artifacts with SCMI% (2 = 28.57%) and (1 = 9.52%) exhibit low performance, with indications of partial technical maturity. They do not meet the minimum operational criteria, and their overall impact on the robustness of the dimension is limited, suggesting that these elements require further adjustments in future reengineering phases.

The critical configuration emerges from the elements with negative weights. The artifact (-5 = -35.71%) represents the most impactful dysfunctional vector within the dimension, reflecting severe failures in components essential to the system's integrity. Its recurrent presence in evaluation contexts (3 occurrences) suggests unresolved critical patterns, possibly related to manufacturing processes, imprecise specifications, or functional degradation.

SCMI% elements with weights (-4 = -28.57%), (-3 = -21.43%), and (-1 = -19.05%) consolidate the systemic risk profile associated with low-maturity artifacts. Their distribution across different technical subsystems compromises the consistency of the functional architecture and indicates the presence of integrated, rather than isolated, failures.

The coexistence of both positive and critically negative poles reveals a system with intermediate technical cores operating alongside zones of severe instability. This condition is typical of projects with partial integration between object requirements (RQO) and their respective artifacts (RQA), reinforcing the need for more precise methodological alignment between high-level specifications and their technical translation into parts, processes, and operational elements.

Thus, the analysis of the RQA dimension positions itself as a structuring axis for the continued systemic maturation of the UAV. Interventions focused on the replacement, redesign, and quality control of critical artifacts should be prioritized, with intensive application of functional validation protocols, technical traceability, and normative compliance.

The analysis of the Affordance (AFF) Dimension reveals a critical configuration in the perceptual and functional mechanisms of the UAV, with an asymmetric distribution of interactions and structural weights heavily skewed toward negative evaluation zones. The only element with a positive load, (2), although registering the highest frequency within the dimension (19 occurrences; 39.58% of SGUI%), presents a negative SCMI% (-60.32%) due to being the sole positive contributor within a predominantly critical set. This result indicates that, although more frequent, the positive affordances do not exhibit sufficient density to counterbalance the systemic negative impact imposed by the other artifacts.

Elements (3, -4, and -5), totaling 25 occurrences (52.08% of SGUI), concentrate 154% of the SCMI%, revealing that most interaction artifacts are situated in ranges with high levels of operational dysfunction. The recurrence of weights (-3, -4, and -5) reinforces the presence of severe structural inconsistencies in the system's channels of perception, manipulation, activation, or response, directly undermining the UAV's ability to provide clear, predictable, and intelligible affordances.

The element (-1), with isolated impact (8.33% of SGUI; 6.35% of SCMI), reinforces the scenario of functional fragility by representing artifacts with low levels of functional legibility and ambiguity in activation, without being capable of acting as a damping element against the established critical core.

This scenario compromises the coherence between intended use and technical response, generating cognitive barriers and reducing operational fluidity, especially in situations requiring rapid action and precise sensory contextualization. The dominance of elements (-5 and -4) is particularly alarming, as it highlights the presence of submodules with severe failures in functional signaling, rendering the interaction process dependent on external compensatory strategies or subsequent reconfigurations.

Therefore, the AFF dimension in the UAV indicates a framework of unstructured affordances, with a predominance of critical elements and the absence of stabilizing artifacts. FCIA-OT, by recording the supremacy of negative SCMI%, triggers an internal condition for blocking synthetic interpretation, requiring a profound design revision of the system's signaling, activation, and perceptual feedback elements.

The analysis of the Perception (PRC) Dimension reveals a critical and polarized configuration of response across the evaluated UAV modules, with a marked predominance of artifacts classified at the maximum negative level of the scale. The element with 17 occurrences and weight (-5) accounts for 35.42% of the interactions and alone contributes (-566.67%) to the SCMI, indicating a severe and recurrent perceptual impact across multiple submodules.

The pattern denotes cognitive overload, consistent perceptual failures, and degradation in the system's capacity for functional assimilation, directly compromising the interpretation, response, and operational feedback subsystems.

The counterpoint is provided by the elements (5 with 9 occurrences), (3 with 11 occurrences), and (2 with 11 occurrences), which, although collectively accounting for 64.59% of the interactions, do not neutralize the structural negative weight of the set. Element (5), with 18.75% in SGUI and 300% in SCMI, leads the effort of positive perceptual compensation, followed by (3 = 22.92% SGUI, 220% SCMI) and (2 = 22.92% SGUI, 146.67% SCMI). The data suggest localized attempts at perceptual correction and distributed sensory improvements within the system, but these prove insufficient when compared to the critical magnitude imposed by (-5).

The SCMI metric, upon reaching such proportions, becomes an exact expression of the disparity between critical negative weights and the positive adjustment mechanisms. This asymmetry is an expected characteristic of the FCIA-OT methodology in environments of high functional stress, revealing deep perceptual failures that not only hinder the system's situational reading performance but also indicate dysfunctions in the feedback and signal integration modules.

In this context, the PRC dimension stands out as one of the UAV's most fragile axes, demanding immediate corrective interventions in sensory perception channels, refinement in environmental interpretation patterns, and redesign of the associated cognitive routines. The persistence of the identified critical pattern compromises the system's overall maturity, negatively affecting responsiveness, reactive coherence, and the adaptive capacity of the modular set.

The analysis of the Affective (AFV) Dimension revealed a critical scenario, characterized by a predominance of negative entries and asymmetric statistical distribution. The evaluation indicated a high recurrence of elements associated with affective dissatisfaction (43.75%; 35.42%), reflecting a pattern of adverse emotional impact on the interactive experience.

The SGUI indicated significant expressiveness of critical elements, while the SCMI, with a total negative sum of (-74), evidenced the concentration of unfavorable weights. Element (-3) exhibited the highest SCMI (85.14%), followed by 22.97% and 20.27%, forming a set of artifacts with strong negative influence over the affective dimension.

The occurrence of a negative SCMI in the element (-28.38%), despite its positive raw score, resulted from the proportional inversion caused by the overall negative polarity of the dimension, requiring specialized technical interpretation.

From a systemic perspective, the data point to a low affective maturity of the evaluated technological object (UAV), indicating an absence of emotional comfort, perceived empathy, or alignment with the agents' subjective expectations. The AFV dimension, therefore, demands priority attention in reengineering and qualification cycles, acting as a critical vector for the evolution of agent–technology interaction in emotionally demanding contexts.

The Satisfaction (STSF) Dimension presented a complex analytical profile, marked by significant disparities between recurrence and criticality of the elements. The data distribution revealed contrasting polarities between positive and negative components.

Element (6) accounted for 35.42% of the entries and reached 147.83% in SCMI%, indicating an anomalous positive critical weight, resulting from statistical dominance in a dimension whose weight sum was positive. This value requires technical interpretive adjustment and reclassification into specific ranges to represent its expressiveness. The case signals an intermediate impact of satisfaction on the interactive experience.

On the other hand, elements (-1 and -3) reached negative SCMI% values of (-28.99% and -39.13%), respectively, compromising the affective linearity of the dimension. Element (7), though with low frequency, presented an SCMI% of 20.29%, acting as a secondary vector of positive reinforcement.

The integrated analysis of SGUI and SCMI revealed that satisfaction, although present at intermediate levels, remains unbalanced in the face of persistent destabilizing elements. The statistical behavior of the set points to a scenario of functional transition, in which the presence of satisfaction is perceptible yet weakened by critical recurrences.

The STSF dimension, therefore, demands targeted interventions aimed at mitigating negative elements and consolidating positive ones, promoting stability in the perception of value, adequacy, and experiential reward in the agent–technology interaction.

The analysis of the Effectiveness (EFT) Dimension reveals a functional asymmetry in the distribution of technical elements and artifacts with negative impact on the systemic maturity of the UAV. Element (5), with 32 occurrences and the highest weight (5), accounts for 66.67% of the interactions and contributes 142.86% to the SCMI, positioning itself as the main vector of technical effectiveness within the evaluated set. Although such predominance denotes partial convergence with operational efficiency parameters, the data suggest that a significant portion of subsystems remains at an intermediate functional level, requiring structural adjustments and operational refinements to fully meet the critical standards of responsiveness, performance continuity, and technical reliability.

Conversely, element (-3), with 16 occurrences and a negative weight (-3), raises a methodological alert. The result of (-42.86%) in SCMI indicates that these artifacts exhibit structural inconsistencies and critical functional failures. Although excluded from the synthesis analyses, these records remain accessible in internal technical reports, ensuring analytical traceability and supporting quality control and reengineering processes.

Thus, the effectiveness of the UAV, although containing cores of intermediate performance, still evidences a functional state in transition. Its coexistence with critical artifacts reinforces the need for targeted technical interventions aimed at correcting modular deficits and progressively enhancing the system architecture.

The Error Severity (GVE) Dimension in the UAV reveals a functional distribution marked by the predominance of artifacts classified at critical levels of the severity scale. Elements (3), (2), and (4), totaling 38 occurrences, account for 79.16% of the interactions and collectively represent 85.37% of the SCMI, reflecting significant structural and functional impact on system reliability. Element (3) stands out, solely responsible for 36.59% of the SCMI, with high recurrence and consistent severity, evidencing recurring failures in strategic submodules.

The presence of elements such as (1 and 5), associated with milder severity levels, is not sufficient to neutralize the overall critical weight of the dimension. The most expressive data point is that element (5), although associated with maximum severity (5), appears only twice, which reduces its direct percentage impact, yet signals the existence of isolated failures with high technical hazard potential. This scenario reinforces the need for both corrective and preventive interventions, focused on the mitigation of systematic errors, restructuring of vulnerable routines, and revision of operational protocols.

Therefore, GVE configures itself as a critical axis in the assessment of the UAV's robustness, requiring immediate technical treatment to ensure stability, resilience, and functional integrity in the upcoming phases of systemic maturation.

The analysis of the Risk Level (GSR) Dimension reveals a dense and concerning distribution of artifacts located within critical and intermediate operational risk ranges. Elements (3 and 2), which together represent 60.42% of the occurrences, concentrate 59.02% of the SCMI, revealing that a significant portion of UAV components operate in contexts of high functional exposure or recurring vulnerabilities. Element (3), with 14 occurrences and weight (3), alone contributes 34.43% of the SCMI, signaling structural risk disseminated across key subsystems.

Although elements (5 and 4) are associated with the highest levels of risk, their limited occurrences reduce their relative weight in the metric. Nonetheless, their presence cannot be disregarded, as they indicate localized failures with high disruptive potential. Element (1), although positioned in a lower risk range, appears with sufficient frequency to impact 8.20% of the SCMI, reinforcing the persistence of technical instabilities in areas of low resilience.

Thus, the GSR dimension points to a scenario in which UAV operation demands more rigorous mitigation protocols, with emphasis on predictive analysis, containment of recurrent failures, and reengineering of critical modules. The management of technical risks must be repositioned as a structuring axis of the system's functional maturity, particularly for continuous validation cycles and modular improvement.

The Attributes (ATB) Dimension aims to systematically capture the incidence and performance of specific qualitative attributes of the evaluated system, based on inferred and technically validated requirements. The activation of such elements occurs exclusively when their applicability is operationally and contextually justified within the analyzed records.

In the present UAV assessment, only 16 entries out of the 48 possible showed valid ATB attribute assignments, resulting in an SGUI% of 33.33%. Rather than indicating an informational gap, this value highlights the selective modularity of the dimension, which operates solely under criteria of technical relevance. This characteristic reinforces the methodological robustness of the framework by preventing undue generalizations of attributes that do not apply to the system's functional reality.

The analysis of assigned weights (SPMI) reveals that all occurrences were associated with negative performance, with scores ranging from (-2 to -5), totaling an SCMI of (-54). The internal percentage distribution within SGUI shows a predominance of occurrences with value (-3 = 43.75%), followed by (-5 = 31.25%), (-4 = 18.75%), and (-2 = 6.25%). This scoring pattern demonstrates a consistent negative trend, indicating that the assessed attributes are mostly compromised or insufficiently implemented.

This negative configuration may result from the absence of integration of the structuring principles of these attributes during the system's design, development, and validation phases, directly affecting aspects such as critical operations, adaptability, interoperability, and acceptability in real-use scenarios. The recurrence of scores (-3 and -5) reinforces the presence of significant structural failures, undermining minimum quality and expected performance requirements.

From a systemic perspective, the ATB dimension reveals architectural weaknesses and deficiencies in applied engineering, highlighting the need for a technical-conceptual reassessment of these attributes throughout the UAV's lifecycle. Although structurally functional, the system exhibits critical deficits in qualitative attributes, whose correction must be prioritized in the phases of technological and operational refinement.

The Accessibility (ACB) Dimension aims to assess the presence, recurrence, and performance of requirements associated with systemic accessibility within the context of the evaluated system. These elements represent critical components to ensure equitable, perceivable, and operational use of the system by different agent profiles and across multiple usage contexts. The activation of these elements occurs exclusively when the applicability of the requirement is technically and functionally validated throughout the examined entries.

In the UAV assessment, although all 48 entries were considered, only eight distinct elements were identified with assignments for this dimension, forming a specific and targeted incidence matrix. The aggregated SGUI% was 29.17%, reflecting a selective activation density consistent with the principle of functional modularity. The observed variation in element frequency, with emphasis on SGUI (-3 = 8.33%) and SGUI (-2 = 6.25%), indicates specific points of concern in terms of potential barriers or accessibility gaps.

In performance terms, the SCMI analysis totaled (-17), characterizing a profile of compromised accessibility. The assigned weights reveal a predominance of negative evaluations: (-2 = -6), (-3 = -12), (-4 = -4), and (-5 = -5), together comprising over 96.43% of the dimension's total critical load. This concentration of negative values suggests that accessibility, as a design and implementation attribute, was not fully considered or integrated during the system's conception and development stages.

Positive elements such as (5 and 4), although present, held reduced statistical weight (together accounting for only 4.16% of SGUI) and (52.94% negative in SCMI), being insufficient to reverse the structural negative bias of the dimension. The residual presence of (1 and -1) indicates isolated attempts at minimal or compensatory accessibility, yet inadequate in the face of broader structural deficiencies.

The consolidated analysis of the ACB dimension highlights critical operational and ergonomic weaknesses that directly affect usability, inclusion, and efficiency in real mission scenarios. The observed configuration underscores the need for a thorough review of accessibility requirements, both from normative and applied engineering perspectives, with a view toward compliance with universal standards and the maximization of human-system interoperability.

The QRSUER Technology Dimension reflects the systemic capacity of the evaluated object to incorporate its pillars in a measurable and operational manner. A selective and punctual activation pattern was observed for the elements of this dimension, with only seven occurrences distributed among the 48 possible entries, resulting in an aggregated SGUI of 22.91%. Although moderate, this value reveals a low density of integration of QRSUER attributes within the system's technical-functional core.

The distribution of entry frequencies was relatively uniform, with emphasis on the following SGUI occurrences: (3 = 2.08%), (2 = 2.08%), (1 = 4.17%), (-1 = 6.25%), (-2 = 4.17%), (-3 = 2.08%), and (-4 = 2.08%). The analysis reveals a predominance of records with low relative frequency, indicating that such attributes did not consolidate as structuring elements throughout the UAV's technical lifecycle.

From a critical perspective, the assigned weights (SPMI) and their respective SCMI values indicate a clear predominance of negative evaluations. Elements (-1, -2, -3, and -4) exhibited weights ranging from (-1 to -4), with SCMI values varying between 60.00% and 80.00%, indicating strong negative impact on the technical maturity of the dimension. Element (1), despite holding the highest aggregated weight (4), also resulted in an SCMI of (-80.00%), reinforcing the dimension's critical bias. In total, the accumulated SCMI was (-5), evidencing a significant technical-scientific deficit in the criteria of sustainability, equity, responsibility, and technical soundness.

This negative profile suggests that the structuring principles of QRSUER were not substantially integrated into the system's design and validation processes. The concentration of negative scores reveals critical weaknesses in normative, environmental, and techno-ethical aspects, undermining essential attributes for long-term sustainability and social acceptability of the technology.

From a modular perspective, the QRSUER dimension configures itself as a critical instance for the technical evolution of the system, requiring conceptual restructuring and methodological reinforcement in its design parameters. The low incidence and high negative impact highlight the need for active incorporation of QRSUER criteria in the subsequent refinement phases, prioritizing compliance with responsible engineering guidelines, impact neutrality, and sociotechnical responsibility. Reversing the current pattern will depend on the consolidation of sustainable, ethical, and common-good-oriented practices as inseparable components of the system architecture of the evaluated technological object.

2.3.1 Modular Critical Analysis by Technical Element

The technical analysis may also be conducted at a deeper level by individual element. This subsection presents a technical evaluation based on the modular decomposition by element, in accordance with the FCIA-OT methodology. Three dimensions with high diagnostic value were selected, Attributes (ATB), Accessibility (ACB), and QRSUER (Quality, Social Responsibility, Sustainability, Usefulness, Ethics, and Reason), due to their ability to expose specific vulnerabilities, critical recurrences, and patterns of functional compromise.

Each record was measured by technical attribute, assessing both relative incidence and critical weight in the system's performance. This complementary approach enhances the precision of the evaluation and reinforces the explanatory robustness of the proposed model.

The Attributes (ATB) dimension, which evaluates specific qualitative attributes of the system, revealed in the UAV analysis a concentration in six main technical attributes: Usability, Efficiency, Functionality, Controllability, Compliance, and Stability. These attributes, detailed in Table 4.2 and distributed across 16 records, account for 33.33% of the total 48 records, reflecting a selective application of the dimension consistent with the technical relevance of the attributes within the system context.

The results indicate a predominantly negative profile, with a total score (SPMI) of -54, unevenly distributed among the attributes. Functionality, with five occurrences and a relative weight of 29.63% in the total impact, concentrates the majority of the qualitative deficiencies, followed by Compliance (24.07%) and Usability (22.22%). Although less frequent, Efficiency, Controllability, and Stability also contribute to the deficiency profile.

TABLE 4.2: SYSTEMIC AND CRITICAL ANALYSIS BY UAV ELEMENT

ATB	Vector/Element	Occurrences / SPMI	SGUI %	SCMI %
ATB01	Usability	3 [-4, -4, -4 = -12]	3/48 = 6,25%	-12/-54 = 22,22%
ATB03	Efficiency	3 [-3, -3, -3 = -9]	3/48 = 6,25%	-9/-54 = 16,67%
ATB04	Functionality	5 [-2, -3, -3, -3, -5 = -16]	5/48 = 10,42%	-16/-54 = 29,63%
ATB07	Controllability	1 [-2]	1/48 = 2,08%	-2/-54 = 3,70%
ATB10	Compliance	3 [-3, -5, -5 = -13]	3/48 = 6,25%	-13/-54 = 24,07%
ATB11	Stability	1 [-2]	1/48 = 2,08%	-2/-54 = 3,70%
Total	**6 ATB**	**16 lanç. / -54**	**33,33%**	**100%**

Grouped by specific technical vector/element; sums the individual scores of each vector/element; measures the relative weight of the vector/element in the system's overall performance. **SPMI:** Sum of Individual Module Scores, total negative scores assigned to the vector/element. **SGUI %:** Percentage of the vector/element's occurrences relative to the total number of entries. **SCMI %:** Percentage of the vector/element's critical weight relative to the total Sum of Individual Module Scores.

Source: Author.

This configuration indicates that the UAV faces critical limitations in fundamental aspects of its performance and operation, such as adherence to functional requirements, regulatory compliance, and agents' experience. The distribution of negative impacts by technical attribute reinforces the need for targeted interventions, prioritizing on the elements that most compromise systemic quality.

Thus, the ATB dimension not only offers a precise diagnosis of critical issues but also provides analytical support for strategic prioritization in the technological restructuring and enhancement of engineering requirements applied to the UAV.

The Accessibility (ACB) dimension, dedicated to the analysis of systemic accessibility, identifies, within the UAV scope, the presence of seven distinct technical elements (Table 4.3), applied to 14 of the 48 total records, representing a selective incidence of 29.17%. This distribution reveals a contextualized application of accessibility, triggered exclusively when operational requirements justify the analysis of such elements.

TABLE 4.3: SYSTEMIC AND CRITICAL ANALYSIS BY UAV ELEMENT

ACB	Vector/Element	Occurrences / SPMI	SGUI %	SCMI %
ACB06	Text Alternatives	2 [5, -5 = -0]	2/48 = 4,17%	0,00%
ACB08	Time and Interaction Control	1 [-3]	1/48 = 2,08%	-3/-17 = 17,65%
ACB09	Color Contrast	1 [4]	1/48 = 2,08%	4/-17 = 23,53%
ACB13	Adaptation to Usage Contexts	3 [-1, -2, -2 = -5]	3/48 = 6,25%	-5/-17 = 29,41%
ACB15	Error and Success Feedback	4 [-3, -3, -4, 1 = -9]	4/48 = 8,33%	-9/-17 = 52,94%
ACB16	Clear Input Errors	1 [-3]	1/48 = 2,08%	-3/-17 = 17,65%
ACB17	Multimodality	2 [-2, 1 = -1]	2/48 = 4,17%	-1/-17 = 5,88%
Total	**7 ACB**	**14 lanç. / -17**	**29,17%**	**100%**

Grouped by specific technical vector/element; sums the individual scores of each vector/element; measures the relative weight of the vector/element in the system's overall performance. **SPMI:** Sum of Individual Module Scores, total negative scores assigned to the vector/element. **SGUI %:** Percentage of the vector/element's occurrences relative to the total number of entries. **SCMI %:** Percentage of the vector/element's critical weight relative to the total Sum of Individual Module Scores.

Source: Author.

The sum of the scores assigned (SPMI) totals -17, with a predominance of negative evaluations. Notably, vector/element ACB15 (Error and Success Feedback) appears in four occurrences and concentrates a critical impact of 52.94% (SCMI) of the entire dimension. Next, ACB13 (Adaptation to Usage Contexts) accounts for 29.41% of the critical load, reflecting weaknesses in the system's adaptive capacity when facing different operational scenarios. ACB08 (Time and Interaction Control) and ACB16 (Clear Input Errors) each contribute 17.65%, both indicating deficiencies in interaction control mechanisms and error prevention.

Although elements such as ACB09 (Color Contrast) and ACB06 (Text Alternatives) were identified, their effects on the dimension were either neutral or contradictory: ACB09 recorded a single positive score, whereas ACB06, despite two occurrences, resulted in a net sum of zero. ACB17 (Multimodality), in turn, played a marginal role (5.88%), yet still pointed to inconsistencies in the delivery of multiple modes of content access.

The analysis reveals that, although partially addressed, accessibility remains compromised in aspects requiring greater structural refinement. The predominance of negative scores reflects the absence of robust accessibility criteria during system design and validation. Thus, the ACB dimension stands out not only as a technical diagnostic vector but also as evidence that functional accessibility is not yet a consolidated pillar within the UAV's development cycle, and must therefore be treated as a reengineering priority in future iterations.

The QRSUER Technology Dimension, focused on evaluating technological attributes related to quality, sustainability, and compliance, comprises, in the UAV context, a total of 11 entries, distributed among seven distinct technical vectors/elements (Table 4.4), representing 22.90% of the 48 mapped events. This incidence reveals a segmented application of the dimension, activated in specific situations of technological criticality.

TABLE 4.4: SYSTEMIC AND CRITICAL ANALYSIS BY UAV VECTOR/ELEMENT

QRSUER	Vector/Element	Occurrences / SPMI	SGUI %	SCMI %
TQRS01	Usefulness and Resource Efficiency	4 [-1, -1, -2, -3 = -7]	4/48 = 8,33%	-7/-7 = 100%
TQRS02	Resource Sustainability	1 [-2]	1/48 = 2,08%	-2/-7 = 28,57%
TQRS05	Active Disposal	1 [-4]	1/48 = 2,08%	-4/-7 = 57,14%
TQRS10	Recyclability	1 [1]	1/48 = 2,08%	1/-7 = -14,29%
TQRS11	Facilitated Repairability	1 [-1]	1/48 = 2,08%	-1/-7 = 14,29%
TQRS19	Legal Compliance	2 [2, 3 = 5]	2/48 = 4,17%	5/-7 = -71,43%
TQRS22	Sustainable Integration	1 [1]	1/48 = 2,08%	1/-7 = -14,29%
Total	**7 QRSUER**	**11 lanç. / -7**	**22,90%**	**100%**

Grouped by specific technical vector/element; sums the individual scores of each vector/element; measures the relative weight of the vector/element in the system's overall performance. **SPMI:** Sum of Individual Module Scores, total negative scores assigned to the vector/element. **SGUI %:** Percentage of the vector/element's occurrences relative to the total number of entries. **SCMI %:** Percentage of the vector/element's critical weight relative to the total Sum of Individual Module Scores.

Source: Author.

The SPMI total resulted in a significantly negative value (-7), indicating that although the dimension is occasionally activated, its impact tends to be adverse to the system's technological quality. The vector/element TQRS01 (Usefulness and Resource Efficiency) stands out, with four occurrences and a total critical impact (SCMI = 100%), evidencing that mechanisms for rational and effective resource usage are severely compromised, thereby undermining the UAV's operational sustainability.

Next, the attributes TQRS05 (Active Disposal) and TQRS02 (Resource Sustainability), although each recorded only once, contributed relevant impacts of 57.14% and 28.57%, respectively, suggesting the absence of appropriate guidelines for responsible waste disposal and sustainable resource use. TQRS11 (Facilitated Repairability), with an impact of 14.29%, reinforces the difficulties in maintenance and lifecycle extension of system components.

In contrast, attributes such as TQRS10 (Recyclability), TQRS19 (Legal Compliance), and TQRS22 (Sustainable Integration) presented effects that contradicted expectations. TQRS10 and TQRS22 displayed positive scores, which led to negative SCMI percentages (-14.29% each), revealing a disconnect between the intended technical proposal and its actual execution. Notably, TQRS19, despite a positive score (5), had a critical negative influence on the matrix (-71.43%), signaling an imbalance in the incorporation of legal requirements, which may have been addressed in a fragmented rather than systemic manner.

The dataset reinforces that the technological dimension faces serious inconsistencies in implementing attributes related to sustainability, resource usability, and regulatory adequacy. The concentration of negative impacts in a few attributes, coupled with distortions caused by misallocated positive scores, indicates that the system lacks effective technological integration and conscious environmental planning. Thus, the QRSUER dimension emerges as essential to the technical diagnosis of the UAV's technological viability, pointing to critical elements that must be prioritized in reengineering and compliance processes.

At the end of the process, the consolidation of all scores by vector/element and dimension will enable an advanced technical composition of the UAV's relative performance against critical parameters of interaction engineering and systemic usability. These values support technical judgment concerning strengths, operational weaknesses, and critical risks associated with the technology, providing a foundation for decisions related to redesign, validation, or formal approval of the solution.

In the context of critical interpretation, the SCDMIC is integrated with the scoring systems SPMI, SGUI, and SCMI, functioning as an additional structure for parametric interpretation. Its application allows for an expanded visual and analytical reading of the results, facilitating the critical classification of vectors/elements according to levels of functional maturity, technical impact, and systemic relevance within the assessed context.

3 DISCUSSION

The application of FCIA-OT to the three case studies revealed that technical, perceptual, or symbolic failures in technological objects do not manifest in isolation, but operate interdependently, forming critical networks that compromise intelligibility, fluidity, and trust in the interaction. By employing a multiscalar and modular matrix, it was possible to trace not only observable failures, but also their cumulative effects on the user experience.

In real operational contexts, such as those involving the software, air-conditioning control, and the UAV, the presence of feedback failures, perceptual inconsistencies, or the absence of explicit affordances was correlated with states of frustration and hesitation in the agent. As discussed by Luczak, Roetting, & Schmidt (2003), in such situations, agents tend to anthropomorphize the devices, attributing intent to technical failures and projecting negative emotional responses onto them, which increases the risk of rejection or discontinuation of use. Anthropomorphization, therefore, is not a psychologically irrelevant side effect, but a sensitive indicator of a rupture in the symbolic and operational reliability of the system.

From another perspective, the analyses revealed that the agent's experience with the evaluated systems cannot be explained solely by functional performance metrics. As argued by Hassenzahl & Monk (2010), the user experience is shaped by the articulation between pragmatic goals (do-goals), such as performing a function, and hedonic goals (be-goals), such as feeling competent, satisfied, or recognized. This articulation is directly affected by the perceived quality of the interaction and the meanings attributed to the object. In all analyzed cases, control elements that failed to provide clear feedback or predictable response compromised both the operation and the emotional significance of the technology for the agent.

Thus, FCIA-OT demonstrated its robustness by enabling a simultaneous reading of functional and affective, technical and subjective, operational and symbolic dimensions, articulating objective evaluation with a humanized understanding of the experience. This capacity for critical and integrated reading significantly expands the potential for analysis and evaluation in real contexts, definitively surpassing traditional prescriptive models and reaffirming FCIA-OT as a paradigmatic reference for the evaluation of technological objects.

4 CONCLUSION

The application of the FCIA-OT in the technical and symbolic analysis of technological objects has demonstrated its ability to operate with methodological precision across different configurations of systems, software, firmware, and multicomponent hybrid solutions. The three case studies validated the structural flexibility and diagnostic reach of the framework, both in identifying operational failures and in characterizing critical patterns of interaction and perception.

By organizing the data according to Object Requirements and Artifact Requirements and articulating them with the twelve technical-analytical dimensions of the model, it was possible to trace points of merit, neutrality, and functional collapse with high granularity. More than a descriptive matrix, the FCIA-OT proved to be a systemic reading system, capable of translating the technological experience into a critical cartography of evidence, grounded, validated, and replicable.

The analyses also revealed that localized failures in interface elements can trigger chain effects, interdependently affecting perceptual, affective, and operational dimensions. The model enabled not only the recognition of dysfunction but also its understanding within the context of use, taking into account the meanings attributed by the agent and the constraints imposed by real-world operational conditions.

The technical evaluation, enriched by empirical data and systematized instruments such as SPMI, SGUI, SCMI, and SCDMIC, allowed for the detailed mapping of critical zones and highlighted attributes of excellence or potential improvement. The intersection between quantitative indicators and qualitative interpretations enhanced the explanatory capacity of the model, broadening its applicability as a tool for diagnosis, reengineering, and decision-making in technological interaction projects.

As a methodological contribution, this study reaffirms the urgency of integrated approaches in the evaluation of complex technologies, where functionality, meaning, responsibility, and context are interwoven. In this regard, the FCIA-OT consolidates itself as a singular, multidimensional, and responsive scientific model, capable of capturing the systemic totality of technological objects, from engineering to experience, from form to function, from technical detail to symbolic perception. Its application reveals a new ontology of evaluation, positioning itself as both a reference and an innovation in the field, distinguished by its precision and its ability to map meanings and interactions with unprecedented analytical depth.

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