C H A P T E R 3

GLOBAL USABILITY AND INTERACTION SCORE (SGUI) AND INTEGRATED MODULAR CRITICAL SCORE (SCMI)

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ABSTRACT — The intensification of systemic complexity in technological objects and the increasing sophistication of interactions between agents and artifacts demand the development of more sensitive, modular, and integrable evaluation metrics. This study presents the technical-scientific proposition of two interdependent analytical devices: the Global Usability and Interaction Score (SGUI) and the Integrated Modular Critical Score (SCMI). Structured within the epistemic-functional architecture of the Integrated and Advanced Core Framework for the Analysis and Evaluation of Technological Objects (FCIA-OT), both operate on the SPMI metric core, enabling structured quantification and standardized visual interpretation of the maturity of evaluated elements. The SGUI introduces a multiscalar percentage-based metric derived from relative frequency, favoring the identification of dominant configurations in complex interaction environments. The SCMI emphasizes the traceability of critical data with high systemic density and low recurrence, functioning as a proportional metric of technical criticality. The formulation of these modules consolidates central metric-reading instances within FCIA-OT, enhancing its diagnostic capacity, inferential precision, and normative robustness in modular evaluation systems, with direct impacts on functional audits, interaction engineering, and the technical governance of technological ecosystems.

KEYWORDS — SGUI; SCMI; FCIA-OT; Interaction Engineering; Metrics; Usability; Systemic; Analysis and Evaluation; Technical Criticality.

1 INTRODUCTION

The intensification of systemic complexities in technological objects, combined with the growing sophistication of interactive dynamics between agents, artifacts, and environments, demands the development of evaluative metrics capable of operating precisely across different levels of criticality, functional maturity, and technical density. Traditional usability analysis models prove structurally inadequate for addressing the heterogeneity of contemporary systems and the semantic complexity inherent in their technical-operational attributes.

The FCIA-OT establishes a technical-epistemological architecture designed for the modular evaluation of technological objects, interfaces, and systems. Grounded in the Systemic Matrix of Integrated Vectorial Dimensions (MSDVI), comprising twelve interdependent dimensions, the model organizes cognitive, affective, functional, contextual, and structural parameters within a synergistic framework, engineered to capture both objective and subjective attributes. This cohesive technical-analytical matrix enables integrated assessments with a high degree of inference regarding systemic performance, technological maturity, and interactional dynamics (see Chapter 1).

Based on this structure, two systemic analytical modules were developed: the Global Usability and Interaction Score (SGUI) and the Integrated Modular Critical Score (SCMI). Both derive directly from the matrix core of the model, the SPMI, responsible for the weighted assignment of values to each evaluated element, and may be integrated, when necessary, into the standardized visual encoding of SCDMIC to enhance the graphic intelligibility of diagnostics (see Chapter 2).

The SGUI introduces a multiscalar, percentage-based metric derived from the relative frequency of attributes in each dimension of FCIA-OT. Its calculation structure enables the identification of recurrent patterns, dominant configurations, and expressive components in highly complex contexts, favoring comparative readings between evaluated objects, modules, or agents. Optional incorporation into the chromatic system of SCDMIC expands the visual expressiveness of results, enhancing their interpretative capacity in technical audits or large-scale modular analyses.

The SCMI operates as a proportional critical metric oriented toward the traceability of elements with high technical density and low statistical incidence. Through the weighted aggregation of SPMI values by element or dimension, the SCMI highlights records that, although infrequent, bear significant systemic weight. This approach prevents the dilution of critical data and ensures the inferential integrity of outputs, strengthening the technical governance of the analyses performed.

Both devices are organically integrated into FCIA-OT not as peripheral extensions, but as central instances of its own evaluative paradigm. Their methodological articulation consolidates a modular reading system endowed with diagnostic precision, technical-functional sensitivity, and inferential robustness. This significantly expands the applicability of FCIA-OT in interaction engineering, in structured usability evaluation, and in the formulation of technical protocols aimed at the systemic maturity of complex technological objects (see Chapter 4).

2 GLOBAL USABILITY AND INTERACTION SCORE (SGUI)

The Global Usability and Interaction Score (SGUI) constitutes an advanced technical-scientific module within FCIA-OT, designed to enhance the granularity, precision, and analytical depth in the evaluation of technological objects from multiple interactional perspectives. Its structure is based on the twelve core dimensions of the framework, offering an integrated approach that combines quantitative and qualitative criteria within a single interpretive core.

The SGUI operates as a relational scoring system per element, in which each entry corresponds to the frequency of occurrence of an evaluative component within the analytical matrix of a specific dimension. This frequency is converted into a relative percentage, according to the following formula:

$$SGUI_{\text{element}} = \left(\frac{Frequency_{\text{element}}}{\sum Frequencies_{\text{all}}} \right) \times 100$$

Source: Author.

Where: $\text{Frequency}_{\text{element}}$ represents the number of times the element was recorded in the matrix of the dimension, and $\sum \text{Frequencies}_{\text{all}}$ corresponds to the total number of records in that dimension.

The resulting percentage value expresses the relative representativeness of the element within the evaluated structure, functioning as an index of technical expressiveness. These data support modular classification processes, comparative positioning, and refined technical judgment, based on analytical ranges organized into three or five levels, depending on the nature of the dimension under consideration.

The SGUI may be complemented by chromatic scales derived from the SCDMIC system, which enhance diagnostic visualization through standardized patterns of recurrence, intensity, and distribution. When applied, this visual resource reinforces the intelligibility of results and supports technical decision-making in localized scenarios or more complex systems.

Consolidated as a high-performance analytical instance within the FCIA-OT ecosystem, the SGUI integrates rigorous epistemological foundations with adaptable practical applications, enabling the evaluation of interactional configurations with depth, comparability, and structural coherence.

2.1 Analytical Dimensions of the SGUI

The SGUI represents the technical-scientific synthesis of methodological evolution in usability and interaction analysis applied to technological objects. Developed from the structural convergence of FCIA-OT's foundations, its modular core incorporates both classical and contemporary references from cognitive sciences, interface engineering, and interactive systems, articulating perceptual, affective, and functional modeling based on advanced principles of agent–technology interaction.

By operationalizing the framework's twelve integrated dimensions, the SGUI enables data extraction at multiple levels of complexity and interrelation, converting interactional phenomena that are difficult to measure into precise, comparable, and technically robust metrics. Its analytical logic supports applications in diverse contexts, from the evaluation of products and systems to the design of new devices and interactive architectures, while preserving scientific integrity and diagnostic adaptability as guiding axes.

The development of SGUI also aligns with the historical critique of traditional metric limitations. Gross & al. (1982) proposed, in software engineering, a complexity model aimed at quality prediction and test prioritization, structured on the correlation between formal attributes and potential production failures. In the interaction domain, Lindquist (1985) introduced specific metrics to assess the semantic and procedural complexity of dialogic structures, while warning of the hybrid nature of interfaces, constructed by both user and system actions, which challenges the direct application of conventional metrics.

In the field of usability, Elmaoun, Fujihara, & Boyle (1991) emphasized the inevitable incorporation of subjective criteria in assessments, due to the direct interference of human perception. McGee (2003) deepened this critique by arguing that usability is a multifaceted perceptual construct with no physical equivalent, rendering ordinal scales such as Likert problematic. In response, he proposed magnitude estimation as an alternative for measuring phenomena derived from multidimensional stimuli, such as interfaces. Consistently, McGee (2004) reinforces that questionnaires like SUS or SUMI are restrictive in scope and that isolated objective metrics do not provide a systemic view of usability, nor do they allow precise comparability between components.

The SGUI emerges as a response to this fragmented landscape. By integrating technical rigor, modular modeling, and intelligent visual systems, it establishes a new standard of analysis in interaction engineering. Its ability to measure, classify, and contrast elements based on multifactorial criteria offers engineers, analysts, and usability scientists an unprecedented tool in both precision and scope. Its calculation logic is based on the relative frequency of elements in each dimension, ensuring comparability and transparency.

The SGUI's interdimensional structure, along with its synergy with chromatic scales derived from SCDMIC, enables the identification of both microphenomena and recurring patterns of interactional complexity, allowing for precise diagnostics and guiding reengineering processes and technological innovation (Tables 1 through 12). The system not only expands the analytical capacity of FCIA-OT but also establishes a new reference for future modular evaluation architectures in contexts of high interactive complexity.

The technical scores of the SGUI's twelve dimensions were developed from a robust inferential base, involving synthetic analysis of real cases and detailed operational mappings (see Chapters 1 and 2). Each dimensional vector was designed to accurately reflect distinct levels of performance, maturity, and contextual adequacy, ensuring internal consistency and diagnostic reliability within the model. The definition of percentage ranges and maturity levels follows a modular structure, allowing for the comparison and monitoring of results across different analytical scales.

The use of chromatic encoding as a visual resource contributes to the immediate clarity of diagnostics, enhancing SGUI's ability to deliver precise and accessible technical assessments, regardless of the profile of the agent, object, or system being analyzed. The following section presents the SGUI dimensions in detail, including their operational definitions, calculation criteria, and interpretation of the respective scores.

2.1.1 Knowledge/Experience Dimension (CEX)

The Knowledge/Experience Dimension (Conhecimentos/Experiência – CEX) measures the cognitive complexity and technical proficiency required for the efficient operation of the evaluated object (Table 1). It functions as a parameter for interpretive calibration, indicating the degree of technological maturity based on the compatibility between the agent's capabilities and the demands imposed by the system. The lower the level of experience needed to achieve high performance, the higher the functional maturity of the technology.

The score is calculated based on three objective criteria: success rate, execution time in comparison to experts, and frequency of reported difficulties. The scores follow an ascending order of technical proficiency and allow for the percentage-based identification of the level of operational criticality involved. High scores, such as 99%, do not indicate failure but evaluator excellence. The value of 100% is reserved for the developer or manufacturer, as it expresses full mastery of the technological structure. In this context, the SCDMIC's chromatic encoding indicates the maximum level of technical demand, not the occurrence of error.

TABLE 1: DEFINITION OF THE STANDARD SCORE FOR KNOWLEDGE AND EXPERIENCE (CEX)

Knowledge/ Experience Levels	Definitions	1	2	3
Beginner	1. Completes up to ≤50% of basic tasks without supervision. 2. Execution time: ≥50% slower than experienced agents. 3. Reported difficulties: ≥70%.	≤50%	≥50%	≥70%
Basic Operator	1. Completes ≥60% of basic tasks successfully. 2. Execution time: ≥30% and <50% slower than experienced agents. 3. Reported difficulties: ≥40% and <70%.	≥60%	≥30% and <50%	≥40% and <70%
Functional Agent	1. Completes ≥70% of tasks successfully. 2. Execution time: ≥20% and <30% slower than experienced agents. 3. Reported difficulties: ≥20% and <40%.	≥70%	≥20% and <30%	≥20% and <40%
Operational Technician	1. Completes ≥80% of tasks successfully. 2. Execution time: ≥10% and <20% slower than experienced agents. 3. Reported difficulties: ≥10% and <20%.	≥80%	≥10% and <20%	≥10% and <20%
Advanced Technician I	1. Completes ≥85% of tasks successfully. 2. Execution time: ≥5% and <10% slower than experienced agents. 3. Reported difficulties: ≥5% and <10%.	≥85%	≥5% and <10%	≥5% and <10%
Advanced Technician II	1. Completes ≥90% of tasks successfully. 2. Execution time: <5% slower than experienced agents. 3. Reported difficulties: <5%.	≥90%	<5%	<5%
Integration Specialist	1. Completes ≥95% of tasks successfully. 2. Execution time: on par with most experienced agents. 3. Reported difficulties: <5%.	≥95%	0%	<5%
Technological Architecture Specialist	1. Completes ≥98% of tasks successfully. 2. Execution time: 0% slower, equal to most experienced agents. 3. Reported difficulties: <3%.	≥98%	0%	<3%
Systemic Professional	1. Completes ≥99% of tasks successfully. 2. Execution time: 0%, equal to the best in the field. 3. Reported difficulties: <1%.	≥99%	0%	<1%
Strategic Level / Developer	1. Completes 100% of tasks with excellence. 2. Execution time: 0%, fully optimized with no room for improvement. 3. Reported difficulties: 0%.	100%	0%	0%

Column headers: (1) Success Rate (%); (2) Execution Time (%); (3) Reported Difficulties (%). The CEX score presents ten progressive proficiency levels based on objective criteria of performance, execution time, and difficulty, enabling inference of technological maturity and operational criticality according to the agent's profile.

Source: Author.

2.1.2 Affordance Dimension (AFF)

The Affordance Dimension (Dimensão Affordance – AFF) evaluates perceptual clarity, implicit functionality, and the congruence between form and purpose in the elements that compose the technological object. This is a critical axis in the analysis of agent–technology interaction, as it concerns the artifact's capacity to signal, induce, or allow actions consistent with its intended function. The structure of this dimension comprises two complementary analytical blocks: Conventional Affordance (Table 2) and Conditional Affordance (Table 2.1).

Conventional Affordance is assessed based on recognition rate, clarity of use, and the need for prior learning. High values indicate that the function is readily recognized and operated without ambiguity, reinforcing usability robustness and design maturity. Critical scores, such as those observed in the levels of Uninterpreted Affordance, point to structural failures in the functional communication of the object, directly compromising interaction and increasing the error rate.

Conditional Affordance, in turn, encompasses functionalities that emerge through practical use and are not necessarily foreseen in the original design. This category unfolds into two types: Emergent and Finalistic. Emergent affordance captures the progressive activation of actions not initially anticipated but functionally valid; whereas finalistic affordance measures the correspondence between the agent's intention, practical execution, and functional outcome. Both are evaluated using percentage-based ranges that qualify stability, predictability, and adaptability of use.

TABLE 2: DEFINITION OF THE STANDARD SCORE FOR AFFORDANCE (AFF)

Types of Affordance	Definitions	1	2	3
Consolidated	1. The object's message is clear and widely recognized, without ambiguity (≥95%). 2. No significant margin for error or incorrect actions (≤5%). 3. No relevant need for learning (≤5%).	≥95%	≤5%	≤5%
Perceptible	1. The message is clear but may require attention (≥90% and <95%). 2. Small margin of error due to direct interpretation (≤10%). 3. Low need for learning (≤10%).	≥90% and <95%	≤10%	≤10%
Interpreted	1. The message requires logical inference or prior association (≥70% and <90%). 2. Moderate margin for error (≤20%). 3. Intermediate learning required (≤20%).	≥70% and <90%	≤20%	≤20%
Requires Additional Information	1. The message depends on external information to be understood (≥50% and <70%). 2. Significant error risk without training (≤40%). 3. Moderate learning required (≤40%).	≥50% and <70%	≤40%	≤40%
Positive Inductive	1. The message is ambiguous or dual but can be learned over time and through context (≥30% and <50%). 2. Moderate error risk (≤50%). 3. High learning requirement (≤50%).	≥30% and <50%	≤50%	≤50%
Dual Interpretation	1. The message is ambiguous and may lead to multiple interpretations (≥10% and <30%). 2. High risk of error (≤70%). 3. High learning requirement (≤70%).	≥10% and <30%	≤70%	≤70%
Negative Inductive	1. The message is inconsistent or confusing, inducing error (≥5% and <10%). 2. Extreme error risk or undesired actions (≤90%). 3. Very high learning requirement (≤90%).	≥5% and <10%	≤90%	≤90%
Uninterpreted	1. The object does not transmit a meaningful message, rendering its use non-operational (<5%). 2. Maximum error risk (>90%). 3. Critical learning requirement (>90%).	<5%	>90%	>90%

Column headers: (1) Recognizability (%); (2) Error Risk (%); (3) Learning Requirement (%). The AFF score establishes percentage-based criteria applicable to conventional affordance, organized into eight gradual levels. Each level combines objective indicators related to perceptual clarity of function, operational error risk, and the need for prior learning. The scale enables diagnosis of the functional maturity of evaluated elements and supports inference regarding the consistency between form, function, and the agent's expected comprehension. Higher levels indicate communicative robustness and a low degree of functional ambiguity; critical levels reveal structural perceptual failures.

Source: Author.

In these conditional categories, the SGUI adopts a systemic conditional model, applying interdimensional rules to assign scores. The system employs an auxiliary chromatic code (blue) in visualizations and reports to indicate that the score results from integrations across multiple dimensions. This code is not static: it is automatically converted into one of the four main colors of the SCDMIC (green, yellow, orange, red, and the conditional blue), according to the final score range inherited from the related dimensions. This architecture ensures logical traceability, interpretive consistency, and methodological integrity in the visualization of the system's analytical data (Table 2.1).

The AFF dimension provides objective and interpretive input essential for validating design solutions, diagnosing usability failures, and guiding technical decisions in real-world use contexts. Its implementation within the SGUI guarantees an advanced level of diagnostic sensitivity, particularly in scenarios involving functional ambiguity, progressive learning, and cognitive adaptation by the agent.

TABLE 2.1: DEFINITION OF THE STANDARD SCORE FOR CONDITIONAL AFFORDANCE (AFF)

Types of Affordance	Definitions	1	2	3	4	5
Emergent	1. (0%): Not applicable. No valid emergent affordance is observed, either due to the absence of recurring practical use or complete disconnection from the artifact's functional context. 2. (>0% ≤30%): The affordance is not designed, but weak signs of functional manifestation appear, perceptible only through intense and highly contextualized use. High error potential; extreme dependence on agent adaptation. 3. (>30% and ≤50%): The emergent affordance begins to manifest with some practical consistency but remains unstable or highly dependent on repetition and context. Learning is still slow. 4. (>50% and ≤80%): A clear functional manifestation of the affordance is observed, with significant agent adaptation. The learning curve stabilizes, and usability becomes predictable. 5. (>80%): Fully validated and functional emergent affordance. Though not originally designed, it operates with stability and efficiency in real-world contexts. Learning becomes organic.	0%	>0% ≤30%	>30% and ≤50%	>50% and ≤80%	>80%

Finalistic	1. (0%): Not applicable. The agent's action did not produce functionally valid outcomes or lacked a clearly defined intention to allow measurement of the intention–function link. 2. (>0% ≤30%): The function is activated but does not achieve the intended final purpose. There may be result deviation, ambiguous understanding, or incorrect execution. 3. (>30% and ≤50%): The action partially fulfills the intended function, but operational failures, inconsistencies, or gaps remain in the intention–action–result correspondence. (Heat map: Orange). 4. (>50% and ≤80%): The action leads to a functionally appropriate result in most cases. The relationship between the activated function and the defined purpose is clear and measurable. 5. (>80%): The intended outcome is fully achieved with efficiency. The correspondence between the agent's intention, the executed action, and the obtained result confirms the functional success of the interaction.	0%	>0% ≤30%	>30% and ≤50%	>50% and ≤80%	>80%

Column headers: (1) Score Level 1 (%); (2) Score Level 2 (%); (3) Score Level 3 (%); (4) Score Level 4 (%); (5) Score Level 5 (%). The AFF score establishes the percentage-based criteria applicable to conditional affordances, structured in two types: Emergent and Finalistic. In the Emergent type, the score reflects the degree of progressive functional manifestation of previously unplanned but viable uses, signaling the object's adaptability. In the Finalistic type, it assesses the congruence between the agent's intention, the practical execution, and the fulfillment of the functional purpose. The percentage ranges qualify the maturity of use, semantic–pragmatic alignment, and operational stability of emerging interaction patterns.

Source: Author.

2.1.3 Perception Dimension (PRC)

The Perception Dimension (Dimensão Percepção – PRC) assesses the perceptual quality of the affordance based on clarity, complexity, and the subjective response of agents upon encountering the object. This is a critical axis within the SGUI, as it marks the initial moment of interaction, when the bond between the agent and the system's functional proposition is established (Table 3).

Scores within this dimension are defined based on three main criteria: the rate of agents who correctly perceive the proposed functionality, the perceived complexity in interpreting the affordance, and the subjective experience reported during the first contact. The greater the immediate perception, the lower the perceived complexity, and the more positive the experience, the higher the assigned score.

The classification of perception types, Instructive, Argumentative, Reactive, Inquisitive, and Exploratory, enables the qualification of the cognitive load required and the level of design clarity. Instructive perception reflects a scenario of high clarity, low complexity, and predominantly positive response, indicating a mature system. Exploratory perception reflects low immediate comprehension, high complexity, and frustrating user experiences, signaling perceptual criticality and failure in functional signaling.

TABLE 3: DEFINITION OF THE STANDARD SCORE FOR PERCEPTION (PRC)

Types of Perception	Definitions	1	2	3
Instructive	1. The system is highly intuitive; ≥95% of agents perceive the affordance immediately and clearly. 2. Minimal complexity, ≤10%. 3. Positive experience; ≥90% of agents interact without difficulty.	≥95%	≤10%	≥90%
Argumentative	1. The affordance is perceived after reflective analysis; ≥70% and <95% of agents identify its function after brief interpretation. 2. Moderate complexity, ≤30%. 3. Adaptable experience; ≥70% of agents comprehend after initial interaction.	≥70% and <95%	≤30%	≥70%
Reactive	1. The affordance is only perceived after ongoing interaction; ≥50% and <70% of agents recognize its function after repeated interaction. 2. Significant complexity, ≤50%. 3. Progressive experience; ≥50% of agents report improvement through practice.	≥50% and <70%	≤50%	≥50%
Inquisitive	1. Initial difficulty in perceiving the affordance; ≥30% and <50% of agents identify its function after substantial learning. 2. High complexity, ≤70%. 3. Limited experience; ≥30% of agents report initial dissatisfaction, but adaptation occurs with effort.	≥30% and <50%	≤70%	≥30%
Exploratory	1. The affordance is not perceived immediately; <30% of agents understand its function, requiring exploratory effort. 2. Extreme complexity, >70%. 3. Frustrating experience; <30% of agents consider the system comprehensible.	<30%	>70%	<30%

Column headers: (1) Affordance Clarity (%); (2) Interpretation Complexity (%); (3) Subjective Experience (%). The PRC score establishes the percentage-based criteria applicable to perceptual types, based on affordance clarity, interpretive complexity, and agents' initial subjective experience. The categories range from highly instructive and intuitive configurations to exploratory scenarios marked by functional ambiguity, cognitive effort, and frustration. The percentage score enables assessment of perceptual efficacy and the design intelligibility of the evaluated object.

Source: Author.

2.1.4 Affectivity Dimension (AFV)

The Affectivity Dimension (Dimensão Afetividade – AFV) captures the agent's emotional response during interaction with the technological object, analyzing affective states that vary in valence, intensity, and duration (Table 4). This dimension considers affectivity as a critical component of the user experience, directly influencing the continuity of interaction, perception of quality, and systemic trust. Within the SGUI, this dimension applies a scale that quantifies, in percentage terms, both positive responses, such as comfort, pleasure, engagement, and empathy, and negative states, such as anxiety, frustration, and withdrawal. The gradation of values enables the measurement of emotional fluctuation, affective stability, and the system's sensitivity in inducing, sustaining, or mitigating emotional responses, even in contexts of high functional complexity.

TABLE 4: DEFINITION OF THE STANDARD SCORE FOR AFFECTIVITY (AFV)

Types of Affectivity	Definitions	1	2	3
Emotional Comfort	1. Perceived comfort level during interaction: Comfort perception rate (≥90%). 2. Probability of perceived discomfort (≤10%). 3. Positive impact on overall emotional experience (≥85%).	≥90%	≤10%	≥85%
Pleasure/ Satisfaction	1. Degree of perceived pleasure or satisfaction during interaction (≥85%). 2. Areas for improvement identified during the experience (≤15%). 3. Overall impact of pleasure/satisfaction on interaction (≥80%).	≥85%	≤15%	≥80%
Curiosity	1. Desire to explore new interface elements: Exploration rate (≥80%). 2. Elements left unexplored (≤20%). 3. Impact on continued interaction motivated by curiosity (≥75%).	≥80%	≤20%	≥75%
Emotional Engagement	1. Degree of perceived emotional involvement during interaction (≥75%). 2. Probability of emotional disinterest (≤25%). 3. Contribution to maintaining emotional interest (≥70%).	≥75%	≤25%	≥70%
Immersion	1. Degree of total involvement in the experience (≥70%). 2. Elements perceived as immersion barriers (≤30%). 3. Impact on perception of full engagement (≥65%).	≥70%	≤30%	≥65%
Trust	1. Confidence level while interacting with the interface (≥65%). 2. Probability of perceived insecurity (≤35%). 3. Trust contribution to overall usability (≥60%).	≥65%	≤35%	≥60%
Surprise	1. Positive reaction to unexpected interface elements (≥60%). 2. Probability of unexpected elements causing frustration (≤40%). 3. Impact of surprise on the experience (≥55%).	≥60%	≤40%	≥55%
Relief	1. Degree of relief after overcoming difficulties (≥55%). 2. Elements that help prevent additional frustration (≤45%). 3. Impact of relief on overall usage perception (≥50%).	≥55%	≤45%	≥50%

Empathy	1. Level of emotional connection promoted by the system (≥50%). 2. Elements that hinder emotional connection (≤50%). 3. Empathy's impact on the overall emotional experience (≥45%).	≥50%	≤50%	≥45%
Neutrality	1. Perceived emotional neutrality (0%). 2. Probability of elements generating relevant emotional impact (balanced positive/negative) (50%). 3. Contribution to emotional stability (0%).	0%	≥50%	0%
Anxiety	1. Degree of anxiety experienced during interaction (≥25%). 2. Elements generating discomfort or apprehension (≤75%). 3. Anxiety's impact on overall experience (≥20%).	≥25%	≤75%	≥20%
Tolerated Frustration	1. Acceptable level of frustration due to perceived value (≥15%). 2. Probability of frustration compromising the experience (≤85%). 3. Contribution to continued interaction despite difficulties (≥10%).	≥15%	≤85%	≥10%
Frustration	1. Level of frustration experienced during interaction (≥5%). 2. Elements amplifying discomfort and dissatisfaction (≤95%). 3. Impact of frustration on abandonment of use (≥5%).	≥5%	≤95%	≥5%

Column headers: (1) Perceived Frequency (%); (2) Oppositional Tolerance (%); (3) Emotional Weight (%). The AFV score establishes the percentage-based criteria applicable to affective responses triggered during agent–technology interaction, classified according to emotional valence, subjective intensity, and impact on the user experience. The scale spans from positive affects, such as comfort, pleasure, and empathy, to critical states like anxiety and frustration. These percentages reflect perception frequency, operational tolerance, and emotional load, allowing for inferences on affective stability, emotional engagement, and experiential resilience of the system evaluated. This is an essential dimension for diagnostics on acceptability, engagement, and affective dissonance in real-world usage contexts.

Source: Author.

2.1.5 Satisfaction Dimension (STSF)

The Satisfaction Dimension (Dimensão Satisfação – STSF) assesses the agent's overall perception of the technological object, expressing gradual levels of contentment or dissatisfaction (Table 5). The STSF score operationalizes percentage-based criteria that reflect perceived quality, the identified need for improvements, and the impact of this assessment on the overall experience. The categories range from extreme satisfaction, indicating an exemplary experience and no need for adjustments, to extreme dissatisfaction, which points to severe negative experiences and critical demands for improvement. This metric provides a direct indicator of acceptance and of the functional and emotional alignment between the agent and the evaluated system, serving as a key parameter for design adjustments and interaction optimization.

TABLE 5: DEFINITION OF THE STANDARD SCORE FOR SATISFACTION (STSF)

Types of Satisfaction	Definitions	1	2	3
Extremely Satisfied	1. The agent is completely satisfied with all aspects of the technological object. 2. Sees no need for improvements. 3. Exemplary experience.	≥95%	≤5%	≥95%
Very Satisfied	1. The agent is very satisfied. 2. Small areas could be improved. 3. Very positive experience.	≥85% and <95%	≤15%	≥85% and <95%
Quite Satisfied	1. The agent is generally satisfied. 2. Improvements are needed for greater contentment. 3. Generally positive experience.	≥70% and <85%	≤30%	≥70% and <85%
Satisfied	1. The agent is satisfied. 2. Several areas require improvement. 3. Partially positive experience.	≥60% and <70%	≤40%	≥60% and <70%
Moderately Satisfied	1. The agent is reasonably satisfied. 2. Identifies multiple improvement areas. 3. Neutral experience with negative aspects.	≥50% and <60%	≤50%	≥50% and <60%
Neutral	1. The agent has a neutral perception. 2. The object partially meets expectations. 3. Balanced experience between positive and negative.	50%	≥50%	50%
Dissatisfied	1. The agent is dissatisfied. 2. Significant issues found. 3. Generally negative experience.	≥40% and <50%	≥60%	≥40% and <50%
Quite Dissatisfied	1. The agent is quite dissatisfied. 2. The object needs substantial improvements. 3. Predominantly negative experience.	≥30% and <40%	≥70%	≥30% and <40%
Very Dissatisfied	1. The agent is very dissatisfied. 2. Multiple problematic areas identified. 3. Clearly negative experience.	≥20% and <30%	≥80%	≥20% and <30%
Extremely Dissatisfied	1. The agent is completely dissatisfied. 2. The object fails to meet expectations. 3. Severely negative and demotivating experience.	<20%	>80%	<20%

Column headers: (1) Perceived Quality (%); (2) Improvement Needs (%); (3) Experience Impact (%). The STSF score establishes percentage-based criteria applicable to the agent's satisfaction with the technological object. It presents a progressive scale of satisfaction levels based on objective indicators that assess perceived quality, the number of improvements required, and the overall impact on the user experience. The classification ranges from extreme satisfaction, characterized by a positive experience and no need for adjustments, to extreme dissatisfaction, indicating severe dissatisfaction and critical improvement demands. This scale enables a detailed evaluation of the alignment between the agent's expectations and the system's performance.

Source: Author.

2.1.6 Effectiveness Dimension (EFT)

The Effectiveness Dimension (Dimensão Efetividade – EFT)) assesses the technological object's ability to ensure the successful execution of proposed tasks, considering both objective and subjective aspects of interaction (Table 6). The EFT score quantifies, in percentage terms, the success rate in task performance, the ease of learning as reflected in the adaptation time, and the perceived clarity during use. This metric integrates quantitative and qualitative data to provide a comprehensive view of the system's functional performance, serving as a key input for accurate diagnostics and improvement strategies. The evaluation encompasses high levels of effectiveness, marked by high success rates and low learning curves, as well as critical levels that reveal significant failures in usability and user satisfaction.

TABLE 6: DEFINITION OF THE STANDARD SCORE FOR EFFECTIVENESS (EFT)

Types of Effectiveness	Definitions	1	2	3
Effective	1. Task success rate ≥95%. 2. Minimal learning curve (adaptation time ≤5% of the typical usage cycle). 3. Subjective clarity assessment: ≥90% of agents consider the system clear and efficient.	≥95%	≤5%	≥90%
Considerable	1. Task success rate between ≥70% and <95%. 2. Noticeable but manageable learning curve (adaptation time >5% and ≤15%). 3. Subjective clarity assessment: ≥70% and <90% of agents find the system understandable after first contact.	≥70% and <95%	>5% and ≤15%	≥70% and <90%
Reasonable	1. Task success rate between ≥40% and <70%. 2. Moderate learning curve, with noticeable error rate (>15% and ≤30%). 3. Subjective clarity assessment: ≥50% and <70% of agents report significant difficulty or moderate frustration.	≥40% and <70%	>15% and ≤30%	≥50% and <70%
Unreasonable	1. Task success rate <40%. 2. High error rate (>30%). 3. Subjective clarity assessment: <50% of agents consider the system usable or understandable, with predominant reports of frustration, abandonment, or dissatisfaction.	<40%	>30%	<50%

Column headers: (1) Task Success Rate (%); (2) Adaptation Curve (%); (3) Subjective Clarity Assessment (%). The EFT score establishes the percentage-based criteria applicable to the effectiveness of the technological object. The scale classifies levels of functional performance based on task success rate, learning curve, and subjective clarity and efficiency assessments. These levels range from high effectiveness, marked by consistent performance and a low learning curve, to insufficient effectiveness, characterized by low success rates, high error incidence, and negative user perception. This metric guides the analysis of the system's ability to support the efficient and understandable execution of intended operations.

Source: Author.

2.1.7 Artifact Object Requirements Dimension (RQA)

The Object Requirements Dimension (Dimensão Requisitos de Objetos – RQO) and the Artifact Object Requirements Dimension (Dimensão Requisitos de Artefatos de Objetos – RQA) articulate to provide a comprehensive analytical approach to complex constructs, including technological and non-technological artifacts. Within the scope of this dimension, the focus lies on RQA, which is responsible for measuring the compliance and performance of the physical and logical components that comprise the evaluated object (Table 7). The RQA Score quantifies the structural and functional adequacy of the artifacts, identifying everything from critical failures that compromise practical applicability to high levels of integration and compliance.

This progressive evaluation scale incorporates rigorous technical criteria, capable of distinguishing artifacts that require corrective intervention from those exhibiting optimized performance and full compatibility with system requirements. The associated color coding facilitates visual interpretation of the results, guiding strategic decisions in engineering and technological maintenance.

TABLE 7: DEFINITION OF THE STANDARD SCORE FOR ARTIFACT OBJECT REQUIREMENTS (RQA)

Artifact Object Requirements	Definitions	1	2	3	4	5
Artefato	1. (0%): Artifacts that do not receive classification. This condition may occur due to the absence of a direct relationship with the analysis, the agent's decision not to assign a score to the artifact, or the application of a "not applicable" logic. (Heatmap: Orange). 2. (-5 to -1): Artifacts present severe structural problems, lack of compatibility, or significant failures that completely compromise their practical applicability (≤30%). (Heatmap: Red). 3. (1 to 2): Artifacts with insufficient performance and moderate failures that significantly limit functionality. Moderate failures that restrict practical applicability (>30% and ≤50%). (Heatmap: Orange). 4. (3 to 6): Artifacts that present acceptable performance, albeit with limitations, covering most average practical application cases (>50% and ≤80%). (Heatmap: Yellow). 5. (7 to 10): Artifacts with high performance, excellent integration, and full compliance with established criteria (>80%). (Heatmap: Green).	0%	>0% and ≤30%	>30% and ≤50%	>50% and ≤80%	>80%

Column headers: (1) Score Level 1 (%); (2) Score Level 2 (%); (3) Score Level 3 (%); (4) Score Level 4 (%); (5) Score Level 5 (%). The RQA Score establishes the percentage criteria applicable to the compliance and performance of Artifact Object Requirements. The scale classifies artifacts into five progressive levels, ranging from lack of application or critical failures to excellent performance and full integration. This classification allows the assessment of the structural and functional robustness of technological components, supporting technical diagnoses and improvement actions. The associated color coding reinforces the visualization of artifact criticality and maturity levels within the FCIA-OT context.

Source: Author.

2.1.8 Error Severity Dimension (GVE)

The Severity Dimension (Dimensão Gravidade de Erros – GVE) evaluates the severity of errors observed during interaction with the technological object, considering both functional and perceptual impact. Errors are categorized into levels ranging from total absence of failures to critical occurrences that compromise the system's usability and reliability (Table 8). The GVE Score is calculated based on three objective criteria: the impact rate of the errors, the frequency of reported failures, and the agents' perceived trust in the system. This classification enables precise identification of error criticality levels, guiding corrective actions and mitigation strategies to enhance system robustness and user experience.

TABLE 8: DEFINITION OF THE STANDARD SCORE FOR ERROR SEVERITY (GVE)

Error Severity Types	Definitions	1	2	3
No Errors	1. Impact rate: 0%. 2. No errors identified (0%). All functionalities operate as expected, without interruptions or failures. 3. Perceived trust: 100% of agents consider the system fully reliable.	0%	0%	100%
Insignificant	1. Impact rate: >0% and ≤5%. 2. Up to 5% of agents report minor issues that do not perceptibly affect usability or functionality. 3. Perceived trust: ≥95% of agents maintain confidence in the system.	>0% and ≤5%	≤5%	≥95%
Minor	1. Impact rate: >5% and ≤15%. 2. Between 5% and 15% of agents report errors that minimally affect usability but do not prevent main tasks. 3. Perceived trust: ≥85% of agents trust the system despite the errors.	>5% and ≤15%	≤15%	≥85%
Moderate	1. Impact rate: >15% and ≤30%. 2. Between 15% and 30% of agents are affected by errors causing frustration and difficulties with main tasks. 3. Perceived trust: ≥65% of agents still consider the system acceptable.	>15% and ≤30%	≤30%	≥65%
Severe	1. Impact rate: >30% and ≤50%. 2. Between 30% and 50% of agents are affected by significant errors that compromise important functions. 3. Perceived trust: ≥40% of agents still trust the system.	>30% and ≤50%	≤50%	≥40%
Critical	1. Impact rate: >50%. 2. More than 50% of agents report critical failures that prevent use or cause data loss. 3. Perceived trust: <40% of agents still consider the system usable.	>50%	>50%	<40%

Column headers: (1) Error Impact Rate (%); (2) Reported Failure Frequency (%); (3) Perceived Trust (%). The GVE Score establishes percentage-based criteria for evaluating the severity of errors detected during the use of a technological object. The progressive scale classifies impact and trust levels, ranging from complete absence of errors with reliable operation to critical failures that severely compromise functionality and reduce user confidence. This dimension is essential for diagnosing system stability and safety, enabling effective prioritization in problem resolution.

Source: Author.

2.1.9 Risk Degree Dimension (GSR)

The Risk Degree Dimension (Dimensão Graus de Risco – GSR) measures the degrees of risk associated with the use of the technological object, classifying the potential impact of failures and problems reported by agents. This dimension is based on three objective criteria: the impact rate of identified risks, the frequency of adverse occurrences, and the agents' perceived safety (Table 9). The evaluation spans from the complete absence of risk to very high-risk conditions capable of negatively affecting trust, operational safety, and the continuity of system use. The GSR Score provides input for the prioritization and efficient management of risks inherent to agent–technology interaction.

TABLE 9: DEFINITION OF THE STANDARD SCORE FOR RISK DEGREE (GSR)

Types of Risk	Definitions	1	2	3
No Risk	1. Impact rate: 0%. 2. No record of failures or dissatisfaction by agents at any stage (0%). 3. Perceived safety: ≥95% of agents consider the system completely safe and reliable.	0%	0%	≥95%
Very Low	1. Impact rate: >0% and ≤5%. 2. Minor inconveniences are reported, with negligible impact (<5%). 3. Perceived safety: ≥85% of agents consider the system reliable despite minor issues.	>0% and ≤5%	<5%	≥85%
Low	1. Impact rate: >5% and ≤15%. 2. Reports of mild discomfort or occasional technical issues (≥10%). 3. Perceived safety: ≥70% of agents report moderate confidence, with some need for adjustment.	>5% and ≤15%	≥10%	≥70%
Moderate	1. Impact rate: >15% and ≤30%. 2. ≥20% of agents report moderate difficulties or relevant risks. 3. Perceived safety: ≥50% of agents still consider the system reliable, though relevant concerns are noted.	>15% and ≤30%	≥20%	≥50%
High	1. Impact rate: >30% and ≤50%. 2. ≥40% of agents report critical impacts or high likelihood of errors. 3. Perceived safety: ≥30% of agents still trust the system, but the risk is considered high.	>30% and ≤50%	≥40%	≥30%
Very High	1. Impact rate: >50%. 2. ≥60% of agents report severe failures, abandonment, or catastrophic events. 3. Perceived safety: <30% of agents trust the system, reporting extreme risk.	>50%	≥60%	<30%

Column headers: (1) Risk Impact Rate (%); (2) Reported Occurrence Frequency (%); (3) Perceived Safety (%). The GSR Score defines the percentage-based criteria for evaluating risk levels in the context of interaction with technological objects. The progressive scale reflects the range from complete absence of risk, marked by safety and reliability, to increasingly severe levels of risk, culminating in very high-risk situations that compromise safety, stability, and the agent's experience. This dimension is essential for preventive and risk mitigation strategies, promoting safety and resilience in evaluated systems.

Source: Author.

2.1.10 Attribute Dimension (ATB)

The Attribute Dimension (Dimensão Atributos – ATB) defines the applicable percentage-based criteria used to assess key aspects related to the functional and qualitative characteristics of the technological object. This dimension encompasses multiple core attributes that influence the agent's experience (Table 10).

Each attribute is classified according to percentage levels that reflect its practical performance, operational impact, and agents' perception during interaction. The scale ranges from non-applicable conditions, through critical or limited levels, up to optimal levels of performance and suitability. The use of chromatic heatmaps (ranging from red to green) enhances the visualization of each attribute's criticality and maturity, supporting the identification of priority areas for improvement and validation..

TABLE 10: DEFINITION OF THE STANDARD SCORE FOR ATTRIBUTES (ATB)

Attribute Types	Definitions	1	2	3	4	5
Usability	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Extremely difficult to understand and requires high effort to use. Agents report severe frustration or total inability to operate (≤20%). (Heatmap: Red).3. (1 to 2): Limited understanding, possible only after significant effort. Indicates non-intuitive use and need for support (>20% and ≤50%). (Heatmap: Orange).4. (3 to 6): Moderate usability, with manageable effort and noticeable learning curve (>50% and ≤75%). (Heatmap: Yellow).5. (7 to 10): Intuitive and efficient use, fast learning, and smooth operation (>75%). (Heatmap: Green).	0%	>0% and ≤20%	>20% and ≤50%	>50% and ≤75%	>75%
Usefulness	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Feature or function has no practical value or relevance, causing frustration or uselessness in the context (≤50%). (Heatmap: Red).3. (1 to 2): Limited function with restricted application and low practical impact. Utility is low, but present (>50% and ≤75%). (Heatmap: Orange).4. (3 to 6): Useful and applicable function with moderate benefits, though not ideal (>75% and ≤90%). (Heatmap: Yellow).5. (7 to 10): Highly relevant, essential, and widely applicable function, providing clear and significant benefits (>90%). (Heatmap: Green).	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%

Efficiency	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Extremely inefficient operation, with average time ≤70% of the ideal, causing significant delays or resource waste. (Heatmap: Red).3. (1 to 2): Low efficiency, with average time >70% and ≤80% of the ideal, resulting in slow but functional performance. (Heatmap: Orange).4. (3 to 6): Moderate efficiency, with average time >80% and ≤90% of the ideal, delivering adequate performance with some limitations. (Heatmap: Yellow).5. (7 to 10): High efficiency, with average time >90% of the ideal, ensuring fast performance and optimized resource use. (Heatmap: Green).	0%	>0% and ≤70%	>70% and ≤80%	>80% and ≤90%	>90%
Functionality	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): The functionality shows severe failures or is completely absent, compromising the primary purpose of the object or system (≤50%). (Heatmap: Red).3. (1 to 2): Basic functionality, but with significant limitations. Operates minimally, but does not meet use expectations (>50% and ≤75%). (Heatmap: Orange).4. (3 to 6): Moderate and reliable functionality, with some limitations, but capable of meeting essential requirements (>75% and ≤90%). (Heatmap: Yellow).5. (7 to 10): Full and robust functionality, with consistent performance fully aligned with the requirements (>90%). (Heatmap: Green).	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%
Accessibility	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Extremely low or nonexistent accessibility, with significant barriers for different user profiles and contexts (≤25%). (Heatmap: Red).3. (1 to 2): Limited accessibility, available only to some profiles and contexts. Requires extra effort or specific adaptations (>25% and ≤55%). (Heatmap: Orange).4. (3 to 6): Moderate accessibility, with acceptable usability and support levels, though some restrictions remain for certain profiles and contexts (>55% and ≤80%). (Heatmap: Yellow).5. (7 to 10): Full accessibility, offering inclusive and effective support for diverse profiles and contexts (>80%). (Heatmap: Green).	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤80%	>80%
Flexibility	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Extreme rigidity, with no ability to adapt to different contexts or changing conditions (≤50%). (Heatmap: Red).3. (1 to 2): Limited flexibility, allowing minimal adaptations, but still dependent on specific configurations or restrictions (>50% and ≤75%). (Heatmap: Orange).4. (3 to 6): Moderate flexibility, with good adaptability, although some limitations persist (>75% and ≤90%). (Heatmap: Yellow).5. (7 to 10): High flexibility, with full adaptability to various profiles, contexts, and conditions (>90%). (Heatmap: Green).	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%

Controllability	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Extremely difficult or nonexistent control, with inconsistent and unpredictable responses to agent commands (≤50%). (Heatmap: Red).3. (1 to 2): Limited control, with partial response to commands. Indicates difficulty adjusting or properly operating the object (>50% and ≤75%). (Heatmap: Orange).4. (3 to 6): Moderate controllability, with consistent responses in most operations, though perceptible restrictions remain (>75% and ≤90%). (Heatmap: Yellow).5. (7 to 10): Total and precise control, enabling detailed adjustments and reliable responses in all operations (>90%). (Heatmap: Green).	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%
Interoperability	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Total incompatibility or severe integration failures with other systems or devices. No effective data exchange or communication (≤25%). (Heatmap: Red).3. (1 to 2): Limited integration, with significant restrictions in communication or data exchange. Requires alternative solutions to interoperate properly (>25% and ≤55%). (Heatmap: Orange).4. (3 to 6): Moderate interoperability, with functional integration in specific scenarios, though limited in more complex environments (>55% and ≤80%). (Heatmap: Yellow).5. (7 to 10): Full compatibility and integration, with fluid communication and no restrictions across various systems and devices (>80%). (Heatmap: Green).	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤80%	>80%
Portability	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Extremely difficult to transport or use in different contexts. Dependent on fixed or heavy infrastructure (≤50%). (Heatmap: Red).3. (1 to 2): Limited portability, with significant restrictions for use in different locations or conditions. Requires additional preparation (>50% and ≤75%). (Heatmap: Orange).4. (3 to 6): Moderate portability, functional in various environments, but with handling or transport limitations (>75% and ≤90%). (Heatmap: Yellow).5. (7 to 10): Highly portable and adaptable, enabling efficient use across a wide range of contexts without fixed infrastructure (>90%). (Heatmap: Green).	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%

Compliance	1. (0%): Not applicable. (Heatmap: Orange).2. (-5 to -1): Does not meet established standards, regulations, or norms, potentially causing incompatibility or severe risks (≤50%). (Heatmap: Red).3. (1 to 2): Partially meets standards and regulations, with significant gaps limiting its use or acceptability (>50% and ≤75%). (Heatmap: Orange).4. (3 to 6): Moderate compliance, satisfying most normative requirements, though adjustments may be needed (>75% and ≤90%). (Heatmap: Yellow).5. (7 to 10): Fully compliant with standards, regulations, and norms, ensuring safety and acceptability (>90%). (Heatmap: Green).	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%
Stability	1. (0%): Not applicable. (Heatmap: Orange). 2. (-5 to -1): Highly unstable, with frequent failures, unpredictable behavior, and significant risk of operational compromise (≤50%). (Heatmap: Red). 3. (1 to 2): Low stability, with intermittent failures affecting reliability and performance (>50% and ≤75%). (Heatmap: Orange). 4. (3 to 6): Moderate stability, with occasional failures and limited impact on usage (>75% and ≤90%). (Heatmap: Yellow). 5. (7 to 10): Highly stable, with reliable operation and no significant failures or interruptions (>90%). (Heatmap: Green).	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%
Aesthetics	1. (0%): Not applicable. (Heatmap: Orange). 2. (-5 to -1): Inadequate or disorganized visual design, causing visual discomfort and low aesthetic acceptance (≤30%). (Heatmap: Red). 3. (1 to 2): Basic or limited aesthetics, with visual elements that fulfill their role but lack appeal or coherence (>30% and ≤60%). (Heatmap: Orange). 4. (3 to 6): Moderate visual design, acceptable, with functional and aesthetically pleasant composition (>60% and ≤85%). (Heatmap: Yellow). 5. (7 to 10): Highly attractive and coherent design, promoting a positive and engaging visual experience (>85%). (Heatmap: Green)	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
Acceptability	1. (0%): Not applicable. (Heatmap: Orange). 2. (-5 to -1): Totally unacceptable due to incompatibility with requirements, expectations, or standards (≤25%). (Heatmap: Red). 3. (1 to 2): Partially acceptable, but with significant reservations (>25% and ≤55%). (Heatmap: Orange). 4. (3 to 6): Moderate acceptability, with certain conditions or limitations (>55% and ≤80%). (Heatmap: Yellow). 5. (7 to 10): Fully acceptable and aligned with expectations (>80%). (Heatmap: Green).	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤80%	>80%

Innovation	1. (0%): Not applicable. (Heatmap: Orange). 2. (-5 to -1): Completely lacking innovation, characterized by repetition of outdated concepts (≤25%). (Heatmap: Red). 3. (1 to 2): Limited innovation, with slightly new elements but without significant impact (>25% and ≤55%). (Heatmap: Orange). 4. (3 to 6): Moderate level of innovation, with noticeable improvements (>55% and ≤80%). (Heatmap: Yellow). 5. (7 to 10): Highly innovative, introducing disruptive approaches (>80%). (Heatmap: Green).	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤80%	>80%
Simplicity	1. (0%): Not applicable. (Heatmap: Orange). 2. (-5 to -1): Extremely complex, confusing, and unnecessarily elaborate (≤25%). (Heatmap: Red). 3. (1 to 2): Partially simplified, but with significant barriers (>25% and ≤55%). (Heatmap: Orange). 4. (3 to 6): Moderately simple, with manageable effort (>55% and ≤80%). (Heatmap: Yellow). 5. (7 to 10): Highly simple and intuitive (>80%). (Heatmap: Green).	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤80%	>80%

Column headers: (1) Score Level 1 (%); (2) Score Level 2 (%); (3) Score Level 3 (%); (4) Score Level 4 (%); (5) Score Level 5 (%). The ATB Score defines the applicable percentage-based criteria for assessing the attributes of the technological object, based on progressively scaled indicators of performance, quality, and suitability. Each attribute is classified according to its operational effectiveness, ease of use, functional relevance, and acceptance by the evaluating agent. The scale ranges from non-applicable or critically deficient levels to high-performance levels, reflecting optimized usability, efficiency, and compliance. Chromatic coding enhances the visual identification of each attribute's condition, enabling precise diagnosis of areas requiring intervention as well as those demonstrating operational excellence.

Source: Author.

2.1.11 Accessibility Dimension (ACB)

The Accessibility Dimension (Dimensão Acessibilidade – ACB) defines the applicable percentage-based criteria for accessibility, subdivided into seven groups that encompass essential aspects of inclusive interaction, from textual alternatives to assistive technologies and temporary adjustments (Table 11). The ACB establishes evaluation ranges that reflect the degree of adequacy, support, and accessible functionality in each criterion, enabling the identification of barriers and progress in the adaptation of the technological object to different agent profiles and usage contexts. This systematic approach ensures precise diagnostics and effective direction for continuous improvement in inclusive usability.

TABLE 11: DEFINITION OF THE STANDARD SCORE FOR ACCESSIBILITY (ACB)

Groups	Code	Criterion Types	Definitions	1	2	3	4	5
AC1: Texts, Images, and Media	ACB01	Text Alternatives (Alt Text)	1. Not applicable.2. Extremely rigid, no descriptions provided.3. Limited descriptions, covering only a few elements.4. Good descriptions, but missing in specific cases.5. Full descriptive coverage provided.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	ACB02	Information Redundancy	1. Not applicable.2. Only one medium used for transmission.3. Two media used, but missing clear alternatives.4. Three media used, with minor gaps.5. Three media fully accessible.	0%	>0% and ≤40%	>40% and ≤65%	>65% and ≤85%	>85%
	ACB03	Interaction with Multimedia	1. Not applicable.2. No accessible controls available.3. Few controls offered, with limited accessibility.4. Accessible controls, but not in all cases.5. Full accessible control in all contexts.	0%	>0% and ≤35%	>35% and ≤60%	>60% and ≤85%	>85%
	ACB04	Multilingual Content Support	1. Not applicable.2. No support for alternative languages.3. Limited support, only for some essential terms.4. Good language support, with some missing terms.5. Full support in multiple languages.	0%	>0% and ≤40%	>40% and ≤65%	>65% and ≤85%	>85%

AC2: Navigation and Interaction	ACB05	Keyboard Navigation	1. Not applicable. 2. Navigation via keyboard is not possible, including lack of support for alternative keyboards. 3. Partial navigation using standard or alternative keyboards, but not intuitive and with frequent failures. 4. Functional navigation for standard keyboards, but with gaps in specific flows or incomplete support for alternative devices. 5. Full integration and intuitive navigation via standard and alternative keyboards, covering all expected interaction flows.	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤85%	>85%
	ACB06	Navigation Consistency	1. Not applicable. 2. Interface structure and organization are inconsistent, impairing usability. 3. Basic structure and navigation, but with frequent inconsistencies in hierarchy or layout patterns. 4. Well-organized navigation, but with occasional inconsistencies in structure or information hierarchy. 5. Organized and predictable navigation, with clear hierarchy and consistent structural patterns.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

	ACB07	Category and Filter-Based Navigation	1. Not applicable. 2. No filter-based navigation options. 3. Limited navigation, with few accessible filters. 4. Good navigation, but with gaps in complex menus. 5. Full access to organized menus and filters.	0%	>0% and ≤35%	>35% and ≤60%	>60% and ≤85%	>85%
	ACB08	Time and Interaction Control	1. Not applicable. 2. No time adjustment or pause options. 3. Limited time control, with few configurable options. 4. Good time adjustments, but with issues in specific cases. 5. Full and adjustable time control across all relevant interaction scenarios.	0%	>0% and ≤40%	>40% and ≤65%	>65% and ≤85%	>85%
AC3: Visual Design and Settings	ACB09	Color Contrast	1. Not applicable. 2. No contrast ensured. 3. Limited contrast, failing to meet all standards. 4. Good contrast, but with issues in some areas. 5. Full contrast adjusted according to accessibility standards.	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤85%	>85%
	ACB10	Font Size and Adjustability	1. Not applicable. 2. Text is non-adjustable or illegible. 3. Limited adjustments, resulting in loss of functionality. 4. Functional adjustments, but with restrictions in specific contexts. 5. Full font adjustability across use scenarios.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

	ACB11	Visibility and Legibility	1. Not applicable. 2. Fonts and spacing are inadequate. 3. Partial improvement in visibility, but issues remain. 4. Good legibility, with some limitations. 5. Full legibility for all agent profiles.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	ACB12	Accessibility Adjustments	1. Not applicable. 2. Basic accessibility features are missing. 3. Limited adjustment options available. 4. Moderate adjustments, with some flaws. 5. Complete and functional accessibility settings implemented.	0%	>0% and ≤35%	>35% and ≤60%	>60% and ≤85%	>85%
	ACB13	Adaptation to Usage Contexts	1. Not applicable. 2. No adjustments for specific conditions. 3. Basic and limited adaptations. 4. Moderate adaptations for most usage conditions. 5. Optimized adaptations for all usage contexts.	0%	>0% and ≤40%	>40% and ≤65%	>65% and ≤85%	>85%
AC4: Forms and Feedback	ACB14	Accessible Forms	1. Not applicable. 2. Forms are confusing and inaccessible. 3. Basic labels are present. 4. Clear structure with minor issues. 5. Full accessibility guaranteed.	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤85%	>85%
	ACB15	Error and Success Feedback	1. Not applicable. 2. Feedback is absent or confusing. 3. Basic and minimally helpful messages. 4. Clear messages, but with some gaps. 5. Efficient and well-implemented feedback.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

	ACB16	Clear Input Errors	1. Not applicable. 2. Errors are not explained. 3. Minimal explanations provided. 4. Useful suggestions, but incomplete. 5. Clear and fully accessible communication.	0%	>0% and ≤25%	>25% and ≤55%	>55% and ≤85%	>85%
AC5: Multimodality and Emerging Technologies	ACB17	Multimodality	1. Not applicable. 2. No multimodal support. 3. Partial support for multiple formats. 4. Moderate functionality across various formats. 5. Full multimodal compatibility.	0%	>0% and ≤35%	>35% and ≤60%	>60% and ≤85%	>85%
	ACB18	AR/VR Accessibility	1. Not applicable. 2. Interfaces not adapted. 3. Basic functionalities available. 4. Adapted functionality with flaws. 5. Advanced and functional accessibility for AR/VR environments.	0%	>0% and ≤40%	>40% and ≤65%	>65% and ≤85%	>85%
	ACB19	IoT Accessibility	1. Not applicable. 2. No accessible integration. 3. Basic integration with limitations. 4. Moderately integrated functionality. 5. Full compatibility with IoT devices.	0%	>0% and ≤35%	>35% and ≤60%	>60% and ≤85%	>85%
	ACB20	Mobile Application Accessibility	1. Not applicable. 2. Mobile interface is inaccessible. 3. Basic functional interface. 4. Functional interface with limitations. 5. Fully optimized and functional mobile interface.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

AC6: Assistive Technologies and Privacy	ACB21	Screen Reading Compatibility	1. Not applicable. 2. No compatibility with screen readers. 3. Partial compatibility. 4. Moderate functionality with adequate reading. 5. Optimized screen reading experience.	0%	≤25%	>25% and ≤55%	>55% and ≤85%	>85%
	ACB22	Compatibility with Assistive Technologies	1. Not applicable. 2. No compatibility with assistive technologies, including lack of standard support. 3. Limited integration, with serious issues interpreting assistive technologies and implementing standards. 4. Functional compatibility, but with gaps in support for international standards. 5. Full integration with assistive technologies, including complete compliance with standards.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	ACB23	Voice Interface Accessibility	1. Not applicable. 2. No voice commands available. 3. Basic voice commands implemented. 4. Clear voice interaction with minor issues. 5. Full voice accessibility and interaction support.	0%	>0% and ≤35%	>35% and ≤60%	>60% and ≤85%	>85%
	ACB24	Accessible Privacy and Security	1. Not applicable. 2. Settings are missing or confusing. 3. Basic functionality provided. 4. Clear settings with minor gaps. 5. Fully accessible and guaranteed privacy configuration.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

	ACB25	Cognitive Accessibility	1. Not applicable. 2. Incomprehensible to users. 3. Basic structure with limitations. 4. Clear navigation, though with some gaps. 5. Full cognitive accessibility with clear and supportive navigation.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
AC7: Experience and Temporary Adjustments	ACB26	Reaction Time and Interactivity	1. Not applicable. 2. No timing adjustments available. 3. Basic adjustments present. 4. Functional and moderately flexible adjustments. 5. Fully adjustable and interactive configuration.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	ACB27	Smooth Responses and Transitions	1. Not applicable. 2. Abrupt and confusing responses. 3. Minimal smoothness implemented. 4. Moderately smooth transitions with functionality. 5. Optimized and seamless transitions and responses.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	ACB28	Accessibility in Temporary Situations	1. Not applicable. 2. No temporary support features. 3. Basic temporary features available. 4. Moderately functional temporary resources with some flaws. 5. Fully guaranteed temporary accessibility.	0%	>0% and ≤35%	>35% and ≤60%	>60% and ≤85%	>85%

	ACB29	Multimodal Feedback	1. Not applicable. 2. No multimodal feedback provided. 3. Basic and limited feedback. 4. Functional and moderately implemented multimodal feedback. 5. Fully integrated multimodal feedback system.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	ACB30	Stress and Well-being	1. Not applicable. 2. Stressful and exhausting design. 3. Basic design with noticeable flaws. 4. Moderately comfortable and functional design. 5. Optimized and user-friendly design that promotes well-being.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

Column headers: (1) Score Level 1 (%); (2) Score Level 2 (%); (3) Score Level 3 (%); (4) Score Level 4 (%); (5) Score Level 5 (%). The ACB Score defines the applicable percentage-based criteria for thirty items grouped into seven categories, each featuring progressive accessibility levels ranging from "not applicable" or critical conditions to full compliance and inclusive support (Levels 1 to 5). These levels are based on clear, evidence-based quantitative parameters and are supported by chromatic coding to enhance intuitive visual interpretation. This detailed framework supports rigorous evaluations and targeted guidance, which are essential for fostering accessible, inclusive technologies adapted to the diverse needs of agents.

Source: Author.

2.1.12 QRSUER Technology Dimension (QRSUER)

The QRSUER Technology Dimension (Dimensão Tecnologia QRSUER) defines the applicable percentage-based criteria for the QRSUER dimension, which assesses the sustainability, efficiency, and socio-environmental responsibility of technological objects (Table 12). This dimension encompasses multiple aspects, including efficient resource management, sustainable design, social impact, ethical compliance, and technological innovation. The progressive scale qualifies the object's performance from absent or unsatisfactory practices to advanced levels of sustainability and positive impact, considering environmental, social, and economic factors. The score provides a comprehensive analysis, essential for ensuring the viability and accountability of technological systems in light of contemporary demands.

TABLE 12: DEFINITION OF THE STANDARD SCORE FOR QRSUER TECHNOLOGY (QRSUER)

Groups	Code	Criterion Types QRSUER	Definitions	1	2	3	4	5
TQ1: Sustainability and Resources	TQRS01	Resource Use and Efficiency	1. Not applicable. 2. Extremely inefficient consumption with no environmental considerations (≤30%). 3. Partially efficient, but still with significant waste (>30% and ≤60%). 4. Moderately efficient, with some optimization practices (>60% and ≤85%). 5. Efficient and environmentally responsible use of resources (>85%).	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS02	Resource Sustainability	1. Not applicable. 2. Predominant use of non-renewable materials and wasteful practices (≤30%). 3. Limited use of renewable materials and partial management practices (>30% and ≤60%). 4. Moderate use of renewable resources with clear sustainability efforts (>60% and ≤85%). 5. Predominance of renewable materials and highly sustainable practices (>85%).	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS03	Emission Reduction	1. Not applicable. 2. Uncontrolled emissions with no mitigation efforts (≤30%). 3. Limited emission mitigation with partial alignment to standards (>30% and ≤60%). 4. Moderate reduction efforts with significant mitigation (>60% and ≤85%). 5. Significant emission reduction with full compliance (>85%).	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

	TQRS04	Solid Waste Management	1. Not applicable. 2. High levels of waste with no reuse or proper disposal practices (≤30%). 3. Partial waste management with limited reuse initiatives (>30% and ≤60%). 4. Moderate management with consistent reuse and proper disposal practices (>60% and ≤85%). 5. Highly efficient management aligned with sustainability standards (>85%).	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS05	Active Disposal	1. Not applicable. 2. Inadequate disposal with no reuse policies (≤30%). 3. Disposal with limited reuse and recycling policies (>30% and ≤60%). 4. Moderate disposal with clear sustainable management practices (>60% and ≤85%). 5. Active disposal focused on sustainability and reuse (>85%).	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS06	Carbon Neutrality	1. Not applicable. 2. High carbon footprint with no compensatory actions (≤30%). 3. Partial emission reduction with limited compensation efforts (>30% and ≤60%). 4. Moderate compensations and partial neutrality actions (>60% and ≤85%). 5. Significant compensation achieving full carbon neutrality (>85%).	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS07	Regenerative Impact	1. Not applicable. 2. No ecosystem regeneration efforts. 3. Limited and ineffective regenerative actions. 4. Moderate regenerative practices. 5. Highly effective regenerative impact.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

	TQRS08	Water Efficiency	1. Not applicable. 2. High water consumption and waste. 3. Low efficiency with limited reuse. 4. Moderate optimization of water use. 5. Advanced conservation and reuse practices.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS09	Biodiversity Protection	1. Not applicable. 2. High ecological impact. 3. Few actions to protect biodiversity. 4. Moderate conservation actions. 5. Exemplary environmental management.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
TQ2: Sustainable Design and Circular Economy	TQRS10	Recyclability	1. Not applicable. 2. No recyclability of materials. 3. Limited recyclability. 4. Moderate potential for reuse. 5. Fully recyclable and reusable structure.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS11	Facilitated Repairability	1. Not applicable. 2. Impossible to repair. 3. Repair is difficult and unfeasible. 4. Moderately accessible repair. 5. Full ease of repair or component replacement.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS12	Modular Adaptability	1. Not applicable. 2. No possibility of adaptation. 3. Limited adaptability. 4. Moderate modularity. 5. Highly adaptable and modular configuration.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS13	Circular Design	1. Not applicable. 2. Linear design with no reuse potential. 3. Partial implementation of circular concepts. 4. Moderately reusable design. 5. Fully circular structure.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

TQ3: Social Impact and Inclusion	TQRS14	Social Impact and Equity	1. Not applicable. 2. Negative and unequal social impact. 3. Partial social impact with limited benefits. 4. Moderate social impact, with efforts to enhance equity. 5. Positive social impact with significant contribution to equity.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS15	Technological Inclusion	1. Not applicable. 2. Complete exclusion of certain groups. 3. Limited and ineffective inclusion. 4. Moderate inclusion with targeted efforts. 5. Broad and effective technological inclusion.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS16	Positive Local Economic Impact	1. Not applicable. 2. Negative or nonexistent impact on local economies. 3. Limited local economic impact. 4. Moderate local economic impact. 5. Positive and significant impact on local economies.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
TQ4: Compliance, Ethics, and Transparency	TQRS17	Transparency and Privacy	1. Not applicable. 2. Total lack of transparency and privacy protection. 3. Limited transparency and privacy safeguards. 4. Moderate transparency with implemented privacy policies. 5. High transparency and full compliance with privacy standards.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS18	Transparency and Traceability	1. Not applicable. 2. No transparency or traceability. 3. Partial transparency and traceability. 4. Moderate transparency and traceability. 5. Full transparency and traceability with high reliability.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

	TQRS19	Legal Compliance	1. Not applicable. 2. Complete lack of compliance with legal standards. 3. Limited compliance with notable gaps. 4. Moderate legal compliance. 5. Full compliance with legal and regulatory frameworks.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS20	Ethics and Transparency in AI Systems	1. Not applicable. 2. Absence of ethical considerations and transparency in AI systems. 3. Limited ethical practices and partial transparency. 4. Moderate adherence to ethical principles and transparency. 5. High ethical standards and full transparency in AI systems.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
TQ5: Innovation and Technological Impact	TQRS21	Material Safety	1. Not applicable. 2. Materials present significant risks to health and safety. 3. Materials with moderate risks and partial mitigation strategies. 4. Materials with moderate safety and effective controls. 5. Safe materials with a high standard of protection.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS22	Sustainable Integration	1. Not applicable. 2. Limited integration of sustainable practices. 3. Moderate integration with some sustainable solutions. 4. Substantial integration of sustainable technologies. 5. Full integration of sustainable technologies and practices.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS23	Responsible Innovation	1. Not applicable. 2. Lack of responsible innovation and high risk. 3. Innovation with limited ethical and responsible considerations. 4. Moderate innovation with social responsibility. 5. Transformative and highly responsible innovation.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%

TQ6: Environmental Conservation and Preservation	TQRS24	Efficient Use of Space	1. Not applicable. 2. Inefficient and uncontrolled use of space. 3. Limited use with space waste. 4. Moderate and optimized use of space. 5. Highly efficient use of space.	0%	>0% and ≤30%	>30% and ≤60%	>60% and ≤85%	>85%
	TQRS25	Environmental Preservation	1. Not applicable. 2. No environmental preservation practices. 3. Limited and ineffective environmental practices. 4. Moderate environmental preservation practices. 5. Robust and effective environmental practices.	0%	>0% and ≤50%	>50% and ≤75%	>75% and ≤90%	>90%
	TQRS26	Preservation of Water and Subsurface Resources	1. Not applicable. 2. Irresponsible use with no preservation of water resources. 3. Limited use with partial preservation practices. 4. Moderate use with efforts toward water preservation. 5. Efficient use with strong preservation of water resources.	0%	>0% and ≤60%	>60% and ≤80%	>80% and ≤95%	>95%
	TQRS27	Air Pollution and Atmospheric Protection	1. Not applicable. 2. Uncontrolled emissions and atmospheric pollution. 3. Limited emissions with partial mitigation. 4. Moderate emissions with mitigation practices. 5. Controlled emissions with strong atmospheric protection.	0%	>0% and ≤60%	>60% and ≤80%	>80% and ≤95%	>95%
	TQRS28	Chemical, Radioactive, and Heavy Metal Contamination	1. Not applicable. 2. Significant contamination with no mitigation. 3. Moderate contamination with some mitigation measures. 4. Limited contamination with effective mitigation. 5. Zero contamination with full mitigation and management.	0%	>0% and ≤60%	>60% and ≤80%	>80% and ≤95%	>95%

	TQRS29	Space Pollution and Environmental Impact	1. Not applicable. 2. High environmental impact with no control. 3. Moderate impact with partial mitigation. 4. Controlled impact with active mitigation. 5. Minimal environmental impact with proactive measures.	0%	>0% and ≤60%	>60% and ≤80%	>80% and ≤95%	>95%

Column headers: (1) Score Level 1 (%); (2) Score Level 2 (%); (3) Score Level 3 (%); (4) Score Level 4 (%); (5) Score Level 5 (%). The QRSUER Score establishes the applicable percentage criteria for twenty-nine indicators grouped into six categories, related to sustainability, resource efficiency, sustainable design, social impact, ethical compliance, and technological innovation. The scale presents progressive levels that qualify the performance of technological objects, ranging from the absence or insufficiency of sustainable practices to excellence in socio-environmental responsibility, providing a detailed assessment of the object's alignment with contemporary environmental, social, and economic standards.

Source: Author.

2.1.13 Architecture of the Global Usability and Interaction Score: Integration of the Twelve Dimension Scores

The structure presented corresponds to the standardized scores of the twelve main dimensions of the FCIA-OT, which constitute the foundational framework of the Global Usability and Interaction Score (SGUI). Each score adopts specific percentage-based criteria to rigorously and multidimensionally measure the properties of the technological object, encompassing functional, affective, effectiveness, and risk-related aspects, among others. The SGUI formula, applied to calculate the percentage frequency of each element in relation to the total entries within the dimension, enables the transformation of these data into standardized percentage levels. These levels make it possible to identify the system's maturity, revealing both its positive and negative qualifications per dimension—or even per element—thus offering a comprehensive instrument for analysis, diagnosis, and continuous improvement. This composition reinforces the precision and applicability of the FCIA-OT in the evaluation of complex systems, combining scientific rigor with practical utility.

3 INTEGRATED MODULAR CRITICAL SCORE (SCMI)

The Integrated Modular Critical Score (Score Crítico Modular Integrado – SCMI) constitutes an advanced analytical component of the FCIA-OT, designed to express the relative critical weight of each element mapped across the system's twelve dimensions. Derived directly from the raw SPMI value, the SCMI not only indicates the statistical presence of an artifact but translates its proportional technical criticality, determined by factors such as severity, functional impact, and operational value of the records.

Unlike the SGUI, which quantifies the relative frequency of registered elements, the IMCS operates on a complementary axis, oriented toward the technical intensity of the data. Its application enables the identification of artifacts with low occurrence yet high functional relevance, which could be overlooked by strictly quantitative approaches. For this reason, the SCMI serves as a fundamental indicator in assessments of maturity, reliability, and effectiveness of technological objects subjected to high-complexity analytical environments. Technically, the SCMI is obtained by calculating the percentage ratio between the SPMI assigned to a given element and the total sum of SPMIs recorded within the evaluated dimension:

$$SCMI = \left(\frac{SPMI_{\text{element}}}{\sum SPMI_{\text{all}}} \right) \times 100$$

Source: Author.

Where: $SPMI_{element}$ represents the sum of the weights assigned to the element throughout its occurrences within the dimension; $\sum SPMI_{all}$ refers to the sum of all SPMI values recorded in the dimension, considering every element involved.

This calculation enables the identification of each artifact's critical proportionality within the analyzed structure, revealing its relative influence over the dimension to which it belongs. The SCMI also integrates with the SCDMIC, allowing for the chromatic representation of criticality and supporting analyses driven by risk, vulnerability, and modular excellence.

When an artifact receives a negative score in the SPMI, due to severe structural failures, lack of functional performance, or noncompliance with minimal technical criteria, the proportional value of the SCMI also becomes negative. This outcome is not merely a numerical deviation; rather, it reflects a substantive adverse impact on the maturity of the evaluated dimension.

To preserve analytical consistency and ensure the integrity of synthetic outputs, the occurrence of a negative SCMI activates the SCDMIC conditional (blue color). This technical protocol prevents the projection of the artifact into overall averages, public visualizations, comparative syntheses, and integrated classificatory outputs. Its purpose is to prevent critical, immature, or early-stage prototype artifacts from compromising statistical accuracy and interpretive fidelity of the results.

It is essential to emphasize that the blue conditional does not eliminate the technical data: both the negative score and the proportional SCMI remain fully recorded within the system, along with all corresponding metrics. The restriction applies solely to graphical and synthetic projection, which remains accessible exclusively through confidential reports intended for interaction engineers, developers, and researchers responsible for quality control, reengineering, and functional evaluation cycles.

In such cases, artifacts are technically classified as below minimum functionality standards and may present lack of interoperability, logical inconsistency, or deviation from critical requirements. This methodological approach fulfills four central functions: preserving the statistical validity of analytical outputs; ensuring continuous traceability of critical data; supporting corrective interventions grounded in technical evidence; and maintaining the robustness, coherence, and logical reliability of the evaluative system.

The presence of negative SCMI values does not compromise the stability of the model, nor does it indicate a systemic failure. On the contrary, it reflects the maturity of the FCIA-OT in handling critical data through methodologically controlled procedures, operating with rigor, traceability, and a continuous focus on systemic improvement.

4 DISCUSSION

The integration of the SGUI and SCMI modules within the scope of the FCIA-OT constitutes a significant technical contribution to the multidimensional assessment of usability and interaction in complex technological objects. While the SGUI operationalizes the quantification of the relative frequency of elements across its twelve dimensions, the SCMI complements this scope by incorporating proportional critical intensity, reflecting the technical severity and functional impact of the evaluated artifacts.

This research expands the analytical scope by overcoming limitations inherent to unidimensional assessments, which tend to prioritize only the recurrence of observed events or data. The SGUI, focused on statistical prevalence, may underestimate the importance of low-frequency critical artifacts, a scenario mitigated by the SCMI, which emphasizes the proportional technical criticality of elements. This synergy enables a more accurate analysis of the maturity, reliability, and effectiveness of the technological object, especially in environments of high complexity and operational criticality.

The proportional calculation of the SCMI facilitates the identification of unbalanced distributions of critical weight within the evaluated dimensions, enabling the early detection of vulnerabilities and structural weaknesses that directly affect the functional integrity of the system. The SCDMIC conditional (blue color), implemented as an exception protocol for artifacts receiving negative scores in analyses and assessments, reinforces the statistical consistency of the model by preventing immature data from distorting aggregated analyses, while preserving the integrity and traceability of critical data for corrective actions and quality control (see Chapters 1 and 2).

This evaluation model, prevalence versus criticality, provides interpretive and technical robustness, establishing the FCIA-OT as a highly precise modular analytical structure for the assessment and management of technological usability and interaction. The clear distinction between the roles of SGUI and SCMI strengthens the framework's ability to support technical decisions grounded in rigorous data, mitigating quantitative bias and extending the analytical scope to encompass both frequency-based and qualitative dimensions of criticality.

The articulation of these modules in the present research, supported by the theoretical foundations and empirical validations presented in the related FCIA-OT articles, establishes a solid foundation for future advancements in usability and interaction engineering, contributing to the formalization of critical metrics that reflect the complexity of contemporary technological systems.

5 CONCLUSION

The formalization of the systemic resources SGUI and SCMI represents a substantial advancement in the modeling and analysis of the technical and functional quality of complex technological objects. By establishing a dual analytical approach that simultaneously considers the relative frequency of elements and their proportional criticality, these modules significantly expand the evaluation spectrum, overcoming traditional limitations that tend to fragment analysis between quantitative and qualitative dimensions.

This integration enables not only the precise identification of recurring patterns but, more importantly, the technical recognition of artifacts that, although less frequent, exert decisive impact on the maturity, reliability, and performance of the evaluated system. As systemic resources, the SGUI and SCMI enhance the FCIA-OT, contributing to the consolidation of the framework as a robust and advanced tool for technological assessment.

The mathematical rigor of the SCMI computation, combined with the modular structure of the SGUI, provides a solid foundation for application in real-world scenarios, ensuring both security and precision in technical decision-making within high-complexity contexts. In this sense, the SGUI and SCMI are established as essential tools for engineers, researchers, and professionals dedicated to the evaluation and continuous improvement of usability and interaction in technological systems.

This methodological formalization sustains a robust scientific foundation that supports future extensions, empirical validations, and transdisciplinary applications, contributing to the advancement of knowledge and technological innovation in the field of interaction engineering.

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