FCIA-OT ARCHITECTURE: ADVANCED OPERATIONAL MANAGEMENT AND MULTIDIMENSIONAL CONTROL OF USABILITY AND INTERACTION

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ABSTRACT — This article systematizes the final stage of the FCIA-OT methodological cycle, consolidating its analytical-operational structure for the evaluation and enhancement of technological objects. Section 3 addresses the second axis of the framework's flowchart, focused on the intake, in-depth analysis, and systematic application of targeted solutions to the components that constitute the evaluated construct. This stage integrates technical standards, hardware and software engineering, modular structuring, and compliance procedures, enabling interventions guided by criteria of effectiveness, efficiency, sustainability, and functional coherence. Section 4 presents the global architecture of the FCIA-OT system as a scientific platform for the continuous management of usability and interaction. Structured as a central unit of integration and control, the framework performs diagnostic, explanatory, and prognostic functions, with the ability to monitor, classify, prioritize, standardize, and reorient technological objects based on multiscalar technical-scientific parameters. Its twelve-dimension integrated matrix operates synergistically with computational subsystems, scoring mechanisms, color scales, global and critical indexes, persona-based analysis, and visual feedback tools. The proposal advances traditional paradigms of technological assessment by incorporating analytical granularity, methodological reproducibility, computational scalability, and transdisciplinary applicability across multiple domains. FCIA-OT establishes itself as both a decision-support system and a platform for scientific-technical innovation, enabling not only the identification of failures but also the structured proposition of corrective solutions and the intelligent reconfiguration of the Agent–Technology Interaction (ATI). Its model departs from conventional descriptive logics, setting a new standard of precision, reliability, and functional accountability in technological evaluation.

KEYWORDS — FCIA-OT; Technological Assessment; Continuous Management; Diagnosis; Usability; Interaction; Transdisciplinarity.

1 INTRODUCTION

The increasing complexity of technological objects and the intensification of their presence in social, productive, and institutional environments have demanded evaluation methodologies that are increasingly robust, integrated, and capable of responding to the structural, functional, and contextual diversity of interactive systems. However, most conventional approaches remain confined to descriptive methods, loosely articulated, with low diagnostic capacity and limited ability to guide corrective or evolutionary interventions.

In response to this analytical scenario, FCIA-OT emerges as a scientific-technical proposal that breaks with heuristic traditions and significantly expands the horizons of technological assessment. Developed from rigorous foundations, the framework establishes an advanced system for the classification, diagnosis, and continuous management of technological objects, structured around twelve operational dimensions and multiple analytical subsystems.

This article presents the architecture of the FCIA-OT, consolidating its function across two critical levels of the evaluative process. The first, of an analytical-operational nature, is responsible for receiving, processing, and applying targeted solutions to the demands identified within the construct, promoting structured improvements based on normative and functional criteria. The second level, systemic in nature, organizes the continuous management of usability and interaction through an integrated matrix and scoring systems, including global and critical indexes, persona-based analysis, and visual feedback mechanisms.

By articulating multiple scientific-technical variables, FCIA-OT positions itself as an innovative and highly reliable methodology, with the ability to operate across different domains and contexts, enabling high-precision evaluation with traceability and functional accountability. It thus consolidates itself as an approach that redefines the role of usability engineering and technological assessment by introducing a new paradigm of control, intervention, and guided evolution of interactive systems.

Building on this consolidated structure, the article advances into the final stage of the FCIA-OT methodological cycle, addressing its systemic foundations and the integrated operation of its analytical-operational modules. These components sustain the framework's functioning as a logical platform for the intake, analysis, intervention, and continuous management of interaction and usability, central elements for repositioning technological evaluation at an advanced scientific level.

2 FCIA-OT ARCHITECTURE: SYSTEMIC FOUNDATIONS

FCIA-OT is structured as a high-complexity methodological system for technological assessment, grounded in normative guidelines, technical constructs of usability and interaction engineering, principles of modularity, and multiscalar integration logics. Its construction encompasses the full spectrum from technical eligibility criteria to advanced systems of scoring, visualization, weighting, and decision support.

By consolidating this architecture across multiple operational, logical, functional, diagnostic, and strategic layers, the FCIA-OT positions itself as a systemic structure that not only evaluates but also interacts with the life cycle of the technologies under analysis. Its Systemic Matrix of Integrated Vectorial Dimensions (MSDVI) integrates technical-functional elements with contextual variables, enabling a comprehensive and responsive analysis aligned with the structural and operational reality of the evaluated objects.

In this article, which concludes the methodological cycle, the focus is placed on the logic of intake, analysis, and application of solutions (second section of the framework's flowchart), as well as on the consolidation of FCIA-OT as a platform for the continuous management of usability and interaction. This stage goes beyond the mere description of processes, establishing a paradigmatic shift in how assessment is operationalized, with emphasis on reliability, intelligent reconfiguration, and systematic control across multiple technological domains.

3 FCIA-OT ARCHITECTURE: MANAGEMENT OF ANALYSES AND EVALUATIONS

The body of theoretical and methodological foundations presented in this section brings together key milestones concerning methods, approaches, and methodological requirements applicable to the usability evaluation of interactive systems, with an emphasis on preliminary stages of the development cycle and the technical support of design decision-making. The approaches outlined here acknowledge the complexity of contemporary interactions, especially in contexts involving multimodality and adaptive systems, and reinforce the need for high-precision methodologies capable of identifying failures, analyzing critical events, and supporting evidence-based decisions.

This set of theoretical foundations provides the necessary scaffolding for the structure of the analyses and evaluations conducted in subsequent stages, serving as a methodological backbone for the practical application of the technical, operational, and behavioral criteria required in the investigation process. The findings derived from

the evaluation of different dimensions of the technological object are systematically categorized and organized. These findings, stemming from both quantitative and qualitative methods, enable the generation of structured and actionable data whose interpretation demands the involvement of experts with multidisciplinary competencies. The consolidation of this information subsequently feeds into critical technical processes within the product development and optimization cycle.

As Neal & Simons (1984) point out, evaluation may begin as early as the initial phases of a project, using prototypes, even rudimentary ones, tested in controlled environments. This anticipation allows for the early identification of faults, provided that the evaluation is accompanied by rigorous measurement criteria tailored to the limitations of non-specialist users.

Along similar lines, Landauer (1988) emphasizes that formative evaluation, grounded in scientific methods from the outset of development, is essential to avoid rework and efficiency losses. It should be based on clearly defined objectives, robust experimental designs, and consistent statistical analysis.

When addressing iterative prototyping as a fundamental practice in interface design, Perlman (1990) stresses the need to link it to continuous empirical and predictive evaluations capable of guiding the progressive refinement of the artifact.

Focusing on the analysis of critical user behavior, Wright & Monk (1991) demonstrate that the identification of unexpected failures relies on attentive listening to spontaneous user comments, which often reveal unfulfilled intentions and latent issues during interaction.

As project complexity increases, Barnard & May (1999) argue that evaluation models must incorporate perceptual, motor, affective, and cognitive phenomena, given the interdependence among interface components in advanced interactive contexts.

Within the scope of continuous evaluation and its practical implications, Gabbard et al. (2003) assert that well-executed usability engineering not only improves system effectiveness, efficiency, and safety, but also reduces lifecycle costs by preventing late-stage corrections and costly interventions.

In consolidating analytical criteria, it becomes essential to integrate cognitive, affective, and methodological dimensions that deepen the understanding of usability in real-world contexts. Khalid (2006) found that traditional approaches focused exclusively on cognitive factors tend to overlook the emotional impact of product design. To overcome this, he argues that affective design requires both theoretical grounding and robust empirical methods, although valid measurement of emotional responses remains a significant methodological challenge.

Moving toward the informational sustainability of evaluations, Rosenbaum (2008) proposed that knowledge management should maximize returns on usability investments by systematically reusing evaluation data. This practice requires the structured organization of findings supported by appropriate metadata, enabling their retrieval and reuse by diverse technical and strategic teams.

In parallel, Hassenzahl & Monk (2010) argued that in the absence of direct interaction with a product, users tend to infer usability attributes based on visual aspects such as aesthetics and graphical proportions, a process referred to as probabilistic consistency, which highlights the entwinement between visual perception and functional judgment.

Continuing the methodological analysis, Weichbroth (2020) observed that usability evaluations often conflate system performance with user performance, leading to ambiguous measurements that compromise the validity of the results. He emphasized that observational data are essential to uncover operational bottlenecks and guide improvements, warning that an uncritical combination of objective and subjective measures may result in inconsistent interpretations of the end-user experience.

The proposed iterative analysis process systematically encompasses each individual and grouped evaluation conducted by the agents. The reports generated from these evaluations are forwarded to teams composed of specialists in strategic fields such as advanced software development, hardware, accessibility, agent relations, and QRSUER technology. Following a technical reading of these reports, the specialized teams discuss the identified demands and draft Document 2, consolidating technical and practical solutions aimed at improving the technological object.

This stage is critical for guiding manufacturers and developers on how to proceed based on the evaluations and analyses carried out by end agents. Document 2 (see Figure 2 in Chapter 1) lays out specific action plans encompassing error mitigation, risk reduction, implementation of technical enhancements, and resolution of issues related to the operation of physical and logical components.

Throughout this process, managers and stakeholders are kept continuously informed, ensuring strategic alignment and supporting evidence-based decision-making. The execution of actions occurs in parallel with the analysis, fostering synergy between the identification of demands and the implementation of the proposed solutions.

This structured approach not only systematizes critical findings but also fosters articulation across different areas of expertise, enabling technically grounded and effective intervention strategies. Through such integration, the process ensures substantial improvements in the evaluated products and services, addressing

detected limitations and enhancing the quality perceived by the end agent. The flowchart in Figure 1 illustrates this iterative process, highlighting the interplay between the conducted analyses and the application of the proposed technical solutions..

FIGURE 1: MANAGEMENT PROCESS OF ANALYSES AND EVALUATIONS AND ITERATIVE EXECUTION OF PROCEDURES
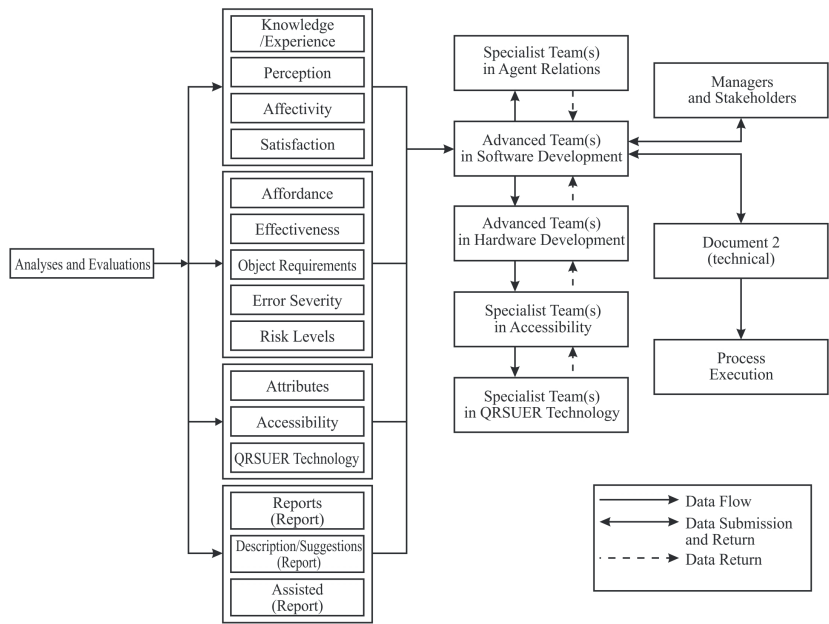
Main blocks: Represent the stages of the process (e.g., analyses, evaluations, report development, solution implementation).
Arrows: Indicate the flow of information and actions between the elements.

Source: Author.

The teams are responsible for proposing solutions that strictly adhere to technical and regulatory standards. In the hardware domain, these solutions must be grounded in high-level criteria of efficiency, effectiveness, and compliance with applicable standards, ensuring robust and reliable performance. Regarding software, the proposals must align with design patterns, modularization standards, modeling techniques, and best practices in software engineering. These models should be designed to ensure the scalability, interoperability, and sustainability of the technological object, maintaining legal compliance and promoting sustainable guidelines for maintenance and continuity.

This integration of hardware and software solutions reinforces the multidimensional nature of the process, ensuring that technological objects meet market demands and overcome the challenges of a dynamic and competitive environment. By consolidating this approach, Document 2 becomes a key guide for the implementation of substantial improvements, ensuring that the technological object achieves high levels of quality, reliability, and efficiency.

4 FCIA-OT ARCHITECTURE: ADVANCED AND CONTINUOUS MANAGEMENT OF USABILITY AND INTERACTION

At the conclusion of a robust development cycle, the FCIA-OT emerges as a highly refined, structured, reliable, and methodologically replicable technical-scientific apparatus. Its complex theoretical, technical, and practical engineering has enabled the creation of a system composed of novel mechanisms for technical analysis and evaluation of technological artifacts, supporting a set of dimensions, modules, submodules, and operational elements.

The FCIA-OT architecture provides modular support for composing requirements tailored to objects, artifacts, environments, and contexts, integrating multidimensional and adaptable evaluation criteria. The framework's operational logic articulates analytical granularity, internal consistency, methodological clarity, and alignment with the technical demands of contemporary evaluative practice. Its ability to adapt to a wide range of technological domains demonstrates the structural flexibility of the proposal, enabling rigorous operationalization of evaluations across different maturity levels and object types.

In defining usability evaluation methods, Andre, Williges, & Hartson (1999) emphasize that the effectiveness of a Usability Evaluation Method (UEM) depends on criteria such as validity, thoroughness, and reliability, dimensions that ensure the accurate identification of relevant issues, with consistency among evaluators. The absence of a reliable UEM compromises the comparability of results, while thoroughness reflects the method's ability to capture the broadest possible range of actual problems. Validity, in turn, requires that identified issues genuinely impact user experience.

Complementarily, Andre et al. (2001) warn about the risks associated with disorganized documentation of issues observed during evaluations, noting that a lack of structure undermines future interpretation, especially amid changes in development teams. Thus, systematic categorization of findings is essential to ensure accurate diagnostics and to prevent ineffective solutions.

At the origin of the evaluative process, Grinstein et al. (2003) assert that usability must be a foundational consideration in tool design, as understanding users' needs ultimately determines utility. This approach positions usability as a prerequisite to functionality.

In a convergent direction, Liljegren (2006) states that the core objective of usability evaluation is to identify, within actual and situated use, the problems that directly affect user efficiency, effectiveness, and satisfaction, with the frequency of these issues indicating the distance between the interface and established principles.

Expanding on this foundation, Hornbæk (2006) advocates for the integration of objective measures, such as task completion time and error rate, with subjective measures that capture user experience. The combination of both broadens the understanding of usability by encompassing qualitative aspects not reflected in quantitative data alone.

In the realm of design action, Wixon (2011) argues that metrics must be functionally actionable, that is, capable of guiding specific changes based on observational data. The integration of iterative measurement into the design process itself fosters convergence between intention and experience, aligning product evolution with user perception.

At the intersection of evaluation and communication, Tullis & Albert (2013) emphasize that clarity in presenting results is crucial for guiding design decisions. Strategic use of metrics not only reveals failures but also allows for their prioritization, optimizing resources and amplifying the impact of interventions. In this regard, the evaluative practice becomes a cumulative learning process, in which past errors enhance future analytical capability.

Based on the theoretical foundation presented, it becomes clear that the FCIA-OT not only engages with established references but also significantly extends them by proposing a technical-scientific system aimed at modular, objective, and deeply integrated evaluative practice.

The proposed set of constructs and dimensions enables diverse technologies to be assessed according to specific criteria, forming a flexible, validatable process compatible with technical, normative, and operational requirements. Each dimension functions as an independent unit of analysis while also interacting with the whole, ensuring both a segmented and holistic view of the artifacts.

This systemic approach addresses recurring gaps in traditional evaluation methodologies, offering a structured and adaptable pathway aligned with the realities of contemporary technology. As illustrated in Figure 2, the FCIA-OT solidifies its implementation through an architecture composed of functional modules.

FIGURE 2: ANALYTICAL-OPERATIONAL FLOW OF THE FCIA-OT
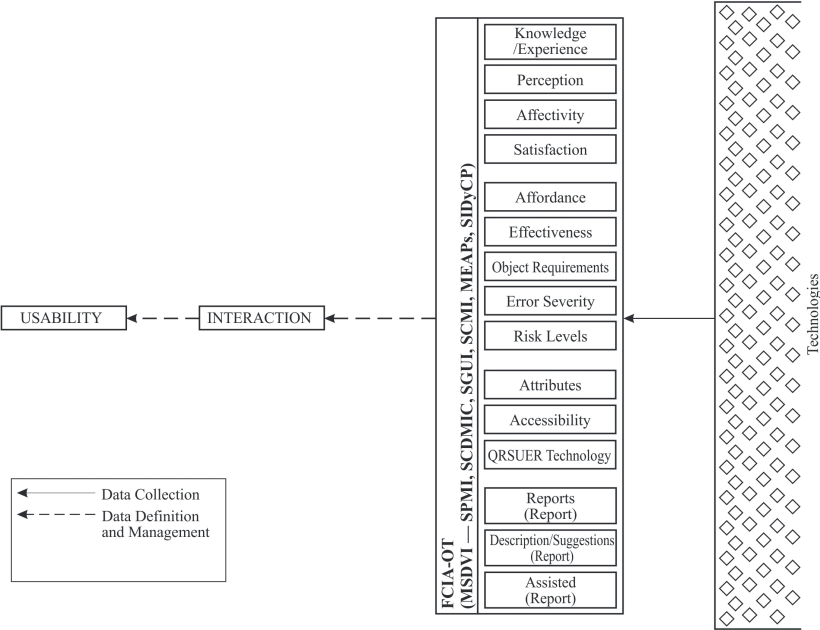
Technologies are subjected to the Integrated Matrix of Twelve Dimensions, which manages interaction and generates a technical usability diagnosis. This operational structure enables advanced analyses and evaluations by articulating methodological precision, modular adaptability, and computational scalability.

Source: Author.

The structural robustness of FCIA-OT, combined with its technical refinement, confers an unprecedented level of analytical rigor (thoroughness) in the field of interactive technology assessment. The composition of its twelve operational dimensions, integrated with scoring systems, color codes, global score, critical score, and personas, enables not only the identification of failures but also the hierarchization of severity levels, the establishment of technological maturity stages, and the indication of scientifically grounded corrective paths. The system exhibits high reliability, a strong degree of replicability, and the capacity to operate with precision in both microstructural analyses (such as the attributes and properties of individual parts and components) and macrostructural usage contexts (such as ethical, social, environmental, and functional impacts).

The operational logic of FCIA-OT shifts the evaluative practice from a merely descriptive model to a diagnostic–explanatory and prognostic model, an approach

that remains extremely rare among current systems. Simultaneously, the presence of visual and adaptable modular subsystems facilitates the framework's use by specialists from diverse fields, broadening its applicability and fostering transdisciplinarity, an essential aspect in a landscape shaped by technological convergence and increasing functional complexity.

The approach advocated here aligns with principles established by both classical and contemporary research in the fields of technology assessment, usability engineering, and interaction analysis, which emphasize the importance of tools capable of encompassing not only the functional aspects of the interface but also its context, structural properties, artifacts, users, real-world use, and resulting impacts. FCIA-OT responds to this demand by expanding the horizons of evaluation and significantly elevating both its depth and technical rigor.

By articulating technical-scientific variables as structured requirements applicable to objects and artifacts, FCIA-OT establishes a logical platform for classification, standardization, and comparative analysis across technologies. Its measurement capability, grounded in percentiles, criticality ranges, and technical scoring, enables the positioning of the evaluated technology within spectrums of quality, risk, and reliability. This reinforces its role not only as a diagnostic tool but also as a decision-support system for strategic planning and improvement design.

From a scientific standpoint, FCIA-OT demonstrates structural validity, internal consistency, and generalizability. Its architecture was built upon robust constructs, meticulously extracted from the specialized literature and operationalized through applicable, measurable, and integrated categories. The case studies confirmed the full functionality of the system, attesting to its stability, flexibility, and adaptability across distinct contexts, from digital to physical environments, from laboratory settings to field applications, and from individual use to sociotechnical ecosystems.

FCIA-OT positions itself not merely as a methodology, but as a new paradigm in technology evaluation: grounded, modular, reliable, ethical, and scientific. Its inception marks the beginning of an era in which evaluation ceases to be an opinion-based exercise or a patchwork of disjointed heuristics and becomes a comprehensive, auditable, reproducible, and technically grounded process, one oriented toward safe, functional, and socially responsible innovation.

5 DISCUSSION

The consolidation of FCIA-OT's structural layers, across both analytical-operational management and continuous usability and interaction control, reveals an innovative model of evaluative engineering. Unlike descriptive or static approaches, the framework integrates a set of intelligent systems that combine technical processing,

semantic analysis, and functional reconfiguration in real time. This ability to operate responsively, iteratively, and in alignment with normative criteria reinforces FCIA-OT's potential as a high-performance decision-support system.

The articulation among its subsystems, including the integrated twelve-dimensional matrix, scoring mechanisms, persona-based analyses, and visualization systems, not only broadens the scope of evaluation but also enables a strategic operation that goes beyond diagnosis to deliver structured prescriptions for solution-building. This approach represents a significant methodological shift, moving the focus of evaluation away from merely issuing technical verdicts and toward a dynamic process of intelligent reconfiguration of technological artifacts.

In terms of applicability, the proposed model demonstrates high relevance across transdisciplinary contexts, adapting effectively to diverse types of technologies, systems, and interfaces. Its modular logic, combined with the robustness of its analytical processes, ensures replicability, scalability, and operational sustainability. As a direct implication of its systemic architecture, FCIA-OT positions itself not merely as an evaluative tool, but as a strategic innovation platform with the potential to reshape practices of technological development, validation, and management across multiple sectors.

6 CONCLUSION

The consolidation of the FCIA-OT methodological cycle, as presented in this article, reveals a profound transformation in how technological evaluation is conceived and operationalized. By integrating mechanisms for reception, analysis, and the systematic application of solutions with continuous management structures for usability and interaction, the framework inaugurates a new level of technical-scientific control over complex technological artifacts.

Departing from descriptive or episodic approaches, FCIA-OT establishes an operative logic capable of supporting adaptive, configurable, and methodologically traceable interventions. Its twelve-dimensional matrix and integrated subsystems, including scoring, visual feedback, persona-based analysis, and critical scoring, enable a refined evaluation process characterized by a high degree of customization and diagnostic accuracy.

The model described herein not only consolidates the proposal's reliability but also expands its applicability across multiple domains, favoring its adoption as a technical support system for innovation, regulation, and the functional evolution of interactive systems. As a forward-looking perspective, FCIA-OT holds significant potential to integrate environments involving applied artificial intelligence, cognitive engineering, and self-adaptive systems, thereby enhancing its strategic role in contexts marked by high technological complexity.

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