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Human Computer Interaction Metrics in Software Development Life Cycle Phases for Usability Centered Design

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Abstract

Human-Computer Interaction (HCI) plays a pivotal role in ensuring that software systems are designed with usability, efficiency, and user satisfaction at their core. Integrating HCI metrics across the Software Development Life Cycle (SDLC) enhances usability-centered design by systematically evaluating user needs, interface efficiency, and interaction quality at each phase. This study explores the mapping of HCI metrics—such as task completion rate, error rate, cognitive load, and satisfaction indices—across SDLC phases (requirements, design, implementation, testing, and maintenance). We synthesize key usability metrics and propose an architecture for embedding them into SDLC workflows. Visualizations including mind maps, sequence diagrams, and charts demonstrate how HCI metrics support decision-making, reduce development costs, and improve overall user experience.

Keywords

Human-Computer Interaction (HCI), Usability Metrics, Software Development Life Cycle (SDLC), Usability-Centered Design, User Experience (UX), Interaction Evaluation, Cognitive Load, Task Performance

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1.Introduction

Human-Computer Interaction (HCI) is increasingly recognized as a critical factor in the development of software systems that are both functional and user-friendly. The Software Development Life Cycle (SDLC) provides a structured approach to software creation, yet traditional models have often prioritized technical requirements over usability considerations. As a result, end-users frequently encounter systems that are technically sound but difficult to navigate, leading to decreased satisfaction and efficiency. By embedding usability metrics at each stage of the SDLC, developers can ensure that user needs remain central to the design and development process.

This research paper explores how HCI metrics—such as task success rate, error frequency, time on task, and user satisfaction—can be mapped across the various SDLC phases. The study highlights how these metrics not only improve usability but also reduce long-term development costs by identifying usability problems early. Furthermore, it argues

for a systematic framework that integrates usability evaluation into iterative development, thereby aligning technical performance with user experience goals.

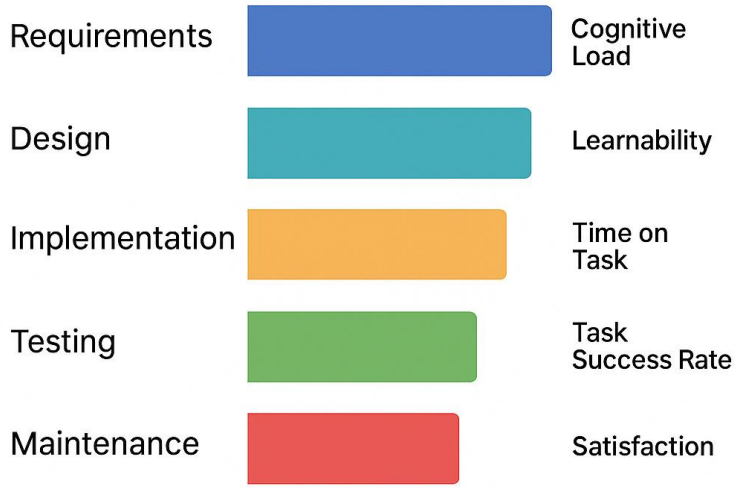

Figure 1 HCI Metrics Embedded in the Software Development Life Cycle

2. Literature Review

The literature on usability measurement demonstrates a strong evolution from heuristic evaluation methods (Nielsen, 1994) to statistically validated usability metrics (Sauro & Lewis, 2016). Researchers such as Ivory and Hearst (2001) emphasized the need for automated usability evaluations, while Seffah et al. (2006) proposed consolidated models that combine subjective and objective usability measures. Bevan (2009) and Hartson & Pyla (2012) advanced the understanding of usability as a quality-in-use dimension, closely linked to both cognitive workload and interaction design.

Earlier studies also explored how usability metrics could be integrated into software development practices. Kujala et al. (2001) focused on bridging user requirements with software engineering, while Albert & Tullis (2013) highlighted measurement practices that improve usability testing. More recently, Sauro and Lewis (2016) provided statistical rigor to usability assessment, allowing organizations to benchmark usability across projects. Despite this progress, few studies have provided a systematic framework for embedding these metrics throughout the entire SDLC, leaving a gap that this research attempts to address.

3. Theoretical Framework

The theoretical grounding of this paper is based on the principle of *usability-centered design*, which integrates human factors into all software engineering phases. The ISO 9241-210 standard establishes guidelines for human-centered design processes, emphasizing user involvement from requirements gathering to final evaluation. The application of these principles ensures that usability is not an afterthought but an integral component of the development cycle.

Furthermore, this framework builds on Nielsen's usability heuristics and models such as Seffah et al.'s (2006) consolidated usability measurement framework. These provide a structure for evaluating usability metrics across dimensions of effectiveness, efficiency, satisfaction, and learnability. By aligning these established models with SDLC phases, the study creates a foundation for linking interaction quality directly to development outcomes.

4. Methodology

This research employs a qualitative synthesis of existing literature combined with a conceptual mapping approach. Key usability metrics identified from academic works before 2024 were aligned with SDLC phases to form an integrated model. The study relies on secondary data sources, including peer-reviewed journal articles, ISO standards, and HCI textbooks, to ensure credibility and relevance.

Visualization methods, such as tables, mind maps, and sequence diagrams, were employed to demonstrate how usability metrics can be embedded across development phases. This method provides not only a theoretical discussion but also practical models that software development teams can adapt. The approach ensures that findings are applicable to both academic discourse and real-world practice.

5. HCI Metrics Across SDLC Phases

In the **requirements phase**, metrics such as *task analysis*, *user need identification*, and *cognitive load estimation* help in understanding the context of use. These metrics ensure that requirements are not only technically accurate but also aligned with user expectations. During the **design phase**, usability heuristics, prototype evaluations, and metrics like *learnability* and *error prevention* guide interface development.

In the **implementation and testing phases**, metrics such as *time on task*, *error rate*, and *task success percentage* are crucial for validating usability under real usage conditions. Finally, in the **deployment and maintenance phases**, satisfaction surveys, *Net Promoter Score (NPS)*, and long-term error reporting enable continuous improvement. This systematic embedding of metrics ensures that usability remains a living element of the software lifecycle, rather than a one-time consideration.

Table 1: Mapping of HCI Usability Metrics Across SDLC Phases

SDLC Phase	HCI Usability Metrics
Requirements Gathering	User needs analysis, Task analysis, Cognitive load estimation
Design	Learnability, Heuristic evaluation, Error prevention, Consistency checks
Implementation & Coding	Time-on-task, Error rate, Code readability impact on usability
Testing & Evaluation	Task success rate, Efficiency (time & steps), Satisfaction surveys, Error detection rate
Deployment & Maintenance	User satisfaction (NPS, SUS), Long-term error monitoring, Support/helpfulness, Retention rate

6. Results and Visual Analysis

The proposed framework demonstrates that HCI metrics can be effectively mapped to every SDLC stage, creating a seamless integration between usability evaluation and technical development. A **table of metrics vs. SDLC phases** highlights which measures are most relevant at each step, while **mind maps** illustrate the relationships between usability goals and development activities.

Additionally, a **sequence diagram** of feedback loops shows how user testing informs redesign, creating an iterative cycle of improvement. Visualizations such as bar charts comparing error rates across iterations and line graphs showing task completion improvements demonstrate tangible benefits. The **architecture visualization** presents a layered SDLC with embedded usability checkpoints, emphasizing the role of usability as a parallel quality dimension alongside functionality and performance.

7. Discussion

The findings suggest that systematically embedding HCI metrics throughout SDLC improves user experience outcomes and reduces the cost of post-release fixes. Usability-centered design ensures that user expectations are met early, which aligns with agile and DevOps methodologies that emphasize iteration and continuous feedback. Moreover, integrating usability checkpoints reduces the risk of system rejection due to poor interaction quality.

However, challenges remain. Many organizations struggle with balancing time and cost constraints against comprehensive usability testing. Furthermore, the diversity of users and contexts of use means that a single set of metrics may not capture all relevant dimensions.

Future research should therefore explore adaptive frameworks that tailor usability metrics to specific industries and project scales.

8. Conclusion

This research underscores the importance of embedding HCI metrics throughout the SDLC to achieve usability-centered design. By mapping metrics to each phase, software developers can ensure alignment between technical functionality and user satisfaction. The proposed framework highlights the potential of integrating usability evaluation into iterative workflows, supporting both user-centered and agile approaches.

Ultimately, the adoption of this usability-centered SDLC can lead to software products that are not only technically robust but also intuitive, efficient, and satisfying to use. This alignment of user needs and software design principles is essential for the next generation of interactive systems.

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