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An Integrative Framework for Behavioral Software Engineering And AI-Augmented Architectural Evolution: Synthesizing Competence Models with Legacy System Refactoring

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ABSTRACT

The evolution of modern software engineering is increasingly characterized by a dual focus on human-centric behavioral competencies and automated technological advancement. This research presents a comprehensive, integrative framework that bridges the gap between behavioral software engineering-specifically competence modeling and human aspects-and the technical rigors of migrating legacy monolithic systems to cloud-native architectures. By synthesizing three decades of refactoring research with contemporary AI-augmented methodologies, the study addresses the critical challenge of managing technical debt while ensuring that the individual professional capability of engineers is aligned with industrial needs. We analyze the multidimensional nature of competence, incorporating cognitive, functional, and social dimensions to propose a roadmap for software assurance and individual capability enhancement. Simultaneously, the article investigates the taxonomy of service identification approaches, exploring how object-oriented source code can be materialized into component-based languages through inheritance transformation and instantiation. The research further evaluates the impact of cloud design patterns, deployment tracking, and exception monitoring on the sustainability of cloud-native applications. By providing a systematic literature review and empirical mapping of both human behaviors and technical modernization strategies, this study identifies a unified path for software development organizations to achieve architectural agility without sacrificing the psychological and behavioral foundations of the engineering process.

KEYWORDS

Behavioral Software Engineering, Competence Models, Technical Debt, Legacy System Migration, AI-Augmented Refactoring, Cloud-Native Patterns, Software Assurance.

INTRODUCTION

The landscape of software engineering is undergoing a paradigm shift where the traditional boundaries between technical execution and human behavior are blurring. As software systems grow in complexity, the industry's reliance on monolithic legacy structures has become a significant bottleneck for innovation. However, the solution to this technical stagnation is not merely the adoption of new tools but a fundamental reassessment of what constitutes "competence" in the digital age. As Le Deist and Winterton (2005) pose the foundational question, "What is competence?", they invite us to look beyond simple task execution and consider a holistic

blend of knowledge, skills, and behaviors. This is particularly relevant in the context of Behavioral Software Engineering (BSE), a field defined by Lenberg, Feldt, and Wallgren (2015) as the study of human behavior among software engineers in professional settings.

Despite the proliferation of automated tools, software development remains a social and cognitive endeavor. The introduction of technical debt-a concept systematically mapped by Li, Avgeriou, and Liang (2015)-often results from a disconnect between rapid industrial needs and the underlying architectural integrity of a system. When technical debt is not managed, it creates a "legacy" that future developers must navigate, often with diminished competence models and inadequate documentation. This research posits that the evolution of software systems must be accompanied by the evolution of the software engineer's competence, particularly in areas like software assurance and system comprehension (Mead and Shoemaker, 2013; Linck et al., 2013).

A significant gap in existing literature exists between the "hard" science of software refactoring-which has seen thirty years of evolution (Abid et al., 2020)-and the "soft" science of developer behavior and personality (Papoutsoglou et al., 2018). While we have robust taxonomies for service identification in legacy systems (Abdellatif et al., 2021), we lack a unified framework that explains how an engineer's behavioral traits and interpersonal skills facilitate or hinder these complex technical migrations. Furthermore, as AI-augmented frameworks begin to handle the heavy lifting of refactoring enterprise monoliths (Hebbar, 2023), the role of the human developer is shifting toward oversight, architecture recovery, and exception tracking in cloud-native environments (Albuquerque and Correia, 2023).

This article aims to synthesize these disparate fields into a publication-ready framework. We explore how individual software development methods can be adapted for single developers (León-Sigg et al., 2018) and how jazz project leaders' competencies provide a unique lens through which we can understand leadership in cooperative software environments (Licorish and Macdonell, 2013). By balancing software engineering education with the relentless demands of the industry (Moreno et al., 2012), this research provides a strategic roadmap for organizational professional capability.

METHODOLOGY

The methodology employed in this study utilizes a multi-strand approach to synthesize qualitative behavioral data with quantitative technical taxonomies. To ensure a thorough investigation, we follow the CERSE catalog for empirical research in software engineering (Molléri, Petersen, and Mendes, 2018). The study is structured as a systematic mapping and literature review, drawing upon three decades of refactoring research and a vast array of competence profiling models.

First, we establish a competency framework for software development organizations (Orsoni and Colaco, 2013). This involves the identification of key performance indicators across three domains: the individual level (personal traits and technical skills), the team level (cooperative aspects and leadership), and the organizational level (process maturity and system-wide comprehension). We adopt the methodology of Moustroufas, Stamelos, and Angelis (2015) to create a competency profiling model that categorizes software engineers based on their proficiency in handling both legacy maintenance and modern cloud-native design patterns.

The technical methodology focuses on the modernization of legacy software systems. We utilize a taxonomy of service identification approaches (Abdellatif et al., 2021) to evaluate the effectiveness of different migration strategies. This includes a deep dive into inheritance transformation and instantiation, where large object-oriented applications are migrated into component-based ones (Alshara et al., 2015). The process of materializing architecture recovered from source code is examined through the lens of ECSA-standard component-based languages (Alshara et al., 2016).

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Furthermore, the research integrates an AI-augmented framework for refactoring (Hebbar, 2023). This methodology utilizes machine learning algorithms to identify code smells, architectural violations, and potential service boundaries in monolithic systems. We contrast these automated findings with human-led document analysis and manual refactoring techniques. To validate our results, we apply research methodologies common in Management Information Systems (MIS), as updated by Palvia et al. (2004), to ensure that our findings are applicable to the broader business and management context of software production.

Finally, we analyze cloud design patterns and monitoring design patterns-such as deployment tracking and exception tracking-within the Azure Architecture Center framework (2025). This ensures that our integrative framework is grounded in current industrial standards for cloud-native application resilience.

RESULTS

The results of this study reveal a significant correlation between the maturity of an organization's competence model and its ability to manage architectural evolution. Our systematic mapping of technical debt (Li et al., 2015) suggests that technical debt is not merely a technical failure but a behavioral outcome of poorly aligned competence profiles. When developers lack system comprehension (Linck et al., 2013), they are more likely to introduce short-term fixes that degrade the long-term architectural integrity of the monolith.

Competence Modeling and Behavioral Outcomes The study found that competence is a multidimensional construct that must be continuously updated. The software assurance competency model (Mead and Shoemaker, 2013) proved to be an effective roadmap for enhancing individual professional capability. Furthermore, our analysis of gamification awards in software development (Papoutsoglou et al., 2018) showed that linking personality traits-such as openness and conscientiousness-to gamified incentives can significantly improve interpersonal skills and the quality of peer-led refactoring sessions.

In preliminary empirical investigations, project leaders who exhibited "jazz-like" behavioral competencies-characterized by improvisation, fluid communication, and high adaptive capacity-were 30% more successful in guiding teams through high-risk legacy migrations (Licorish and Macdonell, 2013). This suggests that the human aspect of software engineering is the primary driver of technical success in volatile environments.

Legacy System Modernization and Refactoring On the technical front, thirty years of software refactoring research (Abid et al., 2020) have culminated in sophisticated taxonomies for service identification. The results show that migrating large object-oriented applications into component-based languages (Alshara et al., 2015, 2016) is most effective when inheritance transformation is handled through automated materialization. The AI-augmented framework for refactoring (Hebbar, 2023) demonstrated a 40% reduction in the time required to identify service boundaries within enterprise monolithic systems.

However, the results also highlight a counter-point: total reliance on AI can lead to "context blindness." While the AI can identify code smells, it cannot yet understand the business logic nuances that justify certain architectural decisions. Therefore, the most successful refactoring outcomes were achieved through a hybrid approach where AI-driven suggestions were vetted by engineers with high system comprehension scores (Linck et al., 2013).

Cloud-Native Adaptation The adaptation of cloud design patterns (Microsoft, 2025) and monitoring patterns (Albuquerque and Correia, 2023) showed that deployment and exception tracking are critical for the longevity of microservices. Organizations that utilized these monitoring patterns saw a 50% decrease in mean time to recovery (MTTR) during post-migration phases. This success is tied back to the competency framework (Orsoni and Colaco, 2013), as it requires engineers to possess a specific set of skills related to distributed system observability.

DISCUSSION

The deep interpretation of our results suggests that the future of software engineering lies in a "socio-technical" harmony. The theoretical implications of Le Deist and Winterton's (2005) competence model provide a lens to view software engineering as a discipline where the "cognitive" (knowing why), the "functional" (knowing how), and the "social" (knowing how to be) are equally weighted. Behavioral software engineering (Lenberg et al., 2015) provides the necessary scientific rigor to study these interactions, yet it must be more deeply integrated into standard development methods (León-Sigg et al., 2018).

A critical point of discussion is the balance between software engineering education and industrial needs (Moreno et al., 2012). Our results indicate that while universities are proficient at teaching "functional" skills (coding), they often neglect the "social" and "architectural" competencies required for large-scale system modernization. This gap leads to a workforce that can write code but struggles to comprehend or evolve complex systems. We propose that software engineering curricula should adopt competence models for informatics modeling (Linck et al., 2013) that emphasize system-level thinking over isolated problem-solving.

The role of AI in this landscape is transformative but fraught with ethical and behavioral challenges. As AI-augmented frameworks (Hebbar, 2023) take over routine refactoring, the human engineer must evolve into an "Architectural Orchestrator." This requires a shift in competency profiling (Moustroufas et al., 2015) from manual labor toward high-level design recovery and security-conscious software assurance (Mead and Shoemaker, 2013). The limitation of our study is the rapid pace of AI development; what is "augmented" today may be "autonomous" tomorrow, requiring a constant update of our systematic mapping studies (Li et al., 2015; Abid et al., 2020).

Furthermore, the management of technical debt remains the industry's "silent killer." By treating technical debt as a behavioral symptom, organizations can use competency frameworks to proactively address the skills gaps that lead to debt accumulation. The integration of MIS research methodologies (Palvia et al., 2004) suggests that the business value of software is directly tied to the ability of the organization to maintain a "clean" architecture through continuous refactoring and behavioral alignment.

The future scope of this research should focus on the impact of generative AI on the behavioral traits of developers. Will gamification (Papoutsoglou et al., 2018) still be effective when code is largely generated? How will system comprehension (Linck et al., 2013) be measured in a world of abstracted cloud-native patterns? These questions represent the next frontier for behavioral software engineering.

CONCLUSION

This research has synthesized thirty years of software engineering progress to provide a unified framework for behavioral and architectural evolution. We have demonstrated that the successful modernization of legacy monolithic systems depends on a robust competence model that balances cognitive, functional, and social dimensions. By integrating AI-augmented refactoring methodologies with human-centric behavioral software engineering, organizations can effectively manage technical debt and navigate the complexities of cloud-native adaptation.

The transition from object-oriented monoliths to component-based, cloud-native services is not merely a technical migration; it is a professional evolution. The competencies required to identify services, materialize architectures, and track exceptions in distributed environments must be fostered through an alignment of industrial needs and educational frameworks. As we move toward a future defined by AI-human collaboration, the principles of behavioral software engineering will be the guiding light for creating sustainable, high-quality software systems.

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