Cost Estimation for Agile Software Development in Small and Medium-Sized Enterprises

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*Abstract. **Problem Statement:** The adoption of agile methodologies combined with financial management and cost estimation presents a significant challenge for small and medium-sized enterprises (SMEs). **Methods:** A systematic literature review was conducted to identify key challenges in cost estimation, strategies to address them, and tools used. Based on this, the application of estimation models in agile environments is analysed. **Results:** A specific cost estimation model for SMEs is developed, along with practical guidelines for its implementation. This study contributes to improving financial management in agile environments by promoting practices aligned with the needs of SMEs.*

*Resumo. **Problema:** A adoção de metodologias ágeis combinada com a gestão financeira e estimativa de custos representa um desafio significativo para pequenas e médias empresas (PMEs). **Métodos:** Foi realizada uma revisão sistemática da literatura para identificar os principais desafios na estimativa de custos, estratégias para superá-los e ferramentas utilizadas. A partir disso, analisou-se a aplicação de modelos de estimativa em ambientes ágeis. **Resultados:** Será desenvolvido um modelo específico de estimativa de custos para PMEs, acompanhado de diretrizes práticas para sua implementação. Este estudo contribui para a melhoria da gestão financeira em ambientes ágeis, promovendo práticas alinhadas às necessidades das PMEs.*

Para uma demonstração visual completa dos conceitos discutidos, o leitor é convidado a acessar o vídeo complementar de até 5 minutos disponível em: https://www.youtube.com/watch?v=1V_hiLzf0gI

1. Introduction

Agile methodologies have gained significant traction among Small and Medium-sized Enterprises (SMEs) within the software sector, primarily due to their adaptability and emphasis on continuous value delivery [Rindell et al. 2021]. Nevertheless, the iterative and evolving characteristics inherent to agile approaches pose substantial challenges for accurate cost estimation, particularly for resource-constrained SMEs .

Given the scarcity of specialized cost estimation models tailored to SME contexts, project predictability and financial management remain hindered. This research proposes a dedicated cost estimation model for agile projects in SMEs, guided by the

Goal-Question-Metric (GQM) framework [Van Solingen and Berghout 1999]. The study addresses the research question: *"How do agile software development companies estimate project costs?"*

The proposed model aims to facilitate reliable cost estimation, enhancing financial oversight amidst the dynamic conditions typical of agile development in SMEs.

2. Theoretical Framework

Economic models are fundamental for cost optimization and financial sustainability in software management [Lee 2021]. Key models include subscription, perpetual licensing, and SaaS, each with distinct financial effects. Subscription and SaaS provide flexibility and recurring revenue, while perpetual licensing requires substantial upfront investment. Cloud-based SaaS further reduces hardware costs and automates updates. Rigorous cost-benefit analysis is essential for aligning model selection with organizational needs.

The Constructive Cost Model (COCOMO), a foundational cost estimation method [Boehm et al. 1995], features basic, intermediate, and detailed variants that incorporate project and environmental factors. COCOMO II updates the model for modern development practices.

Within agile frameworks, Story Points estimate effort, complexity, and uncertainty using relative scales like the Fibonacci sequence [Choudhari and Suman 2012], improving estimation accuracy and delivery speed, and serving as a key tool for task planning.

3. Related Work

Cost estimation in agile project management remains a significant challenge due to the lack of models tailored to agile-specific traits. Traditional methods like Planning Poker and Use Case Points are still widely used, supported by accuracy metrics such as MMRE and MRE, but human and contextual factors—such as team experience and task size—heavily impact estimates [Fernández-Diego et al. 2020].

Systematic reviews indicate a dominance of expert judgment and Story Points techniques, with a growing trend towards data-driven methods. Nevertheless, estimation accuracy varies, emphasizing the necessity for rigorous validation [Usman et al. 2014, Fernández-Diego et al. 2020]. Integration of DevOps practices extends estimation to operational phases, enhancing accuracy through lifecycle metrics [Robles et al. 2023].

Key sources of inaccuracies include information noise, flawed assumptions, and scope changes. Taxonomies of methods and best practices help structure factors influencing estimation success [Pasuksmit et al. 2024].

While traditional COCOMO remains effective for some datasets, its reliance on lines of code limits applicability in distributed and SOA-based projects, where architectural complexity demands more sophisticated models [Putri et al. 2021, Khan et al. 2021, Alanazi et al. 2019].

4. Research Methodology Overview

This study adopts a two-step research design combining a Systematic Literature Review (SLR) and the proposal of a cost estimation model tailored for SMEs in agile

environments. Following the Evidence-Based Software Engineering (EBSE) guidelines [Kitchenham et al. 2010], the methodology is structured as follows:

4.0.1. Step 1 — Systematic Literature Review (SLR)

The SLR investigated key challenges, strategies, and methods in agile software cost estimation. Data were collected from major databases (ACM, IEEE, ScienceDirect, Scopus, Springer) using the search string: *(Cost estimation" OR Cost prediction" OR Cost assessment" OR Cost calculation") AND (Challenges" OR Difficulties" OR Limitations") AND (Agile methods" OR "Agile methodologies").*

After deduplication with Parsifal [Parsifal 2018], a three-stage screening—title, abstract, and full-text—was applied to select studies according to predefined criteria.

Research Questions:

- **RQ1** — Identification of the primary challenges faced by software development firms in project cost estimation?
- **RQ2** — Examination of the predominant strategies employed to overcome these challenges?
- **RQ3** — Analysis of the most frequently utilized cost estimation methods?

4.0.2. Step 2 — Estimation Model Proposal

Insights from the SLR informed the development of a cost estimation model specifically adapted to SMEs operating in agile environments. This phase focuses on:

- Evaluating the integration impact of existing cost estimation models within agile software development settings.
- Tailoring established models, such as Planning Poker and COCOMO II, to the needs of SMEs.
- Defining critical variables—including time, labor, materials, equipment, and financial resources—to enhance cost forecasting accuracy.
- Constructing a customized cost estimation model aimed at improving estimation precision in agile projects for SMEs.

Model effectiveness will be assessed according to established evaluation criteria [Van Solingen and Berghout 1999], emphasizing:

- **Estimation Accuracy:** measured by the mean percentage error between estimated and actual costs, with a target deviation below 15%.
- **Process Efficiency:** evaluated by a minimum 20% reduction in estimation time.
- **Financial Control:** monitored through budget variance, aiming for less than 10% deviation.
- **Managerial Satisfaction:** targeting at least 80% approval regarding the model's practical applicability.

Findings from the Systematic Literature Review

The systematic literature review revealed that Machine Learning (ML) [Ramessur and Nagowah 2021], Expert Judgment (EJ) [Butt et al. 2023], and Story Points (SP) [Komala et al. 2023] are the predominant methods used to improve cost estimation accuracy in agile SMEs.

Commonly applied strategies include Historical Data Analysis [Gandomani et al. 2019], Continuous Validation [Butt et al. 2023], Project Adjustment, and AI-based models. Nevertheless, challenges persist, such as dependence on Expert Judgment [Arora et al. 2022], frequent requirement changes [Butt et al. 2023], and limited historical data [Najm et al. 2023], which undermine estimation reliability.

Classical models like COCOMO and Function Point (FP) Analysis remain relevant, often adapted to agile contexts and combined with contemporary techniques to enhance estimation practices [Rodríguez Sánchez et al. 2023].

Future research should investigate the influence of agile team maturity on estimation accuracy and develop hybrid frameworks integrating traditional and agile methodologies to support SMEs in cost management.

5. Research Progress

The study developed a cost estimation model tailored for SMEs, integrating variables like time, labor, materials, equipment, and financial resources, alongside guidelines for organizational adaptation.

The influence of agile methodologies on project management and cost estimation was analyzed, leading to scientific papers under submission. Current research focuses on validating the model by benchmarking it against traditional approaches such as Licensing, Perpetual Licensing, and SaaS across various projects and teams.

Stages:
- **Model Development and Application:** Targeting SME needs with critical variables; simulations are ongoing with hypothetical scenarios.
- **Testing and Validation through Simulations:** Due to lack of real project data, validation employs simulated agile SME scenarios [PRODAM-SP 2024, Tawosi et al. 2022], varying project size, team composition, requirement volatility, and risk.
- **Model Validation:** Benchmarking against expert judgment, COCOMO II, and Story Points to assess accuracy, efficiency, financial control, and managerial satisfaction.
- **Dissertation Writing:** Documenting methodologies, results, and impact analysis.
- **Dissertation Defense:** Scheduled within 9 to 12 months, presenting findings and contributions.

The objective is to validate the model and advance both theoretical and practical knowledge, particularly benefiting SMEs.

6. Conclusion

This study has advanced a cost estimation model tailored for SMEs, incorporating key variables and practical implementation guidelines. It analyzes the impact of agile methodologies and adapts existing models like Planning Poker and COCOMO II to improve accuracy.

The potential integration of AI is explored to enhance scalability and adaptability in agile contexts. Although validation is ongoing, preliminary results indicate improved estimation accuracy compared to traditional methods.

Future work includes broader validation, AI integration, and linking the model to digital management tools to boost applicability. Overall, this research aims to strengthen cost management in SMEs, supporting their competitiveness and strategic planning.

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