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The Impact of Software Development Practices, Process Efficiency, and End-User Communication on Software Quality

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ABSTRACT

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This study investigates the impact of software development practices, process efficiency, and end-user communication on software quality. The population of the study consists of software development professionals and managers working in diverse technological and organizational contexts across Pakistan, the United Arab Emirates (UAE), and Qatar. The population includes back-end engineers, technology consultants, project managers, and software quality assurance experts who are actively involved in software development and quality improvement processes. The sample for the study is drawn from this population, targeting approximately 300 professionals using a non-probability purposive sampling strategy. The study found that software development practices have the most significant positive impact on software quality, followed by process efficiency and end-user communication. It was found that these relationships were strong, and all hypotheses were supported. This study extends the existing literature by providing a holistic framework in connecting these factors together and illustrating their collective roles in increasing software quality. This research is novel in its integrated approach, in which the relationship between software development practices, process efficiency, and end user communication is emphasized.

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1.0 Introduction

Software quality is a well-known cornerstone of successful software engineering and good quality is necessary for robust functionality, reliability and performance of software systems. The need for innovative and efficient software solutions is growing rapidly in industries and therefore, high quality of software is imperative (Licorish, 2024). Software development lifecycle is a complex phenomenon involving practices, tools, methodologies and human interaction that influence the quality of the software product. These elements also relate to the technical robustness of the software, as well as to the alignment of software deliverables to user expectations (Gunatilake et al., 2024). However, aligning software engineering practice has been a continuously challenging and meriting a deeper look at how these variables are coupled and their joint effect on software quality (Bakar, 2024).

The process of developing a software system from the beginning, design, testing to deployment using a spectrum of methodologies and techniques by developers. Other such approaches include the agile development, integration, continuous delivery, automated testing which helps to improve adaptability, shorten the development cycle and improve collaboration among all stake holders (Nguyen & Weber, 2024). On the contrary, process efficiency is about how the software development process minimizes resource wastage, optimizes the work flow and stay on time. Efficient processes enable delivery of superior software quality, mitigating delays, lowering costs, increasing productivity. In software engineering, the often under estimated dimension of end user communication concerns with the mechanisms that developers use to communicate with users to help with their understanding of needs, give them support, and obtain their feedback throughout the software life cycle (Ajiga et al., 2024). Early engagement of end users in development implies that the final product satisfies end user expectations and the absence of usability problems lead to end user satisfaction. These variables, taken together, form a multidimensional framework for the study of the determinants of software quality (Adesina et al., 2024).

The relationships between software development practices, process efficiency and end user communication are intricately intertwined with one another and determine the outcomes of software projects. Development practices that work by their nature produce efficient processes that eliminate redundancy and shorten workflows. For example, agile methodologies focus on iterative development so that teams can quickly change to new requirements and so can increase both efficiency and quality (Arponen, 2024). Additionally, building strong communication channels with end users allows their growing needs and concerns to be embedded into the development process, so that we deliver something that doesn’t create misalignment. Socio technical system theory and systems thinking serve as theoretical frameworks through which to understand these interactions (Pargaonkar, 2023b). The theory of socio technical systems proposes that organizational outcomes, such as software quality, depend largely on the interaction between social and technical subsystems. However, systems thinking recognizes the holistic nature of these relationships, and that changes in one dimension will affect other dimensions, often requiring a holistic approach to improvement in software quality (Gregoriades & Sutcliffe, 2024).

Although there is a growing body of literature on software engineering, there are still significant research gaps when it comes to understanding how these variables affect one another to create software quality. Existing studies typically take a siloed approach analyzing aspects in isolation (e.g., process efficiency, communication) while ignoring their combined impact (Pargaonkar, 2023a, 2023b). In addition, the significance of end user communication has been acknowledged, but little empirical studies have been conducted into the mechanisms of this form of communication and its effect on software quality (Sun et al., 2023). However, the development of comprehensive strategies for improving software quality is constrained by the lack of integrative models that consider interdependencies among these variables. Furthermore, the relationships between these guidelines and the dynamic nature of software development, characterized by the fast-changing technologies and methods, require constant reassessment to reflect their applicability to the current practice.

This study is driven by the research problem that current empirical studies have not integrated the knowledge of how different software development practices and process efficiency, as well as end user communication, impact software quality. Each of these factors has been studied independently, but their relationships with one another and their combined effects have not been studied. This gap in the literature prevents software development teams from using holistic approaches that address several aspects of software quality in parallel. Furthermore, there is little empirical evidence on how these relationships work, which hinders the ability to develop actionable insights for practitioners and policymakers alike to avoid or mitigate the suboptimal practices prevalent in the industry.

This study is important as it may be able to bridge these research gaps and add to both theoretical and practical developments in software engineering. This research seeks to develop a general framework to understand how these development practices, process efficiency, and end user communication collectively affect software quality, by looking at the interplay between these three factors. The results are expected to guide the design of integrated methodologies that improve software quality encompassing its technical, procedural and user-centric aspects. This study also aims to contribute to the theoretical discourse by extending the socio technical systems theory to the area of software development and adding new insights on the multiple determinants of software quality. This research provides evidence-based strategies for practitioners and organizations to improve development processes, promote communication, and produce software that satisfies or exceeds user needs. This study therefore seeks to improve the state of knowledge in software engineering and encourage the creation of high-quality software systems in a rapidly evolving and competitive arena.

2.0 Literature Review

2.1 Theoretical Background

Socio technical systems theory (Appelbaum, 1997) provides the basis for understanding the relationship between software development practices, process efficiency, end user communication and software quality. It asserts that organizations are comprised of interrelated social and technical subsystems which, if aligned, contribute to the desired organization outcomes.

For the purposes of software development, the technical subsystem represents tools, methodologies and technologies; the social subsystem consists of human interactions, team dynamics and stakeholder engagement. All of these subsystems are synchronized, and when synchronized they result in optimized processes and outcomes like improved software quality (Baxter & Sommerville, 2011). As it is, systems thinking reinforces this view by suggesting that the software development is an ever-changing process that is affected by a number of interrelated forces (Senge, 1990). This thesis presents the theoretical underpinnings that serve as a lens for studying the relationship between development practices, process efficiency and end user communication and how they affect software quality.

2.2 Empirical Evidence

Empirical studies recently conducted emphasize the crucial role of software development practices in enhancing software quality (Alam et al., 2024). Specifically, agile methodologies have been widely documented for their enhancement of quality resulting from Iterative development (Conboy, 2009), collaborative environment, and continuous feedback. Finally, as reported by Highsmith and Cockburn (2001), we found that agile practices increase the adaptability to the changing requirements, resulting in better alignment with user needs and better software quality. Similarly, DevOps integration has become an innovative methodology of integrating development and operations teams to work in a seamless manner, reducing deployment time, and increases the reliability. (Ebert et al., 2016) Testing automation and continuous integration pipelines guarantee quality at the early stages of the software delivery process (Rafi et al., 2012).

Another area of great interest in software quality research has been process efficiency. Research indicates that efficient processes result in less wastage of resources, lower development costs, and fewer delays that lead to high quality software outcomes. As an example, Petersen and Wohlin (2010) proved that lean software development principles minimize the waste and maximize the value, resulting in better software quality metrics. In addition, good practices in project management, for example good scheduling, resource allocation and management of risks, lead to better overall project outcomes, for example, better quality (Kerzner, 2017).

It is more and more understood that end-user communication is a key determinant of software quality (Basri et al., 2024). The exploration of research emphasizes the significance of involving end users in the entire lifecycle of software development in order to collect realistic requirements, confirm assumptions and solve usability problems (Bano et al., 2019). Kujala's (2003) studies stress that early and frequent involvement of end-users in the development process leads to much more usable and accepted final product. Macaulay et al. (1990) also conducted research that showed that methods for effective communication between teams (surveys, interviews, and feedback loops, etc.) improve user satisfaction and software quality. Tools like user personas, journey mapping and prototyping are integrated to enrich the communication process and it’s ensured that the software matches user expectations.

Though these advances have been made, there are still gaps in knowledge concerning how such variables interact with each other to affect software quality. However, most of the existing research focuses on individual dimensions, e.g., agile practices or end user engagement, without considering how they interact with each other. For example, the benefits of process efficiency have been widely documented, but how such efficiencies impact communication practices and the quality of software have been overlooked by studies. Additionally, the effect of end user communication mechanisms in the agile and DevOps environments has been neglected, thus filling the literature gap.

2.3 Hypothesis Development

This study based on the theoretical and empirical evidence proposes several hypotheses to examine the complex interrelationships among software development practices, process efficiency, end user communication, and software quality. In the first, it is hypothesized that software development practices directly affect software quality in a positive way. The reason is empirical as agile methodologies, DevOps integration and automation enhance software reliability and usability (H1). Second, process efficiency is posited to serve as a mediating variable on the relationship between software development practices and software quality. High quality outcomes are created in such an environment where redundancies are minimized and resource allocation is optimized (H2). Third, it is hypothesized that effect of end user communication on software quality is significant (H3).

3.0 Methodology

The methodology of this study is to rigorously investigate the relationships between software development practices, process efficiency, end user communication and software quality. The study uses a quantitative design based on the positivist philosophical paradigm that entails use of structured methods and empirical data to test hypotheses and explain cause and effect relationships. Given that the study aims to measure defined constructs and examine their interconnection, appropriate is the approach used in this study.

The sample of the study includes software development professionals and managers working in various technological and organizational contexts in Pakistan, the United Arab Emirates (UAE) and Qatar. This selection reflects the expertise of the potential authors, ensuring that the research leverages their familiarity with both regional and international practices in the software industry. Back-end engineers, technology consultants, project managers and software quality assurance experts develop and improve software and quality through active participation in software development and quality improvement processes. Due to the global nature of the industry, this population can provide insights that are applicable at different technological and cultural levels.

From this population, the sample for the study is drawn using a non-probability purposive sampling strategy targeting approximately 300 of the professionals. This way also enables the inclusion of participants with experience and expertise in software development, process optimization and end user communication. In this case, purposive sampling is very appropriate as it concerns individuals whose opinions are very important for the realization of the research objectives. An attempt is made to include a balanced representation from different roles, organizations and geographic locations, so that the findings are more generalizable.

A structured survey questionnaire is used to collect data on the key constructs of the study.

The questionnaire consists of validated scales adapted from prior research (reliability and validity). For example, items used in measuring software development practices are derived from Highsmith and Cockburn's (2001) agile development framework; and process efficiency is measured using lean development metrics from Petersen and Wohlin (2010). Communication with end users is measured with items adapted from Kujala (2003) and software quality is assessed with established quality dimensions such as reliability, functionality and usability. The survey is conducted online and is distributed to participants across the regions of interest based on the professional networks of the authors.

A Partial Least Squares Structural Equation Modeling (PLS-SEM) is used to analyze data to explore the complex relationships among latent variables. Using PLS-SEM, we are able to estimate the measurement models and the structural models simultaneously, gaining insights into both the reliability and validity of the constructs as well as the strength and direction of their relationships. The technique is particularly appropriate to the study as it allows for the exploratory nature of the research and the relatively small sample size relative to covariance-based SEM approaches. SmartPLS software is used to perform this analysis, and results are interpreted by the theoretical framework and the relevant prior literature.

The study follows the highest ethical standards which make the research process intact and credible. The participants are given detailed information about the purpose of the study, the procedures in the study, and their rights, in which they have indicated those rights to withdraw at any time without penalty. Data are stored securely and participants are anonymized, and data are used only with informed consent. The ethics committees of institutions and organizations involved review and approve the research protocol, in accordance with the ethical guidelines and local regulations. This study attempts to provide meaningful insight to the field of software engineering by incorporating rigorous methodological design with ethical considerations.

4.0 Findings and Results

4.1 Measurement Model

The reliability analysis confirms that all the constructs possess high internal consistency and convergent validity. The Cronbach's Alpha values of Software Development Practice (0.87), Process Efficiency (0.83), End User Communication (0.85) and Software Quality (0.88) show that each construct has more than 0.70, indicating that the items within each construct are closely aligned and consistently measure the dimensions underlying their constructs. Furthermore, Composite Reliability (CR) scores, indicating the strong internal consistency of this measure are 0.88 – 0.91. The CR values are greater than the threshold recommended value of 0.70 and confirm the reliability of the constructs by taking into consideration the variance shared by their indicators. Convergent validity is validated using the Average Variance Extracted (AVE) for all constructs, which are over 0.50 indicating that the variance in their measurement items is explained by more than 50% of variance due to the respective construct. Software Quality has the highest AVE (0.69), followed by End User Communication (0.67), Software Development Practices (0.65) and Process Efficiency (0.63). These results ensure that the constructs are well defined and that they measure the constructs well. Together the high values of Cronbach's Alpha, CR, and AVE indicate the reliability and validity of the measurement model, and there for the constructs can be thought to be robust to test the hypothesized relationships in the study.

Table 4.1: Reliability Analysis

Construct	Cronbach's Alpha	Composite (CR)	Reliability Average (AVE)	Variance	Extracted
Software Development Practices	0.87	0.90		0.65	
Process Efficiency	0.83	0.88		0.63	
End-User Communication	0.85	0.89		0.67	
Software Quality	0.88	0.91		0.69	

The discriminant validity of the constructs in the measurement model is also validated by the results of the Heterotrait-Monotrait (HTMT) Ratio since each construct is different from the other constructs. HTMT values lower than 0.85 are considered acceptable for discriminant validity, and the degree of similarity between constructs is assessed. In this analysis, all HTMT values are below the threshold; the constructs are not only distinct but specified appropriately within the model. The HTMT values between Software Development Practices and other constructs (0.65 for Process Efficiency, 0.58 for End User Communication, and 0.62 for Software Quality) confirm that Software Development Practices is uniquely defined in relation to these other constructs. Similarly, values of 0.59 and 0.63 for End User Communication and Software Quality respectively suggest that Process Efficiency is different from other constructs. HTMT values of 0.60 are also seen between End-User Communication and Software Quality. Together, these values indicate that all constructs have strong discriminant validity with no overlap beyond what is required.

4.2 Validity Analysis (HTMT Ratio)

4.2 Validity Analysis (HTMT Ratio)

Constructs	Software Practices	Development	Process Efficiency	End-User Communication	Software Quality
Software Development Practices	-				
Process Efficiency	0.65		-		
End-User Communication	0.58		0.59	-	
Software Quality	0.62		0.63	0.60	-

4.3 Multicollinearity Analysis

A Variance Inflation Factor (VIF) analysis shows the absence of multicollinearity among the constructs in the model as all VIF values are below the commonly accepted threshold of 5. The VIF values are the highest for Software Development Practices (1.43), Process Efficiency (1.37) and End-User Communication (1.35). These values show that the predictors in the model are not too collinear indicating that each construct makes an independent contribution to the explanation of variance in the dependent variable. The low VIF values add to the strengthened robustness and interpretability of the model by confirming that the structural equation modeling results are reliable with no concern of multicollinearity among the variables.

4.3 Variance Inflation Factor (VIF) Table

Construct	VIF Value
Software Development Practices	1.43
Process Efficiency	1.37
End-User Communication	1.35

The results of the fit indices on the proposed structural model show that the proposed structural model fits well. While the fit is excellent, as shown by the **Standardized Root Mean Square Residual (SRMR) value of 0.07, which is well below the 0.08 threshold**. Moreover, the value of **Normed Fit Index (NFI)** of 0.92 has surpassed a threshold of 0.90 for sufficient model fit. The model overall goodness of fit is determined from the **Chi-square (χ^2) value of 175.23**, along with **85 degrees of freedom**, but remember that the Chi-square test is sensitive to sample size. As the associated **p-value** = 0.001 then the model is statistically significant and thus the hypothesized relationships are indeed valid. Together, these fit indices indicate that this model is a good fit for the data and, thus, is appropriate for further analysis.

4.4 Model Fit

Table 4.4. Model Fit Indices

Fit Indices	Value	Threshold
SRMR	0.07	< 0.08 (Good Fit)
NFI	0.92	> 0.90 (Good Fit)
Chi-square (χ^2)	175.23	-
Degrees of Freedom	85	-
p-value	0.001	Significant

The structural model path coefficients provide crucial insights into the relationships between the constructs and their impact on software quality. The path from Software Development Practices to Software Quality shows a significant positive effect with a coefficient of 0.42, a t-value of 7.15, and a p-value of less than 0.001, confirming that the hypothesis is supported. This suggests that effective software development practices contribute substantially to enhancing software quality. Similarly, the path from Process Efficiency to Software Quality has a coefficient of 0.30, a t-value of 5.62, and a p-value of less than 0.001, indicating a significant and positive relationship, thus supporting the hypothesis that process efficiency plays a key role in improving software quality. The path from End-User Communication to Software Quality also shows a positive and significant effect, with a coefficient of 0.28, a t-value of 4.95, and a p-value of less than 0.001, further confirming the importance of clear and effective communication with end-users in enhancing software quality. Overall, all hypotheses in the structural model are supported, with each path coefficient demonstrating significant and positive effects, underscoring the importance of these factors in enhancing software quality.

Table 4.5. Structural Model Path Coefficients

Path	Coefficient (β)	t-Value	p-Value	Hypothesis Supported
Software Development Practices → Software Quality	0.42	7.15	<0.001	Yes
Process Efficiency → Software Quality	0.30	5.62	<0.001	Yes
End-User Communication → Software Quality	0.28	4.95	<0.001	Yes

5.0 Discussion and Conclusion

This study findings show the strong relationships that exist between software development practices, process efficiency, end user communication, and software quality and supports the important roles these variables play in improving the quality of software. Results indicate that software development practices have the greatest positive impact on software quality with a path coefficient of 0.42, process efficiency has the next greatest (0.30), and end user communication has the third greatest (0.28). It implies that using the robust development methodologies and practices helps to create high quality software. Moreover, software quality is also involved with process efficiency by ensuring that (1) the workflows and processes are optimized and (2) the practices used in each environment have been optimized. And it makes a case for streamlining processes, removing inefficiencies, from the software development lifecycle. Although communication with end users has slightly lower effect, it is still important for end user communication, meaning that keeping in regular and clear communication with end users is vital to make sure that the software will fulfill their needs and expectations. The results are consistent with previous studies that stress the significance of good development practices, efficient process mechanisms, and communication for the delivery of high-quality software.

Additionally, we find a strong positive relation (0.35) between the path from software development practices and process efficiency, indicating that better development practices result in more efficient process. This matches the idea that well-structured development approaches form the basis for efficient workflows, which in turn improve the overall productivity and quality of software projects. The conceptualization that the factors were not independent but they were interring dependent in determining the final software quality is also supported by the findings. Accordingly, this integrated approach matches the modern software development frameworks focused on continuous improvement, process optimization and stakeholder engagement in the development lifecycle.

The study also confirms that software development practices, process efficiency and end user communication are the main factors that enhance software quality. And it notes that high quality software can only be created by organizations that follow structured development practices, streamline processes, and maintain open communication with end users. The results provide some practical advice to software developers, project managers and organizations looking to enhance the quality of their software.

With these findings, however, some recommendations can be made. In the first instance, companies should focus on adopting of thorough and systematic software development practice like Agile or DevOps that stresses on cooperation, continuous testing and incremental improvement. Second, the process can be automated and the process can be optimized and bottlenecks removed from the process to achieve a very large degree of quality improvement. Finally, organizations should improve their end user communication by involving end users early in the development process, by frequently asking for feedback, conducting surveys, and conducting usability testing. This will ensure the software that will be developed will be close to user needs and expectations.

Implications of this study are broad to academia and industry. For researchers, the study contributes to the body of knowledge relating software development practices, process efficiency, end user communication and software quality. It provides actionable insights to practitioners regarding how large software quality gains can be realized from improvements in development practices, process efficiency and communication. These findings may be used by organizations to develop strategies to improve their software development processes that would yield satisfied customers and a competitive advantage in the software industry.

Mian Muhammad Niaz Shakir: Problem Identification and Theoretical Framework
Muhammad Sohail: Data Analysis, Supervision and Drafting
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