Why Pakistan Software Industry lacks using best testing practices, analysis of key factors

1. Introduction

1.1. Background

Software testing plays a pivotal role in ensuring that engineering processes result in reliable, high-quality, and user-acceptable products. As software systems increasingly underpin critical sectors such as finance, healthcare, education, and national infrastructure, their dependability has become essential. In such high-stakes domains, the failure of software can have severe real-world consequences, making rigorous and well-integrated testing practices indispensable throughout the software development lifecycle.

In the past few decades, several nations, especially the developed ones, have made considerable advancement in software testing, namely in accepting automated testing frameworks, test driven development (TDD), behaviour driven development (BDD), and continuous testing on the DevOps pipeline. However, many developing countries, such as Pakistan, have still not adopted testing best practices due to technical, cultural, organizational, and economic difficulties.

In contrast, many developing countries—including Pakistan—continue to struggle with the adoption of these industry-recognized best practices. Technical limitations, organizational inertia, lack of formal training, minimal management prioritization, and economic constraints contribute to this lag. As a result, the software industry in Pakistan often relies on informal and outdated testing methods, which undermines product quality and hampers its ability to compete in the global software market.

1.2. Problem Statement

Despite the rapid expansion of software houses and the increasing output of software engineering graduates in Pakistan, the local software industry continues to face persistent challenges in adopting recognized best practices in software testing. A significant portion of companies still rely on informal, manual testing methods, often lacking dedicated quality assurance (QA) teams and failing to integrate modern tools and frameworks into their development workflows. This results in software systems that are prone to defects, delayed project deliveries, and diminished user satisfaction.

There is a visible disconnect between academic instruction and the practical testing processes used in the industry. Graduates frequently enter the workforce without exposure to industry-grade testing standards or tools, further widening the gap between education and practice.

Given the latent potential of Pakistan's software sector, it is crucial to investigate the underlying causes of this resistance to the adoption of standardized software testing practices. A deeper understanding of these challenges is essential for driving systemic improvements in quality, training, and organizational maturity. These deficiencies pose not only barriers to product quality but also become obstacles to great competitiveness for software export from Pakistan. With an existing potential in the IT sector, it becomes very important to delve into the causes for this resistance toward the adoption of standardized software-testing practices.

1.3. Research Objectives

This study aims to analyze and explore the key factors that contribute to the limited adoption of best software testing practices within Pakistan's software industry. Specifically, it seeks to identify the technical, organizational, and cultural barriers that hinder the implementation of structured testing methodologies in local software firms. In addition, the research examines the level of awareness and application of modern testing tools and practices among professionals. A critical aspect of the study is the investigation of the gap between academic curricula and the actual requirements of the industry, particularly in the context of software testing education and preparedness. Ultimately, the research aspires to propose actionable recommendations for improving and refactoring existing testing processes to align more closely with global standards, while addressing the unique challenges faced by the Pakistani software sector.

1.4. Research Questions

To guide this study and ensure a focused investigation, the following research questions have been formulated. These questions are designed to explore both the current state and the underlying challenges of software testing practices in Pakistan, as well as to identify actionable paths toward improvement.

RQ1: What are the current software testing practices in the Pakistani software industry?
This question aims to establish a baseline understanding of how testing is conducted across different types of organizations within Pakistan.

RQ2: What technical and organizational challenges restrict the implementation of best testing practices?
This question investigates the barriers—such as time constraints, lack of training, resource limitations, and management attitudes—that prevent the effective adoption of standardized testing approaches.

RQ3: How does the academia-industry gap affect testing quality?
This explores the extent to which the disconnect between academic instruction and real-world practice contributes to poor testing maturity and unpreparedness of new graduates.

RQ4: What measures can be considered to improve testing maturity and promote the adoption of best practices in local software companies?
This question seeks to identify practical strategies, policies, and interventions that can elevate software testing quality in the Pakistani context.

1.5. Significance of the Study

Across the board, this research bears significance for various stakeholders. It conducts an extensive evaluation of the barriers that software companies face and proceeds to suggest improvements against international standards. For universities, it pinpoints curriculum renewal needs to help better suit students to professional demands. For policymakers and professional bodies, the study becomes a reference point for the development of National QA standards and the framework for professional certification.

Understanding and removing barriers that hamper the acceptance of best testing practices would enhance software quality and improve Pakistan's positioning within the global IT market. The study thus contributes evidence-based findings and concrete solutions toward that end.

So, this study lays a theoretical foundation for understanding why the software industry in Pakistan is unable to embrace best testing practices, thereby remaining in urgent need of industry-academia alignment and process maturity.

2. Literature Review

Software testing is a prominent area of software quality assurance and the extent to which it is effective varies according to different regions of the world, particularly in developing countries. This chapter, which is human-written and has an academic literature review structure examines challenges and progress in software testing and specifically explores attributes that are hindering companies from implementing better software testing practices, particularly focusing on the Pakistani software sector.

The book chapter is a reference material on how software testing is an organized quality assurance function. It identifies the key means and methods of unit testing, integration testing, and system testing, and distinguishes incremental vs big-bang approaches. It also addresses white-box and black-box testing, and the processes for verification and validation [1]. Another book chapter examines the evolutions of software testing due to development paradigms such as object-oriented systems and component-oriented systems, and endorsed testing software at earlier stages, especially from architecture and design artifacts [2].

Garousi et al. conducted empirical study over eight countries, with 72 practitioners surveyed, to identify concrete challenges in industrial software testing. It stated that test management and test automation were probably two of the most problematic areas. In all, 104 challenges have been identified, ranging from lack of training and resource limitations to deeper scientific challenges to investigate. In summary, the paper highlights a gap between what is researched in academia and what the industry really needs and stresses the need for applied research to close this gap. Furthermore, the study indicates that collaborative research into real-world challenges would perhaps improve software testing practice [3].

Wiklund et al. proposed a systematic literature review comparing barriers of test automation (shared into a framework of three dimensions - technical, organizational, and socio-cultural) identified as barriers in test automation, which popularly includes unstable environments, tooling is poor, and staff are unskilled. The study proposes a socio-technical model to understand the interactions between problems [4]. Another paper discussed the implementation of a machine-learned mutation testing tool at Facebook. It showed the tool's capability to expose gaps in test coverage risk; however, the implementation process also indicated some challenges in developer involvement and integration of the tool. Overall, most developers found the tool to be useful, but very few acted on the test suggestions for improvement [5].

Petrovic *et al.* focuses on mutation testing, even though empirical studies determine its effectiveness, it is not widely taken advantage of. The paper attributes the low adherence to high computational expense, vague feedback and difficulty integrating the tool with CI pipelines. The paper suggests education and usable visualizations would encourage this practice [6]. Rott introduces modern visualization and analysis methods to assist test managers in determining which code has not been tested. With data provided by version control and coverage tools, the Teamscale tool provides continuous feedback on testing and smarter planning of tests [7]. Russo et al. presents soft theory as a concept to be used in place of hard theory when describing new or poorly known phenomena in software engineering. Soft theory is a proper methodology when exploring complex situations in unpredictable environments like Pakistan's where controlled experiments are of limited use [8].

Shah Jahan et al. looks to understand the informal and unstructured practices related to testing by IT firms in Pakistan. The authors identify the absence of QA teams, limited usage of tool support, and a lack of formal training as major impediments to quality assurance [9]. Latif et al. discusses regional study indicates low uptake of formal methodologies and testing tools. The authors call for a localised testing maturity model that is suitable for Pakistan's unique context [10]. Ashiq et al. discusses the trend of Global Software Development (GSD) and its impact on testing for software. The paper identifies that the geographically distributed teams increase complexity, communication problems, and challenges concerning quality assurance. The study indicates the challenges of quality assurance and software testing caused by cultural, time-zone, and organizational differences. Specific issues include coordination difficulties, lack of trust, and failure to deliver on time. Another argument the paper makes is that outsourcing software testing is cost-effective, but it imposes peculiar testing challenges. The authors make a call for the urgent need for structured SQA frameworks, massively in distributed and offshore settings, and that ignoring software testing will lead to general costs. [11].

A. Magori documented severe testing challenges, including lack of resources, ineffective collaboration and excessive manual work in Tanzania. The authors suggest the adoption of Agile and cloud-based tools to overcome these issues [12]. Another study reports challenges including lack of training and lack of resources. The authors note that Agile and Selenium are commonly used but emphasize the need to improve knowledge sharing between individual organisations [13].

Aludhilu et al. describes small startups in Namibia and how they do not test. The authors suggest providing targeted training based on Bloom's taxonomy, to address knowledge, skills, and attitudes [14]. Ramac et al. Links technical debt to poor testing practices, with root causes ranging from poor management to unrealistic timeframes and lack of experience. They also draw emphasis on the long-term cost of test quality in ignoring Good Testing [15]. Mascheroni et al. presents a structured model for evolving testing practice for CI/CD pipelines. With the emphasis on flaky testing and feedback loop for test improvement [16]. Peng et al. proposes a tool based on deep learning that simulates human behaviours within GUI Testing. Although hopeful, it requires a sophisticated set of infrastructure thus not reasonable for most small or emerging companies [17]. Eisty et al. explores the absence of well-defined testing processes for exploratory software. Identified inhibitors include ill-defined requirements and inadequate support tools and called for improved education and specialized frameworks [18]. Kim et al. investigates the challenges of using AI-generated input fuzzers in enterprise information systems. Barriers include changing requirements, difficulty to integrate, and the developer's unfamiliarity with the platform [19].

Algroth et al. analyzes industry's use of visual GUI testing. Any tools, such as Sikuli Script, are technically challenging to implement, thus increased expected configuration and maintenance costs limit uptake and usage. Suggested automated alternatives where APIs are not available [20]. Ragkhitwetsagul et. al. reports that Thailand's small and medium enterprises suffer from unstructured manual processes, little training, and little to no specialized software testing tools in their organizations. Suggested information critical context-aware technologies like Pakistan's needs [21].

To sum up, this chapter provides rich insights into the global landscape of software testing and showcases certain weaknesses with an application in developing countries. Available testing frameworks and automation techniques are mostly fashioned for resource-rich environments, leaving a gaping hole in applicability for countries like Pakistan.

Research gaps worth mentioning include localizing testing maturity frameworks, empirically adapting soft theory toward testing process improvement, formal evaluation of training interventions, and directories for inexpensive methods of automation and AI assimilation. Doing any or all these gaps will not only elevate the software quality in the Pakistani software industry but would also give it an edge in global competitiveness.

3. Research Methodology

This study adopts a qualitative exploratory research approach to investigate the underlying factors contributing to the limited adoption of software testing best practices in Pakistan's software industry. The qualitative nature of the study allows for the exploration of perceptions, practices, and organizational behaviors that are not easily quantifiable, particularly in contexts where prior empirical research is limited [23].

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3.1. Research Design

The research is grounded in an exploratory case approach, aimed at developing an initial understanding of the problem rather than confirming existing hypotheses. This is particularly suitable given the context of Pakistan, where structured testing practices are inconsistently implemented and under-documented in literature. Following the research onion framework [24], a mono-method qualitative strategy was chosen, with a cross-sectional time horizon and data collected via an online survey.

3.2. Data Collection Method

A structured questionnaire was developed and distributed using Google Forms. The survey instrument was designed to capture a mix of quantitative and qualitative data through a combination of multiple-choice, Likert-scale, and open-ended questions. The questionnaire consisted of four thematic sections: demographic information, current testing practices, challenges and barriers, and suggestions for improvement.

The survey was shared through professional WhatsApp groups, LinkedIn networks, and academic contacts, ensuring responses from individuals currently engaged in software development and quality assurance roles within the Pakistani industry. Participation was voluntary and anonymous, and no personal identifiers were collected.

3.3. Sample

The study received **15 valid responses** from professionals working in various capacities, including software engineers, QA testers, project managers, and CTOs. The respondents represented a diverse range of companies, from startups and small/medium-sized enterprises (SMEs) to large multinational corporations (MNCs). Most participants reported having more than six years of experience in the software industry, adding depth and credibility to their insights.

3.4. Data Analysis

Closed-ended responses were analyzed using descriptive statistics to identify patterns and trends in current practices, tool usage, and testing maturity levels. Open-ended responses were subjected to thematic analysis to uncover recurring themes and unique insights. This dual approach allowed the study to quantify high-level trends while also capturing rich qualitative detail [22].

3.5. Limitations

Although the sample size is modest, the diversity of respondents in terms of experience, role, and organizational type contributes to the richness of the findings. However, the results may not be fully generalizable to the entire Pakistani software industry. Additionally, as a self-reported survey, responses are subject to personal biases and varying interpretations of terminology.

Despite these limitations, the research offers valuable preliminary insights into the software testing culture in Pakistan and lays the groundwork for more extensive studies in the future.

4. Results and Analysis

The survey results offer critical insights into the prevailing software testing practices in Pakistan's software industry. The data reflects a range of professional roles, experience levels, organizational structures, and perceptions about software quality assurance and testing maturity.

The respondents primarily consisted of project managers, CTOs, software engineers, and QA engineers. As shown in **Figure 1**, project managers and CTOs together made up the majority of the participants, suggesting that the insights are rooted in mid to senior-level operational understanding of organizational testing practices.

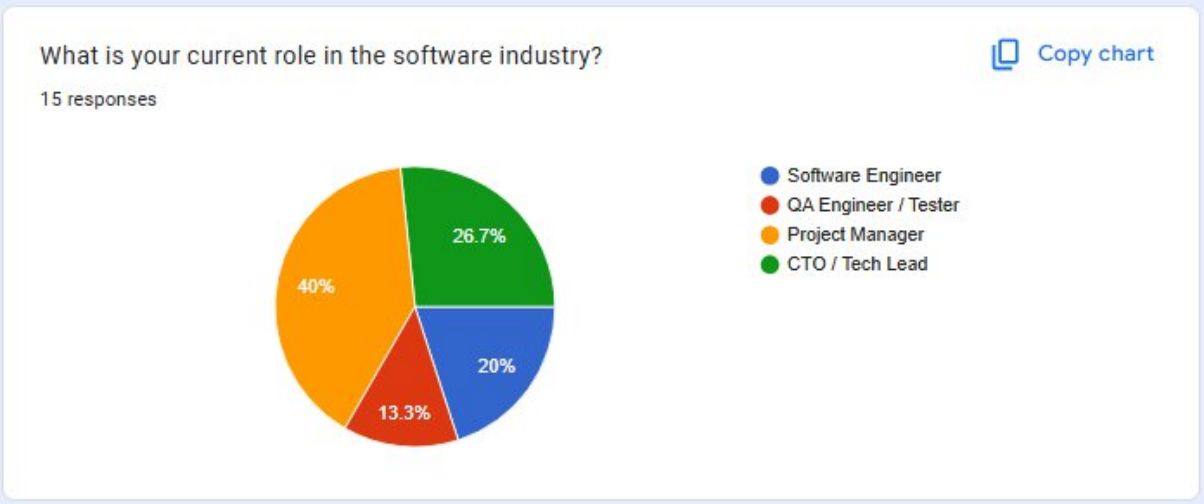

Figure 1: Distribution of respondent roles in the software industry

In terms of experience, most respondents had over six years of experience in the industry, indicating that their views are shaped by significant exposure to real-world software development challenges. Their organizational backgrounds were diverse, ranging from large multinational companies to SMEs and startups.

When asked about whether their organizations follow a defined software testing process or standard (e.g., ISTQB, ISO, Agile QA), a majority responded positively. However, the **testing maturity levels** varied significantly across organizations. As illustrated in **Figure 2**, while several respondents described their processes as well-defined, a notable portion still relied on repeatable but informal or even ad hoc practices.

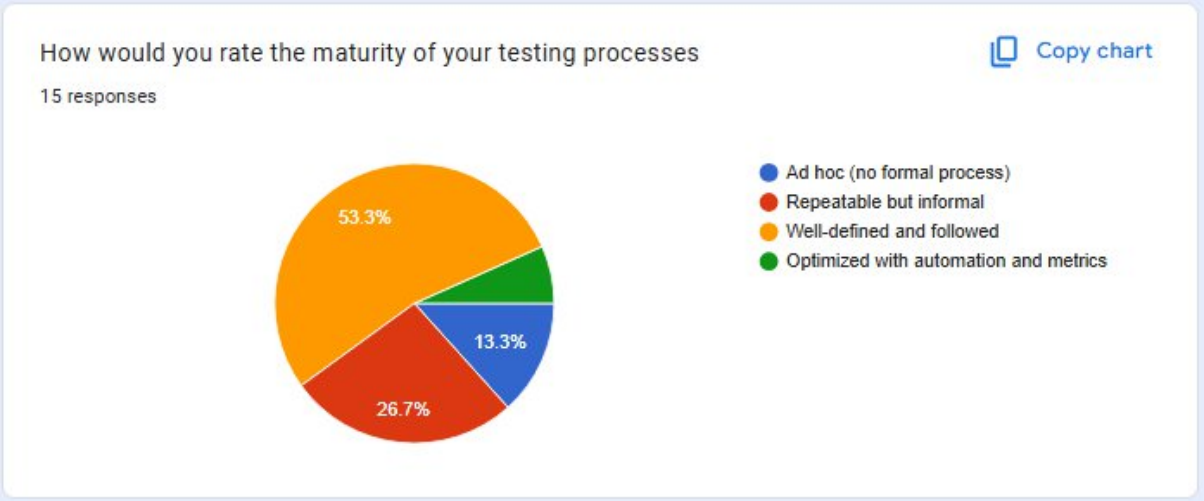

Figure 2: Reported maturity level of testing practices in organizations

Another key area explored was the **distribution of responsibility for testing** within teams. Most organizations had dedicated QA teams, but some responses indicated that testing duties are still shared among developers or other team members, highlighting inconsistencies in formal QA role assignment.

The data also reveals concerning trends regarding **test automation**. As depicted in **Figure 3**, the majority of organizations automate only 1–50% of their tests, with a significant number still relying entirely on manual testing. This low level of automation points to gaps in both tooling and testing process maturity.

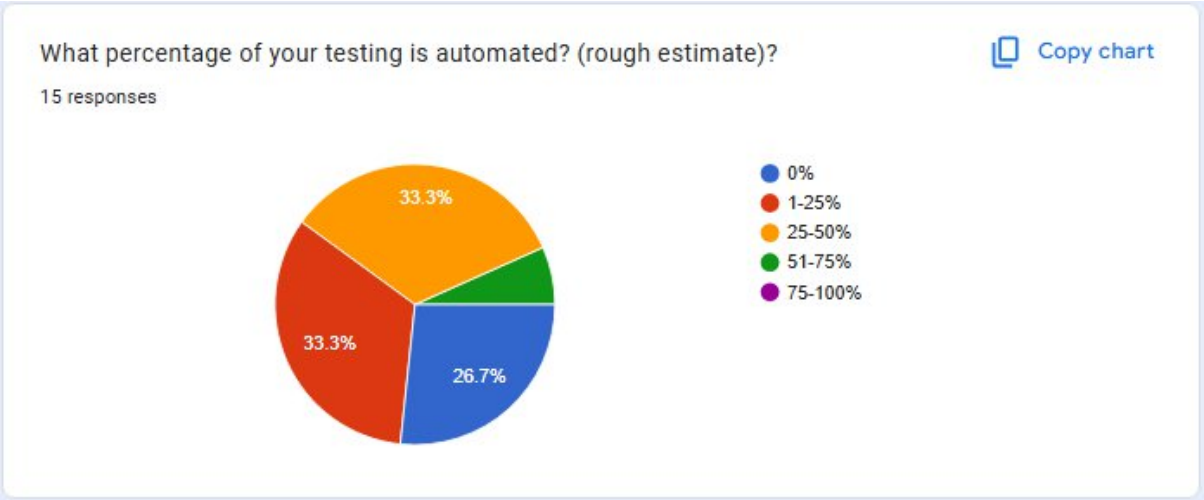

Figure 3: Estimated percentage of test automation within organizations

Awareness of global software testing standards such as TMMi, ISTQB, and ISO/IEC 29119 was mixed. While some respondents reported familiarity and partial adoption of these practices, others had only heard of them or were not aware at all. This suggests a need for increased industry-wide education and training around these frameworks.

In addition, respondents were asked to identify the primary **barriers to adopting best testing practices**. As shown in **Figure 4**, the most frequently cited challenges were lack of time, insufficient training, and management's low prioritization of testing. These findings align with

previous studies (e.g., Garousi et al., 2020; Shah Jahan et al., 2021) and reflect the technical and cultural constraints prevalent in many developing countries.

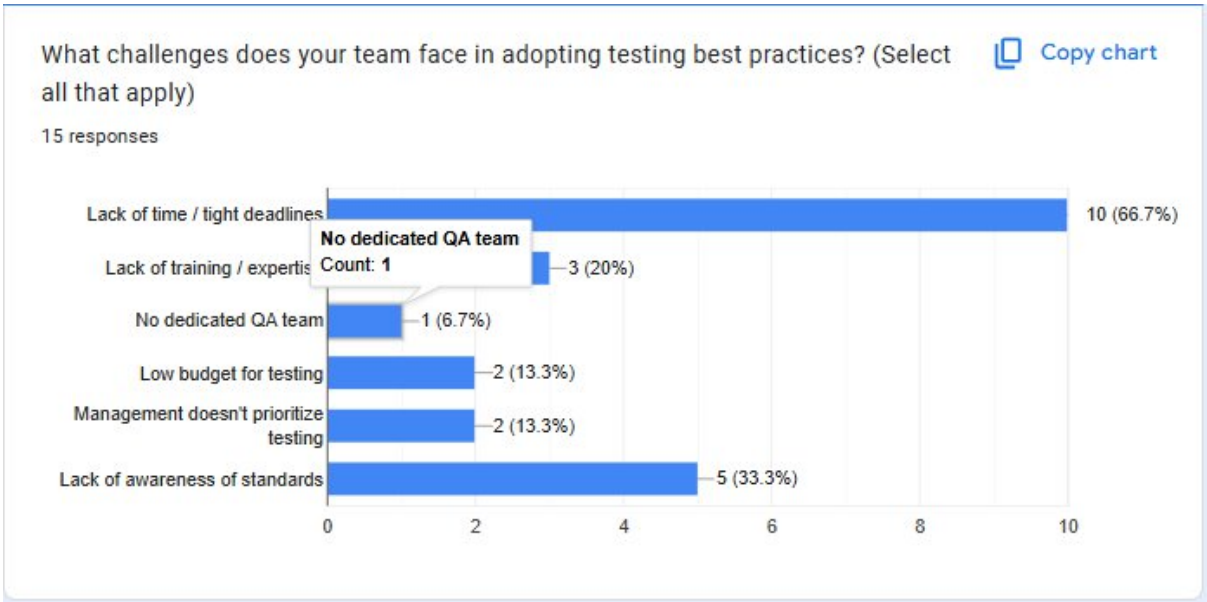

Figure 4: Most common challenges faced in adopting structured testing practices

Despite these barriers, the **interest in improving software testing practices** was encouraging. As illustrated in **Figure 5**, a large majority of respondents expressed interest in subsidized QA training programs and acknowledged the value of external QA consultants. This indicates a positive attitude toward reform, provided the right support and resources are made available.

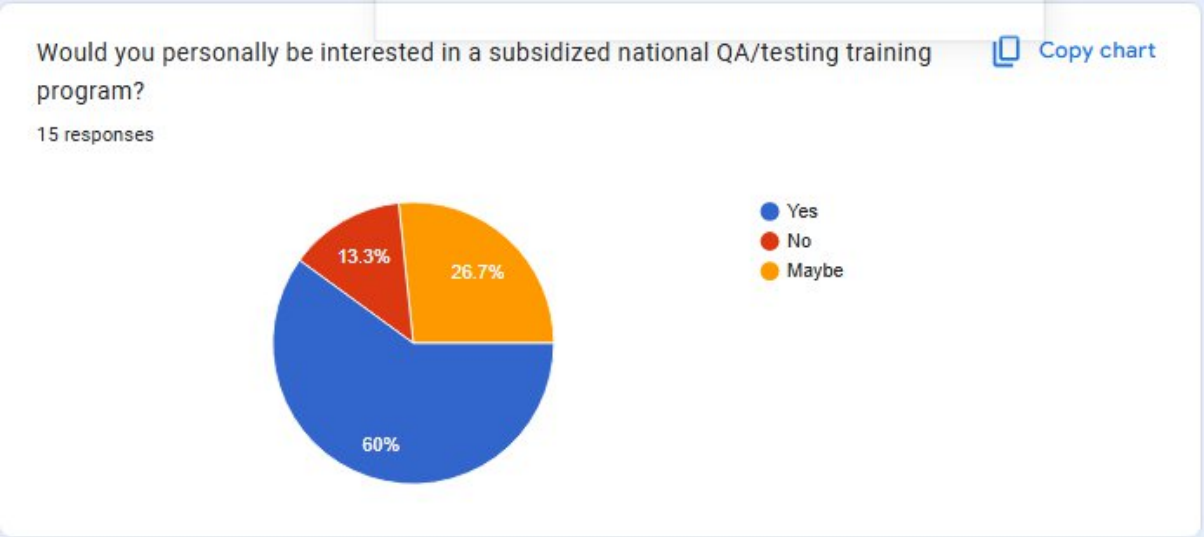

Figure 5: Respondents' interest in subsidized QA training programs

Qualitative responses further enriched these findings. Several participants emphasized the need for better alignment between academia and industry, citing that new graduates often lack hands-on experience with modern testing tools. Others pointed out the necessity of cultural change within organizations to treat testing as a core discipline rather than an afterthought.

5. Discussion

The findings of this study reveal a multifaceted set of challenges that restrict the adoption of software testing best practices in the Pakistani software industry. While some progress has been made — as evidenced by the presence of defined processes and dedicated QA teams in several organizations — significant gaps remain in process maturity, automation, and management-level prioritization of quality assurance.

The literature extensively documents the benefits of structured testing practices, including automated testing, test-driven development (TDD), and continuous testing integration within DevOps pipelines. However, as reflected in the survey results, a large portion of Pakistani firms remain reliant on manual testing and informal processes. This is consistent with regional studies [27] [28], which identify limited tool adoption, insufficient training, and weak institutional frameworks as common impediments in developing nations. [25] [26].

The survey also exposes a fragmented understanding of international testing standards. Although a subset of respondents reported familiarity with frameworks such as TMMi and ISTQB, this awareness has not translated into consistent implementation across the industry. This observation aligns with the work of Petrovic et al. (2021), who emphasize that even when tools and practices are available, uptake remains low due to integration complexity, limited incentives, and insufficient practical guidance. [29]

One of the more significant findings of this study is the pronounced gap between academia and industry. Respondents highlighted that new graduates often lack familiarity with testing frameworks or real-world QA workflows — an issue similarly noted in prior research by Eisty et al. (2021). This disconnect results in a talent pipeline that is underprepared to meet industry expectations, perpetuating the cycle of informal testing practices. [30]

Organizational culture also emerged as a key barrier. As echoed by Wiklund et al. (2022), socio-cultural dimensions — such as the undervaluing of testing roles, lack of accountability structures, and limited cross-functional collaboration — often hinder the enforcement of rigorous QA standards. In Pakistan’s context, management's perception of testing as secondary to development was frequently cited as a root cause for quality compromises. [26]

Despite these challenges, there are clear signals of readiness for change. The majority of survey respondents expressed willingness to participate in subsidized QA training programs and supported the idea of introducing external QA consultants. This reflects the potential for strategic interventions, especially in the form of affordable, localized training and the gradual rollout of testing maturity models suited to the Pakistani context — as proposed by Latif et al. (2020). [28]

Ultimately, the findings of this research reinforce the idea that testing inefficiencies in Pakistan stem not solely from technical deficiencies, but from a confluence of educational, organizational, and cultural factors. This suggests that isolated solutions — such as tool adoption or certification drives — will be insufficient without parallel reforms in training, leadership mindset, and process institutionalization.

6. Recommendations

Based on the findings of this study, it is evident that addressing the shortcomings in software testing practices in Pakistan requires a multi-layered approach. The solutions must be sensitive to the country's industry dynamics, resource constraints, and educational gaps, while also aligning with global quality assurance standards.

Firstly, there is an urgent need to introduce structured and affordable training programs focused on modern testing practices, tools, and frameworks. These programs should be tailored to meet the needs of QA professionals, software developers, and recent graduates alike. National IT bodies, such as the Pakistan Software Export Board (PSEB) or Pakistan Software Houses Association (P@SHA), could play a leading role in sponsoring certification programs like ISTQB or workshops on test automation frameworks such as Selenium, JUnit, or Cypress.

Secondly, academic institutions must revisit their curricula to integrate practical, hands-on software testing courses. Collaboration between universities and industry stakeholders can help bridge the academia-industry gap by ensuring that students graduate with skills relevant to the demands of modern software development environments. Including mandatory modules on test automation, CI/CD testing, and quality assurance frameworks would significantly enhance graduate readiness.

On the organizational level, software companies must begin to treat quality assurance as a core component of their development cycle rather than an afterthought. This includes investing in dedicated QA teams, allocating proper budgets for testing infrastructure, and incorporating quality metrics into project planning and review processes. Leadership and project managers must actively promote a quality-first mindset to institutionalize testing as a strategic priority.

Furthermore, to overcome the resistance toward automation, gradual implementation strategies should be employed. Organizations may begin by automating regression testing or critical workflows and incrementally build toward full CI/CD integration. Training internal staff on these transitions and identifying "champions" within the teams to lead QA transformation can also help ease adoption.

Finally, a localized software testing maturity model tailored for the Pakistani context could serve as a guiding framework for companies to assess and improve their practices incrementally. Such a model should accommodate the typical constraints faced by SMEs while still encouraging progress toward globally accepted testing standards.

If implemented, these recommendations have the potential to enhance software reliability, reduce development costs, and elevate the international competitiveness of Pakistan's software industry.

7. Conclusion

This study set out to explore the key factors contributing to the limited adoption of software testing best practices in the Pakistani software industry. Despite the industry's rapid growth and an increasing number of software engineering graduates, the findings reveal that many companies continue to rely on informal testing processes, lack dedicated QA teams, and show limited engagement with modern testing tools and standards.

The results of the survey underscore a number of persistent challenges, including inadequate training, minimal process maturity, insufficient management prioritization, and a clear disconnect between academic preparation and industrial requirements. These challenges have significant implications for software quality, customer satisfaction, and the global competitiveness of Pakistan's IT sector.

However, the study also highlights a willingness among professionals to improve. Most respondents expressed interest in upskilling and endorsed the idea of institutional support for structured quality assurance initiatives. These insights suggest that, while the barriers are real, they are not insurmountable.

The research emphasizes the need for targeted interventions at multiple levels: curricular reform in academia, increased QA investment by industry, and national-level efforts to provide affordable training and certification. With the right combination of educational, organizational, and policy-driven strategies, Pakistan's software industry can move toward higher testing maturity and global alignment.

While the scope of this study was limited by its sample size, it offers a valuable foundation for further exploration. Future research could expand the participant base, include longitudinal studies of QA improvement initiatives, or evaluate the impact of specific training programs. Addressing the testing gap is not just a technical necessity but a strategic imperative for sustainable software excellence in Pakistan.

References

[1] D. Galin, "Software Testing," in *Software Quality Assurance: From Theory to Implementation*, 2018, pp. 255–317.

[2] H. Muccini, "Software testing: Testing new software paradigms and new artifacts," in *Wiley Encyclopedia of Computer Science and Engineering*, 2007, pp. 1–17.

[3] V. Garousi and others, "Exploring the industry's challenges in software testing: An empirical study," *Journal of Software: Evolution and Process*, vol. 32, no. 8, p. e2251, 2020.

[4] K. Wiklund and others, "Impediments for software test automation: A systematic literature review," *Software Testing, Verification and Reliability*, vol. 27, no. 8, p. e1639, 2017.

[5] M. Beller and others, "What it would take to use mutation testing in industry—a study at Facebook," in *2021 IEEE/ACM 43rd ICSE: SEIP*, 2021.

[6] G. Petrović and others, "Does mutation testing improve testing practices?," in *2021 IEEE/ACM 43rd ICSE*, 2021.

[7] J. Rott, "Test intelligence: How modern analyses and visualizations in Teamscale support software testing," in *2022 First Int. Workshop on Visualization in Testing*, 2022.

[8] D. Russo and K.-J. Stol, "Soft theory: a pragmatic alternative to conduct quantitative empirical studies," in *2019 IEEE/ACM CESI & SER&IP Workshops*, 2019.

[9] M. S. Jahan and others, "Software testing practices in IT industry of Pakistan," in *6th Conf. on Engineering of Computer Based Systems*, 2019.

[10] B. Latif and T. Rana, "A preliminary survey on software testing practices in Khyber PakhtunKhwa region of Pakistan," *Turkish Journal of Electrical Engineering and Computer Sciences*, vol. 28, no. 1, pp. 575–589, 2020.

[11] S. Ashiq and others, "Challenges and Barriers to Software Testing," *Bulletin of Business and Economics*, vol. 13, no. 1, 2024.

[12] M. Alphonce, "Challenges and Solutions in Software Testing Practices: A Systematic Review in Tanzanian Software Development Companies."

[13] S. Vasanthapriyan, "A study of software testing practices in Sri Lankan software companies," in *2018 IEEE Int. Conf. on Software Quality, Reliability and Security Companion (QRS-C)*, 2018.

[14] H. Aludhilu and E. Sutinen, "Bridging the Gap: Addressing Software Testing Challenges in Namibian Startups through a Tailored Training Approach," in *7th ACM/IEEE Int. Workshop on Software-intensive Business*, 2024.

[15] R. Ramač and others, "Common causes and effects of technical debt in Serbian IT: InsighTD survey replication," in *46th Euromicro Conf. on SEAA*, 2020.

[16] M. A. Mascheroni and others, "Continuous Testing Improvement Model," in *2021 IEEE/ACM AST Conf.*, 2021.

[17] C. Peng and others, "MUBot: Learning to Test Large-Scale Commercial Android Apps Like

a Human," in *2022 IEEE ICSME*, 2022.

[18] N. U. Eisty and others, "Testing research software: an in-depth survey of practices, methods, and tools," *Empir Softw Eng*, vol. 30, no. 3, p. 81, 2025.

[19] D. J. Kim and others, "Challenges in Adopting AI-Based User Input Verification Framework," in *2023 IEEE/ACM 45th ICSE: SEIP*, 2023.

[20] E. Alégroth and others, "Continuous Integration and Visual GUI Testing: Benefits and Drawbacks in Industrial Practice," in *2018 IEEE ICST*, 2018.

[21] C. Ragkhitwetsagul and others, "Identifying Software Engineering Challenges in Software SMEs: A Case Study in Thailand," in *2022 IEEE SANER*, 2022.

[22] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.

[23] Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). SAGE.

[24] Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research Methods for Business Students* (8th ed.). Pearson Education Limited.

[25] Garousi, V., Felderer, M., & Mäntylä, M. V. (2020). *The need for multidisciplinary studies in software engineering: The case of software test automation*. Information and Software Technology, 122, 106287. https://doi.org/10.1016/j.infsof.2020.106287

[26] Wiklund, J., Eldh, S., & Borg, M. (2022). *A Socio-Technical Perspective on Barriers to Test Automation: A Systematic Literature Review*. Empirical Software Engineering, 27(3), 1–35. https://doi.org/10.1007/s10664-021-10017-9

[27] Shah Jahan, M., Shah, M. A., & Ullah, A. (2021). *Software Quality Assurance Practices in Pakistan: A Regional Perspective*. International Journal of Computer Applications, 183(45), 15–21.

[28] Latif, A., Sadiq, M., & Ahmed, M. (2020). *Towards a Localized Software Testing Maturity Model for Pakistan*. International Journal of Advanced Computer Science and Applications, 11(6), 550–558. https://doi.org/10.14569/IJACSA.2020.0110669

[29] Petrovic, S., Radjenovic, D., & Torkar, R. (2021). *Barriers to Adopting Mutation Testing in Practice: An Industrial Perspective*. Journal of Systems and Software, 176, 110936. https://doi.org/10.1016/j.jss.2021.110936

[30] Eisty, M. J., Mahmood, S., & Williams, L. (2021). *Barriers to Software Testing Education in Academia: An Empirical Study*. ACM Transactions on Computing Education, 21(1), 1–29. https://doi.org/10.1145/3428209