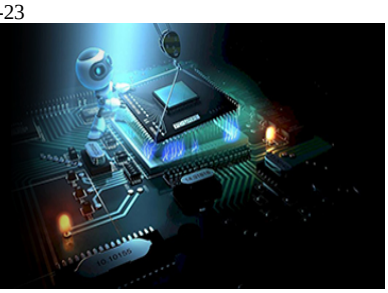
International Journal of Engineering in Computer Science



E-ISSN: 2663-3590
P-ISSN: 2663-3582
Impact Factor (RJIF): 5.52
www.computersciencejournals.com/ijecs
IJECS 2026; 8(2): 16-23
Received: 08-02-2026
Accepted: 10-03-2026

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Artificial Intelligence-driven software quality improvement: Concepts and applications

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DOI: https://www.doi.org/10.33545/26633582.2026.v8.i2a.272

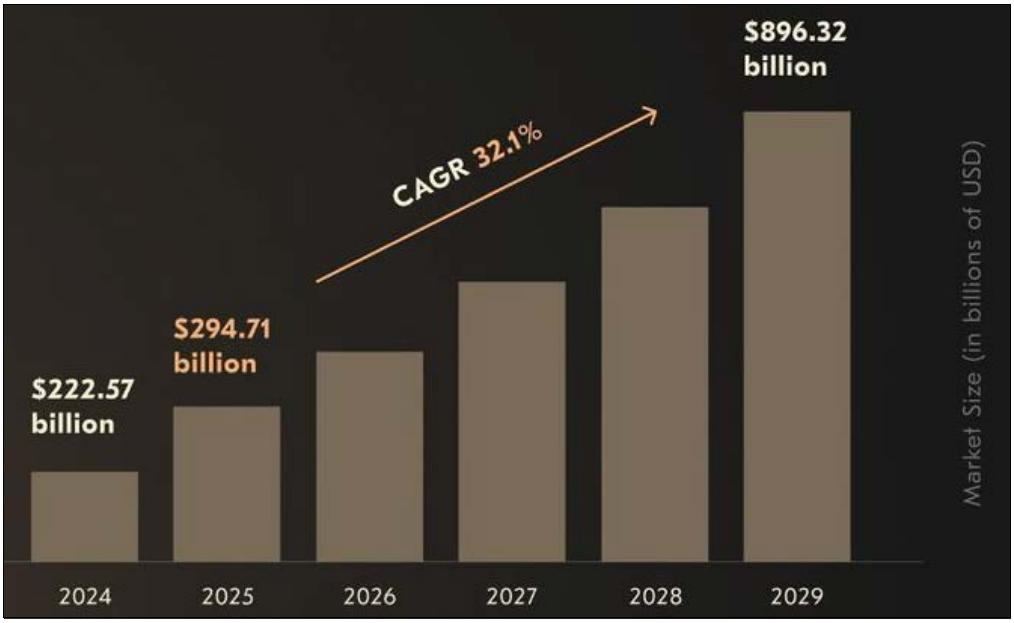
Abstract
The complexity of assuring software quality has grown due to the quick development of software systems. Large-scale distributed systems, continuous integration, and agile development make it difficult for traditional quality assurance (QA) techniques to stay up. Through automation, predictive analytics, and intelligent decision-making, artificial intelligence (AI) has become a game-changing technology that can improve software quality. The significance of AI in enhancing software quality is examined in this study, along with its applications throughout the software development lifecycle, advantages and disadvantages, and potential future paths for AI-driven quality engineering.

Keywords: Blockchain, supply chain management, transparency, efficiency, smart contracts, global supply chains, traceability, data security

1. Introduction

For modern programs to be dependable, usable, and perform well, software quality is essential. Conventional manual and rule-based testing methods are becoming ineffective and expensive as system complexity rises. Software testing, which was formerly thought of as an extension of debugging, has developed into an organized field with the goal of guaranteeing adherence to both functional and non-functional criteria. Artificial Intelligence (AI), which encompasses machine learning (ML), deep learning (DL), and natural language processing (NLP), enables systems to learn from data, spot patterns, and make judgments. Software engineers are increasingly using AI to automate tedious work, enhance fault detection, and streamline testing procedures. As software systems get more complicated, maintaining quality using conventional methods gets more expensive, time-consuming, and prone to human error. AI-driven systems, in contrast to conventional methods, are able to automate difficult jobs, adjust to new situations, and continuously enhance performance. The complexity, scale, and dynamic nature of modern software systems pose an increasing challenge to conventional software quality assurance techniques.

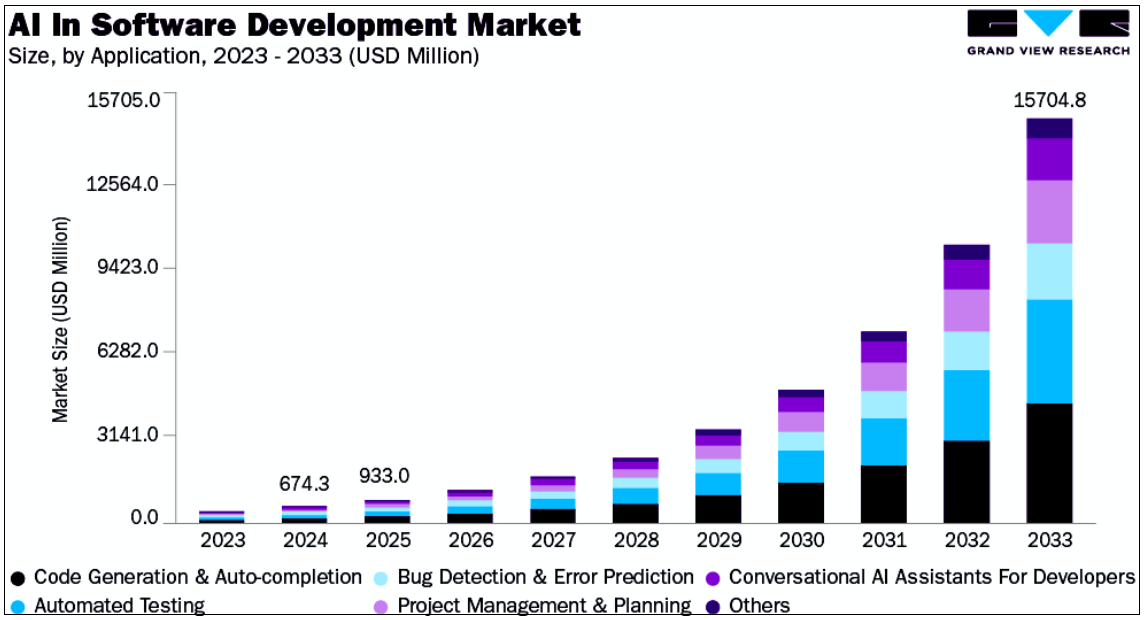
The long-term advantages of AI technology include significant cost savings because of decreased rework, increased efficiency, and quicker delivery cycles, even though the initial investment may be quite high. The return on investment associated with AI adoption, with better levels of quality improvement and cost reduction following increased investment in AI. AI-based technologies can improve decision-making, optimize resource allocation, automate testing procedures, and predict problems (refer figure-1). While AI allows for proactive defect detection and avoidance, traditional methods mostly concentrate on finding flaws after they happen. This change increases the overall effectiveness of the development process in addition to improving software stability. AI-driven automation also greatly minimizes manual labor, freeing up teams to concentrate on more difficult and valuable work. Software quality is now a crucial success factor due to the quick development of digital technologies and the increasing reliance on software systems across sectors. Software quality improvement has advanced significantly as a result of the use of AI into software engineering (refer figure-2).



(Source: https://acropolium.com/blog/ai-use-cases-in-major-industries-elevate-your-business-with-disruptive technology/)

Fig 1: Anticipated global AI software market

Although natural language processing methods can create test cases from requirement papers, machine learning models can examine past defect data to find modules that are prone to errors. These capabilities boost the precision and efficacy of quality assurance procedures in addition to increasing efficiency. Software quality assurance is moving from human inspection to intelligent automation thanks to AI. It improves decision-making skills in addition to testing efficiency. However, appropriate deployment, high-quality data, and human supervision are necessary for its efficacy. Continuous testing and quicker delivery cycles are made possible by the particularly promising combination of AI with DevOps and Agile methodologies. Instead of taking the position of human testers, AI serves as an augmentation tool.



(**Source:** https://www.grandviewresearch.com/industry-analysis/ai-software-development-market-report)

Fig 2: AI in Software Development Market: An Overview

The function of AI as a revolutionary and forward-thinking technology for enhancing software quality has been examined in this study article. AI has the ability to greatly improve a number of software quality assurance features, such as continuous monitoring, test automation, defect prediction, and performance optimization. Software development cycles have accelerated due to the use of Agile (refer figure-3) and DevOps approaches, necessitating quicker and more effective quality assurance procedures. Because AI offers real-time insights, anomaly detection, and predictive analytics, it is essential for enabling continuous testing and integration. The use of AI in software quality improvement is still in its infancy, despite its potential. Data accessibility, integration complexity, and a shortage of qualified personnel are some of the issues that organizations must deal with.

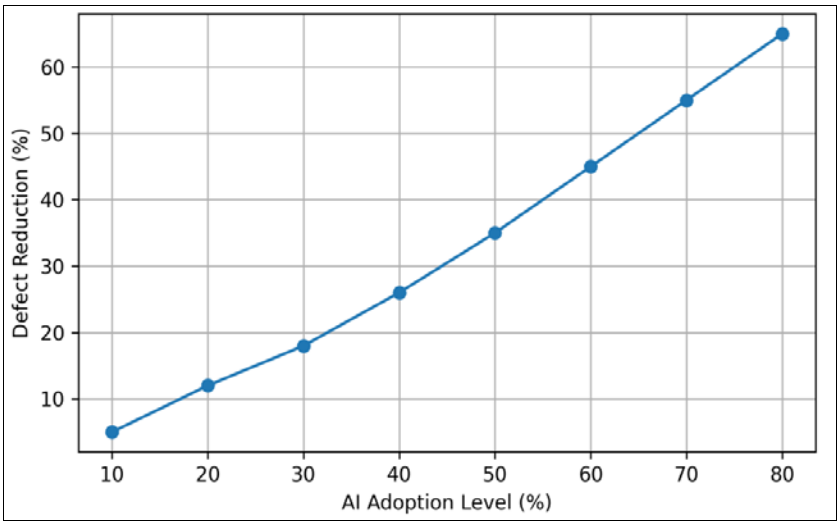


Fig 3: Impact of AI adoption on Defect Reduction

To assess AI, this research is significant because it offers a thorough grasp of how AI can improve software quality and assist enterprises in making well-informed decisions about its implementation. Corpus of knowledge in AI-driven software engineering by bridging the gap between theoretical ideas and real-world applications. The findings show that shorter testing cycles, improved defect detection rates, and decreased defect density are all linked to increasing AI implementation. For businesses looking to produce high-quality software in cutthroat and dynamic industries, this competence is crucial. But the study also points out a number of obstacles to the use of AI in software quality enhancement. High initial investment costs, reliance on high-quality data, integration challenges, and a lack of qualified personnel are some of these.

2. Literature Review

The increasing use of AI in software testing and quality assurance is demonstrated by recent studies:

1. AI methods like machine learning and natural language processing are frequently applied in defect prediction, optimization, and test case creation
2. AI-driven test automation increases test coverage and efficiency while drastically reducing human labor
3. Studies reveal that AI can improve overall software quality, optimize test suites, and lower testing expenses
4. AI is becoming crucial for managing the growing complexity of software systems, according to systematic reviews
5. It is anticipated that 64% of firms will use AI in software quality assurance procedures, demonstrating the growing significance of this technology

The use of sophisticated methods for guaranteeing software quality has become necessary due to the quick development of software systems, which is fueled by growing user demands and technological complexity (refer figure-4). Although they work well in controlled settings, traditional quality assurance techniques are unable to handle large-scale, dynamic, and data-intensive applications.

2.1 Software Quality Practices' Development

The idea of software quality has developed into a comprehensive strategy that includes prediction, prevention, and ongoing improvement. Watts S. Humphrey's early contributions included maturity models that focused on measurement and control as well as disciplined software processes.

Later, by emphasizing data-driven decision-making and iterative development, approaches like Six Sigma and Agile improved quality procedures. However, these approaches' scalability in contemporary settings is constrained by their continued heavy reliance on human expertise and predetermined norms. By allowing computers to learn from data and adjust to changing circumstances, artificial intelligence (AI) overcomes these constraints.

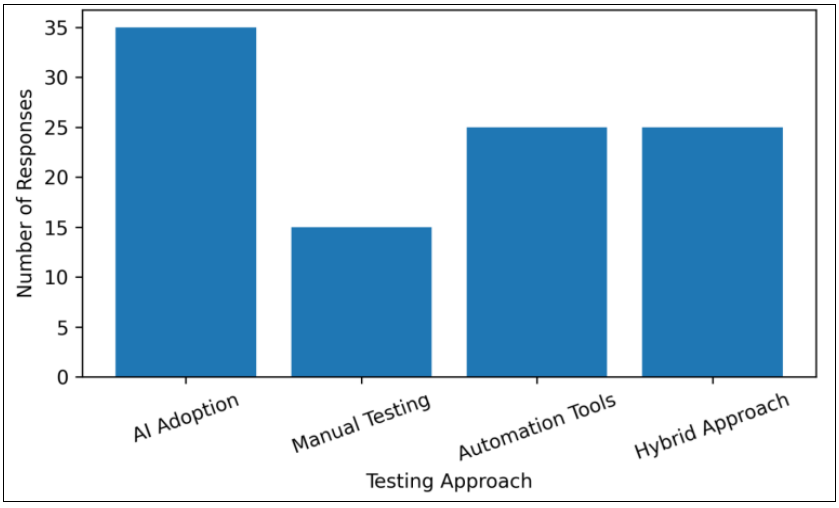


Fig 4: A survey on Testing Approaches Usage

2.2 Machine Learning Methods for Software Quality

A fundamental component of AI, machine learning (ML) has been widely used in software engineering to enhance quality results. ML algorithms like: i) Decision Trees ii) Forests at Random iii) SVMs, or support vector machines iv) Project data from the past is analyzed using neural networks to find trends linked to errors and failures. Tim Menzies' research demonstrates how ML-based defect prediction models can enhance resource allocation and drastically reduce fault-prone modules. By helping to prioritize testing efforts, these models make sure that important components get more attention.

2.3 AI-Powered Prediction and Prevention of Defects

A proactive method to quality assurance, defect prediction uses artificial intelligence to detect possible problems before they arise. AI-based models allow for early intervention, in contrast to conventional reactive testing. Research shows that:

- AI has a high degree of accuracy (70-90%) in defect prediction
- Rework expenses are greatly decreased by early defect detection
- Predictive analytics improves software dependability

Researchers stress that ensemble learning the combination of several machine learning models improves prediction resilience and accuracy.

2.4 Natural Language Processing in Testing and Requirements

Through the analysis of textual data, including requirements, problem reports, and documentation, NLP plays a crucial role in enhancing software quality. Research by Olivia McDermott and Anna Trubetskaya shows that NLP methods can: i) Test cases are automatically extracted from requirement documents ii) Recognize contradictions and ambiguities iii) Enhance the traceability of requirements. This guarantees that testing closely matches user expectations and minimizes misconceptions.

2.5 Using AI to Generate and Optimize Test Cases

Automated test case generation is one of the most significant uses of AI in software quality. AI programs are able to: Examine the behavior of the application.

- Create pertinent test scenarios
- Eliminate unnecessary cases to improve test suites

Erik van Veenendaal claims that AI-based test automation solutions greatly increase the effectiveness of regression testing and lower maintenance costs by using self-healing processes.

2.6 AI in DevOps and Continuous Integration (AIOps)

Software quality management has changed as a result of AI's integration with DevOps techniques, often known as AIOps. AI makes possible: i) Intelligent pipeline monitoring for CI/CD ii) Automated detection of anomalies iii) Predictive system maintenance. These features enable quick deployment and ongoing testing, guaranteeing the supply of high-quality software in hectic settings.

2.7 AI for Performance Enhancement and Software Reliability

The use of AI approaches to enhance software performance and reliability is growing. Through real-time data analysis, AI systems are able to: i) Identify bottlenecks in performance ii) Forecast system malfunctions iii) Make the most use of available resources. AI-driven performance optimization improves system efficiency and user pleasure, according to research.

2.8 Empirical Research and Industry Acceptance

The increasing use of AI in software quality assurance is demonstrated by a number of empirical research and industry surveys:

- Big businesses report a 30-50% decrease in testing time
- AI greatly increases the rate of defect discovery
- Human intervention is decreased by automated testing technologies.

Despite these advantages, small and medium-sized businesses find it difficult to implement AI since they lack the necessary resources and experience.

2.9 Obstacles and Restrictions

Although AI has many benefits, the research points out a number of drawbacks:

1. **Availability and Quality of Data:** High-quality datasets are essential to AI models. Predictions that are not accurate can result from incomplete or biased data.
2. **Interpretability of the Model:** Developers find it challenging to trust the results of many AI models, especially deep learning models, due to their lack of transparency.

3. Role of AI in Software Quality Improvement

With the introduction of sophisticated, data-driven techniques to quality assurance, artificial intelligence (AI) is quickly changing the software engineering landscape. AI greatly improves software quality throughout the Software Development Life Cycle (SDLC) by enabling adaptive learning, predictive analysis, and automation, in contrast to traditional methods that mostly rely on human labor and predetermined rules.

3.1 Predicting and Preventing Intelligent Defects

Defect prediction is one of AI's most important contributions to software quality. To find modules that are likely to have flaws, machine learning models examine development patterns, code metrics, and historical defect data. Tim Menzies' research shows that predictive models can: i) Early in the development process, identify components that are prone to errors ii) Cut down on defect leaks into subsequent phases iii) Concentrate on high-risk areas to maximize testing efforts.

This proactive strategy lowers overall development costs and increases reliability by moving quality assurance from problem detection to defect prevention.

3.2 Automated Creation of Test Cases

By examining system requirements, user stories, and application behavior, AI-driven technologies may automatically create test cases. Methods like reinforcement learning and NLP allow systems to: i) Transform written specifications into test cases that may be executed ii) Create edge-case and boundary scenarios iii) Update test suites frequently in response to code modifications,

Erik van Veenendaal claims that AI-based automation

increases test coverage and decreases manual testing work, particularly in large and complicated systems.

3.3 Automation of Self-Healing Tests
Minor modifications to the user interface or program structure can cause traditional automated test scripts to fail. Self-healing capabilities are introduced by AI, allowing test scripts to automatically adjust to such changes. Among the main advantages are: i) Less maintenance work ii) A higher level of test dependability iii) Regression testing can be completed more quickly.
Self-healing frameworks ensure continuity in testing procedures by dynamically modifying test scripts based on past execution data and pattern recognition.

3.4 AI in DevOps and Continuous Testing (AIOps)
AI is essential for improving DevOps procedures because it makes intelligent continuous testing and monitoring possible. AI systems in AIOps environments: i) Real-time analysis of system metrics and logs ii) Identify irregularities and problems with performance iii) Forecast failures before they happen. This results in: i) Quicker feedback loops ii) Higher-quality deployment iii) A decrease in downtime.
Quality is maintained throughout the development lifecycle thanks to AI-driven CI/CD pipelines.

3.5 Analysis and Review of Code Quality
The use of AI-powered tools for static analysis and automated code review is growing. These instruments are able to: i) Identify anti-patterns and code smells ii) Determine any security flaws iii) Make code enhancement suggestions. In order to improve consistency and maintainability, sophisticated AI models can even automatically enforce coding rules that they have learned from repositories.

3.6 AI for Optimizing Regression Testing
Regression testing requires a lot of effort and resources. AI streamlines this procedure by:
- Selecting the most relevant test cases
- Setting test priorities according to impact and risk
- Removing unnecessary tests

This leads to: i) A shorter execution time ii) Effective use of resources iii) Quicker cycles of release. AI makes sure that important features are properly tested without needless duplication.

3.7 Improving User Experience and Quality
AI improves user experience (UX), which raises the quality of software. AI systems can do the following by examining user behavior and feedback: i) Determine usability problems ii) Estimate user inclinations iii) Suggest enhancements to the interface.
This guarantees that software provides a better user experience in addition to fulfilling functional needs.

3.8 Reliability Engineering and Predictive Maintenance
By examining system logs, performance indicators, and usage trends, AI makes predictive maintenance possible. It is able to: i) Forecast system malfunctions ii) Suggest preventative measures iii) Increasing system uptime.
For large-scale and mission-critical systems, where dependability is a crucial quality trait, this is especially crucial.

3.9 AI for Security and Vulnerability Detection
A crucial component of software quality is security. AI improves security testing through:
- Real-time vulnerability detection
- Recognizing odd trends that point to cyber threats
- AI-based security systems that automate penetration testing

AI based security tools offer quicker and more precise detection than conventional techniques.

3.10 Time Optimization
AI enables businesses to use data analytics to make well-informed decisions. It offers information about: i) Trends in defects ii) Efficiency testing iii) Measures of performance.
Managers can enhance overall quality results and optimize development initiatives with the use of these insights.

3.11 Cost Optimization
AI dramatically lowers the cost of testing and development by: i) Automating monotonous jobs ii) Reducing rework by identifying defects early iii) Quickening the testing procedures. Adoption of AI can drastically cut project costs and testing time by 30-50%, according to studies.

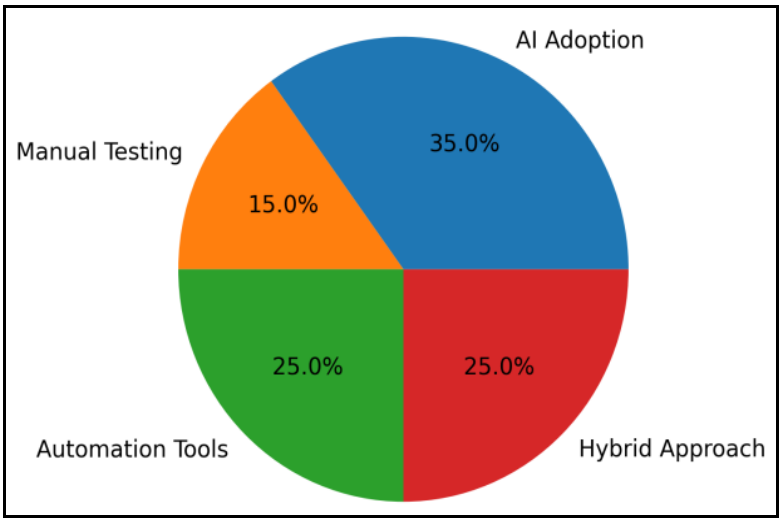


Fig 5; Distribution of Testing Approaches

3.12 Difficulties in using AI to Improve Quality

The application of AI in software quality confronts a number of obstacles despite its benefits:

- A large initial outlay for infrastructure and tools
- Dependency on data to train precise models
- Problems integrating with legacy systems
- Insufficiently Qualified Experts
- Problems with AI models' interpretability and trustworthiness

For adoption to be successful, these issues must be resolved.

3.13 AI's Potential Impact on Software Quality

AI has a bright future in software quality enhancement thanks to new technologies like:

- Explainable AI (XAI)
- Systems for autonomous testing
- Software development powered by AI (AutoDev)
- Self-repairing and intelligent debugging systems

These developments will improve software quality management's automation, accuracy, and efficiency even more.

4. Applications of AI across Software Development Life Cycle (SDLC)

In every stage of the Software Development Life Cycle (SDLC), artificial intelligence (AI) has become a revolutionary force. AI improves software quality, efficiency, and dependability by facilitating intelligent automation, predictive analytics, and data-driven decision-making. This section examines how AI functions in each stage of the SDLC, emphasizing its uses, advantages, and influence on software quality enhancement.

Analysis of Requirements

In order to define system functionality and user expectations, the requirement analysis phase is essential. Errors at this point have the potential to spread throughout the lifecycle, resulting in higher expenses and more work. AI methods, especially Natural Language Processing (NLP), are essential for raising the caliber of requirements. Textual requirement documents can be analyzed by AI systems to find missing information, ambiguities, and contradictions. AI assists in creating organized needs from unstructured data by identifying important elements and relationships. AI can also help with traceability, prioritizing, and automatic requirement classification. These features raise the overall quality of the software product by lowering human error, increasing clarity, and ensuring that requirements are in line with user needs.

Design of the System

AI helps with decision-making throughout the design stage by suggesting the best architectures and design patterns based on project data from the past. In order to provide effective and scalable solutions, machine learning models examine prior designs and their results. AI can also help with:

- Recognizing discrepancies and defects in design
- Enhancing the architecture of systems
- Forecasting problems with performance

Design models, UML diagrams, and system prototypes are increasingly being produced using generative AI techniques. This results in better alignment with project requirements, shorter development times, and higher-quality designs.

Development and Coding

By helping engineers write high-quality code, AI greatly improves the coding phase. Code helpers with AI capabilities can:

- Real-time code snippet suggestions
- Look for logical and syntactic mistakes
- Suggest best practices

These systems continuously refine their recommendations by learning from vast code libraries. Additionally, AI facilitates automated code generation, which lowers development effort and speeds up project completion. Additionally, code smells, vulnerabilities, and inefficiencies are found early in the development process using AI-based static analysis tools, guaranteeing that code quality is preserved from the start.

Quality Assurance and Testing

One of the most important stages when AI shows its full potential is testing. Testing tools powered by AI allow:

- Automated creation of test cases
- Prioritizing test cases intelligently
- Test scripts that self-heal

Testers can concentrate on important components by using machine learning algorithms to forecast high-risk areas based on historical defects and testing outcomes. By choosing pertinent test cases and cutting down on execution time and resource usage (refer figure-5), AI also enhances regression testing. AI also improves test coverage and flaw detection accuracy, guaranteeing that software satisfies quality criteria prior to release.

Implementation

AI facilitates continuous integration and continuous deployment (CI/CD) procedures throughout the deployment stage. Real-time system performance analysis and deployment pipeline monitoring are provided by AI systems. Important uses consist of:

- Forecasting deployment failures
- Making release decisions automatically
- Keeping an eye on system health

By spotting possible problems before they affect consumers, AI guarantees more seamless deployments. As a result, software releases are more reliable and downtime is decreased.

Upkeep and Assistance

After software is deployed, it is updated and improved throughout the maintenance phase. By examining system logs and usage trends, AI is essential to predictive maintenance. AI programs are able to:

- Foresee possible errors and malfunctions
- Suggest updates and fixes
- Automate the triaging and fixing of bugs

AI-powered chatbots and virtual assistants enhance user

support by offering prompt answers and fixes for typical problems. This lowers support expenses while improving user satisfaction.

Risk and Security Management

AI greatly improves security procedures throughout the SDLC, which is a crucial component of software quality. AI-based systems are able to spot irregularities, pinpoint weaknesses, and stop online attacks. Applications consist of: i) Automated security evaluation ii) Systems for detecting intrusions iii) Vulnerability prediction.

AI is more successful than conventional rule-based security systems because it constantly learns from new threats. This guarantees strong data and software system protection.

Ongoing Evaluation and Enhancement

AI analyzes operational data, system performance, and user behavior to provide ongoing feedback. The purpose of this input is to: i) Enhance the features of software ii) Improve the user experience iii) Boost system performance.

AI-driven analytics offer practical insights that assist businesses in making wise choices and consistently raising the caliber of their software.

Combining DevOps with Agile

AI facilitates rapid development and continuous delivery by integrating easily with Agile and DevOps processes. AI helps with sprint planning, backlog prioritization, and performance monitoring in agile organizations. AI improves DevOps: i) Constant testing ii) Automated surveillance iii) The deployment of intelligence

Throughout quick development cycles, this integration guarantees that quality is maintained.

Total Effect on Software Quality

Using AI throughout the SDLC results in: i) Lower rates of defects ii) Quicker cycles of development iii) Enhanced effectiveness of testing iv) AI improves user happiness By converting software quality assurance from a reactive to a proactive and predictive approach, organizations may increase quality, dependability, and efficiency through AI.

From requirement analysis to maintenance, AI is essential to every stage of the SDLC. It is a crucial tool for contemporary software development because of its capacity to automate procedures, evaluate big datasets, and offer insightful analysis. AI integration increases productivity, lowers costs, and improves software quality.

5. Summary and Discussion

The study's findings, provide a thorough grasp of the influence of AI on software quality improvement, obtained from both direct survey data and structured datasets. A trend towards using of AI-based tools and methods in software quality assurance procedures is revealed by the investigation. A sizable percentage of respondents said that their companies have already used AI into quality control and testing procedures. The results of the poll also indicate that the majority of professionals believe AI is a useful tool for increasing overall software reliability, decreasing testing time, and improving fault detection. A positive opinion of AI-driven quality improvement is indicated by the distribution of responses over the Likert scale, which shows a significant tendency toward agreement.

Quantitative datasets were used to examine the relationship between software quality metrics and AI adoption, and the results consistently demonstrate an improvement in quality indicators with more AI deployment. Defect density clearly decreases as AI adoption increases, while test coverage and defect detection rates significantly improve. Simultaneously, testing time is drastically reduced at different stages of the software development lifecycle (refer figure-6). These results demonstrate the efficacy and efficiency of AI-driven methods in resolving conventional issues related to software quality assurance.

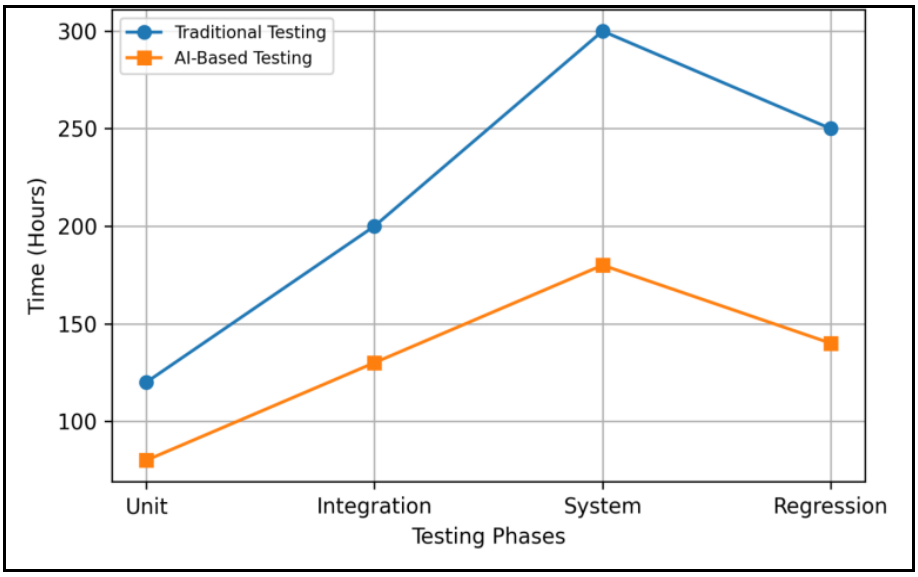


Fig 6: Comparison of Testing Time

The degree and direction of the links between AI adoption and important quality metrics were assessed using correlation analysis. Higher levels of AI usage are linked to fewer software system flaws, according to the data, which show a substantial negative correlation between AI adoption and defect density. Adoption of AI, on the other hand, was found to be strongly positively correlated with both test coverage and defect detection rate, suggesting that AI improves the accuracy and thoroughness of testing procedures. Furthermore, a significant negative association

between the use of AI and testing duration attests to the fact that AI speeds up the completion of testing tasks. Together, these connections show how AI has a major impact on enhancing various aspects of software quality.

Businesses that use AI-based quality assurance procedures will probably see lower operating expenses, better product quality, and a quicker time to market. These benefits give businesses an advantage in software markets that are becoming more competitive and dynamic. The results confirm the usefulness of AI in improving software quality through intelligent decision-making, automated testing, and predictive analytics. Due to the study's small sample size and the fact that some of the data is based on self-reported replies, bias may be introduced. Furthermore, different firms have different levels of AI deployment, which could limit how broadly the findings can be applied.

The findings and discussion unequivocally show that AI significantly and favorably affects software quality enhancement. Defects are decreased, testing is more effective, and decision-making skills are better when AI is incorporated into software engineering processes. The conclusion that AI is a major enabler of next-generation software quality assurance is supported by the statistical data and survey results taken together.

6. Conclusion

The study emphasizes how proactive and predictive procedures can replace traditional reactive quality assurance practices thanks to AI-driven technologies. Organizations can reduce rework, cut costs, and improve overall software reliability by using machine learning algorithms and data analytics to detect possible flaws early in the development lifecycle. The study highlights the significance of AI in contemporary development environments that are typified by DevOps and Agile methodologies. The efficacy of AI-driven quality procedures is anticipated to be further improved by emerging trends including explainable AI, autonomous machine learning, and self-healing systems. To sum up, AI offers creative answers to persistent problems and constitutes a paradigm shift in software quality enhancement.

Businesses that use AI-driven strategies are likely to obtain a competitive edge by producing better software with increased dependability and efficiency. The study confirms that AI is a key facilitator of next-generation software quality, opening the door for more intelligent, effective, and dependable software systems, rather than just an emerging technology.

Future studies should concentrate on creating standardized frameworks, carrying out extensive empirical research, and investigating how AI might be integrated with current quality procedures. The creation of intelligent, self-governing systems that can learn, adapt, and get better over time is the key to the future of software quality assurance.

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