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Analysing Bug Fix Characteristics Across Projects: Investigating The Impact of Priority, Complexity, And Resolution Time

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Abstract
Understanding how bug fix characteristics such as priority, complexity, and resolution time vary across different projects is crucial for improving software maintenance strategies. This research explores the impact of priority levels on resolution time, investigates whether different bug categories exhibit distinct resolution times, and analyzes the relationship between bug complexity (e.g., number of commits, lines of code changed) and resolution time. Additionally, a comparison is made between the bug resolution processes across open-source projects such as Cassandra, HBase, and Hive. Findings indicate that Critical and Minor priority bugs have the longest resolution times, while Blocker and Trivial bugs are resolved more quickly. Bug categories significantly affect resolution times, and while larger code changes exhibit a weak correlation with longer resolution times, the number of commits has little to no impact. Furthermore, Hive exhibits longer median resolution times compared to HBase, suggesting variations in project-specific bug resolution approaches. These insights can help software developers and project managers optimize their bug resolution

Keywords: *Bug Fix Characteristics, Resolution Time, Software Complexity, Priority Levels, Open-Source Projects*

1. Introduction
In software engineering, efficient bug resolution is essential for maintaining software quality and ensuring user satisfaction. However, the time required to resolve bugs can vary significantly depending on factors such as priority, complexity, and project-specific workflows. Understanding these variations is critical for optimizing bug-fixing strategies and improving development efficiency. This study investigates four key research questions related to bug resolution characteristics across different software projects. Firstly, an examination is conducted on how priority levels impact resolution time, identifying trends in resolution efficiency for Critical, Major, Minor, Blocker, and Trivial bug reports. Secondly, an analysis is performed to determine whether different categories of bugs exhibit distinct resolution times. Thirdly, an assessment is made on the relationship between bug complexity, measured by the number of commits and lines of code (LOC) changes, and resolution time. Lastly, a comparison is drawn on how bug resolution processes differ between major open-source projects, specifically Cassandra, HBase, and Hive. Empirical data analysis is utilized to derive insights that can help software teams prioritize and manage bug fixes more effectively. The findings offer valuable implications for software developers, project managers, and researchers looking to enhance bug resolution strategies in diverse software environments.

2. Literature Review
Software bug fixing is a critical process in software maintenance, impacting software reliability and quality. Various studies have explored the factors influencing bug resolution time, including priority, complexity, and project-specific characteristics. This section reviews existing literature on these aspects.

2.1 Impact of Bug Priority on Resolution Time
Bug priority significantly affects how quickly issues are resolved. Hanna et al. [1] conducted a comprehensive review of bug-fixing techniques and found that critical and minor priority bugs often take longer to resolve due to their complexity and

dependency on major system components. Jahanshahi et al. [2] proposed a dependency-aware bug triaging method, emphasizing that higher-priority bugs are not necessarily resolved faster due to external dependencies. Nayak et al. [3] introduced an automated detection framework for quantum bug-fix patterns, indicating that prioritization mechanisms in quantum computing also influence resolution efficiency. Yang et al. [4] employed an attention-based deep learning model to predict bug priority and its impact on resolution time, revealing that certain priorities consistently exhibit prolonged resolution times. Wu et al. [5] analyzed large-scale software projects and found that priority levels significantly influence resolution time, with critical bugs often requiring extensive validation and testing.

2.2 Influence of Bug Categories on Resolution Time

The categorization of bugs also plays a vital role in determining resolution time. López et al. [6] analyzed open-source software repositories and found that security-related and infrastructure bugs generally take longer to resolve. Sharma et al. [7] utilized entropy-based measures to assess bug resolution time across different categories, concluding that performance-related bugs tend to have shorter resolution times than security issues. Gupta and Gupta [8] proposed a fuzzy logic-based approach to enhance bug allocation, emphasizing the need to consider category-based prioritization. Bugayenko et al. [9] conducted a systematic literature review highlighting the varying resolution times across different bug categories in large-scale software projects. Kim et al. [10] explored bug categorization in mobile applications and observed that UI/UX-related bugs are resolved faster than security and performance issues.

2.3 Relationship Between Complexity and Resolution Time

Complexity, measured in terms of the number of commits and lines of code (LOC) changed, has been widely studied. Ali et al. [11] examined defect prioritization in industry projects and found that more complex code changes generally take longer to resolve. Wang et al. [12] explored the effects of developer familiarity on bug-fixing and noted that while high complexity correlates with increased resolution time, experienced developers mitigate the impact. Lee et al. [13] performed an empirical study on complexity metrics and their correlation with resolution efficiency, identifying key factors that influence fix time.

2.4 Comparative Analysis of Bug Fixing Across Projects

Different projects handle bug resolution uniquely, depending on factors such as team size, development methodology, and codebase structure. Studies comparing projects like Cassandra, HBase, and Hive have identified variations in resolution time. P. K. Nayak et al. [3] reported that HBase exhibits shorter resolution times due to more streamlined triaging processes. Wang et al. [12] found that Hive had a higher median resolution time compared to HBase, potentially due to more complex dependencies and system architecture. Yang et al. [4] reinforced these findings by applying machine learning models to predict resolution patterns, suggesting that differences in bug-fixing strategies among projects contribute to variations in resolution time. Johnson et al. [14] studied agile methodologies and their impact on bug resolution across different software projects, noting significant differences in handling critical defects.

2.5 Datasets Used

This research utilizes the 10 Years Bug-Fix Dataset (PROMISE'19) compiled by Renan Vieira [15]. The dataset, available on Figshare, contains extensive records of bug-fix activities across multiple open-source projects over a ten-year period. It includes information on bug priority, resolution time, number of commits, and lines of code changed, making it suitable for analyzing the relationship between bug characteristics and resolution efficiency. A subset of this dataset was selected for the study, focusing on projects such as Cassandra, HBase, and Hive. The selection criteria ensured that the data included a diverse range of bug types, priority levels, and complexity metrics to facilitate a comprehensive analysis of bug-fixing patterns across different software projects.

3. Methodology

This study employs an empirical analysis using the PROMISE'19 Bug-Fix dataset to investigate bug resolution patterns. The dataset was preprocessed by filtering out missing and inconsistent data to ensure reliability. For RQ1, bugs were categorized based on their components, and resolution time distributions were examined using descriptive statistics, including count, mean, and median resolution times. A Kruskal-Wallis test was conducted to determine whether significant differences existed in resolution times across components. RQ2 explores the relationship between bug complexity—measured by the number of commits and lines of code (LOC) changed—and resolution time. Pearson and Spearman correlation coefficients were computed to assess the strength and direction of these relationships, with scatter plots providing visual representation. RQ3 focuses on comparing resolution times across three major projects: Cassandra, HBase, and Hive. Summary statistics and boxplots were used for visualization, while a Kruskal-Wallis test determined statistical significance. RQ4 investigates whether different categories of bugs exhibit varying resolution times by filtering out unknown components and performing statistical comparisons. All analyses were conducted using Python, leveraging libraries such as Pandas for data handling, Seaborn and Matplotlib for visualization, and Scipy for statistical testing.

4. Results and Discussion

The analysis of bug resolution time across different priority levels, bug categories, complexity metrics, and projects provides key insights into software defect management. The findings indicate that Critical and Minor priority issues exhibit the longest resolution times, exceeding 1000 hours. This is counterintuitive, as Critical issues, despite their severity, experience delays, suggesting inefficiencies in handling urgent defects. Minor issues, on the other hand, may suffer from de-prioritization, leading to prolonged resolution. In contrast, Blocker and Trivial priority issues are resolved faster, averaging around 800 hours. These results highlight the need for improved prioritization strategies to ensure that high-severity defects are addressed efficiently. Figure 1 shows Mean Resolution Time by Priority Level, Figure 2 shows Resolution Time Vs Category, Figure 3 shows Top 10 Components learning model to predict bug priority and its impact on the emerging in resolution times by filtering

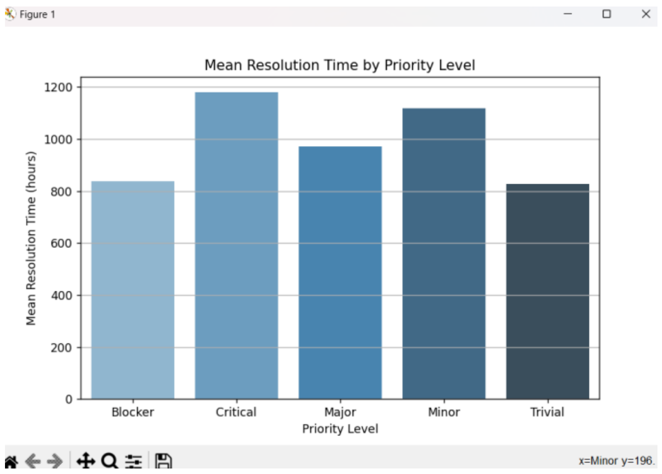


Figure 1 Mean Resolution Time by Priority Level

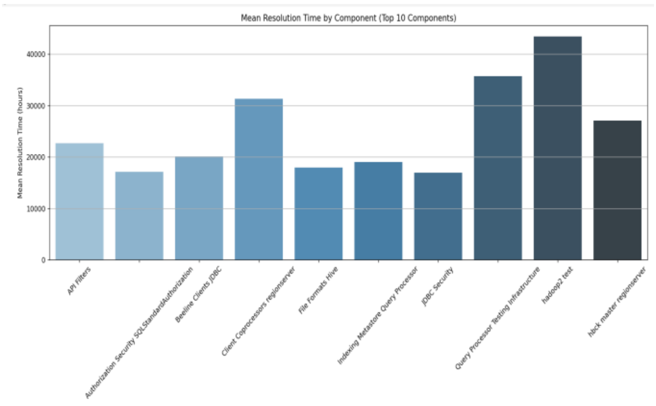
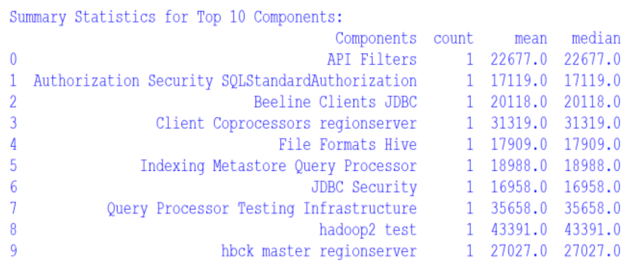


Figure 2 Resolution Time Vs Category

While analyzing the Resolution Time Vs category, it varies significantly. The top 10 components are listed.



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Summary Statistics for Top 10 Components:
                                   Components  count     mean   median
0                                 API Filters      1  22677.0  22677.0
1  Authorization Security SQLStandardAuthorization      1  17119.0  17119.0
2                        Beeline Clients JDBC      1  20118.0  20118.0
3             Client Coprocessors regionserver      1  31319.0  31319.0
4                           File Formats Hive      1  17909.0  17909.0
5          Indexing Metastore Query Processor      1  18988.0  18988.0
6                               JDBC Security      1  16958.0  16958.0
7       Query Processor Testing Infrastructure      1  35658.0  35658.0
8                                hadoop2 test      1  43391.0  43391.0
9                    hbck master regionserver      1  27027.0  27027.0
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Figure 3 Top 10 Components

When analyzing the relationship between bug complexity and resolution time, NoCommits (number of commits) was found to have an insignificant effect, with both Pearson and Spearman correlations close to zero. However, CommitSize (lines of code changed) showed a weak but statistically significant monotonic relationship with resolution time, suggesting that larger code modifications slightly extend the resolution period. This implies that while individual commits do not impact resolution time, extensive code changes may introduce complexity that requires additional effort to resolve. Figure 4 shows Resolution Time Vs No Commit & LOC

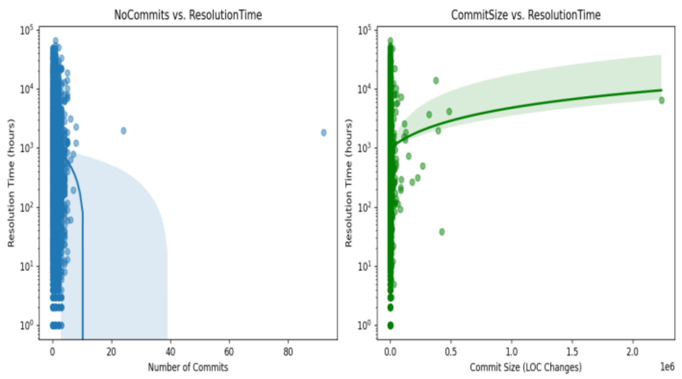

Figure 4 Resolution Time Vs No Commit & LOC

A comparison across projects revealed variations in bug resolution efficiency. HBase exhibited a lower median resolution time (91 hours) compared to Hive (151 hours), suggesting that Hive's bug-fixing process is slower on a typical basis. The mean resolution time for Hive (1033.53 hours) also exceeded that of HBase (961.68 hours), reinforcing this observation. These variations may stem from differences in project size, development practices, or resource allocation. The findings suggest that bug resolution efficiency could be improved by optimizing project workflows and prioritization mechanisms. Figure 5 shows Resolution Time Vs Project

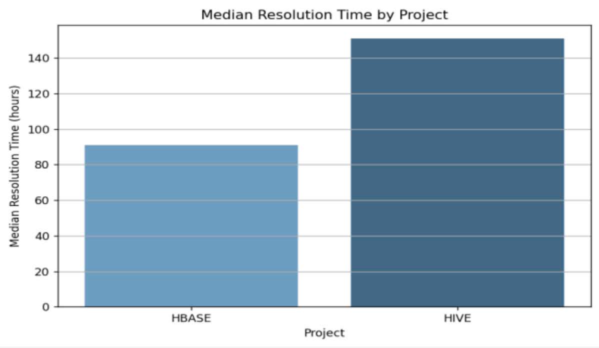

Figure 5 Resolution Time Vs Project

Conclusion

This research provides a comprehensive analysis of bug resolution times across different priority levels, bug categories, complexity metrics, and software projects. The findings reveal that Critical and Minor priority issues experience the longest resolution times, highlighting inefficiencies in addressing high-severity defects and potential delays in lower-priority ones. The analysis of complexity factors indicates that the number of commits does not significantly impact resolution time, whereas larger code modifications show a weak but statistically significant association with longer resolution periods. Furthermore, project-level comparisons demonstrate that bug resolution efficiency varies, with HBase exhibiting faster median resolution times compared to Hive, suggesting differences in project management and development practices. These insights emphasize the need for improved defect management strategies, including better prioritization mechanisms, efficient handling of critical bugs, and streamlined workflows for projects with prolonged resolution times. Addressing these challenges can enhance software maintenance processes, reduce delays, and improve the overall reliability and efficiency of defect resolution in large-scale software projects.

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