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# Perform Scanning and Comparison of Open Source Web Application Testing Tools: Using Strategic Holistic Approach

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***Abstract***

*This study investigates the scanning and comparative analysis of open source web application testing tools using a strategic and holistic approach. As web applications play a crucial role in business operations and customer engagement, the demand for strong security measures is more important than ever. Open source tools provide flexible and cost-effective options for identifying vulnerabilities and ensuring adherence to security standards. However, the wide range of available tools requires a systematic evaluation to assess their effectiveness and appropriateness. Our research utilizes a comprehensive methodology that combines various scanning techniques and tools, allowing for an in-depth evaluation of their capabilities. By conducting direct comparisons, we can pinpoint essential performance metrics, usability aspects, and the tools' effectiveness in detecting vulnerabilities across different scenarios. This holistic approach helps organizations monitor changes in their security posture over time and make informed choices regarding tool selection and vulnerability management. Ultimately, this study aims to offer practical insights for developers and security teams, encouraging a culture of continuous improvement and proactive risk management. By harnessing the advantages of open source tools within a strategic framework, organizations can strengthen their security measures and better safeguard their web applications in an increasingly complex digital environment.*

***Keywords:*** *Fintech, Green Finance, ASEAN, Moderator, Mediator.*

## Introduction

In the context of open source web application testing tools, comparison entails a systematic evaluation and analysis of results obtained from different scanning sessions or testing tools. This process is vital for assessing the effectiveness of security measures, tracking changes over time, and making informed decisions about vulnerability management and the selection of tools

In today's digital environment, web applications are vital for business operations, user engagement, and data management. The growth of e-commerce, online services, and cloud computing has made these applications central to how organizations interact with customers and handle internal processes. However, as these applications become more complex, security vulnerabilities are increasingly concerning. The integration of various third-party services and APIs can pose additional security risks if not managed properly.

Open source tools offer a cost-effective and accessible solution for developers and security experts. Unlike proprietary software, which can be costly and restrictive in terms of customization, open source tools provide the flexibility to meet specific organizational needs. They allow for comprehensive vulnerability scanning, ensure compliance with security

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standards, and promote continuous improvement through iterative testing. This strategy not only bolsters security but also fosters a culture of accountability and transparency within development teams, Open source web application vulnerability analysis refers to the systematic review of web applications to uncover potential vulnerabilities, misconfigurations, and security weaknesses.

Comparison is also crucial. It enables organizations to track changes over time, evaluate the effectiveness of their security measures, and assess different tools or application versions. By comparing outcomes from various scans or testing tools, teams can uncover trends, identify recurring problems, and measure advancements in their security posture. This iterative approach is key to ongoing security improvement and effective risk management.

## Materials and Methods

The materials and methods for conducting scanning and comparison with open source web application testing tools encompass the selection of suitable tools, the establishment of testing scope, and the implementation of a structured scanning process. Essential tools like OWASP ZAP and Burp Suite aid in identifying vulnerabilities, while a properly configured test environment guarantees effective performance. This methodology involves collecting data, performing comparison analysis, and generating reports,

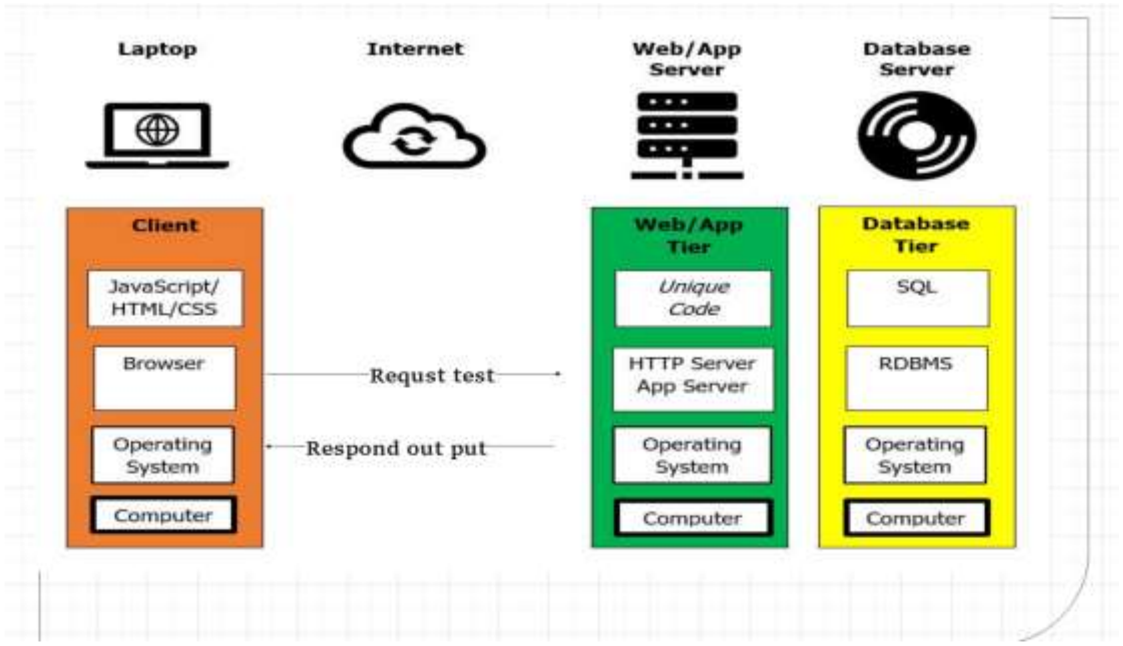
The materials employed in the scanning and comparison process consist of a range of open source web application testing tools crucial for identifying security vulnerabilities. A key tool in this selection open source web application tools and its effectiveness in detecting vulnerabilities within web applications. The primary objective of this research was to identify an efficient and effective tool for web application penetration testing that meets current industry requirements accurately and efficiently.

Selecting a perfect tool for testing of a software could be a tasking sometimes considering the factors to put into consideration before choosing a tool. The decision to choose a test tool is a basic factor in the achievement of test automation. This requires studying the extent of testing and test methodology, then afterward selecting the correct test tool that meets the necessities of automating test-suite for a specific item and release [18]. A testing tool can serve for web application testing, desktop application, mobile application testing or combination of two applications also it may involve any testing functionality like unit test, regression test, integration testing etc. The tools evaluated below were selected based on an inclusion and exclusion criteria of the most discussed testing tools from literature which can also be considered as the widely used tools by industry practitioners. These tools are briefly introduced and a tabular comparison of their strength and weakness highlighted based on certain factors like reusability, reliability and cost etc, these factors were identified from literature and used as a base for comparison (**F. Okezie1, 2019**).

### The Environment Setup

Setting up an effective environment for web application vulnerability testing requires careful attention to hardware and software requirements. For hardware, a computer or server with at least a quad-core CPU, 8GB of RAM (16GB ideal), and 100GB of free disk space is essential for optimal performance.

On the software side, Kali Linux is highly recommended due to its suite of pre-installed security tools, though Windows may be necessary for certain applications. Using virtualization software like VMware Workstation or Virtual Box can facilitate the creation of isolated testing environments, Key tools include Burp Suite for intercepting web traffic, OWASP ZAP for automated vulnerability scanning, Nikto for identifying web server issues and sqlmap for SQL injection testing, by thoughtfully selecting these components, The setup involved two identical machines. One machine serves as the client with performance testing tools installed and a server which hosts the static web pages. These machines are connected via PC-to-PC LAN cable or commonly referred as cross cable connection. The reason for this kind of environment setup is to minimize the network factors from influencing the results of performance test **(Muhammad Dhiauddin Mohamed Suffian, 2012**). The setup is represented in Figure 1 below:



## Some concept of Environment Setup

- **Test Requirements –** Desktop application testing requires the use of at least one computer system or workstation, whereas in the case of **client server application testing**, it requires the use of at least one server for loading the application and one client machine or system and for web application testing, it requires the use of a web browser and internet connectivity on personal computers or laptops.
- **Test Execution –** Desktop application testing can be carried out on a single computer or workstation, but client server application testing should be done on a 2-tier application and **web application testing** should be done on a 3-tier application.
- **Test Environments –** The environment for stand-alone or **desktop application testing** is a user computer because these tests are platform-dependent; in contrast, the environments for client server application testing and web-based application testing are often the intranet and web browsers, respectively.
- **Test Parameters –** When testing desktop or standalone applications, test engineers examine the factors such as performance, GUI, and memory leaks in the backend database. In contrast, when testing client server applications, they examine the factors such as functionality, performance, and GUI. Finally, when testing web applications,

they examine the factors such as browser and OS compatibility, GUI testing, broken link testing, load, and stability.

**Evaluation Approach / Implementation**

The implementation phase consists of several essential steps to thoroughly evaluate open-source web application vulnerability testing tools. Initially, the tools are deployed in a standardized environment, ensuring consistency and control during testing. This standardization helps reduce external factors that could affect the results.

Next, tests are executed by applying the chosen tools to various web applications with known vulnerabilities. This practical assessment is vital for determining each tool's effectiveness in detecting and reporting security issues, allowing for real-world performance evaluation.

After testing, systematic documentation of the findings is crucial. This record-keeping should include information on detected vulnerabilities, scan durations, and any anomalies encountered. Such detailed documentation supports a structured comparative analysis later in the process.

The comparative analysis will focus on several key aspects of each tool. It will involve an in-depth examination of their strengths and weaknesses, providing insights into their capabilities and limitations. This evaluation aids users in understanding the practical considerations of selecting a particular tool.

User experience will also be assessed by analyzing the interface and ease of navigation, as user-friendly tools can greatly enhance assessment efficiency. Finally, the level of community support and engagement will be reviewed, as a strong community can offer valuable insights, updates, and troubleshooting help. This thorough analysis will ultimately assist users in choosing the most appropriate tools for their specific requirements.

The effectiveness of all web vulnerability scanners should be evaluated using a set of "benchmark" web applications and all OWASP Top 10 types of vulnerabilities.

In this section we will discuss the artefact implementation. We have taken two approached to evaluate the scanning, crawling and vulnerability detection capabilities of the tool. We have utilized OWASP Benchmark test tool to evaluate the vulnerability detection and crawling coverage of the tool.

To conduct analysis web applicant testing the testing process for web application scanners involves several systematic steps approach to ensure a comprehensive understanding of each tool's capabilities and effectiveness of testing. Below are the key phases of this evaluation process:

**My evaluation approach involved the following steps**

A. Download the OWASP Benchmark Project: We set up the project using Docker.

B. DNS Registration: We registered a domain with Go Daddy to make the OWASP Benchmark Project publicly accessible.

C. Port Forwarding: We configured port forwarding on our home router to facilitate access.

D. Tool Acquisition: We downloaded the top twenty security tools, each requiring specific environment setups, as detailed in Table 3.

E. Configuration Settings: We configured each tool based on the selected pre-scan type.

F. Execution of Tests: We initiated attacks on the OWASP Benchmark Project using the configured tools.

G. Result Generation: The results were generated in XML format.

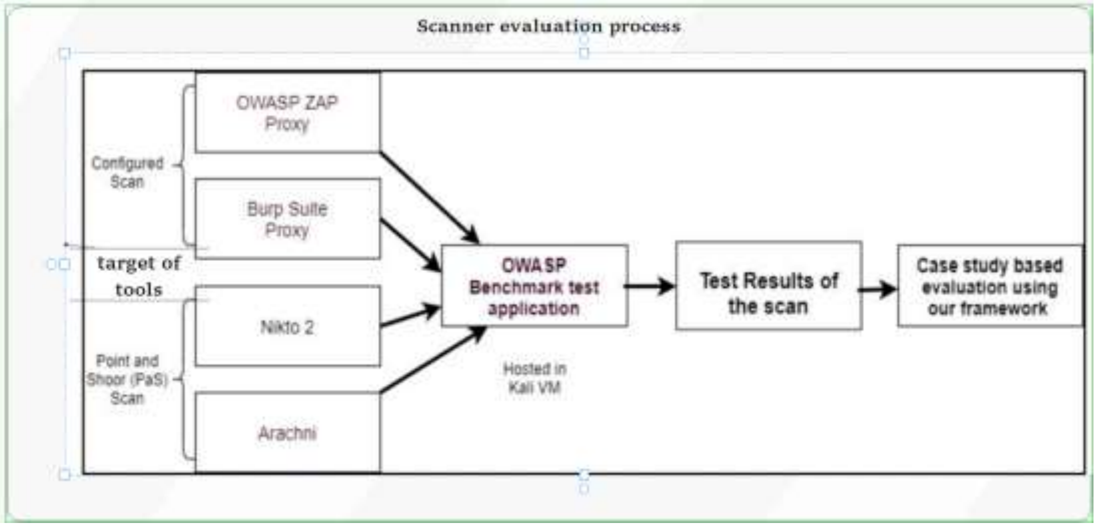
H. Result Integration: We integrated the results into the OWASP Benchmark Project.

I. Score Calculation: We ran the score calculator provided by the OWASP Benchmark Project against the XML reports generated by the tools.

J. Manual Benchmarking: We analyzed the score results and began our manual benchmarking using our proposed framework.

K. Comparison of Tools: Finally, we compared the tools based on the overall benchmarking results.

It is implementation process


Scanner evaluation process
Configured Scan
target of tools
Point and Shoot (PaS) Scan
OWASP ZAP Proxy
Burp Suite Proxy
Nikto 2
Arachni
OWASP Benchmark test application
Hosted in Kali VM
Test Results of the scan
Case study based evaluation using our framework

## Implement Experimental Scenario

In this section, we outline our implementation approaches for the experiment. We adopted two primary test implementation strategies. First, we established the testing environment, ensuring it was properly configured. Next, we set up the scan configurations and initiated benchmarking using the OWASP Benchmark tool to assess the scanners' crawling capabilities and vulnerability detection coverage. Following the benchmarking process, we analyzed the results and conducted a comparative evaluation based on our proposed assessment method.

Implementing an experimental scenario to compare penetration testing tools for detecting web application vulnerabilities involves several key steps. First, clearly define the objectives, such as evaluating accuracy, speed, and ease of use. Next, select a mix of popular open-source tools like OWASP ZAP and Burp Suite. Set up a controlled testing environment using vulnerable applications, and identify the specific types of vulnerabilities to assess, such as SQL Injection and XSS. Establish a standardized methodology for preparation, execution, and data collection, focusing on metrics like the number of vulnerabilities detected, programing logic for rank calculation and user experience. After conducting the tests, compile the results into a comparative format to analyze tool performance and provide recommendations tailored to different use cases for community, the experiment aimed to evaluate the effectiveness of web application security tools by conducting tests against within OWASP Benchmark Project this OWASP Benchmark Project as a standardized framework, the experiment provided a rigorous comparison of how well each tool performed in real-world scenarios, offering insights into their strengths and weaknesses in identifying critical security flaws **(Thota, June 2024**).

## Design of a Framework for Evaluation Criteria

This subsection outlines a detailed comparative benchmark framework for assessing the twenty selected penetration testing tools. We defined specific metrics to evaluate the tools comprehensively. After examining existing web application scanner evaluation frameworks, we developed a new framework that aligns with their methodologies while offering a more extensive set of benchmarking metrics and criteria, thereby enhancing the evaluation process for professionals in the web penetration testing domain.

Our framework includes the following criteria: test coverage, attack coverage, vulnerability detection, and efficiency. During our review of various existing frameworks, such as the OWASP Benchmarking Project, Web Input Vector Extractor Teaser (WAVSEP), and the Web Input Vector Extractor Teaser (WIVET), we noted that many tend to concentrate on specific aspects of automated scanners and provide limited metrics for assessing performance.

To address this limitation, we created a framework that incorporates a broader range of evaluation parameters. Additionally, we employed a scoring system previously established in the literature to facilitate a comparative analysis of each tool. Each key parameter is associated with a specific scoring system as follows **(Marwan Albahar 1, Published: 21 September 2022**):

A. **Scanner Scoring System**: The selected criteria will be kept in mind while benchmarking the top web application vulnerability testing tools. We use the proposed score system in to evaluate the tools.

B. **Criteria and Metric Selection:** The used benchmarking metrics and criteria for tool evaluation are presented as follows: – Graphic user interface (GUI); – Command-line interface (CLI).

C. **Penetration Testing Level**: Recent scanning tools can grasp web application sessions and detect variations in web application source code. Most automated web application testing tools only use the black box test method in authenticated scans

D. **Crawling Types:** There are two types of crawling: passive crawl and active crawl. The active crawl is the first step before the active scanning, which catalogs the found links. However, the passive crawl is best for covering. Score for crawling ability.

E. **Number of URLs Covered:** Web application crawling is a part of the information gathering stage in the PEN-testing process. In this stage, a penetration tester would like to gather as much information as possible about the web application. Crawler coverage can be signified by the number of URLs crawled by the scanner; the more URLs the scanner covers, the higher the score as follows. Score for covered URLs:

F. **Scanning Time:** The automated tools developed by penetration testers cover a greater area in a large web application with less possible time. Therefore, the time taken is important for scanner evolution. Score for scanning time:

G. **Types of Scan**: There are two types of scans in web application PEN-testing, passive and active. In this metric, the scanner with active and passive options takes the highest point. Score for scan type:

H. **Reporting Features**: The reports can be formatted depending on the compliance policy that the penetration tester needs to analyze, which is a recent feature in scanners

I. **Added Features:** Some automated tools have add-ons and extension features that improve the scanner performance in vulnerability detection. Most penetration testers take advantage from these features

J. **OWASP Top 10 Vulnerabilities Coverage**: The OWASP Top 10 Vulnerabilities are essential for evaluating many organizations and penetration testers use penetrating tools to cover the top 10 vulnerabilities in their web applications and protect their assets from the known vulnerabilities

K. **Number of False Positives:** The false positive is an unreal indicator for vulnerabilities in the OWASP benchmark reported by the scanner. Fewer false positive percentages are helpful for penetration

L. **Number of True Positives**: The true positive means that the real vulnerability number in the OWASP benchmark is detected correctly by the scanner. It is the most important metric in vulnerability detection criteria.

| Measurement | Criteria | Metric | Score Range |
|---|---|---|---|
| Test coverage | Percentage of code tested | % of code coverage | 0% - 100% |
| Attack coverage | Types of attacks tested | Number of attack vectors | 0 - N (where N is total) |
| Efficiency | Time taken for testing | Time (minutes/hours) | Low, Medium, High |
| Vulnerability detection | False positives/negatives | Count of false positives/negatives | 0 - N (where N is total) |

**Assessment Metrics for web application security testing**

This table presents essential metrics for assessing web application security testing. Each criterion sheds light on different facets of the testing process:

- **Test Coverage:** This metric indicates the percentage of the application's code that has undergone testing. A higher percentage signifies a more comprehensive evaluation. The scoring range goes from 0% (indicating no code tested) to 100% (meaning the entire codebase has been tested).
- **Attack Coverage:** This criterion evaluates the range of attack vectors that have been applied to the application. The score reflects the number of unique attack types tested, ranging from 0 to N, where N denotes the total number of applicable attack vectors.
- **Efficiency:** This metric assesses the time taken to complete the testing process. Efficiency is classified into three categories: Low, Medium, and High, which indicate the speed of

testing relative to the application's complexity.

- **Vulnerability Detection:** This measures how effectively the testing identifies vulnerabilities, focusing on the number of false positives and negatives. A lower count suggests a more dependable testing process. The scoring range is from 0 to N, with N representing the total number of potentially detectable vulnerabilities.
- **Criteria** refer to the particular elements being assessed to evaluate the effectiveness of the testing process. Each criterion is linked to a metric, which provides a measurable way to gain insights into the performance of the application being tested. For example,
- "**Test Coverage"** assesses the percentage of the application's code that has been examined, while "Attack Coverage" looks at the range of attack vectors utilized during testing. The score range specifies the potential values that the metric can achieve, facilitating a consistent evaluation. For instance, the score range for "Test Coverage" runs from 0% to 100%, indicating how much of the code has been tested, while "Attack Coverage" is represented as a count from 0 to N, where N signifies the total number of relevant attack types. This organized framework allows organizations to effectively evaluate and compare their web application security efforts.
- Metrics are measures of quantitative assessment commonly used for assessing, comparing, and tracking performance or production ,Measurement or criterion utilized within a specialized field or particular framework, although it isn't commonly recognized terminology in web development or application performance metrics.

In summary, these metrics create a robust framework for evaluating the thoroughness and effectiveness of web application security testing. They assist organizations in pinpointing areas for improvement and ensuring strong security protocols are in place.

## Benchmark web application testing tools analysis techniques

Analyzing web application testing tools requires a comprehensive approach that considers various factors, including functionality, performance, user satisfaction, and cost. Employing a combination of different techniques we have been conducted a thorough study to identify and evaluate the most commonly used open source web vulnerability scanner. The evaluation was based on predefined criteria provided by the Web Application Security Consortium. The benchmarking criteria for evaluating tools are based on several parameters, including the tool's strength, its drawbacks, and the corresponding tool mentioned under the strength category or performance. The evaluation of these tools reveals that each tool has its own advantages and disadvantages, positive and negative aspects. However, the strength of a tool is reflected in its usage, which supports various testing strategies such as functional testing, regression testing, automation testing, compliance testing, security testing, and more. Additionally, we conducted a comprehensive analysis of the results generated by the different scanners following the detection stage. Subsequently, we compared and analyzed the performance of the scanners using the OWASP benchmark metric in order to assess their precision the primary requirement for a tool that caters to the needs of the testing team is its ability to support web services while keeping the cost to a minimum. This is the current demand in the industry, we also compared the scanners based on our framework and calculate test score for each of the scanner and rank them. This chapter addresses second and third objective of our research **(Mandar Prashant Shah, 08/01/2020)**

**Selecting of top (20) tools**

Open source web vulnerability scanners. The main objectives of this study are to assess the performance of open source scanners from multiple perspectives and to examine their detection capability. This paper presents the results of a comparative evaluation of the security features as well as the performance of four web vulnerability detection tools. We followed this comparative testing with a case study in which we evaluate the level of agreement between the results reported by twenty (20) open source web vulnerability scanners ,we conclude that the inconsistencies between the reports generated by different scanners might not necessarily correlate with their performance properties. We also present some recommendations for helping developers of web vulnerabilities scanners to improve their tools' capabilities, however we are selected tools to compare in this section, use open-source web application testing tools Performing a comprehensive comparison of open-source web application testing tools using a strategic, holistic approach involves evaluating various tools based on several criteria and, first and foremost, the best tools selection for the sample (**Mansour Alsaleh, 2017**).

In dynamic realm of cybersecurity, open source web application testing tools play a crucial role in identifying vulnerabilities and strengthening defenses. My research focused on systematically selecting the top 20 n tools preferred by seasoned penetration testers, ensuring both academic rigor and practical applicability. I began with an extensive literature review of recent academic studies, which helped us create an initial list of frequently cited tools. To further validate this list, we conducted a survey of cybersecurity experts to gather insights on tool preferences, usability, and emerging trends. This survey allowed participants to rate their favorite tools and share feedback, enhancing our understanding of their practical use. I established selection criteria based on factors such as popularity, functionality, recent updates, and user experience. After analyzing data from the literature review and expert survey, I refined my list to 20 tools that had strong reputations and met our criteria. Furthermore, we ensured that my evaluations were based on the latest versions of these tools, confirming access to the most recent releases during study this research of work, this comprehensive approach resulted in a well-rounded selection of tools that are pertinent to the current cybersecurity Ecosystem.

**Web application security tools: feature and requirement**

Presents the comparison of the tools based on their technical requirements: These tools vary from each other based on the technology they are developed in, the operating system in which they are supported and their requirements which need to be fulfilled before installation.

| No | Tools Name | Requirement | OS Support | Programming Language | Version Used |
|---|---|---|---|---|---|
| 1 | Burp Suite | Java Runtime Environment | Windows, Linux, macOS | Java | 2023.x |
| 2 | OWASP Zap | Java Runtime Environment | Windows, Linux, macOS | Java | 2.12.x |
| 3 | Acunetix | .NET Framework, Web Server | Windows | C# | 14.x |
| 4 | Nikto | Perl | Windows, Linux, macOS | Perl | 2.1.6 |
| 5 | UniScan | Web Server | Windows, Linux | PHP | 7.x |
| 6 | w3af | Python, Web Server | Windows, | Python | 1.6.49 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Linux | | |
| 7 | Vega | Java Runtime Environment | Windows, Linux, macOS | Java | 1.0.1 |
| 8 | SQLMap | Python, Database Drivers | Windows, Linux | Python | 1.6.6 |
| 9 | Arachni | Ruby | Windows, Linux | Ruby | 1.5.0 |
| 10 | Wapiti | Python, Web Server | Windows, Linux | Python | 3.0.0 |
| 11 | Wscan | Python, Web Server | Windows, Linux | Python | 1.0.0 |
| 12 | Webshell | Web Server | Any | N/A | N/A |
| 13 | Skipfish | C Compiler, Web Server | Windows, Linux | C | 2.13b |
| 14 | Dirb | Web Server | Windows, Linux | C | 2.22 |
| 16 | Grinder | Java Runtime Environment | Windows, Linux, macOS | Java | 3.11.0 |

**Description of Web application security tools: feature and requirement**

The table showcases a variety of web application security tools, each designed to meet different user requirements and operating conditions. Here are the main points of comparison:

- **Operating System Support:** Most tools are compatible with multiple operating systems, especially Windows and Linux. However, tools like Acunetix are restricted to Windows, which may limit their use for those on other systems.
- **Programming Language:** The tools are developed using several programming languages, predominantly Java, Python, and C. Java-based tools (such as Burp Suite, OWASP Zap, and Vega) offer cross-platform functionality, while Python tools (like w3af, SQLMap, and Wapiti) provide greater flexibility and user-friendliness.
- **Requirements:** The tools have varying requirements, with some needing specific frameworks (e.g., .NET for Acunetix) or compilers (e.g., Skipfish). These dependencies can impact installation and operation based on the user's environment.
- **Versioning:** There is a wide range of versioning among the tools, from the most recent releases (like Burp Suite 2023.x) to older versions (such as Nikto 2.1.6). It is advisable for users to opt for the latest versions to take advantage of enhanced features and security updates.
- **Specialization:** Some tools, including Webshell and UniScan, are tailored for particular functionalities, such as addressing web server vulnerabilities, while others offer more comprehensive scanning capabilities. This specialization enables users to select tools that align best with their assessment goals.
- **Ease of Use:** Tools like OWASP Zap and w3af are recognized for their intuitive interfaces, making them suitable for beginners, whereas others may demand a higher level of technical skill.

## Design Evaluation Criteria and formula

This subsection presents a detailed framework aimed at evaluating the top twenty penetration testing tools, highlighting specific metrics for assessing these tools from multiple angles. In creating this framework, we drew on existing evaluation methods for web application scanners, refining and expanding them to offer a wider array of benchmarking metrics and criteria for professionals in the web penetration testing domain. Our framework takes a comprehensive approach by incorporating several essential criteria: Test Coverage Criteria examines how well each tool can evaluate various components of a web application, ensuring thorough testing; Attack Coverage Criteria evaluates the spectrum of attack types each tool can simulate, offering insights into their effectiveness against different vulnerabilities; Vulnerability Detection Criteria assesses the accuracy and efficiency with which each tool identifies vulnerabilities, which is vital for effective risk management; and Efficiency Criteria reviews the performance of each tool concerning speed and resource use during testing, ensuring optimal functionality within time limits.

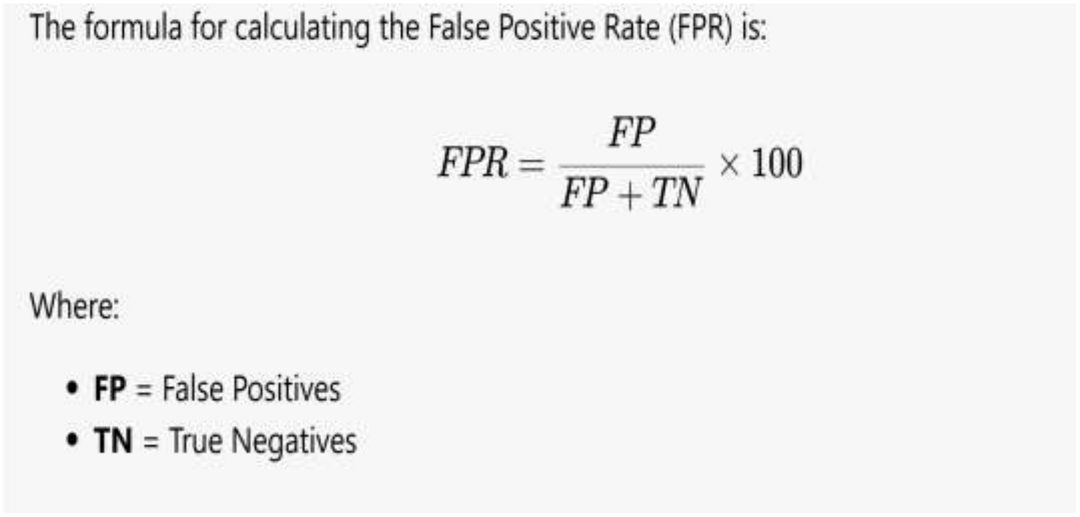
A. **OWASP Top 10 Vulnerabilities Coverage Metric** This metric assesses how well web applications address the OWASP Top 10 vulnerabilities, which is essential for organizations and penetration testers to evaluate their security practices. **Scoring Criteria:**

   - Less than 25% coverage
   - 25% to 50% coverage
   - 50% to 70% coverage
   - 70% to 90% coverage
   - More than 90% coverage

B. **Automation Level Metric** This metric evaluates how effectively a scanner can conduct scans independently, reducing the necessity for manual input from penetration testers. The scoring criteria for automation level are:

   - Requires 100% involvement from testers
   - Requires 80% involvement from testers
   - Requires 70% involvement from testers
   - Requires 50% involvement from testers
   - 5: Requires less than 30% involvement from testers

**C. False Positive Rate (FPR) Formula**



The formula for calculating the False Positive Rate (FPR) is:

$$FPR = \frac{FP}{FP + TN} \times 100$$

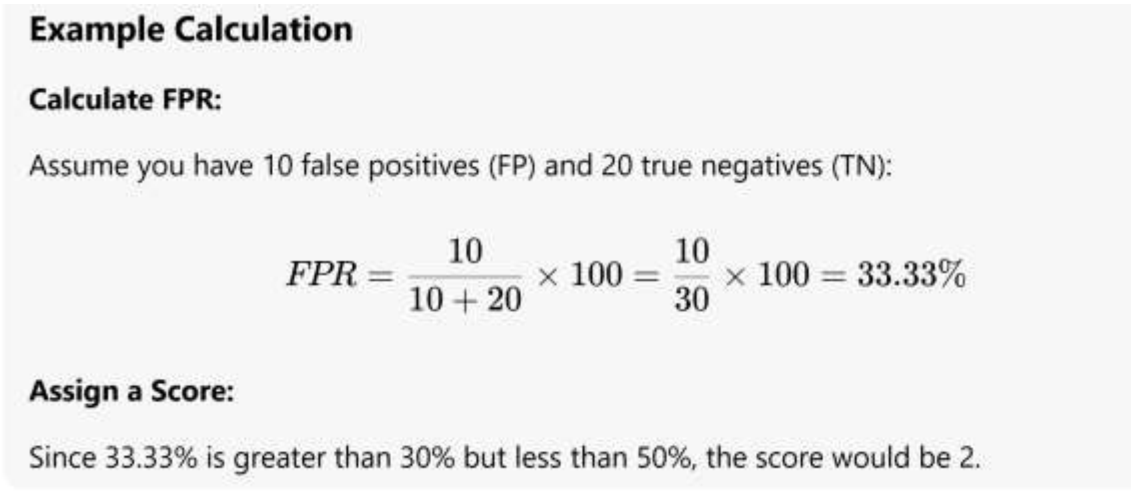
Where:

- **FP** = False Positives
- **TN** = True Negatives

Based on the calculated False Positive Rate (FPR), scores can be assigned as follows:

- Score 1: FPR > 50%
- Score 2: FPR > 30%
- Score 3: FPR < 30%

**Interpretation** Higher scores reflect improved performance in reducing false positives, which is beneficial for penetration testing. In contrast, lower scores indicate a higher number of false positives, making vulnerability assessments more challenging.



**Example Calculation**

**Calculate FPR:**

Assume you have 10 false positives (FP) and 20 true negatives (TN):

$$FPR = \frac{10}{10 + 20} \times 100 = \frac{10}{30} \times 100 = 33.33\%$$

**Assign a Score:**

Since 33.33% is greater than 30% but less than 50%, the score would be 2.

**D. Number of True Positives:**

The True Positive Rate (TPR), commonly referred to as sensitivity or recall, can be calculated with the following formula:

**Where:**

- TP = True Positives (the count of vulnerabilities accurately identified)
- FN = False Negatives (the count of vulnerabilities that were overlooked)

$$TPR = \frac{TP}{TP + FN}$$

**Evaluating Vulnerability Scanner Performance with TPR:**

- A higher TPR reflects improved performance, indicating the scanner is effectively detecting vulnerabilities.
- A TPR of 1 (or 100%) means all actual vulnerabilities were found, while a TPR of 0 indicates none were detected.

### E. Scanner Scoring System

**Criteria Selection** Establish and specify the essential criteria for assessment. Typical criteria consist of:

- Accuracy (maximum of 5 points)
- Speed (maximum of 5 points)
- User-Friendliness (maximum of 5 points)
- Reporting Features (maximum of 5 points)
- Compatibility with Other Tools (maximum of 5 points)
- Cost Efficiency (maximum of 5 points)

### F. Criteria and Metrics Selection

**Scoring Criteria: Based on Experience (UX)**

- GUI: User-friendly design, straightforward navigation, and visual cues.
- CLI: Clear commands, simplicity in recalling commands, and availability of help resources.

**URL Coverage Scoring System**

- In the context of web application crawling for penetration testing, the scoring for URL coverage is categorized as follows:
- Score 1: Coverage is less than 25%
- Score 2: Coverage ranges from 25% to 50%
- Score 3: Coverage is between 50% and 70%

- Score 4: Coverage falls between 70% and 90%
- Score 5: Coverage exceeds 90%

**Scanning Time Scoring Criteria**

- Score 1: Exceeds 6 hours
- Score 2: Exceeds 3 hours
- Score 3: Exceeds 2 hours
- Score 4: Exceeds 45 minutes
- Score 5: Under 30 minutes

This scoring framework enables the assessment of various scanning tools' efficiency based on the time required to analyze a large web application. If you need help with incorporating this into a report or analysis, feel free to ask!

**Scan Type Scoring Criteria**

- Score 1: Only has an active scan or a passive scan.
- Score 2: Includes both active and passive scans.
- Score 3: Features active, passive, or policy scans.

This scoring framework assesses web application penetration testing tools based on the variety of scanning methods they provide, with a focus on those that offer both active and passive scans.

**Reporting Features**

Scanners can customize their reporting capabilities to align with the compliance policies that penetration testers must assess. Recent developments have enabled reports to conform to standards like OWASP Top 10 and HIPAA. Typical report formats include HTML, PDF, and XML. Compliance policy reports tend to be more concise, facilitating easier analysis for penetration testers.

**Scoring for Reporting Features:**

- Score 0: Provides reports in HTML, PDF, and XML formats.
- Score 1: Includes compliance reports based on standards such as OWASP Top 10 and HIPAA.

G. **Youden Index formula Youden's** Index is a metric used to assess the effectiveness of diagnostic tests, especially in the realm of web application penetration testing (PEN-testing) scanners. It is defined as follows, **Youden Index Values**:

- 1: The scanner successfully identifies vulnerabilities with no false positives.
- -1: The scanner only reports false positives, failing to identify any true vulnerabilities.
- 0: The scanner's findings align with the expected results, showing no discrepancies.

**Youden Index Formula:**

$$J = \frac{TP + TN - 1}{TP + TN + TN + FP}$$

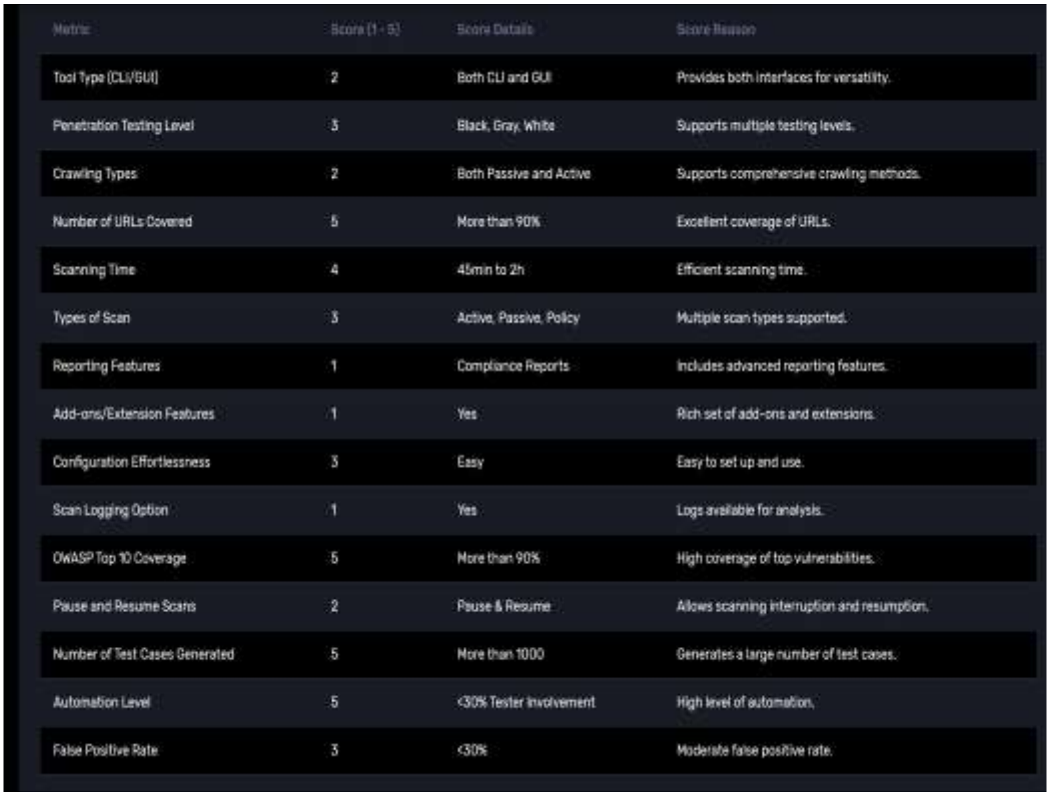
Where:

- TP: True Positives
- TN: True Negatives
- FP: False Positives

Scoring System for Youden's Index:

- Only false positives detected, no true positives (value of -1).
- Results align with expectations (value of 0).
- Vulnerabilities detected correctly (value of 1).

Evaluation criteria parameter (table)



| Metric | Score (1 - 5) | Score Details | Score Reason |
|---|---|---|---|
| Tool Type (CLI/GUI) | 2 | Both CLI and GUI | Provides both interfaces for versatility. |
| Penetration Testing Level | 3 | Black, Gray, White | Supports multiple testing levels. |
| Crawling Types | 2 | Both Passive and Active | Supports comprehensive crawling methods. |
| Number of URLs Covered | 5 | More than 90% | Excellent coverage of URLs. |
| Scanning Time | 4 | 45min to 2h | Efficient scanning time. |
| Types of Scan | 3 | Active, Passive, Policy | Multiple scan types supported. |
| Reporting Features | 1 | Compliance Reports | Includes advanced reporting features. |
| Add-ons/Extension Features | 1 | Yes | Rich set of add-ons and extensions. |
| Configuration Effortlessness | 3 | Easy | Easy to set up and use. |
| Scan Logging Option | 1 | Yes | Logs available for analysis. |
| OWASP Top 10 Coverage | 5 | More than 90% | High coverage of top vulnerabilities. |
| Pause and Resume Scans | 2 | Pause & Resume | Allows scanning interruption and resumption. |
| Number of Test Cases Generated | 5 | More than 1000 | Generates a large number of test cases. |
| Automation Level | 5 | <30% Tester involvement | High level of automation. |
| False Positive Rate | 3 | <30% | Moderate false positive rate. |

## Framework summary for evaluation criteria open source comparison scoring system

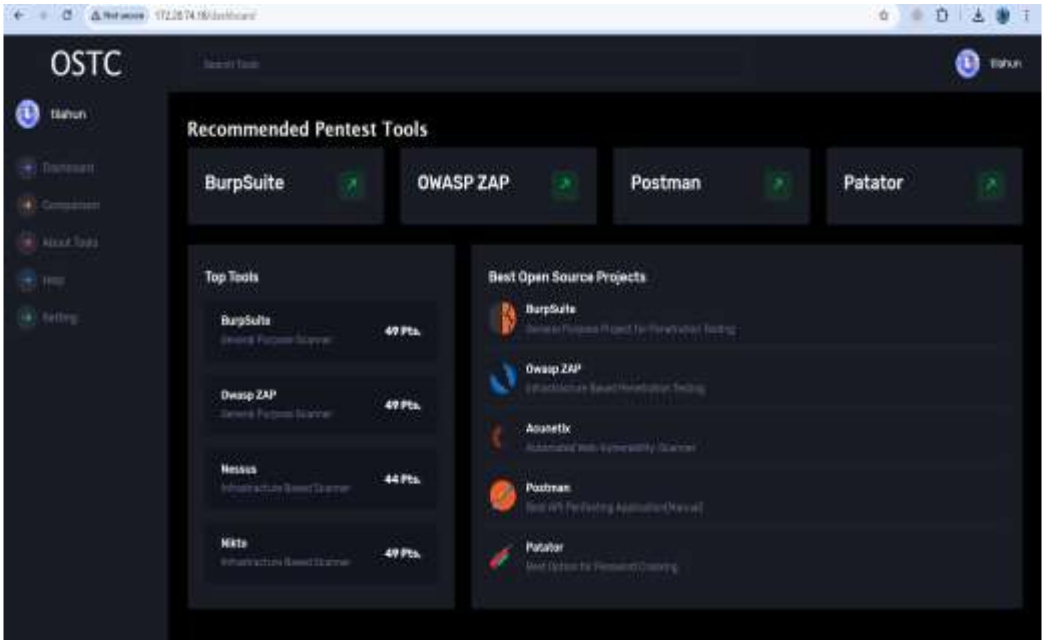
In the context of an Evaluation Criteria and Scoring System, research refers to a structured inquiry focused on developing, refining, and validating the criteria and scoring methods used to evaluate projects, proposals, or performances. This process includes gathering data on different evaluation techniques, analyzing their effectiveness, and understanding the needs of stakeholders. By utilizing both qualitative and quantitative research methods, researchers can pinpoint best practices, ensure alignment with organizational objectives, and improve the reliability and validity of evaluation results. Ultimately, this research supports the creation of a comprehensive framework that promotes objective assessments and enhances transparency and accountability in decision-making processes. The following table is the summary of evaluation criteria indicator.

| No | criteria | Metric | Description | Score Range |
|---|---|---|---|---|
| 1 | Test Coverage | Penetration Testing Effectiveness | Evaluates the overall effectiveness of the penetration testing conducted. | 1–3 |
| | | Unique URLs Tested | Measures the number of distinct URLs assessed during the evaluation. | 1–5 |
| | | Diversity of Test | Assesses the variety and identify vulnerabilities. | 1–5 |
| 2 | Efficiency | Scanning Duration | Time required to complete the scanning process; shorter durations indicate higher efficiency. | 1–5 |
| | | OWASP Top 10 Coverage | Measures the extent to which the OWASP Top 10 vulnerabilities were tested; more coverage indicates | 1–5 |
| | | False Positive Count | Counts the number of false positives reported; fewer indicate better accuracy. | 1–3 |
| 3 | Vulnerability Detection | True Positives Count | Total of actual vulnerabilities detected; higher counts suggest better detection capability. | 1–4 |
| | | Youden Index | A statistical measure assessing the effectiveness of the test, balancing sensitivity and specificity. | 1–3 |
| | | Level of Automation | Evaluates how automated the testing process is; more automation suggests greater efficiency. | 1–5 |
| | | Types of Crawling | Assesses the variety of crawling methods used (e.g., web, API). | 1–2 |

| | | | | |
|---|---|---|---|---|
| | | Additional Features | Counts any extra functionalities that improve the tool's usability or effectiveness. | 0–1 |
| | | Reporting Quality | Evaluates and quality of reports generated after testing. | 0–1 |
| 4 | Configuration | Ease of Configuration | Measures how straightforward it is to set up the tool; simpler configurations score higher. | 1–3 |
| 5 | Other Aspects | Scan Logging Availability | Indicates if logging options for scans are available, aiding in tracking and analysis. | 0–1 |
| | | tool Cost | T not scored but important for comparison. | NA |
| | | Tool Type | Classification of the tool (e.g., commercial, open-source); not scored but relevant context. | NA |
| | | Available Scan Types | Evaluates the different types of scans offered (e.g., full, incremental); more options suggest greater flexibility. | 1–3 |
| | | Pause and Resume Functionality | Ability to pause and resume scans, improving usability during lengthy assessments. | 0–2 |

**Implement experimental scenario**

Implement an experimental scenario for web application testing requires a systematic approach to assess the application's performance, usability, and functionality across different conditions. Below is a step-by-step guide for developing such a scenario:



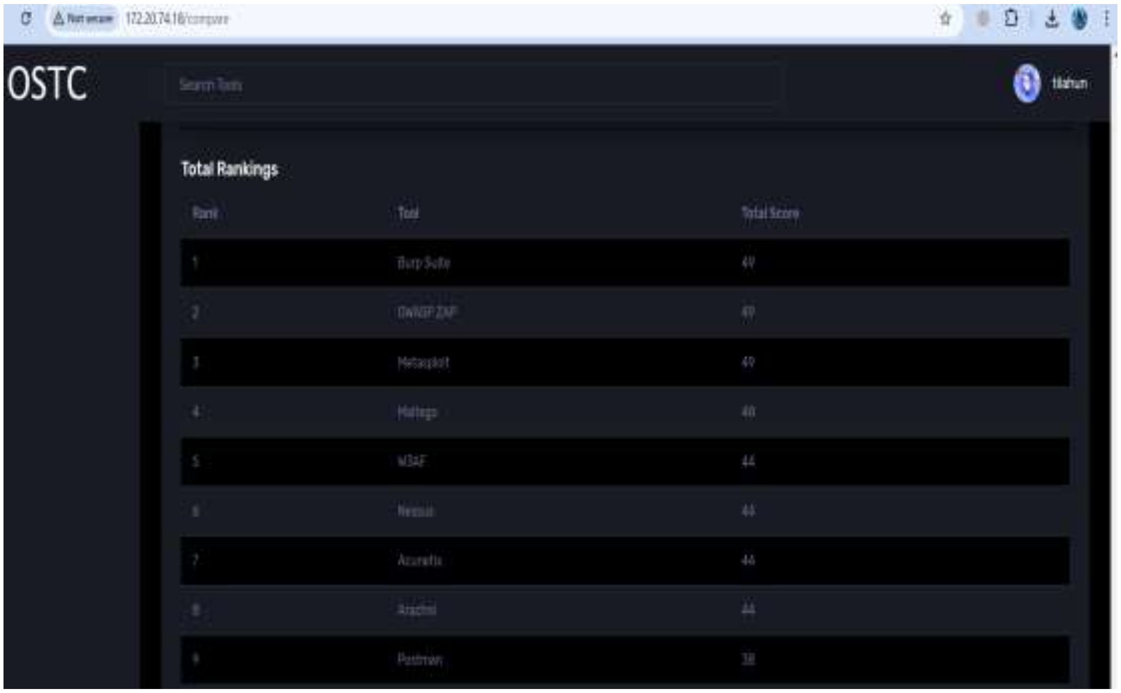
Top Tools

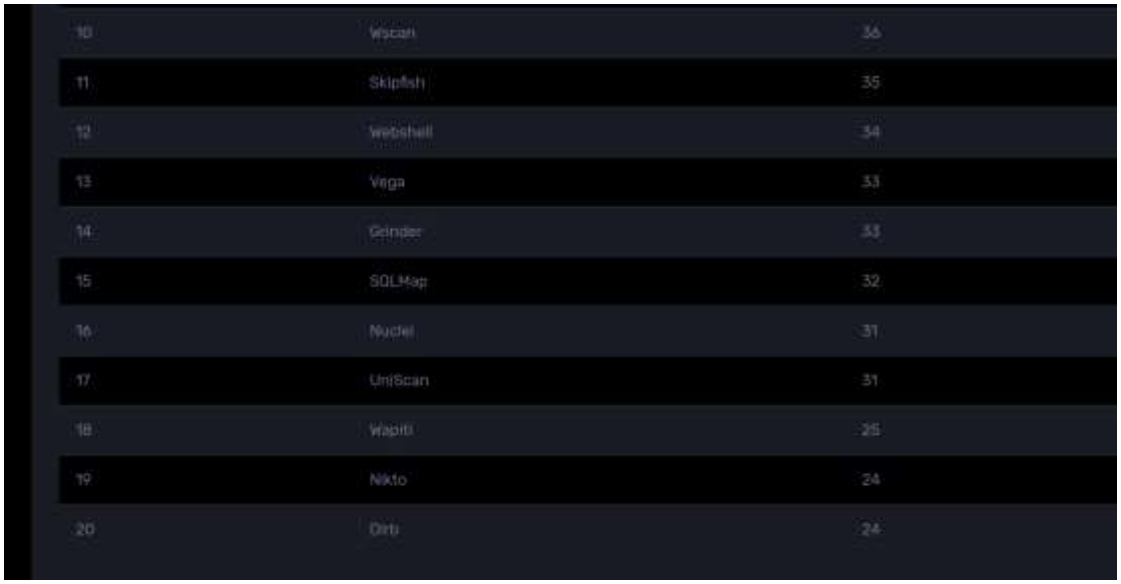
| | |
|---|---|
| BurpSuite<br>General Purpose Scanner | 49 Pts. |
| Owasp ZAP<br>General Purpose Scanner | 49 Pts. |
| Nessus<br>Infrastructure Based Scanner | 44 Pts. |
| Nikto<br>Infrastructure Based Scanner | 49 Pts. |

Best Open Source Projects

- BurpSuite — General Purpose Project for Penetration Testing
- Owasp ZAP — Infrastructure Based Penetration Testing
- Acunetix — Automated Web Vulnerability Scanner
- Postman — Best API Pentesting Application(Manual)
- Patator — Best Option for Password Cracking

**Experiment dash board**





Total Rankings

| Rank | Tool | Total Score |
|---|---|---|
| 1 | Burp Suite | 49 |
| 2 | OWASP ZAP | 49 |
| 3 | Metasploit | 49 |
| 4 | Maltego | 48 |
| 5 | W3AF | 44 |
| 6 | Nessus | 44 |
| 7 | Acunetix | 44 |
| 8 | Arachni | 44 |
| 9 | Postman | 38 |
| 10 | Wscan | 36 |
| 11 | Skipfish | 35 |
| 12 | Webshell | 34 |
| 13 | Vega | 33 |
| 14 | Grinder | 33 |
| 15 | SQLMap | 32 |
| 16 | Nuclei | 31 |
| 17 | UniScan | 31 |
| 18 | Wapiti | 25 |
| 19 | Nikto | 24 |
| 20 | Dirb | 24 |

**Comparison Rank**

**Conclusion and Organization of Examination Results**

This section outlines the final assessment of the analysis results for open-source vulnerability scanner tools applied to web applications. The vulnerability identification process includes documenting the vulnerabilities found, evaluating their impact, and determining their severity. Additionally, we will analyze the results using a design matrix that focuses on key factors such as features, testing performance, accuracy, community support, ease of use, and testing scope. This thorough examination is crucial for the comparative analysis of the research findings, enabling systematic comparisons based on these criteria.

The primary goal of this study is to conduct a detailed evaluation of open-source web application security testing tools. The research seeks to identify the most effective strategies for detecting vulnerabilities in web applications. The findings from this study will provide developers with essential insights for choosing the right web application testing tools. Ultimately, this research aims to improve the security of web applications, benefiting society as a whole. Following the research experiments, I will organize and present the examination results in a structured testing criteria format.

| ***No*** | ***Tools*** | ***Performance*** | ***Accuracy and Reliability*** | ***Easy use*** | ***Community support*** | ***Automation and Scalability*** | ***Comprehensive Coverage*** | ***Integration and Extensibility*** |
|---|---|---|---|---|---|---|---|---|
| **1** | Burp Suite | √ | √ | × | √ | √ | √ | √ |
| **2** | OWASP Zap | × | × | √ | √ | × | × | × |
| **3** | **Metasploit** | √ | √ | √ | √ | √ | √ | √ |
| **4** | maltego | × | × | √ | √ | × | × | × |
| **5** | W3af | × | × | √ | √ | × | × | × |
| **6** | Nessus | × | × | √ | √ | × | × | × |
| **7** | Acunetix | × | × | √ | √ | × | √ | × |
| **8** | Arachi | √ | √ | × | × | √ | × | × |
| **9** | Postman | √ | √ | × | × | √ | × | √ |
| **10** | Wscan | × | × | √ | × | × | × | × |
| **11** | Skipfish | × | × | √ | × | × | × | × |
| **12** | Webshell | × | × | × | × | × | × | × |
| **13** | Grinder | × | × | × | × | × | × | × |
| **14** | SQLMap | × | × | √ | √ | × | × | × |
| **16** | Nuclei | × | × | √ | × | × | × | × |
| **17** | Uni Scan | × | √ | √ | × | × | × | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **18** | Wapiti | × | × | √ | × | × | × | × |
| **19** | Nikto | × | √ | √ | √ | × | √ | × |
| **20** | Dirb | √ | × | × | × | √ | × | × |

**Comparison description test of web application security tools base on metrics**

From the above comparison table I have been determine using two symbols write (**√ )** and x (×) to categorized tools by different metrics (√) for positive indicators and (×) for negative indicators across the specified metrics,

- **(√) for positive indicators** the tool performs outstanding performance, functioning swiftly and efficiently under diverse conditions. It guarantees high accuracy and reliability, consistently producing precise outcomes with few false positives and negatives. Its intuitive user interface makes it easy to use for individuals of all skill levels. Furthermore, a lively community offers a wealth of resources and active forums that improve user support. Designed for automation and scalability, the tool can manage larger projects and intricate tasks without compromising performance. It effectively addresses a broad spectrum of vulnerabilities and attack vectors while providing smooth integration with other tools and platforms for customization and enhanced capabilities.
- **(×) for negative indicators** the tool's performance is compromised by its slow and inefficient operation, especially under heavier loads. It also faces challenges with accuracy and reliability, frequently producing false positives and negatives. Users may struggle with the complex interface, which is not user-friendly, making effective use difficult. Community support is lacking, with few resources or active discussions to help users. Additionally, the tool's automation features and scalability are insufficient for larger projects. It has limited coverage of vulnerabilities, missing many critical areas, and offers restricted options for integration with other tools or customization.

**Result Analysis**

When evaluating open source tools, it is crucial to establish specific criteria and metrics to assess their effectiveness and suitability for your unique requirements. This organized approach aids in identifying the most appropriate tool and ensures that your decisions are based on objective data. Key criteria include functionality, where you examine the available features and user-friendliness; community and support, which entails analyzing the size and engagement level of the user community as well as the quality of provided documentation. Performance metrics, like speed and resource consumption, are vital for understanding how the tool performs under different conditions.

Compatibility is another essential aspect, focusing on how well the tool integrates with other systems and its compatibility across various platforms. Security factors, such as vulnerability management and data protection capabilities, are critical, especially in an era where data sensitivity is paramount. Additionally, licensing is important, as it defines the permissible uses of the tool, particularly in commercial settings.

The evaluation of open-source web application testing tools reveals a multifaceted web application in the digital ecosystem world, with each tool offering distinct strengths and functionalities tailored to various testing needs. Among the most prominent tools are OWASP ZAP, Acunetix, Nikto, UniScan, w3af, and Burp Suite, which are open-source tools.

A thorough comparison of these tools highlights several critical factors affecting their effectiveness. Testing Types: Each tool specializes in different methodologies, such as static analysis (SAST), dynamic analysis (DAST), and interactive application security testing (IAST). Automation Capabilities: The level of automation offered varies.

This comprehensive examination of open-source web application testing tools empowers teams to make well-informed decisions tailored to their specific projects. By assessing the unique features, strengths, and weaknesses of each tool in relation to their testing requirements, this analysis implies organizations can choose the most appropriate tools to enhance their web development processes and use the best tools for testing their web application to measure the security capability of web application security after lot of effort and strategical evaluation and investigation the open source web application testing tools comparison Rank was listed below table.

| Rank | Tool | Total Score |
|---|---|---|
| **1** | Burp Suite | 49 |
| **2** | OWASP ZAP | 49 |
| **3** | Metasploit | 49 |
| **4** | Maltego | 48 |
| **5** | W3AF | 44 |
| **6** | Nessus | 44 |
| **7** | Acunetix | 44 |
| **8** | Arachni | 44 |
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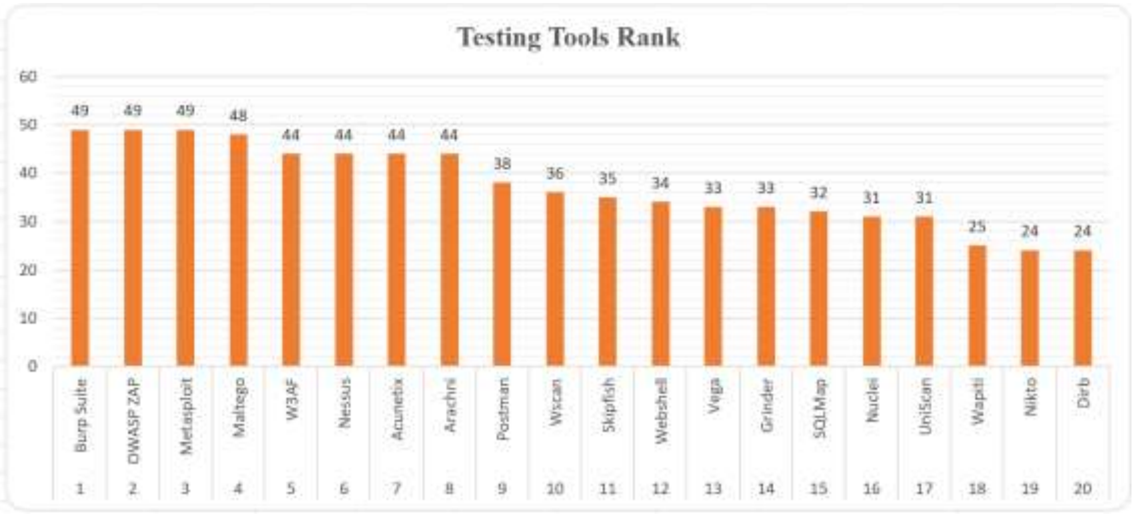
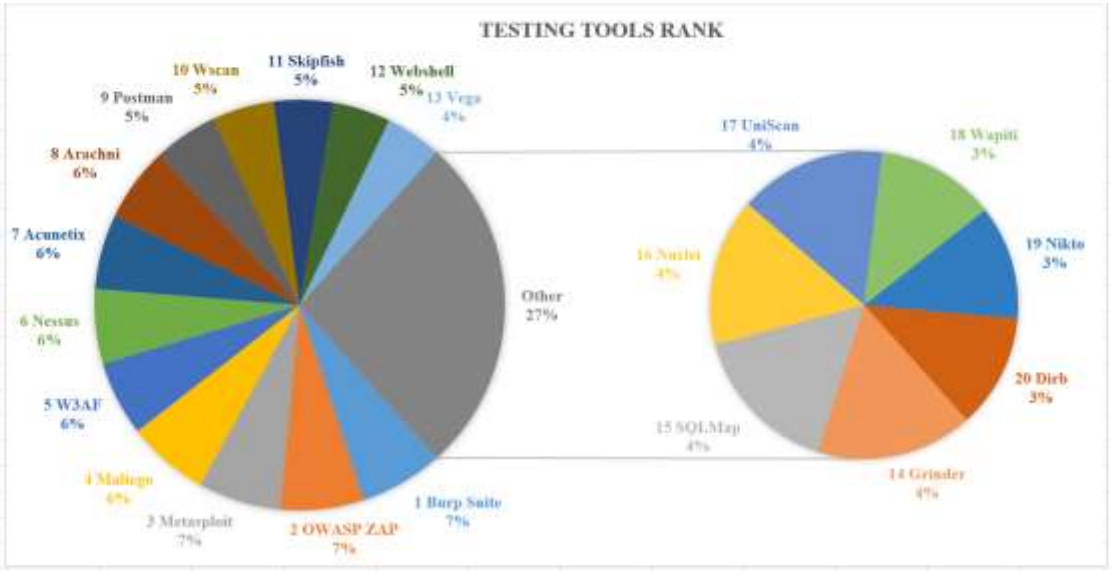
| **16** | Nuclei | 31 |
| **17** | UniScan | 31 |
| **18** | Wapiti | 25 |
| **19** | Nikto | 24 |
| **20** | Dirb | 24 |

**Comparison Rank**





**Graphical analysis of testing tools comparison**

**Conclusion on Tool Evaluation and comparison**

The assessment of various security tools reveals a diverse range, each possessing distinct strengths and weaknesses tailored to different user requirements and contexts.

- **Burp Suite** Burp Suite emerges as a frontrunner in web application security testing, known for its robust performance and substantial community support. Although its complexity may challenge beginners, its extensive features are invaluable for seasoned security professionals seeking thorough analysis.
- **OWASP Zap**: OWASP Zap serves as an excellent starting point for newcomers, thanks

to its intuitive interface and strong community backing. However, its limitations in performance and automation may reduce its effectiveness for advanced users who need detailed evaluations.

- **Acunetix** Acunetix excels across all assessed criteria, making it a versatile option for both novice and expert users. Its seamless automation and comprehensive coverage enable efficient vulnerability identification without significant drawbacks.
- **Nikto and UniScan :** Both Nikto and UniScan cater to basic scanning needs, appealing to users who prioritize simplicity. However, their limited performance and automation capabilities restrict their effectiveness for thorough testing, positioning them more as tools for quick assessments rather than in-depth evaluations.
- **W3af and Vega**: w3af and Vega are accessible for beginners but lack the performance and automation features necessary for comprehensive security assessments. They may serve well for introductory tasks but fall short for users requiring more robust solutions.
- **SQLMap and Arachni :** SQLMap is a powerful tool for SQL injection testing, ideal for those with technical proficiency. Arachni, although effective for automated scans, may require additional effort to fully leverage its capabilities, indicating a compromise between usability and thorough coverage.
- **wapiti, Wscan, and Webshell** These tools, despite being user-friendly, demonstrate poor performance and limited automation, making them suitable only for basic tasks. They may fulfill specific needs but are not advisable for users seeking reliable, comprehensive security evaluations.
- **Skipfish and Dirb**: Skip fish and Drib are straightforward tools for simple tasks, but their lack of performance metrics and advanced features may limit their effectiveness in serious security testing.
- **Grinder** Grinder requires further evaluation, as its absence of documented performance metrics raises concerns about its reliability in practical use.
- **Metasploit** is a powerful exploitation framework ideal for penetration testing, featuring a large array of exploits. However, it demands a higher level of expertise, which can pose challenges for some users.
- **Maltego** specializes in data mining and link analysis, effectively visualizing relationships between data, but it is not specifically tailored for security testing and may require additional tools for complete assessments.
- **Nessus** is well-known for its thorough vulnerability scanning and a wide range of plugins, making it a highly regarded option in the industry; however, being a commercial product, it may be less accessible for certain users. Conversely,
- **Postman** is excellent for API testing, offering a user-friendly interface that facilitates automation and collaboration, though it mainly focuses on API testing and lacks comprehensive security evaluation features.

## Overall Evaluation

In summary, this evaluation emphasizes the necessity of aligning tool selection with user expertise and specific security requirements. While some tools excel in versatility and depth, others cater primarily to basic functions. Users are urged to carefully consider their needs, balancing ease of use with the imperative for comprehensive security assessments to ensure effective vulnerability management.

## Research Validity Evaluation

When we compare open-source web security testing tools, it's crucial to take a comprehensive approach that includes various criteria to gauge their overall effectiveness and usability. This assessment focuses on twenty  important factors:

To Validating the result of a comparison of open-source web application testing tools can be approached systematically using a structured methodology. First, it is crucial to establish evaluation criteria that **performance accuracy and reliability, user-friendliness, community support, automation and scalability, thorough coverage, and integration,** reporting quality **and extensibility.** Next, choose a diverse range of tools for comparison the selective twenty (20) sampling open-source version

**To ensure a thorough evaluation**, develop testing scenarios that replicate real-world use cases. These scenarios should encompass functional testing, performance testing, security testing, API testing, and user experience assessment. For example, the functional testing scenario could automate user journeys on a sample web application, while performance testing could simulate multiple user requests to evaluate load handling. Each scenario should have well-defined objectives, methods, and validation steps to facilitate effective comparison of results.

**After creating the scenarios**, conduct tests under consistent conditions, ensuring that the test environment and application versions remain uniform across all tools. Once testing is complete, gather and analyze results based on the predefined criteria, focusing on metrics such as success rates, average response times, vulnerability detection, and user satisfaction scores.

**Finally**, document the findings in a detailed report that outlines the strengths and weaknesses of each tool, along with recommendations tailored to specific needs. Visual aids like charts and tables can enhance the clarity of comparisons, making the report more accessible and informative for professionals. This structured approach guarantees a comprehensive and objective evaluation of open-source web application testing tools and raking the result based on evaluation criteria.

In summary Validating of a comparison of open-source web application testing tools can be systematically and strategic accomplished through a structured methodology that includes several essential steps and validity procedure:

- **Define Evaluation Criteria:** Establish specific criteria for comparison, emphasizing factors such as user-friendliness, supported features, integration options, community engagement, performance indicators, and the quality of reports.
- **Select Tools for Comparison:** Choose a varied selection of open-source tools for evaluation selective twenty (20) sample open-source version of Postman, and Cypress.
- **Create Testing Scenarios**: Design realistic scenarios that reflect typical use cases. Each scenario should focus on different testing dimensions, including functional testing, performance testing, security testing, API testing, and user experience assessment.
- **Execute Tests:** Conduct each scenario under uniform conditions to ensure equitable comparisons, maintaining a consistent test environment and application versions across all tools.

- **Collect and Analyze Results:** Gather and assess the results according to your criteria, utilizing relevant metrics such as success rates, response times, vulnerability identification, and user satisfaction ratings.
- **Document Findings:** Develop a detailed report that summarizes the comparison, highlighting the strengths and weaknesses of each tool along with tailored recommendations. Visual elements like charts or tables can enhance the clarity of the comparisons.

## Discussion

Analyzing open source web application web testing tools is essential for securing web applications. To facilitate this, we suggest a benchmarking methodology that includes a collection of standardized web applications targeting all OWASP Top 10 vulnerabilities. This method not only sets new standards but also creates benchmark applications across diverse web domains, enabling a thorough comparison and analysis of various scanners' results some key points are below.

- **Standardization of Metrics** The absence of standard metrics in current literature makes it challenging to compare results from different studies. Implementing a benchmarking framework can establish consistent metrics that facilitate meaningful comparisons.
- **Usability and Performance Evaluation** It's crucial not only to identify vulnerabilities but also to evaluate the usability and performance of web vulnerability scanners. This involves assessing how user-friendly the tools are and their scanning efficiency.
- **Literature Survey** Our research indicates that there are few systematic surveys examining the effectiveness of black box web vulnerability scanners. Most existing surveys do not thoroughly explore the specific metrics and characteristics that influence a scanner's effectiveness.
- **Comprehensive Testing** This study underscores the importance of conducting a systematic review of widely used open-source web application vulnerability scanners. By enhancing existing frameworks and focusing on new metrics, we can better summarize the capabilities and performance of these tools.
- **Common Vulnerabilities** The analysis also covers common vulnerabilities identified across various scanners, which aids in understanding the strengths and weaknesses of each tool.
- **Tools Features** Open-source scanners offer a cost-effective solution for organizations with limited budgets, as they are free to use. Their customization capabilities allow users to modify the source code to fit specific needs, enhancing adaptability

## Future Work and Recommendation

Current research on establishing a standardized evaluation framework for commercial web application testing tools is significantly limited. To address this deficiency, we recommend a focused effort in several key areas for future studies.

Firstly, it is crucial to develop a Comprehensive Framework. Subsequent research should aim to construct a thorough evaluation framework that encompasses various aspects of web application testing, such as functionality, performance, security, and usability. This framework would provide clear guidelines for evaluating the effectiveness and reliability of different testing tools, ensuring that all relevant factors are considered in the assessment process.

Secondly, conducting Comparative Studies of commercial web application testing tools is essential. These studies should examine the strengths and weaknesses of various tools in real-world application contexts, offering practical insights for organizations looking to adopt new solutions. By assessing a wide range of tools against standardized criteria, researchers can provide valuable recommendations tailored to different development environments and business requirements. This combined approach of framework development and tool comparison will significantly improve the field of web application testing.

In summary to improve web application testing, it's essential to develop a comprehensive framework that encompasses critical areas such as functionality, performance, security, and usability. Furthermore, conducting comparative studies of testing tools is vital for evaluating their strengths and weaknesses in practical scenarios. This integrated approach will yield valuable insights and recommendations tailored to different development requirements, enhancing the overall efficiency of web application testing.

## Conclusion

Testing a web service is challenging activity that involves many characteristics such as response time, throughput and latency etc. The same web service has been tested for performance with these web service testing tools such as Apache Jmeter, Grinder, HttpRider and results has been compared. The Comparison helps in the selection of the best tool. This research work can be extended to more tools, more web services and different parameters to provide more realistic results (**Shikha Dhiman, 2016)**.

In open source web service tools i.e. Apache Jmeter, Grinder, HttpRider it is evident that each tool had its own architecture and internal processes which form the basis of comparison study of tools in terms of response time. The average response time observed for various tools is shown in Table.

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