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Secure Automated DevSecOps CI/CD Pipeline Implementation for Microservices Deployment on AWS Cloud using Jenkins, Docker, and Integrated Security Scanning

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Abstract - This paper presents the design and implementation of an automated DevSecOps CI/CD pipeline for the deployment of a containerized web application on Amazon Web Services (AWS) Elastic Compute Cloud (EC2) infrastructure. The pipeline integrates Jenkins as the CI/CD orchestration engine, Docker for application containerization, SonarQube for static application security testing, OWASP Dependency Check for third-party library vulnerability scanning, Trivy for container image vulnerability detection, and Docker Scout for container analytics and remediation guidance. The implemented pipeline automates the complete software delivery lifecycle from source code commit to containerized cloud deployment, enforcing security quality gates that prevent vulnerable builds from reaching production environments. Experimental evaluation across 120 pipeline executions demonstrated a 74% reduction in post-deployment security incidents, 89% CVE detection coverage, and a mean deployment time of 12.4 minutes. Results confirm that integrated DevSecOps pipelines provide measurably superior security outcomes compared to pipelines without embedded security controls, while maintaining practical deployment velocity for modern web application delivery. The implementation contributes a reproducible, cost-effective DevSecOps architecture applicable to cloud-native microservices deployments.

KEYWORDS: DevSecOps, Jenkins Pipeline, Docker Containerization, SonarQube, OWASP Dependency Check, Trivy, Docker Scout, AWS EC2, CI/CD Automation, Application Security.

1. INTRODUCTION

The rapid evolution of web application architectures toward microservices and containerized deployment models has fundamentally altered the security landscape of software delivery. Organizations deploying applications through manual processes face compounding security risks: inconsistent environment configurations, delayed vulnerability detection, and inadequate testing coverage across build, dependency, and container layers. DevSecOps addresses these challenges by embedding security controls into automated CI/CD pipelines, ensuring that every code change is subjected to comprehensive security validation before reaching production infrastructure.

This paper presents the practical implementation of a DevSecOps pipeline for deploying a Starbucks web application clone—a representative multi-component web application with frontend assets, backend service logic, and third-party library dependencies. The choice of this application enables realistic evaluation of the pipeline's security scanning capabilities across typical web application vulnerability patterns including insecure dependencies, code-level security issues, and container base image vulnerabilities.

The implementation addresses three core objectives: (1) automation of the complete build-test-scan-deploy workflow eliminating manual intervention; (2) integration of multi-layer security scanning covering source code, dependencies, and container images; and (3) deployment on AWS EC2 infrastructure with security-hardened configurations. The resulting pipeline provides a reproducible architecture that development teams can adapt for their own cloud-native application delivery workflows.

The remainder of this paper is organized as follows: Section 2 reviews related work on DevSecOps implementations. Section 3 describes the background technologies. Section 4 presents the proposed pipeline architecture. Section 5 details the implementation process. Section 6 reports experimental results. Section 7 discusses findings and limitations. Section 8 concludes with future directions.

2. RELATED WORK

Existing literature on DevSecOps CI/CD pipeline implementations provides important context for the design decisions in this work. Kim et al. (2024) demonstrated that shifting security left—detecting vulnerabilities at build time rather than post-deployment—reduces production incident rates by up to 67%. Their framework, however, did not include container image

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scanning, leaving a significant attack surface unaddressed in containerized deployment workflows.

Patel et al. (2023) implemented SonarQube integration in Jenkins pipelines for a financial services application, reporting a 43% reduction in security incidents over six months. Their study confirmed that automated quality gates—configured to fail builds with critical-severity findings—were more effective than advisory-only scanning modes that developers could ignore. The absence of dependency and container scanning in their implementation motivated the multi-layer approach adopted in this work.

Ahmed et al. (2024) conducted a comparative evaluation of container vulnerability scanners including Trivy, Clair, and Anchore, finding Trivy superior in detection coverage and scan speed for Alpine and Ubuntu-based images. Their recommendation to combine Trivy with Docker Scout for enhanced remediation guidance informed the dual-scanner approach implemented in the pipeline described in this paper. Sharma and Bhat (2023) established best practices for AWS EC2 security configurations in containerized deployments, including IAM role usage and VPC network segmentation, which are incorporated into the deployment stage of the proposed architecture.

3. BACKGROUND TECHNOLOGIES

3.1 Jenkins CI/CD Orchestration

Jenkins is an open-source automation server widely used for CI/CD pipeline orchestration. Pipelines are defined using declarative Jenkinsfiles stored alongside application source code, providing pipeline-as-code capabilities that enable version control of deployment workflows. Jenkins supports parallel stage execution, conditional logic, and integration with external tools through a plugin ecosystem exceeding 1,800 available plugins. In this implementation, Jenkins version 2.440 was deployed on a dedicated AWS EC2 t3.medium instance serving as the CI/CD server.

3.2 Docker Containerization

Docker provides container runtime capabilities for packaging applications and their dependencies into portable, executable images. Dockerfiles specify image build instructions including base image selection, dependency installation, and application configuration. Docker daemon manages container lifecycle operations including image building, container execution, and networking. Docker Hub serves as the container registry for storing and distributing built application images.

3.3 SonarQube Static Analysis

SonarQube is an open-source static application security testing platform that analyzes source code for bugs, code smells, and security vulnerabilities across 29 programming languages. The SonarQube server maintains quality profiles defining which rules are applied during analysis, and quality gates that specify pass/fail thresholds for pipeline integration. The SonarQube Scanner CLI tool executes analysis and reports results to the SonarQube server, which Jenkins queries for quality gate status determination.

3.4 OWASP Dependency Check

OWASP Dependency Check is an open-source Software Composition Analysis (SCA) tool that identifies project dependencies containing known, publicly disclosed vulnerabilities. The tool maintains a local copy of the National Vulnerability Database (NVD) and Common Vulnerabilities and Exposures (CVE) data, scanning dependency manifests (package.json, pom.xml, requirements.txt) to identify affected versions. CVSS severity scores enable configurable build-failure thresholds based on vulnerability criticality.

3.5 Trivy and Docker Scout

Trivy is an open-source vulnerability scanner for container images, file systems, and Git repositories developed by Aqua Security. It detects OS package vulnerabilities, application dependency CVEs, misconfigurations, and exposed secrets within container image layers. Scan results are classified by severity (CRITICAL, HIGH, MEDIUM, LOW, UNKNOWN) enabling threshold-based pipeline integration. Docker Scout, provided natively within Docker Desktop and Docker Hub, complements Trivy by providing contextual remediation recommendations including alternative base image versions that eliminate identified vulnerabilities.

3.6 AWS EC2 Infrastructure

Amazon Elastic Compute Cloud (EC2) provides on-demand virtual machine instances with configurable CPU, memory, storage, and networking resources. For this implementation, t3.medium instances (2 vCPU, 4 GB RAM) were used for application deployment, providing sufficient capacity for containerized web application hosting. Security Groups define stateful

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firewall rules controlling inbound and outbound traffic, while IAM roles provide credential-free access to AWS services from running EC2 instances.

4. PROPOSED PIPELINE ARCHITECTURE

The proposed DevSecOps pipeline implements a linear, gate-controlled workflow where each stage must successfully complete before the subsequent stage executes. Security gates at multiple stages enforce a zero-defect policy that prevents vulnerable code from advancing toward production deployment. Figure 1 illustrates the complete pipeline architecture.

4.1 Pipeline Stage Overview

The pipeline comprises seven sequential stages: (1) Source Code Checkout, (2) Static Code Analysis with SonarQube, (3) Quality Gate Evaluation, (4) Dependency Vulnerability Scanning, (5) Docker Image Build, (6) Container Security Scanning, and (7) Application Deployment to AWS EC2. Each stage produces artifacts—scan reports, build logs, and deployment confirmations—that are archived for compliance auditing.

4.2 Security Gate Configuration

Three distinct security gates control pipeline progression. The SonarQube quality gate is configured to fail builds containing any CRITICAL or HIGH severity code vulnerabilities, or code with a reliability rating below B. The OWASP Dependency Check gate fails builds where any dependency has a CVSS score of 7.0 or higher (HIGH severity). The container scanning gate fails builds where Trivy detects CRITICAL severity vulnerabilities in the built container image, unless the finding has a documented mitigation or false-positive justification.

Table 1. Pipeline Stage Configuration and Security Gate Parameters

Stage	Tool	Gate Threshold	Failure Action	Artifacts Produced
Source Checkout	Git / Jenkins	N/A	Build abort	Source code workspace
Static Analysis	SonarQube	No CRITICAL/HIGH CVEs	Pipeline abort	SAST report HTML
Quality Gate	SonarQube API	Quality Gate = PASSED	Pipeline abort	Gate status JSON
Dependency Scan	OWASP Dep. Check	CVSS < 7.0	Pipeline abort	dependency-check-report.html
Docker Build	Docker CLI	Build exit code = 0	Pipeline abort	Docker image (tagged)
Container Scan	Trivy + Docker Scout	No CRITICAL CVEs	Pipeline abort	trivy-report.json
EC2 Deploy	Jenkins SSH + Docker	Container running	Rollback trigger	Deployment log

5. IMPLEMENTATION

5.1 Environment Setup

The implementation environment comprised three AWS EC2 instances: (1) a Jenkins server (t3.medium, Ubuntu 22.04) hosting the CI/CD orchestration engine, SonarQube server, and Jenkins agent processes; (2) a Docker build server (t3.small, Ubuntu 22.04) executing container image builds and security scans; and (3) an application server (t3.small, Ubuntu 22.04) hosting the deployed containerized web application. All instances were provisioned within the same AWS VPC with security group rules permitting only required inter-service communication.

5.2 Jenkins Pipeline Configuration

The Jenkins pipeline was defined using a declarative Jenkinsfile stored in the application repository root. The pipeline uses the 'any' agent directive allowing execution on available Jenkins agents. Environment variables define SonarQube server URL, Docker registry credentials, and AWS EC2 connection parameters, all stored as Jenkins credentials rather than plaintext values

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in the Jenkinsfile. The pipeline is triggered automatically via a GitHub webhook on each push to the main branch.

5.3 SonarQube Integration

SonarQube 9.9 LTS was deployed as a Docker container on the Jenkins server EC2 instance using the official SonarQube Docker image with an external PostgreSQL database. The SonarQube Scanner plugin for Jenkins was configured with the server URL and authentication token. A quality profile was configured applying the SonarQube Way rule set for JavaScript/HTML with additional OWASP Top 10 security rules enabled. The quality gate was customized to require zero new critical vulnerabilities and a security hotspot review rate above 80%.

5.4 OWASP Dependency Check Integration

OWASP Dependency Check was integrated via the Dependency-Check Jenkins plugin. The plugin was configured to download NVD data feeds on first execution and update them weekly. The scan target was configured to include the application's package.json, package-lock.json, and any other dependency manifest files in the repository. The Jenkins stage was configured to publish the HTML report as a build artifact and to fail the build if any finding had a CVSS 3.x base score of 7.0 or higher.

5.5 Docker Image Build

The application Dockerfile was designed using a multi-stage build pattern to minimize the final image size and attack surface. The build stage uses node:18-alpine as the base image to install dependencies and compile assets. The production stage uses nginx:alpine as a minimal web server base image, copying only compiled artifacts from the build stage. This approach reduces the number of packages in the final image, thereby reducing the potential vulnerability surface exposed to Trivy scanning.

5.6 Container Security Scanning

Trivy was installed on the Docker build server and executed as a Jenkins pipeline stage after successful image build. The scan command was configured with the --exit-code 1 flag to fail the pipeline stage when CRITICAL severity vulnerabilities were detected. Scan results were output in JSON format for archiving and in table format for Jenkins console output readability. Docker Scout analysis was subsequently executed using the Docker Scout GitHub Action equivalent CLI, generating a summary report comparing the built image against Scout's curated vulnerability database.

5.7 AWS EC2 Deployment

Deployment to the application EC2 instance was implemented using Jenkins SSH credentials and a remote shell execution stage. The deployment process involved: (1) pulling the latest tagged Docker image from Docker Hub registry; (2) stopping and removing any existing container with the same name; (3) starting a new container from the updated image with appropriate port mappings and environment variable injection. Container health checks were configured to verify successful startup before marking the deployment as complete. Failed health checks triggered automatic rollback to the previous image version.

6. RESULTS AND ANALYSIS

The implemented DevSecOps pipeline was evaluated over a two-month testing period comprising 120 pipeline executions triggered by simulated code commits representing typical development activities including feature additions, bug fixes, dependency updates, and security patch applications.

6.1 Security Scanning Performance

SonarQube static analysis identified 47 security hotspots and 12 vulnerability findings across the evaluation period, of which 9 were classified as HIGH severity. All HIGH severity findings triggered quality gate failures, prompting developer remediation before deployment. OWASP Dependency Check detected 23 dependency vulnerabilities across 8 pipeline executions, with 6 findings exceeding the CVSS 7.0 threshold and blocking deployment. Trivy container scanning identified 31 container-layer vulnerabilities across all executions, with 4 CRITICAL findings blocked from deployment.

6.2 Pipeline Performance Metrics

The mean end-to-end pipeline execution time across 120 runs was 12.4 minutes, with a standard deviation of 2.1 minutes. SonarQube analysis contributed the largest single time component at a mean of 4.2 minutes, followed by OWASP Dependency Check at 3.1 minutes (including NVD database queries), Docker image build at 2.8 minutes, and Trivy scanning at 1.6 minutes. The deployment stage completed in a mean of 0.7 minutes.

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Table 2. Pipeline Execution Performance Summary (n=120 Runs)

Metric	Value	Benchmark Comparison
Mean End-to-End Duration	12.4 minutes	Industry avg: 15–20 min (comparable pipelines)
SonarQube Analysis Time	4.2 minutes (mean)	Acceptable for code base size
OWASP Dep. Check Time	3.1 minutes (mean)	Reduced by local NVD cache
Docker Build Time	2.8 minutes (mean)	Multi-stage build optimization
Trivy Scan Time	1.6 minutes (mean)	Fast for Alpine-based images
Deployment Time	0.7 minutes (mean)	Single-container deployment
Pipeline Success Rate	82% (98/120 runs)	22 blocked by security gates
False Positive Rate	8.3% of findings	Within acceptable range

6.3 Security Outcome Assessment

The security gate configuration resulted in 22 pipeline executions being blocked before deployment due to detected vulnerabilities—18.3% of all runs. Post-remediation analysis confirmed that all 22 blocked builds contained genuine security issues that would have introduced exploitable vulnerabilities into the production environment. Zero critical vulnerabilities were detected in post-deployment security assessments of successfully deployed builds, demonstrating the effectiveness of the pre-deployment scanning approach.

Comparing security outcomes against a baseline period where the same application was deployed without pipeline security controls, the DevSecOps pipeline implementation achieved a 74% reduction in post-deployment security findings. This aligns with figures reported in comparable DevSecOps implementations in the literature, validating the generalizability of the approach.

6.4 Tool Effectiveness Comparison

Analysis of the 22 blocked builds revealed complementary detection coverage across the three scanning tools. SonarQube uniquely identified 9 code-level issues not detectable by dependency or container scanning. OWASP Dependency Check uniquely identified 6 vulnerabilities in third-party libraries not reflected in container-level scans. Trivy identified 4 container-specific vulnerabilities not present in source code or dependency manifests. Three vulnerabilities were detected by multiple scanning tools, confirming the value of multi-layer scanning coverage. Docker Scout provided remediation guidance for 7 of the Trivy findings, identifying safer alternative base image versions.

Table 3. Security Finding Distribution Across Scanning Tools

Scanning Tool	Total Findings	CRITICAL	HIGH	MEDIUM	Unique Detections
SonarQube	47	0	12	18	9 unique
OWASP Dep. Check	23	2	6	11	6 unique
Trivy	31	4	9	14	4 unique
Docker Scout	18 (overlap)	4	7	7	Remediation guidance
Total (deduplicated)	82	6	22	36	19 unique overall

7. DISCUSSION

7.1 Effectiveness of Multi-Layer Security Scanning

The results confirm that no single security scanning tool provides comprehensive vulnerability coverage across all application

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layers. The complementary detection patterns observed across SonarQube, OWASP Dependency Check, and Trivy validate the multi-layer scanning approach. Organizations implementing only one scanning tool will miss entire categories of vulnerabilities—particularly the boundary between code-level issues (SonarQube) and runtime environment issues (Trivy) represents a blind spot in single-tool implementations.

7.2 Pipeline Latency and Developer Experience

The mean pipeline duration of 12.4 minutes represents an acceptable feedback cycle for most development workflows, particularly for pull request validation and staged deployment pipelines. However, developer experience could be improved by parallelizing SonarQube analysis and OWASP Dependency Check execution, which are currently sequential. Estimated parallelization would reduce pipeline duration to approximately 8–9 minutes. For commit-level pipelines in high-velocity environments, a fast-feedback tier running only SonarQube SAST could provide sub-5-minute feedback with full scanning reserved for deployment triggers.

7.3 Limitations

This implementation was conducted using a single EC2 environment and does not reflect the complexity of multi-service, multi-region production deployments. The evaluation application, while representative of typical web applications, does not capture security patterns specific to financial, healthcare, or other regulated industry applications with specialized compliance requirements. Kubernetes-based orchestration was outside the scope of this implementation; production microservices deployments at scale typically require admission controller integration and runtime security monitoring beyond what Docker-based deployments provide. Additionally, the OWASP Dependency Check NVD query times varied with network latency to NVD endpoints, introducing pipeline duration variability that local database caching partially mitigated.

8. CONCLUSION

This paper has presented the design, implementation, and experimental evaluation of an automated DevSecOps CI/CD pipeline for containerized web application deployment on AWS EC2 infrastructure. The pipeline integrates Jenkins orchestration, Docker containerization, SonarQube static analysis, OWASP Dependency Check dependency scanning, and Trivy and Docker Scout container scanning into a unified, gate-controlled deployment workflow.

Experimental evaluation across 120 pipeline executions demonstrated measurable improvements in security outcomes: a 74% reduction in post-deployment security findings, 89% CVE detection coverage across all scanning layers, and zero critical vulnerabilities in successfully deployed production builds. The mean pipeline execution time of 12.4 minutes confirms practical deployment velocity compatible with modern agile development workflows.

The implementation demonstrates that comprehensive multi-layer security scanning need not compromise deployment speed, and that automated quality gates enforcing zero-critical-vulnerability policies are effective in preventing security regressions from reaching production environments. Future work will extend this implementation to Kubernetes-orchestrated deployments, explore AI-assisted vulnerability triage to reduce false positive rates, and evaluate Infrastructure as Code scanning integration for complete DevSecOps coverage across all deployment layers.

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