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A Comprehensive Review of DevSecOps CI/CD Pipeline Architectures for Secure Microservices Deployment on AWS Cloud

Shubham Sharma[1], Dr. Kuntal Barua[2]
[1]M.Tech CSE Research Scholar, Sage University, Indore, India
[2]Associate Professor, Sage University, Indore, India

Abstract - The growing adoption of cloud-native architectures has intensified the need for automated, secure, and scalable deployment pipelines. DevSecOps integrates security practices into every stage of the software development and delivery lifecycle, addressing the shortcomings of traditional manual deployment workflows. This paper presents a comprehensive review of DevSecOps-based CI/CD pipeline architectures tailored for microservices deployment on Amazon Web Services (AWS) cloud infrastructure. The review systematically examines 28 studies covering tools and frameworks including Jenkins, Docker, SonarQube, OWASP Dependency Check, Trivy, and Docker Scout. A structured comparison of security integration approaches, containerization strategies, and cloud deployment models is presented. Findings reveal that automated security scanning at multiple pipeline stages significantly reduces pre-production vulnerabilities while maintaining deployment velocity. Key challenges including tool configuration overhead, pipeline latency, and limited Kubernetes integration are identified. Future research directions toward Kubernetes-native orchestration, AI-assisted vulnerability triage, and multi-cloud DevSecOps strategies are discussed. This review contributes a consolidated reference for practitioners and researchers seeking to design secure, production-ready CI/CD pipelines on AWS cloud environments.

KEYWORDS: DevSecOps, CI/CD Pipeline, Jenkins, Docker, SonarQube, OWASP Dependency Check, Trivy, AWS EC2, Container Security, Microservices Deployment.

1. INTRODUCTION

Modern software development organizations face mounting pressure to deliver applications rapidly while ensuring security and operational reliability. Traditional software delivery models that treated development, operations, and security as separate concerns have proven inadequate in cloud-native environments where deployments occur multiple times per day. DevSecOps has emerged as a transformative paradigm that embeds security controls directly into Continuous Integration and Continuous Deployment (CI/CD) pipelines, enabling organizations to detect and remediate vulnerabilities before they reach production environments.

Amazon Web Services (AWS) provides a comprehensive ecosystem of cloud services that enables scalable, cost-effective infrastructure for hosting containerized applications. Elastic Compute Cloud (EC2) instances offer flexible virtual machine environments where Docker containers can be deployed and managed at scale. However, the availability of powerful cloud infrastructure does not inherently guarantee application security. Without deliberate integration of security scanning tools, CI/CD pipelines can inadvertently propagate vulnerable code, insecure dependencies, and misconfigured container images into production.

This review addresses the gap in consolidated literature examining how DevSecOps principles, cloud-native CI/CD automation, and multi-layered security scanning tools work together to produce secure deployment architectures. The paper systematically reviews 28 studies published between 2020 and 2025 to provide practitioners and researchers with a structured understanding of current approaches, tools, performance outcomes, and remaining challenges in DevSecOps CI/CD pipeline design for AWS-based microservices.

The primary objectives of this review are: (1) to survey existing DevSecOps pipeline architectures; (2) to compare security tool integration strategies across studies; (3) to identify common limitations and research gaps; and (4) to propose future research directions for advancing secure automation in cloud deployments.

2. REVIEW METHODOLOGY

This study follows a systematic literature review approach to analyze research on DevSecOps CI/CD pipeline architectures for

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cloud-based application deployment. The methodology is structured around four phases: literature identification, screening, eligibility assessment, and final inclusion.

2.1 Literature Search Strategy

Relevant research papers were collected from major academic and technical databases including IEEE Xplore, SpringerLink, ScienceDirect, ACM Digital Library, and Google Scholar. Search queries combined terms such as: ("DevSecOps" AND "CI/CD"), ("Jenkins pipeline" AND "Docker security"), ("SonarQube" AND "OWASP" AND "cloud deployment"), and ("container scanning" AND "AWS"). Only peer-reviewed journal articles, conference papers, and credible technical documentation published between 2020 and 2025 were considered.

2.2 Study Selection Process

An initial search yielded 115 research articles. After removing duplicates and clearly irrelevant records, 80 papers were retained for title and abstract screening. Full-text review was performed on 45 papers, of which 28 studies were ultimately selected based on inclusion criteria requiring: (a) focus on CI/CD automation or DevSecOps; (b) inclusion of at least one security integration tool; (c) cloud or containerized deployment context; and (d) empirical or architectural evaluation.

2.3 Quality Assessment

Selected studies were evaluated based on methodological clarity, reproducibility of results, relevance to the research questions, and quality of security tool evaluation. Studies reporting only theoretical frameworks without implementation evidence were excluded. The selection process follows the PRISMA methodology to ensure transparency and rigor.

3. BACKGROUND AND RELATED CONCEPTS

3.1 DevSecOps Overview

DevSecOps is an extension of the DevOps philosophy that systematically integrates security practices, tools, and culture into every phase of the software development lifecycle. Rather than treating security as a post-deployment activity, DevSecOps organizations embed static code analysis, dependency scanning, and container image inspection directly into automated build pipelines. This "shift-left" approach identifies security issues early when remediation costs are lowest and developer context is freshest.

3.2 CI/CD Pipelines

Continuous Integration (CI) refers to the practice of automatically building and testing code changes upon each commit to a shared repository. Continuous Deployment (CD) extends this by automatically delivering validated builds to staging or production environments. Together, CI/CD pipelines reduce manual intervention, accelerate release cycles, and provide consistent, repeatable deployment processes. Jenkins is widely adopted as an open-source orchestration engine that manages pipeline workflows through declarative or scripted Jenkinsfiles.

3.3 Containerization with Docker

Docker enables application packaging into lightweight, portable container images that bundle all dependencies and runtime configurations. Containers provide environment consistency across development, staging, and production deployments, eliminating the "works on my machine" problem prevalent in traditional deployment models. Docker Hub and private container registries serve as distribution points for container images, while Docker Compose orchestrates multi-container application stacks during local development.

3.4 Security Tools in DevSecOps Pipelines

Several specialized tools have been developed to address specific security concerns within CI/CD pipelines. SonarQube performs static application security testing (SAST) by analyzing source code for bugs, code smells, and security vulnerabilities. OWASP Dependency Check scans project dependencies against the National Vulnerability Database (NVD) to identify known CVEs in third-party libraries. Trivy is an open-source container vulnerability scanner that inspects Docker images for OS-level and application-level vulnerabilities. Docker Scout provides enhanced container image analytics with actionable remediation recommendations.

3.5 AWS EC2 for Cloud Deployment

Amazon Elastic Compute Cloud (EC2) provides resizable virtual machine instances within the AWS cloud infrastructure. EC2

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supports Docker runtime environments, enabling containerized application deployment at scale. Security Groups, IAM roles, and VPC configurations provide network-level and identity-based access controls that complement application-level security implemented in CI/CD pipelines.

4. LITERATURE SURVEY

Extensive research has been conducted on various aspects of DevSecOps, CI/CD automation, container security, and cloud deployment. This section categorizes reviewed studies by their primary focus areas.

4.1 DevSecOps Architecture and Frameworks

Kim et al. (2024) demonstrated that integrating security checkpoints at build, test, and deployment stages reduces production vulnerabilities by up to 67% compared to perimeter-only security approaches. Their framework emphasized the cultural and organizational dimensions of DevSecOps adoption alongside technical tooling. Rajput and Singh (2023) proposed a maturity model for DevSecOps adoption categorizing organizations into five maturity levels based on pipeline automation depth and security tooling coverage. Studies consistently identify pipeline-as-code approaches using Jenkinsfiles or YAML-based configurations as best practices for maintaining reproducible, auditable deployment workflows.

4.2 CI/CD Pipeline Security Integration

Research by Patel et al. (2023) evaluated the effectiveness of integrating SonarQube into Jenkins pipelines, reporting that automated static analysis gates preventing builds with critical severity findings reduced post-deployment security incidents by 43%. Similar findings by Gupta and Mehta (2022) confirmed that OWASP Dependency Check integration caught 89% of known CVEs in third-party dependencies before deployment. Studies also highlighted that configuring quality gates—automated thresholds that fail builds exceeding defined vulnerability counts—is essential for enforcing security standards consistently across development teams.

4.3 Container Security Scanning

Container image security has received substantial research attention as Docker adoption has accelerated. Trivy, developed by Aqua Security, has been evaluated in multiple studies as a high-accuracy, low-latency scanner for both base image OS vulnerabilities and application-layer dependency issues. Comparison studies by Ahmed et al. (2024) found Trivy superior to Clair and Anchore in detection coverage for Alpine and Ubuntu base images. Docker Scout, introduced by Docker Inc., provides additional remediation guidance beyond raw CVE listings, suggesting alternative base image versions with reduced vulnerability surfaces. Research indicates that combining Trivy with Docker Scout in sequential scanning stages improves overall detection completeness.

4.4 Cloud Deployment and Infrastructure Security

AWS EC2-based deployment architectures have been studied extensively in the context of microservices security. Sharma and Bhat (2023) demonstrated that using IAM instance profiles instead of embedded access keys reduces credential exposure risk in containerized deployments. Network segmentation using VPC security groups and private subnets was identified as a complementary control to application-level security scanning. Studies also indicate that automated deployment rollback mechanisms triggered by post-deployment security scans provide an additional safety layer beyond pre-deployment pipeline checks.

Table 1. Summary of Key Studies in DevSecOps CI/CD Pipeline Research

Author (Year)	Focus Area	Tools Used	Key Contribution	Limitation
Kim et al. (2024)	DevSecOps Framework	Jenkins, SonarQube, Docker	67% reduction in production vulnerabilities	Limited scalability evaluation
Rajput & Singh (2023)	Maturity Modeling	Multi-tool pipeline	5-level DevSecOps maturity model	No quantitative benchmarks
Patel et al. (2023)	Static Code Analysis	Jenkins, SonarQube	43% fewer post-deployment incidents	Single organization case study

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Gupta & Mehta (2022)	Dependency Scanning	OWASP Dep. Check	89% CVE detection pre-deployment	No container scanning
Ahmed et al. (2024)	Container Scanning	Trivy, Clair, Anchore	Trivy superior detection coverage	No cloud deployment context
Sharma & Bhat (2023)	Cloud Security	AWS EC2, IAM, VPC	Reduced credential exposure risk	Single cloud provider only

5. RESEARCH GAP ANALYSIS

Despite substantial progress in individual areas of DevSecOps tooling, several gaps persist in the current literature. Many studies evaluate security tools in isolation rather than as integrated components of end-to-end CI/CD pipelines. Container scanning research frequently omits cloud deployment context, leaving questions about infrastructure-level security controls unaddressed. Similarly, studies on AWS deployment security often focus on network and identity controls without examining application-layer and container-layer vulnerabilities.

Furthermore, the majority of reviewed studies were conducted in single-application, single-environment settings. Large-scale evaluations spanning multiple microservices, distributed teams, and multi-region AWS deployments are scarce. The absence of standardized benchmarking metrics for DevSecOps pipeline performance—balancing build speed, security coverage, and false positive rates—makes cross-study comparison difficult.

Orchestration platforms such as Kubernetes are increasingly prevalent in production microservices deployments, yet the integration of DevSecOps scanning tools with Kubernetes admission controllers, runtime security monitors, and GitOps workflows remains underexplored. Most reviewed studies rely on single EC2 instance deployments that do not reflect the complexity of real-world production environments.

6. PROPOSED DEVVSECOPS REVIEW ARCHITECTURE

Based on the review of existing literature, a consolidated DevSecOps CI/CD pipeline architecture is proposed that integrates security controls at every stage of the deployment workflow. The architecture comprises six interconnected layers: Source Control, Build Automation, Security Scanning, Containerization, Deployment, and Monitoring.

6.1 Source Control and Trigger Layer

The pipeline initiates upon code commit to a Git-based repository (GitHub or GitLab). Webhooks trigger Jenkins pipeline execution automatically, ensuring that every code change is subjected to the full security scanning and build workflow without manual intervention.

6.2 Static Analysis and Dependency Scanning Layer

Upon build initialization, SonarQube performs static application security testing on the committed source code. Configured quality gates halt the pipeline if critical or high-severity code vulnerabilities are detected. Concurrently, OWASP Dependency Check scans the project's dependency manifest against the National Vulnerability Database, failing the build if known CVEs above a configured severity threshold are found in third-party libraries.

6.3 Containerization Layer

Validated source code is packaged into a Docker container image using a security-hardened Dockerfile employing a minimal base image (Alpine or Distroless). The resulting image is tagged with build metadata including commit hash and timestamp for auditability.

6.4 Container Security Scanning Layer

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The newly built container image is subjected to dual scanning using both Trivy and Docker Scout. Trivy provides comprehensive OS and application CVE detection across the image layers. Docker Scout supplements this with actionable remediation recommendations. Builds containing critical container vulnerabilities are blocked from progression to deployment stages.

6.5 Deployment Layer

Containers passing all security gates are deployed to AWS EC2 instances using Jenkins deployment stages. EC2 instances are configured with IAM roles following least-privilege principles, and Docker containers run within isolated network namespaces with only required ports exposed through Security Group rules.

6.6 Post-Deployment Monitoring Layer

Deployed applications are monitored using AWS CloudWatch for performance metrics and security event logging. Anomaly detection alerts enable rapid response to post-deployment security incidents. Build artifacts and scan reports are archived for compliance and audit purposes.

Table 2. Comparison of Security Tool Categories in DevSecOps Pipelines

Tool Category	Tool Name	Scanning Target	Integration Point	Output Type
Static Code Analysis	SonarQube	Source Code	Pre-build / Build stage	Vulnerability report + Quality Gate
Dependency Scanning	OWASP Dep. Check	Dependencies / Libraries	Build stage	CVE report with CVSS scores
Container Image Scan	Trivy	Docker Image Layers	Post-build stage	CVE list by severity
Container Analytics	Docker Scout	Docker Image + Registry	Post-build stage	Remediation recommendations
Infrastructure Security	AWS IAM + VPC	Cloud Infrastructure	Deployment stage	Access policy enforcement

7. CHALLENGES IN DEVVSECOPS CI/CD PIPELINE IMPLEMENTATION

7.1 Tool Configuration Complexity

Integrating multiple security tools into a unified pipeline introduces significant configuration complexity. Each tool requires specific environment setup, credential management, and output parsing logic. Maintaining consistent tool versions across development, staging, and production pipeline environments requires dedicated infrastructure management overhead.

7.2 Pipeline Performance and Latency

Sequential execution of multiple security scanners increases overall pipeline execution time. Studies report that adding SonarQube, OWASP Dependency Check, and container scanning stages can add 8–15 minutes to pipeline duration. This latency can impede developer feedback loops, particularly in high-velocity development environments with frequent commits.

7.3 False Positive Management

Security scanning tools frequently generate false positive findings—reported vulnerabilities that do not represent actual exploitable risks in the deployment context. Without careful tuning of scanning policies and severity thresholds, development teams may suffer from alert fatigue, leading to systematic suppression of security findings that may include genuine threats.

7.4 Limited Kubernetes and Orchestration Support

Most reviewed implementations target single EC2 instance deployments rather than Kubernetes-orchestrated microservices clusters. Production DevSecOps environments increasingly require integration with Kubernetes admission controllers, Pod Security Policies, and service mesh security configurations that go beyond the capabilities of Docker-only deployment approaches.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 15 Issue 07 , July - 2026

7.5 Secret and Credential Management

Secure handling of API keys, database credentials, and cloud access tokens within CI/CD pipelines remains a persistent challenge. Embedding secrets in Jenkinsfiles or environment variables creates exposure risks. Dedicated secrets management solutions such as HashiCorp Vault or AWS Secrets Manager are recommended but add integration complexity.

8. FUTURE RESEARCH DIRECTIONS

8.1 Kubernetes-Native DevSecOps Integration

Future research should explore the integration of DevSecOps security controls with Kubernetes-native tooling including OPA Gatekeeper, Falco runtime security, and Kube-bench configuration compliance scanning. Kubernetes-native CI/CD frameworks such as Tekton and Argo CD offer opportunities for tighter security integration than Jenkins-based approaches.

8.2 AI-Assisted Vulnerability Triage

Artificial intelligence and machine learning techniques can be applied to reduce false positive rates in security scanning outputs. Predictive models trained on historical vulnerability exploitation data could prioritize findings based on exploitability probability, enabling development teams to focus remediation efforts on highest-risk issues.

8.3 Multi-Cloud and Hybrid Deployment Security

As organizations adopt multi-cloud strategies spanning AWS, Azure, and GCP, DevSecOps pipelines must evolve to enforce consistent security standards across heterogeneous infrastructure environments. Research into cloud-agnostic security policy frameworks and cross-cloud compliance monitoring represents an important future direction.

8.4 Real-Time Runtime Security Monitoring

Pre-deployment scanning provides static security assurance but cannot detect runtime threats such as container escapes, privilege escalation, or zero-day exploits. Integration of runtime security monitoring tools such as Falco or Sysdig Secure into post-deployment pipeline stages represents a promising area for extending DevSecOps coverage beyond build-time.

8.5 Infrastructure as Code Security Scanning

The growing use of Infrastructure as Code (IaC) tools such as Terraform and AWS CloudFormation introduces new security scanning requirements. Tools like Checkov and tfsec can be integrated into CI/CD pipelines to validate IaC configurations against security best practices before infrastructure provisioning, extending DevSecOps principles to the infrastructure layer.

9. COMPARATIVE ANALYSIS OF DEVSECOPS APPROACHES

The reviewed studies demonstrate a clear progression in DevSecOps maturity from basic CI/CD automation toward comprehensive security-integrated deployment workflows. Early approaches focused primarily on build automation and functional testing, with security added as a post-deployment activity. More mature implementations integrate security scanning at multiple pipeline stages with automated quality gates that prevent vulnerable code from progressing toward production.

Container-centric approaches using Docker have demonstrated superior environment consistency and security isolatability compared to traditional virtual machine-based deployments. However, container security introduces new attack surfaces—particularly in base image selection and privilege configuration—that require dedicated scanning tools beyond traditional SAST approaches.

Table 3. Comparative Analysis of DevSecOps Pipeline Approaches

Approach	Security Coverage	Automation Level	Cloud Integration	Scalability
Manual Deployment	Low – post-deployment only	Minimal	Basic	Poor
Basic CI/CD (no security)	None – functional only	High	Moderate	Good

International Journal of Engineering Research & Technology (IJERT)
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CI/CD + SAST	Code-level vulnerabilities	High	Moderate	Good
CI/CD + SAST + Dep. Scan	Code + dependencies	High	Moderate	Good
Full DevSecOps (all tools)	Code + deps + containers + infra	Very High	Comprehensive	Excellent

10. CONCLUSION

This comprehensive review has examined 28 studies on DevSecOps CI/CD pipeline architectures for secure application deployment on AWS cloud infrastructure. The review demonstrates that integrating security scanning tools—specifically SonarQube for static code analysis, OWASP Dependency Check for dependency vulnerability assessment, Trivy and Docker Scout for container image scanning—at multiple stages of automated CI/CD pipelines significantly reduces pre-production vulnerability exposure.

The evidence consistently supports the shift-left security model, where earlier detection of vulnerabilities through automated pipeline gates reduces both remediation cost and production security risk. Container-based deployments using Docker provide deployment consistency advantages but require dedicated image scanning to address container-specific attack surfaces. AWS EC2 infrastructure enables scalable cloud deployment but must be complemented with IAM-based access controls and network segmentation.

Key challenges including pipeline latency, false positive management, tool configuration complexity, and limited Kubernetes integration remain active research areas. Future work should address Kubernetes-native security integration, AI-assisted vulnerability triage, and multi-cloud security policy enforcement to advance the state of DevSecOps practice for modern cloud-native microservices architectures.

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