DOI: http://dx.doi.org/10.26483/ijarcs.v16i4.7306

ISSN No. 0976-5697

Volume 16, No. 4, July-August 2025

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

DEVOPS AND CONTINUOUS DELIVERY ADOPTION: TRENDS, CHALLENGES, AND BEST PRACTICES IN MODERN SOFTWARE DEVELOPMENT LIFE CYCLE

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Abstract—Efficient software development and deployment methods possess high market value due to the rapid advancement of digital technology. The Revolutionary approaches through DevOps and Continuous Delivery (CD) help to make more fast and dependable software releases by collaborating between the development and operations teams. This paper then goes on to provide an analysis of these challenges, categorizing them into organizational and cultural barriers and technical problems including testing inefficiencies, infrastructure management and security concerns. Additionally, there are best practices for implementing successful DevOps and CI/CD; which includes frequent code commits, automated testing, cleaning environments, and continuous monitoring to make reliability and efficiency. This paper also offers a comparative literature review of rudimentary key studies of DevOps methodologies' impact on software development. It examines critical success factors (CSFs), DevOps maturity models, and the role of automation in optimizing CI/CD pipelines. The analysis reveals significant research gaps in AI-driven automation, standardized DevOps frameworks, and the need for empirical validation of proposed methodologies in real-world enterprise settings. Addressing these gaps can further enhance the adoption and sustainability of DevOps practices, ensuring seamless software development and deployment processes.

Keywords—DevOps, Continuous Delivery, Cloud Computing, Software Development Life Cycle (SDLC).

I. INTRODUCTION

The growth of new-age technologies and other advancements have led to software becoming more of a focal aspect of various enterprise that requires faster time to market and better quality. Such kind of demands cannot be met in the traditional software development models that are discreet, which increases the time is takes to deploy software. DevOps and Continuous Delivery (CD) have become well-distinguished techniques or strategies of maintaining continuity and automating the development process to shrink the gap between development and operations. These have reoriented the SDLC and streamlined it, and the advantages of doing so include encouraging more collaboration and improving the levels of automation and reliability that business can sustain in a competitive environment. DevOps can be described as a system of software development and system administration where the two teams work together to facilitate integration and delivery of software builds [1]. The foundation established by Continuous Integration allows Continuous Delivery to create automated pipelines for software releases that minimize manual involvement during the process. Organizations who use CI/CD pipelines to detect and resolve problems early will gain better software quality together with faster time-to-market. The power to release software updates rapidly gives organizations a vital strategic market advantage since modern business success depends on digital delivery.

The adoption of DevOps and Continuous Delivery is driven by cloud computing[2], microservices, and AI-driven automation, enabling scalable and efficient software deployment[3]. Cloud native architectures make architecture more flexible, microservice makes the component more modular and fault tolerant. Testing, anomaly detection, enrollment in infrastructure management are all easier with the help of AI and ML which makes it more reliable. DevSecOps is a logical evolution from DevOps, where security is a cornerstone and is infused in each stage of SDLC via automated scanning, compliance enforcement as well as threat detection. Given the tight regulations to come in force, organizations must deploy security first methods of DevOps to keep systems secured, data kept safe and their delivery pipelines streamlined.

Resource management on hardware and software can become complex and creating a DevOps culture can be challenging in large and established enterprises. To be successful, collaboration has to be fostered, CI/CD pipelines[4], has to be established, cloud native architectures has to be utilized, and security has to be integrated across the development lifecycle. The practices are standardized and observability tools are used to improve efficiency and reliability. As digital transformation advances, refining DevOps strategies and embracing emerging technologies will be key to sustaining long-term success.

A. Structure of Paper

This paper is structured into several key sections: Section II provides the fundamentals of DevOps in software development, including its principles. Section III discusses the role of CI and CD, along with emerging trends and automation. Section IV presents the challenges associated with adopting DevOps and continuous delivery. Best practices for DevOps and continuous delivery are covered in Section V. Section VI presents the background research, while Section VII provides the conclusion and future work.

II. FUNDAMENTALS OF DEVOPS IN SOFTWARE DEVELOPMENT

Development and operations are combined into a set of processes called DevOps. DevOps requires a collection of tools to carry out the integration and combination tasks. Development, testing, and operations are all handled by a single team known as DevOps. There is no break throughout the whole product lifecycle with DevOps[5]. These four aspects make up DevOps: collaboration, automation, measurement, and monitoring. Expanding upon the agile methodology, DevOps focusses on software operations[6][7]. An important part of DevOps is the emphasis on continuous integration and software delivery. Reduced product release delay is another important goal of automation. DevOps enhances cooperation and communication, as well as rapid and continuous delivery, frequent upgrades, dependability, and more. The phases of creating, releasing, and maintaining software applications are all part of the DevOps software development Life Cycle (SDLC)[8]. A more collaborative and iterative approach to software delivery is advocated by DevOps, in contrast to conventional software program development models that may include distinct testing, operations, and development levels. Figure 1 demonstrates the DevOps SDLC at its most advanced stage:

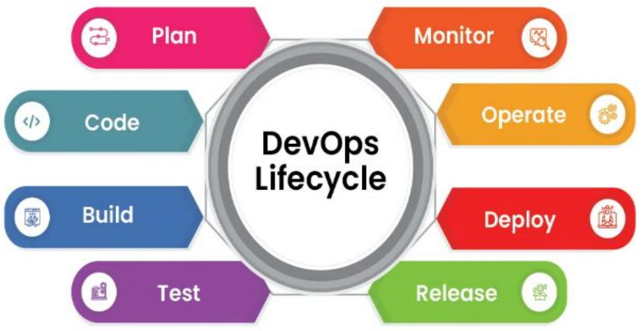

Fig. 1. DevOps Software Development Life Cycle

- **Plan:** Companies Specify Assignment Objectives, Requirements, And Schedules At The Planning Stage. In Order To Guarantee Alignment And Shared Knowledge Of Project Aims, This Diploma Entails Cooperation Between Operations, Improvement, And Other Stakeholders.
- **Code:** Producing, Evaluating, And Revising Source Code Constitute The Code Segment. High Quality Standards As A Part Of Devops Are Things Such As Code Reviews, Version Control As Well As Automated Testing For A Guarantee Of Good Code Quality And Code Maintainability.
- **Build:** During The Build Phase, Code Compilation, Packaging, And Deployment Organization Also Takes Place. Teams Can Learn Their Issues Sooner, In The Development Cycle By Automating The Build Process And Using Automation Tools And CI Servers.
- **Test:** A Part Of The Check Section Includes Running Automated Tests To Test Code Modifications And To Confirm The Software Is Bug Free. Devops Advocates Continuous Testing, Tests Are Placed Into The Development Cycle And Automatically Executed Each Time The Code Is Modified.
- **Deploy:** During Setup Stage, The Code Changes Are Driven To Staging Or Production Environment. Continuous Deployment (CD) Allows Us To Reliably And Quickly Update An Application With Automatically Performed Deployment Process.
- **Operate:** Carryout Phase Involves Metrics Collection, Incident And Failure Response And Application Performance Monitoring. Devops Highly Stresses On Continuous Monitoring And Feedback Loop To Find And Fix Problems In Real Time To Make Its Environments Extremely Available And Reliable.
- **Monitor:** Reading Metrics And Comments To Become Aware Of Improvement Opportunities Is Part Of The Presentation Phase. Embracing A Mindset Of Constant Analysis And Experimentation, Devops Encourages Organizations To Repeat Their Practices And Continuously Improve.

The goal of DevOps is to help software development teams create higher-quality software products more quickly by combining the various stages of the process into an iterative workflow. In order to better adapt to changing requirements and provide value to consumers, teams may take use of the DevOps SDLC's emphasis on collaboration, automation, and continuous feedback.

A. DevOps Principles

The practical method of DevOps still requires a shift in an organization's thinking and culture [9]. Figure 2 shows some of the basic elements that back up this concept.

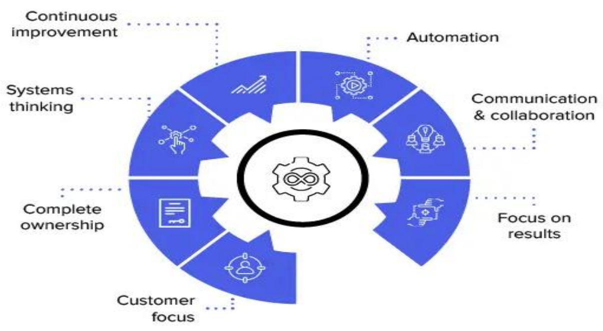

Fig. 2. Principles of DevOps

- **Customer focus:** This means you would have to create an organizational culture that is focused on meeting customers' needs by reviewing performance and identifying processes that can be automated.
- **Complete ownership:** Complete ownership means that the wall doesn't exist between teams, and the DevOps team as a whole is responsible for every stage of product development and the quality of the end deliverable.
- **Systems thinking:** This is another one of the key principles of DevOps that calls for people to change their mindset around development and operations. Instead of working in silos, the approach helps teams see the bigger
- **Picture:** This helps better the team productivity, ensures clear understanding of what needs to be fixed, lowers the response time, and betters the product efficiency.
- **Continuous improvement:** Continuous betterment of the process and product is the next core DevOps principle. With the teams working together focusing on one goal and continuously improving, it becomes easy. This aids teams in being adaptable in the face of change, even in the face of setbacks.
- **Automation:** Automation of processes, new code training, and infrastructure configuration is essential for firms to eliminate redundancy and overwork.
- **Communication and Collaboration:** A culture of open communication and collaboration across the development, operations, and security teams is promoted by DevOps. Effective communication reduces misunderstandings, accelerates problem-solving, and enhances productivity. Collaboration tools like Slack, Microsoft Teams, and Jira streamline workflows, ensuring alignment on goals and priorities.
- **Focus on Results:** DevOps emphasizes delivering business value rather than just completing tasks. Key

performance indicators (KPIs) for teams include customer satisfaction, MTTR, deployment frequency, and change lead time. Organizations may enhance end-user experiences, launch products more quickly, and boost quality by constantly optimizing processes and eliminating bottlenecks.

III. THE ROLE OF CONTINUOUS INTEGRATION AND CONTINUOUS DELIVERY (CI/CD)

development teams cannot execute without, it helps create, test and deploy apps in an efficient manner[10]. Business developers get encouraged to do Continuous Integration (CI) regularly to start automatic testing with each code submission. Improvements in software quality and a decrease in defect risk may be achieved by the early detection and resolution of integration problems using this procedure. The fact that different developers may safely edit the same codebase at the same time is another way in which CI encourages teamwork. CD automates deployment procedures to guarantee that tested code remains continuously ready for deployment according to CI principles[11]. The quick market reaction capabilities of businesses result from CD's elimination of traditional release cycle delays brought on by conventional practices. CD uses automation to strengthen software releases through testing and deployment techniques together with infrastructure provisioning. Software development workflows become smoother through CI/CD while they enable DevOps principles and create programming conditions that are more responsive[12]. The practices achieve faster delivery of software alongside operational process optimization while guaranteeing excellent product quality. The competitive digital market requires companies to use CI/CD practices to achieve continuous innovation. Continuous Deployment (CD) and Continuous Integration (CI) are two methods for delivering software that are at odds with one another. There is a difference in the methods and results, despite the fact that both prioritize automation and quality. Below Table 1 is a comparison of their key features:

Table 1: Clash Between CI/CD

Element	**Continuous Integration**	**Continuous Deployment**
Automation	Involves completely automated integration, build, and testing processes with quick feedback	Fully automated deployment to production, with no manual intervention
Trigger	Occurs immediately after the developer checks in new code	Deliveries happen when the team feels the code is ready to be shipped to production
Testing	Unit tests and business logic tests are required to ensure code quality	Automated testing is required for every new feature or bug fix
CI Server	Requires a CI server to monitor the repository and trigger builds	Requires a CI foundation to enable automated deployments
Test Coverage	The test suite must cover enough of the code base to catch issues early	The test suite must also cover enough of the code base to ensure quality before production
Merge Frequency	Changes are merged at least once a day to the main branch	Every time a change is ready, it is merged and deployed instantly; this happens often throughout the day.
Feature Flags	Feature flags are not typically used in CI workflows	Feature flags are not typically used in CI workflows

A. *Devops Trends: CI/CD Automation*

Continuous Integration/Continuous Delivery (CI/CD) automation is a key component of DevOps methodologies that has recently garnered a lot of attention [13]. Organizations may improve code quality, speed up software delivery, and foster better cooperation between the development and operations teams by automating the CI/CD process. The following noteworthy CI/CD automation trends are shown in Figure 3.

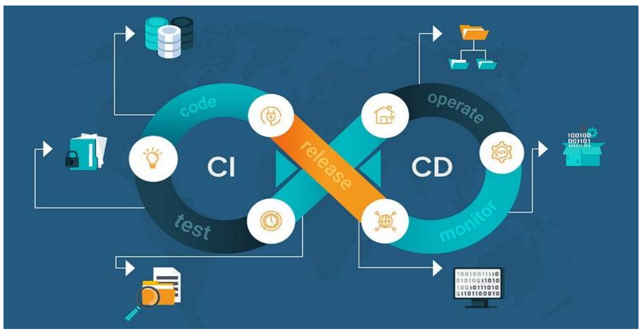

Fig. 3. DevOps trends in CI/CD automation

1) Shift-Left Testing

The focus of shift-left testing is on early and continuous testing from the very beginning of the software development lifecycle at the very beginning[14]. Organizations may enhance their ability to detect and resolve problems faster and decrease the likelihood of errors reaching production by automating testing and incorporating it into the CI/CD pipeline.

2) Infrastructure as Code (IaC)

The term "Infrastructure as Code" refers to a methodology that let's programmatically automate and manage infrastructure resources. It is possible to deploy both application code and infrastructure settings using IaC, which allows for version control, testing, and deployment of both [15]. To provide consistent and repeatable provisioning and management of infrastructure resources, CI/CD automation solutions interact with IaC frameworks like Terraform or AWS CloudFormation.

3) Cloud-Native CI/CD

CI/CD pipelines are changing to accommodate cloud-native apps as more and more organizations use cloud computing and containerization technologies. When developing, deploying, and orchestrating containerized applications, popular tools include Kubernetes and Docker. Automation solutions for CI and CD are evolving to meet the specific needs of cloud-native settings, paving the way for smooth interaction with serverless platforms, orchestrators, and container registries.

4) Machine Learning/AI in CI/CD

CI/CD automation is using ML and AI approaches to optimize software delivery in multiple areas[16]. As an example, algorithms powered by AI can evaluate the quality of code, spot trends, and suggest ways to make it better[17]. Anomalies in

CI/CD pipelines may be anticipated and detected with the use of ML models, allowing for the early detection of such problems.

5) Low-Code/No-Code CI/CD

The trend towards low-code and no-code development platforms has spread to continuous integration and delivery automation tools. To make CI/CD pipeline setup and configuration easier, these systems provide visual interfaces and pre-built connectors. This reduces the need for lengthy code or scripting. Facilitating automation and expediting application delivery, low-code/no-code CI/CD technologies enable non-technical stakeholders to become involved.

IV. CHALLENGES IN ADOPTING DEVOPS AND CONTINUOUS DELIVERY

Many difficulties were mentioned by respondents during the year-long process of implementing DevOps. These are the parts of DevOps that either did not help the implementation run as smoothly as planned or increased the likelihood that the objectives of DevOps would not be achieved[18]. The primary problem locations (rectangular boundaries) and associated problems are summarized in Figure 4. The lines show proposed influence relationships[19]

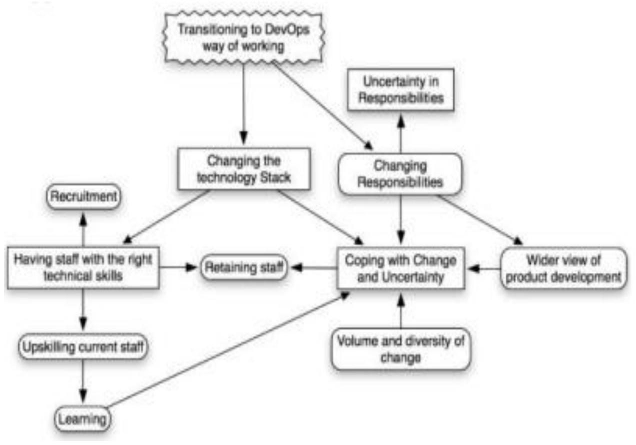
Transitioning to DevOps way of working
Uncertainty in Responsibilities
Changing the technology Stack
Changing Responsibilities
Recruitment
Having staff with the right technical skills
Retaining staff
Coping with Change and Uncertainty
Wider view of product development
Upskilling current staff
Volume and diversity of change
Learning

Fig. 4. Challenges related to DevOps Adoption

A. Organizational and Cultural Barriers

This difficulty frequently arises when upper-level management is resistant to change and doesn't understand DevOps principles. People may be hesitant to embrace DevOps approaches due to a lack of knowledge and understanding. The development and operations teams also often have different conceptual frameworks. This chasm may get in the way of efficient teamwork and the introduction of continuous deployment and development procedures[20]. The solution to this problem lies in encouraging teamwork and lifelong education. The lack of a continuous development environment, which includes continuous integration and testing—essential for smooth implementation—is another big obstacle in DevOps adoption. This may be overcome by giving these practices top priority and by investing in automation and efficiency-supporting tools and technology.

B. Technical Challenges in Implementation

The following are some of the technological hurdles that come with implementing devops and continuous delivery:

- **Lack of Automation:** The whole DevOps process might be difficult to automate. Manual processes that operate without automation tend to result in increased expenses and delays and produce mistakes [21].
- **Security:** Continuous delivery faces the formidable obstacle of security[22]. The deployment of safe code and settings is becoming more critical as code is moved swiftly from development to production.
- **Testing:** An important aspect of continuous delivery is testing. Production may be impacted by bugs and other problems that were not adequately tested.
- **Integration:** The incorporation of many tools and procedures is necessary for continuous delivery. Building and maintaining dependable connections across technologies may be a challenge for organizations.
- **Infrastructure:** The continuous delivery procedure relies heavily on infrastructure. In order to succeed, teams need dependable, scalable, and secure infrastructure.

V. BEST PRACTICES FOR SUCCESSFUL DEVOPS AND CONTINUOUS DELIVERY IMPLEMENTATION

DevOps CI/CD best practices make the process of building, testing, and releasing software efficient and deliver more quickly[23]. DevOps CI/CD services involve delivering and getting timely feedback on the latest changes and therefore it pays to analyze your feedback data to refine your process[24][25]. Here, provide CI/CD best practices in Figure 5 that help align DevOps with business goals.

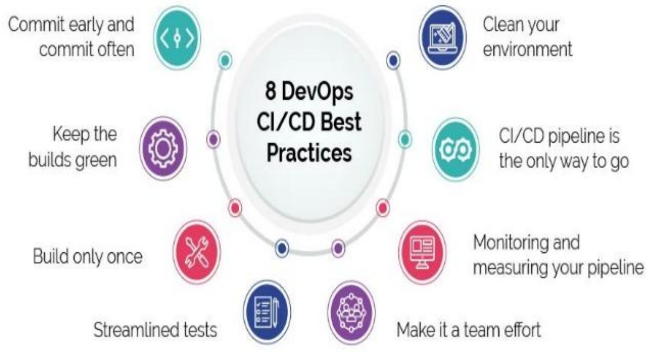
8 DevOps CI/CD Best Practices
Commit early and commit often
Clean your environment
Keep the builds green
CI/CD pipeline is the only way to go
Build only once
Monitoring and measuring your pipeline
Streamlined tests
Make it a team effort

Fig. 5. Best Practices of DevOps CI/CD

A. Commit Early, Commit Often

Frequent and small commits improve collaboration and reduce integration issues. Storing source code, configuration files, scripts, and libraries in version control enables seamless continuous integration. Each commit triggers automated tests, providing immediate feedback and ensuring code quality. Breaking tasks into smaller chunks further facilitates adoption and minimizes conflicts.

B. Keep Builds Green

A stable CI/CD pipeline ensures that code remains in a deployable state. Developers should prioritize fixing broken builds immediately to prevent cascading failures. Running local tests before committing changes helps maintain build integrity. A strong DevOps culture fosters collaboration in troubleshooting issues, preventing delays, and ensuring continuous improvement.

C. Build Only Once

Rebuilding software at different stages introduces inconsistencies. Instead, the same build artifact should move through all pipeline stages to ensure reliability. Builds must be environment-agnostic, with variables and configurations handled separately. Storing artifacts in a central repository rather than source control ensures proper versioning and reproducibility.

D. Streamline Tests

Effective CI/CD pipelines balance speed and test coverage. Fast unit tests should run first to detect immediate errors, followed by integration and system tests[26]. Performance, security, and UI tests add deeper validation before manual acceptance testing. Structuring tests hierarchically ensures rapid feedback while maintaining software quality.

E. Clean Environments

Maintaining pre-production environments over time leads to inconsistencies, affecting test reliability. Regular cleanup ensures a controlled testing setup, reducing drift between environments. Containers and Infrastructure-as-Code (IaC) enable scalable and repeatable environments, supporting parallel testing and faster releases.

F. CI/CD is Mandatory

Skipping CI/CD processes for urgent fixes can introduce undetected issues. Adhering strictly to the pipeline ensures every change is tested and traceable. Automated testing at every stage eliminates last-minute surprises, improving debugging and maintaining deployment reliability. Communicating CI/CD benefits to stakeholders secures organizational support.

G. Monitor and Measure

Tracking CI/CD pipeline metrics helps identify performance bottlenecks and optimize workflows[27]. Analyzing build frequency, test execution time, and failure rates informs infrastructure scaling and parallelization strategies. Continuous monitoring ensures efficient resource utilization and enhances overall development speed.

H. Make It a Team Effort

Successful DevOps adoption relies on a strong culture of collaboration. Breaking down silos between development, operations, and testing teams fosters transparency and shared responsibility. Encouraging cross-functional expertise enhances pipeline efficiency, driving continuous delivery success.

VI. LITERATURE OF REVIEW

This section presents the background research on DevOps and CI/CD integration for software development. This Table 2 presents a comparative analysis of key studies on DevOps, focusing on their objectives, applied techniques and methods, findings, and limitations or future research directions.

Nayak et al. (2024) discuss the key aspects to be considered in the verification and validation processes, that can be engineered to limit the impact on the carbon consumption. they also bring focus to the need for the right trade-off between automated test execution and targeted continuous testing and provide a measurement / formula to help calculate the positive impact that Green CT bring into enterprises. they also cover the need to continuously manage and optimize out test corpus as a part of test management activities. This is an essential governance aspect that will ensure that green IT across test processes is sustainable[28].

Jayakody and Wijayanayake. (2023) focused on investigating DevOps CSFs in order to assess their application to IS development. They identified CSFs by using a comprehensive literature review. Interviewing DevOps practitioners helped to corroborate these characteristics while discovering additional common CSFs in the software development sector. Last but not least, the study offers a conceptual model for DevOps CSFs, which serves as a roadmap for maximizing DevOps' advantages while lowering the barriers to improving IS success[29]

Mowad, Fawareh and Hassan (2022) emphasizes the use of DevOps's CI and CD approach to bridge the gap between developers and operators. In addition, it demonstrates how CI may serve as a bridge between CDs. The paper provides an overview of DevOps and examines the methods, tactics, concerns, and procedures that have been found in relation to the adoption and execution of ongoing practices. their case studies demonstrate the merits of CI/CD as a tool for software engineers. Also, the article introduces DevOps as a fresh approach to bridge the gap between the two departments of software development and operations[30].

Offerman et al. (2022) gather data on how organizations' performance is impacted by DevOps methods and technologies. They found 14 DevOps practices with 47 sub-practices after doing a thorough literature search. They used these principles as a basis for a worldwide survey that they ran to gauge DevOps maturity and learn about their practical implications. With 50% of participants reporting that practices are implemented 'always,''most of the time,' or 'nearly half of the time,' they discovered that 13 out of 14 DevOps techniques are embraced among 123 respondents from 11 different sectors[31].

Toh, Sahibuddin and Bakar (2021) pinpoint the challenges and concerns with the use of DevOps practices that may enhance the CD process. The DevOps and Continuous Delivery were found via a literature review. This research's methodology relies on filtering internet artefacts from the Scopus database. Accordingly, 96 internet artefacts were located for more investigation. Consequently, the success of DevOps adoption in Continuous Delivery depends on four important adoption variables[32].

Toh and Sahibuddin (2019) seeks to enhance the CD process by investigating the benefits and drawbacks of adopting DevOps. The benefits and challenges of DevOps and Continuous Delivery, as well as their adoption, have been identified using a qualitative online survey. They have gathered and analyzed the input from 13 respondents. The results of the study indicate that four major DevOps practices should be explored and refined into a standard set of guidelines for the industry[33].

Table 2: Summary of Research on DevOps Practices, Challenges, and Advancements

Author	Objectives	Technology	Findings	Limitations/Future Work
Nayak et al.	Explore Green Continuous Testing (CT) and its impact	Automated test execution, Continuous Testing (CT), Test Corpus Optimization,	Emphasizes trade-offs in automated vs. continuous testing; highlights governance for	Further validation of proposed measurement/formula

	on carbon consumption	Carbon Impact Measurement Formula	sustainable Green IT in testing	in real-world enterprise settings
Jayakody & Wijayanayake	Identify Critical Success Factors (CSFs) for DevOps in IS development	Expert Interviews, CSF Identification, Conceptual Model Development	Develops a conceptual model for DevOps CSFs; identifies key factors affecting DevOps success	Empirical validation needed for wider industry applicability
Mowad, Fawareh & Hassan	Analyze CI/CD methodologies in DevOps for reducing the developer-operator gap	CI/CD Implementation, Case Study Analysis, DevOps Strategy Evaluation	Demonstrates CI/CD benefits; positions DevOps as a model bridging development and operations	Case studies limited in scope; future work should explore scalability and long-term impacts
Offerman et al.	Study DevOps practices' impact on organizational performance	DevOps Maturity Assessment, Global Survey (123 respondents), Data-Driven Analysis	Identifies 14 DevOps practices and their maturity levels across industries	Requires industry-specific analysis to tailor recommendations
Toh, Sahibuddin & Bakar	Identify challenges in DevOps adoption for Continuous Delivery (CD)	Data Filtering, DevOps Adoption Factor Identification, Continuous Delivery Process Optimization	Identifies four key adoption factors critical to DevOps success	Needs empirical validation of factors in real-world DevOps environments
Toh & Sahibuddin	Investigate advantages and limitations of DevOps adoption in CD	Web-Based Survey, DevOps Practice Evaluation, Adoption Framework Design	Highlights four critical DevOps practices for successful adoption	Limited sample size; more extensive industry surveys required

VII. CONCLUSION

The adoption of DevOps and Continuous Delivery (CD) has revolutionized modern software development, enabling faster, more efficient, and reliable deployments. However, organizations face significant challenges in their implementation, including cultural resistance, technical complexities, security vulnerabilities, and scalability constraints. Overcoming these barriers requires a strategic approach that fosters a DevOps culture, implements robust CI/CD pipelines, automates infrastructure, optimizes monitoring, and integrates security through DevSecOps. However, as identified in this study, several challenges hinder seamless adoption, including organizational resistance, lack of automation, security concerns, testing complexities, integration difficulties, and infrastructure constraints. Addressing these challenges requires a strong cultural shift, continuous learning, investment in automation tools, and a commitment to best practices such as frequent commits, maintaining stable builds, streamlining testing, and enforcing CI/CD as a mandatory process. Furthermore, the literature review highlights various research contributions toward optimizing DevOps adoption. Studies emphasize the importance of critical success factors, DevOps maturity assessments, and strategic frameworks for overcoming technical and organizational hurdles. However, gaps remain in empirical validation, scalability, and industry-specific optimizations, necessitating further research and real-world evaluations. In conclusion, successful DevOps and CD implementation requires a holistic approach that integrates technology, processes, and organizational culture. Future research should focus on refining best practices, developing standardized DevOps adoption models, and exploring AI-driven automation to further enhance efficiency and security in DevOps pipelines.

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