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DEVOPS CULTURE AND PRACTICES FOR IOT APPLICATIONS

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Abstract
The DevOps culture places a strong emphasis on teamwork and encourages businesses to deliver software product features via automated procedures. Industrial endeavors are being impulsively and continuously reformed by the Internet of Things paradigm. Continuous integration, continuous testing, continuous deployment, and continuous delivery are all components of DevOps. Once the IoT application is delivered, ongoing monitoring becomes crucial. Together, these factors enable deployments to be done more quickly and with higher quality. This paper discusses the problems with DevOps in IoT initiatives. In order to analyze problems with the Internet of Things applications related to the DevOps framework, this study analyzed the collected survey data from IT organizations using DevOps for IoT applications. In addition, this study attempted to investigate potential remedies for those problems in the form of suggested models, methods, and guidelines. In order to adopt the DevOps culture in IoT systems, the proposed paper addresses significant obstacles that must be handled. In order to address current issues with the effectiveness measurements encountered while implementing the DevOps framework in IoT applications, this research proposed a new model, the Industrial DevOps Maturity Model (IDMM).

Keywords:CI/CD, Continuous Delivery, Continuous Delivery, Internet of Things, DevOps, DevOps culture, DevOps challenges, DevOps guidelines, DevOps model, Industrial DevOps Maturity Model, IDMM.

I. INTRODUCTION

Development and operations are combined to form the phrase "DevOps," which emphasises the importance of these teams' teamwork. DevOps is a methodology that enables reliable, frequent updates to operational systems. DevOps is a software development culture that helps enterprises to deliver software product features quickly and with high quality via process automation. It encourages teamwork, which boosts productivity throughout the entire software lifecycle management process. Automation can speed up deployment cycles, lower failure rates, accelerate time to release, and shorten recovery times [1].

DevOps is based on an agile approach, where the software development team, QA team, and operations team are expected to work together to produce software continuously, allowing for quicker deployment and less time to incorporate user feedback [2].Version control, device-level monitoring, and alerting are typically used with the DevOps paradigm and its advised practices
Web application development has already undergone a revolution thanks to DevOps. The programme can be updated and developed frequently, but it can also be deployed frequently and clutter-free. The web apps can be continuously updated in this way. In contrast, embedded is designed to make use of this software version control mechanism at the moment. Even reproducible software builds are automated by this system. Offering a set of tools that perform version control, Continuous Integration, and Continuous Delivery all in one pipeline is how DevOps is introduced to connected devices. a platform that streamlines workflows for a company that generally has to create everything from scratch [1].

An understanding between developers and operations is the cornerstone of the DevOps culture. The sharing of responsibility for the software they create and implement is the most important component. Operations and teams team's increased openness, dialogue, and cooperation.

The idea of the "Internet of Things" encompasses the ability to operate linked objects over the internet. When used in conjunction with real-time data processing and/or storage services, these devices may need to publish data regularly. The principles of DevOps provide a framework for improving the creation of IoT systems, which also includes the planning, development, testing, and release phases of the software engineering lifecycle.

II. BACKGROUND AND MOTIVATION

III. RESEARCH METHODS

The proposed research workflow of the paper is in Figure 1.

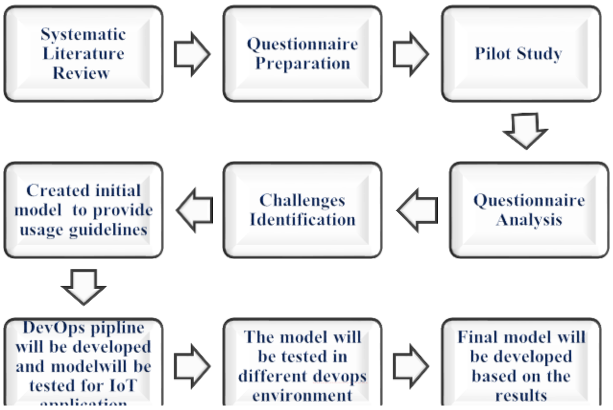

Figure 1. Research Flow

A. Systematic Literature Review

In order to identify the difficulties or problems encountered when adopting DevOps for IoT applications, a systematic literature review (SLR) was carried out. The effectiveness metrics being considered were efficiency, quality, sharing, and collaboration (Business value)[4]. Thus, this study

underscores the difficulties with the mentioned effectiveness measures. SLR is used to identify problems with deploying DevOps and problems with applying DevOps on the Internet of Things.
The following are a few of the difficulties found:
Lack of qualified professionals Saima Rafi and the team highlighted challenges and best practices from SLR and a questionnaire survey of DevOps experts[3]. Igor [5] discusses the challenges of forging a clear connection between DevOps and IoT. Specialized knowledge is required to plan the application's requirements [6].
Culture is the DevOps principle that has the biggest impact on specification [4]. DevOps Culture was also mentioned by Lopez-Pena [7].
Availing the necessary technologies and tools The reasons why Agile techniques have been adopted so little and the challenges that have been faced have both been studied by LEITE [8]. Khalyly, [9] provided a metamodel for the IoT to standardise existing IoT architectures and allow them to embrace CI/CD.
Lack of cooperation: Mali Senapathi [10] noted that employing staff with appropriate technical expertise and skills, and providing current staff with great training, would help. The challenges that came with changing responsibilities caused reluctance to change and uncertainty. M.S. Khan [11]and Ibrahim [12] both made mention of this problem.The benefits of agile software development, particularly the use of cross-functional teams, was emphasized by the use of DevOps techniques in the Internet of Things application, according to Lucy Ellen Lwakatare [13]. Pereira [14] suggests that concepts and techniques be developed to plug the continuous feedback gap.
System testing for IoT: With so many devices, testing and debugging IoT systems can be challenging. A. Taivalsari [18]. In particular for IoT applications, testing environments are not covered by DevOps technologies, necessitating the establishment of methods to deal with it, according to Ramón López-Viana [16]. Lucy Ellen Lwakatare [15] makes notice of the limited visibility to customer environments during test environment design.

Research Gaps:

- The highly dynamic nature of IoT systems presents new difficulties.
- The factor of cultural change toward DevOps has a substantial impact on the organizational working paradigm.
- Need to investigate the relationship between DevOps and IoT software systems from the perspective of experts in the field.
- There is a need for more study in several DevOps-related aspects like culture, quality factors such as Performance Efficiency, Usability, Reliability, and software maintainability,etc.

Researchers proposed a model that provides instructions at every stage of every element of DevOps, such as planning, designing, developing, delivering, deploying, and monitoring, in order to plug these gaps in knowledge. They also planned to further examine this research field using a survey.

B. Survey

We used an online poll as a tool for data collection. Participants were specialists with extensive expertise working for companies developing IoT solutions, selected through the use of the purposive sampling method. The KPIs for DevOps listed below were taken into account when creating the survey questions: The frequency of deployments, the mean time to recovery, the cycle time, and the failure rate of changes. We took information technology firms into consideration (IT).


Figure 4. Data collected across the globe.

Using statistical analytic techniques, the acquired data is examined. We intend to inform the responders of the study's findings. Data about 164 companies was gathered.
To better assess the impact of applying the DevOps culture to IoT applications, hypotheses have been established.

Our research questions (RQ) were as follows:
RQ1. Approximately since when your organization is using DevOps or CI/CD Practices for IoT/Connected devices?
RQ2. Do you feel flexible product design/architecture is possible using DevOps?
RQ3. Do you feel efficiency is increased through automation [i.e. significant change in success/failure rate]?
RQ4.Do you feel Mean Time to Recovery (Time it takes to restore service after production failure) is increased?

The results and findings are as follows:

Hypothesis 1:
H01 DevOps framework is not implemented in IoT based applications.
Ha1 DevOps framework is implemented in IoT based applications.

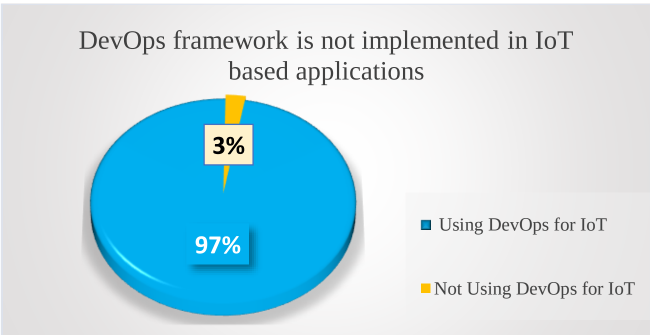

Figure 5. Data analysis for Hypothesis 1.

Hypothesis 2:
H02 There are no issues in the implementation of DevOps tools in IoT applications.
Ha2 There are issues in the implementation of DevOps tools in IoT applications.

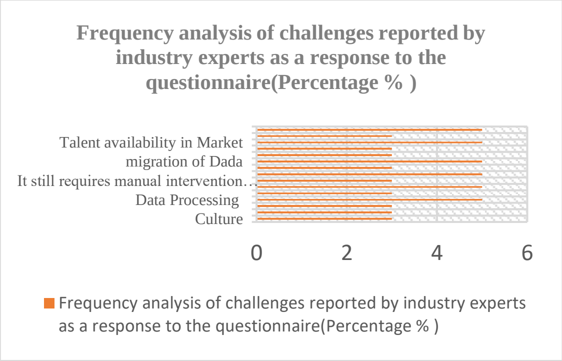

Figure 5. Data analysis for Hypothesis 2.

Hypothesis 3:

H03 DevOps framework does not improve the performance in IoT based application.
H3 DevOps framework improves the performance in IoT based applications.

We applied Chi-squared (X^2) and the results are as follows:
1.Usability(Time to release software to production**):** Hypothesis H03 was rejected because the p-value associated to H0 was, x^2 = "0.565", which was more than "0.05". Hypothesis H3 was accepted.
2. Reliability(Mean time to recover): Hypothesis H03 was rejected because the p-value associated to H03was, x^2 = "0.172", which was more than "0.05". Hypothesis H3 was accepted.
3. Maintainability:
m1: Hypothesis H03 was rejected because the p-value associated to H03 was, x^2 = "0.532", which was more than "0.05". Hypothesis H3 was accepted.
m2: Hypothesis H03 was rejected because the p-value associated to H03 was, x^2 = "0.053", which was more than "0.05". Hypothesis H3 was accepted.
m3: Hypothesis H03 was rejected because the p-value associated to H03 was, x^2 = "0.333", which was more than "0.05". Hypothesis H3 was accepted.
1. Efficiency: Hypothesis H03 was rejected because the p-value associated to H03 was, x^2 = "0.309", which was more than "0.05". Hypothesis H3 was accepted.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.787[a]	7	.565
Likelihood Ratio	6.353	7	.499
Linear-by-Linear Association	.008	1	.929
N of Valid Cases	79		

a. 11 cells (68.8%) have expected count less than 5. The minimum expected count is .76.

Figure 6: Results

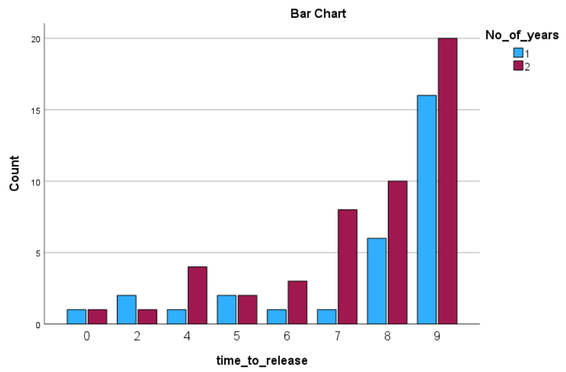

Figure 7: Analysis for H3(Usability).

In fig. 7, Independent variable = No of years DevOps used & dependent variable = quality attributes(Usability-Time to release software to production)
We applied Chi-squared (X^2) statistically significant test and the results are as follows: p-value=0.05

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.469[a]	7	.164
Likelihood Ratio	12.428	7	.087
Linear-by-Linear Association	.190	1	.663
N of Valid Cases	79		

a. 11 cells (68.8%) have expected count less than 5. The minimum expected count is .38.

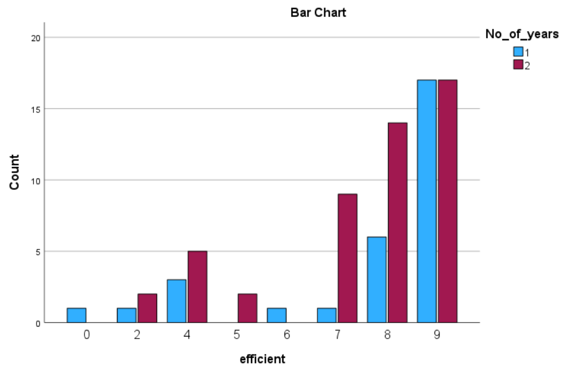

Figure 8: Analysis for H3(Efficiency with no of years of use of DevOps).

In fig. 8, Independent variable = No of years DevOps used & dependent variable = quality attributes(Efficiency)
We applied Chi-squared (X^2) statistically significant test and the results are as follows:

B. Industrial DevOps Maturity Model (IDMM)

In order to build the model's many stages, the CMMI maturity levels were compared to them. Any IoT application can evaluate the maturity of DevOps implementation using the Industrial DevOps Maturity

Model (IDMM). Solutions for various difficulties are provided in the form of practises in each IDMM development stage. All stages prior to a given stage of IDMM must be completed in order to reach that stage.

Stage 1 - First: Improvised communication and a limited implementation of DevOps techniques in IoT applications make up this stage. Many businesses only implement a limited number of DevOps techniques, such as Continuous Integration, Automated Testing, and Continuous Deployment (CD). Some merely use automated testing, continuous deployment, continuous monitoring, or continuous integration (CI/CD).

Stage 2- Managed: The Operations team participates in the planning phase and creates the Technical Design Documents during this stage. It is crucial to include the operations team in the planning process because they can offer some insights on deployment from the standpoint of that environment. Several people have stopped documenting once Agile gained popularity. Technical Design Documentation should be required at the very least.

Phase 3 Defined: For IoT applications, this level involves using only shared tools between the development and operational teams. Tools that are shared between the development and operations teams allow both teams to be informed of the product's status. The author suggested Configuration Management, Integration, Automated Testing, Continuous Deployment, and Monitoring for all IoT applications.

Stage 4- QualitativelyManaged: The development and operations teams must work together at this point to create a win-win situation that will benefit both groups and produce the best outcomes of all DevOps methods. The benefits of visualising consumer settings while setting up test environments are greatest when the product is an IoT application.

***Stage 5-* Optimized**: If the company successfully completed the steps prior to stage 5, we may conclude that stage 5 was done. IoT application development should at this point adopt a DevOps mentality. To gauge how well DevOps is achieving the organization's objectives, metrics must be used.

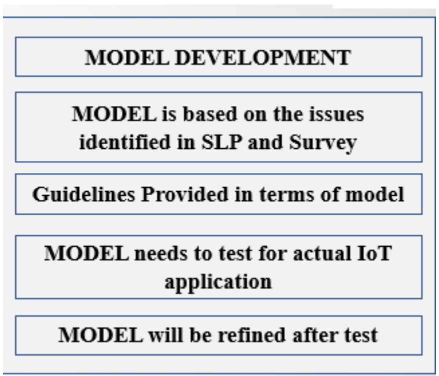

Figure 8. A Refined Industrial DevOps Maturity Model (IDMM) Development Process

Validity Threat

One aspect that could undermine the validity of the results is bias in the use of quality evaluation and data extraction. To lessen this hazard, precise inclusion and exclusion criteria are provided.

IV. CONCLUSION AND FUTURE SCOPE

Several different kind of software design are needed for IoT due to the requirement for version control software at the firmware or device level. It modifies how IoT devices are created. DevOps has provided solutions to the IoT issues through a collection of CI/CD tools and services. Compared to earlier software development methods, developers can update their programmes more frequently and quicker. The DevOps methodology and its recommended practises are frequently used in conjunction with software version control, monitoring, and alerting at the device level. It has outlined the software architecture for IoT devices. Using SLR and survey, this research found challenges with the DevOps implementation of IoT/connected device apps.

The suggested article discusses fundamental challenges that need to be addressed in order to apply the DevOps culture and DevOps methods in IoT applications. Collaboration, sharing, efficiency, and quality are effectiveness metrics that are being taken into consideration. The study identifies difficulties in establishing the DevOps culture that are related to these effectiveness measures. This research presented a new model to provide usage guidelines in order to address current concerns with the effectiveness measurements found while employing the DevOps framework in IoT applications.

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