DevOps Implementation Challenges in the Indonesian Public Health Organization

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Abstract*—The importance of accelerating software development to meet rapidly changing business needs has driven the Indonesian Public Health Organization (IPHO) to adopt DevOps. But after three years, the expected benefits have not been achieved. This research aims to identify the main challenges and obstacles in implementing DevOps at IPHO. A comprehensive examination of existing literature is employed to recognize prevalent difficulties encountered by organizations when implementing DevOps. The main factors are ranked using the Fuzzy Analytic Hierarchy Process (FAHP) based on survey data from DevOps practitioners at IPHO. This study helps fill in some gaps left by empirical studies on the challenges in applying DevOps, especially in the public healthcare sector. It also streamlines the data collection and analysis process by utilizing FAHP, simplifying the survey process, and reducing the number of questions compared to previous approaches. According to the research findings, the primary hurdle that requires attention is the mindset to transform from a traditional approach to continuous delivery. In addition, the lack of understanding about the benefits of implementing DevOps and the lack of cross-functional leadership are also identified as challenges that need to be considered. However, IPHO does not view the use of legacy tools and technologies as a significant impediment to adopting DevOps.

***Keywords*—DevOps; challenges; fuzzy AHP; software development**

I. Introduction

Organizations are currently competing to speed up the conversion of business requirements and business concepts into software applications. The rapidity of software application development plays a critical role in addressing the swiftly shifting business needs of customers and accommodating the ever-changing demands of the business landscape [1]. Software organizations must release effective and sustainable products in a volatile market to compete and maintain a competitive advantage [2]. Therefore, companies that focus on software development must continuously improve their project management practices to achieve higher product quality and enter the market faster [3].

The new approach known as DevOps is often described as a way to deliver software faster and with higher quality through collaboration between development (Dev) and operations (Ops) teams [3]. DevOps is still considered a relatively new approach in software engineering but has garnered significant attention from organizations seeking to improve their software delivery processes [1]. DevOps encompasses various aspects such as tools, organizational culture, practices, and collaboration and can help the software industry achieve better performance and development processes [2].

As Indonesia's largest social insurance company, appointed by the Indonesian government to execute a social health insurance program [4], the Indonesian Public Health Organization (IPHO) is currently attempting to implement DevOps technology in its information system development process. However, the expected benefits have not been realized after running this program for three years. Although IPHO obtained DevOps software licenses and technical support in 2020 [5], no software has yet to utilize DevOps technology in intensive production successfully.

This research aims to identify the key factors that pose challenges and barriers to implementing DevOps at IPHO. The study begins with a literature review to identify challenges and obstacles commonly encountered by companies implementing DevOps technology and culture. A survey is then conducted among the teams at IPHO who have been directly involved in the DevOps implementation process over the past three years. From the survey, the factors posing the main challenges and barriers at IPHO are ranked using the Fuzzy Analytical Hierarchy Process (FAHP) approach.

Comprehensive empirical research on the analysis of challenges in implementing DevOps is currently scarce, especially in sectors such as Public Health Organizations. Hence, this research has the potential to contribute novelty to the domain of DevOps adoption. Furthermore, it will streamline the data collection and analysis of survey data by employing FAHP (Fuzzy Analytic Hierarchy Process). Previous research conducted by M. A. Akbar et al. [6] and A. A. Khan et al. [7] involved two stages of the survey: sentiment assessment of the categories for ranking and pairwise comparison survey. These previous approaches took a long time and required many questions of survey. In this study, the researcher attempts to conduct only one survey stage: a sentiment survey regarding the suitability of categories to real-life events. The researcher will then use the technique of geometric means to translate the scores provided by the survey respondents into Triangular Fuzzy Numbers (TFN) for the computation of pairwise comparisons. The study poses the following research issues regarding this:

RQ1: What are the common challenges and barriers in a company during the implementation of DevOps?

RQ2: What are the main challenges and barriers in implementing DevOps at IPHO?

In this research, the author proposes several sections to provide a clear and comprehensive understanding. Section II provides an in-depth discussion of the research's theoretical foundation, while Section III explains the research methodology used to collect and analyze data. Section IV presents the study results and discussion. Finally, Section V summarizes the study and provides limitations on this research and recommendations for future research directions.

II. Background of DevOps

Evolution tools and methodologies have undergone considerable modifications as a result of the quick development of information technology. Businesses are driven to switch from manual to digital processes because automation can increase efficiency and ensure consistent product quality. The demand for software systems has dramatically expanded [8].

Software organizations continue to seek active development approaches to meet market demands by developing and delivering high-quality software on time and within budget [8]. Dörnenburg [9] suggests that software organizations must adopt new and efficient software development approaches to respond to market demands and effectively address technological changes.

Agile paradigms like Scrum and Kanban have superseded traditional software development methodologies like Waterfall and Spiral to keep up with technological changes and market trends. Because manual processing is prone to mistakes and can cause delays in feedback, production and operational processes have grown more complex [10]. Therefore, a new and more effective software development model known as DevOps has arisen to stay up with the current trend in the software business.

DevOps offers supplemental agile methods based on agile concepts and operational considerations. This strategy facilitates the rapid and continual delivery of developed features over shorter life cycles. DevOps initially had conflicting meanings in the software industry since some communities saw it as a career path requiring expertise in development and operations [11]. Research that defines DevOps as a development environment where growth and operational teams collaborate closely has resolved this issue [11]–[13].

Although there is still a division between developers and operations in DevOps, the operations team oversees changes made to service levels and production [10]. In contrast, the development team consistently creates new features to meet established business objectives. The two teams' tools, procedures, and knowledge bases are distinct. With the help of this system, the development team can continually add new features. In contrast, the operational team works to run the most recent version and control modifications to uphold project quality standards and other non-functional needs [10].

An automated pipeline is needed to address the information flow between the development and operations teams [14]. According to Humble and Farley's [10] automated deployment pipeline, each software version committed to the repository must be prepared for production. To provide a route that enables automated development, testing, and the quick delivery of tested software features to production, Sten [15] highlights the significance of automation procedures. Callanan and Spillane [16] refer to the deployment pipeline as the DevOps platform and emphasize the need for continuous delivery.

III. Research Methodology

The process depicted in Fig. 1 encompasses several stages. To identify the optimal strategies pertaining to DevOps initiatives, a systematic literature review (SLR) was conducted initially. Subsequently, a survey with a questionnaire was carried out to gather feedback and viewpoints from business experts regarding the selected DevOps concepts. The identified challenges were then prioritized using the fuzzy Analytic Hierarchy Process (fuzzy-AHP) method.

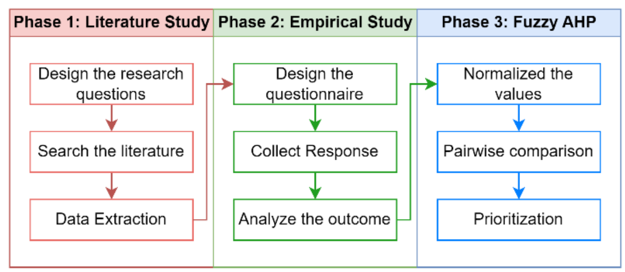

Fig. 1. The utilized research methodology.

- Phase 1: It entailed performing a comprehensive review of the literature to determine the difficulties with DevOps as stated in previous studies.
- Phase 2: It comprised a questionnaire survey aimed at validating the identified challenges empirically, specifically from an industrial perspective.
- Phase 3: Applied the fuzzy AHP methodology to determine the relative importance of the identified challenges in DevOps.

A. *Conducting a Systematic Literature Review (SLR)*

The systematic literature review (SLR) used in this study was conducted following the standards set out by Kitchenham and Charter [16]. The SLR process was divided into three stages: planning, conducting, and reporting.

1) Planning the review: Making the protocols for data collection and analysis is part of planning. The procedures in the review methodology listed below are employed to obtain and evaluate the available literature to respond to the research question.

a) Data Collection Source: Finding literature pertinent to the study's purpose requires carefully selecting data sources. We followed the recommendations of Zhang [17] and Chen [18] in this investigation. The following digital archives found the primary studies relevant to the search:

- Science Direct at https://www.sciencedirect.com
- ACM Digital Library at https://dl.acm.org
- ProQuest at https://www.proquest.com

- Scopus at https://www.scopus.com
- IEEE Xplore at https://ieeexplore.ieee.org

b) Search String: We used the recommendations in the pertinent literature to create the search string for this investigation. First, essential phrases from the relevant papers were determined. Then, the search string was created by combining the "AND" and "OR" operators with the following key phrases and their synonyms: ("DevOps" OR "Development and Operation") AND ("challenge" OR "barriers" OR "obstacles" OR "hurdles" OR "difficulties" OR "impediments" OR "hindrance")

c) Inclusion And Exclusion Criteria: The protocols' primary function is to apply the exclusion and inclusion standards to literature found using search terms. Other information technology research, such as those by Niazi and colleagues [19] and the work of Akbar [20], have also used this strategy. The requirements for inclusion are specified in the procedures below:

- Inclusion Criteria:
  - The publication must be from a credible journal, conference, or book.
  - The publication ought to go into the difficulties of putting DevOps into practice.
  - The report must clearly explain how DevOps is implemented.
  - English must be used in the writing of the chosen article.
- Exclusion Criteria:
  - Only the most comprehensive one will be considered when two studies are relevant to the same project.
  - The paper lacks specific information regarding the implementation of DevOps.
  - Studies unrelated to DevOps will be disregarded.
  - Literature studies will not be considered.

d) Conducting Quality Assessment (QA): The efficacy of the chosen literature in answering the study aim was evaluated using the quality assessment (QA) procedure. The QA procedure adhered to the recommendations made in [16]. The Likert scale is depicted in Table I and was used to evaluate the five questions created. Appendix B (Table XIV) has the full QA scores.

TABLE I. CHECKLIST FOR QA OF THE CHOSEN STUDIES

No	Checklist Questions	Likert scale
QA1	Does the analysis strategy use to answer the questions posed?	"Yes=l, Partial=0.5, NO=0"
QA2	Does the analysis look at the difficulties that come with DevOps?	"Yes=l, Partial=0.5, NO=0"
QA3	Does the report offer a convincing justification for putting DevOps into practice?	"Yes=l, Partial=0.5, NO=0"
QA4	Are the data gathered pertinent for using DevOps techniques?	"Yes=l, Partial=0.5, NO=0"
QA5	Do the outcomes that have been discovered support the research issues?	"Yes=l, Partial=0.5, NO=0"

2) Conducting the Review: In the initial response of the search string on the chosen databases, 906 studies were recovered. The gathered literature was further improved using the tollgate technique created by Afzal [21]. The tollgate technique involves five steps, and each meticulously carried out with the ultimate goal of selecting the studies for data extraction. As indicated in Fig. 2, 24 studies were chosen for the last data extraction procedure (see Table XIII in Appendix A).

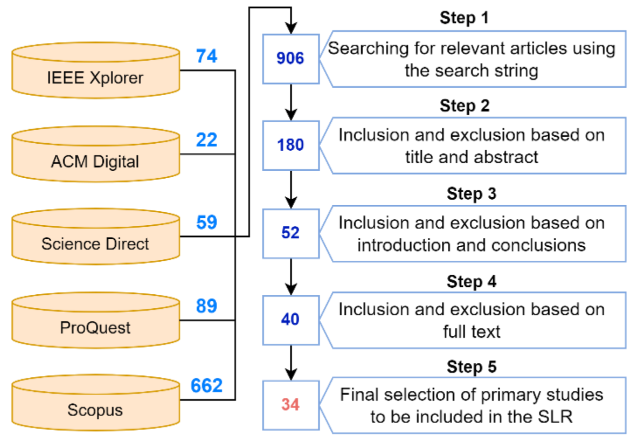

Fig. 2. Filtering formal literature.

a) Assessment of Selected Study Quality: The quality evaluation aims to analyze how well the chosen literature addresses the study's research topic. The selected studies are sufficiently relevant in addressing the research topic since 65% of the papers evaluated had a score of or higher than 60% (see Table XIV in Appendix B). During the quality evaluation procedure, a cutoff point of 50% was selected.

b) Years of Publication of Chosen Articles: During the data extraction stage, we gathered the studies' publication years to investigate the prevalence of DevOps literature. According to the frequency evaluation, the chosen studies cover 2018 through 2023, demonstrating a developing trend in DevOps research. The result indicates that the field of software engineering research is actively interested in DevOps.

B. Conducting an Empirical Study

The questionnaire was created using the Google Forms platform, specifically the docs.google.com/forms platform. The questionnaire was broken up into three different sections for clarity and organization.

The first section's primary goal is to collect bibliographic data from survey respondents to give their comments some context. A set of closed-ended questions aimed at addressing the DevOps difficulties discovered via a thorough and systematic literature review (SLR) research was added in the second part. These closed-ended questions provide respondents with a predetermined range of response alternatives, enabling a complete examination of the problems that have been highlighted.

Finally, the questionnaire's third section includes open-ended questions meant to elicit participants' responses on any additional DevOps security problems that the SLR research might not have covered. Therefore, contributors are encouraged to offer thorough justifications, viewpoints, and proposed solutions in this part to contribute to a thorough knowledge of the topic.

The survey's target population includes all IPHO personnel actively working on the DevOps implementation project, which began in 2020 at the early stages of DevOps adoption and will continue until this research is finished in 2023. The main goal is to have a more profound knowledge of the limitations and difficulties encountered while IPHO embraced DevOps.

C. Utilizing The Fuzzy Analytic Hierarchy Process (Fuzzy AHP)

The fuzzy AHP presents a practical approach for addressing multicriteria decision-making problems. One of the key advantages of utilizing fuzzy AHP is its ease of application and comprehensibility, making it accessible to users. Moreover, it can handle both quantitative and qualitative data effectively. The primary steps employed in implementing the fuzzy AHP methodology are as follows:

- Step 1: Organize the complex decision-making problem into a hierarchy.
- Step 2: Determine the highest and lowest values for each hierarchy element.
- Step 3: Check each pairwise comparison matrix's consistency to confirm correctness.
- Step 4: Establish final ranks for each factor and its corresponding categories.

When assessing the relative importance of various criteria, the traditional Analytic Hierarchy Process (AHP) cannot deal with the ambiguity and vagueness of decision-makers. The AHP approach has been combined with fuzzy theory to solve this issue, creating a fuzzy AHP. As mentioned in the reference [22], this method permits the determination of more precise and dependable judgments in real-time and unforeseen issue scenarios.

In multicriteria decision-making (MCDM) situations, fuzzy AHP is applicable to both qualitative as well as quantitative inputs. The extent analysis approach is used in this method to estimate the priority weight of certain criteria and express preference ratings for the criteria utilizing triangular fuzzy numbers. For this investigation, we used Chang's fuzzy AHP method, which produces more accurate and reliable findings than the traditional AHP method [23].

IV. Result and Discussion

A. Findings of SLR Study

The SLR technique was carefully used to pinpoint DevOps operations' challenging and essential elements. Table II lists the 34 tasks that were examined in total. The five categories of "Culture," "Management," "Process," "Teams," and "Tools," which are seen to be crucial elements for the effective use of DevOps principles in the software industry, were then used to map these challenges. This procedure led to the creation of the structure shown in Fig. 3. This mapping exercise's primary goal is to run a fuzzy AHP analysis.

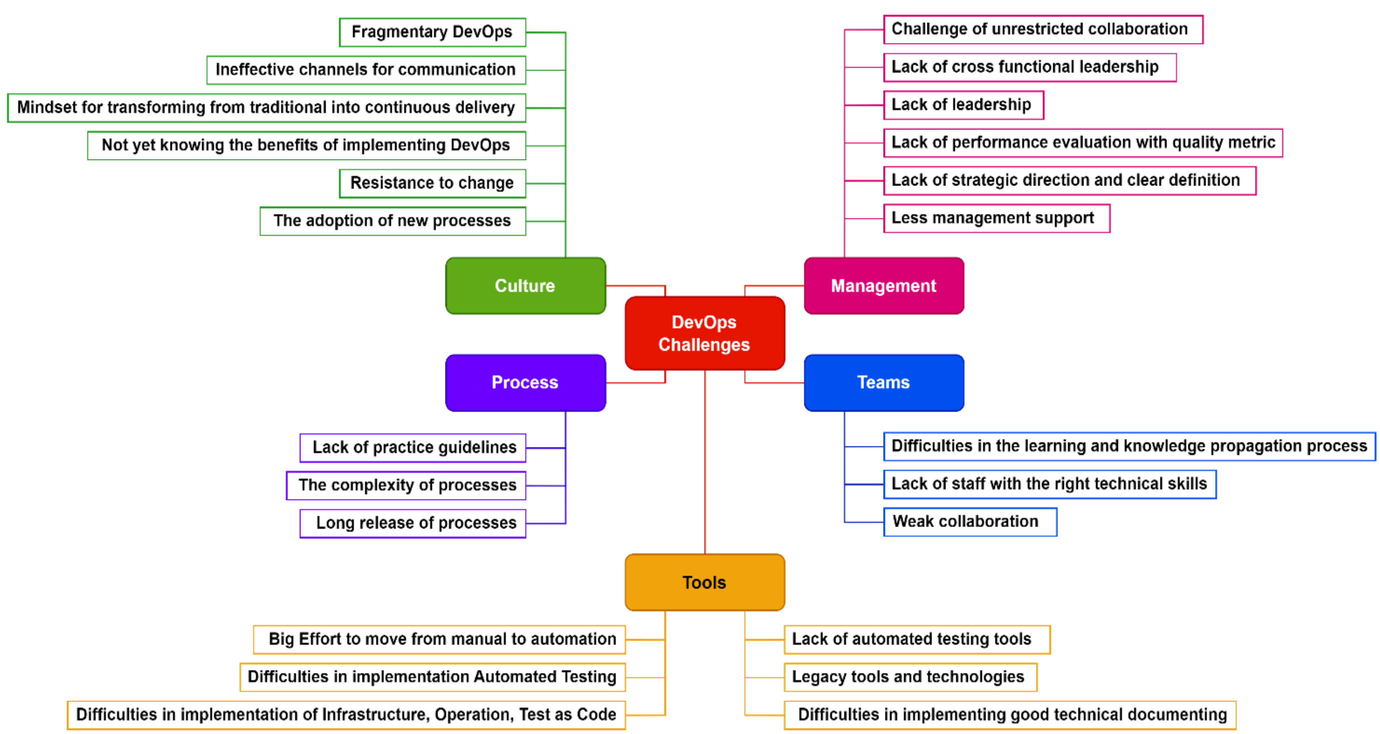

Fig. 3. Mapping of investigated challenges into categories.

TABLE II. LIST OF DEVOPS CHALLENGES

No	Factors	Source
C1	Fragmentary DevOps	[24]–[26]
C2	Ineffective channels for communication	[27]
C3	Mindset for transforming from traditional into continuous delivery	[28]–[30]
C4	Not yet knowing the benefits of implementing DevOps	[28], [31]
C5	Resistance to change	[3], [32]
C6	The adoption of new processes	[3]
C7	Difficulties in allocating resources	[33]–[36]
C8	Lack of cross-functional leadership	[25]
C9	Lack of leadership	[25], [37]
C10	Lack of performance evaluation with a quality metric	[31], [37]–[40]
C11	Lack of a clear concept and strategic direction	[24], [37], [41]
C12	Less management support	[25], [27]
C13	Lack of practice guidelines	[24]
C14	The complexity of processes	[26], [29]
C15	Long release of processes	[29], [42]
C16	Difficulties in the learning and knowledge propagation process	[32]
C17	Lack of technical expertise staff	[25], [27], [29], [41]
C18	Weak collaboration	[24], [25], [27], [41]
C19	Big effort to move from manual to automation	[29], [33], [43]
C20	Difficulties in the implementation of Automated Testing	[34]
C21	Difficulties in implementation of Infrastructure, Operation, Test as Code	[29], [34], [35], [44]
C22	Difficulties in implementing good technical documenting	[35]
C23	Lack of automated testing tools	[34], [45]
C24	Legacy tools and technologies	[26], [29], [37]

B. *Empirical Study Results*

1) Analysis of survey participants' demographic data: Detailed demographic data on the survey respondents was gathered while the data was being collected. According to Patten [46], demographic information is critical for understanding survey respondents and assessing if the participants in a given research are a representative sample of the target population to generalize the findings. According to Finstad [47], bibliographic information on survey respondents might provide insight into the maturity of the gathered dataset. Furthermore, Altman [48] underlined that knowing more about survey respondents aids in comprehending the target population's viewpoints. This study acknowledged the significance of the respondents' bibliographic information, and an analysis of many factors, including respondents' designation and organization size, was done. The following sections explain the findings of this analysis.

a) Designation of the respondent: The importance of the influencing elements, which differ depending on the characteristics of the respondents, were stressed by Finstad [47]. Niazi [19] adds that the practitioner's position affects how a factor has an effect, adding that the influence of a component may be appropriately rated if the responder regularly works with that specific issue. The analysis of respondents based on their titles is shown in Fig. 4, which demonstrates that project managers make up most survey respondents. According to the results, "Junior Programmer (Staff)", "Senior Programmer (Assistant Manager)", and "Senior Programmer (Manager)" are the most often used response designations.

Fig. 4. Job title evaluation in survey.

b) Respondent's Experience: An analysis was conducted on the experience of the survey participants. The median and mean values were computed, resulting in scores of 3 and 2.4, respectively, indicating a relatively young group of participants. Additionally, notable variations in the respondents' experience were briefly observed. Fig. 5 shows a visual depiction of the survey respondents' information.

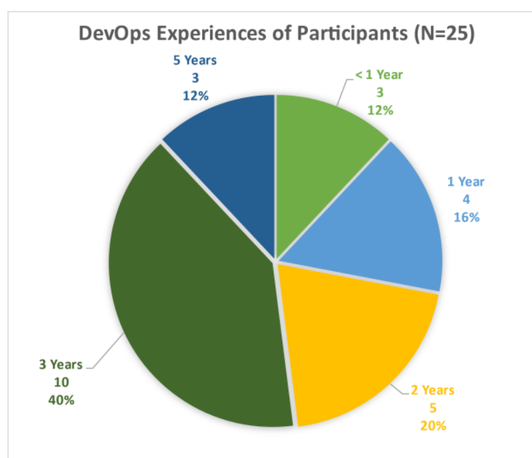

Fig. 5. Survey respondents' experiences.

TABLE III. AN EMPIRICAL INVESTIGATION OF CHALLENGES FACTORS

ID	Challenges List	Number of Responses (P=25)							
		Positive			Negative			Neutral	
		S-A	A	%	D	S-D	%	N	%
P1	**Culture**	**5**	**15**	**74%**	**0**	**0**	**0%**	**7**	**26%**
C1	Fragmentary DevOps	12	7	70%	7	0	28%	1	2%
C2	Ineffective channels for communication	8	14	81%	0	0	0%	5	19%
C3	Mindset for transforming from traditional into continuous delivery	13	11	89%	1	0	4%	2	7%
C4	Not yet knowing the benefits of implementing DevOps	16	9	94%	2	0	7%	0	0%
C5	Resistance to change	10	5	56%	6	1	26%	5	19%
C6	The adoption of new processes	6	12	67%	0	3	9%	6	24%
P2	**Management**	**2**	**20**	**81%**	**0**	**0**	**0%**	**5**	**19%**
C7	Difficulties for allocating resources	7	10	63%	3	1	15%	5	19%
C8	Lack of cross functional leadership	12	13	93%	0	0	0%	2	7%
C9	Lack of leadership	9	16	93%	1	0	4%	1	4%
C10	Lack of performance evaluation with quality metric	6	11	63%	2	2	15%	6	22%
C11	Lack of strategic direction and clear definition	9	11	74%	2	1	11%	4	15%
C12	Less management support	8	8	59%	3	1	15%	7	26%
P3	**Process**	**5**	**12**	**63%**	**1**	**0**	**4%**	**9**	**33%**
C13	Lack of practice guidelines	9	15	89%	1	0	4%	2	7%
C14	The complexity of processes	7	11	67%	4	2	22%	3	11%
C15	Long release of processes	4	14	67%	5	1	22%	3	11%
P4	**Teams**	**5**	**12**	**63%**	**0**	**0**	**0%**	**10**	**37%**
C16	Difficulties in the learning and knowledge propagation process	10	11	78%	1	0	4%	5	19%
C17	Lack of staff with the right technical skills	7	12	70%	2	0	7%	6	22%
C18	Weak collaboration	6	11	63%	5	0	19%	5	19%
P5	**Tools**	**4**	**13**	**63%**	**0**	**0**	**0%**	**10**	**37%**
C19	Big effort to move from manual to automation	11	8	70%	4	0	15%	4	15%
C20	Difficulties in implementation Automated Testing	11	10	78%	2	0	7%	4	15%
C21	Difficulties in implementation of Infrastructure, Operation, Test as Code	10	8	67%	4	0	15%	5	19%
C22	Difficulties in implementing good technical documenting	9	13	81%	1	0	4%	4	15%
C23	Lack of automated testing tools	9	9	67%	3	0	11%	6	22%
C24	Legacy tools and technologies	6	11	63%	5	2	27%	3	10%
Average				**73%**			**10%**		**17%**

2) Analysis of responses to DevOps challenges: The empirical study's primary objective was to learn more from business experts about the difficulties faced by DevOps, as determined by a systematic literature review (SLR). Three categories—positive ("agree, strongly agree"), negative ("disagree, strongly disagree"), and "neutral"—were used to classify the replies given by practitioners. The positive category represents the proportion of survey participants who acknowledged the difficulties that might negatively influence DevOps techniques. The opposing group comprises respondents who frequently disagreed with the challenges noted in the SLR research. The neutral type represents the participants who often expressed uncertainty about how the specified factors will affect DevOps operations. Please see Table III for more specific data.

The study's findings are shown in Table III, which shows that most survey respondents concur that DevOps has a bad relationship with the issues in actual operations. According to the frequency analysis, over 50% of survey respondents considered each challenging element. C4, or "Not yet knowing the benefits of implementing DevOps," was cited as the most challenging problem by survey respondents (94%).

The poll respondents named P2 (Management, 81%) as the most critical categories among the researched complex variables, with P1 (Culture, 74%) placing second. The third most important types of problems are P3 (Process, 63%) and P4 (Team, 73%).

Among the challenges categorized as negative factors, C1(Fragmentary DevOps) emerged as the highest-ranking challenge, with 28% of the respondents disagreeing with its classification as a significant factor in DevOps practices. Following closely behind, and C24 (Legacy tools and technologies, 27%) received the second highest level of disagreement among the respondents.

Additionally, challenges were sorted based on respondents' limited understanding of their impact on both DevOps implementation with neutral response options. The top-ranked challenge, labeled as C6 (The adoption of new processes), received a 24% response rate. It was closely followed by C10 (Lack of performance evaluation with quality metric), C17 (Lack of staff with the right technical skills), and C23 (Lack of automated testing tools), all of which received a 22% response rate and were ranked as the second-highest challenges.

C. Implementing Fuzzy AHP

The fuzzy-AHP used to investigate the rank of challenges and the categories they fall into is presented in this part. The issues were prioritized using the fuzzy AHP step-by-step procedures mentioned in the preceding section.

Step 1 (Hierarchical Categorization of Complex Problems): The complicated problem is separated into linked decision-making components using the method described in [49] and [50] to do the fuzzy AHP analysis. The top level of the problem reflects the primary goal, whereas Stages 2 and 3 show the types of issues and their accompanying challenges. Fig. 6 depicts the suggested hierarchical structure.

Step 2 (The process of pairwise comparisons): On the basis of professional judgments, the pairwise comparison was undertaken. The author continued using the first questionnaire's data (see Table XV in Appendix C) to gather reference values for the paired comparison data process utilizing the geometric mean calculation approach to provide sufficient and quicker pairwise comparison data. Triangular fuzzy numbers (TFNs) can be generated using the geometric mean from survey respondents' judgments. The following geometric mean formula was applied in this study:

$$\text{Geometric mean} = \sqrt[n]{j1 \times j2 \times j3 \ldots jn} \quad (1)$$

j =Individual judgment weights

n =Count of judgments

Step 3 (Verifying the Pairwise Matrix's Consistency): The method for determining if the pairwise comparison matrices are consistent is laid out sequentially in this section. The matrices must show consistency in fuzzy AHP. Consideration is given to the categories on the Likert scale (Table IV). To create the matching Fuzzy Crisp Matrix (FCM) displayed in Table V, the primary categories triangular fuzzy numbers in the pairwise comparison matrix are defuzzification into crisp numbers.

The fuzzy Analytic Hierarchy Process (AHP) can use a comparison matrix that is adequate and trustworthy for many issue categories. The consistency ratio for each category of challenge elements was computed using the same approach, and the results are shown according to Tables VI to X in the appropriate order.

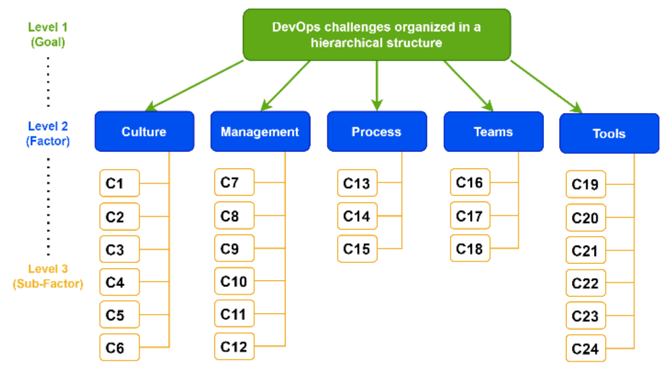

Fig. 6. The hierarchy of the problem structure.

TABLE IV. CONVERSION SCALE OF A FUZZY [51]

Grade	Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
1	Element j holds the same level of importance as element i.	(1, 1, 1)	(1, 1, 1)
2	Slightly of lower importance.	(1, 2, 3)	(0.33, 0.50, 1.00)
3	Somewhat important, falling within the range of slightly important.	(2, 3, 4)	(0.25, 0.33, 0.50)
4	Moderately important, ranging from slightly important to more important.	(3, 4, 5)	(0.20, 0.25, 0.33)
5	Significantly more important.	(4, 5, 6)	(0.17, 0.20, 0.25)
6	Between a more important and highly important.	(5, 6, 7)	(0.14, 0.17, 0.20)
7	Highly important.	(6, 7, 8)	(0.13, 0.14, 0.17)
8	Between highly important and most important	(7, 8, 9)	(0.11, 0.13, 0.14)
9	Most significance.	(9, 9, 9)	(0.11, 0.11, 0.11)

TABLE V. CHALLENGE CATEGORY FUZZY-CRISP MATRIX (FCM)

	P1	P2	P3	P4	P5	Priority Vector Weight
P1	1.00	3.00	8.00	5.00	6.00	0.4995
P2	0.33	1.00	6.00	3.00	4.00	0.2585
P3	0.13	0.17	1.00	0.25	0.33	0.0388
P4	0.20	0.33	4.00	1.00	2.00	0.1216
P5	0.17	0.25	3.00	0.50	1.00	0.0816

TABLE VI. CULTURE CATEGORY PAIRWISE COMPARISONS

	C1	C2	C3	C4	C5	C6
C1	(1.00, 1.00, 1.00)	(0.33, 0.50, 1.00)	(0.17, 0.20, 0.25)	(0.20, 0.25, 0.33)	(3.00, 4.00, 5.00)	(2.00, 3.00, 4.00)
C2	(1.00, 2.00, 3.00)	(1.00, 1.00, 1.00)	(0.20, 0.25, 0.33)	(0.25, 0.33, 0.50)	(4.00, 5.00, 6.00)	(3.00, 4.00, 5.00)
C3	(4.00, 5.00, 6.00)	(3.00, 4.00, 5.00)	(1.00, 1.00, 1.00)	(1.00, 2.00, 3.00)	(7.00, 8.00, 9.00)	(6.00, 7.00, 8.00)
C4	(3.00, 4.00, 5.00)	(2.00, 3.00, 4.00)	(0.33, 0.50, 1.00)	(1.00, 1.00, 1.00)	(6.00, 7.00, 8.00)	(5.00, 6.00, 7.00)
C5	(0.20, 0.25, 0.33)	(0.17, 0.20, 0.25)	(0.11, 0.13, 0.14)	(0.13, 0.14, 0.17)	(1.00, 1.00, 1.00)	(0.33, 0.50, 1.00)
C6	(0.25, 0.33, 0.50)	(0.20, 0.25, 0.33)	(0.13, 0.14, 0.17)	(0.14, 0.17, 0.20)	(1.00, 2.00, 3.00)	(1.00, 1.00, 1.00)

I_{max} = 6.222, CI= 0.044, CR= 0.036

TABLE VII. MANAGEMENT CATEGORY PAIRWISE COMPARISONS

	C7	C8	C9	C10	C11	C12
C7	(1.00, 1.00, 1.00)	(0.20, 0.25, 0.33)	(0.25, 0.33, 0.50)	(4.00, 5.00, 6.00)	(1.00, 2.00, 3.00)	(3.00, 4.00, 5.00)
C8	(3.00, 4.00, 5.00)	(1.00, 1.00, 1.00)	(1.00, 2.00, 3.00)	(7.00, 8.00, 9.00)	(4.00, 5.00, 6.00)	(6.00, 7.00, 8.00)
C9	(2.00, 3.00, 4.00)	(0.33, 0.50, 1.00)	(1.00, 1.00, 1.00)	(6.00, 7.00, 8.00)	(3.00, 4.00, 5.00)	(5.00, 6.00, 7.00)
C10	(0.17, 0.20, 0.25)	(0.11, 0.13, 0.14)	(0.13, 0.14, 0.17)	(1.00, 1.00, 1.00)	(0.20, 0.25, 0.33)	(0.33, 0.50, 1.00)
C11	(0.33, 0.50, 1.00)	(0.17, 0.20, 0.25)	(0.20, 0.25, 0.33)	(3.00, 4.00, 5.00)	(1.00, 1.00, 1.00)	(2.00, 3.00, 4.00)
C12	(0.20, 0.25, 0.33)	(0.13, 0.14, 0.17)	(0.14, 0.17, 0.20)	(1.00, 2.00, 3.00)	(0.25, 0.33, 0.50)	(1.00, 1.00, 1.00)

I_{max} = 6.112, CI= 0.039, CR= 0.031

TABLE VIII. PROCESS CATEGORY PAIRWISE COMPARISONS

	C13	C14	C15
C13	(1.00, 1.00, 1.00)	(6.00, 7.00, 8.00)	(3.00, 4.00, 5.00)
C14	(0.13, 0.14, 0.17)	(1.00, 1.00, 1.00)	(0.20, 0.25, 0.33)
C15	(0.20, 0.25, 0.33)	(3.00, 4.00, 5.00)	(1.00, 1.00, 1.00)

I_{max} = 3.076, CI= 0.038, CR= 0.066

TABLE IX. TEAMS CATEGORY PAIRWISE COMPARISONS

	C16	C17	C18
C16	(1.00, 1.00, 1.00)	(3.00, 4.00, 5.00)	(6.00, 7.00, 8.00)
C17	(0.20, 0.25, 0.33)	(1.00, 1.00, 1.00)	(3.00, 4.00, 5.00)
C18	(0.13, 0.14, 0.17)	(0.20, 0.25, 0.33)	(1.00, 1.00, 1.00)

I_{max} = 2.023, CI= 0.025, CR= 0.043

TABLE X. TOOLS CATEGORY PAIRWISE COMPARISONS

	C19	C20	C21	C22	C23	C24
C19	(1.00, 1.00, 1.00)	(0.14, 0.17, 0.20)	(0.20, 0.25, 0.33)	(0.13, 0.14, 0.17)	(0.25, 0.33, 0.50)	(1.00, 2.00, 3.00)
C20	(5.00, 6.00, 7.00)	(1.00, 1.00, 1.00)	(2.00, 3.00, 4.00)	(0.33, 0.50, 1.00)	(3.00, 4.00, 5.00)	(6.00, 7.00, 8.00)
C21	(3.00, 4.00, 5.00)	(0.25, 0.33, 0.50)	(1.00, 1.00, 1.00)	(0.20, 0.25, 0.33)	(1.00, 2.00, 3.00)	(4.00, 5.00, 6.00)
C22	(6.00, 7.00, 8.00)	(1.00, 2.00, 3.00)	(3.00, 4.00, 5.00)	(1.00, 1.00, 1.00)	(4.00, 5.00, 6.00)	(7.00, 8.00, 9.00)
C23	(2.00, 3.00, 4.00)	(0.20, 0.25, 0.33)	(0.33, 0.50, 1.00)	(0.17, 0.20, 0.25)	(1.00, 1.00, 1.00)	(3.00, 4.00, 5.00)
C24	(0.33, 0.50, 1.00)	(0.13, 0.14, 0.17)	(0.17, 0.20, 0.25)	(0.11, 0.13, 0.14)	(0.20, 0.25, 0.33)	(1.00, 1.00, 1.00)

I_{max} = 6.217, CI= 0.022, CR= 0.018

Tables VI to X indicate that the consistency ratio (CR) is below 0.1, allowing the questionnaire data to be used for the subsequent step, calculating local and global ranking weights.

Step 4 (Weights are determined locally and globally): The weights of the challenges and their associated categories, both locally and globally, were computed. Table XI displays the findings and compares each task's importance to all other challenges (global weight), showing how each problem ranks within its category.

TABLE XI. CALCULATE THE CUMULATIVE WEIGHT OF THE CHALLENGES

Category Weight	**Challenges**	**Local**		**Global**	
		Weight	**Rank**	**Weight**	**Rank**
Culture (0.49952)	C1	0.09543	4	0.04767	7
	C2	0.13911	3	0.06949	6
	C3	0.39976	1	0.19968	1
	C4	0.28827	2	0.14400	2
	C5	0.03210	6	0.01603	15
	C6	0.04534	5	0.02265	14
Management (0.25854)	C7	0.13911	3	0.03597	8
	C8	0.39976	1	0.10335	3
	C9	0.28827	2	0.07453	5
	C10	0.03210	6	0.00830	20
	C11	0.09543	4	0.02467	12
	C12	0.04534	5	0.01172	16
Process (0.03880)	C13	0.69183	1	0.02685	11
	C14	0.07648	3	0.00297	23
	C15	0.23169	2	0.00899	19
Teams (0.08156)	C16	0.69183	1	0.08411	4
	C17	0.23169	2	0.02817	10
	C18	0.07648	3	0.00930	18
Tools (0.12158)	C19	0.04534	5	0.00370	22
	C20	0.28827	2	0.02351	13
	C21	0.13911	3	0.01134	17
	C22	0.39976	1	0.03260	9
	C23	0.09543	4	0.00778	21
	C24	0.03210	6	0.00262	24

Step 5 (Challenges Prioritization): The fuzzy AHP analysis's primary goal is to rank the researched challenges according to their importance to the DevOps paradigm. Table XII lists the final standings for each challenge.

TABLE XII. PRIORITY ORDER FOR THE DIFFICULTIES

ID	Challenges List	Rank
C3	Mindset for transforming from traditional into continuous delivery	1
C4	Not yet knowing the benefits of implementing DevOps	2
C8	Lack of cross-functional leadership	3
C16	Difficulties in the learning and knowledge propagation process	4
C9	Lack of leadership	5
C2	Ineffective channels for communication	6
C1	Fragmentary DevOps	7
C7	Difficulties in allocating resources	8
C22	Difficulties in implementing good technical documenting	9
C17	Lack of staff with the right technical skills	10
C13	Lack of practice guidelines	11
C11	Lack of strategic direction and clear definition	12
C20	Difficulties in the implementation of Automated Testing	13
C6	The adoption of new processes	14
C5	Resistance to change	15
C12	Less management support	16
C21	Difficulties in implementation of Infrastructure, Operation, Test as Code	17
C18	Weak collaboration	18
C15	Long release of processes	19
C10	Lack of performance evaluation with quality metric	20
C23	Lack of automated testing tools	21
C19	Big effort to move from manual to automation	22
C14	The complexity of processes	23
C24	Legacy tools and technologies	24

Based on the global weights, it is decided that C3 (Mindset for changing from conventional into continuous delivery) is the most critical challenge that must be solved to implement DevOps methods at IPHO effectively. Additionally, C4 (Not understanding the advantages of applying DevOps) and C8 (Lack of cross-functional leadership) are listed as the second and third most significant priority difficulties for implementing DevOps methods. It is also important to note that C24 (Legacy tools and technologies) is listed as the least major issue for the DevOps paradigm in IPHO.

V. CONCLUSION

IPHO has adopted DevOps principles due to the significance of expediting software application development to satisfy quickly changing business demands and preserve a competitive edge. The anticipated advantages have not materialized despite this program being in place for three years. This study tries to pinpoint the key variables that IPHO must overcome to use DevOps technology successfully.

The research utilizes a systematic literature review to identify common challenges companies face when implementing DevOps technology and culture. Furthermore, over the past three years, a survey has been conducted among teams directly involved in the DevOps implementation process at IPHO. Using the Fuzzy Analytical Hierarchy Process (FAHP) method, the detected elements that provide significant problems and impediments are rated.

The limits of empirical studies concerning difficulties in DevOps adoption, particularly in the public healthcare sector, are addressed in this study. It also makes data gathering and analysis easier by employing FAHP, which streamlines the survey process and uses fewer questions than earlier methods.

The most critical challenge that has to be resolved for IPHO to apply DevOps methods effectively is C3 (Mindset for transitioning from conventional to continuous delivery), according to the global weights used in the analysis. In addition, C4 (Lack of knowledge about the advantages of applying DevOps) and C8 (Lack of cross-functional leadership) are noted as the second and third priority hurdles in implementing DevOps methods. It is important to note that at IPHO, C24(Legacy tools and technologies) is rated as the least important issue for the DevOps concept.

A. Limitations

Although this study has implemented a comprehensive research methodology, the authors acknowledge the presence of limitations. One of these limitations is the constraint of using only one public health institution as a case study, resulting in a study with a limited scope and more relevant to that specific institution. Additionally, the number of respondents involved in this research is considered inadequate for achieving a more robust analysis.

B. Future Work

In the future, researchers can still conduct multivocal literature studies to examine the factors influencing DevOps practices but expand the research scope to investigate the success and challenges of adopting DevOps in organizations and involve multiple companies for more comprehensive results. Additionally, utilizing multiple case studies within the same sector can provide a larger sample size and generate more comprehensive analyses.

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APPENDIX A

TABLE XIII. SELECTED PUBLICATION

Authors	Title	Journal/Proceedings	Year	ID
Zhou, X., et al.	A Cross-Company Ethnographic Study on Software Teams for DevOps and Microservices: Organization, Benefits, and Issues	The 44th International Conference on Software Engineering	2022	SP1
Li, H., et al.	Adopting Autonomic Computing Capabilities in Existing Large-Scale Systems	The 40th International Conference on Software Engineering	2018	SP2
Luz, W. P., et al.	Building a Collaborative Culture: A Grounded Theory ofWell Succeeded DevOps Adoption in Practice	The 12th ACM/IEEE International Symposium on Empirical Software Engineering	2018	SP3
Debroy, V., et al.	Building Lean Continuous Integration and Delivery Pipelines by Applying DevOps Principles: A Case Study at Varidesk	The 2018 26th ACM Joint Meeting on European Software Engineering Conference	2018	SP4
D\'az, J., et al.	DevOps in Practice – An Exploratory Case Study	The 19th International Conference on Agile Software Development	2018	SP5
Henkel, J., et al.	Learning from, Understanding, and Supporting DevOps Artifacts for Docker	The ACM/IEEE 42nd International Conference	2020	SP6
Maroukian, K., et al.	The Link Between Transformational and Servant Leadership in DevOps-Oriented Organizations	The 2020 European Symposium on Software Engineering	2020	SP7
Gupta, R. K., et al.	Challenges in Adopting Continuous Delivery and DevOps in a Globally Distributed Product Team	2019 ACM/IEEE 14th International Conference on Global Software Engineering (ICGSE)	2019	SP8
Bijwe, A. and P. Shankar	Challenges of Adopting DevOps Culture on the Internet of Things Applications - A Solution Model	2022 2nd International Conference on Technological Advancements	2022	SP9
Batra, P. and A. Jatain	Measurement Based Performance Evaluation of DevOps	2020 International Conference on Computational Performance Evaluation	2020	SP10
Häkli, A., et al.	Towards Cloud Native Continuous Delivery: An Industrial Experience Report	2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion	2018	SP11
Lapointe-Boisvert, A., et al.	Towards Modelling Acceptance Tests as a Support for Software Measurement	2021 ACM/IEEE International Conference on Model Driven Engineering Languages	2021	SP12
Shahin, M., et al.	A Qualitative Study of Architectural Design Issues in DevOps	Cornell University Library, arXiv.org	2021	SP13
Sorgalla, J., et al.	Applying Model-Driven Engineering to Stimulate the Adoption of DevOps Processes in Small and Medium-Sized Organizations	Cornell University Library, arXiv.org	2021	SP14
Mauro Lourenço, P., et al.	DevOps ADOPTION: EIGHT EMERGENT PERSPECTIVES	Cornell University Library, arXiv.org	2021	SP15
Trigo, A., et al.	DevOps adoption: Insights from a large European Telco	Cornell University Library, arXiv.org	2022	SP16
Díaz, J., et al.	DevOps in Practice – A preliminary Analysis of two Multinational Companies	Cornell University Library, arXiv.org	2019	SP17
Garg, S., et al.	On Continuous Integration / Continuous Delivery for Automated Deployment of Machine Learning Models using MLOps	Cornell University Library, arXiv.org	2022	SP18
Theo, T., et al.	A mapping study on documentation in Continuous Software Development	Information and Software Technology	2022	SP19
Minaoar Hossain, T., et al.	A mixed method study of DevOps challenges	Information and Software Technology	2023	SP20
Welder Pinheiro, L., et al.	Adopting DevOps in the real world: A theory, a model, and a case study	Journal of Systems and Software	2019	SP21
Monika, S., et al.	The pipeline for the continuous development ofartificial intelligence models—Current state ofresearch and practice	Journal of Systems and Software	2023	SP22
Muhammad Azeem, A., et al.	Toward successful DevSecOps in software development organizations: A decision-making framework	Information and Software Technology	2022	SP23
Fritzsch, J., et al.	Adopting microservices and DevOps in the cyber-physical systems domain: A rapid review and case study	Software - Practice and Experience	2023	SP24
Pereira, I. M., et al.	Investigating Continuous Delivery on IoT Systems	Association for Computing Machinery	2022	SP25
Patel, A. R. and S. Tyagi	Lightweight Review: Challenges and Benefits of Adopting DevOps	Proceedings of 2022 1st International Conference on Informatics, ICI 2022	2022	SP26
Rowse, M. and J. Cohen	A survey of DevOps in the South African software context	Proceedings of the Annual Hawaii International Conference on System Sciences	2021	SP27
Snyder, B. and B. Curtis	Using Analytics to Guide Improvement during an Agile–DevOps Transformation	IEEE Software	2018	SP28
Senapathi, M., et al.	DevOps capabilities, practices, and challenges: Insights from a case study	The 22nd International Conference on Evaluation and Assessment	2018	SP29
Premchand, A., et al.	Simplification of application operations using cloud and DevOps	Indonesian Journal of Electrical Engineering and Computer Science	2019	SP30
Pallis, G., et al.	DevOps as a Service: Pushing the Boundaries of Microservice Adoption	IEEE Internet Computing	2018	SP31
Lewis and R. Jayadi	IMPLEMENTING CONTINUOUS DELIVERY IN A FINTECH COMPANY: A CASE STUDY	Journal of Theoretical and Applied Information Technology	2022	SP32
Kuusinen, K., et al.	A Large Agile Organization on Its Journey Towards DevOps	2018 44th Euromicro Conference on Software Engineering and Advanced Applications	2018	SP33
Caraturan, S. B. O. G.	Major Challenges of Systems-of-Systems with Cloud and DevOps - A Financial Experience Report	2019 IEEE/ACM 7th International Workshop on Software Engineering	2019	SP34

APPENDIX B

TABLE XIV. QUALITY RATING OF THE CHOSEN STUDIES

ID	Reference	QAl	QA2	QA3	QA4	QA5	Total	%
SP1	[24]	1	1	1	1	1	5	100%
SP2	[33]	1	0.5	1	1	1	4.5	90%
SP3	[45]	1	1	1	1	1	5	100%
SP4	[42]	1	1	1	1	1	5	100%
SP5	[28]	1	1	1	0.5	1	4.5	90%
SP6	[44]	1	1	1	1	0.5	4.5	90%
SP7	[25]	1	0.5	1	0.5	1	4	80%
SP8	[29]	1	1	1	1	1	5	100%
SP9	[27]	1	0.5	0.5	1	1	4	80%
SP10	[38]	1	0.5	1	1	1	4.5	90%
SP11	[39]	1	0.5	1	0.5	1	4	80%
SP12	[31]	1	0.5	0.5	1	1	4	80%
SP13	[34]	1	1	1	1	1	5	100%
SP14	[35]	1	0.5	0.5	1	1	4	80%
SP15	[32]	1	0.5	1	1	0.5	4	80%
SP16	[3]	1	0.5	1	1	0.5	4	80%
SP17	[26]	1	0.5	1	1	1	4.5	90%
SP18	[52]	1	1	1	1	1	5	100%
SP19	[53]	0.5	0.5	1	1	1	4	80%
SP20	[54]	1	0.5	1	1	1	4.5	90%
SP21	[55]	1	0.5	1	0.5	1	4	80%
SP22	[56]	1	0.5	1	1	1	4.5	90%
SP23	[57]	0.5	0.5	1	0.5	1	3.5	70%
SP24	[58]	0.5	0.5	1	0.5	1	3.5	70%
SP25	[59]	1	0.5	1	1	1	4.5	90%
SP26	[60]	1	0.5	0.5	1	0.5	3.5	70%
SP27	[61]	1	0.5	1	1	1	4.5	90%
SP28	[62]	1	0.5	0.5	1	0.5	3.5	70%
SP29	[11]	1	0.5	1	1	1	4.5	90%
SP30	[63]	0.5	0.5	1	0.5	1	3.5	70%
SP31	[64]	1	0.5	1	1	1	4.5	90%
SP32	[65]	0.5	0.5	1	1	0.5	3.5	70%
SP33	[66]	1	0.5	1	1	1	4.5	90%
SP34	[67]	1	0.5	0.5	1	0.5	3.5	70%

APPENDIX C

TABLE XV. SAMPLE SURVEY QUESTIONNAIRE WAS USED TO CONFIRM THE SECURITY ISSUES WITH DEVOPS

<table>
<tr><th colspan="7">Survey questions to determine the challenges with DevOps adoption in IPHO</th></tr>
<tr><th colspan="7">Section A: Personal information of respondents.</th></tr>
<tr><td>Name</td><td colspan="6"></td></tr>
<tr><td>EmployeeID</td><td colspan="6"></td></tr>
<tr><td>Email address</td><td colspan="6"></td></tr>
<tr><td>How long have you been familiar with or using DevOps?</td><td>< 1 year</td><td>1 year</td><td>2 years</td><td>3 years</td><td>4 years</td><td>5 years</td></tr>
<tr><th colspan="7">Section B: Challenges related to security in DevOps and their categorization.</th></tr>
<tr><td colspan="7">The purpose of this section is to identify Challenges that can have a negative impact on the adoption of DevOps in IPHO. Please provide a rating for each challenge based on your understanding and experience.</td></tr>
<tr><td colspan="7">Strongly Agree = 'S-A', Agree = 'A', Neutral = 'N', Disagree = 'D', Strongly Disagree = 'S-D'</td></tr>
</table>

ID	Factors and Categories Identified	S-A	A	N	D	S-D
C1	Does the separation of Developer and Operational teams pose a barrier to implementing DevOps?					
C2	Does ineffective communication channel pose a barrier to implementing DevOps?					
C3	Does the mindset shift from traditional to automated deployment processes pose a barrier to implementing DevOps?					
C4	Does lack of awareness of the benefits of DevOps implementation pose a barrier to its implementation?					
C5	Does resistance to change pose a barrier to implementing DevOps?					
C6	Does adoption of new processes pose a barrier to implementing DevOps?					
C7	Does difficulty in resource allocation pose a barrier to implementing DevOps?					

C8	Does lack of cross-functional leadership pose a barrier to implementing DevOps?	○	○	○	○	○
C9	Does lack of a key leader pose a barrier to implementing DevOps?	○	○	○	○	○
C10	Does lack of performance evaluation with quality metrics pose a barrier to implementing DevOps?	○	○	○	○	○
C11	Does lack of strategic direction and clear definition pose a barrier to implementing DevOps?	○	○	○	○	○
C12	Does lack of management support pose a barrier to implementing DevOps?	○	○	○	○	○
C13	Does lack of examples/guidelines in practice pose a barrier to implementing DevOps?	○	○	○	○	○
C14	Does process complexity pose a barrier to implementing DevOps?	○	○	○	○	○
C15	Does long release cycles pose a barrier to implementing DevOps?	○	○	○	○	○
C16	Does difficulty in learning and disseminating knowledge pose a barrier to implementing DevOps?	○	○	○	○	○
C17	Does lack of staff with good technical skills pose a barrier to implementing DevOps?	○	○	○	○	○
C18	Does weak collaboration pose a barrier to implementing DevOps?	○	○	○	○	○
C19	Does significant effort to transition from manual to automation pose a barrier to implementing DevOps?	○	○	○	○	○
C20	Does difficulty in implementing Automated Testing pose a barrier to implementing DevOps?	○	○	○	○	○
C21	Does difficulty in automating code generation for Infrastructure, Operation, and Test functions pose a barrier to implementing DevOps?	○	○	○	○	○
C22	Does difficulty in implementing good technical documentation pose a barrier to implementing DevOps?	○	○	○	○	○
C23	Does lack of automated testing tools pose a barrier to implementing DevOps?	○	○	○	○	○
C24	Does the use of legacy tools and technologies pose a barrier to implementing DevOps?	○	○	○	○	○
Please give other factors that hinder the implementation of DevOps in IPHO (optional): ----------------------						