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RESEARCH ARTICLE

Prioritizing DevOps Implementation Guidelines for Sustainable Software Projects

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ABSTRACT The DevOps paradigm is increasingly being adopted in the software industry. To achieve sustainable DevOps adoption, organizations need to transform their culture, embrace automation, implement measurement practices, and foster sharing of knowledge and information (referred to as CAMS). Implementing DevOps principles can be complex for software organizations. However, sustainable DevOps implementation can lead to the development of high-quality projects with a favorable return on investment. This evidence-based study aims to explore the guidelines for sustainable DevOps implementation as reported in both the literature and industry practices. By conducting a systematic literature review and questionnaire survey, we identified 48 guidelines for sustainable DevOps implementation. Furthermore, we developed a decision-making framework to assist practitioners in prioritizing these guidelines. The results indicate that culture, among the CAMS aspects, is the most crucial principle for sustainable DevOps implementation. The highest priority guidelines for sustainable DevOps implementation include: (i) fostering a collaborative culture with shared goals, (ii) assessing the organization's readiness for a microservices architecture, and (iii) educating executives about the benefits of DevOps to gain resource and budget support. We believe that this comprehensive study will aid practitioners in understanding the core principles and guidelines for sustainable DevOps implementation.

INDEX TERMS CAMS, DevOps, guidelines, systematic literature review, prioritization.

I. INTRODUCTION

The software industry constantly seeks effective and flexible approaches to develop high-quality software within limited time and cost constraints. In recent years, the DevOps paradigm has gained popularity in the software development process [1], [2]. DevOps provides a platform for development and operations teams to collaborate in the development of software products. It fosters cross-functional shared responsibilities and trust between these teams [3]. DevOps significantly expands on the continuous development goals of the agile movement by supporting the automation of continuous integration and release processes [4], [5]. Leite et al. [6] define DevOps as a cultural effort that automates the infrastructure and software development cycle of an organization, ensuring the reliability of the software product. DevOps offers several benefits to software organizations, such as increased focus on implementation and frequent releases. Furthermore, it automates build, testing, and deployment processes [7]. Forsgren [7] asserts that automated development processes help reduce human effort and enable scheduled automated deployments.

Moreover, it has been emphasized that an automated development environment contributes significantly to the development and quality of software applications [8]. The implementation of sustainable DevOps practices enables software organizations to deliver frequent small releases, enhancing the visualization of modules for end-users [9]. The small and frequent deployments allow development teams to receive valuable feedback from clients, improving

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the overall quality of the product [10]. Despite the numerous benefits associated with sustainable DevOps, software practitioners face several challenges in its implementation, including "fear of change," "conceptual deficit," "blame game," and "complex and dynamic environments" [11]. Similarly, Jabbari et al. [12] identify communication gaps and heterogeneous environments as critical challenges for sustainable DevOps implementation in the software industry.

Despite the challenges, several well-established organizations, such as Etsy, IBM, Netflix, and Flickr, have successfully adopted DevOps [12]. For instance, effective communication and collaboration among both development and operations practitioners at Flickr have helped decrease release time. Implementing DevOps practices in different organizations has revealed that sustainable DevOps enhances system quality and the delivery process [12], [13]. Erich et al. [14] note that practices for sustainable DevOps are being rapidly adopted by software organizations to reap their benefits. The significance of sustainable DevOps in real-world practices motivated comprehensive systematic research to investigate and analyse the guidelines reported in the state-of-the-art literature and industry practices. The objectives of this study are: (1) to conduct a systematic literature review and questionnaire survey to explore and validate guidelines for sustainable DevOps implementation; (2) to prioritize the investigated guidelines using the fuzzy-AHP approach; and (3) to develop a decision-making framework based on the prioritized rankings of guidelines. To address these objectives, the following research questions were formulated:

[RQ1] What guidelines for sustainable DevOps implementation in software development organizations are reported in the literature and industry practices?

[RQ2] How were the explored guidelines prioritized using the fuzzy-AHP approach?

[RQ3] What is the prioritization-based framework for sustainable DevOps guidelines?

The paper is organized as follows: Section II presents the study background. The research methodologies employed are discussed in Section III. The results and analysis are presented in Section IV. Section V provides a summary of the study findings. Threats to the validity of the study findings are addressed in Section VI. Finally, Section VII concludes the paper and outlines future directions of the study.

II. BACKGROUND

Software organizations have shown a keen interest in adopting software development approaches that can expedite the development and delivery cycles. The motivation behind these new approaches stems from the need to effectively address rapidly changing customer requirements. Agile development approaches have been widely adopted in the software industry to tackle the challenges posed by such changes in the software development life cycle [15]. The concept of continuous delivery, which introduced a new software development strategy known as DevOps, has gained significant traction. DevOps emphasizes collaboration between development and operations teams, fostering an environment where they can share common goals, processes, and tools [4], [9], [16], [17], [18]. In the software industry, experts perceive DevOps as a cultural movement that facilitates effective communication, control, and shared responsibilities within the development environment [15], [19]. Various studies have emphasized that collaboration, automation, and service orientation are key aspects of DevOps [9], [20].

Dyck et al. [21] note that the introduction of DevOps has significantly contributed to enhancing the level of trust among practitioners, leading to transformative changes in the development environment of software organizations. Additionally, Smeds et al. [18] highlight that DevOps not only brings about a cultural shift but also improves the development process. The literature also discusses the limitations and significance of the DevOps paradigm [22], [23], [24]. According to Banica et al. [25], the main advantages of DevOps include. improved product quality, services, and continuous collaboration. Similarly, Gupta et al. [26] suggest that DevOps promotes trust-building among development and operations practitioners. They also explore and rank critical DevOps attributes that are essential for evaluating an organization's readiness to adopt DevOps. Furthermore, Gill et al. [27] state that DevOps helps bridge the communication and coordination gap between development and operations teams. Wiedemann et al. [28] argue that DevOps provides a roadmap for project management teams to enhance performance, comprehensibility, integration, and relationships among teams. However, successful adoption of DevOps practices requires strong collaboration, training, skills, and effective automation. Organizations that embrace DevOps also face critical challenges [27], including process and procedure-related issues, cultural conflicts, and problems with operational models.

Existing literature presents evidence-based research on exploring guidelines for achieving DevOps sustainability in software organizations. However, to date, no research has been conducted to analyze sustainable DevOps guidelines using the fuzzy-AHP approach. Through detailed empirical investigations and analysis, this study aims to assist teams in understanding and developing methodologies for the sustainable implementation of DevOps in the software development industry.

III. RESEARCH DESIGN

The research design comprises three distinct steps: systematic literature review (SLR), questionnaire survey study, and fuzzy AHP. The initial phase involved conducting an SLR to identify the guidelines for sustainable DevOps. Subsequently, a questionnaire survey was administered to gather input from industry practitioners regarding the identified guidelines. In the third stage, fuzzy AHP was utilized to rank the guidelines based on their significance for sustainable

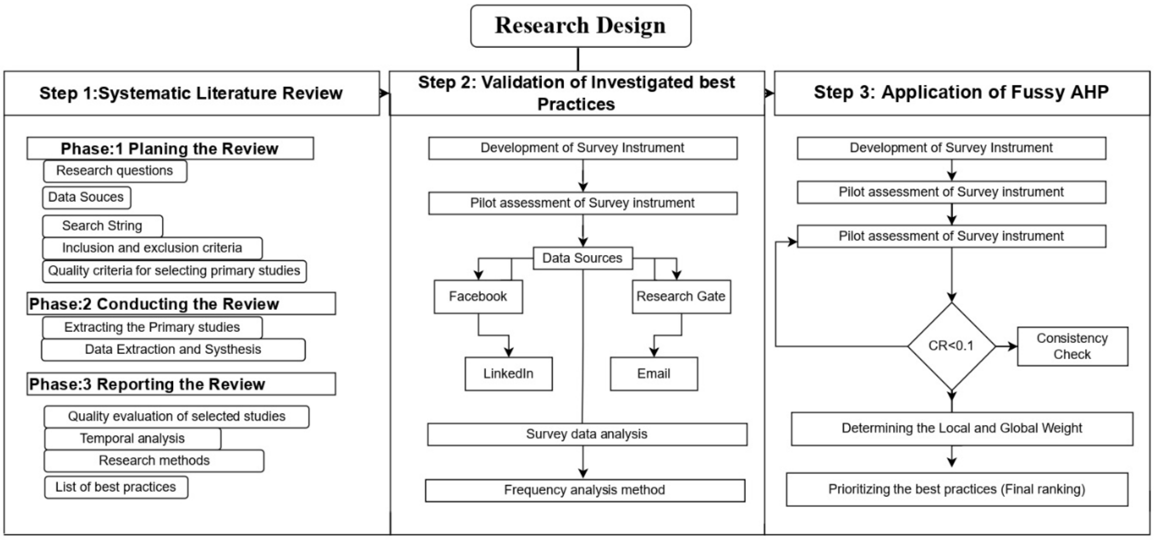

FIGURE 1. Study research design.

DevOps. For a visual representation and detailed depiction of the research design, please refer to Fig. 1.

A. SYSTEMATIC LITERATURE REVIEW (SLR)

The SLR (Systematic Literature Review) approach, as mentioned, is a recognized and rigorous method for collecting and evaluating relevant literature related to specific research questions. It follows a structured and procedural approach to ensure valid and comprehensive results. The procedures outlined by Kitchenham and Charters [29] are commonly followed in conducting an SLR. The SLR process typically consists of three main phases: planning the review, conducting the review, and reporting the review. These phases are further detailed in Fig. 1 and will be described in the subsequent sections.

1) PLANNING THE REVIEW

When it comes to planning the protocols for collecting and analysing data in a research study, it is essential to ensure a systematic and rigorous approach. Based on your statement, it seems that you have adopted review protocols to extract and analyse literature to answer your proposed research question. Review protocols are commonly used in literature reviews and systematic reviews to ensure a structured and comprehensive analysis of existing studies. While I don't have specific information about the protocols you adopted, I can provide you with a general overview of the steps typically involved in developing review protocols for literature analysis:

a: SEARCH SOURCES DATA COLLECTION SOURCE

To collect relevant literature that aligns with the research objectives, the selection of appropriate data sources plays a crucial role. To ensure comprehensive coverage, the recommendations of Chen et al. [30] and Zhang et al. [31] were taken into consideration. Eight digital databases were utilized

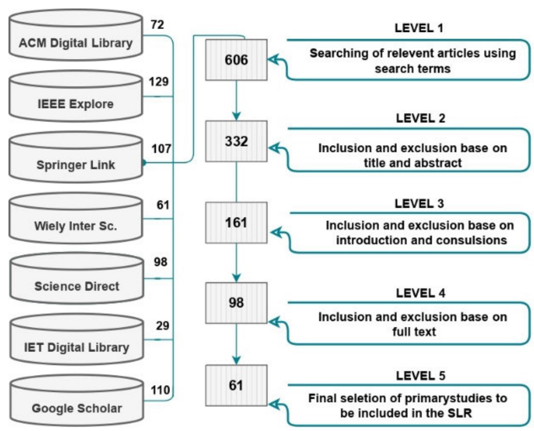

FIGURE 2. Data selection process from digital repositories.

to explore the relevant literature. The selected libraries and the corresponding number of literatures obtained after executing the search string are presented in Fig. 2. These databases were chosen to gather a wide range of scholarly articles and research papers related to the topic of interest.

b: SEARCH STRING

Developing an effective search string is crucial for collecting literature relevant to the study objective. In order to create the search string, key terms and their alternatives were gathered from existing studies [1], [25], [27], [32] following the guidelines provided by [31] and [33]. The search string was formulated using the OR and AND operators to ensure comprehensive results. The complete search string is as follows:

(Key term 1 OR Alternative term 1 OR Alternative term 2 OR ...) AND (Key term 2 OR Alternative term 1 OR Alternative term 2 OR ...) AND ...

By combining the key terms and their alternatives with the appropriate operators, the search string allows for a broad and targeted search across the selected databases.

(“guidelines” OR “practices” OR “motivators” OR “activities” OR “Concerns” OR “techniques” OR “tools” OR “methods” OR “process” OR “evaluation”) AND (“DevOps” OR “Development and Operation” OR “Continues development and operation”.

c: INITIAL INCLUSION CRITERIA

To determine the inclusion of literature obtained during the literature extraction process, specific protocols were established based on relevant studies conducted by Inayat et al. [34] and Niazi et al. [35]. The following protocols were used for inclusion:

1. The article should be submitted to a reputable journal, conference, or book chapter for publication, ensuring the credibility and quality of the source.
2. The essay should specifically discuss the obstacles that hinder the implementation of DevOps, aligning with the focus of the research.
3. The findings presented in the study should be based on empirical data sets, providing a robust and evidence-based perspective.
4. The report should clearly state the importance of adopting DevOps, elucidating its significance and benefits in the context of software development.
5. The selected literature must be written in English to ensure accessibility and comprehension for the intended audience.

By adhering to these inclusion protocols, we aimed to select high-quality, relevant literature that contributes to addressing the research questions and provides valuable insights into DevOps implementation.

d: INITIAL EXCLUSION CRITERIA

To ensure a focused and relevant selection of literature, we implemented refined protocols that involved excluding certain studies obtained from databases at the initial stage. These exclusion criteria were established based on previous research conducted by Inayat et al. [34], Niazi et al [35], and Akbar et al. [36]. The following criteria were used for exclusion:

1. Only the most comprehensive study from a similar research endeavour was considered, avoiding duplication.
2. The article had to provide specific details on DevOps implementation, ensuring relevance to the research's goal.
3. Studies that were unrelated to the research's objective were excluded.
4. Only full or regular papers were included, excluding abstracts or partial content.
5. Studies identified during the literature review phase were not considered for further analysis.

TABLE 1. QA criteria.

SR #	Criteria
QA1	Does the used research method in the selected literature aligned with RQs?
QA2	Does the collected reported the DevOps guidelines?
QA3	Does study elaborate the details of DevOps adoption?
QA4	Are the reported guidelines related to DevOps project management?
QA5	Are the study findings justifying the research questions?

By applying these exclusion criteria, we aimed to refine the literature selection process and ensure that the included studies were highly relevant and aligned with the research's objectives.

e: STUDY QUALITY ASSESSMENT (QA)

The purpose of the QA was to determine the adequacy of the chosen study for the study objective. The QA is carried out in accordance with Kitchemhm and Charctros's guidelines [36]. The five-questions QA method were developed and evaluated using the Likert scale, if the study fully answers the criteria, then the assigned score is 1, for partial=0.5 and 0-score if the study does not give any information about the developed criteria. Several previous studies [34], [35], [37] have used similar criteria. Appendix-A contains the outcomes of the QA.

2) CONDUCTING THE REVIEW

a: FINAL STUDY SELECTION

In the initial search conducted on the selected database, a total of 860 studies were retrieved based on the search string. To refine the collected literature and select relevant studies for data extraction, the tollgate approach developed by Afzal et al. [38] was employed. This approach consists of five phases, each carefully executed to ensure the selection of appropriate studies.

As depicted in Fig. 2, a total of 61 studies were ultimately selected for the data extraction process. These selected studies were assessed based on their relevance and significance in addressing the research questions of the survey. The studies that received excellent reviews were labelled as ‘SP’ to indicate their inclusion in the paper. The comprehensive list of the selected studies, along with their corresponding QA scores, can be found in Appendix-A.

2. Final selected studies.

b: DATA EXTRACTION AND SYNTHESIS

A thorough review of 61 studies (as shown in Fig. 2) was conducted to extract relevant data that aligned with the research goal. The data extraction process involved continuous participation from author no. 1 and 2, with validation of the extracted data by the third and fourth authors. The selected studies provided various information such as claims, primary themes, concepts, practices, and actions, which were synthesized into concise statements resulting in the final set of 48 DevOps implementation recommendations.

To address any potential bias in the study outcomes, an ''inter-rater reliability test'' was performed to assess the agreement among the mapping team [37]. Three external specialists were invited to participate in the mapping process, where they randomly selected 12 research items and conducted their own data extraction. The non-parametric ''Kendall's coefficient of concordance (W)'' was calculated based on the results obtained by the study authors and the external experts [38]. A W value of 1 indicates perfect agreement, while a W value of 0 indicates complete disagreement. The obtained result of W=0.84 and p=0.003 indicates significant agreement between the study authors and external experts, indicating consistent findings in the study.

Overall, these measures were taken to minimize bias and enhance the reliability of the study's findings, ensuring a robust and consistent analysis of the selected literature. The used code is given in this link: *https://tinyurl.com/y5fct4ql.*

3) REPORTING THE REVIEW

a: QUALITY OF SELECTED STUDIES

The quality assessment (QA) of the selected studies was conducted to evaluate how effectively the literature addressed the research questions of the study. Based on the cumulative results of the QA, it was observed that more than 70% of the studies achieved a score of 70% or higher. This indicates that the majority of the selected studies demonstrated a good level of quality and relevance in relation to the research questions of the study. To establish a cutoff point for study inclusion, a threshold of 50 percent was chosen in this study. This means that studies scoring below 50 percent in the QA were not included in the final selection. By applying this cutoff point, the study ensured that only studies meeting a certain level of quality and relevance were included in the analysis. For detailed information on the QA results, please refer to Appendix-A, which provides a comprehensive overview of the individual scores and assessments for each selected study.

b: LIST OF BEST PRACTICES

During the data extraction process, relevant concepts, themes, and ideas were identified and extracted from the selected literature. Through careful analysis and paraphrasing, a comprehensive list of 48 guidelines was developed. These guidelines represent key factors and recommendations for the successful implementation of sustainable DevOps practices in software development organizations. Each guideline captures an important aspect or consideration that can contribute to the overall effectiveness and efficiency of DevOps adoption. These guidelines serve as a valuable resource for organizations seeking to improve their DevOps implementation and ensure long-term sustainability in their software development processes.

B. EMPIRICAL STUDY

To collect the perceptions of industry experts, a questionnaire survey approach was employed. The following steps were undertaken in this process and the used stages are discoursed in the sub-sequent sections:

1) QUESTIONNAIRE DEVELOPMENT (DEVELOPMENT OF SURVEY INSTRUMENT)

To verify the findings of the Systematic Literature Review (SLR), an online survey questionnaire was created using the Google Forms platform (docs.google.com/forms). The questionnaire was designed to gather feedback and opinions from survey participants regarding the identified DevOps guidelines.

The questionnaire survey was divided into three sections.

The first section focused on collecting bibliographic information from the survey participants, including their background, experience, and affiliation. This information would help analyse and understand the characteristics of the participants in relation to the survey results.

The second section of the questionnaire gathered organizational information from the participants. This section aimed to capture details about the size and type of organizations they belonged to, providing insights into the diversity of the respondents' organizational backgrounds.

The third section of the questionnaire consisted of closed-ended questions based on the SLR-identified list of DevOps guidelines. Participants were asked to rate each guideline on a five-point Likert scale, ranging from ''Strongly agree'' to ''Strongly disagree.'' The inclusion of a neutral option in the Likert scale allowed participants to provide unbiased feedback without being forced to lean towards agreement or disagreement [39].

Lastly, the fourth section of the questionnaire was open-ended, allowing participants to add any additional guidelines that were not included in the closed-ended section. This provided an opportunity for participants to contribute their own insights and perspectives, adding value to the survey findings. The participants' feedback was collected through the Google Forms platform, and the Likert-scale responses provided quantitative data that could be analysed for further insights. The inclusion of both closed-ended and open-ended questions in the questionnaire aimed to gather comprehensive and meaningful feedback from the survey participants.

2) PILOT TESTING

To ensure the understandability and effectiveness of the questionnaire, a pilot assessment was conducted prior to the actual data collection process [40], [41], [42], [43]. The purpose of this pilot assessment was to gather feedback from experts and make necessary improvements to the questionnaire. For the pilot assessment, the developed questionnaire was shared with three experts. One expert was from the academic field, specifically from Chongqing University in China, while the other two experts were from industry practices, representing "Virtual force" in Pakistan and "QSoft" in Vietnam. These experts were chosen based on their expertise and experience in the field of DevOps. Upon reviewing the questionnaire, the experts provided valuable feedback and recommendations for improvement. They suggested changes to the layout of the questionnaire and provided insights on collecting bibliographic data from survey respondents. In response to their recommendations, the questionnaire was updated accordingly, incorporating the suggested changes and improvements. One notable recommendation from the experts was to arrange the questions in a table format, which was implemented in the revised version of the questionnaire. This formatting change aimed to enhance the clarity and organization of the questionnaire, making it easier for survey respondents to understand and respond to the questions. the sample of the revised questionnaire used for the data collection process can be found in Appendix B, providing an overview of the questionnaire structure and the types of questions included.

3) DATA SOURCES

To ensure the collection of accurate and reliable data, careful consideration was given to the selection of data sources and the target population for this survey study. The primary objective was to gather expert opinions on the challenging factors related to DevOps, which were identified through a systematic literature review (SLR).To target the appropriate population, various data sources were utilized, including professional email addresses, ResearchGate, and LinkedIn. These sources were chosen to reach out to professionals and experts in the field of DevOps. The snowballing technique, as suggested in previous studies [40], [41], [42], [43], was employed to distribute the survey questionnaire among the intended geographically dispersed group. This technique involves asking participants to recommend and forward the survey to others who may meet the criteria.

The data collection process took place from December 2020 to May 2021. During this period, a total of 102 responses were received. However, upon manual verification, it was found that nine of the responses were incomplete. After consulting with the study team, the decision was made to exclude these incomplete responses from the data analysis process. As a result, the final dataset consisted of 93 complete responses, which were utilized for the subsequent data analysis procedures. The bibliographic information pertaining to the survey participants is presented in section IV-B, providing additional details about their backgrounds, experiences, and affiliations. This information further contributes to the understanding and context of the data collected for the study.

4) SURVEY DATA ANALYSIS

The frequency data analysis approach was employed to analyse the collected responses in order to effectively compare the opinions of the respondents across different variables and within the group of variables. This approach is widely

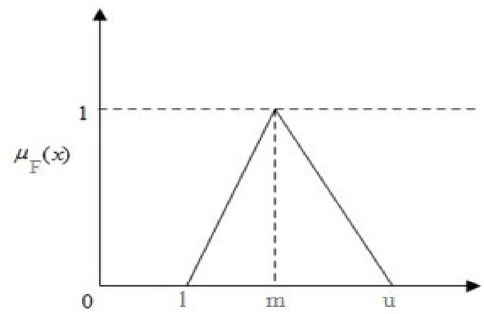

FIGURE 3. Triangular fuzzy number.

regarded as an effective method for examining the distribution and patterns of responses. The adoption of the frequency data analysis approach in this study is consistent with similar studies conducted in the past. Studies conducted by researchers [44], [45], [46] have also utilized this approach to analyse and interpret the collected data. By employing the frequency data analysis approach, the researchers can gain valuable insights into the distribution of responses, identify common trends or patterns, and draw meaningful conclusions from the data. This approach provides a systematic and quantitative means of examining the relationships and variations within the collected data, enhancing the overall rigor and reliability of the analysis.

Phase *3: Fuzzy Set Theory and AHP*

5) FUZZY SET THEORY

The Fuzzy set theory, originally proposed by Zadeh, is an extension of classical set theory aimed at addressing the vagueness and uncertainties present in real-world practices, particularly in multi criteria decision-making problems. In Fuzzy set theory, the fundamental concept is to represent and model vague or imprecise data. This is achieved through the use of membership functions, which map objects to values between 0 and 1, indicating the degree of membership of an object in a fuzzy set [47].

A key element in Fuzzy set theory is the triangular fuzzy number (TFN), which is denoted as (vl, vm, vu), as illustrated in Fig. 4. The membership function μF(x) of the TFN F represents the degree of membership of an element x in the fuzzy set F.

By utilizing the principles and definitions of Fuzzy set theory, decision-makers can effectively handle and analyse uncertain or vague data, allowing for a more comprehensive representation of real-world problems and facilitating the application of multicriteria decision-making techniques. Where vl, vm and vu denotes the crisp lowest, highest priority, and highest possible values. The "algebraic operational laws using two TFNs, namely (V1, V2) are given in Table 2

$$\mu_F(x) = \left\{ \begin{array}{c} \dfrac{t - v^l}{v^m - v^l}, \ v^l \leq t \leq v^m \\ \dfrac{v^u - t}{v^u - v^m}, \ v^m \leq t \leq v^u \\ 0, \quad Otherwise \end{array} \right\}. \tag{1}$$

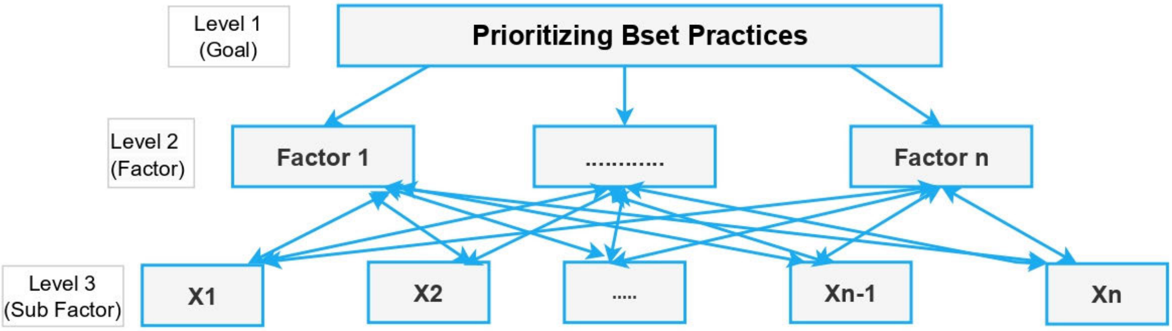

FIGURE 4. FAHP decision hierarchy.

TABLE 2. Triangular fuzzy numbers.

Operation Law	Expression
Addition ($V_1 \oplus V_2$)	$(v^l_1, v^m_1, v^u_1) \oplus (v^l_2, v^m_2, v^u_2) = (v^l_1 + v^l_2,\ v^m_1 + v^m_2,\ v^u_1 + v^u_2)$
Subtraction ($V_1 \oplus V_2$)	$(v^l_1, v^m_1, v^u_1) \oplus (v^l_2, v^m_2, v^u_2) = (v^l_1 - v^l_2,\ v^m_1 - v^m_2,\ v^u_1 - v^u_2)$
Multiplication ($V_1 \oplus V_2$)	$(v^l_1, v^m_1, v^u_1) \oplus (v^l_2, v^m_2, v^u_2) = (v^l_1 * v^l_2,\ v^m_1 * v^m_2,\ v^u_1 * v^u_2)$
Division ($V_1 \oplus V_2$)	$(v^l_1, v^m_1, v^u_1) \oplus (v^l_2, v^m_2, v^u_2) = (v^l_1 / v^l_2,\ v^m_1 / v^m_2,\ v^u_1 / v^u_2)$
Inverse ($V_1 \oplus V_2$)	$(v^l_1, v^m_1, v^u_1)^{-1} = (1/v^l_1,\ 1/v^m_1,\ 1/v^u_1)$
For any real number k (kV_1)	$k\,(v^l_1, v^m_1, v^u_1) = k\,v^l_1, k\,v^m_1, k\,v^u_1$

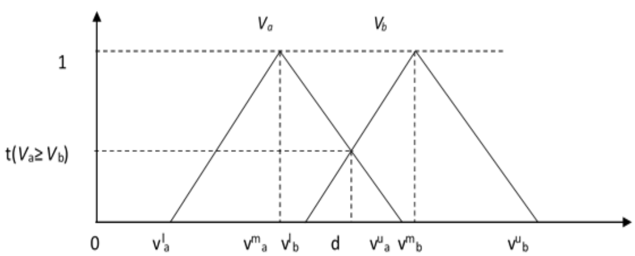

FIGURE 5. Triangular Fuzzy number.

6) FUZZY ANALYTICAL HIERARCHY PROCESS (FAHP)

The FAHP (Fuzzy Analytic Hierarchy Process) is a highly effective and powerful approach used to address multicriteria decision-making problems. One of the key benefits of FAHP is its ability to handle multiple criteria in a relatively straightforward manner. It provides a systematic framework for decision-making that is easier to understand and implement.

The primary steps involved in the FAHP approach are as follows:

Step1: "Develop a hierarchy structure of the decision-making problem" (as given Fig. 5)

Step2: "Use pairwise comparison and calculate the weights."

Step3: "Apply the consistency check.

Step4: "Determine the priority order of each guideline.

Conventional AHP (Analytic Hierarchy Process) has several advantages [48], [49], [50], but it also has some limitations. These limitations include being based on a "Crisp environment," having an unbalanced judgmental scale, and the absence of uncertainty, which can make the selection of judgments subjective. To overcome these limitations and achieve more effective and accurate results, the FAHP (Fuzzy Analytic Hierarchy Process) was developed [51]. The FAHP is designed to handle uncertainties and imprecise judgments by incorporating linguistic variables. The FAHP approach has been applied in various contexts [51], [52], [53], [54]. In our study, we utilized the FAHP methodology proposed by Chang [55], which is known for providing more appropriate and consistent In the prioritization problem, let X = {v1, v2, ..., vn} represent the elements of the main categories as an object set, and U = {t1, t2, ..., tn} represent the values of a particular category as a goal set. Following the approach suggested by Chang [55], each object is measured, and extent-analysis for the objective (gi) is performed. The following Equations (2) and (3) are used to generate (m) extent analysis values for each object:

$$V^1_{gi}, V^2_{gi}, \ldots, V^m_{gi}, \tag{2}$$

$$i = 1, 2, \ldots, n \tag{3}$$

where, $F^j_{gi,}$ (j = 1, 2, ..., m) are fuzzy triangular numbers (TFNs). The Chang's extent analysis [55] is performed in the following steps:

Step **1:** The element of fuzzy synthetic extent (S_i) for the i^{th} object using Eq. (4):

$$S_i = \sum_{j=1}^{m} V^j_{gi} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} V^j_{gi}\right]^{-1} \tag{4}$$

To achieve the expression $\sum_{j=1}^{m} V^j_{gi}$, execute the fuzzy addition operation of m extent analysis using Eq. (5):

$$\sum_{j=1}^{m} V^j_{gi} = (\sum_{j=1}^{m} v^l_{gi}, \sum_{j=1}^{m} v^m_{gi}, \sum_{j=1}^{m} v^u_{gi}) \tag{5}$$

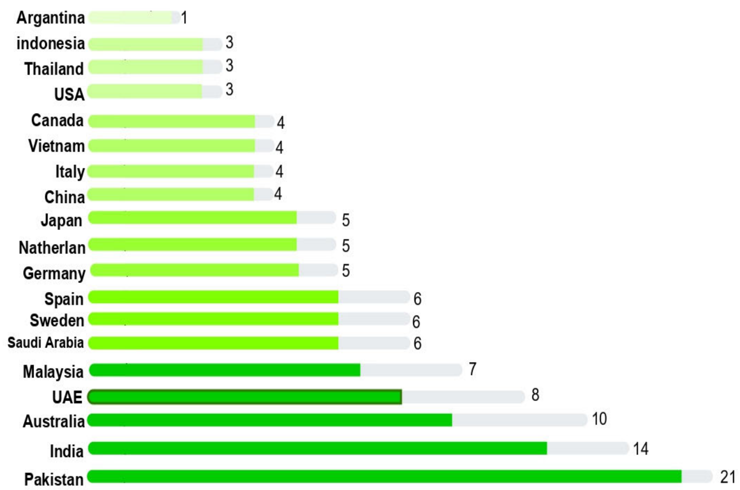

FIGURE 6. Respondent's affiliation countries.

and to make the expression $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} V_{gi}^{j}\right]^{-1}$, the fuzzy addition operation is performed on $V_{gi}^{j}(j = 1, 2, \ldots..m)$ value, as follow using Eq. (6): Figure. 6 indicates the highest intersection point in D, $\mu_{V\mathrm{a}}$, and μ_{Vb} (Fig. 6). The values of $T_1(V_\mathrm{a} \geq V_\mathrm{b})$ and $T_2(V_\mathrm{a} \geq V_\mathrm{b})$ are compulsory for calculating the value of P_1 and P_2.

$$\sum_{i=1}^{n}\sum_{j=1}^{m} V_{gi}^{j} = (\sum_{i=1}^{n} v_i^l, \sum_{i=1}^{n} v_i^m, \sum_{i=1}^{n} v_i^u) \tag{6}$$

To end, the inverse of each vector is determined using Eq. (7):

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} V_{gi}^{j}\right]^{-1} = (\frac{1}{\sum_{i=1}^{n} v_i^u}, \frac{1}{\sum_{i=1}^{n} v_i^m}, \frac{1}{\sum_{i=1}^{n} v_i^l}) \tag{7}$$

Step **2:** As $\mathrm{F_a}$ and $\mathrm{F_b}$ are two fuzzy triangular numbers, then these fuzzy numbers need to be compared that is knows as Degree of possibility i.e. $V_\mathrm{a} = (\mathrm{v_{a,}^l v_{a,}^m v_a^u}) \geq \mathrm{V_b} = (\mathrm{v_{b,}^l v_{b,}^m v_b^u})$ and is compared as follows using Eq. (8) and Eq. (9).

$$V(V_\mathrm{a} \geq V_\mathrm{b}) = sup[min(\mu_{\mathrm{va}}(x), (\mu_{\mathrm{vb}}(x))] \tag{8}$$

$$V\ (V_a \geq V_b) = hgt(V_a \cap V_b) = \mu_{v_a}(d) = \begin{Bmatrix} 1 & if\ v_b^m \geq v_a^m \\ \dfrac{v_b^l - v_a^u}{(v_b^m - v_a^u) + (v_b^m - v_b^l)} & Otherwise \\ 0 & v_a^l \leq v_b^u \end{Bmatrix} \tag{9}$$

Step 3: To calculate the probability that a convex fuzzy number is greater than k convex fuzzy numbers Vi (i = 1, 2, …, k), we can use Equation (10) and Equation (11) as follows:

$$T(V \geq V_1, V_2, V_3 \ldots . V_k) = \min T(V \geq V_i) \tag{10}$$

Assuming that,

$$d'(V_i) = \min T(V_i \geq V_k) \tag{11}$$

for k = 1, 2…, n; $k \neq i$.

With the help of Eq. 12, calculate the weight vector.

$$W' = (d'(V_1),\ d'(V_2),\ d'(V_3), \ldots ..d'(V_n)) \tag{12}$$

where, V_i $(i = 1, 2 \ldots, n)$ are n distinct elements.

Step 4: "The normalized weight vectors are determined by applying Equation 13, which results in a non-fuzzy number (also known as defuzzification). This non-fuzzy number represents the priority weight for the criteria.:"

$$W = (d(V_1),\ d(V_2),\ d(V_3), \ldots ..d(V_n)) \tag{13}$$

where W is a non-fuzzy number.

Step 5: Checking consistency ratio:

In fuzzy AHP, it is essential to ensure the consistency of pairwise matrices [56]. To achieve this, the consistency ratio of each pairwise comparison matrix needs to be evaluated [57], [58]. The graded mean integration technique is employed to defuzzify the matrix, converting a triangular fuzzy number P = (l, m, u) into a crisp number using the following approach:

$$P_{crisp} = \frac{(4m + l + u)}{6} \tag{14}$$

After defuzzifying each value in the matrix, the consistency ratio (CR) can be calculated and examined to determine if it is less than 0.10. This calculation involves two important parameters: the consistency index (CI) and the consistency ratio (CR), which are defined using Equations 14 and 15, respectively.

$$CI = \frac{I_{\max} - n}{n - 1} \tag{15}$$

$$CR = \frac{CI}{RI} \tag{16}$$

IV. RESULTS AND ANALYSIS

This section consists of the results of literature review study (section A) and empirical investigations in Section B.

TABLE 3. RI against each matrix size.

"Size of the matrix"	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
"Random consistency index" (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

A. RESULTS OF EMPIRICAL INVESTIGATIONS

In the process of identifying and categorizing the guidelines for sustainable DevOps implementation, a total of 48 guidelines were extracted from the literature. These guidelines align with the core principles of DevOps, which are culture, automation, measurement, and sharing (CAMS). The CAMS framework, originally introduced by Kim, emphasizes the importance of these pillars in achieving successful DevOps implementation.

Culture plays a vital role in DevOps adoption, as organizations need to prioritize providing high-quality service and develop a DevOps mindset. This involves continuous learning, experimentation, a product-oriented attitude, an engineering culture, and a focus on quality.

Automation is another crucial principle, where routine tasks are automated, allowing team members to focus on engineering tasks that add value to the software delivery process. Automation leads to predictable and standardized results, improving the efficiency and reliability of software delivery.

Measurement is essential for continuous improvement, as organizations need to track key parameters and provide feedback. Integrating measurement and monitoring into daily procedures allows for data-driven decision-making and facilitates feedback loops between development and operations teams.

Sharing is fundamental to DevOps, as it promotes collaboration and knowledge exchange between development and operations teams. Sharing lessons learned from failures and successes within an organization supports successful DevOps deployment.

To map the investigated guidelines to the CAMS principles, a coding scheme was used, and the mapping was performed by the research team, consisting of three authors of the study and two external experts from the industry. The mapping results, presented in Table 4, show how the guidelines align with the CAMS principles.

To ensure the reliability and consistency of the mapping process, an inter-rater reliability test was conducted between the research team and the external experts. Using the non-parametric Kendall's coefficient of concordance (W), the agreement between the researchers and the independent experts was measured. The results (W=0.89, p=0.005) indicate a high level of agreement, demonstrating that the mapping process was unbiased and consistent. Overall, the identified guidelines are categorized based on their alignment with the CAMS principles, and the mapping process has been validated for reliability and consistency through the inter-rater reliability test.

B. RESULTS OF EMPIRICAL INVESTIGATIONS

1) RESPONDENTS' BIBLIOGRAPHIC INFORMATION

The analysis of the bibliographic data of the survey participants plays a crucial role in assessing the authenticity and generalizability of the collected data. By examining the detailed information provided in Appendix-C, researchers can gain valuable insights into the participants' backgrounds, ensuring a comprehensive and representative sample.

The bibliographic data includes important aspects such as participant demographics, professional roles, years of experience, organization sizes, and country affiliations. This comprehensive information allows researchers to evaluate the diversity and relevance of the sample, ensuring a more accurate representation of the target population.

By analyzing the distribution of participants across different professional roles, researchers can assess the extent to which the sample represents the various stakeholders involved in sustainable DevOps implementation. Furthermore, the inclusion of participants with different levels of experience and organization sizes provides a broader perspective on the challenges and opportunities faced in the software industry.

The geographical distribution of participants from 20 different countries is particularly noteworthy, as it indicates a global perspective on the subject matter. This diversity enhances the generalizability of the study's findings, suggesting that the results can be applicable and relevant to software organizations worldwide.

Overall, the thorough analysis of the bibliographic data strengthens the authenticity and validity of the collected data, increasing confidence in the research findings. It demonstrates the efforts made to ensure a diverse and representative sample, contributing to the overall reliability and generalizability of the study.

2) RESPONDENT'S COUNTRY AFFILIATION

The geographical distribution of survey participants was analysed based on their country affiliations. The results, as shown in Fig. 7, indicate that the participants in the survey represent 20 different countries. It is observed that a significant portion of the respondents is from Asian countries. Additionally, the survey also attracted participants from various other regions around the globe.

The diverse representation of survey participants from different countries is a positive aspect of this study. It suggests that the findings and conclusions of this research can be applicable and relevant to the software industry in any country. The inclusion of participants from a wide range

TABLE 4. List of identified guidelines and their mapping in CAMS.

Categories	Sr#	Guidelines
Measurement	G1	Organizations start DevOps practices with small projects
	G2	Include modelling for legacy infrastructure and applications in your DevOps plans
	G3	Consider application architecture changes based on on-premises, cloud, and containers early on in the process
	G4	Avoid fragmented toolset adoption, which can add to your costs
	G5	Effective and comprehensive measurement and monitoring
	G6	Decide which processes and tests to automate first
	G7	Monitor the Application's Performance
	G8	Integrated Configuration Management
	G9	Emphasize Quality Assurance Early
	G10	Active Stakeholder Participation
	G11	Use tools to capture every request
Automation	G12	Decide which processes and tests to automate first
	G13	Continuous integration and testing
	G14	Implement tracking and version control tools
	G15	Have a centralized unit for DevOps
	G16	Reduce handoffs
	G17	Implement Automation in Dashboards
	G18	Use the right and advanced tools
	G19	Use tools to capture every request
	G20	Use tools to log metrics on both manual and automated processes
	G21	Provisioning and change management
	G22	Build Up the Rest of Your CI/CD Pipeline
	G23	Take a 'security first approach'
	G24	Use on-demand testing environments
	G25	Develop automated continues deployment environment
	G26	Standardize and automate complex DevOps environments with cloud sandboxes and other tools
Sharing	G27	Ensure continuous feedback between the teams to spot gaps, issues, and inefficiencies
	G28	Communications and collaboration planning
	G29	Continuous practice and planning to avoid resistance
	G30	Create real-time project visibility
	G31	Increase flow of communication by reducing batch size
	G32	Building trust and share values and goals for effective channel
	G33	Enterprises should standardized processes and establish common operational procedures
	G34	Create a clear plan that includes milestones, project owners, and well-defined deliverables
	G35	Teams need training on DevOps
	G36	Shared code of conduct, a formal roles assignment, and clear and simple processes may help in understanding responsibilities
Culture	G37	Exercise Patience
	G38	Educate executives at your company about the benefits of DevOps, in order to gain resource and budget support
	G39	Cohesive team work to fill gap during Isolation changes
	G40	Keep All Teams on the Same Page
	G41	Enterprises should focus on building a collaborative culture with shared goals
	G42	Consider DevOps to be a Cultural Change
	G43	Select DevOps "Champions"
	G44	Assess your organization's readiness to utilize a microservices architecture
	G45	Become a Psychologist
	G46	Commit daily, reduce branching
	G47	Understand and address your unique needs
	G48	Start toward Your Business Goals

of geographical locations enhances the generalizability and broader applicability of the study's results.

The perspectives and insights provided by professionals from different countries contribute to a more comprehensive understanding of the challenges and opportunities associated with sustainable DevOps implementation in the software industry. Therefore, the results of this study can be considered and utilized by software organizations worldwide to inform their practices and decision-making processes.

3) RESPONDENT'S ORGANIZATION SIZE

The organization size of the survey participants was analysed by examining their bibliographic data. Fig. 8 provides an overview of the distribution of participants across different organization sizes. The results indicate that 26 respondents (22%) belong to small organizations, 49 respondents (42%) belong to medium-sized organizations, and 41 respondents (35%) are from large-scale organizations.

These findings demonstrate that there is a significant representation of survey participants from each size category of organizations. This indicates that the results and findings of this study are relevant and applicable to organizations of varying sizes. The inclusion of participants from small, medium, and large organizations ensures that the insights and perspectives gathered through the survey reflect the diverse nature of the software industry.

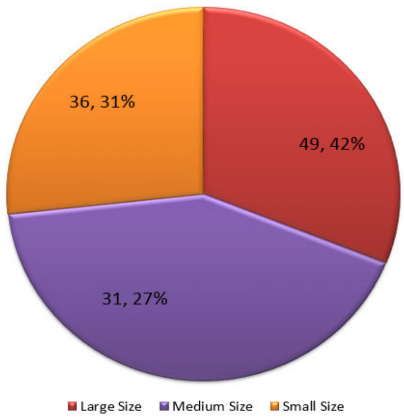

FIGURE 7. Respondents' organization size.

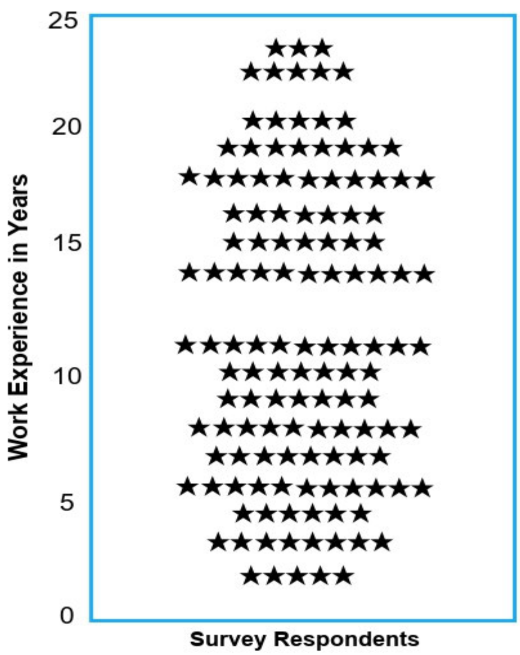

FIGURE 8. Experience of survey respondents.

The study's conclusions and recommendations can therefore be valuable and useful for organizations of any size, as the findings have been informed by a balanced representation of professionals from different organizational contexts.

4) RESPONDENTS WORKING EXPERIENCE

The experiences of the survey respondents were also examined by analysing their bibliographic data. Fig. 9 provides an overview of the years of experience reported by the participants, ranging from two to twenty years. The average and median experience levels were found to be 6 and 5.5 years, respectively. These statistics indicate that the survey participants represent a relatively young and diverse group of individuals.

The researcher notes that the sample of participants includes a good mix of individuals with varied levels of experience in software development operations. This diversity in experience levels is beneficial as it allows for a comprehensive understanding of the perspectives and insights of professionals at different stages of their careers. The inclusion of both experienced practitioners and those with fewer years of experience contributes to the richness and breadth of the survey data, enhancing the credibility and applicability of the study findings.

5) RESPONDENT'S DESIGNATIONS

According to Afzal et al. [38], the responses collected from participants may vary depending on their roles and designations. Niazi et al. [31] also emphasize that the opinions of participants can be more valuable if they have relevant experience and deal with the subject matter frequently. In the current study, the survey participants consisted mainly of project managers and software developers, as depicted in Fig. 10.

6) RESPONDENTS FEEDBACK

The purpose of the questionnaire survey was to gather expert opinions and perceptions regarding the selected guidelines and their associated principles. A total of 116 complete responses were collected and analysed for further examination. The responses from the participants were categorized as Positive (strongly agree, agree), Neutral (neither agree nor disagree), and Negative (disagree, strongly disagree) (Table 5).

The findings presented in Table 5 indicate that most of the survey participants agreed that the identified guidelines have a positive impact on the sustainable implementation of DevOps in software organizations. Notably, G41 (enterprises should focus on building a collaborative culture with shared goals) received the highest agreement rate of 91% among the survey participants, indicating its significance. Additionally, G9 (Emphasize Quality Assurance Early) and G40 (Keep All Teams on the Same Page) were identified as the second most important guidelines, both receiving an agreement rate of 88%.

Furthermore, the survey participants ranked C4 (Culture) as the most important category among the investigated guidelines, with a 93% agreement rate. C3 (Sharing) and C1 (Measurement) were recognized as the second and third most crucial principles, with agreement rates of 88% and 84% respectively, according to the survey participants.

Based on the survey results, it can be concluded that the participants generally agreed on the importance and relevance of the identified guidelines for achieving sustainable DevOps implementation in software organizations. These findings provide valuable insights into the prioritization of guidelines and the significance of different principles in the context of DevOps adoption.

C. APPLICATION OF FUZZY-AHP

The fuzzy-AHP method was employed to rank the identified guidelines based on their significance in ensuring the

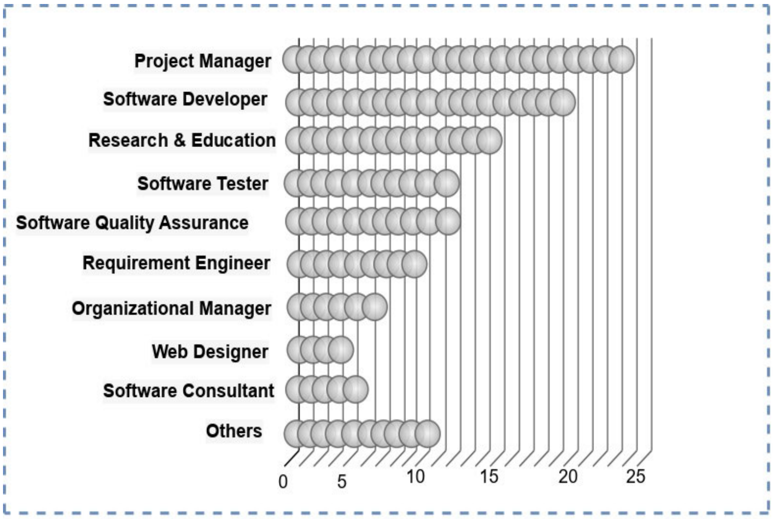

FIGURE 9. Designation of survey participants.

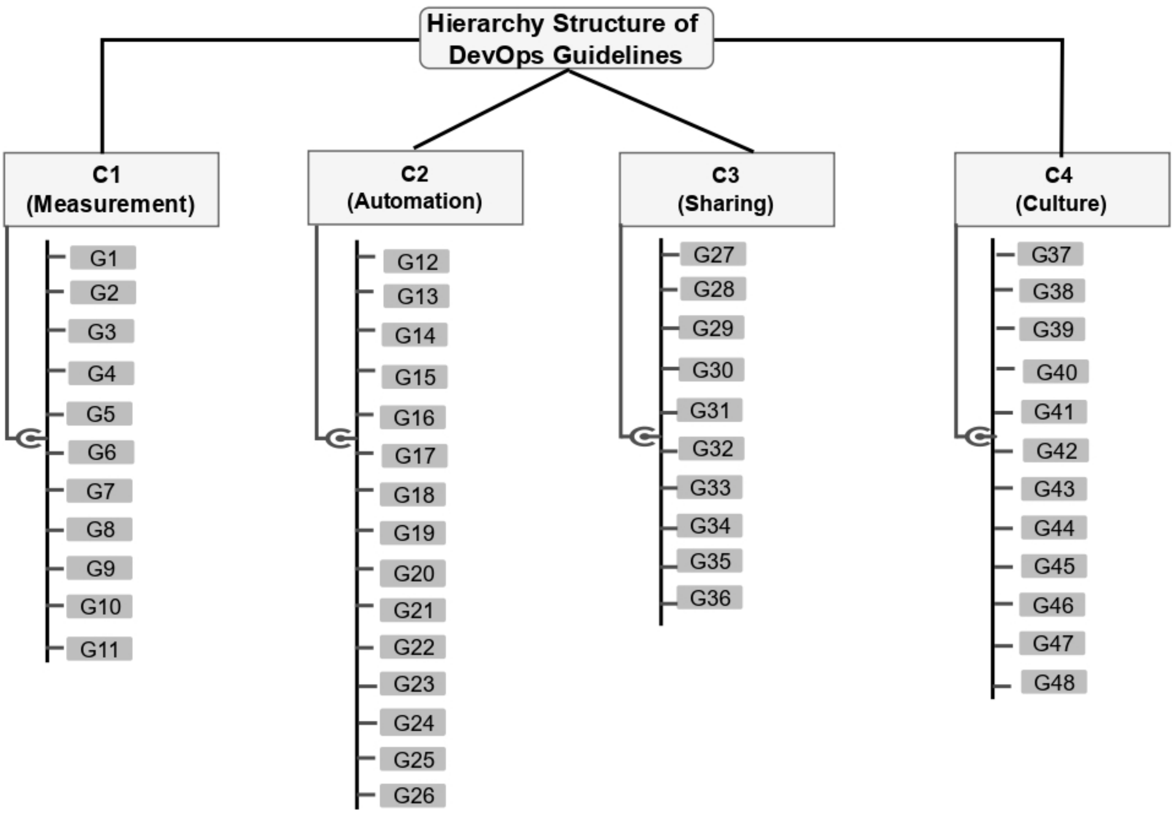

FIGURE 10. Proposed hierarchy structure.

sustainability of DevOps adoption in the software industry. The following sections outline the in the study below phases of the fuzzy-AHP technique that were utilized.

Step-1 (Develop a hierarchy structure of reported guidelines and their categories)

To facilitate the application of fuzzy-AHP, the decision-making problem was structured hierarchically, as illustrated in Fig. 5. The proposed hierarchy structure (Fig. 11) was designed based on the investigated guidelines and their core principles. At the topmost level, the main objective of the study, which is the prioritization of sustainable DevOps guidelines, is defined. The categories and their corresponding guidelines are then organized on levels 2 and 3, respectively. This hierarchical structure provides a systematic framework

TABLE 5. Results of a questionnaire survey study.

	Number of responses =116							
	Positive			Negative			Neutral	
S. No.	S. A	A	%	D	S. D	%	F	%
C1	40	57	84	2	6	7	11	9
G1	40	56	83	4	1	4	15	13
G2	51	42	80	5	5	9	13	11
G3	46	39	73	9	3	10	19	16
G4	40	57	84	2	6	7	11	9
G5	37	51	76	6	4	9	18	16
G6	49	34	72	7	6	11	20	17
G7	37	48	73	6	7	11	18	16
G8	31	61	79	3	6	8	15	13
G9	58	44	88	0	3	3	11	9
G10	41	47	76	7	6	11	15	13
G11	30	64	81	2	6	7	14	12
C2	41	54	82	3	6	8	12	10
G12	39	46	73	8	7	13	16	14
G13	39	48	75	6	8	12	15	13
G14	30	51	70	10	5	13	20	17
G15	39	44	72	14	7	18	12	10
G16	33	40	63	16	5	18	22	19
G17	42	53	82	6	2	7	13	11
G18	39	56	82	8	3	9	10	9
G19	51	47	84	2	3	4	13	11
G20	45	48	80	4	4	7	15	13
G21	33	56	77	8	4	10	15	13
G22	39	53	79	9	5	12	10	9
G23	41	55	83	7	6	11	7	6
G24	35	50	73	7	9	14	15	13
G25	43	44	75	9	4	11	16	14
G26	31	61	79	3	6	8	15	13
C3	58	44	88	0	3	3	11	9
G27	41	47	76	6	7	11	15	13
G28	30	64	81	2	6	7	14	12
G29	41	47	76	6	7	11	15	13
G30	39	46	73	8	7	13	16	14
G31	39	48	75	7	7	12	15	13
G32	37	55	79	7	4	9	13	11
G33	39	49	76	5	7	10	16	14
G34	40	47	75	6	4	9	19	16
G35	46	39	73	8	4	10	19	16
G36	40	57	84	2	6	7	11	9
C4	47	61	93	0	0	-	8	7
G37	49	34	72	7	6	11	20	17
G38	37	48	73	6	7	11	18	16
G39	31	61	79	3	6	8	15	13
G40	58	44	88	0	3	3	11	9
G41	47	59	91	0	4	3	6	5
G42	39	48	75	6	8	12	15	13
G43	39	44	72	6	14	17	13	11
G44	39	50	77	9	7	14	11	9
G45	36	52	76	6	4	9	18	16
G46	46	39	73	8	4	10	19	16
G47	40	57	84	2	6	7	11	9
G48	37	51	76	6	4	9	18	16

C1 =Measurement, C2= Automation, C3=Sharing, C4=Culture

for evaluating and ranking the guidelines based on their significance in achieving sustainable DevOps implementation. The proposed hierarchy structure, as depicted in Fig. 11, guides the fuzzy-AHP analysis and supports the decision-making process in this study.

Step-2 (Conducting the pairwise comparison)

The objective of this study is to rank the identified guidelines based on their importance for long-term DevOps implementation in software development organizations. To achieve this, a questionnaire was created and respondents from the initial survey were contacted to participate in pairwise comparison for fuzzy-AHP analysis. A total of 29 replies were received, and each response was manually examined to ensure no missing data. All 29 replies were deemed complete, as stated in Appendix-C, which includes the instrument used for the pairwise comparison in the second survey.

While a small sample size can be a concern in fuzzy-AHP analysis, previous studies [40], [41], [42], [43] have also

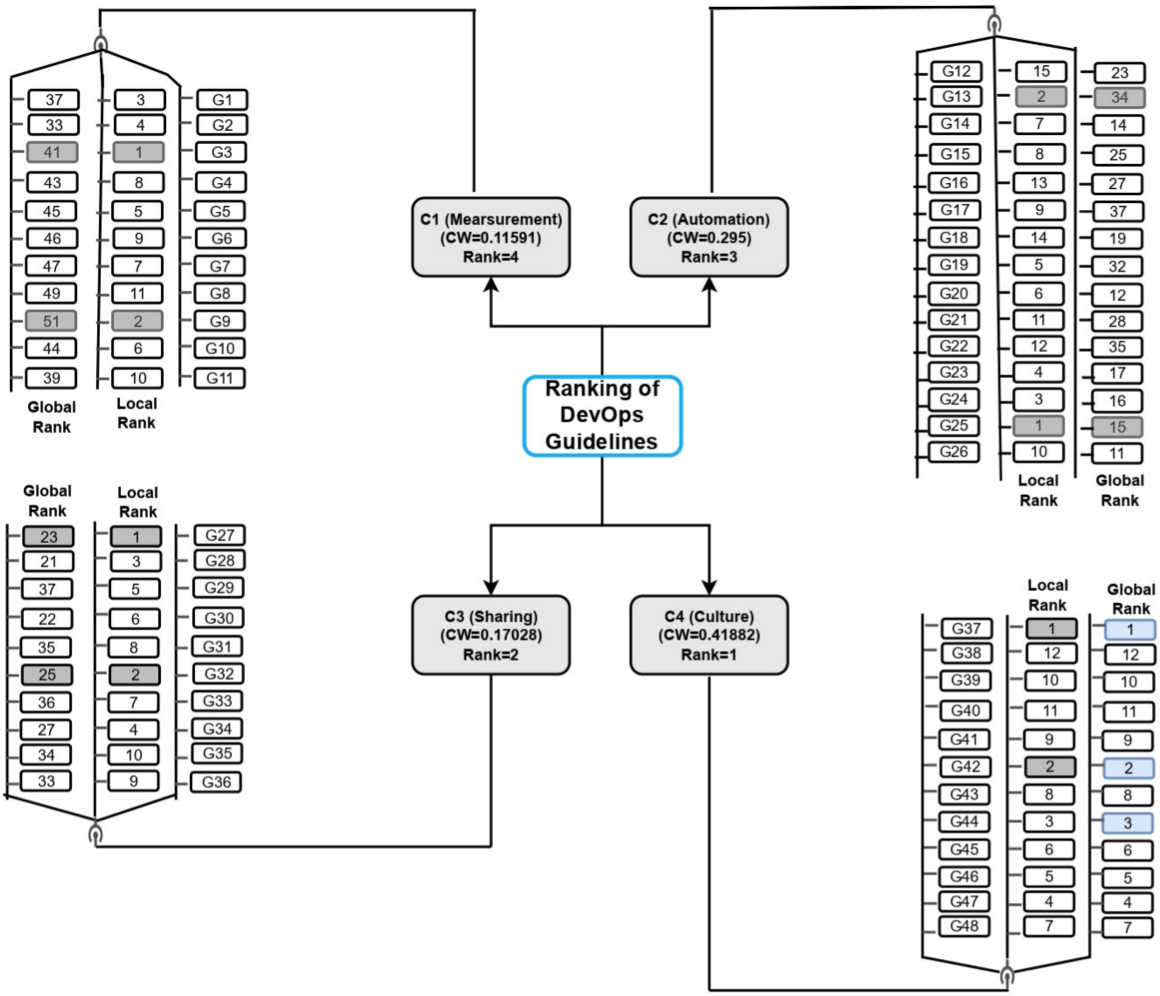

FIGURE 11. **Prioritization based framework of the investigated guidelines.**

used datasets of similar sizes for AHP analysis. For instance, Shameem et al. [56] prioritized agile software development influencing factors based on the opinions of five experts. Cheng and Li [43] prioritized construction collaboration success criteria using data from nine experts. Wong and Li [59] collected feedback from eight experts to prioritize teaching quality factors. Wong and Li [59] conducted an AHP analysis with the responses of nine experts to select an intelligent buildings system. Thus, with 29 experts participating in our fuzzy AHP analysis, we have a sufficient sample size for generalizing the findings of this study. to analyse the pairwise comparison of the DevOps standards and their respective categories, the data obtained from the fuzzy AHP survey was transformed into the geometric mean. The geometric mean is an effective method for converting expert opinions into Triangular Fuzzy Number (TFN) values. The formula for calculating the geometric mean is as follows:

$$GM = n\sqrt{m1xm2 \times m3 \ldots\ldots\ldots.mn} \qquad (17)$$

where, m= response, n= responses

Table 6 presents the linguistic variables along with their corresponding triangular fuzzy Likert scales. These scales, based on the triangular fuzzy conversion scale proposed by Bozbura et al. [61], were utilized to construct the pairwise comparison matrices for the identified guidelines and their respective concepts. The fuzzy Likert scales allow for capturing the subjective opinions of the experts and facilitate the calculation of priority weights for the guidelines in the fuzzy AHP analysis.

Step-3 "(Calculating the local priority weight of each guideline and their respective principle: A numerical example)"

To calculate the priority vector, the pairwise comparison matrix is used. The pairwise comparisons of the principles of the guidelines are presented in Table 6, and the priority vector of the principles of the guidelines is presented in Table 9.

The Local Priority Weight (LPW) of all the principles of the guidelines is calculated using Equation 3. First, the synthetic extent values of the four principles (measurement, automation, sharing, and culture) are calculated. Then, using

TABLE 6. Pairwise comparing between the principles.

	Measurement	Automation	Sharing	Culture
Measurement	(1,1,1)	(0.3, 0.4, 0.5)	(1, 1.5, 2)	(0.5, 0.6, 0.1)
Automation	(2, 2.5, 3)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.1)
Sharing	(0.5, 0.6, 0.1)	(1.5, 2, 2.5)	(1,1,1)	(0.5, 0.6, 0.1)
Culture	(1, 1.5, 2)	(1, 1.5, 2)	(1, 1.5, 2)	(1,1,1)

Equation 4, the priority is determined. The steps used in this process are as follows:

1. Calculate the synthetic extent values for each principle based on the pairwise comparison matrix.
2. Normalize the synthetic extent values.
3. Calculate the priority vector using Equation 4.

For the TFN conversion scale, the guidelines of Bozbura [61] were used. Please note that the specific calculations and steps for determining the priority vector are not provided in the given information.

$$S = (4, 5.1, 6.5) \otimes (0.04386, 0.054945,\ 0.070922) = (0.175439, 0.280220, 0.460993)$$

$$M = (2.2, 2.5, 3.2) \otimes (0.04386, 0.054945,\ 0.070922) = (0.096491, 0.137363, 0.226950)$$

$$C = (2.9, 3.6, 4.6) \otimes (0.04386, 0.054945,\ 0.070922) = (0.127193, 0.197802, 0.326241)$$

$$\sum_{i}^{n}\sum_{j}^{m} F_{gi}^{j} = (1, 1, 1) + (1.5, 2, 2.5) + (1, 1.5, 2)\ldots + (0.5, 0.6, 1) + (1, 1, 1) = (14.1, 18.2, 22.8)$$

$$\left[\sum_{i}^{n}\sum_{j}^{m} F_{gi}^{j}\right]^{-1} = (\frac{1}{22.8}, \frac{1}{18.2}, \frac{1}{14.1}) = (0.04386, 0.054945, 0.070922)$$

$$\sum_{j=1}^{m} F_{g1}^{j} = (1, 1, 1) + (1.5, 2.5, 3) + (1, 1.5, 2) + (1.5, 2.0, 2.5) = (5, 7, 8.5)$$

$$\sum_{j=1}^{m} F_{g2}^{j} = (0.3, 0.4, 0.6) + (1, 1, 1) + (0.4, 0.5, 0.6) + (0.5, 0.6, 1) = (2.2, 2.5, 3.2)$$

$$\sum_{j=1}^{m} F_{g3}^{j} = (0.5, 0.6, 1) + (1.5, 2, 2.5) + (1, 1, 1) + (1, 1.5, 2) = (4, 5.1, 6.5)$$

$$\sum_{j=1}^{m} F_{g4}^{j} = (0.4, 0.5, 0.6) + (1, 1.5, 2) + (0.5, 0.6, 1) + (1, 1, 1) = (2.9, 3.6, 4.6)$$

The "Measurement" (M), "Automation" (A), "Sharing" (S) and "Culture" (C) represent the synthesis values of DevOps principles which were calculated using Equation 4 as follow:

$$A = \sum_{j}^{m} F_{g1}^{j} \otimes \left[\sum_{i}^{n}\sum_{j}^{m} F_{gi}^{j}\right]^{-1} = (5, 7, 8.5) \otimes\ (0.04386,\ 0.054945, 0.070922) = (0.219298,\ 0.384615, 0.602837)$$

The level of possibility for each pairwise comparison matrix was calculated using equation 6. Additionally, equations 7 and 8 were utilized to calculate the priority weights of the pairwise comparison matrices.

The weight vector W' is calculated as (1, 0.030019, 0.69836, 0.36405) according to Table 7. By normalizing the weight vector, the priority weights are determined as W = (0.4789, 0.01435, 0.3337). Based on these calculated weights, it can be concluded that the "culture" principle holds the highest priority among the selected DevOps project management guidelines.

Step-4 (Test the consistency of the pairwise matrix)

The consistency of all pairwise comparison matrices was evaluated, and a step-by-step calculation technique was used to determine their consistency. In this process, we referred to the Table of Principles (Table 8). Equation 14 was employed to defuzzify the triangular fuzzy numbers from the pairwise comparison matrix of the DevOps principles into crisp numbers, resulting in the Fuzzy Crisp Matrix (FCM). The FCM is presented in Table 8.

To calculate the value of λ max for the FCM matrix, we sum the values of each column in Table 8. Then, we divide each value in the column by its corresponding column sum. Finally, we calculate the average of these values to obtain the priority weights for each criterion, as shown in Table 9.

$$\lambda_{\max} = \Sigma([\Sigma\ Cj] \times \{W) \tag{18}$$

where, ΣCj= sum of the columns of Matrix [C] (Table 6),

W= weight-vector (Table 9), therefore

$\lambda_{\max}$ = 2.7*0.11591 + 7.0*0.29500 + 3.7*0.17028 + 5.2*0.41882 = 4.1067

Based on the calculations, the FCM (Fuzzy Comparison Matrix) maximum Eigenvalue (max) is determined to be 4.1067. Since the FCM has 4 elements, we have n = 4. According to Table 3, the Random Consistency Index (RI) for n = 4 is 0.9.To assess the consistency of the FCM, we calculate the Consistency Index (CI) and Consistency Ratio (CR)

TABLE 7. Results of V values for criteria.

	M	A	S	C	d (Priority Weight)
V (M≥….)	-	1	1	1	1
V (A≥….)	0.030018	-	0.26503	0.62273	0.030018
V (S≥….)	0.69837	1	-	1	0.69837
V (C ≥….)	0.36406	1	0.64662	-	0.36406

TABLE 8. FCM for DEVOPS principle.

	Measureme nt	Automatio n	Sharin g	Cultur e
Measureme nt	1.0	2.5	1.5	2.0
Automation	0.5	1.0	0.5	0.7
Sharing	0.7	2.0	1.0	1.5
Culture	0.5	1.5	0.7	1.0
Column Sum	2.7	7.0	3.7	5.2

using equations 15 and 16, respectively.

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{4.1067 - 4}{4-1} = 0.035553$$

$$CR = \frac{CI}{RI} = \frac{0.035553}{0.9} = 0.039503$$

The determined CR is 0.039513<0.10; therefore, the developed pairwise matrixes are constant. Using the same process, the consistency of other matrixes is determined and given at the end of Table 10, 11,12 and 13.

Step 5: Calculating the global weights.

The local weight (LW) of a guideline represents its impact on the overall study objective, which is the prioritization of sustainable DevOps implementation guidelines. On the other hand, the global weight (GW) of a guideline represents its impact on the overall study objective in comparison to all the 48 evaluated guidelines. The GW is calculated by multiplying a guideline's LW by the weight of its corresponding principle. For example, let's consider G1 (Organizations start DevOps practices with small projects) with an LW of 0.099531 and its corresponding principle C1 (Measurement) with a weight of 0.11591. The GW of G1 is calculated as follows: GW of G1 = LW of G1 × Weight of C1 = 0.099531 × 0.11591 = 0.011537 (Table 14). By comparing the local rank of G1 within its mapped principle, it is ranked as the second-highest priority guideline. This indicates that within the principle of measurement, G1 holds significant importance for sustainable DevOps implementation. Upon comparing the global weights (GW) of the guidelines with all the other 48 guidelines, G1 (Organizations start DevOps practices with small projects) stands out as the 39th most important guideline for sustainable DevOps implementation in software organizations. However, the highest priority guideline for sustainable DevOps implementation is G41 (Enterprises should focus on building a collaborative culture with shared goals) with a GW of 0.041591. Following that, G44 (Assess your organization's readiness to utilize a microservices architecture) with a GW of 0.039183 and G38 (Educate executives at your company about the benefits of DevOps, to gain resource and budget support) with a GW of 0.038798 are declared as the second and third most significant guidelines for the DevOps paradigm. The final ranking of all the other guidelines can be found in Table 14.

V. RESULT AND DISCUSSION

This study focuses on investigating the guidelines for sustainable DevOps implementation in software organizations and prioritizing them based on their significance. To achieve this objective, three research questions were formulated, and the key findings for each question are summarized below:

RQ1 *(What guidelines for sustainable DevOps implementation in software development organizations are reported in the literature and industry practices?)*

To gather relevant literature for the study, a comprehensive literature review was conducted. A total of 71 studies were identified through the systematic literature review (SLR) process. These studies were carefully examined, and 48 best practices that have the potential to influence the DevOps paradigm in the software industry were investigated.

To organize and classify these guidelines, they were mapped into the CAMS model, which stands for Culture, Automation, Measurement, and Sharing. This mapping helped establish a hierarchical structure for the investigated guidelines, which was subsequently used in the fuzzy-AHP analysis.

To further validate and scale the investigated guidelines and their categorization within the CAMS model, a questionnaire survey study was conducted with experts. The data gathering process resulted in 116 complete responses from the experts. The summary results of the survey indicated that all the researched guidelines from the literature review are relevant to industry practices. Additionally, the respondents agreed with the categorization of the guidelines into the CAMS model.

The combination of the literature review, mapping into the CAMS model, and the insights gathered from the questionnaire survey study contributes to a robust understanding of the guidelines for DevOps implementation in the software industry, aligning with real-world practices and expert opinions.

RQ2 *(How the explored guidelines were prioritized using fuzzy-AHP?)*

The prioritization of the investigated best practices for the DevOps paradigm was conducted using the fuzzy-AHP approach, following step-by-step protocols. Pairwise matrices were generated for each category of guidelines based on

TABLE 9. Normalized matrix of DEVOPS guidelines.

	Measurement	Automation	Sharing	Culture	Priority
Measurement	(1,1,1)	(0.3, 0.4, 0.5)	(1, 1.5, 2)	(0.5, 0.6, 0.1)	0.11591
Automation	(2, 2.5, 3)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.1)	0.29500
Sharing	(0.5, 0.6, 0.1)	(1.5, 2, 2.5)	(1,1,1)	(0.5, 0.6, 0.1)	0.17028
Culture	(1, 1.5, 2)	(1, 1.5, 2)	(1, 1.5, 2)	(1,1,1)	0.41882

TABLE 10. Pairwise comparison of guidelines of measurement principle.

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	Priority
G1	(1,1,1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.099531
G2	(0.5, 0.6, 1)	(1,1,1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	0.095757
G3	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.089031
G4	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1,1,1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(2, 2.5, 3)	(1, 1.5, 2)	0.094217
G5	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1,1,1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	0.106180
G6	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(1,1,1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.073984
G7	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	0.085232
G8	(1, 1.5, 2)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1,1,1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(1, 1.5, 2)	0.098665
G9	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	0.085852
G10	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.3, 0.4, 0.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1,1,1)	(1.5, 2, 2.5)	0.088277
G11	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1,1)	0.083275

λ= 12.249, CI = 0.12485, CR = 0.082685

expert opinions, and the fuzzy-AHP analysis was performed meticulously. The priority weights of each best practice were calculated, providing a global weight that indicates their significance. The results of the fuzzy-AHP analysis revealed the highest priority best practice for DevOps adoption and progression in software organizations to be G41, which emphasizes the importance of building a collaborative culture with shared goals (GW=0.041591). This finding aligns with the work of Leite et al. [6], who highlighted the necessity of cultural change in software development organizations to successfully implement DevOps and foster continuous collaboration between developers and operators. Gupta et al. [26] and Marijan et al. [62] also underscored the significance of a collaborative culture for the successful adoption of the DevOps paradigm. Additionally, G44 (Assess your organization's readiness to utilize a microservices architecture, GW=0.039183) and G38 (Educate executives at your company about the benefits of DevOps to gain resource and budget support, GW=0.038798) were ranked as the second and third most priority best practices, respectively, for the DevOps paradigm.

These findings highlight the crucial nature of building a collaborative culture, assessing organizational readiness for microservices architecture, and educating executives about the benefits of DevOps in software organizations' successful implementation of DevOps practices.

RQ3 *(What would be the prioritization-based framework of DevOps sustainable guidelines?)*

The taxonomy of the investigated guidelines was developed based on the CAMS model and the rankings obtained from fuzzy-AHP analysis. Both global and local ranks were considered, as shown in Table 14. The aim of creating this taxonomy was to demonstrate the influence of each guideline within its respective principle and on the overall DevOps paradigm. For instance, G1 (Organizations start DevOps practices with small projects) holds the second highest local rank in terms of importance for sustainable DevOps execution in the software industry. However, it is interesting to note that G1 is globally ranked as the 39th. Similarly, G2 (Include modelling for legacy infrastructure and applications in your DevOps plans) is ranked as the fourth most important guideline in the 'Management' category, but it holds the 42nd global rank.

Fig. 12 presents the local and global ranks of each guideline, providing insights into their impact within their respective principle and compared to all the identified 48 guidelines. Moreover, the analysis reveals that C1 (Measurement, CW=0.41882) is ranked as the most significant principle among the investigated guidelines. Furthermore, C2 (Automation, CW=0.295) and C3 (Sharing, CW=0.17028) hold the second and third highest rankings, respectively, in terms of their significance for sustainable DevOps

TABLE 11. Pairwise comparison of guidelines of automation principle.

	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	B22	G23	G24	G25	G26	Priority
G12	(1,1, 1)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(2.5, 3, 3.5)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	0.078232
G13	(1, 1.5, 2)	(1,1, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(2.5, 3, 3.5)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	0.077156
G14	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.2, 0.3, 0.4)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	0.061135
G15	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1,1, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	0.072116
G16	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1,1, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	0.075751
G17	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1,1, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	0.074993
G18	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1,1, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	0.065516
G19	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(2.5, 3, 3.5)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1,1, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	0.077156
G20	(1.5, 2, 2.5)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1,1, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1, 1.5, 2)	0.069726
G21	(0.4, 0.5, 0.6)	(0.2, 0.3, 0.4)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1,1, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	0.052684
G22	(0.2, 0.3, 0.4)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1,1, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.06264
G23	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1,1, 1)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	0.052583
G24	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1,1, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	0.054597
G25	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1,1, 1)	(0.4, 0.5, 0.6)	0.071115
G26	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1,1, 1)	0.054597

λmax = 17.140, CI = 0.15286, CR = 0.09613

implementation. Thus, focusing on these areas can greatly assist organizations in adopting and sustaining DevOps practices. The taxonomy, along with the rankings, offers software organizations a valuable resource to prioritize their efforts based on the impact of each guideline within its principle and for the overall success of DevOps implementation. This enables organizations to make informed decisions and effectively implement sustainable DevOps practices.

VI. THREATS TO VALIDITY

One of the limitations of the study is potential researcher's biasness in the investigated guidelines using a literature review study. To address this comment, the ''inter-rater reliability test'' was performed, and the results shows no significant biasness in the literature study findings. Moreover, the literature was collected from the limited selected repositories that might causes the chance of omitting the related literature. Though, considering the existing studies, this threat is no systematic

Similarly, the small size of the data set poses an external threat to the generalization of the questionnaire survey. We received n=116 responses for this study, which may be insufficient to generalize the findings. However, based on previous research in the software engineering sector this sample size is adequate for generalizing the findings.

Furthermore, the fuzzy-AHP was used to rank the investigated guidelines and their corresponding categories based on the opinions of experts. To mitigate this concern, the consistency ratio of pairwise comparison matrices was calculated, and the results show that fuzzy AHP analysis results have appropriate internal validity.

TABLE 12. Pairwise comparison of guidelines of sharing principle.

	G27	G28	G29	G30	G31	G32	G33	G34	G35	G36	Priority
G27	(1,1,1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	0.110115
G28	(0.5, 0.6, 1)	(1,1,1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.098379
G29	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	0.095144
G30	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1,1,1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	0.089664
G31	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	0.109770
G32	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1, 1.5, 2)	(1,1,1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	0.087082
G33	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(1,1,1)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	0.119216
G34	(1, 1.5, 2)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1,1,1)	(1.5, 2, 2.5)	(1, 1.5, 2)	0.099249
G35	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	0.097639
G36	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1,1,1)	0.093742

$\lambda = 11.278$, CI = 0.14197, CR = 0.095285

TABLE 13. Pairwise comparison of guidelines of culture principle.

	G37	G38	G39	G40	G41	G42	G43	G44	G45	G46	G47	G48	Priority
G37	(1,1,1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	0.089771
G38	(0.5, 0.6, 1)	(1,1,1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	0.092637
G39	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	0.082375
G40	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1,1,1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.074275
G41	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	0.099306
G42	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(1,1,1)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	0.072511
G43	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	0.083396
G44	(1, 1.5, 2)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1,1,1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	0.093556
G45	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	0.074588
G46	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1,1,1)	(1.5, 2, 2.5)	(1, 1.5, 2)	0.092637
G47	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1,1,1)	(0.5, 0.6, 1)	0.071128
G48	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	(1, 1.5, 2)	(1,1,1)	0.073821

$\lambda = 13.542$, CI = 0.14017, CR = 0.094709

One potential limitation of the study is the possibility of researcher bias in the investigated guidelines during the literature review. To address this concern, an ''inter-rater reliability test'' was conducted, and the results indicated no significant bias in the findings of the literature study. Additionally, it should be noted that the literature was gathered from a selected set of repositories, which may have led to the omission of relevant literature. However, based on the existing studies and references [35], [40], and [63]. this limitation does not appear to be systematic.

Similarly, the small size of the data set used in the questionnaire survey poses a potential external threat to generalizing the findings. With n=116 responses received for this study, there is a possibility that the sample size may not be sufficient for generalization. Nonetheless, considering previous research in the software engineering sector [17], [50], [51] this sample size is deemed adequate for drawing meaningful conclusions.

Moreover, the fuzzy-AHP approach was utilized to rank the investigated guidelines and their respective categories based on expert opinions. To address concerns regarding

TABLE 14. Determining global weights.

Category	Principle Weight	Guidelines	Local Weight	Local Rank	Global Weight	Global Rank
C1 (Measurement)	0.11591	G1	0.099531	2	0.011537	39
		G2	0.095757	4	0.011099	41
		G3	0.089031	6	0.01032	43
		G4	0.094217	5	0.010921	42
		G5	0.106180	1	0.012307	38
		G6	0.073984	11	0.008575	48
		G7	0.085232	9	0.009879	46
		G8	0.098665	3	0.011436	40
		G9	0.085852	8	0.009951	45
		G10	0.088277	7	0.010232	44
		G11	0.083275	10	0.009652	47
C2 (Automation)	0.29500	G12	0.078232	1	0.023078	13
		G13	0.077156	2	0.022761	14
		G14	0.061135	11	0.018035	26
		G15	0.072116	6	0.021274	18
		G16	0.075751	4	0.022347	16
		G17	0.074993	5	0.022123	17
		G18	0.065516	9	0.019327	22
		G19	0.077156	3	0.022761	15
		G20	0.069726	8	0.020569	20
		G21	0.052684	14	0.015542	34
		G22	0.06264	10	0.018479	25
		G23	0.052583	15	0.015512	35
		G24	0.054597	12	0.016106	31
		G25	0.071115	7	0.020979	19
		G26	0.054597	13	0.016106	32
C3 (Sharing)	0.17028	G27	0.110115	2	0.01875	23
		G28	0.098379	5	0.016752	28
		G29	0.095144	7	0.016201	30
		G30	0.089664	9	0.015268	36
		G31	0.10977	3	0.018692	24
		G32	0.087082	10	0.014828	37
		G33	0.119216	1	0.0203	21
		G34	0.099249	4	0.0169	27
		G35	0.097639	6	0.016626	29
		G36	0.093742	8	0.015962	33
C4 (Culture)	0.41882	G37	0.089771	5	0.037598	5
		G38	0.092637	3	0.038798	3
		G39	0.082375	7	0.0345	7
		G40	0.074275	9	0.031108	9
		G41	0.099306	1	0.041591	1
		G42	0.072511	11	0.030369	11
		G43	0.083396	6	0.034928	6
		G44	0.093556	2	0.039183	2
		G45	0.074588	8	0.031239	8
		G46	0.092637	4	0.038798	4
		G47	0.071128	12	0.02979	12
		G48	0.073821	10	0.030918	10

this method, the consistency ratio of pairwise comparison matrices was calculated, and the results indicated that the fuzzy-AHP analysis results possess appropriate internal validity.

VII. CONCLUSION AND FUTURE DIRECTIONS

DevOps is an approach that integrates development and operations to enhance agility in the software development process. The implementation of DevOps practices can be complex, necessitating a thorough exploration of guidelines for achieving sustainable DevOps implementation in software development organizations. Through a systematic literature review, a total of 48 guidelines were identified. These guidelines were then aligned with the CAMS model, which represents the key principles of DevOps. Additionally, a questionnaire survey study was conducted to gather insights from experts, confirming that the identified guidelines align with real-world practices.

To prioritize the guidelines further for sustainable DevOps implementation, a fuzzy-AHP analysis was employed. The results emphasized the significance of certain guidelines, such as fostering a collaborative culture with shared goals, evaluating organizational readiness for adopting a microservices architecture, and educating company executives about the benefits of DevOps. By categorizing and ranking the investigated guidelines, a taxonomy was established, serving as a valuable resource for academic researchers and industry practitioners seeking to refine existing strategies and develop effective approaches for implementing DevOps in software organizations.

Moving forward, future work includes conducting multivocal literature reviews and case studies to uncover additional guidelines associated with the DevOps paradigm. Furthermore, critical challenges and success factors that impact sustainable DevOps practices in software organizations will be identified. Ultimately, a readiness model will be developed to assist practitioners in assessing and improving their DevOps implementation strategies.

APPENDIXES

APPENDIX A

"Selected studies along with quality assessment score (https://tinyurl.com/y9 × 3fg3z)"

APPENDIX B

"Sample of questionnaire survey (https://tinyurl.com/y832q5jy)"

APPENDIX C

"Sample of pairwise comparison questionnaire (https://tinyurl.com/y97k7jp9)"

CONFLICT OF INTEREST

Authors declare no conflicts of interest.

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