DevOps Adoption: Eight Emergent Perspectives

ABSTRACT

DevOps is an approach based on lean and agile principles in which business, development, operations, and quality teams cooperate to deliver software continuously aiming at reducing time to market, and receiving constant feedback from customers. However, implementing DevOps can be a complex and challenging mission due it requires significant paradigm shift. Consequently, many failures and misconceptions can occur about DevOps adoption by organizations, despite its numerous benefits.

This work identifies, describes, and compares different perspectives related to DevOps adoption in academy and industry. The perspectives can be understood as factors or variables that influence or help to understand the DevOps journey.

We employed a sequential multi-method research approach, including Systematic Literature Review (SLR) and Case Study. As a result, eight perspectives were found: concepts, models, principles, practices, difficulties, challenges, benefits, and strategies. More specifically, the SLR produced 390 items, which can be understood as occurrences of a perspective. The conducted case study confirmed 75 items, corroborating the SLR findings, while another 29 items emerged. This global view on DevOps adoption may guide beginners, both theorists, and practitioners, to make the necessary organizational transformation less painful.

Keywords Software Engineering, Agile, DevOps Adoption, DevOps implementation, DevOps Dimensions

1 Introduction

Several organizations that develop and use information systems split their software teams structurally into departments. A standard approach is a separation in software development and system operation departments. This division has been debated, and combining those teams is argued in the concept of DevOps. DevOps is about fast, flexible development and provisioning business processes. It efficiently integrates development, delivery, and operations, thus facilitating a lean, fluid connection of these traditionally separated silos [Ebert et al., 2016].

Usually, the Development team is responsible for answering market change needs and delivering new assets in production as quickly as possible. On the other hand, the Operation team is responsible for providing stable, trustful, and secure IT services to clients, ensuring that changes that may compromise the services are not deployed in production [Kim et al., 2016]. Therefore, Development and Operation teams have conflicting stimuli and goals due to the choice between agility and stability. So, the industry has adopted DevOps in an attempt to deal with this disparate of concerns [Fitzgerald and Stol, 2017].
Although DevOps has been an essential movement in industry for more than a decade, it has not received much attention from the academic community until recently [Wiedemann et al. [2019]]. Still, the interest is increasing from both practitioners and researchers. Among the main reasons are results such as increased productivity and quality of IT products and services and reduced development cycle time, and, consequently, faster response to market needs [Dingsøyr and Lassenius [2016]]. Although many organizations have achieved great success with technology transformations, there is still much work to be done — both in the broader industry and within individual organizations [Humble and Kim [2018]].

DevOps adoption is not an easy or direct task. It may require complex changes in an organization, corporate process, and workflows [Bucena and Kirikova [2017]]. As a software process improvement initiative, the route for successful DevOps adoption is exclusive and typical of each organization. However, it is possible to learn from empirical knowledge to plan future DevOps adoption initiatives [Smeds et al. [2015]]. Research on DevOps is fragmented, making it challenging to identify and understand its scope, covered topics and challenges already addressed as well as those not yet addressed [Erich et al. [2014]].

Organizational and cultural changes and adoption of technologies (mainly frameworks) are required to overcome the detachment of Development and Operation teams [Wettinger et al. [2014]]. In addition, given that DevOps practitioner literature is still emerging, and reliable academic research on the phenomenon is sparse, IT organizations lack concrete guidance on how to approach the DevOps paradigm in practice [Nielsen et al. [2017]].

The goal of this work is to identify, describe, and compare different perspectives related to DevOps adoption in academy and industry. These perspectives refer to possible dimensions or ways to interpret or visualize the phenomenon of DevOps adoption. In other words, the perspectives can be understood as factors or variables that influence or help to understand the DevOps journey. We provide a holistic view of these perspectives without delving into any specific characteristics.

This work employed a sequential multi-method research approach, including Systematic Literature Review (SLR) and Case Study. Figure 1 shows a holistic scheme of the applied multi-method research. The SLR aimed to identify, describe and deepen the knowledge about DevOps adoption in the academy and identify the main related perspectives. The case study was conducted with two software development organizations and empirically explored how is going DevOps adoption in industry and compared with the SLR results. The research was exploratory, descriptive, and deductive since it seeks new insights and aims at generating and validating ideas and hypotheses for future work. Deductively, according to [Runeson et al. [2012]], this can lead to confirmed or rejected theories. More specifically, the SLR produced 390 items, which can be understood as occurrences of a perspective, found in the 28 selected primary studies and classified according to our interpretative scheme. The conducted case study confirmed 75 items, corroborating the SLR findings, while another 29 items emerged, expanding what was found in the literature regarding DevOps adoption. This global view on DevOps adoption may guide beginners, both theorists, and practitioners, to make the necessary organizational transformation less painful.
2 Systematic Literature Review

To achieve research objectives, SRL was used as one of the research strategies. This section presents a brief description of the adopted protocol, including selection criteria and discovered limitations, in addition to achieved results.

2.1 Preliminary Bibliographic Research

Initially, it was necessary to conduct preliminary bibliographic research of the literature through snowballing method [Wohlin 2014], i.e., follow references of the most relevant works in the DevOps theme to deepen the understanding and construction of a more robust search string.

During this phase, it became evident the difficulty of defining the most common English-speaking terms related to DevOps. For ensuring more accuracy in the search string’s construction, we performed a generic search for the word DevOps in the search engines ACM Guide to Computing Literature, IEEExplore, DBLP, and Scopus. Three hundred forty-one papers were obtained, excluding duplicate results, unavailable publications, and papers written in languages other than English. After that, a file containing all the titles, abstracts, and keywords of the selected publications was generated and submitted to the Corpus linguistic processor\(^1\) from Insite Linguistics Group, to identify the words with the highest occurrence in the publications. The generated report counted more than 7,000 words. Three stages were used to deal with these words:

- Exclusion of irrelevant or generic words such as pronouns, conjunctions, adverbs, and connectives;
- Combination of words with similar radicals;
- Elimination of words with less than 100 occurrences.

As an example, Figure 2 displays the 15 more relevant words found in the selected publications. We considered the more fitting words to the research objectives to construct the search string, which not necessarily are the more cited ones.

![Figure 2: Top 15 of the most relevant words found in DevOps publications](image)

2.2 Execution

The following search string was assembled from the preliminary bibliographic research:

\[
(\text{DevOps}) \text{ AND (model OR framework OR method OR platform OR solution)} \text{ AND (adoption OR implementation OR introduction)}
\]

Table II relates the number of quotes from the words that make up the search string.

We chose the following scientific bases among the main ones in Computer Science to combine comprehensive search engines with other more specific bases. This combination aims to achieve greater plurality and coverage of scientific events and journals in the investigated area.

- **Scopus** - [www.scopus.com](http://www.scopus.com) - Search Engine

\(^1\)Available at [http://linguistica.insite.com.br/corpus.php](http://linguistica.insite.com.br/corpus.php)
Table 1: Number of Word Citations for Search String

| Word       | Number of Citations |
|------------|---------------------|
| DevOps     | 1344                |
| model      | 242                 |
| framework  | 101                 |
| method     | 109                 |
| platform   | 100                 |
| solution   | 100                 |
| adoption   | 143                 |
| implementation | 163             |
| introduction | 77                 |

- **IEEE Xplore** - [ieeexplore.ieee.com](https://ieeexplore.ieee.com) - Bibliographic basis
- **Science Direct** - [www.sciencedirect.com](http://www.sciencedirect.com) - Bibliographic basis
- **Springer** - [link.springer.com](http://link.springer.com) - Bibliographic basis
- **ACM Digital Library** - [dl.acm.org](https://dl.acm.org) - Hybrid

The Mendeley software was used as a support tool to manage the documents extracted from the scientific bases, generate bibliographies, and add markings in the texts.

In this stage of the SLR, the inclusion and exclusion criteria were applied to increase selected studies’ relevance, as follows in Figure 3.

The Snowballing search was applied to the twenty primary studies initially selected, which added eight new studies, resulting in twenty-eight documents in total. This step was performed to avoid missing relevant works.

### 2.3 Analysis and Results

This section will detail the extraction and organization of information, using spreadsheets, thematic analysis, and mind mapping to present the results. Eight perspectives were generated, *i.e.*, concepts, models, principles, practices, difficulties, challenges, benefits, and strategies.

#### 2.3.1 Concepts

To obtain the author’s view on *DevOps* concepts, we extracted a term definition from each of the 28 studies.

A word cloud was created to provide a more comprehensive view of the various concepts extracted, as shown in Figure 4. The greater the number of words present, the larger the size or highlight shown. Stop words such as pronouns, conjunctions, adverbs, and connectives were not considered. The site WordClouds.com was used to create the word cloud.

This word cloud reinforces some terms related to *DevOps*, such as collaboration, culture, software, practices, quality, delivery, automation, operations, processes, and teams, which shows excellent adherence and convergence to the broad concept *DevOps* represents. Moreover, although there are different interpretations in *DevOps* literature, this word cloud helps to visualize a connection and many similarities between the various authors considered in this study.

#### 2.3.2 Distribution of Primary Studies by Locality

As an additional result from the SLR, in Figure 5, it is possible to visualize, through the illustrated world map, the distribution of the primary studies selected in this phase of the research by country of publication. There is a high concentration in the European and North American continent countries and relevant research in India. From this, it is possible to deduce that there is a scarcity of qualified studies, specialized events, or research focus in the least developed countries, probably due to a low degree of maturity or interest in *DevOps’* adoption. Future research on this topic may be helpful.

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2 Available at [https://www.mendeley.com/](https://www.mendeley.com/) and licensed by UFRJ, the institution of some of the authors.  
3 Available at [https://www.wordclouds.com/](https://www.wordclouds.com/)
2.3.3 DevOps-related Models and Frameworks

Table 2 presents a consolidated view of the models and frameworks found in the 28 studies selected in the SLR, as well as their type, focus, and quantity.

2.3.4 Thematic Analysis and Mind Mapping

Although the kind of results obtained by content analysis techniques cannot be taken as irrefutable proof, it constitutes an illustration that allows corroborating, at least partially, the presuppositions in question [BARDIN 1977].

Carrying out a thematic analysis consists of discovering the “nuclei of meaning” that make up the communication and whose presence, or frequency of appearance, can mean something for the chosen analytical objective. The theme is generally used as a recording unit to study motivations for opinions, attitudes, values, beliefs, and trends. In this sense,
it is possible to consider that the mind mapping technique can be seen as a type of content analysis, even more, a kind of thematic analysis.

Mind maps were chosen because they can represent ideas linked to a central theme. There are a lot of rules for creating mind maps in which the main one is to bring the brain in and use the imagination [Crowe and Sheppard 2012]. Creating mind maps is an easy and natural organization method and visualizing complex data, both as survey methods and as interactions between data. In addition, mind maps can also help people learn concepts better than linear formats and annotations.

Given the large number of occurrences associated with each perspective, it was necessary to adopt a classification scheme using graduated weights. This scheme considers an importance degree (or weight) for each item present in each perspective, from the association of a star that can have three colors (or three weights): red represents the highest degree,

| Type    | Focus                     | Quantity |
|---------|---------------------------|----------|
| Model   | DevOps Adoption           | 4        |
|         | DevOps Maturity           | 2        |
|         | Technology Acceptance     | 1        |
| Framework | DevOps Adoption       | 2        |
|         | DevOps Maturity           | 2        |
|         | Knowledge Sharing         | 1        |
|         | Communication             | 1        |
with value three; **yellow** has value two; and, finally, **blue** represents the lowest degree, with value one. This degree is determined by the number of times the item is cited, considering one citation if the item appears one or more times in the same primary study. On each picture that represents a perspective’s mind map, there is a legend that explains this particular color scheme. The number of citations present in this color scheme may vary according to each perspective, never exceeding the limit of 28 citations, which is the total number of primary studies considered.

In addition, given the possibilities and complexities inherent in the mind map’s construction, it was necessary to create a type called aggregator branch (expressed by a noun). This aggregator refers to a branch that explains, details, or exemplifies the branch or avoids repetition of similar terms, improving semantics. An image of a green check sign represents the aggregator, and a legend is associated with it.

An additional feature of the classification scheme was still necessary to better express the mind maps’ semantics in scenarios of greater complexity and number of items. This scheme was applied in the mind maps of the *Difficulties, Challenges, Benefits, and Strategies* perspectives. To represent the degree of importance of a mind map branch, the sum of the weights attributed to all the branch twigs and leaves, and sub-leaves was considered. This number was represented below the box that represents the topic itself. The number that appears next to the topic is the sum of the number of subordinate items. It is important to remember that the values assigned to the weights always vary from 1 to 3, with an increasing degree of importance. The criterion for framing an item to a given weight is specified in the legend of each mind map. It may vary from perspective to perspective, according to the free criterion adopted by the authors.

To facilitate the visualization and understanding of this internal classification scheme of mind maps, a structural meta-model was created, represented in Figure 6, in which:

- **Root Node = Perspective**
- **Branch = Correlated Item or Aspect**
- **Twigs and Leaves = Items or Aspects’ aggregations or extensions**

Figure 6: Structural Meta-Model of Mind Maps

Given the possible options in drawing a mind map, some clarifications about construction rules are in order. A simple branch directly represents an item or aspect related to the perspective. At most, it can have a few associated branches, only at 1 level of depth, to explain it or correlate similar items or aspects.

On the other hand, the aggregator branch or aggregator topic, present in several perspectives, represents a set of correlated items or aspects. It can contain another branch, a twig, leaf, or sub-leaf. Its existence allows for greater freedom in drawing the mind map, unifying or simplifying several items correlated by some characteristic to improve the semantics and contain any reasonable explanation found in primary studies. It can be considered a complex branch that represents high-density structures with several branches. The main item or aspect, which represents something related to the perspective and which must be considered in the accounting, in any branch, will always have an associated colored star.

The XMind ZEN software tool was used to support the creation of mind maps. Due to the extensive size of mind maps, we provided a Web page with them.

[https://www.xmind.net/](https://www.xmind.net/)
[https://github.com/leogazevedo/devops-adoption-perspectives](https://github.com/leogazevedo/devops-adoption-perspectives)
2.3.5 Principles

We found fifteen principles related to DevOps. Among the five most cited principles are only two of those present in the acronym CALMS, they are: Culture and Automation. Among the most cited are the principles of Communication, Collaboration and Agility. The other principles present in the acronym CALMS (Lean, Measurement and Sharing) also appear, but with fewer citations in the selected studies, thus configuring themselves with less relevance in this research.

In Table 3, there is a description of each principle found in the 28 selected studies, as well as its relevance. This relevance was calculated considering the number of citations, as described below:

- High = Over 19 occurrences
- Medium = Among 10 and 19 occurrences
- Low = Under 10 occurrences

2.3.6 Practices

Eleven direct practices were found represented by simple branches, two indirect practices represented by hybrid branches, and ten aggregator branches were created to facilitate the organization and visualization, as they were considered to represent correlated practices. Aggregator branches represent the number of practices that are grouped, making a subtotal of 60 practices. That is, in total, adding the direct practices (11), plus the indirect practices (2) with the practices present in the aggregator branches (60), 73 practices related to DevOps were found. Practices related to Monitoring, Development, Testing, and Continuous Deployment stand out among the most cited. As a demonstration, the DevOps Practices mind map was represented in 4 parts, for ease of viewing, due to its length, as we can see in the figures 7, 8, 9 and 10. The most cited practices with great relevance (red star) to the DevOps concept are:

- Automated Build
- Continuous Deployment
- Continuous Integration
- Continuous Delivery
- Cloud Computing
- Source Code Version Control
- Automated and Continuous Feedback
- Infrastructure as Code
2.3.7 Difficulties

Forty difficulties were encountered, represented by five aggregator branches. These were created to better semantically represent difficulties related to Tools (4), Client (2), Teams (14), Management (8), and Process (12). The weights of the classification scheme highlight difficulties or problems related to the Team and Process aspects during the adoption of DevOps.

2.3.8 Challenges

Fifty-two challenges were found, represented by four aggregator branches. These were created to better semantically represent challenges related to Tools (4), Teams (11), Management (22), and Process (15). Applying the weights of the classification scheme, challenges or risks related to the Management and Process aspects during the adoption of DevOps are highlighted.

2.3.9 Benefits

Seventy benefits were found, represented by six aggregator branches. These were created to better semantically represent benefits related to Product/Service (9), Customer (8), Teams (19), Market (1), Organization (10), and Process
The weights of the classification scheme highlight benefits related to the aspects of the Process and Teams during the adoption of DevOps.

### 2.3.10 Strategies

Ninety-nine strategies were found, represented by four aggregator branches. These were created to better semantically represent strategies related to Organization (14), Teams (27), Management (18), and Process (40). The weights of the classification scheme highlight strategies related to the aspects of the Process and Teams during the adoption of DevOps.

#### 2.3.11 Summary of Perspectives

To facilitate the comparison between perspectives and consolidate the results achieved, the tables 4 and 5 were created. These tables present four perspectives and the analyzed branches or dimensions. The difference between the tables occurs regarding the use or not of the weights of the classification scheme. The use of weights did not change the order or degree of importance either of the perspectives, comparative scope, or branches or dimensions when viewed in isolation and compared to each other. So, using weights helps reinforce the validity and assertiveness of using the mind mapping technique to encode information extracted from selected studies.

For the Principles and Practices perspectives, there was no need to use specific branches or dimensions due to the ease to analyze and condense the results because of the small number of extracted items, the direct mentions, or good correlation to the perspectives in the analyzed primary studies. For these reasons, these 2 perspectives do not appear in the tables 4 and 5.
3 Case Study

This section presents the case study which was conducted following Runeson et al. protocol [Runeson et al. 2012] as follows:

- **Case study type**: Exploratory, descriptive, multiple, and holistic.
- **Goal**: Analyze the state of the practice comparing with state of the art (*i.e.*, considering SLR results), aiming at bringing new visions, contexts, perspectives, and interpretations enhancing the theory.
- **The case**: Professional experts in DevOps of organizations that handle Software Engineering problems.
- **Selection strategy**: Enterprises that are adopting or are mature in DevOps, even partially, and utilize agile or hybrid methodologies for software development in at least one year.
- **Data collection**: through semi-structure, remote interviews, preferably with audio and video recording consented by the interviewees.
- **Quantity of interviewees**: Four experts were selected considering experience, knowledge, and human factors (relationship).
Figure 10: Mind Map of DevOps Practices - Part 4

Table 4: Summary of Perspectives - Weightless

|                | Difficult | Challenged | Benefits | Strategy | Total |
|----------------|-----------|------------|----------|----------|-------|
| Tools          | 4         | 4          | N/A      | N/A      | 8     |
| Manag.         | 8         | 22         | N/A      | 18       | 48    |
| Teams          | 14        | 11         | 19       | 27       | 71    |
| Process        | 12        | 15         | 23       | 40       | 90    |
| Client         | 2         | N/A        | 8        | N/A      | 10    |
| Organiz.       | N/A       | N/A        | 10       | 14       | 24    |
| Product        | N/A       | N/A        | 9        | N/A      | 9     |
| Market         | N/A       | N/A        | 1        | N/A      | 1     |
| Total          | 40        | 52         | 70       | 99       |       |

• **Validation (pre-test):** with a member of HumânITas research group.

• **Interview duration:** About 120 minutes on average.

First, a semi-structured interview questionnaire with open and closed questions was created based on SLR results. The questionnaire was enhanced considering the feedback of HumânITas research group, and it was composed of three parts:

• **Social-demographic questions:** Questions to characterize the individuals and organization with a focus on the case;

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6Research group of Graduate Program in Informatics of UFRJ (PPGI-UFRJ) which is composed of Ph.D., masters, and students. The group focus is research on human factors about development, adoption, and use of IT. More information available at [http://dgp.cnpq.br/dgp/espelhogrupo/635926](http://dgp.cnpq.br/dgp/espelhogrupo/635926).

7Available at [https://github.com/leogazevedo/devops-adoption-perspectives](https://github.com/leogazevedo/devops-adoption-perspectives)
Table 5: Summary of Perspectives - Weighted

|               | Difficult. | Challenge | Benefit | Strategic | Total |
|---------------|------------|-----------|---------|-----------|-------|
| Tools         | 6          | 10        | N/A     | N/A       | 16    |
| Manag.        | 16         | 31        | N/A     | 50        | 97    |
| Teams         | 24         | 24        | 32      | 63        | 143   |
| Process       | 18         | 24        | 31      | 83        | 156   |
| Client        | 2          | N/A       | 11      | N/A       | 13    |
| Organiz.      | N/A        | N/A       | 14      | 37        | 51    |
| Product       | N/A        | N/A       | 15      | N/A       | 15    |
| Market        | N/A        | N/A       | 3       | N/A       | 3     |
| Total         | 66         | 89        | 106     | 233       |       |

- **Technical questions**: technical questions about DevOps centered on this research goal.
- **Practices knowledge form**: a set of practices and resources found in the literature to validate their representativeness and importance in a practical environment.

Four interviews were conducted by Skype® with four software engineering professions of two distinct organizations. The same set of questions were applied to all interviewees, and other spontaneous questions were made when necessary. The interviewees received disclosure information, and they were asked to present genuine and detailed responses. All interview audios were recorded for data collection with the consent of all interviewees.

Table 6 presents interview details. The four interviewees are anonymized with I1, I2, I3, and I4 codes.

Table 6: Interviews Conduction

| ID | Organization | Date              | Duration   |
|----|--------------|-------------------|------------|
| I1 | A            | May 30th, 2020    | 72 minutes |
| I2 | A            | May 30th, 2020    | 125 minutes|
| I3 | B            | June 22nd, 2020   | 133 minutes|
| I4 | B            | June 22nd, 2020   | 97 minutes |

Table 7 and Table 8 present the demographic data of the interviewees in a personal and organizational context, respectively. Table 9 presents the context of the enterprises considering the case study goal.

Table 7: Interviewee Demographics - Personal Context

| ID | Gender | Age (years) | Qualification            |
|----|--------|-------------|--------------------------|
| I1 | Female | 19 to 29    | Incomplete undergrad.    |
| I2 | Male   | 19 to 29    | Incomplete undergrad.    |
| I3 | Male   | 30 to 39    | Complete undergrad.      |
| I4 | Male   | 40 to 49    | Complete graduation      |

3.1 Results and Analysis

This section presents the results and analysis of the interviews. We preformed a thematic analysis and compared with SLR results, through the following steps, depicted in Figure 11: (i) Transcription; (ii) Organization; (iii) Reading; (iv) Codification; (v) Theme identification; (vi) Theme meaning interpretation.

All interview audio-recorded data were transcribed in a spreadsheet with specific tabs for each interview script stage. The interviewee responses were transcribed in sentences connected to the question goal, and redundant and irrelevant terms were removed. We assigned a unique identification to avoid shuffle and facilitate data analysis. We exhaustively read the transcriptions to be familiarized and have a clear comprehension of the data. The codes in each transcription were assigned, analyzing each one manually. The identified codes were classified into themes according to the perspectives identified in the SLR and their topics. The frequency and relevance of a code were the main criteria to consider. In this work, we defined frequency as answers from more than one interviewee and relevancy as the importance for the literature and this research.

[https://www.skype.com/](https://www.skype.com/)
3.1 Concepts

For individuals I1 and I2, from the same company, the focus is on gaining time and productivity. Therefore, in this company, DevOps is related to the ideas of agility and Lean applied to infrastructure activities. For individuals I3 and I4, from the same organization, it is possible to infer a significant focus on collaboration and delivering value to the customer as motivators of the DevOps initiative.

3.1.2 Models and Frameworks

Only I3 reported the existence of a model focused on organizational topology questions tailored for development and operation team.\(^9\)

However, in general, interviewees stated that there is no single model or framework recognized and widely used as a reference. It is a journey where each organization must seek its path without following something strictly predetermined since each company has its strategic objectives, maturity, and sizes.

They also mentioned that the multidisciplinary working groups are a good choice for DevOps adoption.

Besides, I4 suggested the DevOps adoption through an incremental and on-demand approach using a customized model. That way, the journey is more adaptable to the different business requirements of each client and technology.

3.1.3 Principles

The two interviewees from company A cited specific DevOps practices. Thus, from the items mentioned earlier, it was possible to infer that the adoption of DevOps in this company had a strong foundation in the automation of infrastructure activities, focusing on implementing and improving the software delivery pipeline. For these two interviewees, the principles of Automation, in the first place, and Culture, in the second, present themselves as the most important ones related to the adoption of DevOps.

\(^9\)Available at [https://web.devopstopologies.com/](https://web.devopstopologies.com/)
For the second company, despite the two respondents having different technical expertise, there was a convergence on the most relevant principles considered during the adoption of DevOps, which can be seen as a positive aspect. The Culture and Automation principles are also listed as the most relevant in the view of these interviewees. Therefore, although the two companies and their employees have very different expertise, the principles of Automation and Culture are considered the most relevant in the adoption of DevOps. We observe that these principles have a more tangible and visible character since automation brings several changes and practical improvements to the flow and form of work. In addition, Culture is a principle related to people and has a fundamental role when transforming processes and routines in a way that is as significant as DevOps proposes. However, interviewee I3, depicted that the adoption of DevOps requires considering all the principles since they are necessary and complementary. Adopting part of them can bring difficulties and, of course, internal resistance to the changes that come about.

3.1.4 Practices

Interviewee cited eleven DevOps in total. I3 cited two new practices: InnerSource and Skunkworks. InnerSource allows software developers to contribute to other teams’ efforts, promoting transparency and openness to other people’s contributions. This practice embodies a philosophy of human relations, an approach for rewards and motivations, and a flexible and adaptable set of tools and practices. Skunkworks project is one developed by a relatively small and loosely structured group of people who research and develop a project primarily for the sake of radical innovation. Additionally, Blue Green Deployment was mentioned by I1.

The Continuous Integration practice was the only one cited and recognized by all the interviewees. Continuous Deployment and Continuous Integration were practices cited by three of the four interviewees.

Regarding the companies, Company A focuses on automation practices, while Company B concentrates on automation and is planning to use Cloud Computing. Seven of the eleven cited practices are related to automation. This fact reinforces that, in industry, the DevOps adoption is strongly related to activities of automation practices.

3.1.5 Difficulties

I1 and I2 reported difficulties in writing tests, choosing proper tools, adopting this practice broadly in the organization. I4 highlighted the complexity concerning task automation securely and the human factor, mainly related to convincing and getting team confidence in the new way of working.

3.1.6 Challenges

The interviewees of Company A point out learning and knowledge propagation as a big challenge, which is a fundamental issue for DevOps adoption. One of its basic principles, as RSL confirmed. I3 highlighted Cloud Computing as a prerequisite for DevOps adoption, and the convincing of high management about DevOps adoption may be pretty costly and comprising. I4 points out the challenge already taken but not yet overcome about unique open-source tool adoption for code versioning and the internal challenge about resistance to change.

3.1.7 Benefits

Company A has the increase in delivery speed and improvement of company image in the market as the benefits.
I3 reported delivery speed as a benefit resulted from the DevOps adoption.

Concerning agility increase and workflow simplification, I4 highlighted that process automation reduced the need to take different teams to answer the company requests registered in task control systems.

3.1.8 Strategies

I1 and I2 pointed out the requirement to set up a plan for DevOps adoption, as well as knowledge acquisition and dissemination in an integrated way for the whole organization. So, there is a concern and focus on stimulating the collaborative culture in the company, which is one of the biggest motivations to put forward the DevOps initiative.

I3 highlighted the risks related to DevOps adoption and suggested strategies to overcome them. For him, a very close plan should be taken, presenting a history of broad DevOps use in the organization. Only sell the idea that DevOps solve all the organization areas does not work. On the other hand, the effective approach should present that the whole organization is already adopting DevOps, there are already organization teams with experience in DevOps, and there is evidence that many problems in projects were solved using DevOps. He also considered that DevOps might be difficult and risky to adopt, requiring a high level of adaptation.

I4 reported the strategy employed by his organization in DevOps adoption. He said DevOps adoption resulted from a natural and spontaneous need of the development team. There was a significant organization initiative for DevOps adoption which concluded in the last year when a multidisciplinary working group was created to handle many problems that should be solved with DevOps adoption. There were sparse initiatives in some teams, but the main idea was to turn it into a corporate endeavor. The working group’s goal was to make the DevOps initiative officially in the company. An effective plan was devised, which resulted in DevOps adoption in a bottom-up way.

4 Discussion

This section presents an analysis of the interviewee’s definitions related to the ones found in the SLR, highlighting differences and similarities.

We generated a word cloud from the definitions gathered from the 28 documents selected in the SLR depicted in Figure 4. The most relevant concepts resulting from the interviews were: agility, collaboration, continuous delivery, practices, process, improvements, and culture. These concepts and their variations have high frequency when compared with the word cloud, which demonstrates, in a general view, that literature and industry converge. On the other hand, some items were mentioned a lot in the SLR but were not pointed out by the interviewees, such as software, quality, automation, teams, change, tools, principles, and approach.

The SLR brought 13 models or frameworks from which six are focused on DevOps adoption, while the interviewees did not mention anyone with this focus. It shows that the SLR finds are not commonly used on a large scale, or there is no recognition of its applicability in practice.

The interviewees highlight the way for DevOps is particular to each organization. However, we argue that a model or framework should be used since they are defined from various previous experiences and industry reports.

Culture and automation principles are the most cited principles in SLR and by the interviewees. However, several other principles are very relevant when considering the SLR but were not mentioned by the interviewees, such as Collaboration, Communication, and Agility.

Six practices were cited by the interviewees and found in the SLR: Continuous Deployment, Continuous Improvement, Continuous Testing and Automation, Automating Building, Infrastructure-as-Code, and Cloud Computing.

The majority of items reported by the interviewees were in the Difficulties perspective, which may be an obstacle for the advance of DevOps adoption in organizations.

Table 10 presents a comparison between the number of items found in SLR and the Case Study for the eight identified perspectives. Table 11 presents a comparison of the reinforced items (i.e., appeared in SLR and Case Study) and new items (i.e., emerged from the Case Study).

Since the SLR and Case Study are subjective processes, the presented numbers may have significant variance. The results represent a snapshot in time, and they are not deterministic, i.e., they are tight to the nature of an interpretative process. So, we only compared and verified if there were convergence considering the findings of both methods application. In this case, from the analysis presented in Table 10 and Table 11, we may deduce that there is a majority convergence among SLR and Case Study findings because there was empirical evidence of common elements.
Table 10: Comparative SLR and Case Study

|                  | SLR  | Case Study |
|------------------|------|------------|
| Concepts         | 28   | 4          |
| Models           | 13   | 1          |
| Principles       | 15   | 2          |
| Practices        | 73   | 11         |
| Difficulties     | 40   | 31         |
| Challenges       | 52   | 13         |
| Benefits         | 70   | 21         |
| Strategies       | 99   | 21         |
| Total            | 390  | 104        |

Table 11: Case Study Items

|                  | Reinforced Items | New Items |
|------------------|------------------|-----------|
| Concepts         | 0                | 4         |
| Models           | 0                | 1         |
| Principles       | 2                | 0         |
| Practices        | 8                | 3         |
| Difficulties     | 24               | 7         |
| Challenges       | 11               | 2         |
| Benefits         | 16               | 5         |
| Strategies       | 14               | 7         |
| Total            | 75               | 29        |

5 Conclusions

This research aimed to elucidate the phenomenon of DevOps adoption in Brazilian organizations that develop and holistically maintain the software. For this, a multimethod approach was carried out with two methodological research techniques. Firstly, a Systematic Literature Review to understand the phenomenon, find the gaps and thus bring the main perspectives in their nuances associated with the theme, thus bringing the academy’s view. In a second step, a Case Study was carried out with 2 Brazilian companies, one large and one small, to observe and empirically verify how the phenomenon of DevOps adoption presented itself, thus allowing comparison and complementation to what was found in the literature.

With the development of this research, it was possible to understand and visualize the DevOps phenomenon from the following perspectives found in the literature and sequentially applied in the industry: its most relevant principles, the varied concepts and interpretations involved, the associated practices, the problems faced, the current challenges, the benefits identified and the strategies used. This research result brought a wide range of characteristics and views, both in the literature and in the industry, on DevOps manifestation in organizations.

The SLR brought 390 items, artifacts, or characteristics related to the adoption of DevOps were identified. The case study reinforced or validated 75 items and revealed 29 new items, expanding the literature findings.

Literature reports that the DevOps initiative must be something top-down, with support and sponsorship from top management to be successful in its adoption [Bucena and Kirikova, 2017] [Colomo-Palacios et al., 2018] [Elberzhager et al., 2017]. However, in the case study, it was identified that the bottom-up initiative proved to be fundamental for the successful DevOps adoption in one of the companies. While confronting what was recommended in SLR, this fact converges with the idea that DevOps came from the practical community and has proven itself over time as something beneficial and transformative for software engineering.

In short, it is possible to conclude that DevOps manifests itself in many different ways and perspectives in organizations that develop software because its adoption is something transformative for the entire company, involving people, processes, and tools. Besides, it brings a robust cultural change, the need for new skills, greater collaboration, and organizational restructuring. It is not trivial, as DevOps adoption requires a series of requirements and a very well-designed and structured plan to occur without trauma or at a high cost. This is mainly due to the involved human factor because without people being convinced, the journey can go wrong at all hierarchical levels.
Because it is a relatively new topic and comes from practice, associations need to mature the idea well, discussing it internally before deciding on DevOps adoption. There is no magic guide or formula ready for doing it, a very particular journey for each company. It is pretty challenging to find the ideal path that can connect people, adjust processes and adopt tools combined and not necessarily in that order. In other words, it is a new way of working, requiring a lot of collaboration between teams, support from top management, motivation from both the company and employees, clarity about the objectives, a well-structured plan, with phases, and participatory adoption of ideal tools in the assembly of the pipeline, well-structured documents and processes and continuous review for improvements.

Below is a list of possible future works to be considered from this research:

- Use the Multivocal Literature Review methodology, according to the study of Garousi et al. [2019], to systematically aggregate publications related to Grey Literature, thus taking a stronger view of the industry and practical community;
- Seek generalization of results using a quantitative research approach, such as a Survey to validate the perspectives raised in other development environments;
- Conduct new case studies, in organizations from different branches of industry, in different countries, to seek and aggregate more cultural and organizational contexts;
- Apply new research focused on how the manifestations of the principles influence DevOps adoption, with emphasis on culture and collaboration. There is relevant research on the topic developed that can be used as a reference, as Humble and Kim [2018];
- Adapt or build a model or framework of best practices for adopting DevOps, in addition to testing it in organizations, based on the results of this research.

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