# DevOps Adoption: A Tertiary Study

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**Abstract.** DevOps is an approach that has emerged within teams in the context of developing and operating software to drive collaboration and productivity. Many studies have been published on DevOps, however, there are several secondary studies that have not been organized and do not facilitate the identification and evolution of the research areas. This study aims to identify and organize secondary studies on DevOps. To achieve this objective, a tertiary study was performed. In the selection process, 212 articles were obtained from six databases, and 83 articles were selected. Secondary studies have focused their efforts on finding best practices and recommendations for adopting DevOps. Among these practices, continuous integration and delivery, monitoring, and test automation are the most frequently reported. In addition, collaboration, communication, and continuous feedback are considered as important. Finally, there is a predisposition on the part of development, operation, and management teams to adopt DevOps in organizations.

**Keywords:** DevOps, Tertiary study, Continuous Integration, Continuous Development.

## 1 Introduction

DevOps is an approach to software development that is based on four dimensions [1]: collaboration, automation, measurement, and monitoring. Since its emergence [2], it has been trialed to solve some problems that arise during software development in agile teams [3], [4] using agile method practices such as continuous integration [5], continuous deployment [6], continuous delivery [7] and continuous testing [8], and others [9].

This approach has allowed development and operation teams to work together considering both software and business aspects [10], [11]. One of the benefits of this collaboration is the reduction in product release time [12]. At the same time, as DevOps changes the way the development process is approached, it brings challenges that teams must face in practice [13]. Despite this, its benefits and advantages outweigh the challenges, even those in digital transformation [14], which is why it has become a benchmark in software development [15].

Multiple primary [16], [17], secondary [18], and even tertiary studies have been carried out on DevOps [9]. Among the latter, we can mention one that attempted to find the most accurate definition of the term “DevOps” [9], and another one on DevOps practices in software companies [19]. However, there are several issues that still need to be studied based on the secondary studies on DevOps, especially those related to its adoption.

In this study, we answer research questions on DevOps adoption through a tertiary study based on the guidance of [20] on systematic mapping study and whose object of study is secondary studies. The rest of this article is organized as follows: in Section 2, the work done on DevOps is presented as tertiary studies; in Section 3, the execution protocol is presented to facilitate the replicability of the study; in Section 4, the results are presented and the research questions posed are answered; and, in Section 5, the conclusions are presented.

## 2. Related Work

In scientific literature, many articles have been published on DevOps. In particular, several primary studies have been published [3], [4] on topics such as adoption experiences, DevOps benefits, problems and achievements of organizations, surveys, and experiments, among others. Moreover, a significant number of secondary studies have been published [9], [18] that address diverse topics such as practices, benefits, challenges [13], [4]. Finally, to our knowledge, only one tertiary study has been carried out thus far [9].

In addition, some topics of interest in agile software development [21] to which DevOps belongs in the technical aspect are the methods and practices, and in the non-technical aspect are its adoption and the human factor. Moreover, [22] notes there is a lack of secondary studies on configuration management and development tools. Regarding tertiary studies in DevOps, [9] stated that there are different definitions of some DevOps terms between researchers and practitioners, which jeopardizes the potential impact of the research. However, [23] identified a list of practices that are the most reported, such as software testing, process tracking, continuous integration and builds, product backlog, daily stand-up meeting, small and frequent deliveries.

## 3. Tertiary Study Design

This study is based on the protocol of [20] for systematic mapping study for software engineering. The first step was to perform an initial search for tertiary studies on DevOps and thus determine what had already been researched on the topic. With the data obtained, the research questions were defined. Then, the base string was constructed for the search in six databases, which were Scopus, IEEE, ACM, Science Direct, Web of Science/Clarivate and Wiley. The tertiary study design is presented below.

### 3.1. Research Questions

To define the research questions, we reviewed research questions from the background of this study [9], [23], as well as some secondary studies reviewed in previous studies on DevOps [24]. The questions are:

- RQ1. What is the evolution of secondary studies on DevOps?
- RQ2. What were the main topics addressed in DevOps adoption?
- RQ3. What are the practices used to adopt DevOps?
- RQ4. What are the frameworks or approaches used when adopting DevOps?
- RQ5. What are the tools used in the adoption of DevOps?
- RQ6. What is the interest of company managers, and the development and operation teams in adopting DevOps?
- RQ7. What are the agile methods used when adopting DevOps?
- RQ8. Is DevOps mentioned as offering a competitive advantage?

For categorization of research types in RQ1, we used MSL and RSL. The same was done for other questions that require categorizers.

### 3.2. Search String

The search string was created using the PI technique [20] and as applied in [25]. The keywords for the string were chosen from an initial background review of the topic. The search string was: *DevOps AND ("review of studies" OR "structured review" OR "systematic review" OR "literature review" OR "literature analysis" OR "in-depth survey" OR "literature survey" OR "meta-analysis" OR "past studies" OR "subject matter expert" OR "analysis of research" OR "empirical body of knowledge" OR "systematic mapping" OR "overview of existing research" OR "body of published research" OR "study aggregation" OR "study synthesis" OR "critical review" OR "mapping study" OR "mapping literature").* This string had to be adapted to the syntax and restrictions of each database.

The inclusion criteria (IC) and exclusion criteria (EC) is listed in Appendix A.

### 3.3. Threats to Validity

This section shows the validity of the study based on the guideline of [26], categorizing the validity of the study selection, data, and research.

Study Selection Validity. To ensure the identification of relevant studies, 15 articles were reviewed, including secondary and tertiary studies. This review made it possible to adjust the research questions posed and to obtain the key words to construct the search string, as indicated by [20]. The inclusion and exclusion criteria were discussed by the authors based on those used in previous studies and the background information.

Data Validity. The authors decided to search six databases relevant to software engineering. However, the authors are aware that there are other databases relevant to other contexts, which may contain some relevant studies for this tertiary study. On the other hand, journals and conference proceedings are generally evaluated by the databases before being incorporated; therefore, considering Petersen [20], we chose not to use quality criteria in the study. The categorization scheme was proposed from the planning stage based on the research questions. During categorization, one of the authors reviewed randomly to confirm the categorization.

Research Validity. The three authors are familiar with software engineering research topics, and two authors have experience with secondary studies. The study conducted is replicable considering that all the steps followed to reach the results are reported. In addition, the list of secondary studies selected is listed in (Appendix B). The results can be generalized, considering what is indicated in the previous item, as the secondary studies are covered without distinguishing geographical area or time spectrum.

## 4. RESULTS

The selection process was carried out based on the search string applied to the databases considered. In stage 1, 262 articles were identified (see Table A.1 from Appendix A). After stages 2 and 3, 78 secondary studies were selected. To perform the selection, the Parsifal platform was used [27]. In addition, the authors identified 5 articles in additional searches, which were incorporated, leaving 83 articles as selected studies.

For data extraction, which provided the input to develop the research questions, a template of 18 attributes was defined for data extraction (see Table A.2 from Appendix A). The answers to the research question are presented below.

### 4.1. RQ1. What is the evolution of secondary studies on DevOps?

As can be seen in Fig. 1, secondary studies have been published since 2014, and, as of 2016, the number of publications on DevOps has increased. This shows that DevOps research has reached a level of maturity. Likewise, a minimum of 30 secondary studies were considered, and a maximum of 120 primary articles comprising both systematic literature review and systematic mapping study were selected.

About the publications per year, it stands out in the research of [23], about agile practices, which have a similar pattern to the results of publications per year in this study. This makes sense, since DevOps is part of the agile world, the interest in studying DevOps practices is similar to the interest in studying practices in the agile context.

Furthermore, in [23], the number of publications year by year of agile practices is also presented, which have a similar behavior with Fig. 1 of this study. For example, in 2015 no secondary study was found, from 2016 to 2019 there is an increasing number of publications and in 2021 a decrease.

### 4.2. RQ2. What were the main topics addressed in DevOps adoption?

According to Fig. 2, a total of 43 (52%) secondary studies focused on DevOps implementation, i.e., finding best practices and recommendations to achieve a successful DevOps implementation. Then, 10 studies focused on how automation is achieved in DevOps as well as the challenges involved in adopting it in an organization. We also identified 3 studies that focused on the use of machine learning in DevOps contexts. From the above, it can be seen that there are few secondary studies that focus on looking for interaction with other technologies or topics such as IoT, security, quality, which leaves opportunity to increase research on those topics. In addition, some topics that were reported and should be highlighted are the search for challenges and critical success factors. It is also necessary to conduct more research oriented to experiences in the industry and the adoption of DevOps practices and techniques in small business contexts.

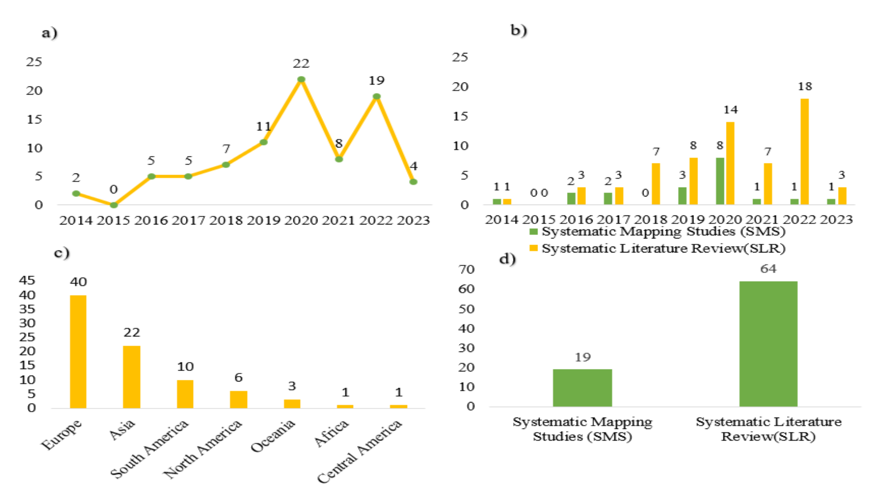


**Fig. 1**. Evolution of secondary studies selected:(a) evolution by year, (b) comparison between SMS and SLR by years, (c) comparison by regions (d) comparison between SMS and SLR

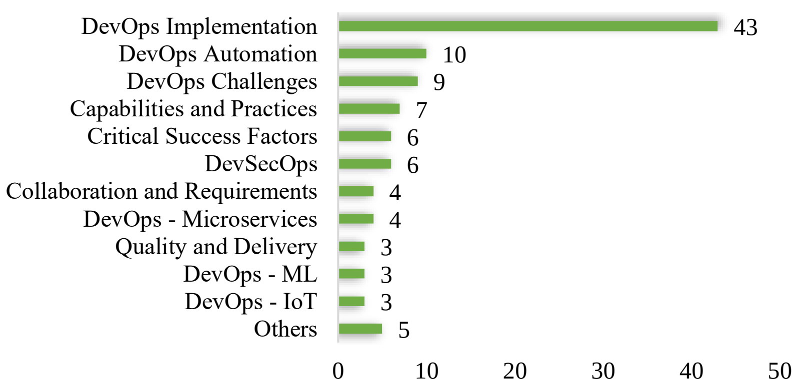


**Fig. 2**. Topics for secondary studies in DevOps

In the tertiary study by [9], using Open Card Sorting method on 41 secondary studies, established a list of terms used in DevOps, being: automation, sharing, measurement, culture, collaboration, quality assessment; those who obtained the highest score. From these terms, automation and collaboration are the most common themes identified in this study.

### 4.3. RQ3. What are the practices used to adopt DevOps?

The results in Fig. 3 reveal that the most studied practices are continuous integration reported in 78 (93%) secondary studies. This is followed by continuous delivery with 77 (92%) studies; continuous monitoring, with 75 (90%) studies; and, test automation, with 62 (75%) studies. In contrast, there are few publications on continuous deployment practices, collaboration, Infrastructure as code (IaaC), continuous feedback, the use of containers, and the security of applications and their infrastructure. All of the above are supported by version control, which is usually included in the tools. Regarding non-technical practices, we found 38 (45%) studies mentioning collaboration and 26 (31%) studies mentioning communication as the most reported practices for DevOps contexts.

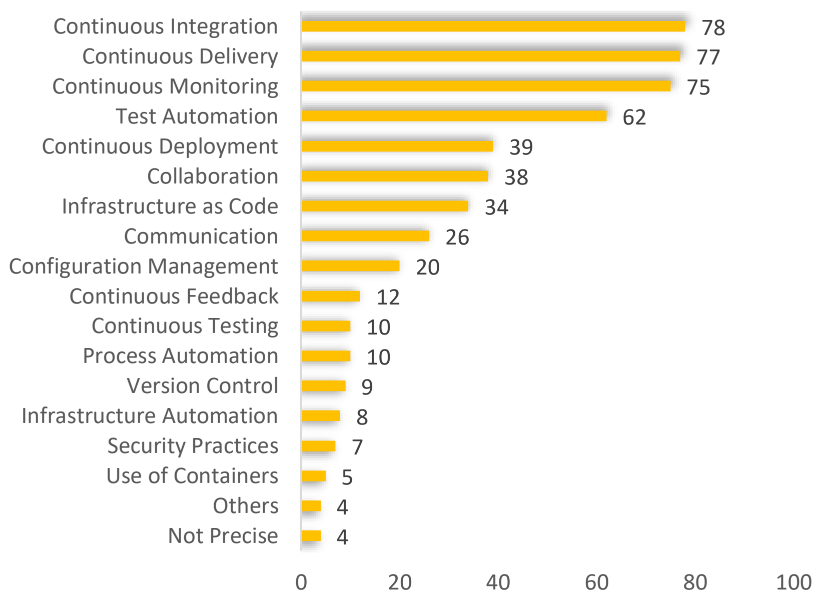


**Fig. 3**. Practices for DevOps according to secondary studies

In this study, all the practices mentioned in each secondary study selected have been recorded, analyzed, taking into account that every study can mention several practices. For [9], the most frequent practices are continuous deployment, software testing and monitoring; which are similar to the practices found in this study. Furthermore, [9] highlights that the use of these practices is a non-negotiable requirement when adopting DevOps.

The study by [23], reports that tests, continuous integration, frequent deliveries and continuous feedback as the most used practices. It also points out that these practices are related to technical aspects and collaboration. These results are similar to what were found in this study.

### 4.6. RQ4. What are the frameworks or approaches used when adopting DevOps?

Regarding the frameworks or approach, a list of techniques used when adopting DevOps is presented in Fig. 4. In particular, 25 (30%) studies mention automation-based approaches, including test automation as well as process automation. Furthermore, in 19 (22%) studies, the term CALMS, which stands for Culture, Automation, Leadership, Metrics, and Sharing, appears as an approach when adopting DevOps. This approach also mentions automation but adds other aspects that are important for adopting DevOps. On the other hand, 15 (18%) studies mention the DevOps maturity model as a method for assessing the maturity of teams working with DevOps and 12 (14%) of the studies mention ITIL. The other secondary studies mention SaFe, CoBIT, SixSigma, DevOps for Microsoft, and others. It should be noted that 2 secondary studies report that they have relied on ISO/IEC 20000 to adopt DevOps.

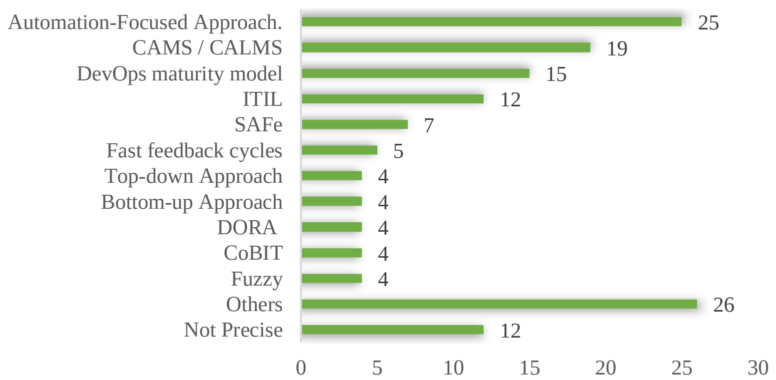


**Fig. 4**. Frameworks used to adopt DevOps according to the secondary studies

In this study, the results show that there are known approaches and frameworks in software engineering that are being applied to DevOps. However, a method for adoption and perform in DevOps has not yet been defined, which is consistent with [9], who points out that there is no widely established methodology in DevOps.

### 4.7. RQ5. What are the tools used in the adoption of DevOps?

According to Fig. 5a, there are several tools that have been used when adopting DevOps. Because DevOps is an automation-based approach, in 73 (87%) studies, the Jenkins tool, which allows automating many routine tasks, is mentioned. However, as alternative tools, Travis with 29 (34%) and AWS Codepipeline with 5 (6%) are mentioned.

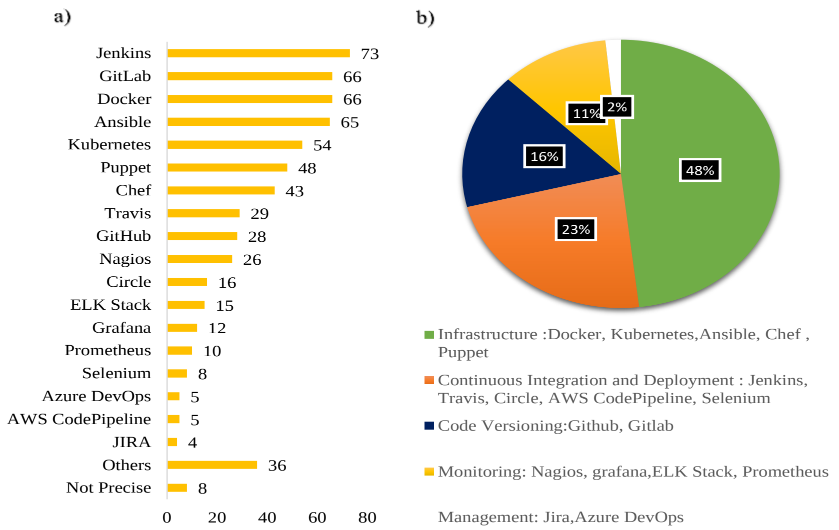


**Fig. 5**. Tools for DevOps according to the secondary studies:(a) Tools used to adopt DevOps,(b) tool categories used to adopt DevOps.

A total of 66 (79%) selected secondary studies mention GitLab as a tool for source code versioning and alternatively Github with 28 (33%). In relation to infrastructure, 66 (79%) studies mention Docker and 54 (65%) Kubernetes. In addition, for infrastructure management, Ansible is mentioned in 65 (78%) studies, Puppet in 48 (57%) studies, and Chef in 43 (51%) studies. Moreover, tools for monitoring have been reported such as ELK Stack with 15 (18%) studies, Grafana with 12 (14%), and Prometheus with 10 (12%).

Some secondary studies report other tools such as Jira, Azure DevOps, or Nagios that support DevOps adoption. In a complementary way, Fig. 5b. shows that several tools support different areas to provide support to the infrastructure as well as for continuous integration and deployment.

According to [18], almost half of the articles found mention that technological tools are the ones that support practices when adopting DevOps. On the other hand, the results of this study show that the most reported tools are Jenkins, Docker, GitLab, ELK Stack. Which confirms what was expressed by [18]. Like [18] and [9], these tools are mostly in continuous integration and deployment activities, as well as monitoring. For [9], the popularity of these tools could generate opportunities to develop skills training to enter the DevOps industry.

### 4.8. RQ6. What is the interest of company managers, and the development and operation teams in adopting DevOps?

In relation to interest of company managers, phrases such as "Organizations chose to adopt DevOps," "The organization gradually embraced the adoption of DevOps," and "The adoption of DevOps in the organization was successful" were detected. The results show that 81 (98%) studies indicate that companies are interested in adopting DevOps. In the other 2%, it could not be determined whether there is of interest or not in adopting DevOps.

In relation to the interest of teams, phrases with words such as “interest,” “acceptance,” or “approval” of the developers or development teams to adopt DevOps were used. The results show that it can be seen that 79 (95%) studies indicate that development and operation teams are interested in adopting DevOps. In the other 5%, it could not be determined whether there is if interest or not in adopting DevOps.

### 4.9. RQ7. What are the agile methods used when adopting DevOps?

Based on the premise that DevOps is based on agile principles and extends them to reach a target, this question shows the most reported agile methods when adopting DevOps. In Fig. 6, it is shown that Scrum and Kanban are the most reported, as Scrum and Kanban are mentioned in 53 (63%) studies each. Moreover, XP is mentioned in 38 (45%) studies, and the Lean approach in 32 (38%). These results reveal that adopting DevOps would not be challenging when teams already work with methods and techniques that are based on agile principles.

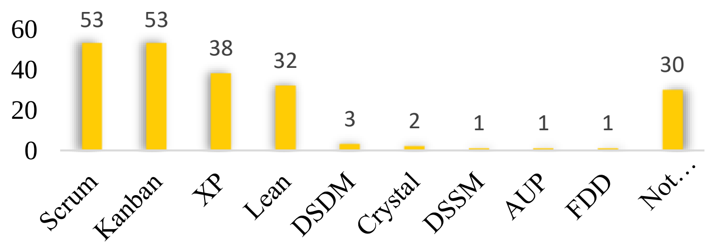


**Fig. 6**. Agile methods to adopt DevOps according to the secondary studies

For [21], Scrum is one of the most reported methods in the articles reviewed in their secondary study, which coincides with the results of this study. Also, in this study, Kanban, XP and Lean are added to the list of methods used, when it comes to adopting DevOps.

### 4.11. RQ8. Is DevOps mentioned as a competitive advantage?

To answer this question, we found phrases such as "software made with DevOps, acquires superiority in the market," "companies that adopt DevOps receive merits and are better positioned in the market". The results reveals that 81 (98%) studies mention

DevOps as an advantage in the organization, which corroborates the results in Fig. 4, as there are multiple benefits that are acquired when DevOps is implemented. The other 2% of the articles reviewed do not mention whether adopting DevOps gives an organization a competitive advantage or not.

From the results of the secondary studies, it can be established that there is a competitive advantage. However, owing to the nature of the secondary studies, it is advisable to design studies, such as surveys, that establish such advantages from the perspective of management.

## 5. CONCLUSIONS

This research presents a tertiary literature study on DevOps. The study is based on the guidance of [20]. In the selection process, 262 studies were found, but 81 were finally selected after the inclusion and exclusion criteria were applied. The selected studies allowed the authors to answer the 11 research questions.

In recent years, secondary studies on DevOps have increased. This shows opportunities to study the application of DevOps in more specific topics such as adoption frameworks, which could be done through a survey. Most secondary studies have struggled to find best practices or recommendations for DevOps adoption. Among the frequently reported practices are continuous integration and delivery, continuous monitoring, and test automation. Non-technical practices include collaboration, communication, and continuous feedback.

To adopt DevOps, the studies reviewed report an automation-based approach, as well as the CALMS framework and the DevOps maturity model. Most of the tools reported are mostly for infrastructure and continuous integration and delivery. Agile methods reported for DevOps adoption include SCRUM, Kanban, XP, and the Lean approach.

Regarding people, it is established that the development and operation teams are well disposed to the adoption of DevOps in their organizations. Regarding organizations, it is established that they do recognize that adopting DevOps represents an advantage for the organization.

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## Appendix A: Tertiary study selected process. URL

## Appendix B: Secondary studies selected. URL

**Note to reviewers**. The appendix below has only been included for peer-review process. The appendix will be available by URL in a camera ready and published version.

# Appendix A: Tertiary study selected process

## Selection Criteria and Process

To select the secondary articles, the following inclusion and exclusion criteria were established.

- IC1. The title and abstract of the article are related to the topic.
- IC2. The study is written in English.
- IC3. The study is a secondary literature research
- EC1. The article is duplicated.
- EC2. The full content of the article is not available.

No quality criteria were established for this study, taking as a reference Petersen's indications. The selected studies were obtained from digital databases that have qualification processes.

The selection process was defined in three stages. The first stage was the extraction of metadata from digital databases. The second stage was the review of abstracts, where IC1, IC2, IC3, and EC1 were applied. The third stage was the rapid content review, where IC2, IC3, and EC2 were applied.

## Selection Process

**Table A.1**. Executed stages in the study

| Source | S0 (Initial) | S1 (EC1) | S2 (IC1, IC2, IC3, EC2) |
|---|---|---|---|
| ACM | 15 | 11 | 9 |
| WOS | 43 | 35 | 20 |
| IEEE | 30 | 12 | 6 |
| ScienceDirect | 15 | 4 | 2 |
| Scopus | 154 | 98 | 40 |
| Willey | 5 | 2 | 1 |
| Total | 262 | 162 | 78 |

**Table A.2**. Data extraction description

| Attribute | Description |
|---|---|
| Source | The study source (Scopus, IEEE, etc). |
| Title | The study title. |
| Authors | The study authors. |
| Year | Publication year of the study. |
| Type | Kind of research (SLR, MSL). |
| Papers reviewed | Number of papers reviewed in the study. |
| Topic | Main topic of the study |
| Practices | Practices mentioned to adapt DevOps |
| Software benefit | Determine if the DevOps adoption benefits are for the software. |
| Company benefit | Determine if the DevOps adoption benefits are for the company. |
| New Method/Tool | Determine if show a new method or tool to adapt DevOps. |
| New Technique | Determine if show a new technique to adapt DevOps. |
| Method | Determine if show a known method is used to adapt DevOps. |
| Definition | Definition of DevOps in the study. |
| Company Interest | Determine if the company interest and acceptance to adapt DevOps is mentioned. |
| Team Interest | Determine if the Dev and Ops teams show interest and acceptance to adapt DevOps. |
| Agile method | Determine what agile method are mentioned to adapt DevOps. |
| Competitive Advantage | Determine if adoption DevOps is mentioned as a competitive advantage to the company. |

## Appendix B: Secondary studies selected. URL


[S01] S. Rafi, M. A. Akbar, A. A. AlSanad, L. AlSuwaidan, H. Abdulaziz AL-ALShaikh, and H. S. AlSagri, “Decision-Making Taxonomy of DevOps Success Factors Using Preference Ranking Organization Method of Enrichment Evaluation,” Math Probl Eng, vol. 2022, pp. 1–15, Jan. 2022, doi: 10.1155/2022/2600160.

[S02] M. A. Akbar, S. Mahmood, M. Shafiq, A. Alsanad, A. A.-A. Alsanad, and A. Gumaei, “Identification and prioritization of DevOps success factors using fuzzy-AHP approach,” Soft comput, vol. 27, no. 4, pp. 1907–1931, Feb. 2023, doi: 10.1007/s00500-020-05150-w.

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