Master of Science in Software Engineering
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# Adopting DevOps in Agile

## Challenges and Solutions

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The authors declare that they are the sole authors of this thesis and that they have not used any sources other than those listed in the bibliography and identified as references. They further declare that they have not submitted this thesis at any other institution to obtain a degree.

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# Abstract

**Background.** DevOps is a hot topic in recent years. It emphasizes the combination of development and operation. Agile is one of the most popular development methods, but Agile mainly focused on software development part, there is no more involvement in deployment and operations. In this case, many companies consider adopting DevOps in Agile to attempt to improve the situation.
**Objectives.** The combination of two different technologies is bound to produce some challenges, whether it is for practitioners or researchers, it is very important to find these challenges and mitigate them, so this article aims to investigate the challenges of adopting DevOps in Agile, then through the systematic literature review and survey questionnaire to determine the corresponding mitigation strategy. Then, in order to detail understand the process of adopting DevOps in Agile, we use interview to research the real process of adopting DevOps in agile.
**Methods.** According to our research question, we used the systematic literature review(SLR), survey questionnaire and interview as our research methodology. Through literature review, we collected data of adopting DevOps in Agile, and summary the challenges and its relevant mitigation strategies. Then survey questionnaire helped us linking the content of literature to the industry, and compare their difference. Through the interview, we explored the actual process of adopting DevOps in Agile in industry, and correspond the challenges to the actual process.
**Results.** Our study summarized the software development process of adopting DevOps based on Agile and revealed 23 challenges and corresponding mitigation strategies. The report also compares the commonalities and gaps between the results from the literature and the findings of real-life adopting of DevOps challenges and mitigation strategies.
**Conclusions.** In this article, we introduced the challenges and corresponding mitigation strategies for adopting DevOps based on agile and summarize the corresponding software development process. The obvious challenges and mitigation strategies were divided into four categories: 1) People 2) Project 3) Process 4) Organization, after which we conducted further discussions based on the actual conditions and compared the results of systematic literature review and the results of questionnaire to detail explore their difference.

**Keywords:** DevOps, Agile, Development Process, Systematic Literature Review

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# Chapter 1

# Introduction

DevOps is a hot topic in software industry recent years, there are plenty of reports about DevOps on the internet, most of them have shown a very positive attitude, but what is DevOps? Ambler defined that DevOps is an effective collaboration between development teams and operations teams by incorporating the processes [1], while DeGrandiss suggested that DevOps means applying agile processes to operational activities [2]. In general, the term DevOps is a combination of development teams and operations teams (or Developers and Operators) [3], and its purpose is bridging the gap between development teams and operations teams [4].

In order to facilitate understanding and discussion in this thesis, we selected the definition by Jabbari et al.: DevOps is a development methodology aimed at bridging the gap between Development and Operations, emphasizing communication and collaboration, continuous integration, quality assurance and delivery with automated deployment utilizing a set of development practices [3].

Agile is currently one of the most popular development methods. It was adopted by many companies, but Agile mainly focused on software development part, and the part of deployment, operation and maintenance always responsible by product operations team or outsourcing company [5]. Using Agile without addressing deployment and operations can cause serious problems [5] and even hinder new features from being presented to users as quickly as possible [6]. In this case, many companies consider adopting DevOps in Agile to attempt to improve the situation [5, 6, 7, 8].

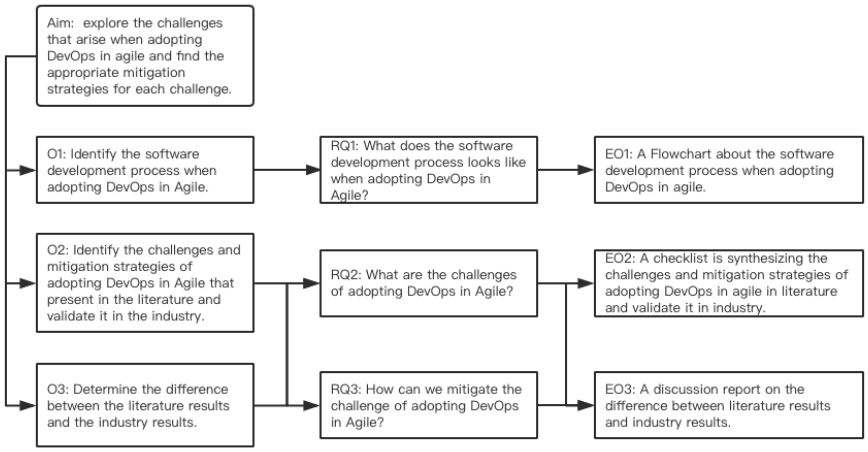
Although DevOps is very promising to eliminate the gap between development and operations, passing this method is not easy. At present, some companies using DevOps in Agile have encountered some problems [9, 10, 11, 12, 13]. However, because of each company's nature, scale, infrastructure, and automation level are different, the challenges they face will be quite different. However, we can get inspiration from our predecessors' experience and actual production to deal with the problems or prepare in advance.

## 1.1 Aims and Objectives

This article aims to explore the challenges that arise when adopting DevOps in agile and find the appropriate mitigation strategies for each challenge.

From figure 1.1, we can see the objective and research questions:

Figure 1.1: Aims, Objectives, Research Question and Expected Outcomes




In this process, we first need to realise how companies adopting DevOps in Agile. At the same time, we need to explore the challenges and mitigation strategies of adopting DevOps in agile both in the literature and industry, then analyzes their differences.

In order to achieve this aim, we have the following objectives:

- O1: Identify the software development process when adopting DevOps in Agile.
- O2: Identify the challenges and mitigation strategies of adopting DevOps in Agile that present in the literature and validate it in the industry.
- O3: Determine the difference between the literature results and the industry results.

## 1.2 Research Questions

In order to achieve our goals, we will develop the following research questions:

- RQ1: What does the software development process looks like when adopting DevOps in Agile?
- RQ2: What are the challenges of adopting DevOps in Agile?
- RQ3: How can we mitigate the challenges of adopting DevOps in Agile?

## 1.3 Expected Outcomes

The expected outcomes of this thesis are these three points:

- EO1: A Flowchart about the software development process when adopting DevOps in agile.

- EO2: A checklist which is synthesizing the challenges and mitigation strategies of adopting DevOps in agile in literature and validate it in industry.
- EO3: A discussion report on the difference between literature results and industry results.

## 1.4 Structure of Thesis

Section 1 is the introductory section where we will explain in detail the purpose and objectives of the study, and then we will present research questions and expected outcomes. Section 2 is mainly for related work, we will separately introduce agile, DevOps and adopting DevOps in agile; Section 3 is research methodology, for our research questions, we will use systematic literature review and survey to answer questions 2 and 3, and use interviews to answer question 1. The research result will be presented in section 4, the analysis and discussion will be shown in Section 5. Section 6 is validity threats, we will describe the validity threats of SLR, survey and interview. Section 7 mainly responsible for conclusion, contribution and future work.

# Chapter 2

# Related Work

More and more organizations tend to use Agile in the development process [14], but generally, Agile mainly focused on the development part, and they mainly responsible for software delivery [15, 16]. It is not good at the part of deployment and operations. The emergence of DevOps seems to be making up Agile's inadequate of operation and deployment aspects. But currently, there is little research on the combination of Agile and DevOps, and some research only involves the use of DevOps challenges without corresponding mitigation strategy, some research only focused on the part of DevOps, such as continuous deployment or continuous integration, not involved other factors of DevOps, and some research only focused on special industry. Therefore, in related work, we reviewed the existing literature on agile and DevOps, then explained the gap between existing research and our research.

## 2.1 DevOps

Diel et al. [10] research focus on the use of DevOps in distributed agile teams, which define communication challenges (geographic distance, socio-cultural distance, time distance) and its mitigation strategies (frequency, direction, shape, content). But their study only involved the communication challenges.

Lwakatare et al. [11] mainly studied the challenges of using DevOps in the embedded system. The study was conducted through agile development methods and continuous integration practice, but there was not much involved in how DevOps was applied to agile.

Perera et al. [17] researched the relationship between quality, responsiveness to business needs, agility and DevOps implementation. And then identified the challenges and its mitigation strategy. But their research only aimed at Sri Lankan's Software Development Organizations.

In addition, Smeds et al. [12] provided some insight into the hindrances of adopting DevOps in initial stages. Riungu-Kalliosaari et al. [13] did a case study to research the DevOps benefits and challenges but they didn't give the solutions. Bang et al. [8] researched how knowledge, skills, and abilities support DevOps and analyze with Scrum. Airaj [6] through the cloud DevOps to overcome the obstacles of using DevOps in software development process.

Since DevOps is a novel concept, there is little research in this area, especially the combination challenges of Agile and DevOps, or some researchers only focused on its challenges and did not provide the relevant mitigation strategy.

With Agile and DevOps were used more and more frequently, many organizations have begun to try to combine Agile and DevOps. And we will analyze the existing literature, summarize the challenges and mitigation strategies, through the survey questionnaire to investigate industrial perspective, then compare the results between the literature and the industry.

## 2.2 Agile

Agile is a general term for a variety of development methods that follow agile thinking. Agile aims to increase the efficiency and flexibility of software development and try to avoid unnecessary documentation and unproductive work [18]. Agile was first used in small-scale organizations, but in recent years it has also been implemented in large scale organizations and projects, also include distributed software development. This change was also reflected in the articles of adoption of agile methods.

In previous years of studies, agile methods have shown to increase customer satisfaction and provide flexible responses to possible problems in the development process. It's also proven to effectively improve project success rates [19].

A. Cockburn and J. Highsmith [20] mentioned that some agile practices emphasize the human factor, and agile development pays more attention on the technique and skills of singles. L. Cao et al. [21] thought that understanding the roles and responsibilities of the people involved in Agile is important in order to the success of the project. Conboy et al. [22] found that some developers are scared of Agile methods because they are reluctant to expose their own technical flaws.

In addition, Asnawi et al. [23] believes that when manager's mind turns to Agile direction it's more conducive to Agile implementation and process improvement. There is a similar view in Tolfo et al. [24] paper, they have an idea that if Agile wants to be successfully implemented, then participants' thinking must be subordinated to agile principles. If participants only familiar with agile processes, but their thinking cannot accept the principle of agile, that this generally leads a result that this organization is not very willing to adopt agile methods[22].

## 2.3 Adopting DevOps in Agile

More and more people are concerned about Agile and DevOps, and many companies in their project development process also tend to use Agile [24]. But with the continuous development of the software industry, in a short time to the product to market, while maintaining quality, customer expectations and the use of new technology have become the mainstream [8]. Actually, Agile enables fast delivery of software, but it

cannot deployment and operational as soon as possible [6].

The agile team mainly has three roles: product owner, master and development team [25]. In the common situation, the development team members need responsible for the development and test. And in order to make their new features or modify part sends to the customer as soon as possible, they need a special operations team [5].

In this case, for solving these questions, many companies consider adopting DevOps to try to improve the situation [6, 7, 8]. DevOps is a development approach designed to bridge the gap between development and operations [18]. One benefit of DevOps is the accelerated feedback loop [13]. With timely feedback from the end-users, software developers deliver products that may be more satisfying and even surprising [15].

Despite DevOps is very hopeful for eliminating the gap between development and operations, adopting this methodology in Agile could not be very easy. For example, when agile methods are expected to be adopted, amount of redesign for maintenance work process is commonly necessary, and all studies point that is difficult to implement [26].

We researched other challenges and mitigation strategies related to adopting DevOps. Shahin et al. [27] distinguishes the challenges of continuous delivery(CDE) and continuous deployment(CD), and investigates some of the limitations and factors that have shifted from CDE to CD. Nonetheless, they only focused on the CDE and CD part, not involved other factors of DevOps, and they did not specify which development method this transition from CDE to CD was aimed at. Yiran et al. [28] studied the challenges and mitigation strategies of the use of DevOps, but their research focused on the whole development process, not only for agile. Lucy et al. [11] conducted a multi-case study of four companies, introduced the concept of DevOps adopting of the embedded systems field, and then determined the key challenges that DevOps adopted. However, they only focused on embedded systems field. Laukkarinen et al. [29] studied the challenges of adopting DevOps in Agile, but the challenges were aimed at medical standards, the scope was greatly limited. Authors confirmed that DevOps is not well-suited to some standards of medical criteria, it needs to improve the process of DevOps.

We also analyzed the existing systematic literature review(SLR), but there is little existing systematic literature review used to describe the challenges and mitigation strategies of adopting DevOps in Agile. Table 2.1 displays the differences between their articles and our articles: The first article focuses on the process from agile to DevOps. It just mentions some of the challenges that their company has encountered and has not conducted an in-depth analysis. The second article concentrated on the challenges of adopting continuous deployment. The third article used SLR to define the DevOps, and uses an interview to identify the challenges. And the last one, it focuses on all development methods, not just agile.

Table 2.1: The Existing SLRs

| No. | ArticleArticle | DescriptionDescription |
|---|---|---|
| 1 | From Agile Development to DevOps: Going Towards Faster Releases at High Quality Experiences from an Industrial Context [30] | Their article focused on how to from Agile to DevOps. Mainly listed some of the problems encountered by their own companies and through the report of the other two companies discussed the objectives, strategies, development and operation cooperation and the impact of architecture. Our paper focuses on all the challenges and mitigation strategies from agile to DevOps. |
| 2 | On the journey to continuous deployment Technical and social challenges along the way [31] | These article focused on the challenges of adopting continuous deployment. DevOps includes continuous integration, continuous deployment, continuous delivery, etc. Continuous deployment is only part of it. |
| 3 | DevOps: A Definition and Perceived Adoption Impediments [12] | Through literature review, they define the concept of DevOps, then use interview identified some early stage challenges. |
| 4 | The challenges and mitigation strategies of using devops during software development [28] | They studied the challenges and mitigations of the usage of DevOps, but their research focused on the whole development process, not only for agile. |

# Chapter 3

# Method

Refer to our research question, we plan to use interview, systematic literature review(SLR) and survey questionnaire as our research methodology. Through the interview, we can explore the real process of adopting DevOps in agile, through a systematic literature review, we can collect data of the adopting DevOps in Agile, and summary the challenges and its relevant mitigation strategies. The survey questionnaire can help us linking the content of literature to industry, and compare their difference. The following Table 3.1 shows each research questions and the relevant methodology:

Table 3.1: Research Question and its relevant Methodology

| **ResearchResearch QuestionQuestion** | **DescriptionDescription** | **Methodology** |
|---|---|---|
| RQ1 | What is the software development process looks like when adopting DevOps in Agile? | Interview |
| RQ2 | What are the challenges of adopting DevOps in Agile? (In Literature) | Systematic Literature Review |
| | What are the challenges of adopting DevOps in Agile (In Industry) | Survey Questionnaire |
| RQ3 | How can we mitigate the challenges of adopting DevOps in Agile? (In Literature) | Systematic Literature Review |
| | How can we mitigate the challenges of adopting DevOps in Agile? (In Industry) | Survey Questionnaire |

## 3.1 Systematic Literature Review

### 3.1.1 Why choose Systematic Literature Review

Systematic literature review is a kind of method of identifying all available relevant information from other scholarly papers to a specific research question [32]. In this paper, we use the systematic literature review to help collect the papers published

so far about our research questions. We are located in the process of systematic literature review proposed by Kitchenham: Planning review, conducting review and reporting the review [32].

During the planning stage, we identified the research issue. Then, we will customize some limiting factors to screen the papers to ensure that the accuracy of the information.

The common reasons to choose Systematic literature review are it can summaries the existing challenges and mitigation strategies and identify the gap between the previous research and ours, to appropriately position further research activities [32].

Since our research questions are focused and precise, and our findings need to be evidence-based, therefore, in this case, systematic literature reviews are more accurate than systematic mapping studies(SMS) and literature reviews(LR) [33].

In our researches, RQ2 and RQ3 all need to use SLR to determine the challenges and the applicable mitigation strategies of adopting DevOps in Agile in the literature. It can enable us to understand the pertinent knowledge and make us summarize the existing evidence clearly.

### 3.1.2 Necessity of the Review

After we conducted a preliminary paper search, we found that there are few system literature reviews about adopting DevOps in Agile, and most of the research is still at exploratory stage, such as explore the DevOps challenges and mitigation strategies for a certain company or an industry. For example, Smeds et al. predicted the possible obstacles from three perspectives when the organization adopted DevOps [12]. However, the author did not provide corresponding solutions. In addition to Smed et al.'s research, some companies have encountered some problems in DevOps, and we have collected them on our list. So, in order to fully understand the challenges and mitigation strategies of adopting DevOps in the Agile, we need a systematic literature review to explore current research status and weaknesses, and summarize the current challenges and mitigation strategies in the literature.

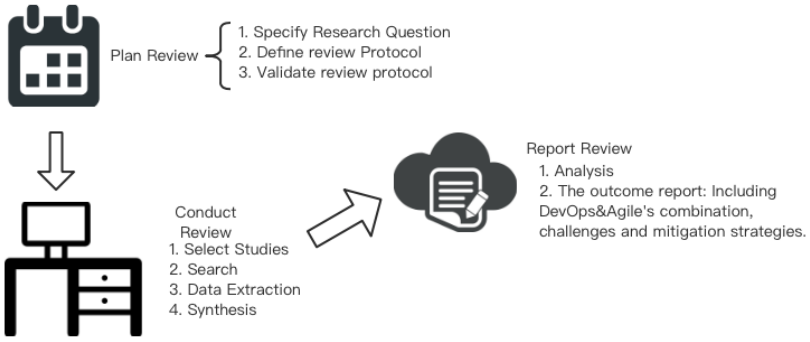
### 3.1.3 Research Process

As it showed before, Kitchenham et al. [33] defined the review process of three steps:

- Planning the review
- Conducting the review
- Reporting the review

And Figure 3.1 shows the whole process:

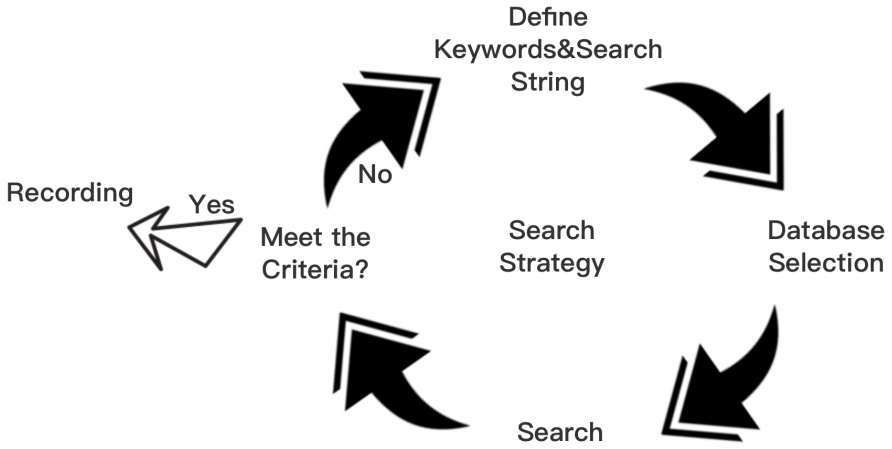
Figure 3.1: Systematic Literature Review Process




### 3.1.4 Search Strategies

Search strategies of this research mainly followed by Kitchenhama guideline [32], and we will show the detail process on Figure 3.2:

Figure 3.2: Search Strategies



### 3.1.5 Search String and Keywords

In order to find the appropriate literature to answer our research question, we need to define the appropriate keywords and search strings. We use the keyword and its synonyms and alternative terms, then limit them in the context of software engineering. We also checked the usual terms of DevOps and Agile to ensure that some important keywords are not missing. We use the Boolean operator "And" and "Or" to form a search string and render it in Table 3.2:

Table 3.2: Search String:((A1 OR A2 OR A3 OR A4) AND (B1 OR B2 OR B3) AND (C1 OR C2 OR C3 OR C4))

| ID | Keywords |
|---|---|
| A1 | DevOps |
| A2 | Continuous Delivery |
| A3 | Continuous Integration |
| A4 | Continuous Deployment |
| B1 | Agile |
| B2 | Scrum |
| B3 | Kanban |
| C1 | Challenge |
| C2 | Problem |
| C3 | Mitigation |
| C4 | Solution |

In this table, due to Scrum and Kanban are the most representative and extensive method in Agile, considering that many papers written about adopting DevOps in Scrum or Kanban directly, so choose Scrum and Kanban as a synonym for Agile. And due to continuous integration and continuous deployment is the core technology of DevOps [34], so we also use continuous integration and continuous deployment as DevOps's synonym.

### 3.1.6 Database Selection

The search of literature mainly from the following databases: ACM Digital Library, Web of Science, Wiley Online Library, IEEE Xplore, Scopus, Springer. Table 3.2 statistics the number of research papers from different databases. And we mainly use Zotero to manage the reference.

### 3.1.7 Selection Criteria

Since DevOps is a relatively new concept, there are not many academic papers related to DevOps. In order to ensure that no critical articles are missed, we set the following criteria:

- Studies that provide full text

- Studies that wrote in English
- Peer-reviewed studies
- Studies that focus on adopting DevOps in Agile
- Studies that contents the challenges or mitigation strategies of adopting DevOps in Agile

And our research excludes the following criteria:

- Studies that not available for full text
- Studies that not wrote in English
- Not peer-reviewed studies
- Duplicates studies
- Proceeding studies
- Studies that were only involved Agile or DevOps

### 3.1.8 Quality Assessment

For those papers that meet our inclusion/exclusion criteria, we further apply the following quality assessment criteria. The criteria's design is based on the Database of Abstracts of Reviews of Effects(DARE) in York University's Centre for Reviews and Dissemination (CDR) [35].

- Search Adequate: Does our systematic literature search cover all relevant research?
- Research Process: Has the basic data and process of the study been adequately described?
- Research Result: Does the study has a sound research process that illustrates the challenges and mitigation strategies of adopting DevOps in agile?
- Research Quality: Is the validity and quality of the study evaluated?

### 3.1.9 Data Extraction

In order to obtain valid data during the systematic literature review, we designed Table 3.3, which shows the data extracted from each study:

Table 3.3: Data Extraction Form

| Data Extraction |
|---|
| Data source and references |
| Article title and keywords |
| The author's name and organization |
| Publication date and publication location |
| Research Method Type (SLR, Case Study, Experience, Interview, Survey) |
| Researcher type: Researchers or industry personnel |
| Main research questions and conclusions |
| Validity threats and research limitations |
| What are the challenges to adopting DevOps in agile and how to mitigate them |

The two authors extracted the articles separately and conducted a unified inspection after the extraction was completed. When the disagreement occurred in the extraction process, the two authors state their opinions and discuss each other until the opinions are unified.

### 3.1.10 Data Analysis

We have obtained a total of 22 major studies used to the systematic literature review. The data is shown below:

- The number of effective studies adopting DevOps in Agile (addressing RQ2 and RQ3).
- The challenges of adopting DevOps in agile (addressing RQ2).
- How to mitigate the challenges of adopting DevOps in agile (addressing RQ3)?

### 3.1.11 Complete Steps in SLR

We use Evernote to manage the references in this study. The following is our steps of the systematic literature review: 1. First, keyword search was conducted on the database and the list of papers was sorted out and distributed to the two researchers. The search string is displayed in the preceding Table 3.2. A total of 313 related papers were obtained. 2. The author screens paper according to the Inclusion/exclusion criteria. There are many papers discussing other fields, such as medicine, pedagogy. DevOps only mentioned in some context. So we chose to explore through the abstract, introduction and conclusion parts of each article. Highly relevant papers were excerpted from the content. 3. After step two, we got 22 papers that meet the requirements. And these 22 papers were analyzed and reviewed in detail, based on the extracted data, we obtained the challenges and mitigation strategies of adopting DevOps in Agile.

## 3.2 Survey Questionnaire

### 3.2.1 Why choose Survey Questionnaire

Kitchenham et al. defined that survey is a comprehensive research method for collecting information to describe, compare or explain knowledge, attitudes and behavior [36], it aims to generalize the opinion of a large population by interviewing a representative sample of the predetermined population.

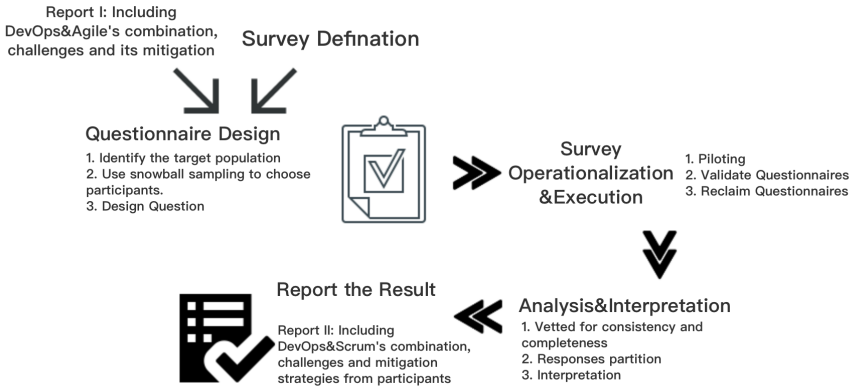
In our study, the challenges and mitigation strategies have already been found in the literature, in order to explore the realities of the industry, we need to communicate with DevOps employees, identified the challenges and mitigation strategies in the industry. Our research questions aim to results for a large sample of the population, so survey questionnaire was acted as the appropriate research method.

### 3.2.2 Research Process

In order to explore the challenges and mitigation strategies of adopting DevOps in agile in the industry, we plan to use the survey questionnaire to collect the data. The research process mainly has six steps by Kitchenham et al.: Survey definition, design the survey, operationalization, execution, analysis and interpretation and Reporting [36].

Against to our research, we mainly use the systematic literature review's outcome and the survey definition to design the questionnaire. Figure 3.3 shows the survey process:

Figure 3.3: Survey Questionnaire Process




### 3.2.3 Questionnaire Design

#### Form of Data Collection

In this process, we use Google Forms to post surveys and retrieve data(Appendix C: Questionnaire Forms).

#### Population of the Study

Since we aim to find the challenges of adopting DevOps in Agile, our target population is:

- Agile related practitioners.
- DevOps related practitioners.

We posted a questionnaire on the DevOps platform and asked friends in the software industry to help spread. In order to make the results more valuable, we designed a question in our questionnaire is asking if they know DevOps. If participants did not know the meaning of DevOps, and after they see the definition, they still think that they have never used it before, the participants will not be allowed to enter the next topic.

#### Demographic Information

The basic information section of the questionnaire contains five demographic questions. These questions focus on the interviewees basic information, work experience and background. The questions are as follows:

- Which country are you from?
- How many years have you worked in software field?
- What is your role when you work?
- Size of your team?
- What is the type of your products/domain?

### 3.2.4 Survey Question

The survey question is based on the results of a systematic literature review and the definition of the survey. The goal of the survey is to answer RQ2 and RQ3, and capture information to see if the challenges in the SLR can be confirmed from the industry, and obtain other possible challenges and mitigation strategies.

Except the first part of demographic information, the remaining survey questions consist of five parts: DevOps basic, adopting DevOps, adopting DevOps challenges, adopting DevOps mitigation strategies and additional questions. DevOps basic and adopting DevOps describes the definition of DevOps to ensure that participants understand this area and exclude those who have not previously used DevOps.

The purpose of adopting DevOps challenges section is to investigate what questions the interviewee has encountered. The options list some of the results we obtained in the systematic literature review, that is, questions that may arise when adopting DevOps in Agile, and ask if any other challenges have been encountered.

The purpose of the adopting DevOps mitigation strategies section was to investigate what strategies the interviewees had adopted for the problems they had encountered. The options listed included some of the results we obtained in the SLR, that is, the mitigation strategies we faced in the challenges and asked whether there are other solutions.

Both of these sections are set as multiple options. In order to increase the reliability of the questionnaire, understand the impact of DevOps on employees and help improve the questionnaire, we also designed the following additional questions:

- What do you think of adopting DevOps in agile?
- Do you think DevOps has a good impact or a bad impact on your work?
- Any thing you want to talk about this questionnaire?

### 3.2.5 Survey Piloting

First, we designed the questionnaire based on the results obtained from the SLR and then filled in the questionnaire by ourselves to modify the questionnaire. We strived to make the question easy to understand and to simplify the question format as much as possible to reduce the respondents' resistance to respond to the questions.

After the design was completed, we have sent the questionnaire in advance and get feedbacks. The feedback includes reorganizing the classification of questionnaire questions and adding explanations of the questions. Based on feedback from tutors, we added some additional questions, such as an understanding of the type of products/domain.

Finally, after repeated modifications, we finalized the final questionnaire.

### 3.2.6 Quality Assessment

The validity of the questionnaire is an important indicator of the quality of the questionnaire. First, the formulation of the questionnaire was designed and discussed by the two authors, and the questionnaire was then sent to colleagues or friends who had DevOps knowledge or experience and improved the questionnaire based on their suggestions and comments, then we sent the new version to our supervisor for further improvement. We designed the following standards to ensure the questionnaire's quality:

- Define and explain some concepts before the problem;
- Use a simple language to clearly define the problem;
- The option settings are as complete as possible and easy to understand;
- One question at a time, and one answer at a time;

After making adjustments to the questionnaire based on feedback, we are ready to send the survey to factory personnel with experience in DevOps and Agile to investigate. Since one of the author's internship units is also trying to use DevOps for development, the questionnaire was first sent to the company's management and development operations staff and disseminated through them.

Before the questionnaire was disseminated, we interviewed some participants to find out whether the question and structure of the questionnaire were reasonable. Most of the participants said that the questionnaire is easy to understand, they can clearly understand the meaning of the question and answer it, but two participants think that the setting of the challenges and mitigation strategies is confusing and not easy to correspond. So we numbered the challenges and then match the order of mitigation strategies with challenges.

## 3.3 Interview

### 3.3.1 Why choose Interview

In order to figure out the actual process of adopting DevOps in agile, and correspond the challenges with the actual process, we chose interview as our research method. Through interviews, we can summarize the opinions of large groups from representative samples of specific populations. In the process, we hope to get some general information and opinions to help us to conduct research and improvement.

In order to ensure that the interviews more coherent and interactive, we chose semi-structured interviews. Because of the semi-structured interviews, based on respondents' responses, we may design new issues to facilitate the acquisition of information. In addition, direct communication of this language allows us to establish a rapport with respondents to improve the quality of the answers [35].

### 3.3.2 Interview Execution

In order to respond to RQ1, we concluded our analysis of data collected from interviews with 9 practitioners from four companies in three countries. Interviews are semi-structured and there are 6 open questions.

Since we and all interviewees are located in different regions of the world, and there is also a problem of jet lag, so we did not conduct face-to-face interviews. We first sent our questions to the participants via email to help them understand the issues and clearly state their opinions, then conduct interviews via Skype.

The interview was conducted by two authors. One of them is responsible for the interview, and the other is responsible for a simple record of the results of the interview. The results of the record are used for analysis and discussion after the end of the interview.

During the interview process, we adjusted some questions based on the respondents' feedback and designed new questions based on respondents' responses in order to explore this part more deeply.

All interviews were audio-recorded and transcribed for further analysis. We promised to all interviewees that the contents of the interviews are confidential, including the audio, audio transcription and personal information.

### 3.3.3 Interview Process

The interview process has four steps:

- Explained Objectives: We explained the objectives of our research to respondents and ensured that all data were used for research and did not disclose personal privacy.

- Basic Information: We describe Agile and DevOps terms for interviewees, and then ask respondents to introduce themselves to their fields and current work.

- Questions and Answers: Ask the participants questions and design new questions based on participants' responses, such as the key point to the combination of agile and DevOps, how to drawing their process's flow chart, the role of some iterations, the duration of the iterations, or the effectiveness, substitutability, etc. of some third-party tools.

- Additional Questions: Discuss with the participants a simple record of the interview process to ensure the accuracy of the results. Ask the interviewee, if there are any comments or questions that they need us to know. Then, end the interview and thank the participants.

### 3.3.4 Interview Questions Formulation

We aimed to identify the software development process when adopting DevOps in Agile, and respondents were asked the following six questions:

- Generally speaking, what roles will be involved when you start work with DevOps?

- What are the steps or stages in an iterative cycle?

- How do Developments and Operations coordinate work?

- Will you use third-party tools to help you to work?

- Are there any comments or questions that you like us to know?

### 3.3.5 Participants

We used a purposive sampling strategy [37] to determine respondents. We mainly identified potential participants through our personal social network. These people are mainly working in companies using DevOps. We analyzed the basic information of these people to make sure they have sufficient experience and expertise to help us to conduct the study. We contacted them through friends and colleagues, then emailed them an interview invitation. In order to prevent too much bias in the results of the interviews, we chose respondents from different organizations with different roles and areas and sizes. And we have used Snowballing technique [38] to raise the number of participants, we always asked people to introduce potential interviewees when we finished the interview.

# Chapter 4

# Results

## 4.1 Result of Systematic Literature Review

### 4.1.1 Search Result

In section 3.1, we defined the keywords and the search string, selected the database and identified the selection criteria. In this section, we will show the search result of systematic literature review in Table 4.1:

Table 4.1: Search String and Result

| **Database** | **Search String** | **Papers** |
|---|---|---|
| ACM digital library | ("devops" OR "continuous integration" OR "continuous deployment" OR "continuous delivery") AND ("scrum" OR "agile" OR "kanban") AND ( "challenge" OR “problem” OR “mitigation” OR “solution” ) | 34 |
| IEEE Xplore | (devops OR continuous delivery OR continuous deployment OR continuous integration ) AND (scrum OR agile OR kanban) AND (challenge OR mitigation OR problem OR solution) | 22 |
| Springer | ("devops" OR "continuous integration" OR "continuous delivery" OR "continuous deployment" ) AND (agile OR scrum OR kanban) AND (challenge Or problem Or mitigation Or solution) | 69 |
| Scopus | TITLE-ABS-KEY ( ( "devops" OR "continuous integration" OR "continuous delivery" OR "continuous deployment" ) AND ( agile OR scrum OR kanban ) AND ( challenge OR problem OR mitigation OR solution ) ) | 116 |

| | | |
|---|---|---|
| Web of Science | ("devops" OR "continuous integration" OR "continuous delivery" OR "continuous deployment" ) AND (agile OR scrum OR kanban) AND (challenge Or problem Or mitigation Or solution) | 65 |
| Wiley Online Library | ("devops" OR "continuous integration" OR "continuous delivery" OR "continuous deployment" ) AND (agile OR scrum OR kanban) AND (challenge Or problem Or mitigation Or solution) | 67 |
| **Total** | | **313** |
| Duplicates Article (Automatic) | | -105 |
| Duplicates Article (Manual) | | -3 |
| No English | | -4 |
| Irrelevant | | -80 |
| No Full-Text | | -17 |
| No Peer-review | | -12 |
| Remove Proceeding | | -13 |
| Not belong to SE | | -3 |
| **Remaining** | | **76** |
| Remove after full-text reading | | -54 |
| **Total** | | **22** |

From the first review, we found a total of 313 papers, and then removed 108 duplicate papers through automatic and manual inspections. Four other articles were not in English, 80 papers were only involved one or two parts of our research questions. Due to Springer, Web of Science and Wiley Online Library have some book chapter, they cannot be obtained full-text, so 17 articles were eliminated, 12 papers were not peer-reviewed, 13 papers were proceedings, and 3 papers were not in the field of software engineering, these papers were removed. In the end, 76 papers were left for further review. After the full-text inspection, we excluded the 54 papers that not explicitly involved adopting DevOps in agile, and left 22 studies in the end.

The selection process was divided by two authors for review. During the review process, any papers involving adopting DevOps in Agile were identified as potentially relevant and documented. After the initial review, a subsequent review of potentially relevant papers was conducted to obtain accurate results.

In order to obtain clear and accurate results for SLR, we have designed the following Table 4.2. Papers that meet the screening criteria will be recorded. Some papers only address the challenge of adopting DevOps, but no corresponding miti-

gation strategy; Some papers are specifically aimed at a certain issue and propose corresponding mitigation strategies, so we will use "O" to represent that the paper involved related content, and use "X" to indicate that the paper does not involve related content. [1]

Table 4.2: Systematic Literature Review Result

| No. | Year | Title | Challenge | Mitigation |
|---|---|---|---|---|
| S1 | 2017 | On Continuous Deployment Maturity in Customer Projects | O | O |
| S2 | 2015 | DevOps Meets Formal Modelling in High-criticality Complex Systems | O | O |
| S3 | 2017 | Software Specification and Documentation in Continuous Software Development: A Focus Group Report | O | O |
| S4 | 2017 | Specification in Continuous Software Development | O | O |
| S5 | 2014 | Introduction of Continuous Delivery in Multi-customer Project Courses | O | X |
| S6 | 2017 | DevOps in Regulated Software Development: Case Medical Devices | O | O |
| S7 | 2017 | Deployment Specification Challenges in the Context of Large Scale Systems | O | X |
| S8 | 2017 | Factors inhibiting the adoption of DevOps in large organisations: South African context | O | O |
| S9 | 2016 | Towards DevOps in the Embedded Systems Domain: Why is It So Hard? | O | X |
| S10 | 2018 | Using Analytics to Guide Improvement During an Agile/DevOps Transformation | O | O |
| S11 | 2017 | Continuous Delivery: Overcoming adoption challenges | O | O |
| S12 | 2017 | A qualitative study of DevOps usage in practice | O | X |

[1] "O" means Yes, "X" means No

| | | | | |
|---|---|---|---|---|
| S13 | 2016 | Evaluating the impact of DevOps practice in Sri Lankan software development organizations | O | O |
| S14 | 2017 | Simplifying the devops adoption process | O | X |
| S15 | 2017 | From agile development to devops: Going towards faster releases at high quality - Experiences from an industrial context | O | O |
| S16 | 2016 | DevOps culture and its impact on cloud delivery and software development | O | O |
| S17 | 2016 | Communication challenges and strategies in distributed DevOps | O | O |
| S18 | 2014 | On the journey to continuous deployment: Technical and social challenges along the way | O | O |
| S19 | 2014 | Towards agile and beyond: An empirical account on the challenges involved when advancing software development practices | O | X |
| S20 | 2017 | Continuous scrum: A framework to enhance scrum with DevOps | O | O |
| S21 | 2016 | Faster is Better and Cheaper | O | O |
| S22 | 2016 | On the Impact of Mixing Responsibilities Between Devs and Ops | O | X |

Table 4.2 presents the results of the review of 22 studies. In this list, [S15] is the same from agile to DevOps, but this study focused on how to from agile to DevOps. Mainly listed some of the problems encountered by their own companies, and through the report of the other two companies discussed the objectives, strategies, development and operational cooperation and the impact of architecture. And [S18] focused on the challenges of adopting continuous deployment. DevOps includes continuous integration, continuous deployment, continuous delivery, etc. Continuous deployment is just part of it.

### 4.1.2 Challenges and Mitigation Strategies of Adopting DevOps in Agile

In these 22 studies, seven of them only illustrate some of the challenges of adopting DevOps. The rest of the articles present both the challenges and the corresponding

mitigation strategies.In Table 4.3, we will summarize the challenges mentioned in 22 papers, and list their corresponding mitigation strategies in Table 4.4 for the challenges.

Table 4.3: Adopting DevOps in Agile: Challenges

| No | Challenges | Reference |
|---|---|---|
| C1 | Lack of support for improvement from the customer's practices or processes. | [S1], [S9], [S11], [S18] |
| C2 | Limited or non-existent tool support. | [S1], [S7], [S10] [S11], [S16], [S18] |
| C3 | Team practices and team member's attitudes. | [S1], [S8], [S11], [S12], [S18] |
| C4 | The obscurity of the meaning of DevOps. | [S1], [S8], [S13], [S14],[S15] |
| C5 | Insufficient communication. | [S2], [S5], [S8], [S12], [S14], [S17] |
| C6 | Changing team roles, member needs adapt new roles | [S18] |
| C7 | Cultural matters. | [S8], [S12], [S13], [S15], [S21] |
| C8 | The cooperation between Dev and Ops is difficult, friction between development and operations person. | [S12], [S15], [S16], [S22] |
| C9 | Lack of staff to meet DevOps conditions (e.g. need a wider array of skills) Or Team members are at different skill levels. | [S2], [S12], [S13], [S14], [S15], [S19] |
| C10 | Have problems with evaluating staff progress, and the close collaboration tends to blur responsibilities. | [S9], [S15] |
| C11 | Difficulty automating everything, some automation operating architectures need to change | [S16], [S19] |
| C12 | Configuration management of test environments and runtime adaptivity. | [S7], [S9], [S11] |
| C13 | Insufficient Infrastructure. | [S2], [S7], [S9], [S11], [S18] |
| C14 | Continuous software engineering need to constantly deal with software specifications and documentation in the development process. Sometimes specification not completeness | [S3], [S4], [S7], [S18] |
| C15 | Does not meet the criteria of some special industries (For example, medical software). | [S6] |
| C16 | The initial costs of automation, continuous deployment, etc. are high, and productivity is limited | [S13], [S18], |
| C17 | DevOps implementation does not have a proper software process management framework. | [S8], [S20] |
| C18 | Get continuous support in a complex and changing enterprise environment | [S11] |

| | | |
|---|---|---|
| C19 | The organizational challenge is to change the existing structure of the organization. | [S11], [S16], [S19] |
| C20 | Process challenges, to change the past process | [S11], [S12], [S19] |
| C21 | Some legacy systems are difficult to continue with new development methods | [S11], [S18] |
| C22 | And due to the DevOps cost, efficiency, risk is not clear,management are skeptical for this. | [S12], [S13], [S14] |
| C23 | Difficult to establish an effective rollback mechanism and customer analysis mechanism | [S19] |

For the above challenges, the corresponding mitigation strategies are listed in Table 4.4.

Table 4.4: Adopting DevOps in Agile: Mitigations

| **Relevant Challenge No.** | **Mitigation** |
|---|---|
| C1 | Conduct continuous communication with customers [S1] to understand where the customer's pain points are, ensure that continuous delivery can resolve customers' pain points [S18], and show customers new features to seek support [S11]. |
| C2 | Create a solution, provide some plugins related to known products [S1, S10, S18], then gathered the clear requirements for tools and procedures to be used in the DevOps environment [S15]. |
| C3 | Strengthen communication with employees, let employees understand their own team and organization [S2], understand the benefits of change, affirm the value of new roles, and allow each employee to participate in the decision [S8]. In addition, providing a visual CD pipeline framework that shows a complete view of the CD duct can inspire the team [S11]. Then management, human resources and administrative departments must strongly support [S13]. |
| C4 | First confirm the direction of DevOps before the start, to ensure the structure and goal orientation, then deepen the common understanding of DevOps [S15], organize the corresponding lectures and team building training [S1, S8, S11, S13], and strive for all members to understand DevOps , and have a certain understanding of their own team and organization [S2]. |
| C5 | Find out silo and promote communication [S8],improve communication and collaboration [S1, S2]. Not only Dev and Ops, but management as well as further stakeholders must be involved [S15]. |

| | |
|---|---|
| C6 | Determine the value of the new role [S8] and let the entire team work closely [S18]. |
| C7 | The company organizes cultural changes [S1], conducts team building training [S13], and strengthens all employees' understanding of DevOps [S15]. |
| C8 | Strengthen communication between Dev and Ops [S2], determine the value of the new role [S8], clarify the concept of DevOps, which enables integration between development, sales, and operations teams [S16]. If friction increases, you can set up a mediator or In-depth intervention (retraining or permanent replacement) [S21]. |
| C9 | Organizations invite experts to provide training and practice [S1, S8, S11, S13], or create a dedicated team with members covering multiple disciplines [S11]. |
| C10 | Management must manage feedback and track project progress and performance [S8, S13] and clearly define success criteria [S15]. |
| C11 | Looking for existing tools to support automation [S2], or [16] proposed a new architecture to achieve speed and stability across implementations and deployments |
| C12 | The first step is to understand your own model and code [S2] and to clarify the requirements for using tools and programs in the DevOps environment [S15]. Conduct continuous testing to ensure thorough testing [S18]. |
| C13 | First of all, we must understand our own model and code [S2]. If the infrastructure is insufficient, we can start with a simple but important part [S11], and then actively provide more hardware resources for the CI server of the product so that the software product can Continuously integrate as needed so that software products can be deployed at any time [S18]. |
| C14 | There are generally three solutions. First, the practice of refactoring source code can be applied to document processing [S3]. Second, through the continuous software design specification model to gives a specification guide [S4]. Third, adopting "social rules" and it must be observed when deploying software [S18]. |
| C15 | Need further development of DevOps,to fit with the special standards [S6]. |
| C16 | Pereira et al. provide SNAC Framework Can Solve Some Complex Organizational Issues at the Initial Stage of DevOps [S13], or using the old and new systems at the same time, gradually upgrade to achieve a smooth transition [S18]. |
| C17 | A new framework "continuous scrum" was proposed, describing the continuous part of DevOps [S20]. |

| | |
|---|---|
| C18 | Find the pain points for each stakeholder, and make sure, continuous delivery,can help resolve this pain point and use continuous delivery for continuous delivery [S11]. |
| C19 | Recognize the value of the new role [S8], create a dedicated continuous delivery team with members covering multiple disciplines [S11], or [S16] use the concept of DevOps as a service that integrated development, sales, operation teams, business entities and DevOps common services. And [S13] proposed the SNAC Framework Can Solve Some Complex Organizational Issues at the Initial Stage of DevOps. |
| C20 | Let employees understand the benefits of change [S8], starting with small changes and selecting a manageable context supports the introduction of DevOps [S11, S15]. |
| C21 | Start with a simple but important part [S11], and run the old and new systems at the same time and gradually upgrade [S18]. |
| C22 | The project manager needs to track team performance [S13], and it need strengthen the communication between developers and managers [S18]. |
| C23 | Enhance communication with customers [S1], and frequent deployment of software to customers without negatively affecting customers [S18], to collect interaction data for customers and features.<br>If any code changes leave the software in a less than fully functioning state, continuous deployment can fixing bugs quickly, and roll back software to a previous version [S18]. |

## 4.2 Result of Survey Questionnaire

In the following sections, we first describe the statistics of the basic information about the people involved in the survey, and then summarize the main challenges and mitigation strategies of adopting DevOps in the agile in industry.

The 29 participants were mainly from three companies: Agraf (Norway), Unimail System AB (Sweden) and WangDao Online (China). But this does not mean that these 29 participants only came from these three companies. Some colleagues and friends helped us spread the survey, at the same time, they were also put the link on some forums or platforms. Therefore, some participants' companies could not obtain.

### 4.2.1 Basic Information

The following table summarizes the basic information of the participants. A total of 31 respondents to the survey, but two of them did not know anything about DevOps, so there are only 29 agile or DevOps practitioners:

- Geographical distribution, participants from a total of five different countries (Table 4.5).
- How many years have participants was working on software field? (Table 4.6)
- What is the responsibility of participants in their work? (Table 4.7)
- Size of participants team. (Table 4.8)
- What is the type of participants products/domain? (Table 4.9)

For the 29 people, two persons had never been exposed to DevOps, five people had heard of DevOps, but they did not clearly understand its specific meaning. So, people who chose the option "No, never" or "I have heard of it but I don't know its mean" on this question will be directed to the interpretation of DevOps, then they will be asked again:" Have you ever adopting DevOps in your work without knowing its conception" ? These five people all have opted for "yes". Therefore, we only removed the survey results of participants who had not been exposed to DevOps in the survey results.

Table 4.5: Geographical Distribution

| **Country** | **Count** | **Percentage** |
|---|---|---|
| China | 12 | 42.9% |
| India | 5 | 17.9% |
| Italy | 1 | 3.6% |
| Norway | 6 | 21.4% |
| Sweden | 4 | 14.3% |
| | **29** | **100%** |

Table 4.5 shows the geographical distribution of the participants. Of the 29 responses received, the participants came from a total of five different countries. There are twelve respondents from China, five participants from India, six participants from Norway and four participants from Sweden.

Table 4.6: Working Years of Each Participants

| **Working Years** | **Count** | **Percentage** |
|---|---|---|
| Less than one year | 6 | 20.7% |
| 1 ∼5 years | 13 | 44.8% |
| 5 ∼10 years | 8 | 27.6% |
| More than ten years | 2 | 6.9% |
| | **29** | **100%** |

We can see from Table 4.6 that the number of participants working from 1 to 5 years is the largest, followed by 5 to 10 years. There are only six participants less than one year and two participants over ten years.

Table 4.7: Roles of Participants

| Roles | Count | Percentage |
|---|---|---|
| Manager | 7 | 24.1% |
| Developer | 18 | 62.1% |
| Tester | 15 | 51.7% |
| Operations | 12 | 41.4% |

From Table 4.7, we obtained 52 roles, but only 29 participants. This is because some participants are responsible for more than one role in their company. In some smaller companies, management is also mandated to development and maintenance, and most developers will also take on the task of testing, and some testers will also focus on the operation. So, the sum of the roles is not 29 people.

Table 4.8: Participants Team Size

| Team Size | Count | Percentage |
|---|---|---|
| Less than 10 | 1 | 3.4% |
| 10 ∼50 | 18 | 62.1% |
| 50 ∼100 | 9 | 31% |
| More than 100 | 1 | 3.4% |
| | **29** | **100%** |

Table 4.8 shows the team size of respondents. As can be seen from the table, the response rate of the medium-sized team is high, with only one participant from each of the small team (less than 10) and the large team (more than 100) participating in the survey.

Table 4.9: Domain Type of Participants

| Domain Type | Count | Percentage |
|---|---|---|
| Automation | 4 | 26.7% |
| Communication | 4 | 26.7% |
| E-commerce | 1 | 6.7% |
| Bank System | 1 | 6.7% |
| Internet | 3 | 20% |
| Publication | 1 | 6.7% |
| Printing Process Design | 1 | 6.7% |
| | **15** | **100%** |

Table 4.9 is mainly described the domain type of participants. Only 15 people answered this question. Among them, there are four participants each of communication and automation, three of participants are the Internet, and one participant for e-commerce, bank system, publication and process design.

We interviewed several participants randomly after obtaining the response. Participants stated that there were many fields involved and they wanted to make multiple choices rather than textual responses.

We have listed a list of basic information (Appendix B) that counts the number of challenges and the number of time the mitigation strategy is used, that occur under different situations (team sizes, roles, work experience). We highlight the highest number of votes in red. This form can help those who are interested in adopting DevOps to consider and prepare according to their specific situation.

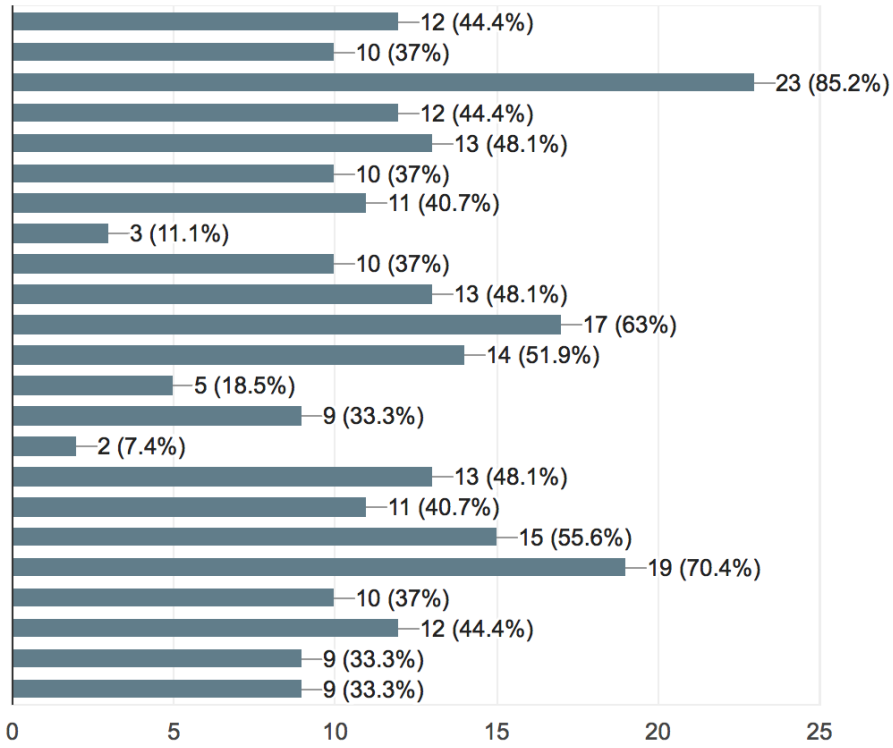
### 4.2.2 Main Finding

In the following subsections, we will summarize the main results of RQ2 and RQ3 obtained through the survey questionnaire.

**RQ2: What are the challenges of adopting DevOps in Agile?(In Industry)**

From Google forms, we can get the summary Figure 4.1:

Figure 4.1: Adopting DevOps in Agile: Challenges




In order to make the results easier to understand, we use Table 4.10 in detail describes this figure:

Table 4.10: Adopting DevOps in Agile: Challenges

| Challenges | Count | Percentage |
|---|---|---|
| C3 | 23 | 85.2% |
| C19 | 19 | 70.4% |
| C11 | 17 | 63% |
| C18 | 15 | 55.6% |
| C12 | 14 | 51.9% |
| C5, C10, C16 | 13 | 48.1% |
| C1, C4, C21 | 12 | 44.4% |
| C7, C17 | 11 | 40.7% |
| C2, C6, C9, C20 | 10 | 37% |
| C14, C22, C23 | 9 | 33.3% |
| C13 | 5 | 18.5% |
| C8 | 3 | 11.1% |
| C15 | 2 | 7.4% |

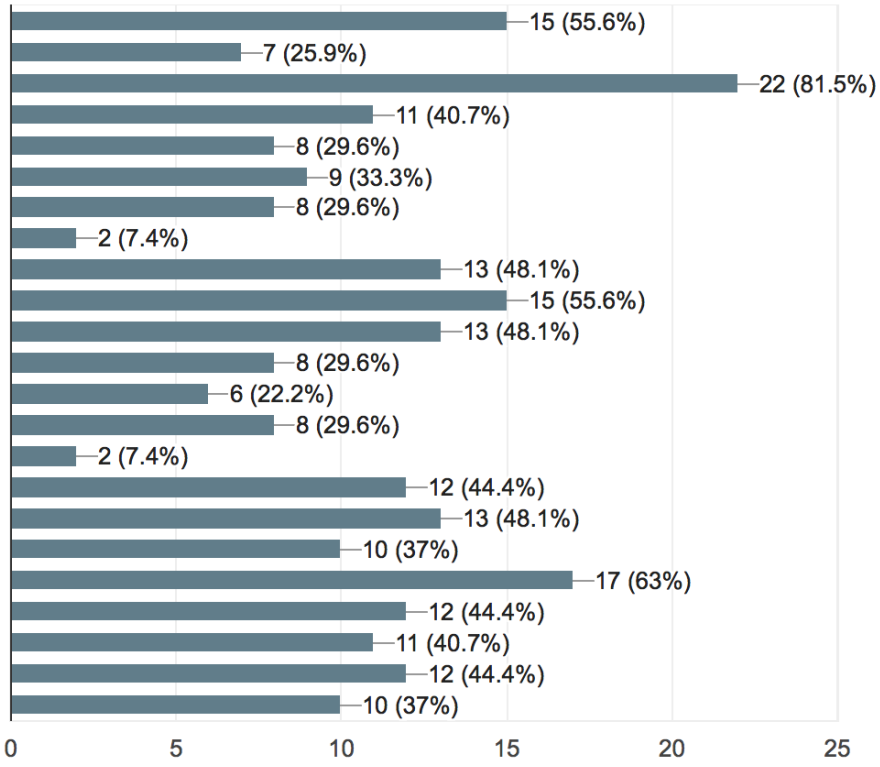
As can be seen from Table 4.10, team practice and team member attitudes are the most common challenges, accounting for 85.2%. We can say that most teams will have the challenges of team practice and team member attitudes when using new technologies. Then there is a change in the existing structure of the organization, which accounts for 70.4%. Changes in the development process have led to changes in the original organizational structure, new job requirements have emerged, and the work content of each role has also changed. The challenge caused by automation accounts for 63%. DevOps relies heavily on automation. However, the original system configuration of the enterprise may not support all automation. The architecture or configuration environment of some automatic operating systems needs to be changed. Other challenges are also very important, like getting continuous support in a complex and changing enterprise environment, configuration management of test environments and runtime adaptivity .etc, most of them accounting for 50% more or less.

Of the 23 challenges we researched, three have a relatively low share of the industry: First, inadequate infrastructure; Second, cooperation between Dev and Ops will create friction; and third, DevOps will not meet the standards of some special industries. The relationship between Dev and Ops is very important in literature. Because of different roles but closely cooperation, the two often make friction. However, in the industry, since most of our investigations are small teams, many developers themselves are responsible for part of the operation, or they themselves have long-term close cooperation, so there is rarely a problem of friction. The special standard challenge has only two answers because there are fewer people involved in a particular industry.

**RQ3: How can we mitigate the challenges of adopting DevOps in Agile?(In Industry)**

From Google forms, we can get the summary Figure 4.2:

Figure 4.2: Adopting DevOps in Agile: Mitigation Strategies




In order to make the results easier to understand, we use Table 4.11 in detail describes this figure:

Table 4.11: Mitigation Strategies

| Mitigations | Count | Percentage |
|---|---|---|
| C3 | 22 | 81.5% |
| C19 | 17 | 63% |
| C1, C10 | 15 | 55.6% |
| C9, C11, C17 | 13 | 48.1% |
| C16, C20, C22 | 12 | 44.4% |
| C4, C21 | 11 | 40.7% |
| C18, C23 | 10 | 37% |
| C6 | 9 | 33.3% |
| C5, C7, C12, C14 | 8 | 29.6% |
| C2 | 7 | 25.9% |
| C13 | 6 | 22.2% |
| C8, C15 | 2 | 7.4% |

It can be seen from Table 4.11 that the attitude of team members is still the one with the most feedback, followed by the change in organizational structure. The situation of special industry standards still has only two answers. The survey results for the overall mitigation strategies basically correspond to the survey results for the challenges.

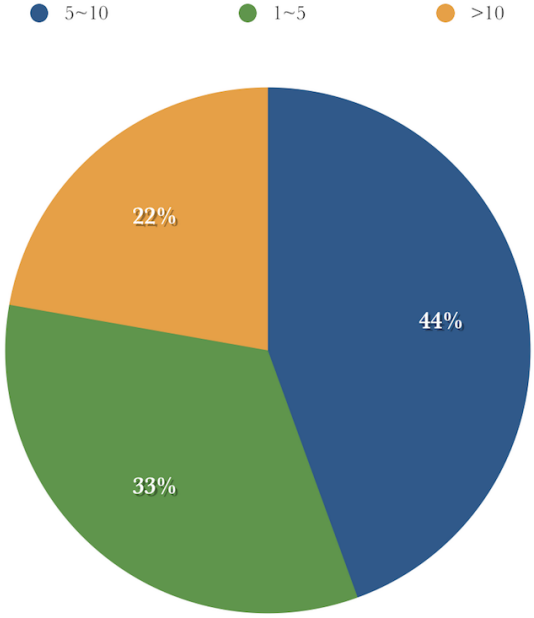
## 4.3 Result of Interview

In the following subsections, we first describe the interviewee's characteristic, then through their response to summary the real process of adopting DevOps in Agile.

### 4.3.1 Basic Information

For respondents' work experience in the software domain, there were 2 respondents with more than 10 years of work experience, 4 respondents had work experience between 5 and 10 years, and 3 respondents, had work experience is between 1and 5 years(Figure 4.3).

Figure 4.3: Respondents' Work Experience




About the respondent's work role, three of these participants are currently Managers, two participants are currently operators, and the remaining four participants are developers (Figure 4.4). All respondents were from Internet domain.

Since the respondents' work environments are different, the roles and responsibilities of the team are also different. We recorded all the roles mentioned by the respondent(Table 4.12), and we will show the respondents of each item in the description(hereinafter represented by P1-P9). Please note that these roles do not necessarily coexist, therefore their responsibilities may be duplicated.

Figure 4.4: Respondents Roles of work

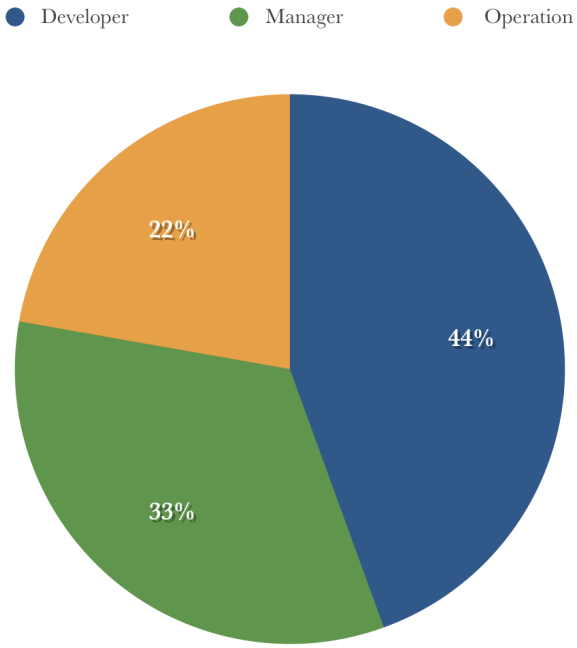



Table 4.12: Roles and Responsibilities

| Roles Of Work | Post Name | Responsibility |
|---|---|---|
| **Manager** | Product Manager | 1. Understand users' requirement(P1-P9)<br>2. Manage team(P1, P2, P4, P6, P9)<br>3. Create budget plan(P1, P2, P4, P6, P7, P9)<br>4. Create hiring plan and development plan(P1-P9)<br>5. Analyze technology, resource needs, and market demand(P1, P2, P3, P5, P6, P8, P9)<br>6. Assist customer supports in addressing customer issues(P1-P9) |
| | Software Engineering Manager | 1.Understand project requirements(P3, P4, P5, P8)<br>2. Manage development team(P3, P4, P5, P7,P8)<br>3. Plan and assess the feasibility of projects(P4, P5, P8)<br>4. Supervise software development(P3, P5, P7)<br>5. Define milestones(P3, P4, P7)<br>6. Recruit, train, and supporting other staff(P5, P8) |

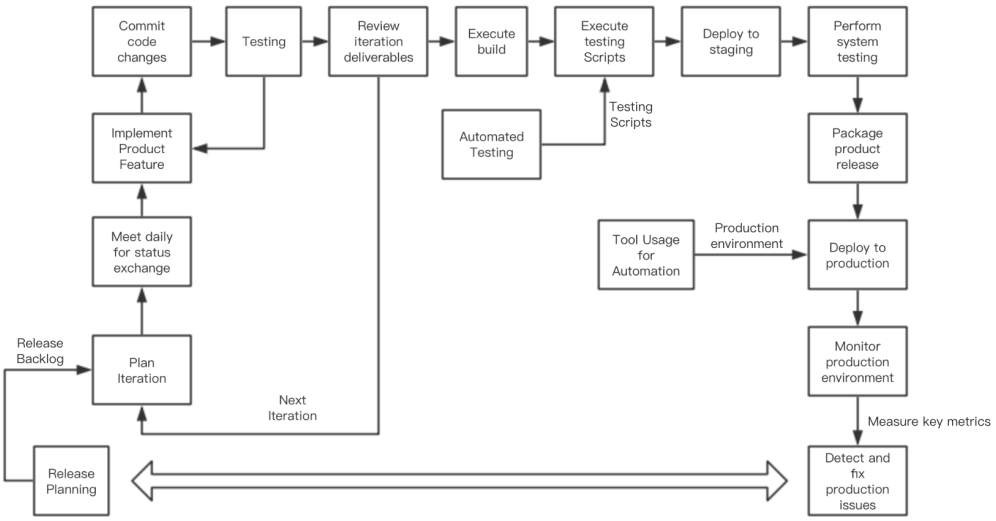
| | | |
|---|---|---|
| **Developer** | Software Engineer | 1. Implement all functions regarding user requirements(P1-P9)<br>2. Identify and conduct analysis on business system requirement(P1, P2, P5, P6, P7, P9)<br>3. Collect founded problems/risks and customer feedback.(P2, P5, P6, P8, P9)<br>4. Write user guide and conduct training to users (P5, P6, P7, P8)<br>5. Design, development and unit testing on product features.(P3, P4, P5, P6, P7)<br>6. Software maintenance and enhancement with timely response.(P1, P3, P4, P6, P7, P9) |
| | Programmer | 1. Participate in the formulation, design and follow-up of software development plans. (P3, P4, P5, P6, P8, P9)<br>2. Write corresponding software R&D documents according to requirements documents(P2, P6, P7, P9)<br>3. Encoded according to the design documents (P2, P3, P6, P7, P9)<br>4. Unit testing and BUG repair(P3, P6, P7, P9) |
| | QA Engineer | 1. Reviewing quality specifications and technical design documents to provide feedback(P4, P5, P6, P7).<br>2. Creating test plans and test cases(P4, P5, P6).<br>3. Estimating, prioritizing, planning and coordinating quality testing activities(P4, P5, P6, P7).<br>4. Prepare and deploy test environment(P4, P5, P6).<br>5. Execute functional automation tests, file bugs and report test results(P4, P7). |
| | DevOps Engineer | 1. Responsible for the application's life-cycle(P2, P3, P4, P8,P9).<br>2. Develop and execute plans for monitoring systems. (P2, P3, P4, P8).<br>3. Develop, implement and support a continuous improvement concept(P2, P3, P4, P8, P9).<br>4. Setup and maintain infrastructure components for the project(P3, P4, P7, P8, P9).<br>5. Develop and manage the methods of automated deployment and integration(P3, P4, P7, P8, P9).<br>6. Perform script maintenance and updates due to changes in requirements or implementations (P2, P3, P4, P7).<br>7. Manage the processes and tools(P9).<br>8. Assist Manager and lead to drive DevOps adopting(P3, P5, P7, P8, P9) |

| | | |
|---|---|---|
| **Tester** | Tester | 1. Test all functions in all possible situations. (P1, P2, P3, P7, P8, P9)<br>2. Manage and track the bugs base on process.(P1, P2, P3, P8,P9)<br>3. Generate and publish test report. (P1, P2, P3, P8,P9)<br>4. Support developers with bug reproduce and log.(P3, P8,P9)<br>5. Maintain and optimize test tools.(P8,P9) |
| **Operation** | Operator | 1. Responsible for software system installation, commissioning and maintenance.(P1, P5, P6)<br>2. Follow up the end user feedbacks(P5)<br>3. Responsible for routine maintenance of company server hardware.(P1, P5, P6)<br>4. Responsible for system deployment, maintenance and operation analysis to ensure efficient, stable and reliable operation of the system(P1, P5, P6) |

### 4.3.2 The Process of Adopting DevOps in Agile

Since the research question in this part focused on the software development process when integrated Agile with DevOps, the data we got was semantically complex, so we decided to use human coders. At the same time, open coding was used to determine the process area, then we reviewed the initial process, and the final process was presented in Figure 4.5. In this figure, the organization was periodically and has

Figure 4.5: Final Process




release cycles of proper duration. The Release plan is generated during the Product management phase and result in a release backlog, and then the release backlog

used to plan out individual sprint iterations. Before start the deployment process engineers need to make tests(including functional tests), if testing success, then they start to execute build. For the purpose of reducing delivery duration, some product testing can be automated. And one characteristic of DevOps is the use of third-party tools, these tools could be reused in server configuration, infrastructure provisioning, deployment management and so on, without the need to understand their internal workings. Based on this, engineers deploy the package product to production then monitor the production environment, and they will measure the critical metrics and determine if these metrics meet the requirements, at last engineers detect and fix production issues.

# Chapter 5

# Analysis and Discussion

In this chapter, we will conduct a comprehensive analysis of three research questions.

The first is RQ2 and RQ3. We will analyze the results of systematic literature review and the results of survey questionnaire to explore the similarities and differences between them.

Then we will analyze the results of RQ1 and correlate the process challenges in RQ2 and RQ3 with the results of RQ1.

## 5.1 RQ2&3: What are the challenges of adopting DevOps in Agile and how can we mitigate the challenges?

### 5.1.1 Basic Result Analysis

We analyzed the final 22 papers, then we obtained the Table 4.2, Table 4.3 and Table 4.4. Table 4.2 provides a summary of 22 papers, it explains which articles involved challenges and mitigation strategies, and which articles only covered the challenges. Table 4.3 lists the challenges that were extracted from each article. We obtained a total of 23 different challenges and its relevant references, and then we presented their mitigation strategies for each challenge in Table 4.4.

In mitigation part, some articles only involve challenges [S5, S7, S9, S12, S14, S19, S22], some articles have involved resolving challenges and involved unresolved challenges [S11], some articles proposed mitigation strategies can solve multiple challenges. For example, the company invites experts to organize training, it cannot only solve the problem of staff lack of skills [C9], but also enable employees to have a more in-depth understanding of the concept and organization of DevOps [C4]. In addition, this behavior could have a positive effect on employee attitude [C3].

We mainly use editing approaches and grounded theory [39] to analyze the challenges and mitigation strategies of adopting DevOps in Agile. As more and more documents are collated, the degree of coincidence between the challenges contained in different articles and the types of mitigation strategies are also increasing. Many

challenges from the different references are the same. After detailed analysis and review, we have summarized and classified different challenges(Table 5.1).

Then we refer to the adopting agile methodologies factors model proposed by Shahane et al. [40] and divide the challenges into four categories: people, process, project, and organization. The specific categories we will list in Table 5.1:

Table 5.1: Categories of Challenges and Mitigation Strategies

| **Categories** | **Challenges And Mitigation Strategies** |
|---|---|
| People | C3, C5, C6, C8, C9 |
| Project | C1, C4, C13, C15, C16, C21, C23 |
| Process | C2, C11, C12, C14, C17, C20 |
| Organization | C7, C10, C18, C19, C22 |

In the following part, we will analyze the four categories:

***People*** Changes in the development process and roles will inevitably affect team members. Likewise, these changes will require major changes in people's thinking and behavior. This means that people are the main factor of adopting new technologies in agile technology [41, 42].

From the above studies, we found that the human factor has the following problems: The first one is the attitude of the team members. Some members do not see the benefits of the new method and do not want to make changes. Therefore, they passively deal with the implementation of new technologies [S1, S8, S11, S12, S18]. Communication is another key point of human factors. Lack of communication may cause misunderstandings, give customers a bad impression, and can also affect the efficiency of work [10, 43]. The solution given in the literature is to strengthen the communication with employees, let employees understand their own team and organization [S2], understand the benefits of change, affirm the value of new roles, and allow each employee to participate in the decision [S8]. In addition, providing a visual CD pipeline framework that appears in a complete view of the CD duct can inspire the team [S11]. Then management, human resources and administrative departments must strongly support [S13].

Communication include Dev and Ops's communication, team member's communication, team member and stakeholder/customer's communication, team member and management's communication [S2, S5, S8, S12, S14, S17]. There are many factors that have caused the communication problem: geographical factors, cultural differences, different time, different roles, communication methods, directions, content, etc. [10] all can cause poor communication. So it need to find out silo and promote communication[S8] improve communication and collaboration [S1, S2]. Not only Dev and Ops, but management as well as additional stakeholders must be involved [S15].

The third is the roles change, people need to adapt to their new role[S18], this means that people need to determine the value of the new role[S8], and then again the entire team to work together closely link[S18]. As the cooperation becomes ever more frequent, friction will increase, especially the friction between Dev and Ops [S12, S15, S16, S22]. This situation requires strengthen communication between them [S2] and mediate when necessary[S21].

The use of new technologies in agile will inevitably lead to the lack of employees who meet the DevOps conditions. Therefore, team members need to acquire new skills while broadening their knowledge[S2, S12, S13, S14, S15, S19]. It needs organizations invite experts to provide training and practice [S1, S8, S11, S13], or create a dedicated team with members covering multiple disciplines [S11].

***Project*** The project classification is mainly related to the practice of the project, such as the customer's support for the project [S1, S9, S11, S18], the project's own concept and meaning [S1, S8, S13, S14, S15], the project needs some of the infrastructure [S2, S7, S9, S11, S18], some special industry projects will have some special standards [S6], the introduction of new technologies for project automation or continuous deployment will result in high costs [S13, S18], some legacy systems are difficult to adopt new technologies for continuous development due to differences in development methods, tools, and documentation [S11, S18], and continuous deployment is difficult to establish an effective rollback mechanism and customer analysis mechanism [S19].

***Process*** As we can see from section 3.1, there are many challenges in the process of adopting DevOps in Agile. The first is the limitations of the tools [S1, S7, S10, S11, S16, S18]. Because the concept of DevOps is relatively new, there are not enough tools to support its implementation, such as the tools needed for various automated processes, and tools for continuous integration or continuous deployment. It needs organizations create a solution, provide some plug-ins related to known products [S1, S10, S18], then gathered the clear requirements for tools and procedures to be used in the DevOps environment [S15], finding tools for specific needs.

Secondly, it is difficult to automation everything, the old architecture and process need to change [S16, S19], so it need looking for existing tools to support automation [S2], or [16] proposed a new architecture to achieve speed and stability across implementations and deployments.

The test environment configuration also need fit for the new technology [S7, S9, S11]. Team member need to understand their own model and code[S2] and to clarify the requirements for using tools and programs in the DevOps environment [S15]. Conduct continuous testing to ensure thorough testing [S18].

There are some other challenges, such as constant changes in the continuous deployment process, which will lead to specification needs to be dealt with all the time, which is very difficult for novices [S3, S4, S7, S18]; there is no proper framework for the implementation of DevOps, which makes it difficult for the team to determine the

direction from the beginning of the development process [S8, S20]; and it is difficult to change the past process, not only the legacy system, but also various complex environment and process [S11, S12, S19].

***Organization*** Organizational issues are an important consideration in the successful implementation of DevOps in agile. First of all, the differences in DevOps culture [S8, S12, S13, S15, S21] make it necessary for companies to organize cultural changes [S1] and conduct team building training [S13].

Second, for managers, since new technologies require close cooperation among team members, this creates ambiguity in responsibilities and makes it difficult to assess the actual effectiveness of employees [S9, S15]. Management must manage feedback and track project progress and performance [S8, S13] and clearly define success criteria [S15].

After that, the organizational structure is required to change due to the merger of development and operation [S11, S16, S19]. It is necessary to make employees aware of the value of the new role [S8], establish a dedicated team covering multiple disciplines [S11], or use the SNAC Framework proposed by [S13], it can solve some complex organizational issues at the initial stage of DevOps.

Finally, due to the uncertainty of the cost, efficiency, and risks of DevOps, management is skeptical [S12, S13, S14] that it is difficult for organizations to obtain continuous support in a complex and volatile corporate environment [S11]. This requires identifying the pain points for each stakeholder and ensuring that continuous delivery can help to resolve the problem. Management tracking team performance [S13] and their need to strengthen communication between developers and managers [S18].

Then by statistic the number of papers mentioned in each paper, we can calculate the weight of each of the classifications so that we know which type of challenge is the most frequent. Table 5.2 shows that the reference status of the four categories and their percentage.

Table 5.2: Challenges Categories Status

| **Categories** | **Reference** | **Percentage** |
|---|---|---|
| People | S1, S2, S5, S8, S11, S12, S13, S14, S15, S16, S17, S18, S19, S22 | 64% |
| Project | S1, S2, S6, S7, S8, S9, S11, S12, S13, S14, S15, S18 | 55% |
| Process | S1, S3, S4, S7, S8, S9, S10, S11, S12, S16, S18, S19, S20 | 59% |
| Organization | S8, S9, S11, S12, S13, S14, S15, S16, S19, S21 | 45% |

We can see that in the four types of challenges, the challenges posed by people issues are the most involved, followed by the challenges posed by process, both of which are around 60%; and the project challenges account for 55% of the total. Organizational challenges only account for 45%.

In the same way, we can calculate the percentage of each category so that we know which type of mitigation strategy is most frequent. Table 5.3 shows the four categories of reference states and their percentages.

Table 5.3: Mitigations Categories Status

| Categories | Reference | Percentage |
|---|---|---|
| People | S1, S2, S8, S11, S13, S15, S16, S18, S21 | 41% |
| Project | S1, S2, S6, S8, S11, S13, S15, S18 | 36% |
| Process | S1, S2, S3, S4, S8, S10, S11, S15, S16, S18, S20 | 50% |
| Organization | S1, S8, S11, S13, S15, S16, S18 | 32% |

We can see that in the mitigation strategy, the process type mitigation strategy is the most mentioned type in the literature, followed by the mitigation strategy of the people type, and then the lowest is still the organization type. This is basically the same as the proportion of challenges, but because some papers only involve challenges and do not involve mitigation strategies, there are some differences in order and proportion.

### 5.1.2 Comparative Analysis of the Results of the System Literature Review and the Questionnaire

Through systematic literature reviews and questionnaire surveys, we obtained the challenges and mitigation strategies encountered in adopting DevOps in agile in the literature and in the industry respectively.

In this section, we will combine the challenges and mitigation strategies of literature and industry and then conduct an unified analysis. The challenges and mitigation strategies are still divided into four categories. We will count the number of citations and the number of questionnaire votes for these four types of challenges and mitigation strategies.

#### Challenges

Table 5.4 shows the proportion of each category of challenges in the literature and industry:

Table 5.4: Challenge Categories

| Categories | Reference Porpotion | Survey Count |
|---|---|---|
| People | 14(64%) | 59 |
| Project | 12(55%) | 65 |
| Process | 13(59%) | 71 |
| Organization | 10(45%) | 67 |

From the table 5.4, it can be observed that there are some differences between the results of the systematic literature review and the results of the factory survey. The main findings is that in the literature review, the people factors accounted for the largest proportion of challenges, and organizational factors caused the smallest proportion of challenges. However, this situation is basically the opposite of the results of the factory survey. In factory surveys, the challenges posed by organizational factors are second only to process challenges, while people challenges are the least. In the following sections, we will analyze four categories one by one to find out the specific reasons for this:

***People*** There are five challenges in terms of people categories[C3, C5, C6, C8, C9]. We have found that the attitudes of team members[C3] and insufficient communication[C5] are the most mentioned challenges, both in the literature and in the survey. The challenges of team members fail to meet DevOps conditions[C9] are also involved in both parts. Only one article mentioned some team members are hardly adapted to the new role[C6], but 10 people mentioned this challenge in the survey questionnaire. After discussion we believe that this is because of many of our respondents are responsible for multiple roles, their own ability allowed them to quickly perform role adjustments, and, this makes the friction between Dev and Ops[C8] not as frequent as the literature mentioned. Therefore, the personnel challenges referred to in the literature are more, but they are the least in the survey.

***Project*** The challenges of project categories have the majority in the four categories[C1, C4, C13, C15, C16, C21, C23]. Lack of customer support [C1] and confusion of DevOps concepts [C4] have been mentioned numerous times in both literature and surveys. The problem of inadequate infrastructure [C13] was mentioned in numerous articles, but only 5 people selected this challenge. After discussing with some participants, we learned that the team of the participants began adopting new technologies after their infrastructure was basically complete. Or when they want to adopt new technologies, they will start from the existing simple parts, then gradually upgrading their facilities. As the team began to upgrade their infrastructure as much as possible, resulting in a relatively high initial cost [C16], that made the challenge in the survey are quite different. In addition, the issue of upgrading the legacy system [C21] and the establishment of the rollback mechanism [C23] are little mentioned in the literature, but they are often mentioned in the survey, these two parts will need more research in the future. For some special industries' special standards [C15], whether in literature or in the survey, are relatively rare.

***Process*** There are six [C2, C11, C12, C14, C17, C20] challenges in the process category. The most significant difference is the limitation of tools [C2], which is often mentioned in the literature. But this challenge's response rate of surveys is not high. After discussion, we believe that the main reason is the timeliness of the literature. Since the surveys are all current, but the literature generally came from one to two years ago. During this period, the development of the software is changing with each passing day, in particular, more and more people need this feature. Second, it is difficult to automate everything [C11] and the configuration management of the test environment [C12] are not prepare. These two challenges have a high response rate in surveys, exceeding 50%, but only two or three articles mentioned. Some other challenges, such as continuous changes in specifications resulting from continuous software engineering [C14], DevOps implementation have neither an appropriate management framework [C17], and the old process needed to be changed to latest[C20]. These challenge both in the literature and surveys, and their proportion is basically the same.

***Organization*** In organizational category challenges [C7, C10, C18, C19, C22], the lack of continuous support [C18] and organizational structural change [C19] are the two most obvious challenges. The change in organizational structure is particularly prominent. Although some members play multiple roles on one team, the organizational structure adjustment still brings them many challenges. Then due to unfamiliarity at the beginning of the project and the environment complex and ever-changing, it may be difficult to go on receive support. The team size involved in the survey is relatively small and the members are relatively young, the learning ability and adaptability are relatively strong, so the response rate of the cultural issue [C7] in the industry is not very high. Other performance assessments[C10] and management [C22] challenges are not much in the literature. And in surveys, due to the role of team members, the response rate is quite low.

### Mitigation Strategies

In general, mitigation strategies should be corresponding with challenges. However, when we systematically reviewed the literature, much of the literature mentioned only challenges and did not describe the mitigation strategies for these challenges. Therefore, compared with the challenges, we have achieved fewer mitigation strategies. The following table is the mitigation strategy in the literature review citations and industry survey votes:

Table 5.5: Mitigation Strategies Categories

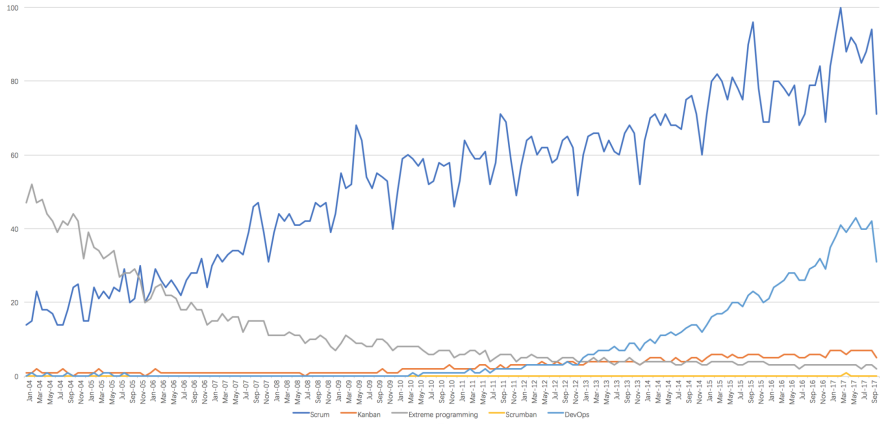
| **Categories** | **Reference Porpotion** | **Survey Count** |
|---|---|---|
| People | 9(41%) | 54 |
| Project | 8(36%) | 67 |
| Process | 11(50%) | 61 |
| Organization | 7(32%) | 62 |

From the above table, we can see that the process category challenges of the systematic literature review are the most, reaching 50%, while other types of challenges are relatively small. In the survey, the most concerned is the challenge of project type. This shows from another point of view that in different environments, different roles have different focuses. Researchers pay greater attention to the design of the development process, while industry personnel are more concerned about the success of the project.

## 5.2 RQ1: What does the software development process looks like when adopting DevOps in Agile?

Agile includes a variety of methods, such as Scrum, Kanban, Scrumban, etc. We compared the Scrum, Kanban, Extreme Programming, and Scrumban searches on Google from 2004 to the present. And we found that extreme programming search volume was declining trend, Kanban and Scrumban search volume has been relatively small, and the rising trend is not obvious, only Scrum and DevOps search volume are relatively large and an upward trend. Figure 5.1 shows this situation:

Figure 5.1: The search volume of Scrum, DevOps, Kanban, Extreme Programming and Scrumban



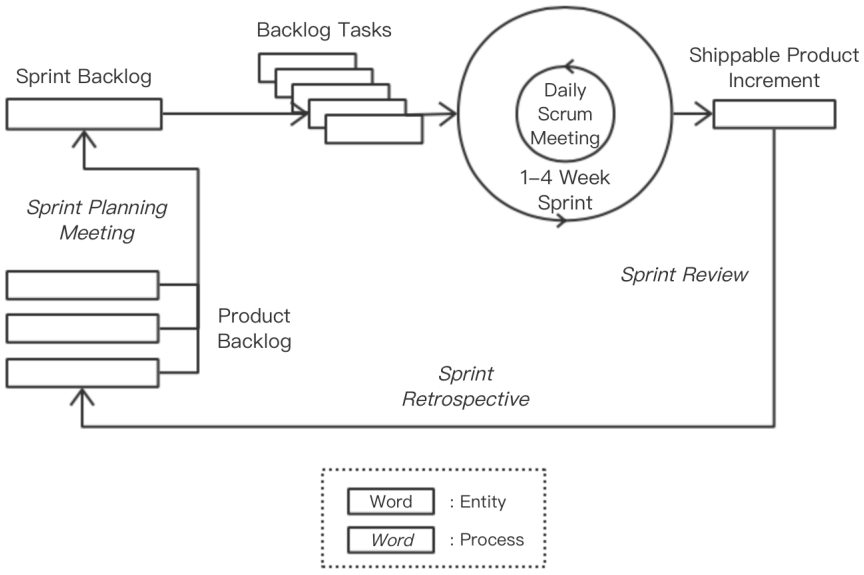

This figure demonstrates that more and more people are concerned about Scrum and DevOps. Many companies in their project development process also tend to use Scrum [25], of the nine people interviewed, there were seven persons transferred from Scrum to DevOps. So we decide to summarize the process of Scrum to combine with DevOps.

Scrum team mainly has three roles: product owner, scrum master and development team [26]. Scrum Master usually takes on the job of helping and facilitating team members to successfully complete Scrum [44]. Scrum master plans and implements events through leading the organizations. Essentially, Scrum master promotes the smooth progress of all processes. Product Owner is responsible for maximizing

the work and product [44]. According to product requirements, product owner will sort out an ordered, clear and understood list of product backlog. Anybody on the team can do these things, and the product owner is responsible for maintenance.

In Figure 5.2, we could see that the sprint is the core of the Scrum process. Sprints will continue until the product is fully developed. Sprints are always lasts one to four weeks, and during this period, the product increment will develop to the extent that it can be released [44].

Figure 5.2: Scrum Process




Before each sprint begins, the entire Scrum team will work together in order to develop a Sprint planning. Sprint planning lasted about eight hours, and it's aimed at finding out what increments can be delivered in the next Sprint and how to finish it [44]. Daily scrum meeting is an inspection and adapt meeting which used to sum up the work of the previous day and plan what should be completed today.

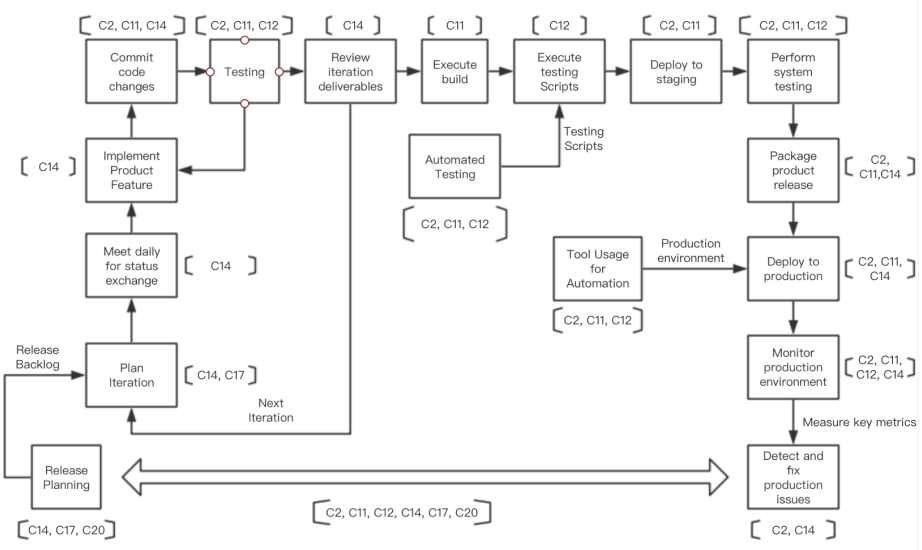
After the sprint is accomplished, the team will hold a sprint reviews meeting to check and optimize product increments while getting feedback for revising the product backlog to start the next iteration.

Based on the interviewee's interview results and the scrum process, we designed the process of adopting DevOps in agile, and table 4.5(Section 4) shows the whole process.

Then after the discussion of the process and the process challenges from the result of RQ2 and RQ3, we attached the possible challenges [C2, C11, C12, C14, C17, C20] on each step of the process to the flow chart and provided this figure as a reference to the relevant employees so that they can prepare in advance. Figure 5.3 shows the

process and its relevant challenges.

Figure 5.3: Corresponding Challenges to the Process




In Figure 5.3, we mainly discuss process challenges such as limited or non-existent tool support [C2], difficulty automating everything, some automation operating architectures need to change [C11], continuous software engineering need to constantly deal with software specifications and documentation in the development process and sometimes specification not completeness [C14], DevOps implementation does not have a proper software process management framework [C17], hard to change the past process [C20].

The submission of the code, the execution of the test, the deployment and release of the product, and the monitoring of the product environment all require the support of tools and automation. Test-related steps require configuration of the test environment.Continuous iteration, continuous delivery, continuous integration and continuous deployment make the system continuous change, so the system specifications also require constant changes and integration. In the process of releasing the plan, we must also consider the management framework and the changes to the past process, and these two issues also run through the entire development process.

# Chapter 6

# Validity Threats

The validity of a study indicates the credibility of the results, that is to say the extent to which the results are true and reliable, without subjective influence of too many researchers [45]. Although we try to avoid researcher bias, there are always some ingredients influenced the reliability of the research results. We list the possible threats to systematic literature review, survey questionnaire and interview.

## 6.1 Validity Threats of Systematic Literature Review

This section mainly describes the validity threats of the systematic literature review. We will explain from the three perspectives of publication bias, objectivity, and construct validity.

### 6.1.1 Publication Bias

DevOps is new and popular, internal validity is one of the major threats to this study. In order to cope with this threat, two authors searched at the same time and recorded the problematic literature for discussion. All papers were screened by inclusion criteria and the final study list was determined. Our supervisor helped us to examine the review process, then verified and advised the implementation steps.

### 6.1.2 Objectivity

Since the limitation of keyword search, we may have mishandled some significant publications in the process of SLR. To mitigate this threat, we try to use synonyms of keywords and retrieve in multiple databases. Our supervisor helps us define keywords and give suggestions for search strings.

During the screening process, some of the papers belong to books' chapter, so these papers were not able to obtain the full text and were eliminated. We finally obtained a total of 22 papers, and the total number of these eliminated papers was 17, which accounts for a relatively large proportion, so there may be some cases where the challenges are missed.

### 6.1.3 Construct Validity

There are three main threats to the construct validity. First, the same research by the same author is easy to find when searching in different databases and there are subtle differences in some of the duplicated research titles that can lead to the inability to remove duplicates mechanically. So the two authors manually reviewed all the articles after mechanically deduplicating all papers.

Followed by the research domain issues, there are some articles do not belong to the field of software engineering. For this part, we exclude any other domain's article by keyword positioning and abstract review.

In order to avoid the loss of important data in the literature review process, we used Evernote to manage the literature data, documenting the main challenges and mitigation strategies of adopting DevOps in agile. Two authors can access shared folders at the same time to edit and review the data.

## 6.2 Validity Threats of Survey Questionnaire

This section mainly describes the validity threats of the survey questionnaire. We will explain from the three perspectives of internal validity, external validity and construct validity.

### 6.2.1 Construct Validity

The comprehensibility of the questions and answers in the questionnaire may be a source of threat. In response to this threat, we designed the interview questions using the results obtained from the systematic literature review. Before the questionnaire was disseminated, we interviewed some participants to find out whether the questionnaire could be accurately understood, and our supervisor also gave us some suggestions to help us improve the structure of the questionnaire.

In addition, there are only 31 participants in the survey and only 29 valid answers. Most of the 29 participants were from small and medium-sized organizations, which resulted in the poor adaptability of our results to larger organizations and affected the accuracy of the results. We will investigate different sized organizations in the future to increase the accuracy of the results.

### 6.2.2 Internal Validity

When we took back the questionnaire, it was difficult to see if the answer was true, and we did receive several incomplete answers. In addition, the questionnaire itself makes it easy for respondents to identify our intentions, and then give or deliberately avoid the answers they think we want [45]. To overcome this threat, we avoid using subjective terms on the questionnaire and avoiding guiding issues.

In addition, in order to avoid the situation in which the investigators could not answer due to the unreasonable design of the questionnaire, we designed some open-ended questions after the questionnaire, and the participants could explain the suggestions for the questionnaire.

### 6.2.3 External Validity

If the sample population is not correct, it will lead to the validity of the questionnaire we received and lead us to bring to the wrong conclusion. Therefore, during the research process, we sent the survey to factory personnel with experience in DevOps and Agile to investigate to ensure that all interviewees had certain relevant knowledge. In addition, we only infer from the respondent's answer that the actual behavior in their lives is also an external validity problem [39]. Therefore, when we designed the questionnaire, we avoided the ambiguous sentences and hoped that the interviewees would be straightforward and concise when they responded, allowing our analysis to get closer to the real situation.

We also designed some questions in the questionnaire to understand how well participants knew DevOps. If the participant is ignorant of DevOps, his questionnaire will jump to the last part and end the survey.

## 6.3 Validity Threats of Interview

This section mainly describes the validity threats of the interview. We will explain from the two perspectives of internal validity and external validity.

### 6.3.1 Internal Validity

Selecting respondents who are not experienced or experienced may result in erroneous results for our data collection and analysis. In order to address this problem, we strictly screened respondents and adopted snowballing techniques to increase the number of people. In addition, our results may be affected by certain role biases, so we avoid making those threats by choosing respondents who have different roles in software development. The inherent threat to the effectiveness of retrospective studies is that respondents may experience memory ambiguity [46]. In order to reduce this bias, we sent them interview questions in advance and adopted semi-structured interviews to ask the same questions to 9 respondents. According to the respondent's response, we will ask new questions at any time and encourage interviewees to talk about the details of some work during the interview. We promised the respondents to collect data for research purposes only and keep them confidential so as to obtain real and effective answers.

### 6.3.2 External Validity

In order to avoid the one-sidedness of the research results as much as possible, we have screened multiple respondents who play different roles, have different experiences, work in organizations with different scales, and live in different regions.

# Chapter 7

# Conclusions and Future Work

## 7.1 Conclusion and Contribution

In this article, we introduced the challenges and corresponding mitigation strategies for adopting DevOps based on agile and summarize the corresponding software development process. The obvious challenges and mitigation strategies were divided into four categories: 1) People 2) Project 3) Process 4) Organization, after which we conducted further discussions based on the actual conditions and compared the results of systematic literature review and the results of questionnaire to detail explore their difference.

There are three kinds of our research methods: Systematic literature review, survey questionnaire and interviews. Through systematic literature review, we obtained 22 articles and summarized four categories, 23 challenges and mitigation strategies. Through the questionnaire, we identified these challenges and mitigation strategies in the industry. Then we compared these results separately, analyzed and obtained reports on the challenges of adopting DevOps in agile and figure out how mitigate these challenges. Then, through interviews with nine practitioners, we have summarized the real process of adopting DevOps in agile, then we corresponded the process challenges from the systematic literature review and questionnaire to the real process.

Afterwards, we conducted the data analysis and discussion separately. This study reveals the use of DevOps in real life to help the practitioner and researcher to solve problems that have previously occurred or to prepare in advance. We also identified future research directions that will apply mitigation strategies to the development process and help simplify the recommendations for continuous development and automatic deployment.

Our contribution is divided into two aspects. For academic research, this paper presents a summary of the challenges and mitigation strategies of using DevOps in agile to help researchers conduct further research. In addition, the exploration of the development process can help researchers directly locate the part that they want to study, and determine the challenges and mitigation strategies for that part.

For the industry, the challenges and mitigation strategies presented in this paper can provide more reference value for companies to implement new development methods. Discussion of the development process can help practitioners to adjust to

the challenges of different processes to better adapt to actual production.

## 7.2 Future Work

In the future, we will try to use the process of RQ 1 in actual production to identify the challenges and mitigation strategies in the process, then make improvements. In addition, we will carry out a large number of surveys for organizations of different sizes, to explore in a large team, if the members only have one single role and whether they will achieve different results from the small and medium-sized teams.

# References


[1] Scott W Ambler. Disciplined agile delivery and collaborative devops. *Cutter IT Journal*, 24(12):18, 2011.

[2] Dominica DeGrandis. Devops: So you say you want a revolution? *Cutter IT Journal*, 24(8):34, 2011.

[3] Ramtin Jabbari, Nauman bin Ali, Kai Petersen, and Binish Tanveer. What is devops?: A systematic mapping study on definitions and practices. In *Proceedings of the Scientific Workshop Proceedings of XP2016*, XP '16 Workshops, pages 12:1–12:11, New York, NY, USA, 2016. ACM.

[4] Johannes Wettinger, Uwe Breitenbücher, and Frank Leymann. Devopslang – bridging the gap between development and operations. In Massimo Villari, Wolf Zimmermann, and Kung-Kiu Lau, editors, *Service-Oriented and Cloud Computing*, pages 108–122, Berlin, Heidelberg, 2014. Springer Berlin Heidelberg.

[5] J. Sutherland and R. Frohman. Hitting the wall: What to do when high performing scrum teams overwhelm operations and infrastructure. In *2011 44th Hawaii International Conference on System Sciences*, pages 1–6.

[6] Airaj Mohammed. Enable cloud devops approach for industry and higher education. *Concurrency and Computation: Practice and Experience*, 29(5):e3937. e3937 CPE-15-0382.R1.

[7] Marta Olszewska and Marina Waldén. Devops meets formal modelling in high-criticality complex systems. In *Proceedings of the 1st International Workshop on Quality-Aware DevOps*, QUDOS 2015, pages 7–12, New York, NY, USA, 2015. ACM.

[8] Soon K. Bang, Sam Chung, Young Choh, and Marc Dupuis. A grounded theory analysis of modern web applications: Knowledge, skills, and abilities for devops. In *Proceedings of the 2Nd Annual Conference on Research in Information Technology*, RIIT '13, pages 61–62, New York, NY, USA, 2013. ACM.

[9] Erich F. M. A., Amrit C., and Daneva M. A qualitative study of devops usage in practice. *Journal of Software: Evolution and Process*, 29(6):e1885. e1885 smr.1885.

[10] E. Diel, S. Marczak, and D. S. Cruzes. Communication challenges and strategies in distributed devops. In *2016 IEEE 11th International Conference on Global Software Engineering (ICGSE)*, pages 24–28, Aug 2016.

[11] L. E. Lwakatare, T. Karvonen, T. Sauvola, P. Kuvaja, H. H. Olsson, J. Bosch, and M. Oivo. Towards devops in the embedded systems domain: Why is it so hard? In *2016 49th Hawaii International Conference on System Sciences (HICSS)*, pages 5437–5446, Jan 2016.

[12] Jens Smeds, Kristian Nybom, and Ivan Porres. Devops: A definition and perceived adoption impediments. In Casper Lassenius, Torgeir Dingsøyr, and Maria Paasivaara, editors, *Agile Processes in Software Engineering and Extreme Programming*, pages 166–177, Cham, 2015. Springer International Publishing.

[13] Leah Riungu-Kalliosaari, Simo Mäkinen, Lucy Ellen Lwakatare, Juha Tiihonen, and Tomi Männistö. Devops adoption benefits and challenges in practice: A case study. In Pekka Abrahamsson, Andreas Jedlitschka, Anh Nguyen Duc, Michael Felderer, Sousuke Amasaki, and Tommi Mikkonen, editors, *Product-Focused Software Process Improvement*, pages 590–597, Cham, 2016. Springer International Publishing.

[14] Dave West, Mike Gilpin, Tom Grant, and Alissa Anderson. Water-scrum-fall is the reality of agile for most organizations today. *Forrester Research*, 26, 2011.

[15] Dana Pylayeva. *Introduction to DevOps with Chocolate, LEGO and Scrum Game*. Apress.

[16] K. Gohil, N. Alapati, and S. Joglekar. Towards behavior driven operations (BDOps). pages 262–264.

[17] P. Perera, M. Bandara, and I. Perera. Evaluating the impact of devops practice in sri lankan software development organizations. In *2016 Sixteenth International Conference on Advances in ICT for Emerging Regions (ICTer)*, pages 281–287, Sept 2016.

[18] Tina Karrbom Gustavsson and Anette Hallin. Rethinking dichotomization: A critical perspective on the use of "hard" and "soft" in project management research. *International Journal of Project Management*, 32(4):568 – 577, 2014.

[19] Pedro Serrador and Jeffrey K. Pinto. Does agile work? — a quantitative analysis of agile project success. *International Journal of Project Management*, 33(5):1040 – 1051, 2015.

[20] A. Cockburn and J. Highsmith. Agile software development, the people factor. *Computer*, 34(11):131–133, Nov 2001.

[21] Lan Cao, Kannan Mohan, Peng Xu, and Balasubramaniam Ramesh. A framework for adapting agile development methodologies. *European Journal of Information Systems*, 18(4):332–343, Aug 2009.

[22] K. Conboy, S. Coyle, X. Wang, and M. Pikkarainen. People over process: Key challenges in agile development. *IEEE Software*, 28(4):48–57, July 2011.

[23] Tolfo Cristiano, Wazlawick Raul Sidnei, Ferreira Marcelo Gitirana Gomes, and Forcellini Fernando Antonio. Agile methods and organizational culture: reflections about cultural levels. *Journal of Software Maintenance and Evolution: Research and Practice*, 23(6):423–441.

[24] S. Sharma and N. Hasteer. A comprehensive study on state of scrum development. In *2016 International Conference on Computing, Communication and Automation (ICCCA)*, pages 867–872, April 2016.

[25] Howard Lei, Farnaz Ganjeizadeh, Pradeep Kumar Jayachandran, and Pinar Ozcan. A statistical analysis of the effects of scrum and kanban on software development projects. *Robotics and Computer-Integrated Manufacturing*, 43:59 – 67, 2017. Special Issue: Extended Papers Selected from FAIM 2014.

[26] Lise Tordrup Heeager and Jeremy Rose. Optimising agile development practices for the maintenance operation: nine heuristics. *Empirical Software Engineering*, 20(6):1762–1784, Dec 2015.

[27] M. Shahin, M. A. Babar, M. Zahedi, and L. Zhu. Beyond continuous delivery: An empirical investigation of continuous deployment challenges. In *2017 ACM/IEEE International Symposium on Empirical Software Engineering and Measurement (ESEM)*, pages 111–120, Nov 2017.

[28] Zhou Yiran and Liu Yilei. The challenges and mitigation strategies of using devops during software development, 2017.

[29] T. Laukkarinen, K. Kuusinen, and T. Mikkonen. Devops in regulated software development: Case medical devices. In *2017 IEEE/ACM 39th International Conference on Software Engineering: New Ideas and Emerging Technologies Results Track (ICSE-NIER)*, pages 15–18, May 2017.

[30] Frank Elberzhager, Taslim Arif, Matthias Naab, Inge Süß, and Sener Koban. From agile development to devops: Going towards faster releases at high quality – experiences from an industrial context. In Dietmar Winkler, Stefan Biffl, and Johannes Bergsmann, editors, *Software Quality. Complexity and Challenges of Software Engineering in Emerging Technologies*, pages 33–44, Cham, 2017. Springer International Publishing.

[31] Gerry Gerard Claps, Richard Berntsson Svensson, and Aybüke Aurum. On the journey to continuous deployment: Technical and social challenges along the way. *Information and Software Technology*, 57:21 – 31, 2015.

[32] B A. Kitchenham. *Kitchenham, B.: Guidelines for performing Systematic Literature Reviews in software engineering. EBSE Technical Report EBSE-2007-01.* 01 2007.

[33] K. Petersen and N. B. Ali. Identifying strategies for study selection in systematic reviews and maps. In *2011 International Symposium on Empirical Software Engineering and Measurement*, pages 351–354, Sept 2011.

[34] John Allspaw and Paul Hammond. 10+ deploys per day: Dev and ops cooperation at flickr. In *Velocity: Web Performance and Operations Conference*, 2009.

[35] *Database of Abstracts of Reviews of Effects (DARE): Quality-assessed Reviews*. Centre for Reviews and Dissemination (UK).

[36] Barbara A. Kitchenham and Shari L. Pfleeger. *Personal Opinion Surveys*, pages 63–92. Springer London, London, 2008.

[37] Lawrence A. Palinkas, Sarah M. Horwitz, Carla A. Green, Jennifer P. Wisdom, Naihua Duan, and Kimberly Hoagwood. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, 42(5):533–544, Sep 2015.

[38] Leo A. Goodman. Snowball sampling. *The Annals of Mathematical Statistics*, 32(1):148–170, 1961.

[39] Colin Robson and Kieran McCartan. *Real World Research*. John Wiley & Sons, Jaunary 2016. Google-Books-ID: ADGOCQAAQBAJ.

[40] D. Shahane, P. Jamsandekar, and D. Shahane. Factors influencing the agile methods in practice - literature survey amp; review. In *2014 International Conference on Computing for Sustainable Global Development (INDIACom)*, pages 556–560, March 2014.

[41] Taghi Javdani Gandomani, Hazura Zulzalil, AA Abdul Ghani, Abu Bakar Md Sultan, and Khaironi Yatim Sharif. How human aspects impress agile software development transition and adoption. *International Journal of Software Engineering and its Applications*, 8(1):129–148, 2014.

[42] P. Bootla, O. Rojanapornpun, and P. Mongkolnam. Necessary skills and attitudes for development team members in scrum: Thai experts' and practitioners's perspectives. In *2015 12th International Joint Conference on Computer Science and Software Engineering (JCSSE)*, pages 184–189, July 2015.

[43] Evelyn van Kelle, Per van der Wijst, Aske Plaat, and Joost Visser. An empirical study into social success factors for agile software development. In *Proceedings of the Eighth International Workshop on Cooperative and Human Aspects of Software Engineering*, CHASE '15, pages 77–80, Piscataway, NJ, USA, 2015. IEEE Press.

[44] Jeff Sutherland and Ken Schwaber. The scrum guide. the definitive guide to scrum: The rules of the game. *ScrumGuides. com*, 2013.

[45] Per Runeson and Martin Höst. Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, 14(2):131, Dec 2008.

[46] E. Murphy-Hill, T. Zimmermann, C. Bird, and N. Nagappan. The design space of bug fixes and how developers navigate it. *IEEE Transactions on Software Engineering*, 41(1):65–81, Jan 2015.

# Appendix A

# Reference List of Systematic Literature Review

Table A.1: Reference List of Systematic Literature Review

| No. | Title |
|---|---|
| S1 | Antti Virtanen, Kati Kuusinen, Marko Leppänen, Antti Luoto, Terhi Kilamo, and Tommi Mikkonen. On continuous deployment maturity in customer projects. In Proceedings of the Symposium on Applied Computing, pages 1205–1212. ACM, 2017. |
| S2 | Marta Olszewska and Marina Waldén. Devops meets formal modelling in high-criticality complex systems. In Proceedings of the 1st International Workshop on Quality-Aware DevOps, pages 7–12. ACM, 2015. |
| S3 | Uwe Van Heesch, Theo Theunissen, Olaf Zimmermann, and Uwe Zdun. Software specification and documentation in continuous software development: A focus group report. In Proceedings of the 22nd European Conference on Pattern Languages of Programs, page 35. ACM, 2017. |
| S4 | Theo Theunissen and Uwe Van Heesch. Specification in continuous software development. In Proceedings of the 22nd European Conference on Pattern Languages of Programs, page 5. ACM, 2017. |
| S5 | Stephan Krusche and Lukas Alperowitz. Introduction of continuous delivery in multi-customer project courses. In Companion Proceedings of the 36th International Conference on Software Engineering, pages 335–343. ACM, 2014. |
| S6 | Teemu Laukkarinen, Kati Kuusinen, and Tommi Mikkonen. Devops in regulated software development: case medical devices. In Software Engineering: New Ideas and Emerging Technologies Results Track (ICSE-NIER), 2017 IEEE/ACM 39th International Conference on, pages 15–18. IEEE, 2017. |
| S7 | Miguel Jiménez, Norha M Villegas, Gabriel Tamura, and Hausi A Müller. Deployment specification challenges in the context of large scale systems. In Proceedings of the 27th Annual International Conference on Computer Science and Software Engineering, pages 220–226. IBM Corp., 2017. |

| | |
|---|---|
| S8 | Morgan B Kamuto and Josef J Langerman. Factors inhibiting the adoption of devops in large organisations: South african context. In Recent Trends in Electronics, Information & Communication Technology (RTEICT), 2017 2nd IEEE International Conference on, pages 48–51. IEEE, 2017. |
| S9 | Lucy Ellen Lwakatare, Teemu Karvonen, Tanja Sauvola, Pasi Kuvaja, He- lena Holmström Olsson, Jan Bosch, and Markku Oivo. Towards devops in the embedded systems domain: Why is it so hard? In System Sciences (HICSS), 2016 49th Hawaii International Conference on, pages 5437–5446. IEEE, 2016. |
| S10 | Barry Snyder and Bill Curtis. Using analytics to guide improvement duringan agile–devops transformation. IEEE Software, 35(1):78–83, 2018. |
| S11 | Lianping Chen. Continuous delivery: Overcoming adoption challenges. Jour-nal of Systems and Software, 128:72 – 86, 2017. |
| S12 | FMA Erich, C Amrit, and Maya Daneva. A qualitative study of devops usage in practice. Journal of Software: Evolution and Process, 29(6), 2017. |
| S13 | Pulasthi Perera, Madhushi Bandara, and Indika Perera. Evaluating the impact of devops practice in sri lankan software development organizations. In Advances in ICT for Emerging Regions (ICTer), 2016 Sixteenth Interna- tional Conference on, pages 281–287. IEEE, 2016. |
| S14 | I. Bucena and M. Kirikova. Simplifying the devops adoption process. volume1898, 2017. |
| S15 | Frank Elberzhager, Taslim Arif, Matthias Naab, Inge Süß, and Sener Koban. From agile development to devops: going towards faster releases at high quality–experiences from an industrial context. In International Conference on Software Quality, pages 33–44. Springer, 2017. |
| S16 | M Rajkumar, Anil Kumar Pole, Vittalraya Shenoy Adige, and Prabal Mahanta. Devops culture and its impact on cloud delivery and software de- velopment. In Advances in Computing, Communication, & Automation (ICACCA) (Spring), International Conference on, pages 1–6. IEEE, 2016. |
| S17 | Elisa Diel, Sabrina Marczak, and Daniela S Cruzes. Communication challenges and strategies in distributed devops. In Global Software Engineering (ICGSE), 2016 IEEE 11th International Conference on, pages 24–28. IEEE, 2016. |
| S18 | Gerry Gerard Claps, Richard Berntsson Svensson, and Aybke Aurum. On the journey to continuous deployment: Technical and social challenges along the way. Information and Software Technology, 57:21 – 31, 2015. |
| S19 | Helena Holmström Olsson and Jan Bosch. Towards agile and beyond: an empirical account on the challenges involved when advancing software development practices. In International Conference on Agile Software Development, pages 327–335. Springer, 2014. |
| S20 | Saliya Sajith Samarawickrama and Indika Perera. Continuous scrum: A framework to enhance scrum with devops. In Advances in ICT for Emerging Regions (ICTer), 2017 Seventeenth International Conference on, pages 1–7. IEEE, 2017. |

| | |
|---|---|
| S21 | Wouter JW Geurts. Faster is better and cheaper. In INCOSE International Symposium, volume 26, pages 1002–1015. Wiley Online Library, 2016. |
| S22 | Kristian Nybom, Jens Smeds, and Ivan Porres. On the impact of mixing responsibilities between devs and ops. In International Conference on Agile Software Development, pages 131–143. Springer, 2016. |

# Appendix B

# Survey basic information statistics

## B.1 Challenges

Table B.1: Basic Information Statistics of Challenges

| | **Work Experience** | | | | **Roles*** | | | | **TeamSize** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <1 | 1∼5 | 5∼10 | >10 | D | M | T | O | <10 | 10∼50 | 50∼100 | >100 |
| C1 | 1 | 6 | 4 | 1 | 10 | 2 | 9 | 3 | 0 | 9 | 3 | 0 |
| C2 | 3 | 3 | 3 | 0 | 8 | 2 | 6 | 5 | 0 | 11 | 3 | 0 |
| C3 | 3 | 13 | 7 | 1 | 16 | 5 | 11 | 7 | 1 | 16 | 5 | 0 |
| C4 | 3 | 7 | 1 | 2 | 9 | 4 | 12 | 4 | 0 | 10 | 3 | 0 |
| C5 | 1 | 5 | 4 | 1 | 11 | 3 | 9 | 3 | 0 | 7 | 3 | 0 |
| C6 | 1 | 4 | 4 | 1 | 8 | 3 | 5 | 4 | 0 | 8 | 3 | 0 |
| C7 | 2 | 4 | 6 | 1 | 11 | 5 | 7 | 7 | 0 | 9 | 3 | 0 |
| C8 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 0 | 2 | 1 | 0 |
| C9 | 2 | 5 | 2 | 1 | 8 | 2 | 6 | 4 | 1 | 10 | 4 | 0 |
| C10 | 2 | 6 | 3 | 1 | 11 | 3 | 7 | 4 | 0 | 14 | 3 | 0 |
| C11 | 5 | 8 | 2 | 2 | 9 | 3 | 8 | 5 | 0 | 7 | 4 | 0 |
| C12 | 2 | 7 | 3 | 2 | 10 | 6 | 9 | 6 | 0 | 10 | 4 | 0 |
| C13 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 3 | 0 |
| C14 | 2 | 3 | 4 | 1 | 7 | 4 | 4 | 4 | 0 | 7 | 2 | 0 |
| C15 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 2 | 0 | 2 | 0 | 0 |
| C16 | 0 | 7 | 3 | 1 | 10 | 3 | 6 | 6 | 1 | 8 | 3 | 0 |
| C17 | 2 | 5 | 2 | 1 | 7 | 4 | 5 | 5 | 0 | 8 | 4 | 0 |
| C18 | 3 | 11 | 4 | 2 | 13 | 4 | 9 | 4 | 0 | 16 | 4 | 0 |
| C19 | 2 | 10 | 6 | 1 | 15 | 4 | 10 | 5 | 0 | 12 | 4 | 0 |
| C20 | 1 | 4 | 4 | 0 | 7 | 3 | 4 | 4 | 0 | 6 | 3 | 0 |
| C21 | 4 | 5 | 5 | 1 | 11 | 3 | 8 | 6 | 0 | 8 | 5 | 0 |
| C22 | 1 | 5 | 1 | 1 | 5 | 4 | 5 | 3 | 0 | 7 | 2 | 0 |
| C23 | 3 | 3 | 4 | 0 | 8 | 2 | 3 | 4 | 0 | 6 | 3 | 0 |

[1]

[1]* D: Developer M: Manager T: Tester O: Operations

## B.2 Mitigations

Table B.2: Basic Information Statistics of Mitigations

| | **Work Experience** | | | | **Roles*** | | | | **TeamSize** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <1 | 1∼5 | 5∼10 | >10 | D | M | T | O | <10 | 10∼50 | 50∼100 | >100 |
| C1 | 2 | 5 | 4 | 1 | 10 | 4 | 7 | 5 | 0 | 12 | 6 | 0 |
| C2 | 0 | 2 | 3 | 0 | 5 | 3 | 4 | 3 | 0 | 3 | 4 | 0 |
| C3 | 4 | 8 | 5 | 2 | 14 | 3 | 11 | 6 | 1 | 15 | 7 | 0 |
| C4 | 2 | 5 | 4 | 2 | 8 | 3 | 7 | 5 | 0 | 8 | 3 | 0 |
| C5 | 2 | 1 | 3 | 2 | 4 | 2 | 6 | 4 | 0 | 5 | 3 | 0 |
| C6 | 2 | 0 | 6 | 1 | 8 | 2 | 1 | 4 | 0 | 5 | 4 | 0 |
| C7 | 2 | 2 | 3 | 1 | 8 | 2 | 5 | 2 | 0 | 5 | 3 | 0 |
| C8 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 2 | 0 | 2 | 0 | 0 |
| C9 | 2 | 4 | 4 | 1 | 9 | 4 | 8 | 6 | 1 | 8 | 5 | 0 |
| C10 | 3 | 7 | 4 | 2 | 10 | 6 | 8 | 5 | 0 | 10 | 5 | 0 |
| C11 | 3 | 3 | 4 | 1 | 9 | 3 | 8 | 4 | 0 | 6 | 7 | 0 |
| C12 | 2 | 0 | 4 | 2 | 6 | 3 | 5 | 4 | 0 | 6 | 2 | 0 |
| C13 | 1 | 2 | 2 | 1 | 6 | 2 | 5 | 2 | 0 | 4 | 2 | 0 |
| C14 | 1 | 2 | 4 | 0 | 7 | 3 | 4 | 4 | 0 | 5 | 3 | 0 |
| C15 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 3 | 1 | 3 | 0 | 0 |
| C16 | 2 | 5 | 3 | 1 | 9 | 3 | 8 | 6 | 1 | 8 | 5 | 0 |
| C17 | 2 | 4 | 3 | 2 | 9 | 5 | 7 | 8 | 0 | 9 | 5 | 0 |
| C18 | 2 | 3 | 3 | 2 | 7 | 4 | 7 | 5 | 0 | 5 | 5 | 0 |
| C19 | 3 | 8 | 5 | 0 | 12 | 4 | 8 | 7 | 0 | 7 | 6 | 0 |
| C20 | 2 | 5 | 2 | 1 | 9 | 4 | 8 | 5 | 0 | 7 | 5 | 0 |
| C21 | 4 | 3 | 3 | 1 | 8 | 2 | 6 | 5 | 0 | 7 | 4 | 0 |
| C22 | 2 | 3 | 5 | 1 | 8 | 5 | 6 | 5 | 0 | 8 | 4 | 0 |
| C23 | 2 | 3 | 4 | 1 | 9 | 3 | 6 | 4 | 0 | 6 | 4 | 0 |

# Appendix C

# Questionnaire

# Adoption DevOps in Agile

We are Software Engineering students at BTH, and now we are working on the master thesis(Adopting DevOps based on Agile: challenges and solutions). The audience for this questionnaire is the Agile participant. We designed this questionnaire for collecting the latest and factual information about the challenges and mitigations. Your answer is very important for us, and it will take you about 15 minutes, very appreciate for your Participate!

We fully respect your personal privacy, all of the information is for our data statistics. We will not disclose your
personal information to any third party without your consent.

Cheng Wang
chengw1121@gmail.com

Changling Liu
chli16@student.bth.se

*Required

## Basic Information

1. **Which country are you from?**

_____

2. **How many years have you worked in software field?**
   *Mark only one oval.*

   - ◯ Less than one year
   - ◯ 1 ~ 5 years
   - ◯ 5~10 years
   - ◯ More than 10 years

3. **What is your role when you work?**
   *Tick all that apply.*

   - ☐ Developer
   - ☐ Manager
   - ☐ Tester
   - ☐ Operations
   - ☐ Other: _____

4. **Size of your team?**
   *Mark only one oval.*

   - ◯ <10
   - ◯ 10~50
   - ◯ 50~100
   - ◯ >100

5. **What is the type of your products/domain?**
   Work domain, like Network Service, Medical Software . etc

   _____

## DevOps Basic

DevOps is a development law aimed at bridging the gap between Development and Operations, emphasizing communication and collaboration, continuous integration, quality assurance and delivery with automated deployment utilizing a set of development practices

6. **Have you ever heard of DevOps?**
   *Mark only one oval.*

   - ◯ No, never *Skip to question 7.*
   - ◯ I have heard of it but I don't know its mean *Skip to question 7.*
   - ◯ Yes, I know what's mean *Skip to question 9.*
   - ◯ I have used it/I am using it now *Skip to question 9.*

## Adoption DevOps

7. **"DevOps is a development law aimed at bridging the gap between Development and Operations, emphasizing communication and collaboration, continuous integration, quality assurance anddelivery with automated deployment utilizing a set of development practices". Do you want to adoption DevOps in your team?**
   *Mark only one oval.*

   - ◯ Yes, it looks awesome
   - ◯ No, i don't like that *After the last question in this section, skip to question 13.*
   - ◯ May be, I am not sure
   - ◯ Other: _____

8. **Have you ever adoption devops in your work without knowing its conception?**
   *Mark only one oval.*

   - ◯ Yes
   - ◯ No *Skip to question 13.*
   - ◯ I am not sure

# Adoption DevOps Challenges

9. **Have you encountered challenges when adopting DevOps?** *
   *Tick all that apply.*

- [ ] C1: Lack of support for improvement from the customer's practices or processes.
- [ ] C2: Limited or non-existent tool support.
- [ ] C3: Team practices and team member's attitudes.
- [ ] C4: The obscurity of the meaning of DevOps.
- [ ] C5: Insufficient communication.
- [ ] C6: Changing team roles, member needs adapt new roles
- [ ] C7: Cultural matters.
- [ ] C8: The cooperation between Dev and Ops is difficult, friction between Dev and Ops.
- [ ] C9: Lack of staff to meet DevOps conditions(e.g. need a wider array of skills)
- [ ] C10: Have problems with evaluating staff progress, and tends to blur responsibilities.
- [ ] C11: Difficulty automating everything, some Automation Operating Architectures Need to Change.
- [ ] C12: Configuration management of test environments and runtime adaptivity.
- [ ] C13: Insufficient Infrastructure.
- [ ] C14: Continuous software engineering make the specifications difficult to handle.
- [ ] C15: Does not meet the creteria of some special industries (For example, medical software).
- [ ] C16: The initial costs of automation, continuous deployment are high, and productivity is limited.
- [ ] C17: DevOps implementation does not have a proper software process management framework.
- [ ] C18: Get continuous support in a complex and changing enterprise environment.
- [ ] C19: The organizational challenge is to change the existing structure of the organization.
- [ ] C20: Process challenges, to change the past process.
- [ ] C21: Some legacy systems are difficult to continue with new development methods.
- [ ] C22: And due to the DevOps cost, efficiency, risk is not clear,management are skeptical for this.
- [ ] C23: Difficult to establish an effective rollback mechanism and customer analysis mechanism.

10. **Have you encountered another challenges when adopting DevOps?**

## Adoption DevOps Mitigations

11. **What mitigations have you used/are you going to use for overcoming the challenges? (Multiple-choice, Order is consistent with challenge)**

*Tick all that apply.*

- [ ] C1: Continuous communication with customers, understand their pain points and try to solve it.
- [ ] C2: Clear requirements for tools and provide some plugins related to known products.
- [ ] C3: Strengthen communication, and company executives provide strongly support.
- [ ] C4: Confirm the direction, then deepen the conception, organize the lectures and team building training.
- [ ] C5: Identify silos and promote communication with full participation.
- [ ] C6: Determine the value of the new role and let the entire team work closely.
- [ ] C7: The company organizes cultural changes, conducts team building training.
- [ ] C8: Strengthen communication between Dev and Ops, or set up a mediator to In-depth intervention.
- [ ] C9: Organizations invite experts to provide training and practice.
- [ ] C10: Clearly define success criteria and actively track project progress and performance.
- [ ] C11: Looking for existing tools to support automation, or use new architecture posted by other company.
- [ ] C12: Understand own model and requirements, conduct continuous testing to ensure thorough testing.
- [ ] C13: Provide more hardware resources for the CI server of the to Continuously integrate as needed.
- [ ] C14: Refactoring specification or use continuous software design specification or adoption social rules.
- [ ] C15: Need further development of DevOps,to fit with the special standards.
- [ ] C16: Use SNAC Framework or use old and new system smooth transition.
- [ ] C17: A new framework continuous scrum was proposed, describing the continuous part of DevOps.
- [ ] C18: Make sure continuous delivery can help resolve stakerholder's pain point.
- [ ] C19: Create a dedicated continuous delivery team, recognize the value of the new role, or use SNAC.
- [ ] C20: Let employees understand the benefits of change, and starting with small changes.
- [ ] C21: Start with a simple but important part, run the old and new systems to gradually upgrade.
- [ ] C22: Manager needs to track team performance, and should strengthen the communication.
- [ ] C23: Enhance communication, frequent deployment software to collect interaction data.

12. **Based on the challenges you encountered before, do you have any other mitigation strategies to solve your problem?**

## Additional question

13. **What do you think of the cooperation between DevOps and Agile?**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Terrible | ◯ | ◯ | ◯ | ◯ | ◯ | Excellent |

14. **Do you think DevOps has a good impact or a bad impact on your work?**
*Mark only one oval.*

- ◯ Good
- ◯ Bad

15. **Any thing you want to talk about this questionnaire?**

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