Uncertainty Management in Software Projects - An Action Research

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Abstract. Project management has become a core business process for many companies both at strategic and operational level. However, there is no doubt that many projects fail, IT projects are notoriously disaster-prone, not necessarily because of technological failure but often due to their uncertainties. In this article it is shown an investigation aiming to build a guide to manage the uncertainties in project management. An action research has been made with the objective to evaluate the uncertainties in a software development innovative project. This action research aimed to verify which applied practices could be formally developed, guide efforts to uncertainty reduction and to guarantee the success of the project.

Keywords: Software Project Management; Action Research; Uncertainties in Projects Management; Uncertainty in Software Projects

1 Introduction

Companies face a great commercial competition nowadays demanding fast decisions, better resource allocations and a clear focus definition. in a typical software development environment it is not different. Many project types are proposed with different objectives in which strategic management according to organizational goals is needed.

Projects are essential for the success of any company combining activities which lead them to new products, services and new business development. successful projects increase the sales, reduce the costs, improve the quality, the client satisfaction, the work environment, among other benefits. Therefore, a growing number of companies use their project management as a fundamental strategy to maintain the competition adding value to their business.

However, many projects with all the ingredients for success, fail. It happens because executives, managers and project team are not used to evaluate the uncertainties and complexities involved beforehand and fail to adapt their management style to the situation [28].

The uncertainty and risk management should be considered complementary approaches, while risk management keeps on being an important tool, the project manager also needs strategies to manage uncertainties, or else, to deal with risk management areas that are unknown.

According to [3] uncertainty is much less susceptible to analysis; it is what is left behind when all the risks have been identified. Uncertainty represents a threat, but we cannot be sure what form it will take. If it was otherwise we would identify it as a risk. We may be able to see that there is a gap in our understanding but, unlike a risk, we do not perceive what it is that we do not know. Not until uncertainty manifests itself into a specific problem is the nature of the threat revealed and by then it may be too late to deal effectively with the consequences.

In order to treat the uncertainties some studies [28, 26, 3, 17, 32, 19, 24] criticize the current project management practices which are based on previous planning. They indicate the use of differentiated approaches according to uncertainty and complexity combination. Furthermore, many authors [25, 26, 22, 17] state that risk management based on planning is not enough to manage uncertainties generated by restrictions and the project areas which are not clearly defined.

This paper aims to present an investigation done in a software project conducted through the action research method and through an approach generated to manage uncertainties in software projects. For Sjberg et al.[29], the action research represents "the kind of study where a more realistic research scenario is found", once it involves a real industrial context to investigate concrete actions results. Therefore, this paper explores actions taken in a real project aiming to reduce the uncertainties.

Besides the introductory section, this paper is structured as follows:Section 2 discusses about Evidence-Based-Software Engineering; in Section 3 presents a action research application in a software development project and finally Section 4 contains the conclusion.

2 Evidence-based Software Engineering

Evidence-based software engineering aims to provide means by which the best evidence from research can be integrated with practical experience and human values in the decision-making process considering the development and software maintenance [16]. The essence of evidence-based paradigm is systematically collect and analyze all available data about a phenomenon for a more comprehensive and broader perspective than one can capture through a single study.

Kitchenham et al. [16] believe that software engineering can provide evidence-based mechanisms needed to help the professional to adopt appropriate technologies and avoid unsuitable ones, aiming the best practices and procedures. Some studies suggest that software engineering professionals (researchers) must consider the use of evidence-based software engineering support to improve their decisions about which technologies to adopt [16, 14, 31, 10, 15].

According to Dick, [7] it has been common the use of action research in the evidence-based research paradigm context in these domains as means of connecting theory and practice, or else, academia and industry in both directions. In the following sub-section is about action research.

2.1 Action Research

Most of the empiric research methods attempt to observe the world as it is currently; the action researchers aim to intervene in the studied situations with the explicit objective of improving the environment. the action research has its origin associated to the first interventionist practices done by Kurt Lewin [7] in the decade of 1940 in psychotherapy. Currently, it is used in several other areas as education, business and nursing. Its goal is to perform simultaneously research and action. The action is usually associated with some transformation in a community, organization or programme, while research is characterized by a greater transforming phenomenon understanding by the researcher (research community) or interested (client), or both [27].

A prerequisite for action research is making the problem owner disposed to contribute both to identify a problem and to engage in an effort to solve it. In action research, the problems owners become research collaborators. In some cases, the investigator and problem owner may be the same person. In addition, it is important for the action research that the researcher engage in a critical reflection process about their past, adding the researcher‘s current and planned actions to identify how they actually helped (or not) to solve the problem [11].

Easterbrook et al. [11] argue that a lot of software engineering research is actually a disguised action research. Indeed, many key ideas in software engineering were originally developed by experiencing them in real development projects and reports on experiences. In this sense, Dittrich [8] describes the cooperative systems development as a ideal action research way for empirical software engineering. By adopting the action research structure more explicitly, it is likely that the design and evaluation of such research may become stricter.

According to Davison *et al* [4], the different types of action research usually include the following activities: **Diagnosis**: It consists in finding the search field, stakeholders and their expectations in a holistic perspective; **Planning**: Step where actions are defined for the diagnosed framework; **Intervention**: Corresponds to the planned actions implementation; **evaluation**: Activity which we perform the action effects analysis facing the theoretical support used as a starting point for the actions definition; **Reflection and Learning:** It involves the information flow between participants and other organization parts.

This process may be incrementally conducted. It usually occurs when the diagnosis can not be fully done. In addition to these activities, the research environment requires a contract/agreement that legitimizes the actions, potential benefits for both parties (researchers and organization) and other issues, which make up the so-called client-system infrastructure.

3 Applying an Action Research in a Software Development Project

To develop and report the action research it was used the model described in [9] derived from the authors' experience in conducting different studies of action research in Software Engineering. Each step of action research will be presented.

3.1 Diagnosis

Problem Description The study was carried out in the High Performance Research Group at the Information Technology Center at the Federal University of Pernambuco, Brazil, under the name of HPCIn.

Throughout years the group attempted to manage projects under the traditional model, however they were not so successful. So they went on to implement an agile approach in which vast improvements were obtained. Even so the project did not guarantee the awaited success neither for by the team or the sponsors. The first project the group adopted the agile approach was the one known as "Dynamically Reconfigurable System for High Performance Computing," whose main objective was to implement the simulation acceleration for the petrol industry, in particular for Petrobras. It was developed in a hybrid computing model utilizing not only solutions based on common PCs in order to form a cluster, but also inside a new hardware architecture based on reconfigurable electronic devices, worldwide known as FPGA (Field Programmable Gate Array). The idea was to use a new cluster model which due to its intrinsic characteristics of parallelism can supply larger computing resources which are smaller and consume less energy. The project in question was developed but not successfully completed.

Once the project was over, even though it did not continue, the research group developed and awakened interest in other Petrobras sponsors groups. They immediately put forth a new project called "High Performance Solutions for Modeling and Seismic Migration Based on FPGA devices". This project aimed to implement the 2D algorithm in a reconfigurable and scalable platform for the simulation models processing in order to recognize strategic points for the petrol extraction which are currently extremely complex and require a high amount of computer processing. In this case the client, the manager and the team adopted an agile model and it was developed between 2008 and 2011 [21].

The 2D Seismic project was partially delivered. In this case, the client, the manager and the team adopted an agile model but forgot that both the solution and the target had a large uncertainty level related to it. Furthermore, they failed to observe the uncertainty sources, such as technological uncertainty, which was a factor that was quite relevant for the project.

Despite the partial project delivery and because of major technological uncertainties, the results achieved aroused interest in the sponsors for a new investment, so they signed a new project with the group. This time the project called "Modeling and 3D Migration Using FPGA's" is going to be called 3D Seismic Project. The project took place between 2012 and 2013. Due to the great group's concern with the commitment to deliver a quality product that effectively contributed to the customer, it was proposed by the manager to conduct an action research to investigate which practices and tools could contribute to project success taking into consideration its related uncertainties. The practice was accepted by the project coordinator (a teacher responsible for the group) and all the teamwork.

Project Context The 3D Seismic Project aimed to provide the study and development of a computer system based on a hybrid architecture with coprocessors implemented from FPGAs reconfigurable logic devices. The hardware and software modules design developed were tested on a reconfigurable platform. This system is able to solve problems with a high computational performance, being of interest to the Oil and Gas sector with performance comparable to multi-core technologies and GPUs or better. To further clarification of the issue, this process can take months to complete a certain region simulation, and at the same time,the competitiveness with oil discoveries in Brazil in the pre-salt layer, whose volume is estimated to be about 10 billion barrels of oil [1], requires new strategies implementation to accelerate the definition of favorable drilling points for its extraction. With the obtained results of this project Petrobras may achieve gains in performance if compared to general purpose CPUs. Such project was made for 21 people, with 1 coordinator, 1 consultant, 1 project manager, 1 chief scientist, 1 administrative secretary, 3 technical leaders, 8 computer engineers and 5 trainees. Besides UFPE Center for Informatics and Petrobras, the following organizations were involved: the University Foundation, responsible for administrative and legal support to the project and a third party, that we will call here XW, company responsible for a FPGA board development specified by the project team.

Research Subject According to the scenario previously presented, the investigation subject is defined as: a continuous uncertainty investigation related to the project; an evaluation of which practices (techniques and strategies) may contribute for the uncertainty reduction. Furthermore, an approach to manage the uncertainties in software projects.

3.2 Planning

The action research planning was conducted based on the methodology proposed by Dias Neto, Spinola and Travassos in [6] together with action research step model by Santos and Travassos [9]. Thus, in 2011 a research began*Ad Hoc* literature on uncertainty management in software projects, described in [19]. Then we conducted a systematic review of the literature presented in [19] and associated to it an action research was conducted.

In this section the planning phase is described and it starts with a literature technical survey where some papers on the research subject are examined. So the intervention focus could be organized with the research objectives and expected results establishment. Finally, instruments, tools and techniques used in the research are presented.

Literature Research Loch et al [17] criticize the actual practices in project management. These are based in preplanning. They have suggest the use of different approaches by combining uncertainty and complexity. For this, they suggest a prior diagnosis about the level of uncertainty and complexity.

Shenhar et al [28] offer an adaptive approach which the authors call "The Diamond Approach", and is used to correctly classify projects and choose the best way to manage them. O'Connor and Rice [24] present a study in companies with 12 radical innovation projects and group uncertainties encountered in these projects. They classify these uncertainties and cite as latency and criticality factors that must be weighed in the projects.

Martisuo et al [20] presented how to deal with uncertainty in program management. In particular, the authors want to understand how the portfolio managers deal with the threats and opportunities that generate uncertainties. More specifically, they want to understand the consequences of uncertainty in portfolio management. They seek interpretive alternatives and control strategies that managers use when facing different uncertainties types.

The uncertainties in projects have a strong relationship with the early signs. The term weak signals was created by Igor Ansoff in the decade of 1970 in which he presented the first version of his weak signals theory [2]. Ansoff says the world is awash in information, often ambiguous, imprecise and incomplete. Still, that can be transformed into significant advantages for companies. The starting point of Ansoff is information that a company receives from its environment.

In the context of projects, these early signs are of great importance, especially innovative projects once they have various associated uncertainties. Nikander and Eloranta in [23] address this subject in project management context. The authors studied a number of early signs that have been identified in project managers interviews. Kappelman et al [13] conducted extensive literature research to develop an early signs preliminary list in IT projects. The authors added new items to develop a list of 53 early signs.

Action Focus Action research was conducted to **goal** establish practices that could manage the uncertainties in software projects and generate an approach to manage uncertainties. Our **research question** was: what practices may contribute to uncertainties management in the software projects? As **expected results** create an approach that can be adopted by software projects to reduce uncertainties. We point out that as action researchers agree with Thiollent [30], action research is not only a simple data collection but a research where researchers want to play an active role in the very reality of the observed facts, or else, throughout all the research process we operate actively in the project in order to support the uncertainties management.

Operacional Definitions Aligning with our focus, we established techniques for better conduction of action research; they were: semi-structured interviews, focus groups, follow-up meetings, retrospective meetings and follow-up activities. To support our activities we used **tools** such as: a specific directory in the project server to store all artifacts produced and used in the research, as well as electronic versions of publications, generated data sheet, partial reports and other documents.

3.3 Actions

As previously mentioned, a literature search *Ad Hoc* and a systematic review have been prepared to support an action research. The actions that were carried out during the research are presented:

Action 1 - Adapting Management Style to the Projects Type: As shown by HPCIn group, the adopted methods were not appropriated in the research and product development, so we decided to investigate how better adapt the group's management style to their need in order to apply a better approach that helped in managing uncertainty.

Action 2 - Project Planning: Due to technological uncertainties, the stakeholders were asked to attend meetings for a better project understanding. The brainstorming technique was used in four meetings attended by two Petrobras leaders,as well as the coordinator, consultant, project manager, chief scientist and 3 technical leaders. In addition, the project manager asked the chief scientist and 3 technical leaders a study in the area to verify the project feasibility. After that, we created a macro schedule (a Petrobras requirement) and adopted an agile planning, which raised all the user stories we learned so far (among them there were various activities of studies and prototyping). We applied the *planning poker* at that stage, except from the secretary, all staff was involved in the estimation process and we applied the rate of error percentage of the team (based on the history, because as we mentioned, all data from 2D design was managed in an agile way). Adding the error percentage, the activities completion estimation was 18 months. However we still had uncertain components, such as: outsourcing the development of a FPGA board, the team suffered a little personnel turnover, we had restrictions imposed by the client in choosing the company that would develop the board, and as we were still in a university, we depended on the Administrative Foundation. Based on those uncertainties, we asked our client a deadline of 24 months.

Action 3 - Creating Prototypes: For innovative projects there are uncertainties related to the goals and the solution. In most projects those aspects are both learned and defined as part of project execution. For R&D projects the development cycle must contain research and prototype construction to converge on a goal by supporting a solution. Thus, we tried to perform prototyping since the beginning of the project.

Action 4 - Continuous Early Warning Signs Investigation: We established an early signs investigation during the project. A constant observation was carried out during project implementation. We investigated which early signs arose during the project, we did a retrospective with the reported signs and performed a sensemaking to make a decision regarding the perceived signals every fortnight. The signs investigated in the project were listed by Nikander and Eloranta in [23] and Kappelman et al [13]. Because of limited page number, Table 1 just contains four signals observed during the project development. We must highlight that we also had a risk plan.

Action 5 - Dealing with Uncertainty when They Happen: Project managers may try to contain uncertainty in its source, but never have one hundred percent success. Therefore, we try to be able to quickly detect and respond to unexpected events in our project. For unexpected results a project manager must then decide how best to deal with the uncertainty.

Action 6 - Uncertainty Management Technique Adoption: We adopted several practices that contributed to a better project understanding and thus reduce uncertainties such as: managing stakehoders'expectations, project success qualitative measures, early signs identification, flexible management and acting change, stimulus for team ideas generation, creativity techniques such as: brainstorming, collaborative work, continuous integration, multidisciplinary team.

3.4 Evaluation and Analysis

This section explores the study results, such as the learning design. Thus, these results will be exploited with the purpose of their organization and reflection on the knowledge gained from the actions.

After two years of project we completed the delivery as planned. The board we had ordered was not ready because the XW company had not completed its development in time, and because of that, our project was delivered in a lower performance board but with all algorithm working and processing seismic images properly. The customers received the project in time and said the goal was achieved and because of that other projects could be ordered.

We conducted a focus group with the team to assess the project completion and all the interventions made during the it. The team agreed that all practices embedded in the project contributed to its success, they praised the care taken in the research that was conducted with the project and that way contributed to: the staff acquire more knowledge, learn more about the project, learn how to behave when facing uncertainties and early signs, act when something unexpected happens and actually run the risk plan.

We interviewed the project coordinator, the consultant, the scientific leader and technical leaders, they were all in favour of interventions. The coordinator said in his interview that: "adopted practices ensured the project and the team success", yet, "At first, the uncertainties were plenty, but with this management style we could reduce uncertainty and achieve our goals". The scientific leader said: "It was like I was working from home, the environment, the people were united with one goal, of course there were differences, but all had cooperation in

Table 1. Early Signs Investigation

Uncertainty Source	Early Signs	Description
Socio-Human	intuition	**Event:** Despite believing in the board development in a short term of twelve months, the team had the intuition that the outsourced company would not deliver it on time. In spite of the CEO of the outsourced team's technical knowledge, the company was new in the market, as well as its team. **Decision-making:** We warned our clients so, but they insisted on developing it with XW, then we prepared an alternative for delivery. We tried to modularize the maximum our application to suit the other board. Furthermore, we had three FPGA boards with inferior performance that we would build with XW company, but we made them an alternative to the project delivery. **Result:** That alternative for delivery saved the project. XW company did not finish the project on time, so we delivered our algorithm on the boards we had.
Environment	Personnel changes	**Event:** There was a concern to keep people in the project and in case of changes, finding the right people for the project **Decision-making:** The environment were changed with the aim of turning it nice for the building process team. Stations, chairs, tables, white boards were exchanged. We also added a coffee machine, a refrigerator and games for the team. When we needed to select people, we invited a psychologist and created dynamics based on agile methodologies and sociodrama [5]. **Result:** The stimulated to work team and people who joined them during the process in that environment got easily involved due to the chosen profile in the dynamics.
Technology	Success criteria of the project undefined	**Event:** In the 2D project there was no success definition. **Decision-making:** A meeting was conducted between team and stakeholder to define project success criteria. **Result:** There have been various criteria. Among them, the plan to deliver the boards we had (with lower performance) the algorithm, was a success criterion in case XW company did not finish the FPGA boards in time.
Market	The main project stakeholders did not participate in the major review meetings	**Event:** The main stakeholder (Petrobras) was not able to participate in important project meetings. **Decision-making:** We started to document the meetings and activities done and send them a summary. **Result:** The stakeholder themselves found it an excellent alternative, thanked the information sending and made sure they were updated with what was happening in the project.

mind. The interventions were essential for doing so." One of the technical leaders said: "Despite all technological uncertainties, the XW not having delivered the board, we showed our customers that our team managed to reach the goal" The consultant said: "The elaborated practices here should be written for other people to use!".

3.5 Reflections and Learning

From the actions taken, we identified some practices that can help que uncertainty management, such as: knowledge strategies, mindfulness culture, multiple perspective, prototype, differentiated management methodology, stakeholder management, contractual terms with suppliers including uncertainties, early identification, historical/past review, creativity techniques, learning strategies. Furthermore, by answering the research question, we could manage the uncertainties and prepare a preliminary guide to help project managers to reduce uncertainties. This guide was built by the action research experience and theoretical studies in *ad hoc* research [19] and systematic review [18] is shown in Figure 1 described below.

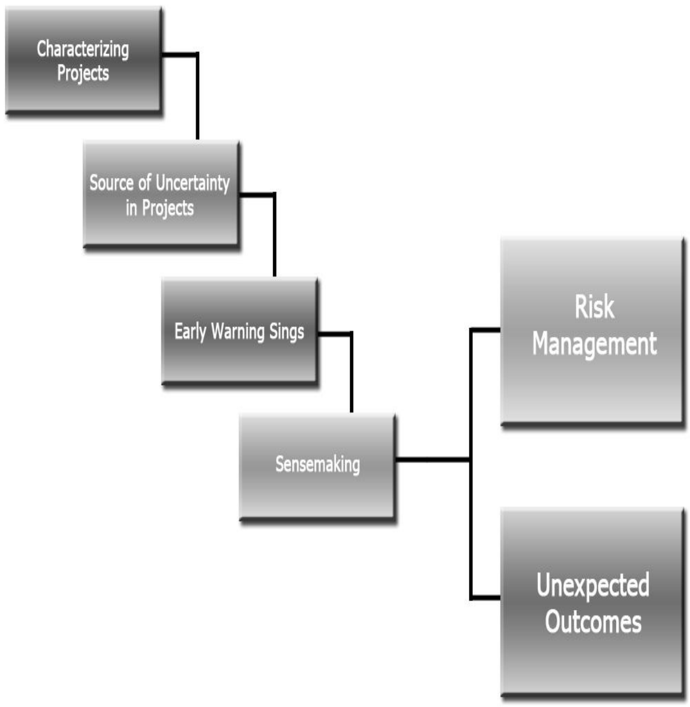

Fig. 1. Preliminary Guide for the Management of Projects.

Characterizing Projects Phase It is necessary to identify the type of project. The Characterizing Projects phase is a mixture of selling the idea, establishing the business value of the project, brainstorming possible approaches, forming the team, and getting everyone on board and excited about what they are about to undertake. It is definitely a time for team-building and creating a strong working relationship with the client.

Source of Uncertanty Phase The uncertainty management starts with the understanding of the uncertainty sources. We may not always be aware of a specific uncertainty, but we can be alert to factors that may influence the success or failure of the project, it is important to understand the uncertainties sources.

Knowledge maps are a practical way for dealing with uncertainty in the project. The knowledge map building process helps clarify what is known in the project. In doing so, it is often possible to find out which are the sources of uncertainty that the project is more susceptible to.

Early Warning Signs Phase Early signs can be verbally manifested, as contradictions in speech; non-verbally, such as messages tone and people's mood; in writing, as indicators report, and events such as late delivery by a supplier. Through the early signs we could treat the first symptoms in an attempt to verify corrective actions for management. For the early signs anticipated recognition it is necessary their identification, as well as the comprehension of their meaning.

Based on an analysis of uncertainty sources it is possible to detect projects early signs. Although, to accomplish that it is necessary to adopt the practice of **Mindfulness** describing a state of mind, that is, the project team has to be alert to the various unexpected situations that arises. There are five attributes that can be shared with the software projects in order to detect the signs, they are:

- **Failure Concerns:** In order to find the signs it is necessary to watch out for them questioning whether there are different explanations with seemingly obvious results. The best way to accomplish that is to make the project team aware of the failure possibility;
- **Reluctance to simplify interpretations:** The project manager struggles to understand what is happening within the project and there is a natural tendency to look for evidence to support preconceived ideas and reject what does not fit. However, all evidence must be considered;
- **Operations Sensitivity:** The early signs tend to be subtle. Your trifles sometimes make them easy to ignore. As a result, many problems may remain undetected. The entire team must be ready, alert to detect, monitor, analyze and determine if there really is an uncertainty associated with the identified signal;
- **Commitment to resilience:** Recognize that any project aspect may be subject to uncertainty. There are no off limits aspects. All that matters is that the team is ready and willing to face any uncertainty symptoms as soon as they are detected;

– **Skills Consideration:** When a problem arises within the project, experts in a given subject can be the best strategy to solve them, although other members should not simply push the problem to the expert, instead of that the team must try to learn with the expert and the problem resolution.

Sensemaking Phase Sensemaking is the process by which organizations and individuals work uncertainties, ambiguities, changes and problem situations generating inventions and new situations that result in actions that lead to problem solution and environmental stability. The most important thing is that there is sense in the identified signal or else, it is plausible to those involved [32]. Project manager activities along this phase are:

– **Interpret the signal:** The manager does not impose his understanding, but he tries to bring the issue in the project perspective, resulting in a co-construction of the meaning for project's team members;
– **Objectively Translate the Sign:** Transforming the sign is not only carry out task distribution, but also to make each team member realize their meaning in the project;
– **Reveal assumptions and beliefs:** When there is a conflict, project manager should clarify the real meaning, by identifying the beliefs in use and the assumptions made by the stakeholders;
– **Building a shared meaning:** The project relevance must always be remembered, not only in formal meetings, but also in daily tasks.

Risk Management Phase If the signs are early detected and a sense for them is created, strategies can be used to contain the uncertainties. These strategies can help to learn more about the uncertainty nature, for example, through problem formulation by representing or modeling future scenarios and prepare for them. Using discovery techniques such as the construction of a knowledge map. Once uncertainty is revealed, analytical techniques such as risk management can be used in project management [12].

Unexpected Outcomes Phase Project managers may try to contain the uncertainty in its source but will never be a hundred percent successful. Therefore, a project needs strength and should be able to detect and respond quickly to unexpected events. For unexpected results a project manager must then decide how best to cope with uncertainty.

4 Conclusion

It is no secret that many software projects fails not necessarily due to technological failure, but often due to uncertainties. Several project management approaches do not consider the impact that uncertainty has on projects. The project manager faces a dilemma: decisions must be made now about future situations that are inherently uncertain. Uncertainty management use within the project management can be a determining factor in project success.

This article introduced the construction of a uncertainty management guide designed by an action research were conducted in a software project carried out in the Informatics Center of the Federal University of Pernambuco.

The search results provide the academic community a better understanding of the challenges of dealing with the uncertainties in project management and therefore, show gaps in the area that can be good opportunities for future research. As future work, it is expected to refine the guide through qualitative analysis. The verification with third parties through surveys with project managers and scholars in the management area. Furthermore, it is expected to replicate the guide in different projects and compare the collected results.

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