Using InnerSource for Improving Internal Reuse: An Industrial Case Study

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ABSTRACT

Background: InnerSource consists of the use of open source development techniques within the corporation. It helps improve software reuse through increased transparency and inter-team collaboration. Companies need to understand their context and specific needs before deciding to adopt any specific InnerSource practices since they cannot apply all InnerSource practices at once. **Aim:** This study aims to support the case company in assessing its readiness for adopting InnerSource practices to improve its internal reuse, identify and prioritize the improvement areas, and identify suitable solutions. **Method:** We performed a case study using a questionnaire and a workshop to check the current and desired status of adopting InnerSource practices and collect potential solutions. **Results:** The study participants identified that the company needs to prioritize the improvements related to the discoverability, communication channels, and ownership of the reusable assets. In addition, they identified certain InnerSource practices as solutions for the prioritized improvement areas, such as better structured repositories for storing and searching the reusable assets and standardized documentation of the reusable assets. **Conclusion:** The questionnaire instrument aids the case company in identifying the improvement areas related to InnerSource and reuse practices. InnerSource practices could improve the development and maintenance of reusable assets.

Keywords: InnerSource, software reuse, readiness

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1 INTRODUCTION

Software reuse has been investigated for more than 50 years since McIlroy introduced component-based reuse in the late 1960s [22]. Studies found software reuse is associated with many benefits, such as increased product quality and reduced development time [2, 25]. To improve internal reuse, companies use approaches such as software product line (SPL), component- and model-based development [2]. Companies also use commercial-off-the-shelf/government-off-the-shelf (COTS/GOTS) software in their products and solutions[2]. Companies started to practice opportunistic reuse, which refers to "*developing new software systems by routinely reusing and combining components (open source components and modules online) that were not designed to be used together*" [24].

There are mainly two types of stakeholders in software reuse: producers responsible for developing reusable assets and consumers who reuse and integrate reusable assets in their solutions. Platform-based internal reuse has a dedicated team (producers) for developing reusable assets. However, they face challenges when the consumers want changes (e.g., adding new features and requiring bug fixes) in reusable assets, resulting in producers needing more bandwidth to complete the tasks within the consumers' asking deadline [26]. Such a scenario may lead to a situation wherein the producer teams become a bottleneck due to a large number of change requests and bug fixes in the reusable assets [28]. In open source software development, this bottleneck issue is addressed by making the code openly available and encouraging all stakeholders to contribute with new features and bug fixes. Inspired by the open source way of working, Tim O'Reilly coined the term InnerSource (IS) [9] as "*the use of open source development techniques within the corporation*". IS way of working has the potential to improve the development and maintenance of reusable assets due to its focus on transparency and collaboration among different teams and developers (e.g., producers and consumers of reusable assets). To address the transparency issues, Lucent Technologies [14] and Hewlett-Packard Company [10] used IS practices to develop a central space for sharing common reusable assets, which further promoted their internal reuse practices.

This study is part of a project on open source inspired reuse. The project aims to help companies improve their internal software reuse practices. In our previous study [8], the case company identified the reuse challenges in discoverability, transparency, and ownership of reusable assets. We also found such challenges can be addressed by adopting InnerSource practices. Bauer [3] suggested that understanding the companies' needs and context is one of the success factors for adopting IS. Existing IS frameworks [13, 32] and maturity model [11] help the companies understand their needs and IS context. However, the studies did not investigate the selection and prioritization of IS improvement areas. In addition, the existing literature often report IS adoption in large companies [20, 29], while small- and medium-sized companies are less investigated. In this study, we investigated the readiness of a medium-sized company to adopt IS practices for improving internal reuse practices. We made the following contributions:

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(1) We developed and used an instrument to help the case company assess its current and desired status regarding adopting IS practices related to the development and maintenance of reusable assets.
(2) We developed and used a two-dimension scheme – based on the importance and cost of implementing the improvements to help the case company prioritize the improvement areas.

The remainder of this study is structured as follows: Section 2 presents the related works. We introduced the research methodology in Section 3. Section 4 consists of the results related to the questionnaire and the workshop. Section 5 presents discussions of our findings and the validity threats of the study. Section 6 presents the study conclusion and future work.

2 RELATED WORK

Edison et al. [12], and Capraro and Riehle[7] conducted literature reviews and found IS helps avoid duplicated work and promote software reuse. Such benefits motivated many large-scale companies as well to adopt IS, e.g., Lucent Technologies [14], Philips [20], and Hewlett-Packard [23]. The case company also showed interest in adopting IS patterns, such as Trusted Committer[1], developed by InnerSource Commons[2], to improve the development, maintenance, and ownership of reusable assets.

Adopting IS is not without challenges. In the early phase, culture - hierarchical organizational structure [10, 23], proprietary mindset [21], and silo mentality [27, 29] hinder the IS adoption. During the adoption and practicing phase, integrating the IS practices into the existing development process and building organizational-wide infrastructure are challenging [10].

The IS teams may lack domain knowledge to build the shared assets [33] and may not provide necessary documentation [29, 33]. The developers outside the IS teams may not be able to follow the IS teams' contribution process [14], not have time to contribute to the common reusable assets[26], submit unfit contributions [33], may be reluctant to contribute [29, 33], and treat IS team as a provider only [33]. After the other developers submit the contributions, the IS teams may be reluctant to accept the contribution [33]. In addition, the IS teams need to balance the work between code review for the contributions and the implementation of new functionalities [14]. It is also hard to determine who should be responsible for the maintenance of the contributed part if it needs some bug fixing in the future [8]. Therefore, the ownership of the shared reusable assets becomes really important [15].

Before adopting IS practices in any company, it is important first to understand its context, motivation, and readiness - i.e., to what extent and which IS practices are appropriate for the company's needs and context. Bauer [3] reported a failed IS adoption case and concluded that adopting IS requires a good understanding of the company's needs and context. Gaughan et al. [13] proposed a framework to help firms understand when and how to adopt IS. Stol et al. [32] proposed another framework with three themes - software product, practices & tools, and organization & community, covering nine key factors supporting inner source adoption. Linåker et al. [17] used the framework from Stol et al. [32] and successfully assessed the inner source practices between two small development teams. Riehle [28] created an example IS charter to guide the companies adopting IS. InnerSource Common developed a maturity model pattern[3] to help teams to self-assess their status with regards to different practices - i.e., at what level the teams are following different IS practices. Eckert et al. [11] also proposed a maturity model to assess IS implementation in a large medical diagnostics corporation.

In this study, we selected the maturity model pattern as our base to develop a questionnaire instrument to help the case company assess the current and desired IS and reuse practices and identify the improvement areas. We chose the maturity model pattern because it covers more areas compared to the existing frameworks [13, 32], charter [28] and maturity model [11]. In addition, we conducted a follow-up workshop to help the company prioritize the identified improvement areas based on the importance and costs to the company. During the workshop, we also collected the potential solutions for the prioritized improvement areas.

3 RESEARCH METHODOLOGY

We performed a case study to investigate the case company's need to adopt IS practices and identify the InnerSource-related practices to improve internal reuse. We used a questionnaire and a workshop to collect the data.

3.1 Research questions

To guide the study, we formulated the following research questions (RQs):
RQ1: Which InnerSource-related improvements are needed to enhance the development, maintenance, and ownership of the reusable assets in the case company?
RQ2: Which identified InnerSource-related improvement areas should be prioritized and how to implement them?
RQ1 aims to identify those InnerSource-related improvement areas that the study participants desire to implement in the case company for improving the development, maintenance, and ownership of reusable assets. RQ2 aims to develop and use a mechanism to prioritize the improvements identified in RQ1. Furthermore, RQ2 also focuses on identifying the specific solutions for implementing the prioritized improvement areas.

3.2 Case company and unit of analysis

The case company is S-GROUP Solutions[4], which is a medium-sized Swedish company [1]. The company develops geographical information systems (GIS) to help digitize the city development plan, traffic control, water and sewage. The targeted customers are mainly local governments and authorities.

At the time of the study, the company had three development teams responsible for four solutions areas. The developers from one of the teams are responsible for two solution areas. Each team has about five developers, a corresponding project manager, a product owner, and a tester. The development teams are based in Sweden and Lithuania. The case company works with different lead roles, such as lead web developer and lead backend developer, to guide the

[1] https://patterns.innersourcecommons.org/p/trusted-committer
[2] https://innersourcecommons.org/
[3] https://patterns.innersourcecommons.org/p/maturity-model
[4] https://www.sgroup-solutions.se/

reuse practices. The development teams follow agile practices, use Azure DevOps and perform continuous integration and delivery (CI/CD). S-Group Solutions AB is migrating some of its monolithic proprietary software to a microservices-based architecture for better reuse. The reusable code assets in the case company are npm packages[5] and NuGet packages[6]. We focus on analyzing the internal software reuse practices, especially the collaboration among teams. The case company is in the initial phases of the reuse journey, and two development teams are active in reuse collaboration, and we refer to them as Team 1 - producers and Team 2 - consumers in this paper. Furthermore, the case company aims to expand the reuse collaboration to Team 3 - consumers in the future. In our previous study, the case company also showed interest in adopting IS practices to improve the development, maintenance, and ownership of reusable assets.

3.3 Data collection

We used two methods to collect the data: a questionnaire and a workshop.

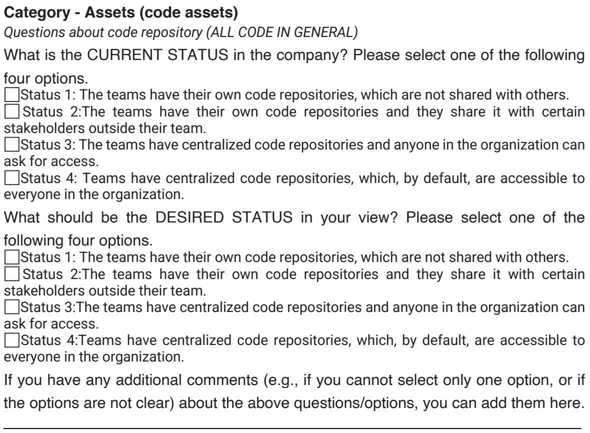
Table 1: Proposed IS readiness instrument: categories and areas

Categories	Areas
Assets	Code repository (all code), reusable code repository, documentation of reusable assets, discoverability of reusable assets, support for contributing/maintaining, the reusable code assets, plans/roadmaps for all projects, plans/roadmaps for reusable assets, sprint/release planning for reusable assets, reusable test cases, traceability for reusable assets, other knowledge
Process	Code review process of reusable assets, ownership and maintenance of the reusable assets, continuous integration of reusable assets
Collaboration	Communication channels
Measurement	Measuring/Monitoring reuse
Rewards	Rewards for contributing to reusable assets
Culture	Attitude about collaboration on reusable assets, managers' views on reuse collaboration

3.3.1 *Questionnaire.*

Questionnaire design: We used the questionnaire to collect the practitioners' views about the case company on the current and desired state of IS and reuse practices. The questionnaire consists of a set of questions that helps gather information more quickly and cost-effectively [31]. We followed the survey guidelines from Linåker et al. [18] to create the questionnaire. The questionnaire consists of two parts: demographic questions and reuse-specific questions.

The demographic information includes the role, the team information, working experience, and the involvement of the reuse practices (development, consuming or maintaining reusable assets). We followed the IS maturity model pattern to check the company's readiness to adopt IS as explained in Section 2. The authors are familiar with the company context from previous work on the project. The first and second authors customized the IS maturity model pattern based on the case company's reuse context and its scale: medium-sized company. In total, we have 19 areas for the IS and reuse practices, covering six categories: reusable assets, reuse process, reuse collaboration, the measurement for reuse, rewards for reuse, and culture regarding reuse (see Table 1). Each area has two forms, asking respondents about the current and desired status of software reuse (see an example in Figure 1). Under each area, we have four options, ranging from Status 1 to Status 4. The lower status number means the area is less systematic and less mature. The higher status number means the area is more systematic and has additional requirements. We asked about the current and desired status of the IS and reuse practices per area so that the participants do not need to read the four options twice. We also provided an open text field for respondents to comment on for each area. We also provided definitions for specific terms to help respondents understand their meaning.



Category - Assets (code assets)

Questions about code repository (ALL CODE IN GENERAL)

What is the CURRENT STATUS in the company? Please select one of the following four options.

□Status 1: The teams have their own code repositories, which are not shared with others.
□Status 2:The teams have their own code repositories and they share it with certain stakeholders outside their team.
□Status 3: The teams have centralized code repositories and anyone in the organization can ask for access.
□Status 4: Teams have centralized code repositories, which, by default, are accessible to everyone in the organization.

What should be the DESIRED STATUS in your view? Please select one of the following four options.

□Status 1: The teams have their own code repositories, which are not shared with others.
□Status 2:The teams have their own code repositories and they share it with certain stakeholders outside their team.
□Status 3:The teams have centralized code repositories and anyone in the organization can ask for access.
□Status 4:Teams have centralized code repositories, which, by default, are accessible to everyone in the organization.

If you have any additional comments (e.g., if you cannot select only one option, or if the options are not clear) about the above questions/options, you can add them here.

Figure 1: Questionnaire example

The third author reviewed the questionnaire based on the suitability of the study, the distinguishability and the understandability of the scale, and the inclusion relationship between the categories and areas. We addressed the disagreements in a joint meeting. We also send the questionnaire to the contact person - the project manager, for an expert review. Once we got the approval, we emailed the questionnaire invitation to the candidates. We used Google Forms as our questionnaire tool. The questionnaire[7] was estimated to take about 25 -30 mins. The questionnaire was open for about a month (from January 11th, 2022, to February 9th, 2022).

Questionnaire participants selection: The project manager had an internal discussion with the head of system development and identified the producers and consumers of the reusable assets are potential candidates for the questionnaire. In total, we identified eight questionnaire candidates, of which seven answered the questionnaire. We assured the candidates that we would protect their personal information and use the data in an aggregated format for analyzing and reporting.

3.3.2 *Workshop.*

Workshop design: The workshop aims to discuss and prioritize the improvement areas selected from the questionnaire results and brainstorm possible solutions. We conducted a workshop so the participants could share their opinions and also discuss and exchange

[5] https://www.npmjs.com/
[6] https://www.nuget.org/
[7] The questionnaire is available at https://doi.org/10.5281/zenodo.7849269.

ideas among multiple stakeholders. We followed the guidelines from Brem [4] and planned a 90 mins workshop. The workshop took place at the university the research group works since the external environment influences the practitioners less and thus allows more ideation [4].

To prioritize the selected improvement areas, we prepared a two-dimension scheme - importance and cost. The importance dimension represents how important the improvement area is for the case company. The cost dimension reflects how costly it is for the case company to implement the solutions for the improvement area. We used a four-point Likert scale for each dimension. The first author also identified solutions from the literature, such as InnerSource patterns[8], to aid the discussions, which the second author reviewed.

Before the workshop, each participant received a card book comprising several paper cards. Each paper card has two questions about one selected improvement area related to the importance and the cost. Our workshop has three phases as follows:
Phase 1: We explained our workshop's purpose and process to the participants. Moreover, we gave a brief presentation about the questionnaire results, explaining to the participants why the areas were selected for the workshop. *Phase 2:* We collected the participants' views on the importance and the costs to the company for each selected area. For every selected area, we started with a group discussion about its questionnaire results so that the participants could have a shared understanding of the selected area and brainstorm the corresponding potential solutions. We had 10 mins for each area. Once the time is up, the participants are required to give their rates on the paper card. The first author collected the paper card and plotted the paper cards on the whiteboard according to the answers. The plot diagram showed how different participants viewed the area, and the participants could give their reflections based on the results. Phase 2 ends when all the selected areas have been discussed and prioritized. We also encouraged the participants to lead the discussion to make them more involved. *Phase 3:* We asked the feedback from the participants on the workshop activities and summarized the workshop.

Workshop participants selection: As described previously, we aim to prioritize the improvement areas according to their importance to the case company and the costs of implementing the solutions. Therefore, it is essential to include both technical and management views. We suggested to the project manager a list of roles and teams and requested him to include as many participants as possible. Due to the candidates' availability, we eventually got five participants - four developers and one project manager, who were all from Team 1. In total, we had seven participants, including the five selected participants from the case company and the first and second authors from the research group. The first and second authors only acted as a note-taker and a moderator during the workshop. Before the workshop, we asked the project manager to share the questionnaire results with the workshop candidates.

3.4 Data analysis

3.4.1 Questionnaire data analysis. We followed the principles of survey research proposed by Kitchenham and Pfleeger [16] to analyze the questionnaire results.

First, we validated the questionnaire results and sorted out the incomplete answers. Then, we investigated why the participants left the answer empty and decided whether to include their data for later analysis. Second, we used the frequency analysis method to count the number of different statuses selected for each area and evaluate the company's overall situation. Third, we partitioned the responses based on the reuse role of the participants - producers and consumers, to evaluate which areas different roles were satisfied with or wanted improvements. Satisfied with the current status means that the respondents selected the same options for the current and desired status, and wanted improvements means that the respondents selected higher-level status for the desired one than the current.

To reduce the researchers' bias, we presented the questionnaire results to the project manager and asked for feedback. The project manager agreed with the results related to the questionnaire and agreed to conduct a workshop for a detailed improvement areas discussion.

3.4.2 Workshop data analysis. We prioritize the selected improvement areas based on the two-dimension scheme. For the proposed solutions, we identified the problems and analyzed the context. We shared the workshop results in the form of a report with the project manager, and he commented that the report concluded the workshop without missing any important information.

4 RESULTS

This section provides the results of the questionnaire and the workshop.

4.1 RQ1

We received seven out of eight potential participants' responses. Table 2 shows the questionnaire participants' demographics and experience in the case company. The main reusable asset is code. Few developers also reuse requirements and test cases. We got two responses that had incomplete answers. One respondent left one question empty since he was not involved in such reuse practices. The least experienced (four months) respondent did not answer eight areas, and we understand that it takes time for a newly recruited employee to grasp the company software practices. Each area stands for different IS and reuse practices, and the answers will not interfere with other areas, so we decided not to remove any data from the analysis. In the following subsections, we present the overview of the company IS and reuse practices status (both current and desired) and then detail the findings by partitioning the answers into different categories.

Table 2: Questionnaire participants' demographics and experience in the case company

Participants ID	P1	P2	P3	P4	P5	P6	P7
Role	Developer	Developer	Lead web developer	Developer	Developer	Tech lead developer	Developer
Team	Team 1	Team 1	Team 1	Team 1	Team 2	Team 2	Team 3
Experience	8 years	5 years	4,5 years	4 months	6 years	14 years	8 years

[8] https://patterns.innersourcecommons.org/

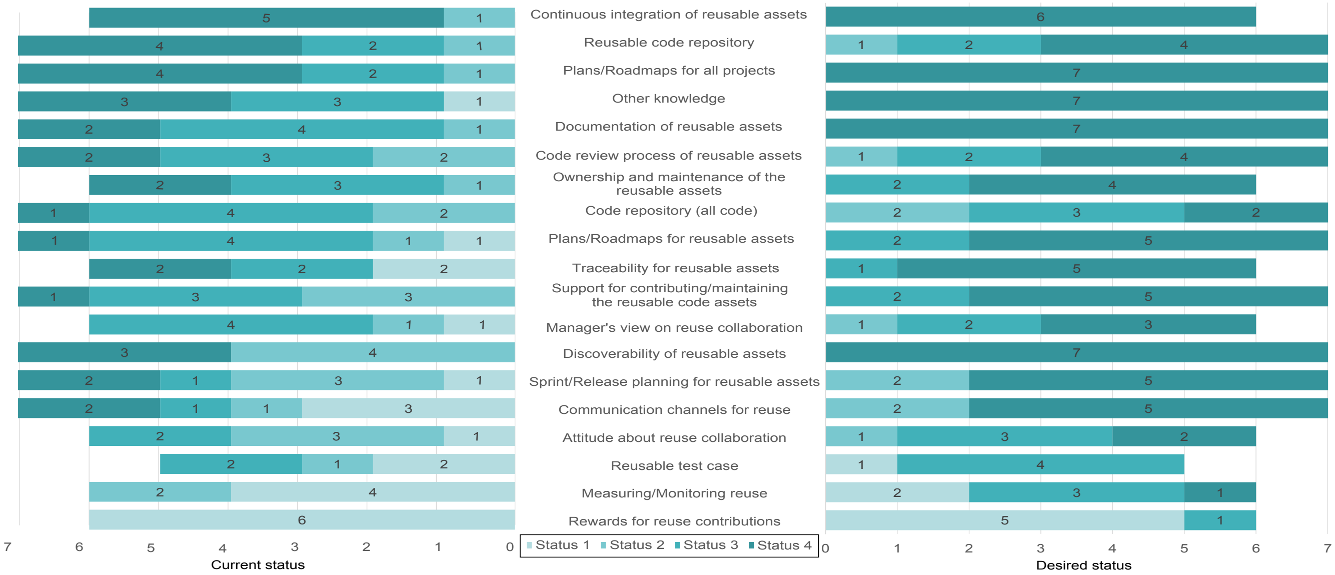


Figure 2: Participants' view on the current and desired status of the IS and reuse practices in the case company

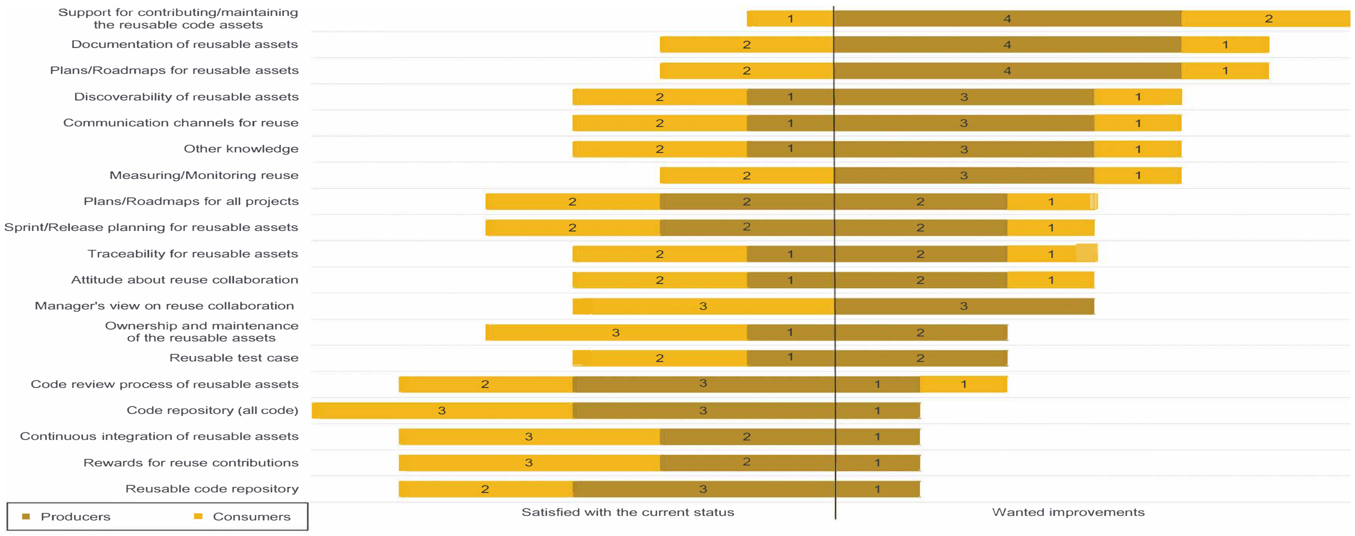


Figure 3: What the participants think about the IS and reuse practices in the case company

4.1.1 *Overview of the current IS and reuse practices status.*

Figure 2 - left side, shows the overview of participants' views on the current status of the reuse practices in the case company. We used gradient colors to present different statuses; lighter colors represent lower status, and darker colors represent higher status. The number on each bar represents the number of respondents who selected the corresponding status. Most areas have seven responses, except for the eight areas, which have one or two responses less. In addition, we sorted the areas in order of status numbers - from high to low.

The following seven areas are less systematic and less mature according to the respondents' answers - the number of Status 1 and Status 2 responses is more than the number of Status 3 and Status 4: *rewards for reuse contribution*, *measuring/monitoring reuse*, *reusable test case*, *attitude about reuse collaboration*, *communication channels for reuse*, *sprint/release planning for reusable assets*, and *discoverability of reusable assets*. On the other hand, the following four areas are relatively more mature according to the respondents' answers: *reusable code repository*, *plans/roadmaps for all projects*, *other knowledge* and *continuous integration of reusable assets*. Moreover, *continuous integration of reusable assets* is appropriately taken care of based on the responses. We also found three areas of the most diverse answers that need company-wide consensus: *communication channels for reusable assets*, *sprint/release planning for reusable assets*, and *plans/roadmaps for reusable assets*.

The results indicate that currently, the transparency of the reusable code assets and the plans/roadmaps for overall projects are relatively mature. To increase the reuse collaboration between teams, the case company needs to focus on increasing the reuse incentive, building communication bridges between teams, monitoring the internal reuse progress, and enhancing the discoverability and maintenance of the reusable assets.

4.1.2 Overview of the desired IS and reuse practices status. Figure 2 - right side, shows the overview of participants' views on the desired status of the IS and reuse practices in the case company. All respondents seek higher status for the IS and reuse practices, except for the rewards for reuse contribution. There are five areas - four about the assets and one about the process, that all respondents agreed to have the highest status: *documentation of reusable assets*, *discoverability of reusable assets*, *plans/roadmaps for all projects*, *other knowledge* and *continuous integration of reusable assets*. Respondents held the most different opinions on six areas: *reusable code repository*, *code review process of reusable assets*, *code repository (all code)*, *manager's view on reuse collaboration*, *attitude about reuse collaboration* and *measuring/monitoring reuse*, which indicates a need of shared understanding.

The results indicate that the respondents want to achieve systematic and mature IS and reuse practices in the future for most areas. Compared to the current status of the IS and reuse practices, we can see that there are many areas that the respondents want to improve.

4.1.3 Producers' and consumers' view on the IS and reuse practices. Figure 3 reflects the participants' views on what the case company needs to improve to achieve better IS and reuse practices. We used two colors to represent the producers and the consumers, and the data label represents the number of participants. The data are divided into two parts: satisfied with the current status and wanted improvements. We ranked the areas according to the number of participants who wanted improvement - from the largest to the smallest. A significant proportion of participants wanted improvements in support for *contributing/maintaining the reusable code assets*, *documentation of reusable assets*, *plans/roadmaps for reusable assets*, *discoverability of reusable assets*, *communication channels for reuse*, *other knowledge* and *measuring/monitoring reuse*. They are more satisfied with the *reusable code repository*, *rewards for reuse contributions*, *continuous integration of reusable assets* and *code repository (all code)*. In addition, there are three areas that the participants voted equally in having changes in the future or staying as it is: *traceability for reusable assets*, *attitude about collaboration on reusable assets* and *the managers' view on reuse collaboration*.

The equal number of votes drove us to further break down the answers into different roles. We found that producers wanted more improvements in IS and reuse practices than the consumers, e.g., *ownership and maintenance of the reusable assets* and *measuring/monitoring reuse*. Consumers are more eager to see the changes in *support for contributing/maintaining the reusable code assets*. For the areas of *plans/roadmaps for all projects* and *sprint/release planning for reusable assets*, we got the same proportion of producers satisfied with the current situation and wished for improvements. All producers wanted more management support, while all the consumers were pleased by the current manager's status. If we only focus on the producers, we found five more improvement areas: *traceability for reusable assets*, *attitude about reuse collaboration*, *manager's view on reuse collaboration*, *ownership and maintenance of the reusable assets* and *reusable test cases*.

Figure 3 shows that the producers are less satisfied with the current situation than the consumers. Except for the areas in that all respondents wanted changes, the producers also wanted to see changes in the other four areas – *reusable test cases*, *traceability for reusable assets*, *ownership and maintenance of the reusable assets* and *manager's view on reuse collaboration*.

According to the questionnaire results, we sorted out nine areas that most participants wish to have changes and aim for a higher status in the future - initially, we identified eight areas. We added the area of *ownership and maintenance of the reusable assets* since it is closely related to the top selected area: *support for contributing/maintaining the reusable code assets*. The identified improvement areas cover all categories except rewards. We present the nine areas and their corresponding categories as follows:

Assets: *Documentation of reusable assets*, *Discoverability of reusable assets*, *Plans/Roadmaps for reusable assets*, *Support for contributing/maintaining the reusable code assets*, and *Other knowledge*.

Process: *Ownership and maintenance of the reusable assets*.

Collaboration: *Communication channels for reuse*.

Measurements: *Measuring/Monitoring reuse*.

Culture: *Manager's view on reuse collaboration*.

We selected six areas for later prioritization and omitted areas related to the documentation, other knowledge, and the manager's view because of the following reasons:

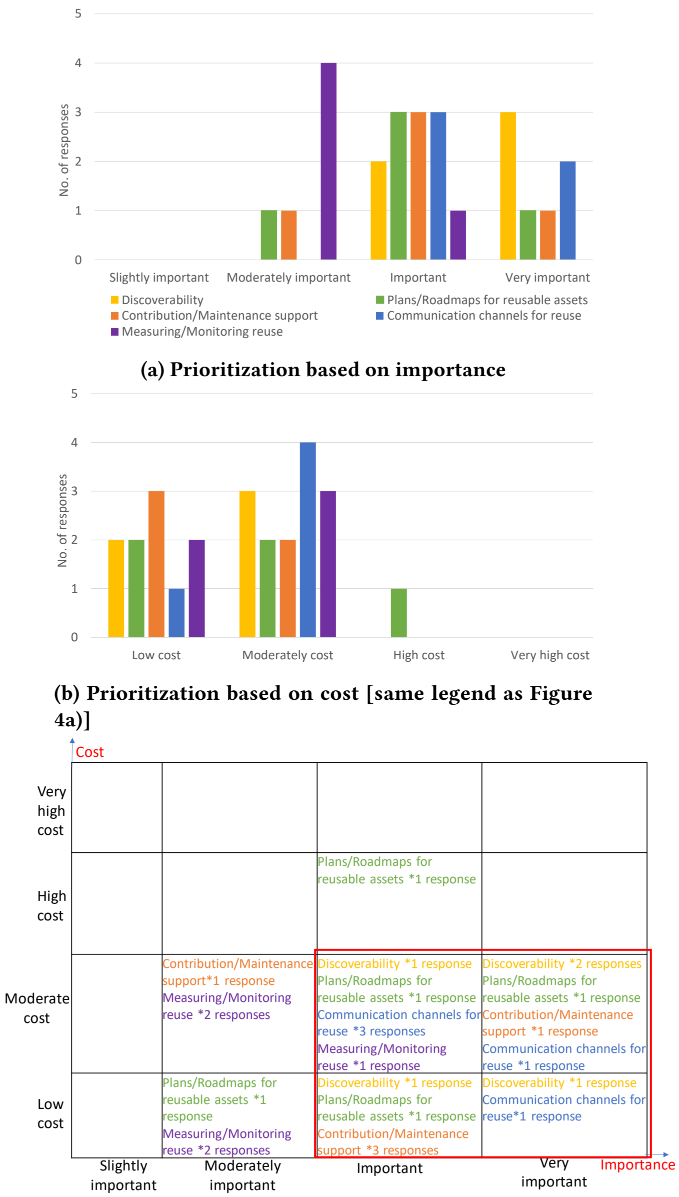
- Documentation and other knowledge will be reflected in discoverability. In addition, we were informed by the case company that they have partially addressed the documentation problem.
- The current status for the manager's view is already in a relatively high-level stage.

4.2 RQ2

The workshop took approximately 100 mins. According to the questionnaire results, we selected six areas for prioritization. During the workshop, *support for contributing/maintaining the code of reusable assets* and *ownership and maintenance of the reusable assets* were discussed together and merged into one area as *contribution/maintenance support*.

The workshop results show that the top prioritized areas are *discoverability of reusable assets*, *communication channels for reusable assets* and *contribution/maintenance support*. We present the prioritized results based on importance, costs and both in the following subsections (see Figure 4).

Figure 4a and Figure 4b show the prioritization results of the selected six areas based on importance and cost. According to Figure 4a, there are no areas that were considered less important by the workshop participants. The majority thought *discoverability of reusable assets* was the most important one and *communication channels for reusable assets* were the second. *Plans/Roadmaps for reusable assets* and *contribution/maintenance support* are in third place and have the same prioritization rate. Based on Figure 4b,



(a) Prioritization based on importance

(b) Prioritization based on cost [same legend as Figure 4a)]

	Slightly important	Moderately important	Important	Very important
Very high cost				
High cost			Plans/Roadmaps for reusable assets *1 response	
Moderate cost		Contribution/Maintenance support*1 response Measuring/Monitoring reuse *2 responses	Discoverability *1 response Plans/Roadmaps for reusable assets *1 response Communication channels for reuse *3 responses Measuring/Monitoring reuse *1 response	Discoverability *2 responses Plans/Roadmaps for reusable assets *1 response Contribution/Maintenance support *1 response Communication channels for reuse *1 response
Low cost		Plans/Roadmaps for reusable assets *1 response Measuring/Monitoring reuse *2 responses	Discoverability *1 response Plans/Roadmaps for reusable assets *1 response Contribution/Maintenance support *3 responses	Discoverability *1 response Communication channels for reuse*1 response

(c) Prioritization based on importance and cost

Figure 4: Workshop prioritization results

there are no areas perceived as very costly by the workshop participants. The majority thought *contribution/maintenance support* had the lowest cost. The *discoverability of reusable assets*, *measuring/monitoring reuse*, and *communication channels for reusable assets* had a similar cost level - the second place. *Plans/Roadmaps for reusable assets* had relatively higher costs than the others.

Figure 4c shows the final plot results for all the selected areas. The results show that all participants had similar opinions on each improvement area. We did not ask the participants to finalize their answers to a single opinion since the workshop's purpose is to help participants discuss the differences and have a shared understanding of the improvement areas. In addition, the differences between answers are not drastic. Overall, we can see there are no areas that were less important and very costly to implement. If we focus on the four cells in the bottom right corner, we can see that *discoverability of reusable assets*, *communication channels for reusable assets*, and *contribution/maintenance support* were the most important to the company and less costly to fix, which indicates they are potentially the low-hanging fruits to initiate.

During the workshop, we also asked the participants for potential solutions for each selected area. In the following subsections, we will first elaborate on the problems in the reuse area identified in the company and explain the context. Then we will provide the solutions that the respondents provided. We discuss the connection between the proposed solutions and existing IS reuse practices in Section 5.2.

4.2.1 Discoverability solutions. **Problem:** The developers do not have a clear picture of which reusable assets exist in the company and how to use them. **Current situation:** 1). All the reusable packages are stored in the Azure DevOps repository. 2). There are two types of reusable packages: npm packages are properly documented and have associated readme files, while NuGet packages are not. 3). It is easier to identify the reused npm packages since they are React packages and are more visible in reuse. However, NuGet packages are more backend packages and less visible in reuse.

Solutions proposed by the participants:

(1) The company should collect the information and knowledge about the repository, such as creating a list of existing (and planned) reusable assets, and briefly describe what they do and where they are located by adding necessary links.
(2) The repository should be restructured so that the developers can find the reusable assets easier, e.g., in addition to the basic search function, the repository could have some filtering functions based on, such as the type of reusable packages.
(3) The developers should enhance the documentation of the NuGet package, such as readme files and changelogs.
(4) The developers should enhance the traceability between the reusable assets and the application and modules that reused them.

4.2.2 Plans/roadmaps for reusable assets solutions. **Problem:** The teams do not have plans/roadmaps for reusable assets or plans for the reusable assets upgrade in existing applications. **Current situation:** 1) The reusable assets are initiated by developers when they realize the assets can be reused in multiple applications. 2) The company has a shared prioritized backlog; however, it does not include the reusable assets plan. 3) There is no policy for upgrading the reusable assets in existing applications.

Solutions proposed by the participants:

(1) Instead of a bottom-up strategy (developers initiate the development of the reusable assets), the product owner and project leader should plan the reusable assets for development based on the requirements.
(2) The team should have a plan for upgrading the reusable assets in the existing applications to the latest version, even though it will cost more in testing.

(3) There should be an owner or manager to maintain the roadmaps of the reusable assets.

4.2.3 Contribution/Maintenance support solutions. **Problem:** When there is a need for a fix, where should the developer modify — the reusable code assets or application? The owner of the reusable assets is unknown. Even though the contribution and maintenance guidelines (step-by-step guide) are in place, people still have many issues. No clear roles and responsibilities are defined. The teams lack knowledge sharing about reusable assets. **Current situation:** 1) It depends on the developers to decide whether to fix bugs in the application or modify the reusable assets. 2) Team 1 is responsible for developing npm packages, and Team 2 is responsible for developing NuGet packages. 3) It takes effort for developers to find the right person for contribution and maintenance support. 4) For the code review, one developer from the corresponding team should review the pull request. For the reusable assets code review, two developers responsible for different solution areas should review the pull request.

Solutions proposed by the participants:

(1) The reusable assets should have an owner responsible for their maintenance and review.
(2) The company should prepare and enhance the review process for later when reuse scales up. For example, write a clear policy about who should review the reusable assets.
(3) The reusable assets information should be written in the readme file, and someone should be responsible for maintaining it.
(4) The developers should write the contact person in the readme file.

4.2.4 Communication channels for reusable assets solutions. **Problem:** The company lacks communication between the teams when creating reusable assets. **Current situation:** 1) No cross-team communication for the reusable assets. 2) The company uses Teams and webhooks for communication within and across teams. 3) The pull request is announced in Teams. 4) It is hard to find the changelogs which are stored in the wiki.

Solutions proposed by the participants:

(1) When there is a new release for the reusable packages, developers should use Teams to notify others.
(2) The reusable assets might be released multiple times in a day and have many versions. To save time, the developers should only communicate the major changes.
(3) The reusable assets should have a guardian so the stakeholders know whom to contact.
(4) The wiki changelogs should have a better search facility.
(5) The Teams channels should have an easy-follow structure for storing readme files and communicating the new major updates.

4.2.5 Q16 Measuring/Monitoring reuse solutions. **Problem:** The company lacks information about reuse measurement to track the progress of reuse. **Current situation:** Around two years, the company used the reuse rate (lines of code for reusable assets/ lines of code for the application) to measure the reuse progress.

Solutions proposed by the participants:

(1) The developers should tag the bugs related to the reusable assets to enable future measurements.
(2) The developers should have traceability links between reusable assets and the applications that reuse them.

5 DISCUSSIONS

Section 5.1 discusses the identified improvement areas and compares our instrument with related works. Section 5.2 discusses the possible improvement solutions with related works, and Section 5.3 presents the threats to the validity of this study.

5.1 The improvement areas

According to the questionnaire results, the current IS and reuse practices in the case company are not systematic, and respondents seek higher status in most areas, except rewards. In addition, we found that the producers wanted to improve more areas than the consumers. That is because the case company is at the early stage of the IS and reuse journey. The producers are more involved in the IS and reuse practices than the consumers.

Although in the case company, all developers have access to the reusable code assets, discoverability is still a challenge - developers face problems in knowing which reusable assets exist in the company and how to search for the needed ones. In addition, to increase the reuse contribution and facilitate team collaboration, the case company needs to improve the transparency of the reusable assets plans/roadmaps, the contribution support, ownership of the reusable assets, and build communication channels between teams. The reuse measurements need enhancements so that the case company understands the benefits of doing IS and reuse practices.

The participants understand the current situation regarding IS and reuse practices covered by our questionnaire instrument. However, low-level status does not mean the area needs improvements since it might be the best situation according to the company's needs. Therefore, we introduced the concept of the current and desired status in our instruments, which helped the case company to identify the needed improvement areas by understanding also where and what they want to achieve.

Existing frameworks [13, 32], charter [28] and maturity model [11] can help companies understand their IS context. Like our instrument, the above related works comprise the IS areas related to shared assets/transparency, process, collaboration, culture and incentive. For shared assets, only Stol et al. [32] and Gaughan et al. [13] mentioned the selection of the IS seed product. We have reusable assets as the initial seed product in the case company. Therefore, we omitted this part. Stol et al.'s framework [32] and the IS maturity model pattern mentioned the standardization of tools. However, our instrument did not include tool standardization since the case company is medium-sized and teams use the same tools. We think it is necessary to consider tooling standardization when adopting IS in large-scale companies that use many different tools. Existing works also investigate the transparency of reusable assets. In addition, our instrument asks about the discoverability and the traceability of reusable assets, which helps the practitioners understand more about the existing reusable assets in the company and how to search for them. Collaboration is more related to the communication channel, especially between teams. The culture consists of the managers' and individuals' views on IS reuse collaboration. In addition to the related works, we asked the case company about measurements in reuse monitoring. Such measurement is important since it provides persuadable facts to the managers about the benefits of software reuse and IS collaboration.

5.2 InnerSource solutions

The case company aims to create a centralized shared space for reusable assets, with the necessary documentation, good search facilities, and tracking functions for improving discoverability. Such infrastructures are widely used in large companies and resulted in better internal reuse, such as Hewlett-Packard Company [10], SAP [29], Nokia [20], Ericsson [34]. We found the infrastructure systems reported in existing literature are usually web-based, have good search facilities, and contain all reusable code assets and documentation, wiki page, mailing lists, and monitoring metrics. For example, Ericsson's marketplace [34] advertises the top contributors on the homepage to encourage more contributions, categorize the microservices according to the maturity level, and has a good search and filtering mechanism. Companies can learn from the existing infrastructure systems and customize them according to their needs. Linden [19] also suggests using open source software to reduce the effort of building the infrastructure systems.

Communication channels are essential for IS practices, especially when communicating the changes. To reduce the impact of significant changes, we suggest utilizing the existing communication tools to achieve the desired goals. Currently, the case company uses Microsoft Teams and its channels to communicate updates, pull requests, and releases within the teams. We noticed from the questionnaire results that teams had different opinions on communication tools. Therefore, a company-wide communication channel is also needed. Besides, the communication results should be logged systematically and regularly maintained, especially for the decisions. Mailing list and wiki can be used to facilitate company-wide communication and log the necessary documentation [33]. In addition, specific roles [28] should be introduced to maintain the documentation.

So far, the case company did not have major problems in contribution and maintenance support. However, the participants are concerned about the contributions and maintenance when IS and reuse scale up to all teams. The participants found that the contributor tends to contribute without reading the readme file, resulting in more problems. We suggest the practitioners learn from the Standard Base Documentation pattern [9] developed by InnerSource Commons. InnerSource Commons also stated that explicit roles such as guardian and trusted committers would ease communication. InnerSource Common also developed a 30-Day Warranty pattern [10] to deal with the issues from the contributed work.

The case company used the reuse rate to measure the reuse progress. To improve that, the participants suggested tracking the applications that used reusable assets to increase traceability and identity the dependencies. In addition, measuring defects for reusable assets could also enhance the quality of the reusable assets and reduce the risks for other applications to use them. Capraro et al. [6] developed a patch-flow method to measure the IS collaboration. Buchner and Riehle [5] used metrics related to worked time to calculate the costs of IS collaboration.

Plans/Roadmaps for reusable assets are not only limited to identifying or designing the reusable assets but include the maintenance of the old versions of the reusable assets. To enhance the planning, the participants suggested involving the product owners and project managers in planning the reusable assets, adding views from both customers and project managers. The tracking from the reuse monitoring helps developers identify the projects with reusable assets, making the maintenance plan easier.

We also found solution overlaps between improvement areas. For example, discoverability and contribution/maintenance support both involve improving information provided in readme files. Traceability improvements between reusable assets and applications that use them are required in both improvement areas of discoverability and communication channels. Such overlap offers a starting point for determining which solutions to prioritize.

5.3 Threats to validity

We followed the four scheme validity from Runeson and Höst [30]: construct validity, internal validity, external validity, and reliability.

Construct validity: The construct validity demonstrates whether the studied operational measurements answered the research questions and performed as the researchers expected. The questionnaire was developed iteratively by the first and second authors and reviewed by the third author and the project manager from the case company. We provided definitions for specific terms used in the questionnaire so that the respondents understood the meaning. We also provided open text fields in the questionnaire so the respondents could comment on each area. In addition, we presented the questionnaire results before the workshop so that the participants understood how we selected the improvement areas for prioritization.

Internal validity: We have not investigated the causal relations in this study. To ensure the findings are valid and consistent, we asked the study participants - the project manager and the workshop participants, to review the questionnaire and workshop results multiple times.

External validity: The external validity represents the generalizability of the findings. In our study, we only applied the instruments in one medium-sized company. However, we described the company context in detail. We only included one team in the workshop since the other teams were not available. The proposed solutions are perceptions from producers only. Companies similar to the case company context can reuse our instrument to assess their company situation for IS and reuse practices. Companies could also learn from our findings, especially the proposed IS solutions.

Reliability: The reliability validity refers to the researchers' bias on the data and the analysis. The first and second authors developed the questionnaire instrument based on the IS maturity model pattern. The third author and the project manager reviewed the instrument. We presented the questionnaire results to the project manager, who agreed that the results reflected reality. The questionnaire results are presented again to the workshop participants to help them understand how we selected the improvement areas

[9] https://patterns.innersourcecommons.org/p/base-documentation

[10] https://patterns.innersourcecommons.org/p/30-day-warranty

for prioritization. We presented the workshop results at the end of the workshop and shared the results in the form of a report with the project manager. In addition, the project manager also reviewed this paper which did not lead to any major changes. Though two authors were involved in the workshop, they only acted as facilitators and had little influence on the discussions and the prioritization results.

6 CONCLUSION AND FUTURE WORK

In this study, we developed and used an instrument to help the case company assess its readiness to adopt IS for improving the development and maintenance of the reusable assets.

The customized instrument helped assess the current and desired status of the IS and reuse practices and identify the improvement areas. The highest InnerSource status may not be the best case for companies in adopting InnerSource practices for reuse. The identified improvement areas for the case company are documentation, discoverability, support for contributing/maintaining the reusable code assets, plans/roadmaps for reusable assets, other knowledge, ownership and maintenance of the reusable assets, communication channels for reuse, measuring/monitoring reuse, and managers' view on reuse collaboration. The prioritized improvement areas are discoverability, communication channels, and ownership and maintenance of the reusable assets. The possible solutions indicate that IS practice can help improve the internal reuse of the case company.

In the future, we plan to investigate which IS solutions the case company adopted and measure whether IS helps to improve internal reuse using productivity and quality related metrics. In addition, we also want to enhance the generalizability of our questionnaire instrument by applying it to more companies that wish to adopt IS to improve internal reuse.

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