The final publication is available at Springer via https://doi.org/10.1007/978-3-319-77243-1_10

The Problem of Consolidating RE Practices at Scale: An Ethnographic Study

Rebekka Wohlrab[1,2](✉), Patrizio Pelliccione[1], Eric Knauss[1], and Sarah C. Gregory*[3]

[1] Chalmers University of Technology | University of Gothenburg, Sweden
wohlrab@chalmers.se, {patrizio.pelliccione, eric.knauss}@cse.gu.se
[2] Systemite AB, Sweden
[3] Intel Corporation, USA
sarah.c.gregory@ieee.org

Abstract. [**Context & Motivation**] Large-scale requirements engineering contexts often involve hundreds of experts that collaborate to specify the characteristics and functionality of an integrated product. As diverse disciplines and locations are involved, it is not uncommon that the understanding of processes and concepts differs between departments and teams. [**Question/problem**] In practice, it is challenging to allow for flexibility and diversity between organizational units and at the same time establish consistent practices and sufficient alignment among them. Yet, it is desirable to balance this tradeoff, so that short time to market at reasonable cost can be achieved. [**Principal ideas/results**] This paper presents an ethnographic study focusing on a three-year project in a large-scale industrial company that tried to consolidate requirements engineering practices and customize a tool solution to the company's needs while maintaining autonomy of individual units. [**Contribution**] We present challenges of the company's initiative and share mitigation strategies based on our lessons learned. Specifically, we give indications on when to consolidate and unify, and when to allow for diversity in RE practices.

Keywords: Large-scale requirements engineering · Ethnographic study · Industrial requirements engineering · Aligning requirements engineering practices

1 Introduction

Industrial requirements engineering faces the challenge of scale—both when it comes to the size of software systems and also because a large number of stakeholders from different disciplines and diverse organizational contexts are involved [1]. In these often globally distributed contexts, processes and tool differences are a common challenge [2]. Focusing on self-organizing teams that make local decisions has been observed to be successful [3] and it has been argued that this strategy allows software organizations to scale [4].

* Intel Corporation was not involved in the industrial case underlying this study.

However, when trying to develop one integrated and aligned end product, it is challenging to deal with too heterogeneous systems engineering approaches. Especially with respect to requirements engineering and laying the foundations for development and testing, it is essential to find a trade-off between diversity and alignment of requirements engineering practices in organizations [5].

In order to explore this issue in a practical context, we conducted an ethnographic study [6,7]. We followed a three-year project in a large-scale industrial company that aimed to align requirements engineering practices and support this alignment by employing a systems engineering tool solution.

In this paper, we present experiences from the project and describe what changes in the tool solution and organizational context were made and for what reasons. Moreover, we share our lessons learned and mitigation strategies to counteract the challenges the project faced. We found that especially whenever communication with external stakeholders plays a role, it is necessary to have aligned practices. However, for activities like requirements elicitation, diverse methods should be supported. It is of central importance to carefully select stakeholders and document design rationales. Commitment from the top level of the organization and incentives for teams adapting practices are beneficial to successfully consolidate requirements engineering practices.

The remainder of the paper is structured as follows: In Section 2, we describe the industrial context of the company and the project to consolidate RE practices. Section 3 presents related work. Section 4 describes our research method. In Section 5, we elaborate on the findings of the initiative to consolidate requirements engineering practices. Section 6 presents a discussion of our findings and Section 7 concludes the paper.

2 Industrial Context

The main focus of this study lies on CompanyX, an automotive manufacturer with more than 10,000 employees. They are distributed across five countries. In the specific project that we focus on in this study, there were three locations involved. The organizational structure of CompanyX is characterized by departments related to the traditional architectural decomposition of a vehicle, e.g., powertrain, chassis, and electrics. Functional requirements, the focus of this paper, are specified in these departments. Moreover, there exists a department focusing on the vehicle as a complete system and specifying attributes for it.

Within CompanyX, we mostly interacted with Function Owners, a role responsible for the specification, development, and integration of user-visible functions in the system. These were typically engineers who had been involved in the development for many years before becoming responsible for the development of one or more functions in their area of expertise. Some of them additionally had the role of function developers who define the lower-level design of functionality and software components. The project was driven by a project manager with a background in requirements engineering and business processes. Another stakeholder was responsible for the configuration and user training related to the current and future use of the systems engineering tool within CompanyX.

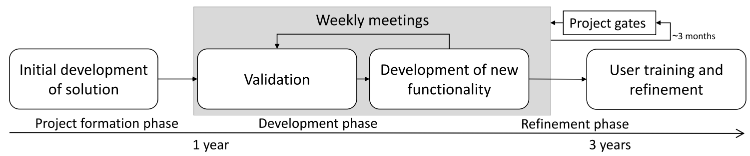

Fig. 1. The activities of the project

Figure 1 shows the activities of the project we focus on in this study. The project consists of a formation phase in which an initial solution is developed. Three application engineers from the tool vendor are involved, as well as the project manager and a stakeholder for the configuration of the systems engineering tool. After the formation phase, the stakeholders involve function owners from several departments, a responsible manager for the breakdown of functions, and another application engineer from the tool vendor for the iterative analysis, validation, and refinement of the proposed solution in weekly meetings. The initially-defined tool solution, decisions, and suggested changes gain maturity over the course of those weekly meetings. Project gates constitute an external mechanism to follow the project's progress. The project gates were evaluated by a steering group consisting of high-level managers. Once a sufficient level of maturity is reached, the project proceeds with user training and refinement. This is mostly driven by the project manager and a stakeholder for the configuration of the systems engineering tool.

CompanyX decided to collaborate with a tool vendor that develops, customizes, and supports the use of a configurable systems engineering tool. The tool is a customizable information management tool used mainly in the automotive domain for requirements engineering, architecture, design, and testing.

In CompanyX, initial requirements engineering approaches on the functional level differed significantly between departments. While the high-level processes are prescribed by the company, different practices are followed in different departments.

Figure 2 presents an abstraction of the organizational structure and various tools used for requirements engineering. In this figure, three departments are shown, two of which collaborate with suppliers, and one that does internal development. In some departments, the RE approach is based on textual documents, which is not unexpected due to these applications' pervasiveness across industry and the relative unfamiliarity with RE tools among those who do not possess a strong background in RE. Besides textual documents, also a requirements management tool and a systems engineering tool are used. The text documents are edited by function owners and stored in a document repository.

Depending on the department, different tools are used for the requirements engineering process. Some departments have an intense collaboration with third-

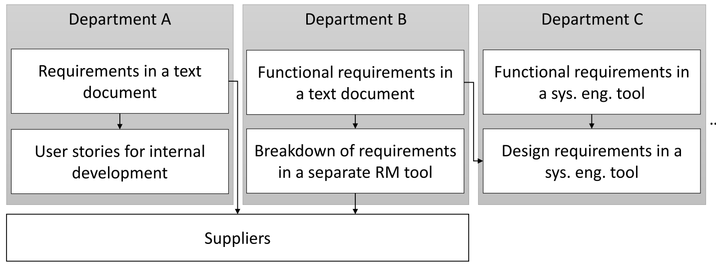

Fig. 2. Excerpt of organizational structure and tools used for requirements engineering

party suppliers whereas others use more internal development (potentially across departmental borders, as in the case of Department B and C). Functional requirements are intended to be on an abstract level to describe system-level functionality that is later broken down in more detailed component-level requirements that trace back to the higher, system-level specification.

Functional requirements are typically on a high level, for instance, "when the driver opens the door, the interior lights should be turned on." However, some groups do not do a stepwise breakdown but rather use the functional requirements specification as the only requirements document (e.g., Department A). In this department, the requirements are used to create user stories for internal agile development. In Department C, the systems engineering tool was used already before the project to specify requirements on a functional level, and also analysis and design requirements and models. This is especially typical when the function owner also fulfills the role of a developer.

CompanyX is currently following the V model systems engineering process and data structure [8]. Some initiatives to implement agile practices have been started. In the current way of working, it is challenging to align the work of different groups to create an integrated product that facilitates development and testing activities. Requirements do not accurately represent the final product. Moreover, the departmental structure makes it difficult for individuals to see how their work fits into the overall system. As the company develops a product line of different systems, it is another challenge to actually see the final product and orient the own work towards it.

The project to change and align requirements engineering practices in different departments was initiated to counteract these issues. Later on, the project managers saw the necessity to establish a common tool supporting traceability between different development and testing phases. The goal was to start with the functional requirements and ensure that they explicitly capture the connections to final products and release dates.

3 Related Work

Carrillo de Gea et al. [9] assess 38 requirements engineering tools. Although the paper was published over five years ago, the challenges outlined reflect similar issues experienced by CompanyX, including those which influenced their decision to select and standardize on the chosen systems engineering tool. They found that insufficient support exists for requirements management, including baseline and project management features and "ensuring that the requirements actually reflect the product." Moreover, the authors discuss that in large organizations, critical requirements engineering data is often scattered across several systems and organizations. The complexity resulting from heterogeneous requirements management environments should be considered when selecting requirements engineering tools. Harmonizing requirements engineering practices by establishing a common tool, as in the case of CompanyX, alleviates the issue of scattered data and facilitates more disciplined requirements management and traceability.

Inayat et al. [10] state that agile RE helps overcome several challenges, for instance, integrating requirements engineering with development tasks and supporting collaboration between teams. While our study focuses on technical and organizational issues with a concrete project on the alignment of requirements engineering practices, we consider the aspect of agility a very interesting complementary perspective. CompanyX has started to use agile methods in parts of the organization, however, not for functional requirements engineering. We expect that the use of agile methods for this phase will impact the alignment-diversity perspective of requirements engineering practices.

Eliasson et al. [11] conducted a study on requirements engineering and information flows in automotive software development. Two challenges they discuss are dependencies between different research and development departments and the trade-off between under- and over-specification of product requirements. They proclaim the need to "bring cross-functional groups together to identify the right abstraction level for requirements." Our study focuses on bringing diverse groups together and find common requirements engineering practices.

Knauss et al. [12] present a case study dealing with an automotive OEM trying to implement more continuous integration practices. They arrive at the conclusion that more "unified, controlled, and consistent data" is needed in order to enable effective continuous integration. To align heterogeneous teams, it is important to also support unified data approaches and find an appropriate tool solution that can support these product development practices.

Weber and Weisbrod [13] describe how DaimlerChrysler established a generic requirements engineering process that was used in tailored forms across business units as they matured their own requirements engineering practices. They stressed the benefit of using a structure of atomic requirements and generating text documents from them. Weber and Weisbrod note that practitioners do not typically struggle with the actual requirements specification as functionality in automotive is often developed in an evolutionary manner. However, it is difficult to structure and present requirements in a comprehensive way. A more recent approach for Daimler's systems engineering is presented in [14]. They currently transition from text-based requirements engineering to model-based specifications. Haasis concludes that available tools do not address practitioners' needs, but organizational implications are not named. In this study, we describe organizational and tool aspects of a project related to requirements engineering.

In an analysis of industrial needs for requirements engineering in the embedded systems domain, Sikora et al. [15] conclude that the use of models for requirements engineering and different levels of abstractions for requirements would be beneficial. They motivate further studies in the areas of quality assurance and traceability between requirements and design. In contrast to our study, the authors of this paper also did not focus on tool or organizational aspects.

4 Research Method: An Ethnographic Study

We conducted an ethnographic study, a technique that originally stems from the areas of sociology and anthropology and that is particularly suitable to study human behavior in a specific context [6]. One common ethnographic approach involves the immersion of one or more researchers into the natural setting of a cultural group as a participant-observer and typically happens over an extended period of time [7]. The ethnographic researcher is acting both as an "outsider," gathering objective information about the context, artifacts, and interaction, but is also as an "insider," engaging in the same pursuits as those who are normally part of the environment under study.

We were interested in the study context as it allowed us to follow a large-scale industrial project aiming to find trade-offs between diversity and consolidation in requirements engineering. While we immersed ourselves in the study and did not aim to confirm a hypothesis, we specified guiding questions:
RQ1: What are challenges and their consequences when trying to consolidate RE practices in large-scale industrial systems engineering contexts?
RQ2: What are mitigation strategies when trying to consolidate RE practices in large-scale industrial systems engineering contexts?

4.1 Description of Research Method

The first author of this paper conducted this study as a participant during a period of 1.5 years. She works as an application engineer and business analyst at a tool vendor for a systems engineering tool and also pursues a PhD degree at Chalmers University of Technology. Besides the author, there were three other application engineers from the tool vendor involved during the course of the project. Whereas the first author was involved during the development and refinement phases, the other application engineers participated mostly in the project formation and development phases (see Figure 1). To mitigate the risk of bias, long discussions with the other authors were used with the other authors (who were all external to the project). Moreover, in internal discussions to reflect on the progress of the project, all application engineers provided input with their own critical observations. Moreover, we discussed the findings presented in this paper with them as an opportunity to validate the analysis.

The activities of the observer included participating in weekly meetings at CompanyX's site with the project's stakeholders, presenting proposed solutions, configuring the metamodel and views of the systems engineering tool, joining the team for coffee breaks and lunches, and other activities, both related to the project work itself and of a more social focus. In ethnographic studies involving participant observation, it is encouraged that the observer engages in day-to-day activities with the others present ("informants"), rather than merely remaining a detached researcher. During the course of the study, the observer took notes of observations for future analysis, typically as a diary using notes hand-written on a notebook. The research questions were used as guiding questions for the note-keeping. For instance, decisions during the meetings were considered in the notes, but also other interesting points that emerged in discussions or breaks. Moreover, emails and meeting notes by the project leaders were recorded. The development and refinement phases were the periods in which data was collected by the observant. In order to mitigate threats to validity, we triangulated this data with notes, emails, and project documentation gathered over the course of the whole project. Additionally, to gather input after the study, two interviews of approximately one hour were conducted with the project manager and another participant of the project. In these interviews, we discussed lessons learned from the project and mitigation strategies to counteract the identified challenges.

The study took place directly at CompanyX. A consistent 2 hour time slot was taken for the meetings and booked several weeks in advance. The weekly meetings typically took place in a meeting room with 12 seats around a larger table. Additional participants from two distributed sites joined via a video conferencing system. To facilitate this task, the project manager typically shared their computer screen.

During the first three months of the study, the observer focused on getting a good understanding of stakeholders and their viewpoints. Technical details and input for the creation of new solutions were other aspects that the field notes focused on. With time, the understanding of the project's context and dynamics increased. The data was analyzed in several iterations during which themes emerged, following a sequential analysis approach for ethnographic data [16]. We immersed ourselves in the project and started to identify the themes depicted in Figure 4 during the development phase of the project. Over time, these themes were refined based on the notes, discussed, and renamed. We worked in an iterative fashion, both alone and in group discussions among. Two senior researchers and application engineers were involved in these discussions.

The themes were refined, grouped, and analyzed to arrive at connections and implications.

4.2 Threats to Validity

We consider several threats to validity in our ethnographic study [17].

The study was conducted by one researcher directly involved as an observant in the ethnographic study. Notes were taken to document incidents and activities which allowed us to analyze them. However, due to misconceptions and different understandings of terminology, there exist threats to *descriptive and interpretative validity*. We discussed our findings with fellow researchers and also conducted two one-hour interviews with participants of the project. This validation also helped to mitigate *theoretical validity* threats, especially the critical discussions of potential biases with fellow researchers.

Any qualitative study is influenced by researchers' backgrounds and preconceptions and therefore subject to *researcher bias*. The primary researcher in our study was employed at the tool vendor. While it is desirable that the ethnographic researcher is also an insider, it has an influence on how observations are interpreted. As described in Section 4.1, the remaining authors were external to the project and we used discussions with them and with internal project members to critically discuss and reflect on the findings during the course of the study. To further mitigate the threat, the paper was reviewed by an industry RE professional who cannot identify the company nor the tool. However, the industry RE professional attests to the generalizability of the findings and consistency with her own experience. Besides the experience with requirements engineering, she has worked extensively with ethnographers and anthropologists at her company for many years. She was involved in their Usage to Platform Requirements effort, and helped develop and conduct training on Usage Models, as well as ethnography-based requirements elicitation.

The review conducted by an industry RE professional mentioned in the last paragraph helped to mitigate threats to *generalizability*. However, in most contexts, tool vendors do NOT deploy trained personnel along with the tool. Other companies might select and use a tool, but would not have representatives from that vendor on-site participating in project meetings and helping with deployment. In our ethnographic study, the observer played the role of an active agent. This could have influenced the results and constitute a threat to *reactivity*.

The sample size of the study and the scope of the project were limited. However, the general research method might be fruitfully employed elsewhere (as it is described in detail in this section). This can help to analyze the replicability of our results.

5 An Initiative to Consolidate RE Practices

As presented in Shahrokni et al.'s work [18], development organizations occasionally reorganize themselves, which can be supported by tools or tool chains that are customizable to different processes and organizations. Figure 3 depicts how the reorganization of processes or organizations can be supported and is strongly intertwined with changes related to employed tools.

For the initiative to consolidate requirements engineering practices in CompanyX, both organizational and tool aspects turned out to bring their own challenges. The processes on a large scale did not undergo significant change (and were not the scope of the project), but the concrete methods changed supported by the tool. In this section, we present the high-level vision and scope of the

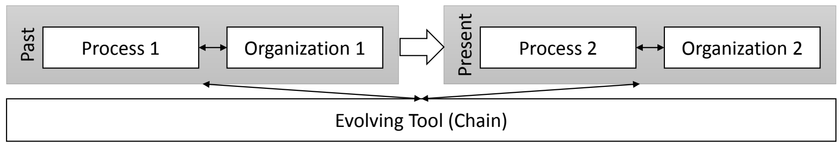

Fig. 3. Evolution of processes and organizations supported by a tool, adapted from [18]

project in Section 5.1, then technical and method challenges (Section 5.2), and organizational challenges (Section 5.3).

5.1 Initial Vision and Scope of the Project

When the ethnographic study began, the project formation phase had already been completed. The project managers had already evaluated tool solutions and decided to collaborate with the tool vendor. The justification was that CompanyX saw the flexibility of the systems engineering tool and its adaptability to different processes as an advantage. Another application engineer from the tool vendor had created an initial conceptual model of general functional requirements. Functional requirements are used to describe the high-level functionality of a system and are used both for subsequent phases of analysis and design, and finally for functional testing.

In the first phase of the project, the tool vendor aimed to get an understanding of the customer's needs and find ways to formalize relevant information in a metamodel. In discussions with the project manager and other stakeholders, the goal was described to align functional requirements engineering practices by stressing the perspective of the final products and concrete release dates. The idea was to structure functional requirements specifications not according to each product function, but rather use the concrete products and release dates as the high-level structure. Requirements would be organized in "containers" related to products and their release dates. This facilitates the testing process, as testing is always directly connected to a final product. Also the idea of a "common container" for requirements for all products was discussed.

However, with time, this approach was discarded. As the function owners have a traditionally stronger focus on their own functions and requirements, it is a bigger effort to rewrite the functions and their structure to instead reflect the focus on products with release dates. Testing and development stakeholders were underrepresented in the weekly project meetings and their information needs were neglected. Related aspects are presented in Section 5.3.

5.2 Technical and Method Aspects

The project established the systems engineering tool as a common tool for functional requirements engineering. Today, it is accessible for all function owners—however, the project has not been closed yet and some users are still in the process of transitioning from their old way of working. Key decisions in the project have been made and key milestones have been reached, but work is still in progress for the widespread adaptation of the tool. Several changes in the tool were made and concepts were introduced to support sufficiently aligned requirements engineering practices:

To facilitate variability management on a lower level, the project worked on the integration of the systems engineering tool with a variant database using an API. This allows that a standard way of describing low-level variants for requirements is supported.

Another decision was to support use case modeling [19] on two levels. On one hand, casual use cases or use case summaries can be specified for initial elicitation of requirements. This involves describing the high-level purpose of a use case and the actors, but no formal scenario description. These use cases are often included in functional requirements specifications to make the function's purpose and structure clearer. On the other hand, formal specifications of use cases with basic course of events ("BCE") are supported which also encompass alternate paths. Typically, these ways of specifying are not combined: In some departments, casual use cases are more common, whereas others use formal specifications to a larger extent. It should be noted that some function owners also specify "situations" or "use conditions" regarding the weather or traffic to describe different modes of the function. They are commonly required by test teams as well as quality and reliability engineers.

Functional safety analysis is supported as well with a solution for hazard analysis and risk assessment. It allows function owners and other safety experts to specify hazards in a grid, deduce ASIL levels, derive safety requirements, and enable traceability. The feature of safety analysis was not considered from the very beginning, but plays an important role when eliciting requirements for functions. As safety is an essential concern for automotive companies, it must be considered already on the highest level of requirements specification.

There were common discussions regarding IDs of requirements. After a long discussion, a standard way of defining requirements IDs was achieved, using a common prefix and a sequential number. Especially for the collaboration with suppliers, it is essential to have unique and persistent requirements IDs to ensure traceability between the specification and their deliveries. For in-house development, it is not as central, especially if the systems engineering tool is used. The tool assigns unique and persistent IDs to all artifacts entered and supports traceability between all artifacts.

There was a change in the data presentation to support different stakeholders' concerns. For instance, functionality was added to provide a top-level overview of functions and responsibilities in a grid. Approximately ten different views and reports for variability and safety concerns were created. For instance, a grid view can be generated to show all requirements of a function with the relevant variants they are valid for. These views facilitate the function owners' work so that they can get an overview of their function and evaluate the correctness of the specified information. Moreover, application engineers from the tool vendor supported the company with the automatic generation of functional requirement specifications as PDF documents. These documents are both required for safety certification and are the traditional interface to suppliers. The need for document generation features has been voiced by practitioners in the past [13].

To summarize, the technical features that were implemented cover different areas: The specification of variants, both casual and formal use cases, safety analysis, requirements IDs, a higher level overview of functions and responsibilities, and several views, grids, and reports. The project decided to allow for diversity (e.g., when it comes to use cases), but in some areas also enforced commonality (e.g., when discussing requirements IDs and the need to find a consistent way of specifying them to collaborate with suppliers).

5.3 Organizational Aspects

Many participants in our project articulated a feeling that they are unable to change processes or organizational structures. The project originated from the middle of the organization. A project manager noted that it was challenging to get support for decisions from both the management organization and engineers who specify, design, and develop a system. We found relevant organizational aspects in both the high-level management organization and the system development organization.

Several issues were identified related to how the project was handled at the management level: The steering group (consisting of higher-level managers) did not have a full understanding of systems and software engineering concerns, in part because core stakeholders' background is in mechanical engineering. The different backgrounds and understandings, e.g., related to how terms like "function" are used, was challenging for the project. The project leaders observed the widely shared assumption that everybody in CompanyX could follow the same methods in detail. However, this assumption does not generally hold, as results depend a lot on the nature of the individual function compared to the individual's own area of expertise, e.g., how much software or mechanics is involved. Due to this lack of understanding, the steering group's vision was unclear and they did not aim to change things at a larger scale. Moreover, there were a few leadership changes during the improvement program that impacted the scope of the project. For instance, new concerns were raised when a manager with a background from a different department joined the project who suggested that different views on the data would be beneficial.

On the other hand, it was also challenging to convince the system development organization to adopt new practices. One of the issues was that people did not share the same vision of aligning traceability practices. They had become comfortable with their ways of working within their own area of responsibility and did not see the lack of a "big picture" as a crucial issue. The project managers' approach to align the ways of working was to try to find function owners who support the project to influence others to adopt it as well. Following this approach and trying to consider everybody's needs made it difficult to actually have an impact. However, it allowed motivated individuals to influence the scope of the project and question decisions. As a consequence, ideas were discarded (e.g., the approach of structuring requirements according to release dates) and new ideas came in. Sometimes new people questioned decisions made prior to their arrival after rationales behind those decisions had been forgotten. As a consequence of this lack of organizational memory, about a year after the initial decision had been taken, it was discussed whether the way of modeling casual and formal use cases should be discarded again. Ultimately, not many stakeholders actually stood behind the earlier decisions. This lack of alignment around earlier decisions impacted the level of trust stakeholders had in future decisions.

A test database was used to try out different metamodels and configurations in the systems engineering tool, but few people actually found the motivation to write specifications there. They saw the changing nature of the project and decided they did not have time to model their functions in a database that could potentially be discarded later on. CompanyX rewards project management milestones (e.g., opened project gates), but there was a lack of incentives for teams and leaders to adapt aligned practices and use the systems engineering tool for requirements engineering.

Core stakeholders were only temporarily involved in the process of defining the systems engineering framework and changes in RE practices, although they might have had important information needs that should have been considered. For instance, project managers (who would be interested in tracking how a project is proceeding and how many requirements of the vehicle with release date X are specified and implemented) were not involved. Also testers were only temporarily involved and did not influence the course of the project.

6 Summary and Discussion

This section presents a summary and discussion of our findings. Section 6.1 discusses challenges and consequences and Section 6.2 discusses solution candidates to deal with the challenges.

6.1 Challenges and their Consequences (RQ1)

This section discusses the identified challenges and consequences and answers RQ1: What are challenges and their consequences when trying to consolidate RE practices in large-scale industrial systems engineering contexts?

Figure 4 shows an overview of the findings. The project tried to find a tradeoff between diversity and alignment by supporting several tool features and methods. In some areas, alignment is of central importance, especially when it comes to requirements IDs that constitute an external boundary to suppliers. In the case of use case modeling, which is used for elicitation and to structure the specification document of a particular function, more diverse methods and tool solutions are supported.

Both the management and the system development organizations came with particular characteristics. The management organization underwent several leadership changes, core stakeholders had different professional backgrounds and

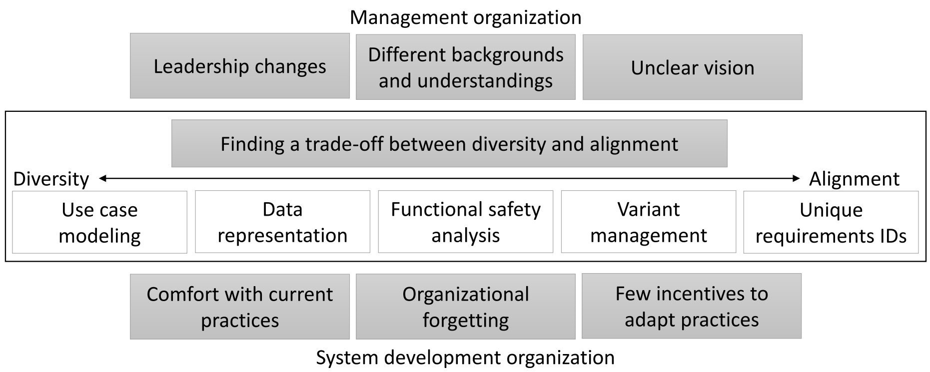

Fig. 4. An overview of the findings related to challenges and their consequences

understandings of the project, and the vision of the project was unclear. The system development organization felt comfortable with the existing practices, suffered organizational forgetting as design decisions were not recorded, and did not perceive many incentives to adopt the project's practices.

Based on the experiences of this project and the interviews, we present potential mitigation strategies in the following section and give improvement ideas for practitioners that are involved in similar programs.

6.2 Mitigation Strategies (RQ2)

Based on our analysis of challenges, we discussed mitigation strategies in two interviews with project participants. This section presents the discussion of mitigation strategies and lessons learned from our study. We give answers to RQ2: What are mitigation strategies when trying to consolidate RE practices in large-scale industrial systems engineering contexts?

Involve the right stakeholders The project in CompanyX struggled with finding a suitable team for the improvement program. At the beginning of a project, a careful analysis of stakeholders should be conducted to identify which roles and individuals should be represented. While there exist standard methods for this step, it can be challenging in practice. For instance, in this study we found that it is important to consider both the management and system development perspectives. If neither the top-level managers believe in the project's vision nor does the system development organization support and execute the practices, it is impossible to have an actual positive impact. For projects improving requirements engineering practices and their alignment, the consumers of the written requirements are the most important ones to include and have on board.

Engage all participants and make decisions with data Some of the solutions in the project arose from situations in which individuals' opinions resulted in unmanaged changes to project plans or abandonment of previously-established commitments. This should be considered when selecting stakeholders for a project and when taking decisions based on what attitudes are voiced. Stakeholders with strong opinions should not be excluded solely on that basis, but ground rules must be established to ensure that all participants are able to be engaged. Decisions need to be made with data, not merely because of a participants' strongly-held feelings.

Focus on a final vision We observed a tendency to work with details—e.g., in the case of long discussions on requirements IDs. Requirements IDs are important when working with suppliers, but one needs to prioritize what the focus of meetings should be. It is important to focus on measurable goals and relate decisions to those goals. The scope of a project can easily drift and it is important to keep a final vision in mind.

Try to enforce aligned practices only if you have good reasons We found that it is desirable to align practices to a certain extent, especially when they are relevant to collaborate with external groups or stakeholders (as in the case of requirements IDs). However, it is of vast importance to understand required boundaries where alignment is necessary, but to allow for diversity otherwise. Especially for requirements elicitation, as in the case of use case modeling in CompanyX, diverse methods are beneficial to foster creativity and arrive at a complete set of requirements. It should be possible to periodically reassess and adapt the boundaries of alignment.

Carefully assess what to change (and when to change back to an initial solution) A reoccurring issue in the project was that solutions were discarded after some time and it was decided to go back to an initial state. We learned that one should not underestimate that the current solution might actually be the best. However, when discarding solutions, one should document why they did not work. Document rationales for decisions to counteract "organizational forgetting." We recommend to keep these rationales as first class entities also in the tool, and link them to relevant requirements or design elements related to those decisions.

Discuss a concrete tool solution to make people formalize their concerns Whenever abstract process issues or general questions regarding the way of working were discussed, it was harder to arrive at conclusions. Talking about the systems engineering tool and its metamodel made discussions a lot more concrete and helped people formalize their concerns. The iterative process of the project (presenting a solution and gathering feedback in weekly meetings) made it easier to arrive at concrete conclusions and find ideas for improvement.

Keep traceability in mind: How can artifacts be connected? What other areas and phases need this information? When trying to find a common requirements engineering approach, it is important to keep in mind how these artifacts will be used in the future, and how the alignment with subsequent phases can be facilitated. For this reason, it is beneficial to keep opportunities to extend the methods and tools in mind. Ensuring traceability between different artifacts can be a strong enabler to support system-level thinking in the future.

Add incentives to teams and leaders who support and meet objectives in the organizational transformation Although the systems engineering tool was configured and accessible early in the project, few stakeholders decided to actually work with it. It would have been beneficial to create actual incentives to support the project and encourage others to follow their footsteps. Organizations planning a similar program should assess what incentives or bonuses are valuable and show their appreciation for stakeholders supporting the program's objectives.

7 Conclusion

In this ethnographic study, we explored the issue of aligning diverse requirements engineering practices in a practical context. Focusing on a three-year project in an automotive company, we analyzed technical and organizational aspects of the project and supported the establishment of a systems engineering tool supporting requirements engineering.

We found that it is not desirable to find generic solutions and expect all methods to be alignable in detail, but that diverse practices are desirable especially for requirements elicitation, as in the case of use case modeling. For other concerns, especially the communication with external customers or suppliers, alignment (e.g., using requirements IDs) and traceability are needed. Organizations need to have an alignment between senior leadership and the people working in tactical roles. Stakeholders should be carefully selected for RE initiatives and decision rationales need to be recorded for the project's change-management practices and to counteract organizational forgetting. Continued and visible commitment from leadership and incentives for the team as a whole are required to successfully consolidate requirements engineering practices.

Our findings can be used by practitioners in similar programs and by researchers who work towards facilitating organizational alignment and diversity in requirements engineering contexts. Future work can compare the experiences and mitigation strategies to other projects and companies and suggest actionable guidelines for practitioners. We also consider the alignment of RE practices in agile requirements engineering an interesting area of future work.

Acknowledgments

We are grateful the support of participants in the case projects and we thank for all the clarifications provided when needed. This work was partly funded by Software Center Project 27 on RE for Large-Scale Agile System Development and the Wallenberg Autonomous Systems and Software Program (WASP).

References

1. Cheng, B.H., Atlee, J.M.: Research directions in requirements engineering. In: Future of Software Engineering (FOSE '07), IEEE (May 2007) 285–303

2. Damian, D.: Stakeholders in global requirements engineering: Lessons learned from practice. IEEE Software **24**(2) (Mar 2007) 21–27
3. Fricker, S.: Requirements value chains: Stakeholder management and requirements engineering in software ecosystems. In: REFSQ'10, Essen, Germany (2010) 60–66
4. Feiler, P., Gabriel, R.P., Goodenough, J., et al.: Ultra-Large-Scale Systems: The Software Challenge of the Future. Software Engineering Institute (2006)
5. Knauss, E., Yussuf, A., Blincoe, K., Damian, D., Knauss, A.: Continuous clarification and emergent requirements flows in open-commercial software ecosystems. Requirements Engineering Journal (REEN) (2016)
6. Sim, S.E.: Evaluating the evidence: Lessons from ethnography. Workshop on Empirical Studies of Software Maintenance (1999) 66–70
7. Creswell, J.W.: Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. 3 edn. Sage Publications Ltd. (2008)
8. Walden, D.D., Roedler, G.J., Forsberg, K., Hamelin, R.D., Shortell, T.M., eds.: Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. 4 edn. Wiley, Hoboken, NJ (2015)
9. Carrillo de Gea, J.M., Nicolás, J., Fernández Alemán, J.L., Toval, A., Ebert, C., Vizcaíno, A.: Requirements engineering tools: Capabilities, survey and assessment. Information and Software Technology **54**(10) (Oct 2012) 1142–1157
10. Inayat, I., Salim, S.S., Marczak, S., Daneva, M., Shamshirband, S.: A systematic literature review on agile requirements engineering practices and challenges. Computers in Human Behavior **51** (Oct 2015) 915–929
11. Eliasson, U., Heldal, R., Knauss, E., Pelliccione, P.: The need of complementing plan-driven requirements engineering with emerging communication: Experiences from Volvo Car Group. In: RE'15, IEEE (Aug 2015) 372–381
12. Knauss, E., Pelliccione, P., Heldal, R., Ågren, M., Hellman, S., Maniette, D.: Continuous integration beyond the team: A tooling perspective on challenges in the automotive industry. ESEM 2016 (2016)
13. Weber, M., Weisbrod, J.: Requirements engineering in automotive development: experiences and challenges. IEEE Software **20**(1) (Jan 2003) 16–24
14. Haasis, S.: Systems engineering for future mobility. In: REConf. (2016) `https://www.hood-group.com/fileadmin/projects/hood-group/upload/Images/REConf/2016/vortraege/mittwoch/auditorium/Keynote-Systems_Engineering_for_future_mobility.pdf`.
15. Sikora, E., Tenbergen, B., Pohl, K.: Requirements engineering for embedded systems: An investigation of industry needs. In: REFSQ'11. (Mar 2011) 151–165
16. Fielding, N.: Ethnography. In Gilbert, N., ed.: Researching Social Life. SAGE Publications (2008) 266–284
17. Maxwell, J.: Qualitative Research Design: An Interactive Approach. Applied Social Research Methods. SAGE Publications (2012)
18. Shahrokni, A., Söderberg, J., Gergely, P., Pelliccione, P., Söderberg, J., Pelliccione, P.: Organic evolution of development organizations - an experience report. In: SAE World Congress and Exhibition - Model-Based Controls and Software Development. (2016) 1–9
19. Adolph, S., Cockburn, A., Bramble, P.: Patterns for Effective Use Cases. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA (2002)