Identifying and Structuring Challenges in Large-Scale Agile Development based on a Structured Literature Review

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***Abstract*—Over the last two decades, agile methods have transformed and brought unique changes to software development practice by strongly emphasizing team collaboration, customer involvement, and change tolerance. The success of agile methods for small, co-located teams has inspired organizations to increasingly apply agile practices to large-scale efforts. Since these methods are originally designed for small teams, unprecedented challenges occur when introducing them at larger scale, such as inter-team coordination and communication, dependencies with other organizational units or general resistances to changes. Compared to the rich body of agile software development literature describing typical challenges, recurring challenges of stakeholders and initiatives in large-scale agile development has not yet been studied through secondary studies sufficiently. With this paper, we aim to fill this gap by presenting a structured literature review on challenges in large-scale agile development. We identified 79 challenges grouped into eleven categories.**

I. Introduction

Emerging in the 1990s, agile software development methods, such as Extreme Programming (XP), Feature-Driven Development, and Scrum, have transformed and brought unprecedented changes to software development practice by strongly emphasizing change tolerance, continuous delivery, and customer involvement [1], [2]. Many enterprises are already using agile methods to maximize customer value and quality of delivered software products, but are uncertain how to introduce them at scale, since they are originally designed for small, co-located teams [1], [3]. This problem is exacerbated by the fact that the adoption of agile methods at larger scale entails new challenges, such as inter-team coordination and communication, dependencies with other organizational units or general resistances to changes [3], [4]. Despite these known challenges, there is an industry trend towards adopting agile methods in-the-large [3], [5].

Compared to the rich body of agile software development literature describing typical challenges (cf. [6], [7] or [8]), challenges in large-scale agile development has not yet been studied through secondary studies sufficiently [3]. Dikert et al. [3] made a first attempt to solve this problem by presenting a systematic literature review of large-scale agile transformations. They identified 35 reported challenges and 29 success factors for large-scale agile transformations. However, the presented challenges are not directly related stakeholders in order to provide appropriate proven solutions for addressing them. In our larger study, we aim to fill this gap by introducing the concept of large-scale agile development patterns and to provide best practices for recurring challenges of stakeholders and initiatives in large-scale agile development. Our study is inspired by the pattern-based approach to Enterprise Architecture Management (EAM) [9]. As a starting point of our study, we present our qualitative findings on stakeholder- and initiative-related challenges in large-scale agile development with the help of a structured literature review. Based on this objective, three research questions (RQ) were formulated

- *RQ1: Which stakeholders exist in large-scale agile development?*
- *RQ2: What are challenges of stakeholders and initiatives in large-scale agile development?*
- *RQ3: What are generalizable findings on stakeholder- and initiative-related challenges in large-scale agile development?*

A. Research methodology

The goal of the literature review is to identify challenges of stakeholders and initiative in large-scale agile development. In order to achieve this goal and to ensure the rigor and relevance of the research, we applied a structured literature review approach as recommended by Brocke et al. [10] that consists of four phases. In the first phase, we defined the review scope and formulated adequate research questions about challenges in large-scale agile development. In the second phase, we identified key concepts by concept mapping, which also provided us the opportunity to obtain relevant search terms: *Agile and Lean Software Engineering*, *Large-Scale Agile Development*, *Agile Transformation*, and *Challenges, challenges and Problems*. These search terms were used in the subsequent literature search in the third phase. We examined a range of different Information Systems journals, conference proceedings using ACM Digital Library, IEEExplore, Scopus, and Web of Science. Having compiled the aforementioned list of search terms, we then used them in electronic full-text search queries. Initially, 67 sources were identified as

relevant, given their focus on the topic, after analyzing a total of 560 sources (title, abstract, and outline). Additionally, we conducted a backward search, resulting in additional 6 sources. In total, we obtained 73 relevant sources. In the fourth phase, we coded the primary studies using a deductive approach as proposed by Cruzes and Dybå [11]. We established an a priori list of codes inspired by the EAM pattern language elements [9], which includes stakeholders, challenges, methodology patterns, architecture principles, viewpoint patterns, and anti-patterns. In the initial step, we started with the actual coding of the data structured by the aforementioned code categories. During the coding, we also identified the relationships between the codes of the different code families. Particularly, we related challenges to respective stakeholders and solutions, such as methodology patterns or architecture principles. For instance, we can determine typical challenges of solution architects and how they are trying to address them based on this structure. After creating preliminary codes, we refined and consolidated our codes by merging related ones and removing duplicates. In the final step, we grouped related challenges into eleven categories: *culture & mindset*, *communication & coordination*, *enterprise architecture*, *geographical distribution*, *knowledge management*, *methodology*, *project management*, *quality assurance*, *requirements engineering*, *Software Architecture*, and *tooling*. Table I presents a description of the codes families and the final state of the coding. Note that in this paper, we only discuss the results related to challenges and stakeholders, and that it as such forms a part of a larger study. In our larger study, we aim to introduce the concept of large-scale agile development patterns, which builds on and extends the idea of the proven pattern-based approach to EAM [9]. The aim of this new pattern language is to address typical problems of stakeholders and initiatives in large-scale agile development.

The remainder of this paper is structured as follows. In Section II, we provide an overview of related works describing challenges and success stories in large-scale agile development. In Section III, we present our findings on large-scale agile development challenges identified in the literature. We discuss the main findings in Section IV before concluding the paper with a summary of our results and remarks on future research in Section V.

II. Related work

Dikert et al. [3] conducted a systematic literature review of industrial large-scale agile transformations focusing on reported challenges and success factors in the transformation. 47 out of 117 relevant papers were selected to obtain 35 challenges and 29 success factors for agile adoption. They grouped the challenges in nine categories and the success factors in eleven categories. Paasivaara and Lassenius [12] validated and deepened these findings with a pilot study. The result is an improved and weighted version of the success factors and challenges. However, there is no relationship to stakeholders that are affected by these challenges. Viswanath [13] observed more than 400 employees in a company during their five years long lean transformation. The employees were analyzed while facing challenges, pitfalls and success factors according to three dimensions: Process, Product and People. Viswanath [13] showed that every stakeholder in a company is involved in the lean transformation. Nevertheless, detailed relations of challenges to stakeholders is also not existing in this paper. Bjarnason et al. [14] reported that agile transformations does not affect only software developers but also other disciplines like requirements engineering. The challenges of over-scoping and communication gaps can be addressed with agile approaches. Some of the to be faced challenges are similar to the traditional way but the transformation cause also new challenges like finding the right balance between agility and stability. Bjarnason et al. [14] also presented that requirements engineering is affected by the agile transformation and have to face new challenges. Unfortunately, there is right now no collection of stakeholder specific challenges that directly mention stakeholders like requirement engineers.

III. Challenges in large-scale agile development

A. Stakeholders in large-scale agile development

In our structured literature review, we identified 40 stakeholder roles that are involved in large-scale agile development. Many of them are either already present in traditional software development or are used as a synonym for another role. We consolidated the 40 roles to 14 stakeholder roles. One example of this consolidation is the role of the Chief Architect [15] which has been merged with the Enterprise Architect because of their similar areas of responsibilities. The following 14 stakeholders were obtained in large-scale agile development:

- Development Team (47)[1],
- Product Owner (33),
- Scrum Master (30),
- Software Architect (21),
- Test Team (18),
- Product Manager (13),
- Program Manager (4),
- Agile Coach (4),
- Enterprise Architect (3),
- Business Analyst (3),
- Solution Architect (2),
- Portfolio Manager (2),
- Support Engineer (2), and
- UX Expert (1).

B. Challenges in large-scale agile development

In total, we identified 79 challenges of which 41 newly arose by large-scale agile development and 38 are strengthened by large-scale agile development (see Table II and Table III).

IV. Discussion

A. Key findings

Let us now reflect on the three research questions described in Section I. ***RQ1: Which stakeholders exist in large-scale***

[1]The number in parentheses stands for the number of documents that mention the respective role.

TABLE I
OVERVIEW OF CODE FAMILIES AND CODES

Code family	Description	Examples	# Identified elements	Codes
Stakeholders	A person with a challenge in a large-scale agile development	Product Owner, Scrum Master, Software Architect	14	770
Challenges	Stakeholders or initiatives are confronted with challenges that have to be addressed in large-scale agile development	Ensuring that non-functional requirements are considered by the Development Team	79	286
M-Patterns	Methodology patterns (M-Patterns) are defined as concrete steps that are performed to address recurring challenges in large-scale agile development	Scrum of scrums, community of practices, creating an architectural runway	88	196
Architecture Principles	Architecture principles define the underlying general rules and guidelines for the use and deployment of all IT resources and assets across the enterprise	Loose coupling of systems or services, reuse of functionalities, buy before make	4	5
V-Patterns	Viewpoint patterns (V-Patterns) are defined as documentations of proven practices to recurring problems for specific contexts in form of viewpoints for the creation of views	Burndown chart, context map, pulse chart	9	12
Anti-Patterns	Anti-patterns detail on typical mistakes in large-scale agile development, and present revised solutions, which help pattern users to prevent these pitfalls	Do not put individual goals over team goals, do not adopt all agile practices in one go, do not overshoot coordination meetings	17	68
		Total		1378

agile development? In the literature review, we observed 40 different stakeholder roles in large-scale agile development. We consolidated them to 14 final stakeholder roles. The stakeholder roles include roles from agile software development as well as new roles, like Software Architects or portfolio managers.

RQ2: What are challenges of stakeholders and initiatives in large-scale agile development? We identified 79 challenges for large-scale agile development (see Table II and Table III). These challenges can be either program-specific or related to specific stakeholders. Thereby, we assigned the challenges either to the in RQ1 observed stakeholder roles or marked them as program-specific.

RQ3: What are generalizable findings on stakeholder- and program-related challenges in large-scale agile development? *Architecture becomes more important the more complex the task or system is.* Although, Software Architects are not included in many agile methods, such as XP or Scrum, they face several challenges in large-scale agile development. Furthermore, more than 20% of the challenges are related to architecture-related topics. All of these challenges newly arose with large-scale agile development. *New stakeholder roles are involved when scaling agile development.* Although, the role of the architect was not intended in agile software development, because it only contains the role of a Product Owner, Scrum Master and the Development Team and additional ones are not mentioned [65]. Nevertheless, we observed in the literature analysis further roles like software and enterprise architects or product managers. *Scaling agile development entails new communication and coordination challenges.* Additional stakeholder roles help to manage big software programs. This includes also the management of multiple agile teams. In the literature review, we identified eight communication and coordination challenges and 75% of them newly arose from large-scale agile development. *Challenges in agile development may still exist in large-scale agile development.* 38 of 79 identified challenges still exist in large-scale agile development. These challenges are typical for agile development and are reinforced by large-scale agile development. *Stakeholders that are successfully isolated by the Scrum Master from external influences have less challenges in large-scaled agile development.* Only 7% of the observed challenges are either challenges for the Development or Test Team. Furthermore, the top challenge topics are inter-team coordination and communication problems as well as architecture related issues. Stakeholders that are isolated by the Scrum Master from external influences are not affected by these challenges and face less challenges in large-scale agile development.

B. Limitations

This paper has a few limitations, which should be mentioned at this point: First, although, we spent much time and effort into developing a suitable search string and conducted a structured database search, there is still a certain chance that not all important contributions have been identified. We found additional literature through a backward search of the analyzed papers in the literature search process. Some relevant studies might have evaded our attention in spite of our best efforts. Second, the initial coding procedure was conducted by only one researcher, which might have led to biased classifications. It might have been better if two researchers had been involved working on a pair coding mode from the beginning.

TABLE II
LARGE-SCALE AGILE DEVELOPMENT CHALLENGES

Name	Challenge Category	Novelty	Relationship to Stakeholders	Number	Sources
Coordinating multiple agile teams that work on the same product	Communication & Coordination	yes	Program Manager	15	[3], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29]
Considering integration issues and dependencies with other subsystems and teams	Software-Architecture	yes	Solution Architect	14	[3], [12], [18], [20], [23], [24], [26], [28], [30], [31], [32], [33], [34], [35]
Coordinating geographically distributed agile teams	Geographical Distribution	yes	Scrum Master	8	[3], [12], [19], [25], [29], [33], [36], [37]
Facilitating shared context and knowledge	Knowledge Management	no	Initiative-Related	7	[13], [21], [31], [33], [38], [39], [40]
Managing technical debts	Software-Architecture	no	Software Architect	7	[13], [28], [29], [33], [41], [42]
Dealing with incorrect practices of agile development	Methodology	no	Agile Coach	7	[12], [21], [25], [32], [33], [41], [43],
Dealing with doubts in people about changes	Culture & Mindset	no	Agile Coach	7	[13], [21], [31], [33], [38], [39], [40]
Ensuring that non-functional requirements are considered by the Development Team	Software-Architecture	yes	Software Architect, Solution Architect	6	[3], [12], [26], [30], [33], [44]
Finding the right balance between architectural improvements and business value	Software-Architecture	yes	Software Architect	6	[26], [28], [30], [31], [33], [45]
Creating precise requirement specifications for the Development Team	Requirements Engineering	no	Product Owner	5	[3], [12], [37], [44], [46]
Obtaining management buy-in	Culture & Mindset	no	Initiative-Related	5	[3], [12], [42], [47], [48]
Providing sufficient tools and infrastructure for remote communications	Tooling	no	Initiative-Related	5	[27], [36], [39], [49], [50]
Sharing common vision	Knowledge Management	yes	Program Manager, Product Owner	5	[3], [13], [31], [51], [52]
Creating a proper upfront architecture design of the system	Software-Architecture	yes	Software Architect	5	[28], [30], [32], [47], [53]
Eliciting and refining requirements of end users	Requirements Engineering	no	Product Owner	5	[3], [12], [25], [26], [37]
Establishing self-organization	Communication & Coordination	no	Development Team	5	[3], [21], [29], [33], [54]
Splitting large and complex requirements into smaller requirements	Requirements Engineering	yes	Product Owner, Program Manager	5	[3], [12], [13], [33], [55]
Dealing with internal silos	Knowledge Management	yes	Initiative-Related	5	[3], [12], [25], [28], [56]
Dealing with increasing workload of key stakeholders	Project Management	yes	Initiative-Related	4	[3], [31], [33], [34]
Facilitating communication between agile teams and other teams using traditional practices	Communication & Coordination	yes	Product Owner	4	[3], [37], [42], [48]
Managing dependencies to other existing environments	Enterprise Architecture	yes	Enterprise Architect	4	[3], [26], [37], [42]
Balancing short-term and long-term goals	Requirements Engineering	no	Product Manager	4	[3], [12], [25], [57]
Establishing a common scope for different stakeholder groups	Knowledge Management	yes	Initiative-Related	4	[29], [34], [39], [49]
Creating team spirit and trust among agile teams	Culture & Mindset	yes	Initiative-Related	4	[19], [29], [33], [41]
Managing and integrating heterogenous subsystems of different Development Teams	Software-Architecture	yes	Solution Architect	3	[3], [28], [44]
Aligning and communicating architectural decisions	Software-Architecture	yes	System Architect, Solution Architect	3	[3], [28], [58]
Managing and sharing knowledge about system components and their dependencies with stakeholders	Enterprise Architecture	yes	Enterprise Architect	3	[3], [21], [28]
Communicating business requirements to Development Teams	Requirements Engineering	no	Product Owner	3	[25], [26], [59]
Facilitating agile teams to participate at cross-shore meetings	Geographical Distribution	yes	Scrum Master	3	[3], [39], [50]
Synchronizing working hours of cross-shore agile teams	Geographical Distribution	yes	Scrum Master	3	[3], [36], [39]
Dealing with geographical distance between agile teams	Geographical Distribution	yes	Initiative-Related	3	[19], [36], [39]
Dealing with lacking team cohesion at different locations	Geographical Distribution	yes	Scrum Master	3	[33], [36], [39]
Building trust of stakeholders in agile practices	Culture & Mindset	no	Scrum Master	3	[3], [41], [52]
Ensuring the reuse of enterprise assets	Enterprise Architecture	yes	Enterprise Architect	3	[28], [47], [53]
Defininning clear and visible priorities	Requirements Engineering	no	Product Owner	3	[29], [46], [54]
Establishing automated testing	Quality Assurance	no	Test Team	3	[3], [12], [13]
Creating lightweight documentation	Knowledge Management	no	Development Team	3	[26], [37], [47]

TABLE III
LARGE-SCALE AGILE DEVELOPMENT CHALLENGES (CONTINUED)

Name	Challenge Category	Novelty	Relationship to Stakeholders	Number	Sources
Facilitating standardization across agile teams	Enterprise Architecture	yes	Enterprise Architect	3	[3], [12], [60]
Establishing a culture of continuous improvement	Culture & Mindset	no	Scrum Master, Agile Coach	3	[25], [56], [61]
Applying agile practices for developing or maintaining legacy systems	Software-Architecture	yes	Software Architect	3	[13], [44], [47]
Dealing with unplanned requirements and risks	Project Management	no	Program Manager, Product Owner, Product Manager	3	[31], [33], [37]
Rearranging physical spaces	Tooling	no	Scrum Master	3	[3], [12], [50]
Enforcing customer involvement	Culture & Mindset	no	Product Owner	3	[26], [47], [46]
Dealing with communication gaps with stakeholders	Communication & Coordination	yes	Initiative-Related	3	[26], [49], [56]
Dealing with black and white mindsets	Culture & Mindset	no	Agile Coach	2	[3], [42]
Dealing with closed mindedness	Culture & Mindset	no	Agile Coach	2	[3], [42]
Dealing with higher-level management interferences	Culture & Mindset	no	Scrum Master	2	[28], [58]
Demonstrating the value of architecting	Software-Architecture	yes	Software Architect	2	[45], [58]
Dealing with increased efforts by establishing inter-team communication	Communication & Coordination	yes	Initiative-Related	2	[20], [31]
Dealing with lacking sense of ownership responsibilities for developed services	Culture & Mindset	yes	Initiative-Related	2	[20], [33]
Ensuring that agile teams adhere to architecture-related activities	Enterprise Architecture	yes	Enterprise Architect	2	[28], [53]
Providing agile teams appropriate automation and scalable infrastructure	Tooling	no	Enterprise Architect	2	[17], [33]
Ensuring traceability of tests and requirements	Quality Assurance	no	Test Team	2	[3], [62]
Making a cost and schedule estimation	Project Management	no	Product Owner, Product Manager, Program Manager	2	[26], [34]
Creating a teamwork centric rewarding model	Project Management	no	Initiative-Related	2	[3], [12]
Defining clear roles and responsibilities	Project Management	no	Initiative-Related	2	[12], [46]
Decomposing agile teams in smaller independent teams	Enterprise Architecture	yes	Program Manager, Enterprise Architect	2	[34], [56]
Dealing with loss of management control	Culture & Mindset	no	Initiative-Related	2	[31], [47]
Establishing a common understanding of agile thinking and practices	Methodology	yes	Agile Coach	2	[3], [12]
Creating and estimating user stories	Requirements Engineering	no	Product Owner, Development Team	2	[3], [12]
Dealing with cultural differences between cross-shore agile teams	Geographical Distribution	yes	Scrum Master	2	[19], [49]
Dealing with fixed price contracts in agile software development	Project Management	no	Product Manager, Program Manager	2	[47], [63]
Explaining requirements to stakeholders	Communication & Coordination	no	Development Team	2	[25], [51]
Defining a lightweight formal review process for new technologies	Enterprise Architecture	yes	Enterprise Architect	1	[42]
Dealing with office politics	Culture & Mindset	no	Initiative-Related	1	[42]
Fostering technical excellence	Software-Architecture	yes	Software Architect	1	[58]
Encouraging Development Teams to talk about tasks and impediments	Culture & Mindset	no	Agile Coach, Scrum Master	1	[39]
Writing understandable automated tests	Quality Assurance	no	Test Team	1	[62]
Establishing requirements verification	Requirements Engineering	no	Product Owner	1	[26]
Defining high-level requirements a.k.a. epics	Requirements Engineering	yes	Portfolio Manager, Product Owner	1	[12]
Measuring the success of the large-scale agile development program	Project Management	yes	Product Owner	1	[47]
Considering required competencies when assigning teams to tasks	Project Management	yes	Initiative-Related	1	[31]
Dealing with decreased predictability	Project Management	no	Initiative-Related	1	[47]
Empowering agile teams to make decisions	Culture & Mindset	no	Initiative-Related	1	[29]
Forming and managing autonomous teams	Communication & Coordination	yes	Initiative-Related	1	[12]
Coordinating tests and deployment with external parties	Quality Assurance	no	Test team, Development Team	1	[31]
Establishing a lightweight review process for adopting new technologies	Enterprise Architecture	yes	Enterprise Architect	1	[17]
Building an effective coaching model	Methodology	no	Agile Coach	1	[64]
Synchronizing sprints in the large-scale agile development program	Communication & Coordination	yes	Scrum Master	1	[60]

V. Conclusion and future work

In this study, we presented a structured literature review on recurring challenges of stakeholders and initiatives in large-scale agile development. We analyzed 73 papers, in order to describe reported challenges for large-scale agile development. In total, 79 challenges were identified and grouped into eleven challenge categories. We will extend our preliminary study by collecting data from our large-scale agile development workshops and case studies with industry partners. In parallel, we will perform a structured survey among companies in Germany to demonstrate the applicability of our large-scale agile pattern language, which provides the structure for documenting practice-proven solutions to recurring large-scale agile development challenges. After a huge data collection and evaluating the new pattern language, we will publish the Large-Scale Agile Pattern Catalog containing patterns and challenges.

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