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ADAPTING AGILE METHODS TO DEVELOP SOLUTIONS FOR THE INDUSTRIAL INTERNET OF THINGS

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Abstract

The Internet of Things (IoT) is evolving from a technological buzz-phrase into a substantiated organizational and private reality with interconnected devices over the Internet. However, with literature focusing on the technological aspects of IoT, research on the development process of IoT solutions remains scarce. This is particularly captivating, since agile methods provide a natural fit for the requirements associated with the development of IoT solutions, ranging from continuous and flexible improvement of products to integrating developers' interdisciplinary expertise. We bring together these two areas of interest by conducting a study on the adaptation of agile methods in organizations that develop and distribute industrial IoT solutions. In this paper, we derive a theoretical model based on adaptive structuration theory and develop our empirical research design. Our multiple-case study research approach across relevant companies and industries is currently in process of data collection and analysis. Nonetheless, our preliminary findings reveal interesting insights into the specific adaptation of the agile development method of Scrum in the industrial IoT context. In terms of our finalized study, we provide a sound theoretical basis for future research and offer relevant practical guidance for organizations that are implementing agile methods to develop their industrial IoT solutions.

Keywords: Internet of Things, Agile Methods, Adaptive Structuration Theory, Case Study.

1 Introduction

The vision of objects "equipped with identifying, sensing, networking and processing capabilities" (Whitmore et al., 2015, p. 261), embedded in a dynamic global network and the ability to communicate among each other as well as with related services over the Internet is being summarized as the 'Internet of Things' (IoT) (Li et al., 2015). IoT comprises the "potential to transform how companies deliver innovation, create differentiated customer experiences and optimize global operations" (Brody and Pureswaran, 2015, p. 36). Various application areas in private and organizational contexts, such as smart logistics, healthcare, or social IoT, exist for IoT solutions (Porter and Heppelmann, 2014; Whitmore et al., 2015). For instance, private homeowners can create 'smart homes' by equipping their houses with IoT technologies to facilitate the controlling of applications such as lights and heating as well as to enhance security by surveillance. From an organizational view, smart logistics embrace the idea of integrating IoT technologies in the supply chain to analyze real-time data and optimize processes by reducing inefficiencies such as the bullwhip effect (Li et al., 2015; Whitmore et al., 2015).

Despite a growing number of publications, most of the IoT literature focuses on technological aspects (e.g., Fang et al., 2015) and largely misses out on management issues (Whitmore et al., 2015). The majority of studies remains theoretical, for instance by conducting literature reviews and discussing a general IoT definition (e.g., Li et al., 2015; Whitmore et al., 2015). Even the small share of literature that outlines emergent business opportunities mainly stays theoretical (e.g., Porter and Heppelmann, 2014), and only few studies address these gaps by conducting empirical research on IoT management topics. For instance, Prince et al. (2014) show, by means of a case study, "how innovation networks are orchestrated in developing a strategic innovation initiative around the Internet of Things" (p. 106).

We seek to contribute to this scarce portion of literature by exploring the development of IoT solutions across companies and industries. We focus on the adaptation of agile methods in the context of industrial IoT solutions' development (e.g., machines and related software for 'smart factories') (Li et al., 2015), following the logic of Cao et al. (2009), who define this adaptation "as the process of changing agile methods to align them with [organizational] needs" (p. 333). Agile methods such as Scrum or eXtreme Programming (XP) are 'lightweight', iterative approaches for information systems (IS) development (Schwaber, 2009). These methods do not only provide a conceptual fit for the requirements of IoT development, but are increasingly employed in practice (Rigby et al., 2016). The development of IoT solutions is portrayed as complex, since it comprises different technological layers including hardware and software (Porter and Heppelmann, 2014). Besides the feasibility of agile methods for complex development projects, these concepts enable cross-functional teamwork, which facilitates the sampling of diverse developer expertise needed for fruitful IoT solutions (Highsmith, 2010; Schwaber and Beedle, 2002). IoT solutions entail continuous improvements according to users' requirements. Agile methods are a natural fit in this context, since they emphasize customer satisfaction, responsiveness to changing market conditions, and product timeliness (Beck et al., 2001a; Wallgren, 2016).

The adaptation of agile methods is a rich research field with relevant practical implications, since agile methods are not adopted one-to-one from guidelines but are tailored to the implementing company (e.g., Fitzgerald et al., 2006). By capturing these adaptations, we can enhance the understanding of IoT development and can provide companies with guidance. Therefore, we pose the research question:

How are agile methods adapted and implemented in the development of industrial IoT solutions?

To answer this question, we view the adaptation of agile methods through the theoretical lens of adaptive structuration theory (AST) and conduct case study research on three companies from different industries that are developing industrial IoT solutions. Case studies are feasible for our explorative study, since the investigated phenomenon is present and relevant in practice (Rigby et al., 2016), but remains under-researched from an empirical management perspective (Whitmore et al., 2015). We contribute to empirical research on IoT and offer specific insights into the employed management concepts in industrial IoT solutions' development. Our modified AST model provides a theoretical basis for studying the adaptation of agile methods and we further exemplify a suitable research design. With our final study, we aim to derive practical implications for related companies and to offer guidance for the successful implementation of agile methods in the development of industrial IoT solutions.

Our paper is structured as follows: In Section 2, we discuss agile methods and derive a modified conceptual model of the AST to guide our empirical research approach. This is followed by our case study research design including the sample selection as well as the data collection and analysis. Subsequently, we present the preliminary results from our first case and close this research in progress paper with an outlook on the finalization of the research project and our anticipated contributions.

2 Theoretical and Conceptual Background

2.1 Research on agile methods

Agile methods, such as XP (e.g., Beck and Andres, 2004) or Scrum (e.g., Schwaber and Beedle, 2002), have emerged as answers by practitioners to the 'heavyweight', plan-based approaches to software development such as the waterfall model (Abrahamsson et al., 2009; Dyba and Dingsøyr, 2008). Aside the various forms of agile methods, all types are based on the principles of the *Agile Manifesto* (Beck et al., 2001a, b), including an iterative approach to development, responsiveness to changing requirements, and a focus on and active integration of customers (Beck et al., 2001a, b). Agile methods are not exclusively used in software or IS development, but disseminated in areas such as project management, where Scrum is a well-known practice (e.g., Buxmann et al., 2013; Highsmith, 2010).

Since the initial codification, research on agile methods has increased rapidly (Abrahamsson et al., 2009), and several literature reviews have been conducted (e.g., Dyba and Dingsøyr, 2008; Dingsøyr et al., 2012) to identify current and future research directions. One literature stream discusses agile methods in contrast to traditional plan-based methods, evaluating differences and issues in the transition process (e.g., Vinekar et al., 2006; Wang and Vidgen, 2007). While earlier works focused on the challenges in adopting agile approaches (e.g., Boehm and Turner, 2005), more recent publications emphasize the realizations and consequences of agile usage (e.g., Senapathi and Srinivasan, 2012; Vidgen and Wang, 2009). Research on agile methods also covers IoT related areas such as embedded systems development (e.g., Kaisti et al., 2013; Srinivasan et al., 2009). Empirical studies show that the adoption of agile practices in embedded systems development can be beneficial in terms of successful development projects (e.g., Könnölä et al., 2016; Salo and Abrahamsson, 2008). However, agile methods require tailoring and adaptation to the specific context of embedded systems, especially concerning the interplay between hardware and software development (Kaisti et al., 2013; Könnölä et al., 2016).

We build on the versatile applicability of agile methods as well as their coverage in IoT related areas by employing the concept in the development of industrial IoT solutions (Rigby et al., 2016).

2.2 Adaptive structuration theory as a theoretical foundation

AST is a theoretical framework that stems from social theory and is applied in IS research to study the adoption and use of advanced information technologies and their effects on organizations (Jones and Karsten, 2008). Based on Giddens' (1979) structuration theory, AST argues that the context of a technology's usage and its application mutually influence each other and form a technology's adaptation. AST has been employed in various IS research areas, such as computer-supported virtual teams (e.g., Majchrzak et al., 2000), or in studying the adaptation of information technologies by individuals (e.g., Schmitz et al., 2016). In the context of agile methods, AST has been used to explore the adaptation of agile methods in software development (e.g., Cao et al., 2009) as well as the adaptation of traditional information technology funding processes to agile projects (e.g., Cao et al., 2013).

We rely on AST as a theoretical lens for our study since it enables us to analyze the implementation of agile methods in industrial IoT solutions' development by capturing the ongoing adaptation processes in the organizations (Cao et al., 2009; DeSanctis and Poole, 1994). Therefore, based on the original AST (DeSanctis and Poole, 1994) and the adapted model of Cao et al. (2009), we derive our AST model consisting of three parts: *input*, *process*, and *output*; shown in Figure 1.

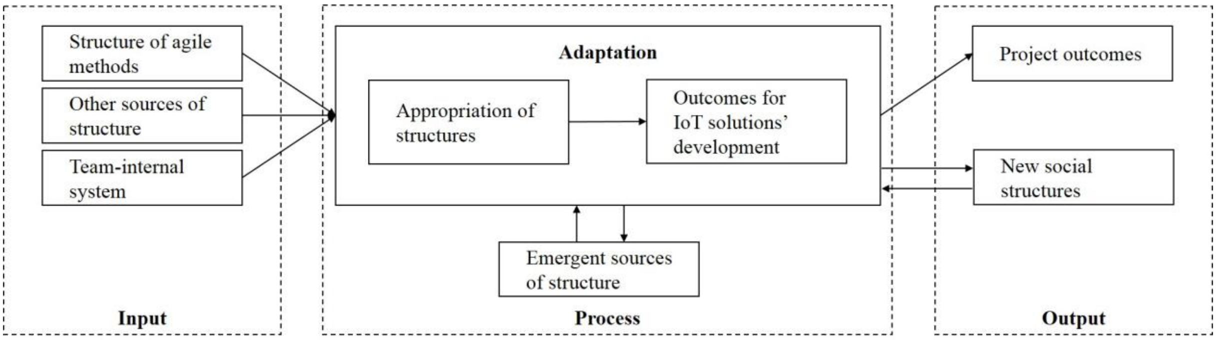

Figure 1. Modified adaptive structuration model (adapted from Cao et al., 2009).

The model's *input* section comprises social structures, which represent core components of the AST and are defined as "rules and resources provided by technologies and institutions as the basis for human activity" (DeSanctis and Poole, 1994, p. 125). However, social structures can originate not only from technologies, but also from processes, which enables the interpretation of concepts such as agile methods as a possible source of structure. We identify three initial *input* elements that influence the adaptation of agile methods: a) the structure of agile methods, b) other sources of structure, including the task or project characteristics and structure determined by the organizational environment as well as c) a team's internal system as a further impact factor (Cao et al., 2009; DeSanctis and Poole, 1994).

The *structure of agile methods* is established by their *structural features* – their inherent types of rules, resources, and capabilities – and their *spirit*, referring to the underlying values. Agile structural features include agile principles such as an iterative development approach and continuous product testing. The agile spirit can be portrayed as a customer-oriented approach with a focus on communication (Beck et al., 2001a, b). The specific *task or project characteristics* under which terms the precise agile method is applied, such as the complexity of a project or its interdependency with other projects, also represent a source of structure. In addition, the *organizational setting* such as strong hierarchies or an organization's culture determine structure and influence the adaptation of an agile method. A final *input* element is a *team's internal system*, comprising the leadership and behaviors in a team and the members' experience with the employed agile method (Cao et al., 2009; DeSanctis and Poole, 1994).

In the *process* stage, the social structures are brought into action (e.g., by implementing Scrum in an IoT development project), which is called *structuration* (Giddens, 1979). The subsequent, apparent "application of [social] structure[s] in a particular context" (Cao et al., 2009, p. 334) can be defined as the *appropriation of structures* (Ollman, 1971). Appropriation generates so-called '(social) structures in action', which refer to the employment of the *input* structures (Cao et al., 2009; DeSanctis and Poole, 1994). For instance, a development team applies Scrum and allocates the responsibilities of the related roles according to their project tasks. Although appropriation is context-specific, four aspects of appropriation can be identified from literature: appropriation moves, faithfulness of appropriation, instrumental use, and attitudes towards appropriation. Appropriation moves describe the ways in which a team appropriates structure and applies it in their context (i.e. how Scrum is used in practice). The team also determines the faithfulness – the extent to which the structures in action are consistent with the agile methods' spirit – and the purpose of appropriation, which is referred to as instrumental use. Finally, the attitude towards appropriation considers the teams' opinion on the appropriation of agile methods in terms of, for instance, their usefulness (Cao et al., 2009; DeSanctis and Poole, 1994).

We discuss the adaptation of agile principles in the context of the *outcomes for the IoT solutions' development*, since the appropriation of structures influences the organization of work in the development teams. We follow the proposed breakdown of Cao et al. (2009), presented as development process-related, developer-related, and management-related outcomes. The first outcomes refer to changes in the development procedure, such as the implementation of a short-cycle development rhythm. Developer-related outcomes consider the changes for the teams and their leaders, such as a stronger empowerment of the teams. Management-related outcomes encompass such factors as shifts in an organization's hierarchy or its culture (Cao et al., 2009; Nerur et al., 2005; Schwaber, 2009).

As the *input* structures are employed, results for agile methods, tasks, or projects and the organizational setting are generated. These results can become *emergent sources of structure*. For instance, by applying Scrum to an IoT development project, relevant knowledge is created and disseminated, constituting a new source of structure that influences the adaptation of Scrum (DeSanctis and Poole, 1994).

As an *output* of the adaptation, changes in *project characteristics* such as quality, costs, or schedules may occur. Structures in action "are produced and reproduced" (DeSanctis and Poole, 1994, p. 129), whereas this interaction may result in *new social structures* over time. These new structures refer to all *input* elements and can, for instance, result in new development routines such as monthly task rotation as a social structure, which in turn can influence the adaptation process (DeSanctis and Poole, 1994).

3 Research Methodology

3.1 Case study research

We employ positivist case studies, which postulate a physical world with fixed social relationships independent from the researcher that can be objectively analyzed (Myers, 2009). Specifically, we follow an exploratory approach to define "questions, constructs, propositions, or hypotheses" (Paré, 2004, p. 235) for further empirical studies. We selected case studies, since they are best suited to answer ‘how’ and ‘why’ questions and to explore a current phenomenon within its real-life context (Yin, 2013). In line with Benbasat et al.’s (1987) requirements, our research objective a) cannot be studied outside its natural setting, b) constitutes a present development, c) needs no control or manipulation of research subjects, and d) does not have an established theoretical basis. To refer to concerns regarding the scientific rigor of case studies, we closely adhere to the methodological procedures from literature (i.e. Benbasat et al., 1987; Dubé and Paré, 2003; Paré, 2004) and comply to quality criteria for positivist case studies such as construct validity, internal validity, external validity and reliability (Yin, 2013).

3.2 Case selection and sample description

We aim to conduct a multiple-case study, since it allows for cross-case analyses and is less vulnerable to criticism concerning the method’s generalizability (Yin, 2013). We purposefully selected relevant companies according to two steps (Patton, 1990). First, by following the criterion sampling logic stated by Patton (1990), we searched for companies that develop industrial IoT solutions and employ agile methods. Second, we applied a theoretical replication logic that aims to generate contrasting results by choosing heterogeneous cases and enhances the study’s external validity (Yin, 2013). We selected three companies that differ in a) size, b) experience with agile methods and IoT solutions’ development, and c) industry (see Table 1). All three companies offer a wide range of products and services, besides having a common strategic focus on industrial IoT. In our case study we solely focus on the organizations’ industrial IoT development. With the data collection in process, we will add cases until theoretical saturation, which is defined as “the point at which incremental learning is minimal because the researchers are observing phenomena seen before” (Paré, 2004, p. 241), is reached. We use a case study protocol, including all relevant data such as a project overview, an interview guideline, and rules for field procedures to ensure the reliability of our research (Paré, 2004; Yin, 2013).

	Case 1	**Case 2**	**Case 3**
Industry	Engineering	IT	Various
Revenue (in € for 2015/16)	~ 3 bn.	~ 21 bn.	~ 71 bn.
Employees	> 11,000	> 75,000	> 370,000
IoT products	Hardware and software	Software	Hardware and software
Planned/Conducted interviews	6/6	5-6/0	5-6/0

Table 1. Sample overview.

3.3 Data collection and analysis

As our primary source of data, we aim to conduct five to six interviews with managers, team leaders, and project members who are actively engaged in the agile IoT solutions’ development at each company. The interviews are led by a semi-structured guideline with open-ended question and are planned to last between 60 and 120 minutes. The guideline consists of four parts including a) a general section about IoT as well as b) a company-specific part about IoT solutions and their development. The latter two sections comprise c) the usage history of agile methods and d) the accompanied adaptation and its results. Selected interviews are carried out by two researches of which one is a senior researcher. If possible, all interviews are tape-recorded and transcribed verbatim afterwards (Miles et al., 2013). To enhance the rigor as well as construct validity of our study, we conduct data triangulation for our findings with secondary data including publicly available and relevant interviews, press releases, information from the firm websites as well as management reports (Paré, 2004; Yin, 2013). To build a case database, analyze and code all of our data, we utilize the software ATLAS.ti. Based on the coded data, we set up detailed descriptions for each case and perform a cross-case analysis. The initial coding is guided by our AST model, whereas further codes are iteratively added to facilitate a better case understanding and increase the internal validity of our qualitative study (Miles et al., 2013; Yin, 2013).

So far, we have collected the data for case 1. We conducted six telephone interviews with representatives of the firm in June 2016 that lasted between 60 and 90 minutes. To ensure confidentiality, we call the first case company EngTech. The interviewees comprised two managing directors, the head of software development, and two senior managers for software development and project management as well as a work council. The interviews for the remaining two cases are planned and scheduled.

4 Preliminary Results

We will now present case 1 (EngTech) with a specific focus on EngTech's IoT development and the adaptation of agile methods in its IoT development based on our modified AST model. A summary of our initial findings is also presented in Table 2.

Context: EngTech is a medium-sized engineering company. In the digital age, the customer and market demands have changed and increasing competition arises with IT companies offering software solutions for industrial machines. Instead of being degraded to a hardware manufacturer, EngTech aims to develop hardware as well as software solutions. Therefore, EngTech has strategically emphasized IoT and has employed new business models that address the evolution of IoT. First, EngTech provides its business customers with individual IoT software solutions for optimizing their production and related lead times. Second, EngTech established a spin-off firm that offers an IoT platform for manufacturers on which corporate and third-parties' IoT solutions are made available. Heading to production automation in terms of a smart factory, EngTech develops and deploys both IoT hardware (e.g., tool machines) and related IoT operating software. Both parts of a holistic industrial IoT solution are increasingly developed based on Scrum. Overall around 200 IoT software and about 120 IoT hardware developers currently work in medium-sized Scrum teams of seven to twelve members. A majority of these developers take part in a recently launched interdisciplinary project to develop a holistic industrial IoT solution consisting of a new machine concept and the corresponding operating software. The project comprises 200 IoT hardware and software developers to equal parts working in Scrum teams.

Input	• Implementation of Scrum according to its common application and underlying values • High task complexity and project interdependency owing to IoT characteristics and connectivity of IoT hardware, IoT software and IoT platform • Prior knowledge existed owing to the previous implementation of Lean
Process	• Scrum is well adopted in IoT development teams, especially in IoT software development teams, but also increasingly in IoT hardware development teams • Prevailing positive attitude towards Scrum; purpose and adapted practice are deemed useful • Implementation of 12-week overall project phases with autonomous sprint allocation enables IoT software as well as IoT hardware teams to deliver products and fosters their cooperation • Empowerment of development teams increased and shaped new team roles • Additional support for agile projects emerged owing to the enhanced popularity of Scrum
Output	• Faster pace of product development with constant quality • Specialized team roles (e.g., people manager) become institutionalized

Table 2. Overview: Initial findings for case 1.

Input: Scrum was implemented in the IoT development of EngTech according to the methods' common codifications. Thus, tenets such as a) the sprint logic (i.e. short-term development cycles), the related sprint reviews, retrospectives and daily standups (i.e. reports on development progress), as well as the use of a product backlog (i.e. overall plan that is incrementally developed and improved), b) basic roles, including product owners (i.e. team members responsible for the final product) and empowered development teams, and c) the production of working products constitute the *structural features* of Scrum. The *spirit* of Scrum at EngTech involves continuous and open communication, contributing valuable products, and a flexible and quick response to changes. The *task/project scope* of developing industrial IoT hardware as well as software solutions required EngTech to adapt the agile practices to a greater frame. The interdependency of smart, connected IoT hardware and the compatibly developed IoT software as well as their connectivity to EngTech's IoT platform increase the complexity and the coordination of the projects. IoT solutions also need to be developed and deployed in a timely manner as well as flexible to changing market conditions and customer requirements. Concerning the *organizational setting*, a new head of software development was employed, who pushed the issue of agile methods. Regarding the *teams' internal system*, several development members and team leaders had knowledge and some first experience with the concept of agile methods owing to the previous introduction of Lean in manufacturing and office operations. Nonetheless, prior to the implementation of Scrum, the development teams were managed and led in a command-and-control style.

Process: Regarding the *appropriation* of these structures, EngTech's IoT development teams adopted Scrum and its principles and values well. Currently, most of the IoT software development teams apply Scrum, whereas many of the IoT hardware development teams still employ the waterfall model. However, first teams are shifting to agile development with Scrum. This can be ascribed to a positive attitude towards Scrum by team members and managers. Especially the underlying purposes of agile methods – to foster flexibility and reduce development time – are perceived as desired benefits. Since the adopted practices support these properties, they are deemed useful and in line with the agile spirit.

Next, we describe the *outcomes for the IoT solutions' development* and the related adaptation of Scrum at EngTech. Concerning the IoT development process, a 12-week 'overall project phase' was implemented. At the end of this phase, each IoT hardware and software project is reviewed by leading managers and other teams to synchronize the projects. This review results in a higher transparency between teams and a closer cooperation between IoT hardware and software development. During the 12 weeks, the teams can autonomously decide on sprint cycles and prioritization. While most IoT software development teams employ a three-week sprint with standups held three times a week, the autonomous sprint allocation is crucial for teams that require machines for product testing, since some machines have production rhythms of up to six weeks. With IoT hardware development teams requiring a longer time to develop a product, the 12-week phases enable them to deliver a workable product. The development processes are supported by two new tools: a communication tool and a specific wiki to foster knowledge management. Concerning the developer-related outcomes, an increasing empowerment of the development teams occurred. However, the empowerment entailed the difficulty that team members, especially in the IoT hardware development, had to familiarize with thinking of a 'collective' product, whereas before they could relate to 'their' creation. It also resulted in a loss of power for the team leaders. In the early stages of Scrum adoption, the team leaders turned into product owners, but kept their disciplinary responsibility, which made it difficult for the teams to negotiate their projects' scope, since they were in fear of being misjudged in the annual assessment. To solve this issue, the product owners lost these responsibilities and transferred into the role of experts who guide the teams. In turn, the disciplinary lead was pooled in the new role of the people manager. This adaptation, in which new leadership roles – such as the people manager and the master product owner (i.e. supervising all development teams in their field) – arose, refers to management-related outcomes.

New sources of structure emerged owing to the application of Scrum in EngTech's IoT development teams. For instance, the central project management office, which supports projects in the whole organization recently shifted its focus on the increasingly popular Scrum methodology, and now offers agile coaching and actively assists agile projects or teams who seek to work agile. In addition, the aforementioned interdisciplinary pilot project fosters the dissemination of agile methods at EngTech.

Output: To sum up, the currently adapted and applied Scrum method at EngTech's IoT hardware and software development comprises a 12-week project phase with autonomous sprint allocation during this phase, technology-supported communication and documentation, specialized team roles such as the people manager, and a mindset of empowered team members and collective ownership for interconnected hardware and software products. The discussed adaptation also resulted in relevant *out-*

comes for the projects. The IoT solutions are developed faster than before, with constant quality; however, we can make no statements about budget or cost changes. One *new structure* that emerged due to the adaptation of Scrum are the novel profiles for leaders, including the specialized people manager. Further new structures might emerge, since the adaptation of Scrum at EngTech is still ongoing.

5 Outlook and Anticipated Contribution

Up to this point in our research project, we have collected, coded, and analyzed the EngTech case study. In the next steps, we aim to complete the data collection process by conducting the interviews with case companies 2 and 3 by spring 2017. After triangulation, we will compile individual within-case analysis and will compare the results against each other by means of a cross-case analysis.

This research in progress paper presents a sound concept, based on the theoretical foundation of AST, to study the adaptation of agile methods in IoT development, and shares initial empirical findings from a case study. From these findings, we can derive the understanding that the adaptation of agile methods fosters the cooperation of IoT hardware and software teams by implementing an overall project phase. Nonetheless, the IoT hardware development is not yet able to fully exploit the emerging possibilities of agile methods owing to difficulties concerning the mindset of developing collective products and achieving quick usable results. Additionally, the structural rethinking of leadership, team role and task perceptions as well as responsibilities might induce the biggest challenges for medium to large scale organizations with predefined hierarchical structures in transitioning to agile IoT development.

In our final paper, we will provide contribution for both theory and practice. From a theoretical perspective, we will offer requested empirical research on a relevant IoT management issue (i.e. the development of IoT solutions) and will provide a fresh theoretical lens for assessing the adaptation of concepts such as agile methods in this context. From a practical perspective, our final results will improve understandings of the development process of IoT solutions. Thus, we will be able to provide guidance for companies to successfully manage their adaptation of agile methods. This may not only support already implementing organizations with the employment of agile methods. It will also help indecisive companies which consider to apply agile approaches for the development of their industrial IoT solutions to evaluate the methodology’s fit and to identify key success factors and challenges.

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