Description of Constituent Characteristics of Agile Development Processes for Technical Systems

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Abstract: The transformation of the market environment with an increasing demand for customer-specific products and shortened product life- and innovation cycles confronts manufacturing companies with new challenges. In order to meet these challenges, iterative and flexible agile product development processes are increasingly being implemented. These tend to accelerate product development and achieve a higher degree of fulfilment of customer requirements. At the same time the increasing complexity of technical products and the decreasing depth of added value of manufacturing companies due to a major focus on core competencies have led to the fact that the integration of suppliers in product development has become a critical success factor. The increasing use of agile development processes has resulted in new requirements for the design of supplier integration, as there is a divergence from the established plan-oriented approaches. The aim of the paper is to concretize this divergence by identifying constituent characteristics of agile development processes for technical systems.

1 INTRODUCTION

Companies are confronted with complex market conditions. The market environment is especially characterized by globalization and shorter product life cycles. Also product complexity increases, in order to meet all customer requirements (Dombrowski et al. 2015; Schuh 2012). Meeting these customer needs is one of the main tasks of product development. However, volatile market requirements make it difficult for companies to anticipate them, forcing them to act under uncertainty. The increasing customer orientation in the dynamic business environment favours this uncertainty and creates an innovation pressure on companies (Cooper, 2014). Plan-driven processes based on a sequential structure can no longer meet the requirements of short development times and high flexibility (Cooper, 2014; Schuh et al. 2017).

Agile development processes are therefore being used in product development, as they enable faster development at lower costs (Backblaze 2015). They are hereby characterized by an empirical-adaptive character. The processes are less prescriptive than plan-driven processes and are distinguished above all by their high flexibility (Kniberg and Skarin 2010). Within agile development processes there is no fine-granular predetermination of the contents, but a continuous adaptation.

Takes place during the execution of the project, whereby a consideration of changing customer requirements can be guaranteed (Böhmer, 2016).

The high level of uncertainty and complexity in the development of mechatronic systems places new demands on processes, which must also be adapted to the high flexibility of agile models. Manufacturing companies are also mainly focusing on their own core competencies and increasingly outsourcing development services to suppliers, which reduces the depth of value added and makes the integration of external partners a critical success factor (Spath and Dangelmaier 2017; Groher 2003). In this context, cooperation between companies and their suppliers continues to increase in intensity (Dombrowski, 2015). The supplier integration in product development faces companies with the challenge of the efficient and effective design of this integration. The design has to be adapted for agile product development processes since designs for

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plan-driven approaches are no longer applicable owed to divergence (Schuh and S. Schröder, 2019).

In order to enable the adaptation of supplier integration to the boundary conditions of agile development processes in the development of technical systems, a precise knowledge of the nature of agile development processes is necessary. This paper therefore presents a description model of agile development processes, in which constituent characteristics of disseminated processes are identified to concretize the discrepancy between plan-driven and agile processes. The analysis is part of an overall solution approach for the demand-oriented design of supplier integration in agile development projects (Takeuchi and I. Nonaka, 1986).

The framework comprises different characteristics of agile development processes used for the development of technical systems and represents one of five partial models of an overall solution hypothesis for the development of type-based supplier integration forms for agile development processes (Takeuchi and I. Nonaka, 1986). The overall solution concept aims to provide a model that allows companies to choose the best possible cooperation with development partners. The core of this work is therefore to identify constituent characteristics of agile development processes for technical systems, which then can be used to derive the resulting new requirements for the design of supplier integration forms.

2 LITERATURE REVIEW

In this paper agile development processes are analysed by identifying their constituent characteristics. Since agile development processes originate from software development and are predominantly in this area, they are optimized for these specific boundary conditions. However, agile processes are increasingly used and adapted for the development of technical systems. The literature does not yet describe any agile product development processes for technical systems, which is why the analysis in this paper is based on agile software development processes.

In 1986 the first agile development concept from TAKEUCHI & NONAKA was created in order to make product development faster and more flexible (Takeuchi and I. Nonaka, 1986). Since then, a multitude of different agile models have been established in software development. All agile methods are based on the values and principles of the agile manifesto

(Komus et al, 2016/2017) .The Agile Manifesto was designed in 2001 by 17 software developers. It sets out the basic ideas and principles on which agile development is based (Komus et al, 2016/2017). Core elements of agility, which are highlighted in the agile manifesto and define agility in the sense of software development, are early implementation, strong interaction with the customer and permanent testing (Schwaber, 1997).

Thus, not all agile development processes can be transferred to the development of technical systems. However, the proportion of IT-related and non-IT activities in which agile methods are used is growing (Rubin, 2013). Rather than rejecting agile methods for hardware development because they are not designed for it, individual values and elements benefiting the product development are identified. These elements have to be adapted and implemented in order to match the individual requirements. (Backblaze, 2015). They make development processes more flexible and do justice to the volatile business environment (Schuh et al. 2017). Due to the possibility of quick reaction to unforeseen events or changing requirements, their application is also possible under extreme uncertainty (Schwaber, 1997).

Due to the multitude of agile process models, this paper concentrates on the most widely used models in industrial practice. Only those models are considered which are suitable for the development of technical systems. These are Scrum, Kanban and Design Thinking, whose distribution in industrial practice is shown in Figure 1. The three mentioned agile product development processes are briefly explained in the following.

2.1 Scrum

Scrum is an agile management framework whose main field of application is the development of innovations (Rubin, 2013). It is strongly process-focused and provides rigid framework conditions for the development process. However, it does not define concrete development practices and methods. Instead, it focuses on the project management aspects of development. (Hanser, 2010) For this reason, it is often combined with other agile models that offer concrete methods for the development process. Characteristic are an incremental-iterative development methodology as well as self-organizing and interdisciplinary teams (Rubin, 2013). Within this framework the development team is given a high degree of freedom regarding the design of the product as well as the development process itself, which is open for adaption in order to achieve optimization (Kniberg and Skarin 2010; Abrahamsson et al, 2003).

2.2 Kanban

Kanban was introduced to the Japanese automotive industry in the 1950s and is a flow control mechanism for just-in-time production using pull control. Upstream processing activities are triggered by the downstream demand signals (Proceedings, 2003). Since Toyota's first industrial application, where it was used for efficient production control, Kanban has evolved into a generic process that has been transferred to other business areas (Ahmad et al, 2013). It should be noted that Kanban is not a development methodology, but a process improvement methodology by which a system can be understood and optimized. Due to its nature, an initial system is required that can be optimized. (Stellman and Greene, 2015).

2.3 Design Thinking

Design Thinking can be described as a human-centred design process that identifies problems and generates ideas for them. These ideas are quickly transformed into tangible solutions using prototypes. The aim is to reconcile the needs of the customer taking into account the technological feasibility and a viable business strategy. (Cole and Scotcher, 2015) The iterative character of the design thinking process enables a steady increase in knowledge as well as a continuous improvement of the solution (Freudenthaler-Mayrhofer and Sposato, 2017). With regard to idea generation, there are initially no restrictions in the process (Stellman and Greene, 2015). The design thinking process is always subject to an individual design, and is adapted according to the working method, problem definition and general conditions. Thus, there is a multitude of different Design Thinking process models.

2.4 Interim Conclusion

The empirical nature is characterized by the fact that the processes of the methods are individually adapted to the requirements of the project and thus the methods do not specify the process in total. They provide a basic set of tools for process optimization and are widely used due to their general applicability. (Kniberg and Skarin, 2010) Even if the considered agile development processes differ in their approach, all methods are based on common constituent features, which can thus be assumed to be generally valid for agile development processes. These are identified and described in the following section.

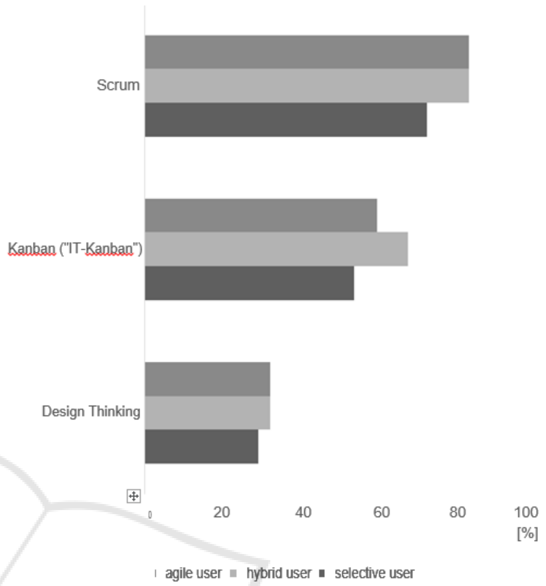

Figure 1: Use of agile development processes (Komus et al, 2017).

3 RESEARCH METHODOLOGY

This paper is part of a doctoral thesis, which is developed for the integration of supplier in agile development processes. The research methodology of applied science according to ULRICH (Schallmo, 2018) is the basis of the research design (see Fig. 2). In order to derive potential solutions, a structural approach is used to identify a practical problem with its theoretical deficit and to examine existing approaches to literatures. Chapter I names and structures a relevant practical problem as well as the underlying theoretical problem in accordance with the process of applied sciences according to ULRICH. The necessity of research in this area is also pointed out. Chapter II includes a literature search and identifies existing relevant approaches that correspond to steps B and C of the model based on ULRICH. Chapter IV presents the results, followed by a conclusion. In the context of the process of applied science, this includes steps D and E (Schallmo, 2018).

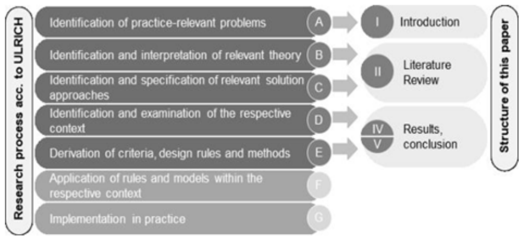

Figure 2: Structure of this paper according to Ulrich (Schallmo, 2018).

4 RESULTS

The aim of this paper is to identify constituent features that enable agile product development processes to be described in general and to distinguish them from plan-driven methods. Two successive steps were carried out for this purpose. First, the selected three agile product development processes were analysed by means of a literature review and process-specific characteristics for each individual process were identified. Subsequently, the general characteristics for agile product development processes were derived from these process-specific characteristics and the model was formed. For the derivation, the following criterion of universal applicability was established: Characteristics that can be identified in at least two of the most frequently used agile development processes are assumed to be universal applicable, as they can be transferred to the majority of the analysed development models.

For this purpose, the intersection of agile characteristics was formed and congruent characteristics for the model were identified. The constituent characteristics and their derivation from the respective agile development processes are listed in Figure 3.

4.1 Incremental Processing using Time-boxed Iterations

A fundamental feature of all considered agile development processes is the implementation of the project by means of time-boxed iterations. During the implementation of the development project, an incremental processing of the requirements is pursued. For each iteration loop, a specific focus is defined at the beginning, which is then processed in a previously defined time frame. (Abrahamsson et al, 2013; Cole and Scotcher, 2015; Ulrich, 1984).

In Scrum these temporally defined iterations are named sprints (Abrahamsson et al, 2003). All sprints have an identical duration in which the previously defined dedicated task planning is processed. After each of these sprints, the results are validated, and the product requirements adjusted if necessary. The next sprint is then planned using this adjusted target direction for setting the focus and the scope. (Anderson, 2010).

4.2 Low Specification of the Product at the Beginning

The product is only roughly defined at the beginning and has a low degree of specification, which gives a lot of freedom in the design of the process and the design of the product. This is the reason for the creative freedom of agile processes. At the beginning of a development project, general requirements are set for the product, but the way in which the requirements are going to be fulfilled is kept completely undefined. (Backblaze, 2015; Cole and Scotcher, 2015).

Looking at the design thinking process, it shows that the tasks and problems to be solved, which are the basis for the subsequent process, are formulated initially (Freudenthaler-Mayrhofer and Sposato, 2017). Comprehensive and complex problems are broken down into manageable problems in order to make processing easier (Cole and Scotcher, 2015). In order to first determine the direction of the development, a basic understanding of the needs of the target group is built up.

4.3 Early Delivery of Intermediate Results

Through the incremental processing of the requirements and a precisely defined development scope in time-limited iteration loops, results can be shown early in the development project when using agile development processes. These are functional at the beginning and do not claim to be complete or perfect. (Backblaze, 2015; Proceedings, 2003; Schwaber, 2004).

When using Scrum, individual increments are created in the sprints. In agile process models, an increment is a result, which is constantly extended and supplemented (Lewrick, and Leifer, 2018). These increments are aligned to the specific development focus defined for the sprint and only consider specific requirements

(Backblaze, 2015).Thus, an increment is completed after each iteration, i.e. each sprint (Rubin, 2013). This can be defined as new functionality and should be theoretically directly implementable after the sprint (Anderson, 2010). That result must be directly linkable with the previously created and existing results and functional for tests

4.4 Early and Continuous Testing of Development Result

Due to the early availability of intermediate results, the requirements processed in the iteration loops can be validated early. The intermediate results are oriented to the incremental development focus, meaning they only fulfil the narrowed product requirements defined for the sprint. Thus they can be tested and further developed after each iteration. (Backblaze, 2015; Schwaber, 2004).

When applying the Design Thinking methodology, the solution idea is tested under real conditions and in the context of the final product. The aim is to gain new insights into the needs of end users and to further optimize the prototypes by developing an understanding of these needs. For this purpose, several iteration loops are performed, gaining further insights into the interaction between humans and prototypes, which are then incorporated and tested again. The aim is to develop a precise concept which can then be quickly implemented as a solution. (Cole and Scotcher, 2015).

4.5 User Stories Instead of Requirement Specifications

The customer requirements for the product are recorded in user stories. In contrast to defined requirements in specifications, these are kept as general as possible. They define what benefits the customer has and thus determine the direction of development without specifying requirements in detail. (Ahmad et al, 2013; Ulrich, 1984).

In Scrum, a user story is defined as a short sentence that represents part of a functionality. This story does not contain any information about the way the requirements are fulfilled, but should trigger a discussion in the development team, which then solves the design questions for each story. The totality of the user stories represents all required product functionalities. (Kusay-Merkle, 2018).

4.6 Strong and Constant Involvement of the Target Group in the Process

The user will be involved in the development by the team in the best possible way. He serves as most relevant information source in the development project regarding the product requirements but is not necessarily the customer and therefore not financially involved. The early feedback of the users can be implemented into the process and support a target-oriented development and optimization of the prototypes. (Cole and Scotcher, 2015; Lewrick et al, 2018).

In Design Thinking, the target group is strongly involved into the validation of physical prototypes. These can be constantly tested by the target group. Through rapid prototyping and direct testing by the target group, optimization potential and misalignment of the product specifications can be identified early on. Furthermore, different versions of the solution can be tested. The prototypes mature by an iterative advancement of rough solution concepts to matured products, which fulfil the customer requirements in the best possible way. (Cole and Scotcher, 2015).

4.7 High Personal Responsibility and Interdisciplinarity of the Participants

The development team, which is responsible for the technical development of the product, has the task to apply agile development processes. It is interdisciplinary and self-responsible, which means that each team member has competences in several areas and not every task is delegated by the manager, but planned by the team member itself (Backblaze, 2015; Kniberg and Skarin, 2010). The team members hereby have the responsibility for initiating changes as well as for the general task planning and execution. The empowerment of the project team reduces the development time, as long decision paths with the involvement of the management are avoided and fast decisions are made possible (Proceedings, 2003).

4.8 High Adaptivity of the Process

Within agile models there is no fine-granular predetermination of the contents, but characteristic is an adaptation during the execution of the project (Böhmer, 2016). The exact design of the development process and the product requirements are adaptive and can be changed by the participants after each iteration (Rubin, 2013). Changes are considered good and are part of the culture. This culture promotes early feedback which leads to rapid development of important specifications and effective process improvement. (Stellman and Greene, 2015; Schwaber, 2004).

In design thinking, for example, the process structure is open to dynamics and changes, which enables continuous further development. Only the basic structure of six phases (Understand, Empathize, Define, Ideate, Prototype, Test) is fixed. The design within the framework can be redesigned and is flexible during the development process. (Cole and Scotcher, 2015; Schwaber, 2004).

4.9 Individual Design of the Process

Regarding the high adaptivity of agile processes the restrictions for the adaptions are low. The empirical character of agile development processes permits individual adaptation and gives developers freedom in process design. Only basic specifications are mentioned as process frameworks, but the specific process design is not defined. Therefore, the process can be adapted during the whole process (see characteristic 8) with a high degree of freedom regarding the design. (Backblaze, 2015; Kniberg and Skarin, 2010; Abrahamsson et al, 2003).

The example of Kanban shows, that processes designed using Kanban can differ within the same company. Every team is required to find the optimal process for the individual development project. Kanban only provides the tools enabling the design of the process. Nevertheless, all processes are derived from the same principles, therefore every team member is capable of adapting when reassigned from one team to another. (Ulrich, 1984).

4.10 Continuous Improvement of the Process

In addition to the product to be developed, in agile development processes the process itself is adapted and continuously improved through feedback mechanisms anchored in the method. This is possible because of the individual process design as well as the high adaptivity in agile development processes. (Kniberg and Skarin, 2010; Rubin, 2013; Cole and Scotcher, 2015; Anderson, 2010; Anderson, 2010; Gloger, 2013).

Thus, when using Scrum, feedback loops are performed after each iteration. These feedback loops focus on the product and the degree of fulfilment of the product requirements as well as on the process. The generated lessons learned should lead to an optimization of the process and enable a higher degree of product requirement fulfilment as well as an optimized process for subsequent sprints. (Rubin, 2013).

	Characteristic	Mention in literature					
		Scrum		Kanban		Design Thinking	
1	Incremental processing using time-boxed iterations	✓	Abrahamsson	✓	Anderson	✓	Freudenthaler-Mayrhofer
2	Low specification of the product at the beginning	✓	Backblaze			✓	Freudenthaler-Mayrhofer
3	Early delivery of intermediate results	✓	Backblaze	✓	Ahmad & Markkula	✓	Lewrick & Link
4	Early and continuous testing of development results	✓	Cole & Scotcher			✓	Lewrick & Link
5	User stories instead of requirement specifications	✓	Cole & Scotcher	✓	Anderson		
6	Strong and constant involvement of the target group in the process	✓	Gloger			✓	Freudenthaler-Mayrhofer
7	High personal responsibility and interdisciplinarity of the participants	✓	Abrahamsson	✓	Ahmad & Markkula		
8	High adaptivity of the process	✓	Rubin	✓	Stellmann & Greene	✓	Lewrick & Link
9	Individual design of the process	✓	Abrahamsson	✓	Kniberg & Skarin		
10	Continuous improvement of the process	✓	Kniberg & Skarin	✓	Womack & Jones	✓	Freudenthaler-Mayrhofer

Figure 3: Literature mention of constituent characteristics of agile development processes.

5 CONCLUSIONS

More and more companies implement agile development processes to meet the challenges of the increasing pressure to innovate. In the world of physical product development, with its significantly lower depths of value creation in recent decades, however, the implementation of agile approaches can only be of benefit if suppliers are successfully integrated into these new processes. As mentioned in this paper, it is imperative to adapt the design of the customer-supplier relationship and the integration form according to the needs of this new process for effective and efficient supplier integration. The constituent characteristics of agile development processes presented in this paper are intended to provide a clear differentiation from plan-driven development approaches and thus identify the needs for adaption in supplier integration. Based on a consideration of existing agile development processes with the widest distribution in industrial practice, the paper summarizes the characterization of agile development and therefore, which constraints are set for the supplier integration. The developed description model of agile development processes is a partial model of an overall method for the situational design of supplier integration forms. In order to conclude this method, future research must derive requirements for supplier integration from the characteristics presented in this paper. Furthermore, a logic for the design of a suitable design of supplier integration should be developed.

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