Evaluation of Challenges in the Implementation of Scrum in a large German Plant Engineering Company: Derivation of Hypotheses for an Improved Introduction of Agile Approaches into the Processes of Physical Product Development

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Abstract

More and more companies in the field of mechatronic system development are becoming interested in agile working. Although this topic has been researched for a long time, there are still problems with the introduction of agility. In this paper, a failed introduction of Scrum in a large German company is reviewed. For the investigation and analysis of this case, contact was made with a project manager of the company, who gave representative information about the processes, problems and possible reasons for the unsuccessful introduction. In addition to obvious problems, difficulties that are not that easy to recognize at first are also to be uncovered here. Following this, recommendations for action for companies with the same initial situation are developed and important theses for future research on transformation processes are created. Furthermore, reasons are given why the sustainable introduction of agility is a problem-solving process that requires a comprehensive understanding of the use case-specific target state. The research contributes to further activities in the implementation of agility combined with the approach of Systems Engineering.

1. Motivation

Changes in user behavior and the resulting requirements, as well as the need to comply with stricter legal constraints, have led to the further development of technical systems through digitalization technologies (Dumitrescu et al. 2021, 10). This results in an increasing share of automated and connected systems in the usage phases combined with increased service shares in the value creation, which leads to an overall *System of Systems* (*ISO/IEC/IEEE 21839:2019*) with uncertain usage scenarios and dynamic requirements (Keating et al. 2003; Albert Albers et al. 2018). In order to secure the economic success within complex and dynamic markets, companies are increasingly incorporating agile methods and practices as well as Systems Engineering into their processes. (Pfeiffer, Held, and Lee 2018; Albert Albers et al. 2020) At the same time, however, there is a lack of suitable methods for accompanying change management (Pfeiffer, Sauer, and Ritter 2014; Sauer 2017; Jonas Heimicke et al. 2021). For successful product development, engineers have long since been required to have more than just technical knowledge of their discipline. Instead, they need interdisciplinary knowledge as a precondition for the mutual adoption of perspectives, which is what makes successful cooperation with other areas of product development, but also with customers, possible in the first place. Systems Engineering and agile cooperation do not make specialized technical knowledge obsolete, but

employees are increasingly expected to have social and communicative skills that cannot be easily taught in a curriculum. This requires both the willingness and ability of employees to learn and change an organizational working environment that systematically supports and rewards such competences (Neumer et al. 2021; Hoda and Noble 2017). The change of traditional ways of working and thinking does not take place in a seminar room, but in practice, i.e. in trying out, evaluating and, if necessary, readjusting, and needs time. In order for employees to (be able and willing to) support such change processes, which are often imposed from above, their necessity must be well justified and the goals or objectives must be formulated in a comprehensible way. If the employees concerned are involved in the further development of the objectives and in the design of the structures and processes at an early stage, and if their experiences and critical objections are taken seriously, it is not only possible to avoid undesirable developments, frustration and resistance. Already in the implementation process, a learning and training field opens up for all participants with regard to their communication and teamwork skills as well as their willingness to cope in conflict and compromise. For this, interdisciplinary skills are necessary from the very first phase of product development, which describes not only the knowledge of different domains such as mechanics, software, legal studies, sociology and others, but also different phases of the product life cycle. (Eigner, Roubanov, and Zafirov 2014, 9)

2. Literature

2.1. The Approach of Systems Engineering

Systems Engineering is an interdisciplinary approach to support and enable the development of complex systems in an integrated and iterative way (Walden et al. 2015). Basing on the *systems* concept according to ROPOHL (1975), ALBERS (2010) states, in the understanding of Systems Engineering, product development can be described by the interaction of three systems: the system of objectives, the system of objects and the operation system. In this understanding, according to ALBERS, "[…] product engineering can be described as the transfer of an (initially vague) system of objectives into a concrete system of objects by an operating system" (Albert Albers 2010).

Nowadays, methods, processes and concepts of Systems Engineering are often realized using a variety of different documents and tools. *Model-Based Systems Engineering* (MBSE) is an advanced concept of Systems Engineering aiming at replacing those unstructured documents by interdisciplinary and interconnected models (INCOSE 2015). MBSE aims at supporting requirements engineering, design, analysis, verification and validation of a product over its whole lifecycle. An exemplary approach to use MBSE in the development of complex interdisciplinary systems is described by KLEINER ET AL. (2017).

2.2. Agility in Product Engineering

Besides achieving economic success for a company, the goal of product development is always to satisfy specific customer needs with high quality and at lowest cost as possible. Here shorter product life cycles, faster technological changes, higher competitive intensity and globalized markets cause an increase of complexity (Link 2014), which is summarized by the general term *VUCA – Volatility*, *Uncertainty*, *Complexity*, *Ambiguity* (Bennett and Lemoine 2014; Geraldi, Maylor, and Williams 2011). In order to meet these challenges, many companies are implementing agile approaches in product development to increase their responsiveness to changing development environments (Schmidt and K. Paetzold 2016; A. Albers et al. 2019; Jonas Heimicke et al. 2019).

Scrum – the most established agile approach – is a framework, which was initially designed to improve the development of physical products (Takeuchi and Nonaka 1986) but was established in software development (Jiang and Eberlein 2009) and is increasingly being used in the area of physical product

development (Atzberger et al. 2020; Goevert et al. 2019). Scrum consists of a few clear rules, assigns the three responsibilities *Product Owner*, *Developers*, *Scrum Master* and increases incremental as well as iterative development. An essential working method of Scrum is the continuous provision of intermediate results, which is intended to prevent differences and uncertainties in the requirements and the solution approaches in the initial planning phase. In *Scrum*, various activities are carried out in designated *events*. The transformation of goals and requirements (in Scrum: *User Stories*) into a result (in Scrum: *Increment*) takes place in the *Sprint* (usually about 4 weeks). The planning of the *Sprint* takes place at the beginning in *Sprint Planning*. The team keeps itself updated daily about progress and problems in the *Daily* (each day 15 Minutes). At the end of the *Sprint*, the *Product Owner* reviews the results (in *Sprint Review*), which is followed by a retrospective review of the Sprint (*Sprint Retrospective*) with suggestions for improving the future process. The *Developers* are responsible for implementing the results of the sprint (Increment) and ensuring its quality. The *Product Owner* works with the stakeholders and ensures that their goals and requirements are known and can be implemented by the team. The *Scrum Master* ensures the team's ability to work by ensuring compliance with the Scrum rules and removing impediments that might hinder the team's work (e.g. capacity bottlenecks). (Schwaber and Sutherland 2020)

An approach which aims at supporting the agile development of mechatronic systems is the *ASD - Agile Systems Design* according to ALBERS (2019). It bases on the premise that the development of new products does not begin on a blank sheet of paper, but rather builds on a reference system within the model of PGE - Product Generation Engineering according to ALBERS (Albert Albers, Bursac, and Wintergerst 2015). The approach consists of a total of nine basic principles and supports the integrated development of mechatronic systems, the associated product strategy, validation systems and production system (Albert Albers, Jonas Heimicke, and Trost 2020). Following the Approach of ASD – Agile Systems Design, the product engineering process is supported at multiple operational levels (cf. Figure 1) (Albert Albers et al. 2019).

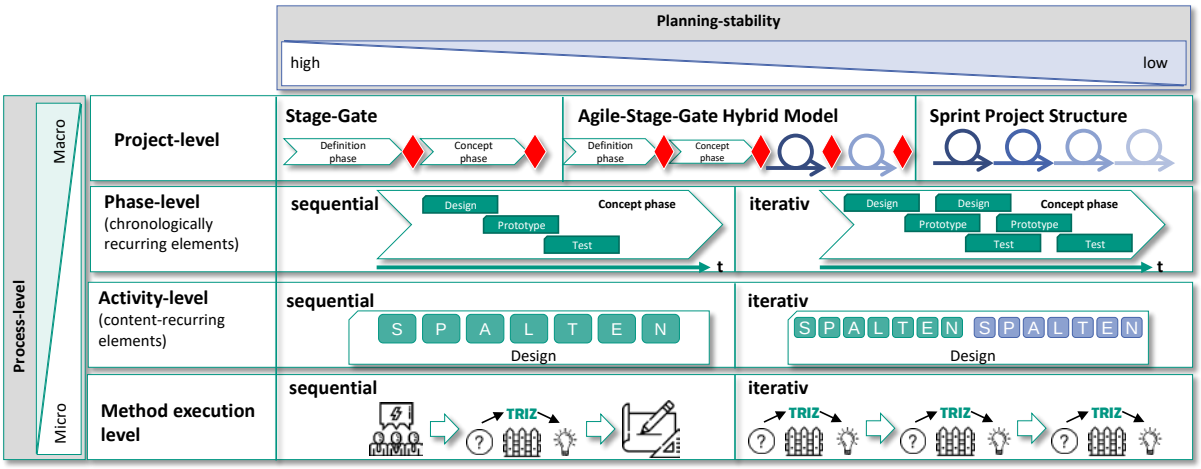

Figure 1 Supporting the Development Process by a combination of process oriented and agile mechanisms on different operational levels (Albert Albers et al. 2019)

Developers can choose between using iterations or a fixed sequence of activities. This ensures that the most appropriate approach for the type of problem can be chosen, while the team does not have to radically adapt the established product development process. (Albert Albers et al. 2019)

2.3. Change Management

Companies are permanently confronted with changes such as market changes due to megatrends or new competitors, stricter requirements for products due to legal limits or technologically in terms of digitalisation (Lauer 2021).

LEWIN developed a 3-phase model, which represents social changes in a society (Lewin 1947). Actually, it was first intended only for change processes in social groups, however, today it is one of the most relevant theories of organizational change management (Burnes 2004). The model consists of the 3-phases *Unfreezing*, *Moving* and *Freezing*, see Figure 2:

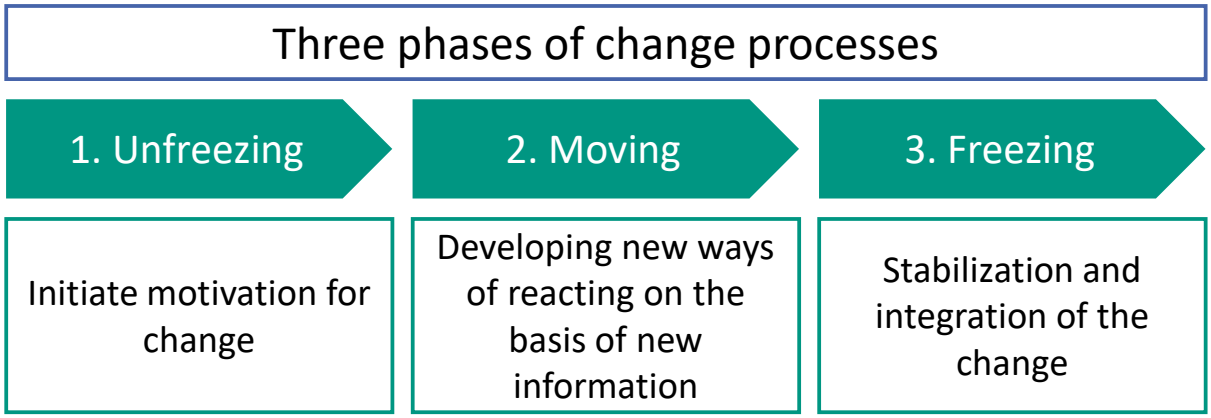

Figure 2 The 3-step Model of Change by Kurt Lewin (1947)

The first phase is about preparing for the change by communicating the plans to those affected and creating motivation for them to follow through. The second phase is about introducing new standards, for example a training for those affected and with constant monitoring by those responsible. The last phase is to solidify the changes that have been created. (Lewin 1947)

Especially when it comes to transformations towards agility, the involvement of employees and their practical knowledge of concrete processes is crucial for more understanding and acceptance of such changes. While staff experiences are important in designing new workflows that actually function in reality, involving staff in the design process also makes them respected and valued as experiential practitioners with specific and valuable knowledge (Sauer, Böhle, and Bolte 2018; Sauer and Pfeiffer 2012; Sauer 2017). In order to identify and define areas, which have the potential to be modified, employees or developers are closer to the process or product. Thus have a much better insight and knowledge than higher level employees like managers. With this participatory approach, the outcome can be better adapted to real work conditions and thus more effective and appropriate. The inclusion of employees as designers regarding the change process, might also have a positive impact regarding their motivation and participation as well as the success of the change in general.

3. Research Design

3.1. Aim of Research

There is already a large amount of agile approaches and methods from the software industry, which cannot be adopted one-to-one by physical product development. It is still very difficult to create a balance between agile and traditional approaches. In mechatronic product development, however, approaches that combine agile and further techniques are becoming increasingly popular. However, challenges can also arise in the combination of these elements. In order to understand possible

challenges and best practices based on the introduction of agile elements into the development environment of mechatronic systems, this paper answers the following research questions:

Research Question 1: *Which conflicts and best practices may arise during the introduction of Scrum in a company that has its focus on mechatronic product development?*

Research Question 2: *What implications can be derived from this for future processes for introducing agile elements into the development of mechatronic systems?*

These research questions are to be answered by gaining insights from an interview with a project leader from industry. Furthermore, theses for companies that are in the same starting position like the analysed company will be presented.

3.2. Methodology and Context

The company under investigation here is a Foundation & Co. KG (limited partnership) and generates annual sales of over 759 million euros with 5.500 employees. An independent company within this large enterprise is focused. The company develops and creates special machines in the field of assembly technology of the highest quality and tool making and injection moulding technology. In the special purpose machine manufacture work about 56 people, 15 of whom are involved in development and design. The development team consists of mechanical construction, electrical engineering and programming. The team members switch from project to project and do not stick together.

When the project of introducing Scrum in this company was cancelled, the authors of this paper sought an interview with a representative of the company. For this interview a guiding questionnaire was set up, which led in detail through the interview. A transcript was then prepared, which was approved by the representative, and the difficulties as well as the problems that arose during the implementation were noted and analysed. The findings from this were submitted to the involved person for revision and he expanded and adapted them.

4. Results

4.1. Description of Agile Transformation at a German Plant Engineering Company

Before the introduction of Scrum, an internal company survey was conducted in which the employees were asked to indicate in percent how agile they saw their department. The result of this survey was an average of only 20%. In itself overall product engineering works modular and implicit agile in some areas (e.g. testing), but especially in construction, very conservative processes and methods still dominated. In order to improve communication between the departments, but also with the customer, interdisciplinary approaches were initially pursued in the sense of Systems Engineering. The resulting closer cooperation with the customer then had the advantage that the product ended up being a better fit for the customer than before, but the frequent *interference* of the customer led to time delays.

The introduction of Scrum seemed promising at the beginning and the successful implementation did not seem very far away, because the IT of the examined company already had many points of contact with agile methods. The difficulty, however, was convincing the development teams of the change, because "*they had been designing things for years and the bottom line was that they didn't care what happened afterwards*". The parent company developed a guideline for the introduction, which all departments (including the subsidiary) were to implement. However, according to our interviewee, this went "*too deep into the IT sector*". The subsidiary, which is mainly active in mechanical

engineering, therefore adapted the guidelines specifically for itself. In addition, a Scrum Master was brought in to monitor the introduction of Scrum and agile working and to discuss progress and challenges with the employees in a so-called *15 minute daily*. Other measures included the use of a backlog and the implementation of sprints.

The company's goal was to extend the agile elements that IT had been using for some time to other parts of the company and to introduce agility in the sense of Scrum as quickly as possible. Important goals were to eliminate communication problems, both internal and with the customer, and to simplify the development of machines through process adjustments.

4.2. Overview of Best Practices and Problems in Agile Transformation

The process of agile transformation lasted a total of nine months before it was terminated. During this time, three pilot projects were carried out in which the various teams were to work with Scrum.

In the run-up to and at the beginning of the pilot projects, it can be concluded from the statements that there was insufficient communication from middle management about the necessities and possible benefits of a changeover to Scrum. Instead of first creating a uniform understanding of agility among all participants in a discursive process, "*picking them up*" so to speak, the focus was on introducing the method and individual tools. The project managers had the feeling from the beginning that it would be difficult to convince product development and design engineers of the new methods, and this assumption was to be confirmed in the course of the agile transformation.

The agile approaches were not individually adapted to the different departments. The project managers here quickly noticed the overly strong tendency of the measures to software development and tried to go their own way. To support the agile transformation in this area, a Scrum Master was hired. The *15 Minute Daily* that followed seemed to go very well. This disciplining by the Scrum Master was subsequently assessed by participants as a necessary functional condition. Every time someone digressed into the technical, the Scrum Master pointed out that this should not be the substance of this meeting. After the Scrum Master left the company, in-house employees, after attending Scrum training, were supposed to continue the meetings. However, they were not able to keep the meetings purely focused on the change process, and thus the conversations became more and more related to technical topics. Weekly planning, backlog filling, and sprint execution thus became less and less from meeting to meeting. Likewise, the time to focus on the changes and plan them further became less. The reason for this was that Scrum was introduced at a time when the company was growing rapidly, many projects had to be managed simultaneously and the development teams were consequently busy with multiple projects at the same time. This made it even more difficult for employees to comply with the new constraints, which further reduced motivation. In addition, the methods of Scrum and the previously introduced Systems Engineering approaches became mixed up, leading to confusion among employees.

The next point, which was pointed out, is that Scrum was deprived of the chance to establish itself in the company too early. After conducting three pilot projects in which the changes were not properly implemented, the decision was already made to discontinue Scrum. However, new ways of working and, above all, new ways of thinking cannot be consolidated in such a short time. From the employees' point of view, there was too little time to gain sufficient experience with the new agile way of working and to readjust it in everyday use. "*We would have needed further, guided pilot projects here in the same team constellation. [...] Then two or three more pilot projects would have been enough and we would still be doing it that way today.*"

5. Theses for Agile Transformations

Change management can be described as a problem-solving process, especially in the field of agility (Kostka 2017). On the one hand, the current state of a company is usually not sufficiently known, is perceived differently by different employees and changes over time. In the case considered here, a guideline was initially dictated from above by the management. This means that it was not checked in advance whether the selected procedure was suitable for all departments and the various divisions of the company. The resulting misfit led to many misunderstandings, especially in product development, also because Systems Engineering approaches had only been practiced here for a short time. In order to be able to counteract this, active participation of the employees would have been required already in the planning phase to generate the agile process solution, as well as in the creation of the guidelines.

The target state is often very vaguely defined in many organizations, which is due to the fact that no one can accurately estimate how realistic the goals set actually are. In addition, the target state is highly dependent on the use case. These difficulties also arose in the company under consideration here - especially since many sub-areas exist in this company and short- and long-term goals were to be defined for each of these sub-areas.

On the way from the actual state to the target state, there are also many challenges to be mastered and obstacles to overcome. A common problem with change is the lack of enthusiasm for it, which often results from insufficient awareness of upcoming changes. Likewise, it leads to demotivation among employees when there is too much to consider at once, a missing continuity, and too many projects are carried out in parallel. This problem was also observed in this case. By taking on many new projects, which was due to the rapid growth of the company, the employees were not aware of where exactly the focus was now.

One important practice is the regular holding of short meetings in which at least one employee from each department takes part and in which the current status of the transformation and recognizable results are discussed. These meetings, which in this case were also conducted in the form of a *15-minute daily*, are also highly relevant because the ACTUAL and TARGET states are to be adjusted in these meetings. If conducted correctly, these meetings can strengthen team spirit, cooperation and communication internally. However, if they are conducted incorrectly, they can also have the opposite effect, such as a different understanding of agility or conflicts among each other. In this case, the Scrum Master suddenly left the company and the management decided to put their own employees into a short Scrum training, who should continue the meetings afterwards. However, they were not able to keep the meetings purely focused on the discussed points of reflection, evaluation and change. Rather, the conversations lost themselves more and more on a purely technical level and thus, in addition to the important discussion of agile measures, the filling of the backlog and the execution of sprints became less from meeting to meeting.

To prevent misunderstandings at the very beginning of the transformation process, a systematic is needed whose basis is to grasp each situation and identify the specific problem. Likewise, an understanding of known problems and challenges must be created from the very beginning. In addition, the respective approach to agile development (consisting of processes, methods and techniques) should be generated according to the identified needs. Its introduction in the iterative sense is important for agile techniques, so that continuous questioning and measurement of success can be ensured.

The following theses can be stated from the analysed case:

- *Agile transformation strategies must be individually adapted to the respective departments.* The goals and benefits for the employees have to be communicated in a comprehensible way to avoid misunderstandings early on.
- At the beginning of the change process, a uniform understanding or guiding principle of agile working should be developed and communicated, otherwise there is a danger that one will only concentrate on the introduction of methods and tools. The central aspect of the change process, the cultural change, which takes time and experience, is thus lost from view.
- If one of the central ideas of the agile way of working, the strengthening of the self-organisation and autonomy of teams, is taken seriously, then the *employees concerned should also already be involved in the conceptualisation and planning of such a profound change process*. As experts of their own work, they have a specific and also detailed picture of their department and the work processes. In this way, a suitable agile process solution that differs from the standard Scrum framework could have been successfully adapted very likely and introduces in this company as well. (Neumer et al. 2021)
- *Agility and Systems Engineering must be introduced hand in hand.* If this is not the case, there will be uncertainty regarding the prioritization of the two approaches, as in the case described.
- *Agile roles – in this case the Scrum Master – should not be taken lightly and require the highest level of professionalism.* Otherwise, the agile mechanisms as events or artefacts will be executed counterproductively and are perceived as an unnecessary burden.

6. Conclusion and Outlook

When introducing Scrum or other agile process models, a blanket introduction is not recommended - it may even cause more damage and lead to confusion among employees. It is mandatory to adapt the agile approaches and their introduction to the different departments. Employees should be seriously involved in the process at an early stage and their experience as well as their expert knowledge around work processes should be used to ensure motivation on the one hand and the fit of structures and processes on the other. Autonomy and self-organization are thus not only encouraged in the later process, but already during planning and introduction. Problems cannot be prevented in an introduction process - this is precisely why it is so important to view the introduction of agility as a problem-solving process. In this paper, a specific case was studied, but it is very important to observe and study more cases in the future. Furthermore, there is still a need for research in the development of an efficient method that finds the right agile process model for a company and supports it during the introduction.

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