SHORTENING OF PRODUCT ENGINEERING PROCESSES BY AGILE ENGINEERING METHODS

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Abstract
Due to growing globalization, increasing connectivity and a greater competitive pressure, products tend to have an ever-shorter lifetime in the market. Therefore, an effective, efficient and well-structured developing process for new products is inevitable to ensure a company’s long-term success. The following approach is intended to help accelerating and improving the engineering process of physical products. The approach is based on the agile developing method Scrum, which is an established approach in software engineering. Its key elements are free task selection of employees, the “anyone can do it” principle and clearly defined roles and regulations. This paper demonstrates the opportunities and limitations of applying the agile method Scrum to physical product engineering. Finally, the topic is discussed critically and further research potential is pointed out.

Keywords:
Methodical product engineering, scrum, knowledge management.

1 STARTING POINT AND MOTIVATION
As a first step, the initial situation of the market will be evaluated and the last four decades are hereby emphasized. Since the 1980’s, a global trend of ever shorter product lifecycles can be seen ([2], [4], [9], [24], compare figure 1).

![Figure 1. Trend of product lifecycles [24].](image1)

According to Ellinger [7], a product lifecycle is the period of time in which a product is available on a market. As shown in figure 2, a product lives through several phases during its lifecycle. Those are defined as introduction, growth, maturity, saturation, and decline. The product lifecycle ends if the product is withdrawn from the market or replaced by a successor product [23].

![Figure 2. Product lifecycle by Heinen [13].](image2)

Based on the ever-shorter product lifecycles, Allweyer [2] claims that companies need to accelerate the engineering process and product introduction to stay competitive. However, respecting the complexity and knowledge intensity of the product engineering process and shortening the development period at the same time requires appropriate methods regarding knowledge management [16]. Hence, the motivation for developing a method for accelerating product engineering derives. The objective of this method is to prematurely introduce products to the market in order to establish a good and secured position for the company in the market and thereby ensuring the company’s long-term success.

At this point, the central scientific issue is deduced: Which method is able to accelerate the physical product engineering process without negatively influencing other parameters such as quality or cost?

2 STATE OF THE ART
This section discusses two methods which aim to accelerate the product development process; one out of the area of physical product engineering and one out of the area of software engineering. In the area of physical product engineering, the method Simultaneous Engineering is illustrated and in the area of software engineering the agile development method Scrum is elaborated. An agile method has been selected as it is distinguished both by a modern feedback culture and direct communication within teams [25].

2.1 Simultaneous Engineering
In so far as the area of physical product engineering is concerned, only one method is applied which explicitly aims to accelerate the product development process: the Simultaneous Engineering [14]. The basic concept is already starting the following development steps before completing the previous one which consequently accelerates the product development process [5]. In contrast, the sequential approach of conventional product development methods is to completely finish one development step before starting the next one [27].
customers, management as well as supervisors are primarily relevant [21].

Procedure of Scrum

Figure 4 illustrates the procedure of Scrum schematically. Below, the single processes of Scrum are explained in detail. Before the actual Scrum planning begins, a product concept is set up which defines product properties, functions and target figures. This product concept serves as a basis for creating the product backlogs.

Within the product backlog all requirements of the product to be developed are collected. The creation and maintenance of the product backlog are the responsibility of the Product Owner. They have to ensure the product backlog is accessible and transparent for everyone at all times [12].

Each product requirement comprises of specifications such as priority of single entries, risks and estimations of how long the implementation of each requirement is going to take. The priority is the sort criterion of the product backlog [12]. The time estimations are given by the Product Owner in collaboration with the development team. These two parties are also responsible for preparing the Sprint Planning when finishing the product backlog. For every Sprint there is a Sprint Backlog, which specifies exactly what has to be done during the respective Sprint [3]. According to Goll and Hommel [12], the Sprint Backlog is a list of all tasks defined in the Product Backlog which are supposed to be implemented within the current Sprint. Depending on the literature, a Sprint or development cycle has a duration of two to four weeks [3] or days [18]. During a Sprint there is a short meeting of about 15 minutes at the beginning of the day [18]. This is called the Daily Scrum and has the aim of informing the team about the current task status. The whole Scrum Team participates in the Daily Scrum and the Scrum Master moderates the proceedings. Within the scope of the Daily Scrum, the tasks of the day for the development team are selected from the Sprint Backlog. All non-selected tasks remain in the Sprint Backlog. The Product Owner updates the Sprint Backlog and the remaining tasks of the Sprint are provided for selection the next day. The result of each Sprint is a working piece of software. After finishing a Sprint, a Sprint Review and a Sprint Retrospective are done. In the Sprint Review, the Product Owner presents an overview on how the Sprint had evolved and whether the initially defined goals had been achieved. If necessary, the Product Backlog has to be adjusted. The Product Owner examines the result and decides if the software can be validated. After the Sprint Review, the Sprint Retrospective follows. This is a feedback round moderated by the Scrum Master and is ought to continuously improve the development process [20]. Thereby, the Scrum Team revises its working methods in order to improve them for future projects [19].

In conclusion one of the greatest advantages of the Scrum method is the ‘anyone can do it’ principle. In addition, Scrum stands out for a high degree of self-determination of the employees. Employees choose their tasks according their personal degree of knowledge and their individual talents [18]. They work in motivated self-
organized teams which encourages direct communication and results in direct feedback loops [28]. Further characteristics of this agile procedure model are the transparency of project’s progress and obstacles, daily team meetings as well as continuous readjustments of the product requirements.

2.3 Intermediate conclusion
There are methods aimed at accelerating the product engineering process in the physical product development as well as in software engineering. Parallelizing work steps characterizes Simultaneous Engineering out of the environment of physical product development. But this Parallelizing comes with the disadvantage of various iteration loops. In the area of software engineering, the agile method Scrum is a good possibility for accelerating the product engineering process. However, agile methods such as Scrum thus far are rarely applied in physical product development [15].

Therefore, it is worth considering which elements of Scrum can be applied within physical product development and where the boundaries of such an adaption are. At first sight, the comparison of physical product engineering and software engineering appears to be quite difficult, as these two areas of product development have completely different structures and demands.

3 TRANSFER APPROACH
In order to evaluate the possibility of a transfer approach it is necessary to identify the requirements of a development method applicable in the area of physical product development.

Relating to the Scrum Team, only a few adjustments have to be made. In particular, an adaption concerning the technical suitability of the development team is necessary. The software developers will be replaced by hardware developers and mechatronics engineers are replaced with calculation engineers.

In contrast, there is a great demand for adaption regarding the product complexity. In the area of physical product engineering, complex products comprising of various different assemblies and components are developed. At this stage, the first step is to identify the product requirements, the different assemblies the product comprises of and the intended product functions. Usually, a list of requirements containing demands and desires for the product and a specifications sheet are created during the planning phase of the physical product development process [8]. This is a crucial step of the physical product development because it is this that the whole development process is based on and constantly measured against these initially defined requirements. Conversely, this means that functions or requirements which had not been defined in the beginning will not be found in the final product realization.

This first step of defining the requirements to the product being developed has to be at a central position as well when applying an agile method to physical product development. Which format of defining product requirements to the respective product can be used in the scope of an agile method in the area of physical product development is to be examined. For instance, a ‘Kick-Off-Workshop’ could be utilised. Moderated by the Scrum Master, the Product Owner and the Development Team can determine all relevant requirements to the product being developed. Analog to the established approach in the area of software engineering, the Product Owner is then able to prepare and prioritize the Product Backlog based on the defined requirements.

Subsequently, the Product Owner decides how many tasks of the Product Backlog are to be in the Sprint Backlog. The amount or scope of tasks processed during a single Sprint depends highly on the duration of the respective Sprint. When Scrum is applied in software engineering, a Sprint usually takes two to four weeks according to Brandt-Pook and Kollmeier [3]. It is to be examined which duration of a single Sprint is applicable in the area of physical product development but potentially the Sprint duration applied in software engineering is too short for the development of physical products. Therefore, an adaption of the Sprint duration for the physical product development is needed and should be included in a transfer approach. Defining an average duration of developing physical products is currently almost impossible because the requirements and functions of each product vary enormously. In order to identify appropriate Sprint durations for the area of physical product development, experimental values have to be gained.

Further demand for adaption exists in relation to the communication within the Scrum Team. Regular meetings and increasing consultation between all involved parties have proven successful in the area of physical product development [6]. Whereas Scrum does not include such regular consultations a single Sprint. Only the amount of completed tasks of the Sprint Backlog is documented. This approach is not feasible in order to realize a smooth engineering process for physical products. Inconsistencies and coordination problems during a Sprint have to be resolved as soon as possible as they may otherwise stall the development. It is clear that a new methodical approach has to address the communication structures and demands of the area of physical product development as a fundamental part.

An additional challenge regarding the possibilities and boundaries of an agile developing method are the interfaces in the area of physical product development. The lowly fragmented development of software pieces, which can later be easily implemented into the existing software structure, is characteristically for Scrum. Nevertheless, when developing a physical product, the segmentation into assemblies has to be examined in the first place in order to guarantee a practical composition in the end. A possible transfer approach has to meet this basic requirement and include constant verification and subsequent adjustment of the interfaces otherwise additional interfaces can be overlooked, which may result in missed adaptions. This in turn allows components and assemblies to be developed which could not be composed to a final product.

If the application of the transfer approach should include the development of highly complex products, the organizational and structural demands have to be identified. Highly complex products evoke highly complex development tasks which are unlikely to be coped with by a single Scrum Team. This hypothesis leads to the demand for examination in what way the segmentation of products into individual assemblies (Figure 5) can be a possible method of resolution. The segmentation into individual assemblies organizationally results in several Scrum Teams working on the development of different assemblies. This fact highlights the importance of interfaces once again.

![Figure 5. Product segmentation.](image)

In this context, the structural organization of the Development Team also gains importance. To be
examined is whether introducing an additional hierarchy level in the form of a superordinate Scrum Team meets the organizational requirements after the segmentation into individual assemblies even for highly complex products. The latter places entirely separate standards on all parties involved. The responsibility of the whole product lies with the superordinate Scrum Team, whereas subordinate Teams are responsible for the development of the individual assemblies.

4 CONCLUSION AND PROSPECT

In summary, the transfer approach of the agile method Scrum to the area of physical product development definitely has potential. The transfer is conceptually possible but is certainly subject to a few restrictions. These include, amongst others, the previous defined interfaces. This implies that the transfer is difficult when completely new products are to be developed as the interfaces of individual assemblies and components are often not known in the beginning. This problem decreases for development projects which aim to adjust or to create a new version of an existing product because in these cases, most interfaces can be defined from the start. Another issue is the structural changes needed within a department or company. Implementing a new method requires a certain amount of willingness to this change from employees and management. Regarding the development of highly complex products, the transfer of the method Scrum to the area of physical product development is a chance but only if structural and organizational adaptations are made.

Still open for debate is how an agile product development method can be established in the practical application of physical product development. Another prospective possibility applying the transfer approach is using it in order to remove obstacles which occur during a conventional sequential product development and may endanger the progress of the project. Therefore, a customized approach of Scrum could be applied to solve problems in the project and afterwards continue with the conventional sequential product development process. This utilization aims at accelerating the sequential product development process by selectively eliminating obstacles in the project using agile methods. Against this background, an analysis of the transfer approach with regards to the possibility of practical application appears worth the effort.

5 REFERENCES