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A framework for generating agile methods for product development

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Abstract

Increasingly, companies are integrating agile approaches in the processes of physical product development, although they may have different reasons for doing so (e.g. shorter production times, better product quality, etc.). The number of different agile approaches has also increased over time. Despite the various agile approaches, it has been shown that companies in product development have difficulties in integrating these approaches and a change process is extremely complex. This results in the need for suitable methodological support that generates situation-dependent and company-specific process solutions and thus addresses and achieves different and individual goals. For this, the complex and company-specific adaptation of an organizational unit needs to be tailored to the needs and situation of the affected organization. This is made possible by an individual agile-structuring process solution, which is generated on the basis of a methodical support in the form of a framework, which is developed in this article on basis of current research. Based on this framework, process authors are enabled to generate an agile structuring process solution for the organizational unit concerned, which enables a suitable, company-specific combination of agile and plan-driven approaches and elements. By applying the framework, a specific organizational unit is given the ability to implement an appropriate degree of agility in its development process through the generated process solution. This reduces the expected difficulties of agile approaches in product development and enables the organization to react more flexibly and adaptively to unpredictable and changing situations.

Keywords: Agile Development; Adapting Agility; Product Development; Process Optimization; Agile Transition

1. Introduction

A shortening of product life cycles and increase of the importance of time to market due to digitalization can be observed [1]. Furthermore, a trend towards individualized products has been observed in recent years, as a result of the goal of increasing customer benefit [2]. The desire for agility results from the changing development environment [3] and the challenges described above. In order to meet these challenges, companies implement agile methods into their development processes [4]. But the implementation of agility involves an extensive change process in organizations [5]. An agile transition comprises the change of organizational behavior as well as the roles and responsibilities of the people involved [6], thus the change of the structural and process organization of a company.

However, the majority of agile approaches originates from software development, which is why they are not easily applicable to product development [7] [8]. Product development in particular is characterized by a high complexity, dynamic and uncertainty [4], which increases the desire for more agility [9] and in this context an agile transition. Since the purposes that are pursued with the use of agile approaches and the areas of application are individual, the agile transition must also be individual [10].

In order to support the process of identifying individual aims, which are to be pursued with the use of agile approaches and the development of a suitable situation- and demand-oriented agile methodology, a systematic is presented in this article. It structures the creation of an individual agile methodology, which is appropriate for the respective use case and thus increases the probability of sustainably embedding agility in the development processes of manufacturing companies.

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2. Literature Background

2.1. Agile product development

Companies operating in the field of (physical) product development, which we focus on in this paper, increasingly use agile approaches in their processes in order to be able to react to unexpected and expected changes in the dynamic context of product development [4]. "*Agility - based on the system triple approach - is the ability of an operating system to continuously check and question the validity of a project plan with regard to the planning stability of the elements of the system triad and, in the case of an unplanned information constellation, to adapt the sequence of synthesis and analysis activities according to the situation and requirements, thereby specifically increasing the benefits for customers, users and providers.*" [8]

In particular approaches like Scrum are applied to increase the agility of operation systems. Scrum is a project management method that focuses on the course of the project. Within the method there are different artifacts and activities [11] as well as the three defined roles: *Product Owner*, *Development Team* and *Scrum Master* [12]. In addition, the project is structured in the form of sprints (development cycles of several weeks) [13]. Based on the sprints a product is incrementally developed that ultimately fulfills the customer's wishes in the best possible way. During each sprint, a potentially shippable increment is generated, tested and evaluated in order to be used for further development in the next sprint by adding further increments. The self-organizing Scrum teams work with a high degree of autonomy and responsibility as well as cross-functionally, while the Product Owner defines the aims of the development together with relevant stakeholders. Based on the aims (user perspectives) and a prioritization of these, a product backlog is created, which is iteratively processed in the sprints and leads to a finished product by meeting all requirements in the product backlog. The Product Owner and the team are trained by the Scrum Master during the development process so that Scrum is applied skillfully. Additionally, he supports the team and protects it from external impediments. [12]

However, several problems arise when introducing agile approaches in a non-software environment [14]. In their study, ATZBERGER ET AL. [4] have identified different challenges with regard to the agile development of physical products. In particular, these include a common understanding or view of agile development of physical products, including the establishment of the right mindset. In addition, different restrictions pose a great challenge. In particular, time restrictions due to waiting or manufacturing times and physical restrictions such as physical limitations or splitting into appropriate increments present agile development with great challenges. In addition to this, conflicts of a social nature also result, such as the loss of power of the managers, the feeling of being overstrained or the challenge of no longer climbing classical career paths. [4] Accordingly, for a sustainable establishment, the cultural change of the organization must also be considered [10]. Agile principles are often introduced based on general assumptions [15]. As promising results in initial studies have shown [16], traditional approaches are extended by agile approaches in order to minimize the challenges of a pure implementation of agile approaches in the development of mechatronic systems [17].

2.2. ASD – Agile System Design

As described, there are problems with the introduction of existing agile approaches to the development of mechatronic systems. Therefore, an approach is needed that implements agile approaches starting from the culture in mechatronic system development [18]. For this purpose, the approach of ASD - Agile System Design according to ALBERS has been developed based on more than 20 years of application oriented product development research [19]. The agile values and principles related to the development of mechatronic systems are defined in the ASD approach by nine basic principles, which are applied by selected methods [20]. The structures in mechatronic system development are considered in order to integrate flexibility at appropriate points. Accordingly, ASD - Agile System Design pursues the goal of enabling a practicable combination of structuring and agile elements. [20] Based on observation of real and successful development projects [18] this approach serves as methodological guideline for development teams in the development of mechatronic systems [20]. An important element of the ASD is the universal problem-solving method SPALTEN [21], which can serve to structure an individual and situation-specific problem solving e.g. agile transformation [18]. SPALTEN is a German acronym for the seven problem solving activities the process is divided into [21]: 1. Situation Analysis (***S**ituationsanalyse*), 2. Problem Containment (***P**roblemeingrenzung*), 3. Alternative Solutions (***A**lternative Lösungen*), 4. Selection of Solutions (***L**ösungsauswahl*), 5. Consequence Analysis (***T**ragweitenanalyse*), 6. Make Decision and Implement (***E**ntscheiden und Umsetzen*), 7. Recapitulate and Learn (***N**achbereiten und Lernen*).

This process is universally applicable and can be characterized as a dynamic, fractal and case-oriented problem-solving process [21]. Another central element in ASD is the product profile [22]. It is the model of a bundle of benefits. Within it, intended provider, customer and user benefits are made accessible in order to carry out a validation during product development. In addition, it serves as a basis for the development of new product generations and their validation, since it roughly describes a product, e.g. by means of essential characteristics and functions. [22] By using a validated product profile and in conjunction with appropriate marketing and sales strategies, the probability of market success is increased [23].

2.3. Agile adaption of organizational units

In order to be able to cope with the increasing dynamics in product development and to be able use agile elements in development, an adaption of organizational units may be necessary. In particular, it must be ensured that the persons involved are not overwhelmed and a subsequent adaptation of the implemented agile approaches is avoided. Therefore, DIEBOLD ET AL. describe a step-by-step transformation towards the right degree of agility as necessary. Especially the interaction of technical and cultural agility, which influence each other, is crucial in this process. [10] Accordingly, the roles and responsibilities of the people involved as well as the organizational behavior need

to be changed [24]. Therefore, the agile development is based on a holistic way of thinking rather than individual tools or practices [25]. The agile mindset must be spread throughout the entire company in order to be successful as an agile organization [9]. In addition to the change in corporate culture, an agile organizational structure is important, but this does not require the entire organization to be agile. Although some structures facilitate the implementation of agility. [26] The biggest challenge here is the exchange of information between agile and plan-controlled parts within an organization [27].

To adapt an organization towards agility, the focus must be on the unique and sophisticated interaction of operational, strategic or cultural aspects. To achieve this, existing practices, models, tools and frameworks need to be complemented by an agile transformation context, within the context of effective change management. [28] Change management is used to structure and control a planned organizational change process. In order to implement it effectively, situational requirements must be considered. The goal is to increase the ability of a company to solve problems, in order to react faster and more flexibly to new requirements. According to INVERSINI [29], during the change process, selected change principles should not be rigidly adhered to, but it should be possible to act in a demand-oriented and flexible way. [29] This seems particularly important in an agile environment, especially with regard to the insight from various sources that agile methods are best introduced using "an agile way of implementing agility" [30] [31]. Furthermore, it should be considered that each change process of a company is unique and individual [32], i.e. each agile transformation must be individually designed [33].

3. Aim of Research

There is a variety of agile approaches and research has been established in this area for several years now. Nevertheless, companies face various challenges in physical product development when they try to introduce agility. To meet these challenges, change must be implemented at different organizational levels with different specific goals. Since there is no general approach to establish a suitable combination of structuring and flexible elements for each individual company, companies are faced with the challenge of effectively and successfully implementing an appropriate level of agility. For this reason, the goal of this article is to develop a generally applicable methodological support that enables situation- and demand-oriented action and the introduction of a suitable degree of agility. Therefore, a method in form of a framework will be developed which generates individual agile-structuring process solutions. The following research questions are answered in this article:

1. *What are the requirements for a method to introduce agility into the processes of mechatronic system development according to the situation and needs?*
2. *How is a methodology designed that enables a situation- and need-based development of agile-structuring process solutions in the development of mechatronic systems?*

In order to answer the research questions, a literature search was conducted with the aim of understanding the context of product development, the agile product development and the adaption of organizational units. The extracted information was condensed in a method profile and discussed in a workshop with 10 product development researchers and 4 employees from development departments of different companies. Based on this, the framework was developed. For this purpose, the respective problem-solving activities were supported by selected methods in order to support the individual development of agile process adaptations within the overall framework.

4. Results

4.1. Profile for the Framework to adapting Agility

Through a literature research, the requirements, conditions and contents of the framework were derived and collected in the methodological profile. Agile approaches are increasingly used in the development of mechatronic systems, but these have their origin in software development and are based, for example, on an incremental understanding, which does not meet the requirements of mechatronic system development and creates new challenges (see DIEBOLD ET AL. [10]).

Accordingly, the agile approaches cannot easily be adopted in physical product development. In summary, companies in the development of mechatronic systems lack the ability to use a suitable method to make existing processes so flexible that development risk and customer integration are adequately integrated. This leads to the demand for individual, company-specific methodical support to implement a suitable degree of agility in the processes. Consequently, certain requirements result for such methodical support. In particular, it should serve to support a user in introducing a suitable degree of agility into the organizational and operational structure by identifying a situation- and demand-oriented, suitable combination of flexible

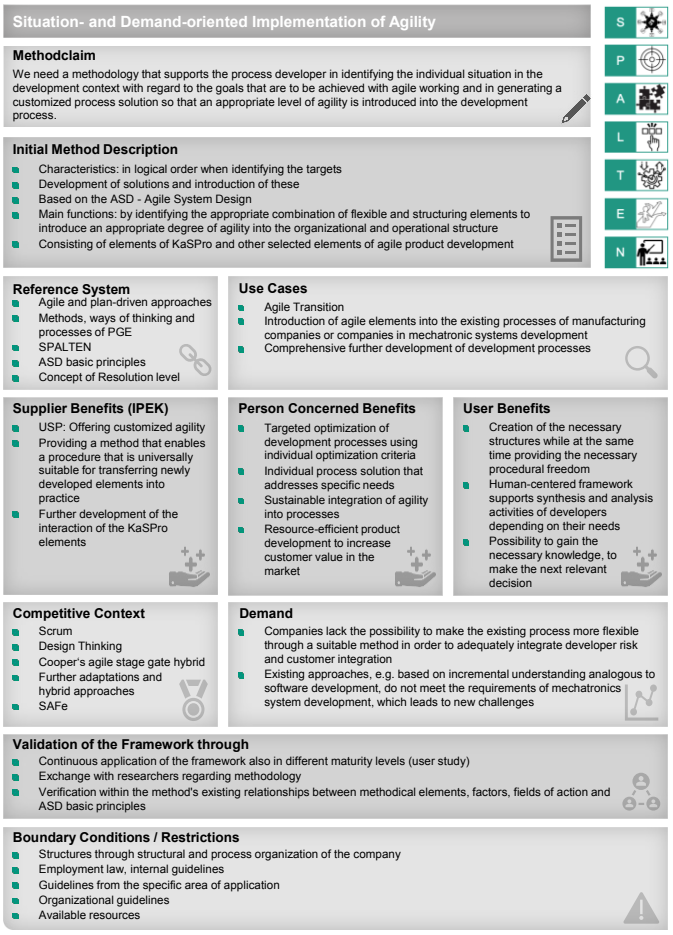

Fig. 1. Method profile following ALBERS ET AL. [22]

and structuring elements. The method should support the identification of goals, the development of process solutions and their introduction in a logical sequence, based on the problem-solving process SPALTEN. The contents of the method should be based on the ASD – Agile System Design and other selected elements of agile product development. Altogether the method can use different agile and plan-driven approaches as a reference. The method can be applied in different levels of context (see Level of Resolution [34]).

To ensure a successful transformation towards more agile working and to support the user in the best possible way, the company-specific restrictions must be considered. In this regard, the structures of the company's structural and process organization, as well as labor law and internal guidelines must be identified and implemented. Furthermore, guidelines from the specific area of application and organizational guidelines must be integrated and the available resources must be considered. With the help of the framework, the user can create necessary structures, but at the same time create necessary process-related freedom, always considering the individual, specific use case. Moreover, the human-centered framework supports the synthesis and analysis activities of the developers as required.

In addition to the user benefit, the use of the framework also results in a benefit for the persons concerned. In contrast to the users who actively apply the framework and are entrusted with the development of the structural and process organization of the affected organizational unit (mainly process developers), the affected persons are only affected by the process solution that is generated and implemented using the framework. This includes all persons who are involved in the process and are part of the affected organizational unit. These affected persons benefit from the targeted, individual optimization of the development processes and the individual process solution, which is tailored to the specific needs. The sustainable integration of agility in the processes supports and is beneficial for all persons involved in the process and enables resource-efficient product development, which leads to an increase in customer value in the market. This benefit, an agility that is individually adapted to the company-specific needs and the company-specific situation, is so far unique. By providing appropriate methods, the framework enables an approach that universally allows newly developed elements to be transferred into practice. The relationships described in this section are summarized in the Method Profile in Figure 1.

4.2. Framework for development of specific agile methods

The basic structure of the developed framework is based on the framework of a *Systematic approach for strategic potential identification* [35] by MARTHALER ET AL. Each step of the process forms a separate column in the framework, resulting in seven columns, which are structured by the activity-based modeling technique (ABMT). By running through the individual steps, the user is enabled to identify his individual aims and requirements (*System of Objectives*) regarding the agile method to be developed. Tool-supported, several process models as well as methods and practices are suggested, which fulfill the individual aims in the created system of objectives. These elements come from a collection and evaluation of a huge number of agile and plan-driven frameworks, methods and practices. [36] The suggested selection of elements is the base for generating an individual process solution, which realizes an individual degree of agility. With the ABMT the essential aspects of each step are represented. It is divided into input, description of the activity, methods and output. In particular, each output represents the input of the following step. In the following, the specific steps of the framework are described. (cf. Figure 2)

Situation Analysis: The Situation analysis is designed to help the user gain an understanding of his situation within the company, but also of the situation on the market and in competition. Based on the desire to become more agile and a resulting vague potential for improvement, the application of the framework can be started based on the project initiation. Thereby the user should gain a precise understanding of the company-specific ACTUAL situation, especially of the current agile capabilities, the structural and process organization. In the course of this, it is important that the user identifies possible information deficits with regard to his situation and solves these deficits through research. In addition, it is especially important that the user understands the reasons why the company should be adapted or why (more) agility should be implemented. In the situation analysis, an as-is analysis provides methodological support for the user in order to finally gain an understanding of the corresponding organizational structure and to define the explicit goals that are to be achieved through agile working.

Problem Containment: On the basis of the information obtained previously, the understanding, the explicit objectives and an initial idea about a possible improvement potential, the core of the optimization potential can be identified. Influencing factors are identified that are particularly relevant from the user's point of view in order to derive the individual system of objectives (*the target state*) for the process solution to be generated. Two methods can be used for support. On the one hand a target-actual comparison and on the other hand a methodology to align the change towards agile working [18]. This second methodology serves as a tool to calculate a weighting of the ASD principles, support the selection of fields of actions (3-5 out of 30 [18]) and factors (20 out of 225 [18]), from which the system of objectives can then be derived. Factors and fields of action are related to the individual optimization potentials, while based on this the ASD principles are determined and ordered and display the direction of optimization. The results of this method and the target-actual comparison are finally combined in the system of objectives to the process solution.

Search for Alternative Solutions: The basis for the search for alternative solution proposals is on the one hand the need, based on the ACTUAL situation of the company, to achieve a target state defined in the previous step and on the other hand relevant factors that have been identified to introduce more agility at suitable points. In addition to capturing, analyzing and documenting in order to be able to fall back on another process solution if necessary, all ideas should be concretized. Thereby the relevant criteria, which can be suggested by a tool as well as by the user, are considered tool-supported. This tool is used to perform a calculation based on the specific relevant criteria and to identify and propose suitable methods and practices for the specific application. For this purpose, the fields of action, the relevant factors and the weighting of the ASD basic principles from the step of problem definition are evaluated with the help of an algorithm. The tool then proposes three superordinate process models (out of 15) for the macro level and five

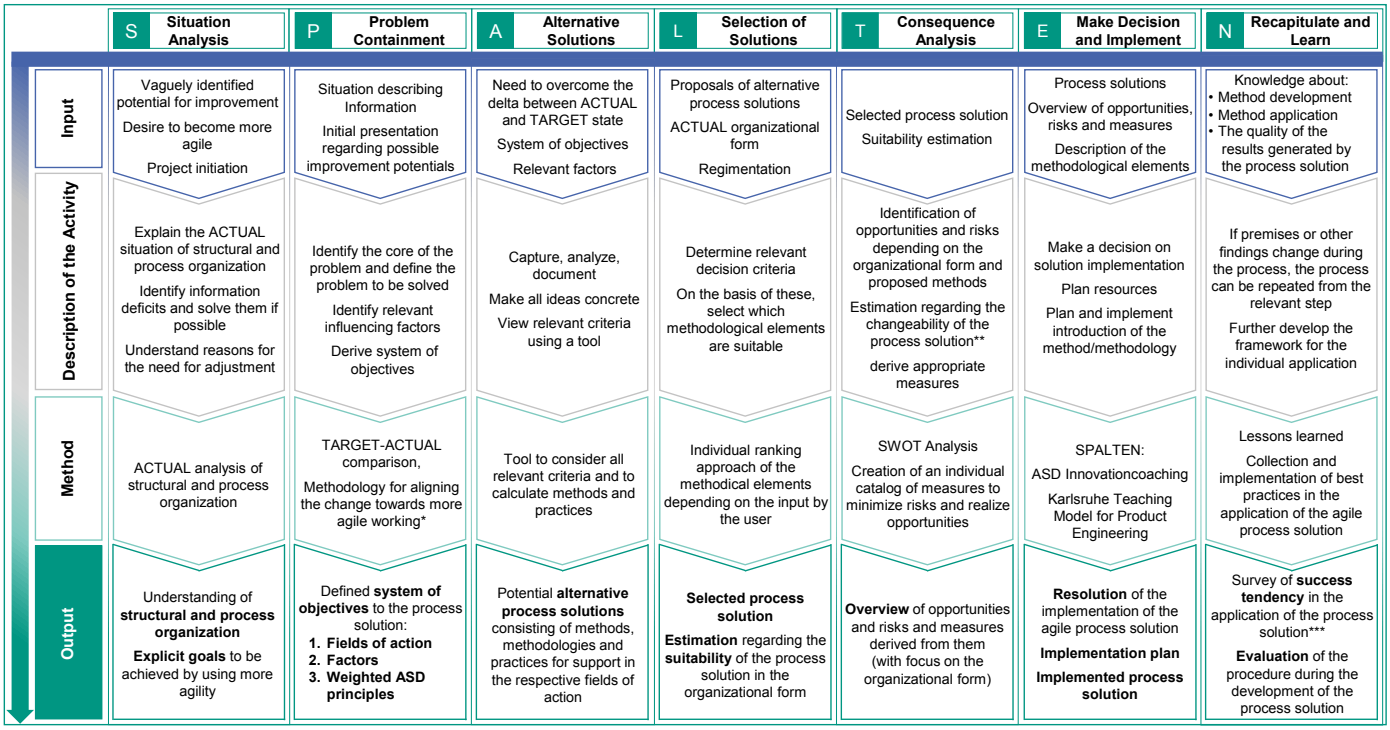

Fig. 2. Framework for a situation- and demand-oriented implementation of agility

agile practices (out of 145) per selected field of action. The results are proposed in the form of various process solutions, from which the user can choose one in the next step. [36]

Selection of Solutions: Based on the proposed alternative process solutions, the user selects in this step one of these process solutions to be implemented later. Considering the current form of organization and the company-specific regulations, decision criteria (e.g. complexity of the system in development, existing process models) are determined. These are used to examine which process solution or which methodological elements are particularly suitable for the transformation of the current organizational form towards a more agile work. As methodical support for this, an approach is used which classifies the methodical elements in an individual ranking depending on the input, i.e. the selected fields of action, factors and criteria, by the user. Finally, depending on the ranking resulting from the specific application, the user selects one of the proposed process solutions (he chooses 1 process model and several agile methodological elements), which is then examined more closely and finally implemented in the following steps.

Consequence Analysis: The consequence analysis determines the scope of the selected process solution in terms of the implementation effort and the risk in relation to the ACTUAL state of the organizational form. The opportunities and risks in relation to the proposed methods and organizational form are determined. Based on the identified opportunities and risks as well as the assessment regarding the changeability of the process solution, additional measures are derived. For these activities a SWOT analysis is used, which is linked to a method that creates an individual catalog of measures to minimize the risks and realize the opportunities. In this step the user determines that a transformation towards more agile working on the basis of the selected process solution is promising, feasible and appropriate. At the end of this step, the user is thus provided with an overview of the opportunities and risks of implementing the selected agile process solution and the measures derived from it with regard to his specific use case.

Make Decision and Implement: In this step, a decision on the implementation of the selected process solution is made on the basis of the opportunities, risks and measures identified in the previous steps. Once the decision for implementation has been made, resources and implementation are planned in order to actually implement the selected process solution. For the process of decision making and implementation the problem solving process SPALTEN can be used again complemented by other methods. Once this step is completed, there is not only a decision to implement the selected agile-structuring process solution, but also an implementation plan.

Recapitulate and Learn: In this step, the insights and knowledge about method development, method application and the quality of the results generated by the process solution are used to adapt the developed and implemented process solution if necessary and to further develop the framework both in general and for individual applications. An adaptation of the process solution only takes place in case of changed premises or other insights gained during the course of the process that make an adaptation necessary. The entire process, i.e. the application of the framework, is run through again from the respective affected step until no further changes are necessary. Various methods can be used to check for an adaptation, e.g. lessons learned or an individual collection and implementation of best practices in the application of the agile process solution. The learning is repeated and serves to ascertain the success tendency resulting from the application of the process solution.

5. Conclusion and Outlook

As described by DIEBOLD ET AL. [10], a step-by-step transformation towards the right degree of agility is necessary. The situation- and demand-oriented implementation of agility in the processes of mechatronic system development companies is a highly complex matter. A simple adoption of agile approaches from software development is not possible without further effort. In order to consider this conflict in a company-specific way, a method in the form of a framework was developed in this paper, which supports a user in considering both agile and plan-driven applications and enables the generation of an agile-structuring process solution suitable for the specific requirements. With the help of this framework, agility can be implemented to a suitable degree. The validation of the framework is particularly relevant for the further procedure. Actually, there is a validation with users and affected persons of a company to improve the framework.

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