31st CIRP Design Conference 2021 (CIRP Design 2021)

Agile product development: an analysis of acceptance and added value in practice

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Abstract

Manufacturing companies are increasingly integrating agile approaches into their development processes. This is expected to improve customer integration, enhance responsiveness to changes in the development context and ultimately lead to improved process and product quality. However, since agile approaches mostly originate from the culture of software development and have been formulated on the basis of observations of successful software projects, new challenges arise in the application of these approaches in physical systems development. Often the approaches fail due to false expectations or lack of acceptance, which causes agility not to be deeply integrated into the processes. For this reason, this contribution presents an understanding of the current state of acceptance of agile working and the expected and perceived added value of using agile approaches in practice. Based on this understanding, future research will develop a systematic by means of which agile elements can be introduced into development processes in a way that is appropriate to the situation and needs, thereby increasing acceptance and perceived added value. Since it is empirical research, which analyses real-world processes, a survey was chosen as a suitable research method. 235 participants from different branches in the area of physical product development in Germany participated. The results were analyzed using usual statistical methods. An assumption that there are discrepancies between strategic and operational views on agile working could not be confirmed. However, optimization criteria in the area of acceptance of agile approaches were identified. The research contributed to the understanding of the current performance level in the field of agile development of physical systems. The identified potentials in the area of acceptance and perceived added value in agile work can now be measured specifically for each individual application and realized with suitable methods, what contributes to a sustainable integration of agile methods into the development processes.

Keywords: Agile Product Developmen; Acceptance of Agility; Development Processes; Agile Transition

1. Introduction and Background: Agile Development

The transition from the development of physical products to the development of product service systems as a combination of technical system, service and business model has significantly changed product development [1]. For example, the fact that technical systems operate during their utilization phase in a superordinate System of Sytsems (SoS) [2] makes validation significantly more difficult [3]. Furthermore, not only the classical domains of mechatronics are involved in the development [2]. In order to remain reactive to changes in the development context, manufacturing companies are increasingly introducing agile approaches to their development processes [4]. However, since these approaches originate from software development, they lead to new challenges [5]. *In order to make the introduction of agile approaches sustainable, this contribution derives an understanding of the existing status in practice regarding acceptance and perceived added value of agile work.*

Agile approaches are mostly based on the agile manifesto, which was written by several software developers in 2001. It places the delivered value that software offers to a customer in the focus of development. [6] The best known agile approach, which is also used in the development of physical systems, is *Scrum*, which was even initially intended for physical product development [7], but became widely accepted in software development [8]. Three values are at the core of the approach:

transparency, review and adaptation, which are implemented through different roles, events and artifacts in the development process [8]. Especially the short cyclical planning (usually so-called 4-week sprints) and the continuous delivery of working software as well as regular testing and revision are typical characteristics of the approach [8, 9] and at the same time reasons why its implementation in the development of physical systems is not possible without adaptation of the approach [5].

Another agile approach, which is widely used in innovation management, is *Design Thinking* [10]. It consists of six phases that can be repeated in any number of iterations [11]. In each phase a variety of development methods are provided [12]. Central to Design Thinking is to put oneself in the position of the user of a product. Based on the knowledge gained here, concepts are developed and prototyped in a fast pace. This is followed by a test, from which new insights can be gained for a repetition of the phases. [11] However, the focus of Design thinking is very much on the integration of product users [13].

In the approach of *ASD - Agile Systems Design* according to ALBERS [14], the development of products, the associated validation system and production system is considered integrated. The approach is based on 9 basic principles for the agile development of mechatronic systems [15] under continuous integration of existing product and process knowledge [16, 17]. The core of the approach is the provision of selected agile elements and the integration of these elements into the existing structures of manufacturing companies. ASD is not a recipe for successful product development, but rather provides a situation- and demand-oriented combination of flexible and structuring process elements, depending on the application and the respective goals of the developers. [18, 19] This ensures an agile transition, considering the culture prevailing in the context [20].

In different studies it was determined, how the current conditions of the application of agile approaches are in the practice of producing enterprises. The spread is mostly limited to individual areas in the companies with focus on software development as part of the overall system development. However, it could be determined that the basic working method is seen as quite positive. Challenges exist especially in a non-uniform understanding of agility, physical limits of technical systems (and their effects on production systems and validation systems [21]) and in dealing with hierarchies. [5, 22, 23]

2. Research Design

In order to successfully introduce agile approaches into the processes of physical product development and to optimize them at the right areas, the acceptance of developers regarding agile work and its relevant criteria are examined. Additionally, the expected and perceived added value of agility is examined and compared. The adjustments of a new understanding to work lead to a field of tension between management view and developer view [24]. In order to resolve this, the influences on acceptance and perceived added value of agile work must be understood especially from these different viewpoints in the development process. The derived research hypothesis is: *There are discrepancies in the understanding, the actual and expected added value as well as the acceptance of agile approaches between participants in the development process who take the management or the developer view or both views.*

If this hypothesis is accepted, it means that discrepancies between the views lead to conflicts when applying/implementing agile working. However, if this hypothesis is rejected, then there must be no particular focus on the interface between strategic and operational levels in the use/implementation of agile working. Accordingly, the approaches must be introduced in line with needs and situations along the needs and culture of the entire organization.

In order to observe, analyze and understand real-world processes and challenges, an empirical study is conducted according to the definition of ECKERT ET AL. [25]. Since it is empirical research, which analyzes real-world processes, the survey was chosen as a suitable method. It captures the perception and attitudes of the participants to predefined questions. It allows a quantitative approach, which can be analyzed statistically to derive the findings for a specific group. [26] For these reasons, a quantitative cross-industry survey is be conducted with participants experienced in agile collaboration.

The survey comprised three possible survey routes (appendix A). First, a simple and understandable introduction is provided by querying demographics D.1-5, understanding and goals U.1-3. Next in the agile background AB.1-9 are the agile work experience measured with question AB.1 and the level of knowledge about agile methods evaluated due question AB.8 are checked to divide the participants into the three survey paths. The agile **experienced participants** answer the complete questionnaire with the challenges C.1, the acceptance A.1-28 and the actual added value AAV.1-8 of agile working methods. The **other participants** are divided according to whether they know agile working or not (AB.8). The participants with a **knowledge of agile** approaches, will answer the area of expected added value EAV.1-8, which is the counterpart of the actual added value area. The **inexperienced participants** are then finished. The study is oriented in design and content on the studies from [5, 23, 27].

The study design has been tested by experts from business (software & hardware background) and science (physical product development). This ensures the quality, comprehensibility and logic of the survey. A freely accessible online survey should enable the widest possible dissemination. The survey was distributed via company mailing lists, association mailing lists and personal contacts via e-mail and direct messaging. Additionally, the study was distributed via the newsletters of several German Associations. This selection and the study design ensured that the participants had experience in agile collaboration. A total of 346 people completed the survey in whole or in part. For the analysis in this publication, 235 participants were considered relevant and their data was used for the analysis.

3. Results

Firstly, the demographic profiles of the participants and their understanding of agile approaches are evaluated and presented. Afterwards the collected data is analyzed by the added
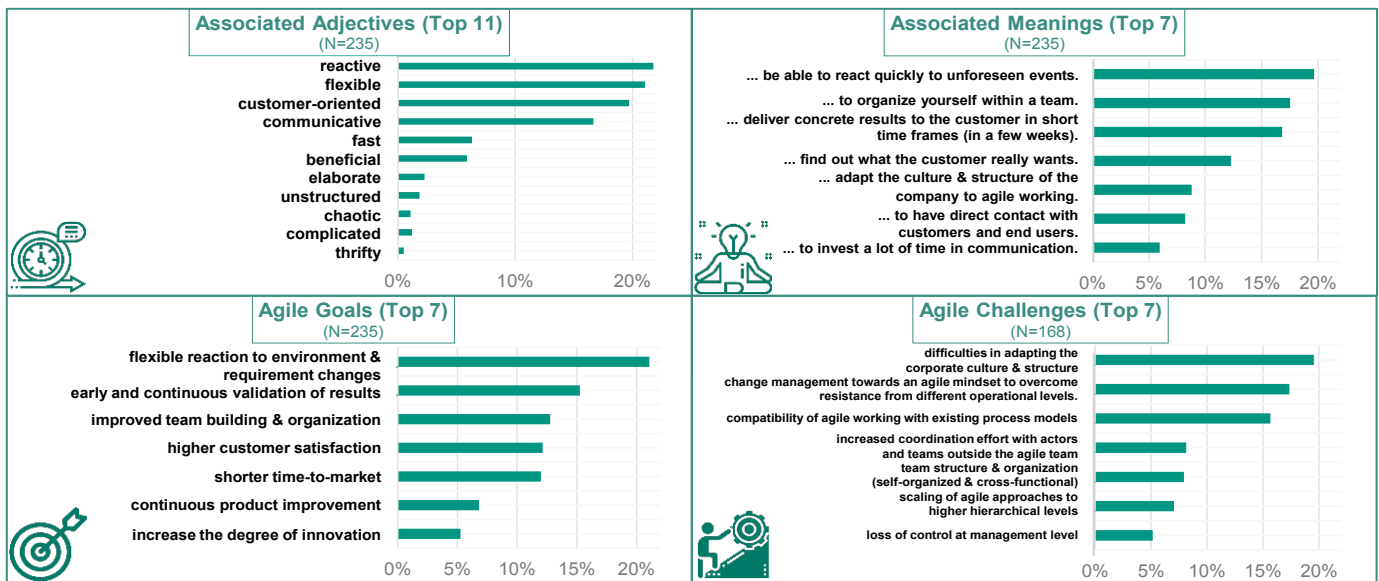
Fig. 1 Diagrams for agile comprehension

value and acceptance of agile methods (see Fig. 1). Predominantly, the study is analyzed by means of descriptive statistics in order to prepare and clearly present the amount of data using graphics. Additionally, the applied percentages indicate the primary selection of participants. The used 5-step Likert scale enables further statistical analysis methods. The summed up mean values for acceptance, actual and expected added value are further statistically evaluated among each other or between the three views of the development process. For this purpose, the independent T-test p is used for statistical relevance, COHEN's d for determining the effect strength and the correlation coefficients r to calculate the correlation of the hypotheses [30, 31].

3.1. Profile of participants and their understanding of agile

For the evaluation of physical product development, 235 participants from the agile development of physical systems answered the questionnaires. The average study participant works in a small- to medium-sized company with up to 5,000 employees (>60%) in the German-speaking area, has more than 10 years of professional experience (>60%) and mainly accompanies a position in lower management (>35%) or is a specialist (>20%). He/She is experienced in agile work with over 1 year of experience (>50%). In development process the study participant takes both views (>44%). The understanding of the average study participant associates the fast reaction to unpredictable results, the self-organization of teams and the delivery of concrete results in short periods of time to the customer with agile working. In addition, he/she links the adjectives *reactive*, *flexible* and *customer-oriented* with agile approaches. This results in the goals of agile working as flexible reaction to environment & requirement changes, earlier and continuous validation of results and shorter time-to-market for the use. Fig. 1 shows the distribution of the participants' understandings in the area of agility. In particular, associated adjectives, the associated meanings, the goals, but also the addressed challenges were queried, which can all be components of an overall understanding. The most commonly mentioned components of agile work in this study lead to the following understanding: *Flexible reaction to unexpected events in self-organized teams to deliver regularly validated as well as concrete results to the customer, so that a shorter time-to-market can be achieved.*

3.2. Added value of agile

The added value of agile working methods has a decisive influence on their acceptance. For this reason, the eight different factors from Fig. 2, with the 5-step Likert scale in the study, are collected and added together to obtain the overall added value. The mean value of this overall added value is 3.66 for the actual added value and 3.92 for the expected added value, which means that the expected added value of agile working methods is higher than it is in reality. Both values are above the middle of 3, so regardless of expectations and actual, the participants see an added value of agile methods compared to the previous used approaches. The discrepancy of 0.26 between the actual and expected added value is confirmed as statistically significant according to the independent unpaired T-test [28, 29] with p = 0.024. In addition, the calculation of the effect strength with COHEN's d = 0.391 results in a small to medium effect. Finally, the correlation coefficient r = 0.192 shows a small to medium positive correlation. [30, 31] Thus, the expected added value is statistically significantly higher by 0.26 on average than the actual added value (95%-CI[.03, .48]), t(198) = 2.27, p = .024, d = .391 r = .192.

This means that for the representative group, the expected added value is higher than the real one and that this is statistically significant, a small to medium effect and positive corre-
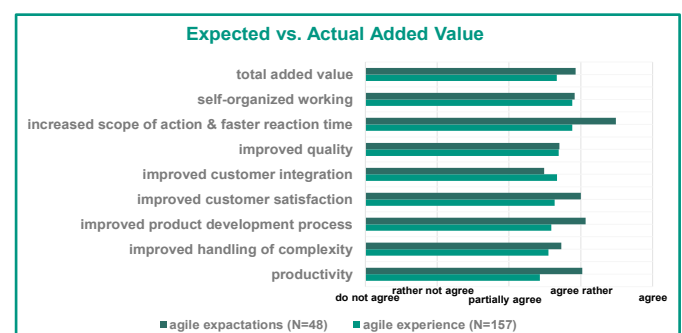

Fig. 2 Participants' average notion of agile added value and its factors

lation. This results in a statistically significant discrepancy between actual and expected added value. *Specified on the direction of the discrepancy it can be stated that the actual added value does not meet the expectations of agile work.* A detailed analysis of the individual factors in Fig. 2 reveals the following criteria show the greatest difference between actual and expected added value and have the greatest potential for improvement (actual added value vs. expected added value):

- Increased scope of action & fast reaction time (Δ = -0.61)
- Increased productivity (Δ = -0.59)
- Improved product development process (Δ = -0.48)
- Improved customer satisfaction (Δ = -0.36)

When comparing the views on the actual added value, no statistically significant difference is recognized, but the developer sees the actual added value of agile work at its highest. People who occupy both views also reflect the average value of the other two views. The factors identified by the study with the greatest differences between the developer and management view are the following (management view vs. developer view):

- Self-organized working (Δ = -0.20)
- Improved product development process (Δ = -0.30)
- Improved customer integration (Δ = -0.31)
- Increased scope of action & fast reaction time (Δ = 0.17)

The analyses of this study highlight the factors of increased scope for action & fast reaction time, self-organized work, improved quality and improved customer integration as the most important added value factors and thus for agile approaches.

3.3. Acceptance of agile

The degree of satisfaction of the study participants with agile working is showed in Fig. 3. This discloses a high potential to optimize it especially in comparison to the personal assessment of the respective opinion and the own acceptance of agile approaches. This is also reflected in the calculated total value of the acceptance criteria. One explanation for this is the unconvincing consequence of introducing agile work approaches. This reveals one of the decisive factors for good and convinced application of agile approaches. In the more detailed analysis of the acceptance criteria in Fig. 4 it should be considered that the criteria *work structure lost*, *fear of change*, *method complexity* and *tuning time expenditure* are potentially negative in nature and therefore inverted, so that their values show the acceptance impact of agile methods and have a corresponding impact on the overall value of acceptance. Subsequently, five criteria stand out, which are considered to have a high optimization potential, due to their low value in the study. These criteria include the *changed direction of work instructions into the team* (3.41) and the *cooperation between manager and team*
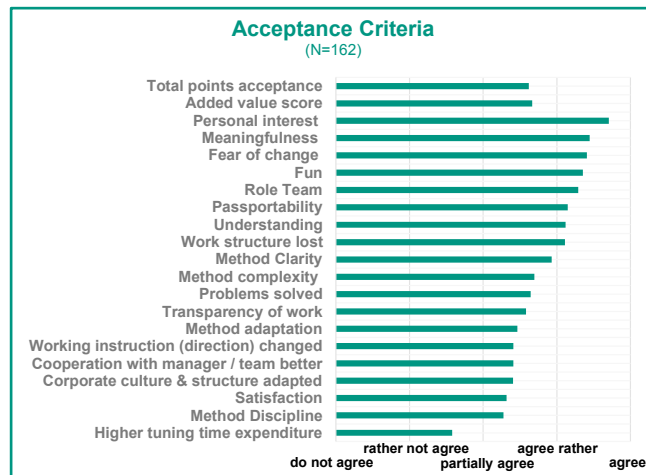

Fig. 5 Acceptance Criteria to agile development

(3.41). These points are directly related to each other. The cooperation is directly related to the direction in which work orders are given to the team and can therefore be optimized together. Furthermore, they influence the next factor of acceptance of agile working, the *adjustments of the corporate culture and structure* (3.40). When the values and principles of agile approaches are implemented in the culture and structure, this also implies the direction of the work instruction as well as the cooperation between manager and team. These dependencies can be extended to the fourth factor, the *methodological discipline*. If the agile method is implemented in a disciplined manner, the appropriate adjustments are made in the company. Finally, the fifth criterion is to identify satisfaction. It depends on the use of agile approaches and is strongly related to acceptance. The view comparison for the acceptance value does not reveal statistical significance. Both views have minimal the highest value of 3.66, but the values differ only marginally from the management view with 3.58 and the developer view with 3.61. These values and the value of all participants with 3.62 reveal the fundamentally positive acceptance of agile work in the study. Fig. 5 shows the individual factors with the greatest differences between the views. It becomes obvious that with adaptability, method clarity, method discipline and method adaptation, factors directly related to the applied methods and their implementation become apparent. For a high acceptance of agile work between the views it is elementary important that the right methods are used and above all that they are implemented correctly and consistently. *Finally, the study analyses reveal the criteria corporate culture and structure,*
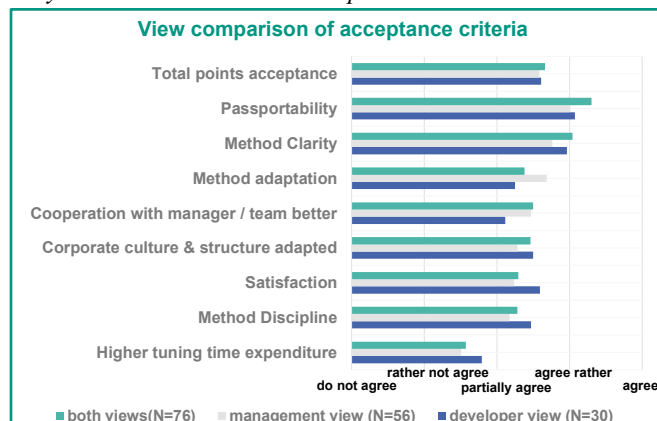

Fig. 3 Participants' personal assessment of agile acceptance

Fig. 4 View comparison of selected acceptance criteria

method discipline, direction work instruction, cooperation executive and team as the acceptance criteria, which need a detailed optimization and adjustment. In summary, these can mainly be integrated into the company-specific adaptations of methods, organization, communication and cooperation.

4. Conclusion and Outlook

The basis for the measurement was given components of understandings, but these have already been identified as relevant in previous studies. For this reason, the statements in this paper can naturally only refer to this understanding in terms of acceptance. The sustainable implementation of agile approaches in the development processes of manufacturing companies is directly dependent on the acceptance of these approaches by the employees and on their perceived added value. In addition, there are different objectives in the use of agile approaches between the strategic and the operative view on projects. Using a quantitative study with 235 participants from companies in Germany optimization criteria in the area of acceptance of agile approaches were identified: *corporate culture and structure, method discipline, direction work instruction, cooperation executive and team.* Furthermore, it was shown that the expected and real added value in the use of agile approaches diverge.

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Appendix A. Study Questionnaire

Demography	
D.1	Are you a consultant?
D.2	How many years of professional experience do you have?
D.3	How many people work in your company
D.4	In which economic sector is your company active?
D.5	In which industry do you work?

Understanding of agile working	
U.1	Please select the three most appropriate adjectives which you associate with agile working.
U.2	Agile work means for you... (Please choose your top 3 in order of importance)
U.3	Please select the three most important goals you think the introduction of agile working should pursue.

Agile Background	
AB.1	How long have you been working agile?
AB.2	What was your position in the company before the change to agile working?
AB.3	Please indicate the field of your expertise:
AB.4	Please assign yourself and your tasks in agile product development to either the management or the developer view.
AB.5	What is your role in agile working?
AB.6	How was the agile working method introduced?
AB.7	Do you have experience with agile scaling models?
AB.8	How much experience do you have with agile work?
AB.9	Please enter the agile approaches/methods/frameworks you have mainly used so far:

Challenges of agile working	
C.1	Please select the three biggest challenges you see in connection with agile working.

Acceptance of agile working	
To what extent do you agree with the following statements about agile working methods? (5-level Likert scale)	
A.1	The coordination time required for agile work is less than before with the classic method of working.
A.2	Agile work suits me and my tasks.
A.3	I find the methodological guidelines for agile work complex.
A.4	Agile work has created more problems than it has solved.
A.5	I am satisfied with the way we do agile work.
A.6	The team strictly adheres to the process/meeting guidelines which were/are introduced with agile working.
A.7	The corporate culture & structure is the same as before the transition to agile working.
A.8	I can understand that we have changed our working method to agile.
A.9	The path of a requirement into the team has not changed through agile working.
A.10	I enjoy working agile.
A.11	The methodological guidelines for the agile work approach used are clear to me.
A.12	I find the cooperation between management and the team to be better when working in an agile way.
A.13	Through agile work we have thrown ourselves into complete chaos.
A.14	The transparency of agile working allows an easier overview of the performance of each team member.

Acceptance of agile working	
A.15	The introduction of agile working has shifted the responsibility for setting development goals to the team.
A.16	I understand the relevance & importance of agile working in the modern work environment.
A.17	I like the easier monitoring of the work performance.
A.18	Agile work does not suit our company.
A.19	I like self-organized & cross-functional teams. (cross-functional = the team has all the necessary skills to develop the product)
A.20	I am interested in how we can continuously improve.
A.21	I am rather skeptical about changes at work.
A.22	The team works self-organized and self-determined.
A.23	The development process has lost structure due to agile work
A.24	The agile way of working was adapted to the company.
A.25	Agile work has solved many problems of the classical way of working.
A.26	Please mark your opinion towards agile work.
A.27	In your opinion, how consistently was the changeover to agile working carried out?
A.28	How do you rate your acceptance of agile working methods?

Expected added value of agile working	
If we were to introduce agile working methods, my Expectations are: (5-level Likert scale)	
EAV.1	Increased flexibility to meet changing requirements.
EAV.2	Increased productivity of the team.
EAV.3	A better handling of complexity.
EM.4	Improved integration of the customer into the development process.
EAV.5	Increased customer satisfaction.
EAV.6	An improvement in the product development process.
EAV.7	A better quality of results.
EAV.8	Enabling self-organized work.

Actual added value of agile working	
My actual experiences with agile work are: (5-level Likert scale)	
AAV.1	We have increased our scope of action & accelerated the handling of changed requirements.
AAV.2	We have improved our approach to complexity.
AAV.3	We have integrated customers more intensively into the development process.
AAV.4	We have increased customer satisfaction.
AAV.5	We have improved the product development process.
AAV.6	We have improved the quality of earnings.
AAV.7	We work self-organized.
AAV.8	We have increased our productivity.

Feedback	
F.1	If possible, please give one or more reasons why you are not working agile.
F.2	We would appreciate feedback on the survey.