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Relation between purpose of individual agile elements and the need for their adaptation in product design & development

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Abstract

Empirical studies show that adaptations of existing agile methods are necessary for developing physical products creating obstacles and challenges. This paper aggregates the gathered findings from several cross-sectional industry surveys and establishes a relationship between the extent of utilization of individual agile elements based on Scrum and the need to adapt these elements in applying agile procedural models. The emphasis of examination resides in the purpose perspective of agile elements with the aim of facilitating context-specific adaptations more effectively.

Keywords: agile development, agile management, Scrum, adaptation, process improvement

1. Introduction

"Design science studies the creation of artifacts and their embedding in our physical, psychological, economic, social, and virtual environments." (Papalambros 2015, p.1). According to (Blessing 1994), a correlation exists between the product's quality and the quality of the underlying process. To achieve a comprehensive understanding of the process, it is essential to thoroughly comprehend the constituent elements that shape and operationalize it. In this context, particular significance is attributed to the design process, which can be operationalized as a sequence of processes and activities (Hales and Gooch 2004). Methodologies and methods are used to support designers within the design & development process, and the aim of these is to achieve a specific result (Gericke et al. 2020). Modifying and adapting design methodologies and methods to align with specific contextual parameters is imperative for enhancing their acceptance and expanding their applicability (Gericke et al. 2013). The design process can be effectively structured and supported through a situation-specific combination and adaptation of elements (Heimicke et al. 2021). Due to intensifying uncertainties, enterprises need to incorporate agile elements and methods into their design processes to remain responsive (Pendzik et al. 2023). Within this context, uncertainties may be conceptualized as discrepancies, inconsistencies, and incompleteness existing in the data, information, and their respective flows (Paetzold 2022). A study indicates that particularly companies within the manufacturing industry are increasingly confronted with the necessity to adopt agile methods (Nicklas et al. 2021). Furthermore there is an insufficient understanding of the underlying mechanisms (Michalides et al. 2022). Moreover, the authors highlight that inadequate comprehension results in practices being executed devoid of a clear purpose (Orejuela et al. 2023). The fundamental configuration of the Scrum framework, established as a quasi-standard, comprises distinct elements that will be subject to in-depth analysis throughout this paper. We are analysing the elements because we have identified adaptations that prove to be more challenging rather than easy (Nicklas et al. 2021).

We assume that examining adaptations from a purpose perspective could lead to better understanding. To theoretically substantiate the adaptation of this particular framework and enhance its applicability, this paper addresses the following research question: *What is the relation between the extent of utilization of agile elements and their need for adaptation within the Scrum framework from a purpose perspective?* To analytically address this relationship, the distinction between purpose and benefit is positioned as a premise and perspective. In this paper, purpose refers to the deliberate intention of a desired outcome of an action or process (Lindemann 2009). Benefit refers to the actual value in the form of a yield, advantage, or outcome of an action, in accordance with (Höffe 2013).

2. Essential related work

Context of Product Design & Development

The value proposition inherent in design & development processes resides in the systematic generation and utilization of data and information, which serves to fabricate functional products (Paetzold 2022). These transformation processes are significantly influenced by uncertainties, which demand effective action (Paetzold 2017; Paetzold 2022). Companies must possess the capability to create customer-centric value that is context-specific, align prices with market demands, and expedite development cycles, enabling them to achieve a competitive edge in the market (Lindemann 2009). Depending on the context, influences that cause a need for adaptation can be of different intensity (Hales and Gooch 2004). Consequently, this adaptation necessity requires companies to modify their processes and methods to respond effectively to changing circumstances (Gericke et al. 2013). Therefore, it is of particular importance for companies to understand this need for adaptation, to make adaptations specific to the situation and context in order to achieve the intended benefits (Gericke et al. 2020).

Agile Development of Physical Products

Originating in software development, companies increasingly establish agile approaches to address expected and unexpected changes in the design & development process (Albers et al. 2020). Agile approaches rely on incremental and iterative procedures, wherein discrete deliverables are sequentially integrated into the overarching product. This entails a step-by-step accumulation of partial results to form the final product in agile development (Conforto and Amaral 2016). Due to the origin of agile methods in software development, challenges arise regarding the application in product development (Schmidt et al. 2018b), as well as different interpretations of the agile understanding related to the development of physical products (Albers et al. 2019). When agile methods and frameworks, such as Design Thinking or Scrum, are applied in domains beyond software development, challenges frequently arise owing to inadequate comprehension of these methods and frameworks (Heimicke et al. 2019). In particular, Scrum, which has established itself as a quasi-standard in the development of physical products (Atzberger et al. 2020; Nicklas et al. 2021), comes along with challenges and barriers in its application (Ovesen 2012; Ovesen and Sommer 2015). The Scrum framework, often characterized as a project management methodology, facilitates the design process of a self-managing project team by emphasizing principles of transparency, communication, and alignment (Heimicke et al. 2019; Sutherland and Schwaber 2020). Scrum consists of different roles, events and artifacts, which intend to help the organization produce added value for the customer. Despite the Scrum Guide's acknowledgment of deliberate incompleteness (Sutherland and Schwaber 2020), substantial gaps persist concerning the applicability of Scrum in diverse contexts, particularly regarding the individual components that constitute the framework. Empirical studies that have already been carried out show that there is a need for adaptation to the context (Atzberger et al. 2020; Nicklas et al. 2021; VersionOneInc 2021). The rudimentary descriptions of the individual elements of Scrum can be found in the following literature (Sutherland and Schwaber 2020; Žužek et al. 2020; Orejuela et al. 2023). The absence of a comprehensive description concerning the applicability of Scrum in the realm of physical product development necessitates adaptation to roles, events, and artifacts. However, only agile procedural models were the focal point of inquiry so far (Atzberger et al. 2020; Nicklas et al. 2021). The aim is to illustrate the current utilization of agile components within the Scrum framework and to clarify their interconnections with the imperative of adaptability in the subsequent discourse to enhance understanding. Moreover, we seek to understand industry adaptations.

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3. Research approach

The research methodology employed is expounded upon in this section. To successfully introduce agile approaches into the realm of product design & development and optimize them effectively, elements need to be analysed from a systems-theoretical perspective and assessed for their impact, cf. (Haberfellner et al. 2019). Design scientific research suggests considering the application environment, knowledge base, and other scientific research (Hevner 2007; Gericke et al. 2020). We employ the design methodology derived from (Hevner et al. 2004) as guidance, which initially emerged during investigations into the Information Systems Research Framework (Dresch et al. 2015). According to the design methodology, the investigation focused on the aggregation of data gathered through empirical research over a period of several years, as depicted in Figure 1 (Schmidt et al. 2018a; Schmidt et al. 2019; Atzberger et al. 2020; Nicklas et al. 2021). These studies addressed topics of applicability, understanding, and scaling of agile development. The underlying empirical surveys focus on the German-speaking regions. Further data collection and analysis information can be found in (ibid). The current study concentrated on the same geographical region and utilized same methods for data collection and analysis. A total of 137 participants from the manufacturing industry (e.g. machine and plant engineering) took part. Pure software industries were excluded. For further information see (Weiss et al. 2023). This contribution investigated the necessity for adaptation of elements of the Scrum framework, which is the prevailing procedural model in current usage. In order to enhance the comparability of item selections, an equivalent parameterization was applied, as depicted in Table 1. We will explain this in the following section. Through the annual cyclical elaboration of individual fragments, relationships between the purpose perspectives of agile elements and their degree of utilization as well as the adaptation needs are derived through systematic synthesis and analysis. From these insights, indications are deduced on how organizational units can adapt existing agile elements to maximize their holistic benefits. Consolidating the findings concerning the relations between agile development and its elements leads to expanding the knowledge base in the product development domain.

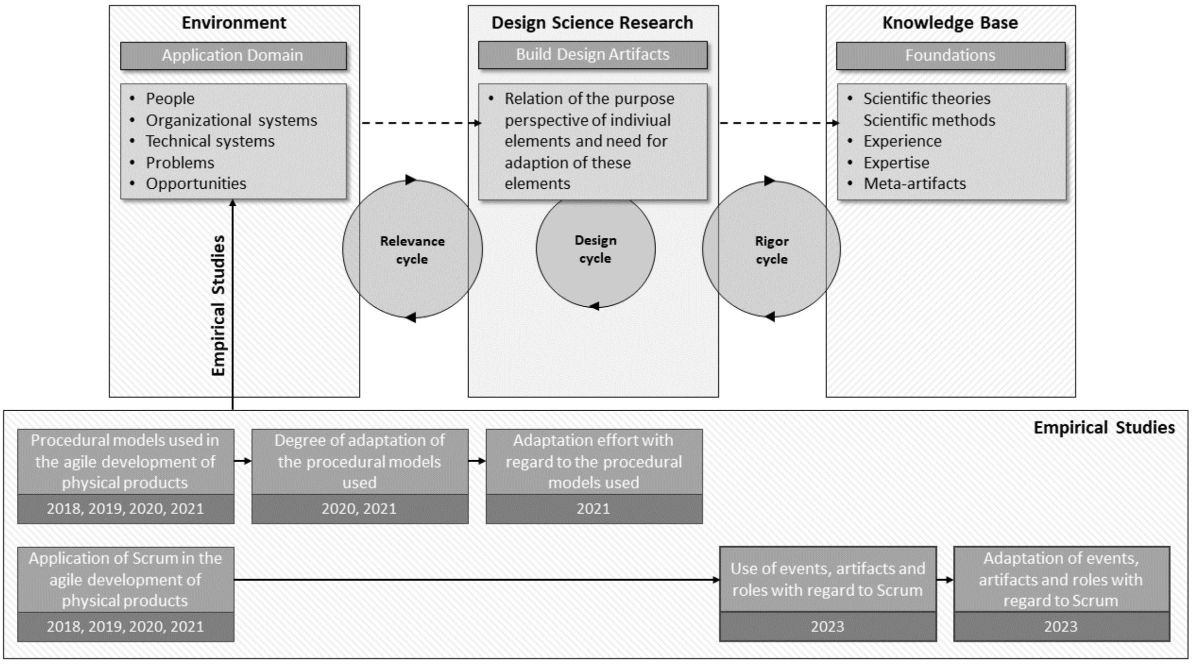

Figure 1. Research approach according to Hevner et al. (2004)

4. Findings

This section presents the information collected from previous and current empirical studies. Upon this foundation, a comparative analysis is conducted based on the presented understanding of purpose and

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benefit. Drawing upon prior research, this presentation offers pertinent insights into the adaptation rate, the extent of utilization, and the purpose of agile elements. Figure 2 shows the previous results of empirical studies, which constitute the starting point of the present paper (Schmidt et al. 2018a; Schmidt et al. 2019; Atzberger et al. 2020; Nicklas et al. 2021). The discrete facets have been organized into distinct graphic boxes, facilitating a clear differentiation between past and current empirical results. Figure 2 illustrates the temporal processing of individual investigations. Thus, from 2018 to 2021, we repeatedly observed the application of Scrum. In 2020-2021, we then examined further aspects. In 2023, we took a closer look at the individual elements.

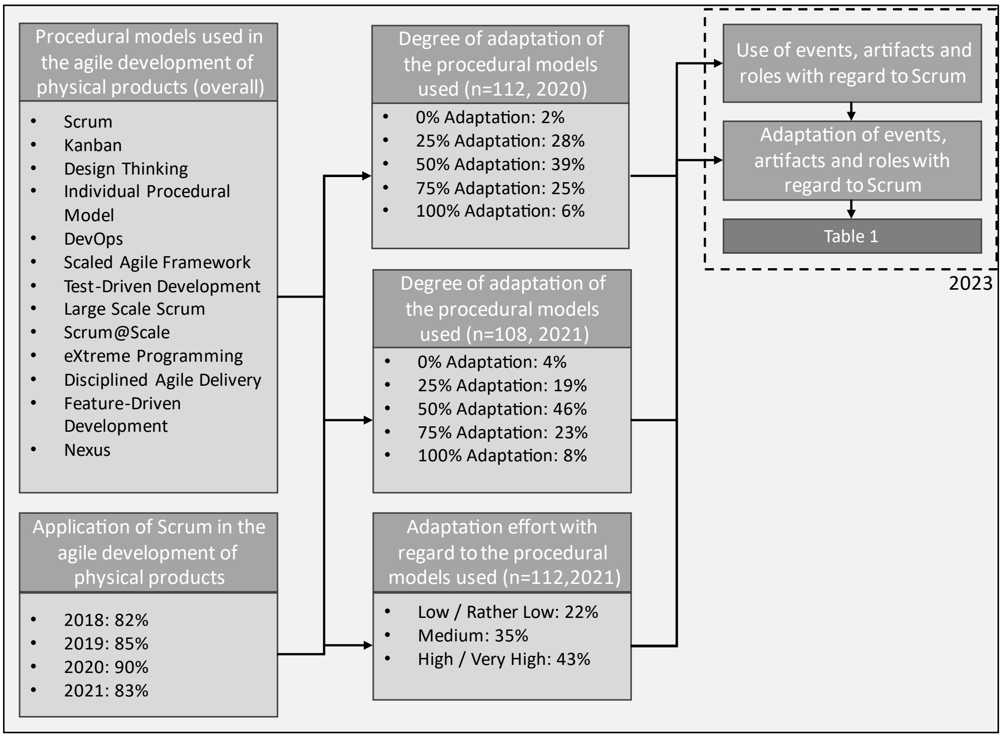

Figure 2. Visual representations of past research findings alongside a comparison to the current empirical results

Adopting a comprehensive perspective on agile development within physical products, the studies mentioned above specifically investigated the applicability and comprehension of agile procedural models. Among these agile procedural models examined, Scrum, Kanban, and Design Thinking predominated in their applications. Notably, the Scrum framework emerged as the preeminent procedural model. More than 80% of respondents longitudinally reported using Scrum. In 2021, 90% of the respondents who indicated the application of Scrum demonstrated the highest occurrence. Owing to the sustained outcomes concerning the Scrum framework, the subsequent studies did not further investigate these inquiries. These longitudinal findings catalyzed exploring the 'degree of adaptation of the utilized procedural models' and the 'effort expended in adapting the procedural models'. Nevertheless, the primary focus of the inquiry revolved around comprehensively documenting the necessity for adapting agile procedural models. The investigation revealed a significant requirement for adaptation (no adaptation <5%), wherein a higher level of adaptation was associated with more substantial effort rather than minimal effort. 78% of respondents indicated an adaptation effort that was moderate to very high, whereas 43% respondents attested a (very) high effort. The authors will further explore these interrelationships in the subsequent discussion section.

In view of the establishment of the Scrum framework as the predominant procedural model in product design & development, the authors sought to ascertain more precisely the specific elements incorporated within the Scrum framework and those subsequently subject to adaptation. Figure 3 shows the survey results. The results were based on a multi-level Likert-type scale. The first row of each element shows the agile elements in terms of their degree of utilization (from 'always/often' - 'rearely/never'). The need

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of adaptation (from 'adapted' - 'not adapted') is visualized in the second row of each element. The initial row is arranged in ascending order from top to bottom, leading to a utilization pattern where the uppermost elements are employed less frequently in comparison to those listed last. The need for adaptation visualized in the second row corresponds to the first row of each element. The consistent or recurrent application of the concept of the 'Minimum Viable Product' as well as the artifact of 'Increment' is declined. Furthermore, only about half of the participants use 'Product Backlog Refinement'. Among the elements employed, 'Developers', 'Sprint Review', and ' Sprint/Fixed-length events' stand out as the most frequently utilized, while approximately 20% of respondents refrain from incorporating these elements into their practices. What remains noteworthy in aggregate is that none of the elements is consistently employed. By means of the orientation lines, an initial tendency regarding the utilization and corresponding adaptation effort is obtained. The greater the rightward displacement of the grey orientation line, the higher the propensity for utilization of the element. The further to the right the black orientation line is, the higher the need of adaptation is potentially.

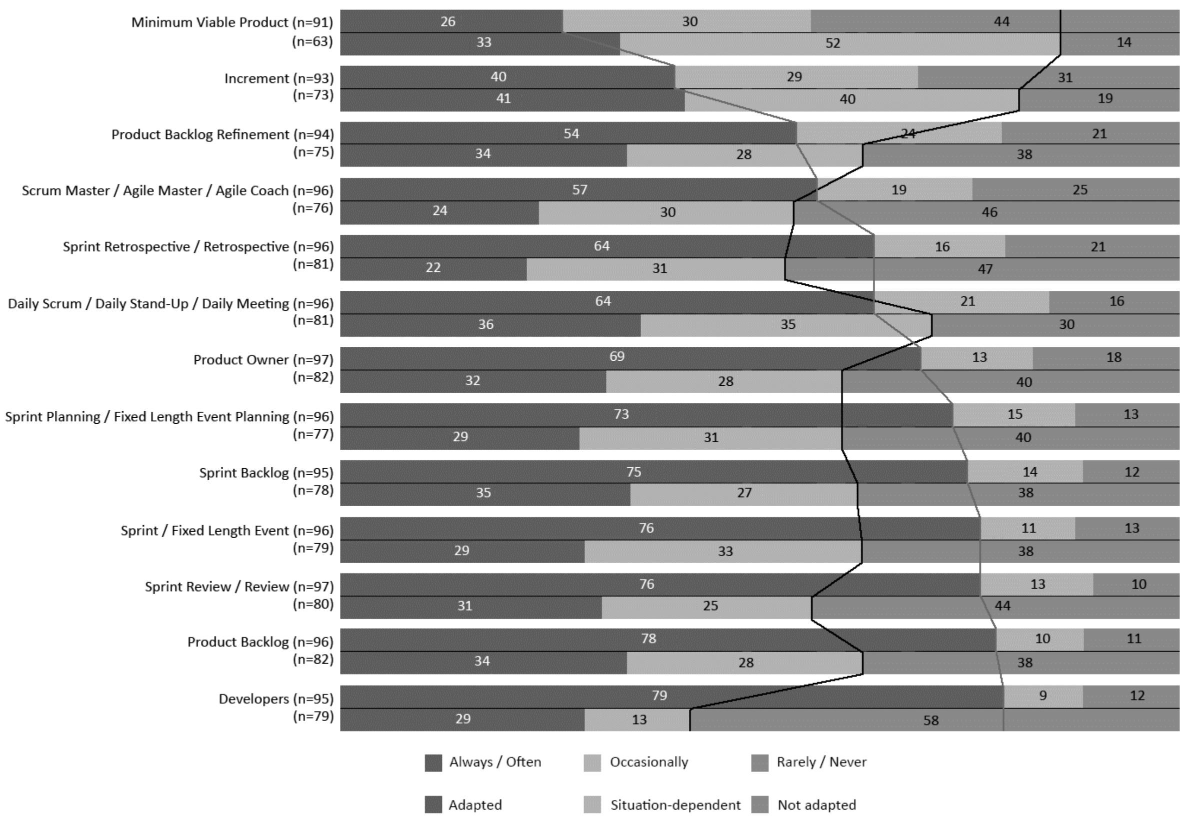

Figure 3. Representation of agile elements related to degree of utilization (first row) and the need of adaptation (second row); Guideline Gray represents the usage 'always/often'; Guideline Black represents 'not adapted', percentages are rounded values, summarized categories for clarity, n= participants

From a statistical perspective, it is fundamentally infeasible to mathematically aggregate Likert-type categories in relation to the mean value. However, for the purpose of further analyzing the results and presenting simplified trends, the mean values were parameterized. We have thus summarized the empirical data, which are already presented differently (3 categories) for clarity in Figure 3. The individual elements, as displayed in Table 1, were then assigned a respectively purpose corresponding to each respective element. The quantification of the degree of utilization was achieved by parameterizing the values from (1), (3) to (5), where the rating of (1) corresponds to the category 'never/rarely', and the rating of (5) corresponds to 'always/often'. Through the segmentation of the respondents engaged in the survey, the resultant mean value corresponding to each item row was

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derived. A similar procedure was applied to assess the need for adaptation. In this context, a parameterization was employed based on the following values (1), (3), and (5), where (1) corresponds to the category 'not adapted'. The selection of intervals was motivated by the aim of facilitating a more intuitive cross-column comparison. As the value (3) corresponds to the category 'situation-dependent', the tendencies toward 'not adapted' or 'adapted' can be calculated by subtracting the average values from the value (3). These trends are not shown in the Table 1. The results presented in the table reveal that as the degree of utilization increases, there is an inclination towards a decreased level of need for adaptation. This tendency can only be vaguely discerned through methods such as averaging, primarily because the authors have formulated an intermediate domain by utilizing the 'situation-dependent' category.

Table 1. Presentation of the collected data related to the mean values of the degree of utilization, mean values of need for adaptation of the elements, and their corresponding purpose (Sutherland and Schwaber 2020)

Listed elements Events / Artifacts / Roles	Degree of utilization of listed elements	Need for adaptation of the listed elements	Purpose of the element
Minimum Viable Product	Ø 1,75	Ø 3,38	…is to determine the satisfaction of needs (related to the function) by the customer
Increment	Ø 2,15	Ø 3,43	…is to provide value that meets and corresponds to the Definition of Done.
Product Backlog Refinement	Ø 2,50	Ø 2,89	…is to refine and the act of breaking down work items of the Product Backlog
Scrum Master / Agile Master / Agile Coach	Ø 2,56	Ø 2,55	…is to act as a role who is accountable for establishing Scrum and the team's effectiveness.
Sprint Retrospective / Retrospective	Ø 2,70	Ø 2,50	"…is to plan ways to increase quality and effectiveness."
Daily Scrum / Daily Stand-Up / Daily Meeting	Ø 2,81	Ø 3,12	"…is to inspect progress toward the Sprint Goal and adapt the Sprint Backlog as necessary, adjusting the upcoming planned work."
Product Owner	Ø 2,70	Ø 2,82	…is to act as a role who is accountable for maximizing the value of the product resulting from the work of the Scrum Team.
Sprint Planning / Fixed Length Event Planning	Ø 3,06	Ø 2,76	…is to delineate a comprehensive and prioritized list of work to be addressed during a sprint.
Sprint Backlog	Ø 2,70	Ø 2,92	…is to express the work to be done during the sprint by highlighting the why, what, and how.
Product Backlog	Ø 3,14	Ø 2,92	…is to express the work to be done, which is needed to improve the product.
Sprint / Fixed Length Event	Ø 3,12	Ø 2,82	…is to establish a time-boxed and focused development cycle to create and deliver value.
Sprint Review / Review	Ø 3,19	Ø 3,00	"…is to inspect the outcome of the Sprint and determine future adaptations."
Developers	Ø 3,20	Ø 2,41	…is to as a role to create value in the form of various work steps.

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5. Discussion

This discussion now engages in an argument of the relationship between the degree of utilization and the need for adaptation from the perspective of purpose. This discourse is contextualized within the preceding findings to assess plausibility and ensure consistencies. Each component or element within the Scrum framework fulfils a distinct purpose contributing to the holistic value and outcomes achieved through the implementation. The tangible benefit of Scrum lies in augmenting customer satisfaction through the periodic validation of interim results in the form of a 'Minimum Viable Product'. Researcher contend that attaining the 'Minimum Viable Product' within a few Sprints is often unfeasible in the development of mechatronic systems, prompting propositions for adaptations to be put forth (Schuh et al. 2018; Nicklas et al. 2020). This aligns with the outcomes of conducted studies and the current findings represented in Figure 3. Merely 26% ('always/often') consistently employ the 'Minimum Viable Product' element, while the potential for adaptation exists in over 80% of cases. This is probably since the 'Minimum Viable Product' cannot be developed in a single 'Sprint'. To attain benefit within the Scrum framework, there exist constituent elements designed for specific purposes in this regard. For instance, the purpose of the 'Daily Scrum' is "...to inspect progress toward the 'Sprint Goal' and adapt the 'Sprint Backlog' as necessary, adjusting the upcoming planned work.", (Sutherland and Schwaber 2020). The purpose becomes apparent when considering the surrounding conditions. Control mechanisms must be enacted considering these environmental factors, as the intended benefit might remain unattainable. Regarding applying this element, it appears to be misleading to label it as 'Daily' given the significant variability of environmental conditions across different companies. The implied daily execution of the 'Daily Scrum' is only appropriate when considering the contextual dynamics daily as well. The findings might reflect this consideration. The identified need to adapt this element could indicate that companies have already recognized this and, therefore, deem a daily prescribed meeting impractical. Furthermore, the utilization rate suggests that adherence to textbook usage is also not prevalent due to the abovementioned reasons. The 'Daily Scrum' element holds universal applicability and is not constrained by its purpose being contingent on physical presence. Furthermore, it is notable that approximately one-third of participants do not utilize the 'Sprint Retrospective' element, with over half of the respondents identifying a need for adaptation, albeit this need might also be contingent on situational factors. The purpose of 'Sprint Retrospective' is to enhance effectiveness and performance within the team. A potential disparity between this element's purpose and benefit becomes apparent. The prospect of improvement is not universally acknowledged, even though internal team enhancements could lead to the higher work quality. A comprehensive understanding of the element itself might be lacking in this context. One potential explanation, however, could be that due to the prioritization of other tasks, this event is one that can most easily be foregone. The role of the 'Scrum Master' or its equivalent is applied by nearly half of the respondents. A quarter of the participants do not utilize this role. The duties associated with this role encompass supporting the agile mindset as well as facilitating the adoption and implementation of agile methods. The need for adaptation suggests that the role might undertake additional tasks distributed across multiple teams, or such support might not be deemed necessary. The first two arguments indicate a resource allocation tendency within the organizations. Findings concerning the purpose imply that even without operating at total capacity as a 'Scrum Master', the corresponding benefits are still attainable, aligning the need for adaptation and utilization rate with the reality of developing physical products. The 'Product Backlog' is employed by nearly four-fifths of the respondents, serving as an emergent list of features to be completed. Regarding its purpose, adaptation needs stem from unavoidable norms and certification requirements in product development, legal obligations typically tracked in the requirements specification document, and the inclusion of flexible formulations in specifications. Of particular interest is the utilization of the 'Product Backlog Refinement' element, which is applied 'always/often' by only about half of the respondents collectively. The need for adaptation is higher rather than lower in this context. 'Product Backlog Refinement' aims to enhance or incorporate specifications based on verification and validation, contributing to customer satisfaction. This results in a concretization of the acquired items (contents), ensuring that developers and product owners share a uniform comprehension of the fulfilment criteria (e.g., a test). Therefore, it appears questionable why this element is only partially employed. One possible explanation could be that changes during the project's progression are no longer feasible or have significant cost implications.

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On the other hand, specific changes resulting from norms and certification are non-negotiable. Alternatively, development teams might need more awareness of this element, leading to an absence of adaptation, even though it could constitute a crucial factor for enhancing satisfaction. Forty percent of the respondents utilize the 'Increment' 'always/often', while approximately 30% employ it 'occasionally'. In contrast, the adaptation need is also substantial. The 'Increment' serves the purpose of providing value in accordance with the 'Definition of Done'. The same applies to the 'Minimum Viable Product', particularly when the 'Increment' is perceived as a temporal segment or building block. However, there needs to be a specification as to what constitutes an 'Increment' in the context of physical product development. While it is an additive element in software development, this is not necessarily the case in product development, which explains the need for adaptation in terms of its purpose. Furthermore, the interpretation of the term 'Increment' to achieve holistic benefit remains ambiguous. Could 'Increments' encompass technical drawings, demonstrators, prototypes, or other artifacts that can be used for validation, or is it more aligned with the continuous progress envisaged in the overall product purpose? This question holds particular significance in product development, as this terminology strongly relates to the 'Constraints of Physicality'. Failure to adapt likely leads to inadequate success, as the stringent demand stipulated in the Scrum Guide is not directly applicable to physical product development. The more frequently employed elements such as 'Sprint Backlog,' 'Sprint,' and 'Sprint Review' appear well understood concerning their purpose, while adaptation needs are attributed to factors such as time duration and the specific characteristics of physicality. Consequently, 'time-boxed events' need to be slightly extended to achieve adequate results and artifacts.

6. Conclusion

This article establishes linkages between the utilization level of agile elements and the corresponding need for adaptation of these elements, with respect to the overall benefit of the Scrum framework and the purpose-oriented perspective of individual elements. The aim was to derive relations between the purpose perspective of individual agile elements based on Scrum and their need for adaptation so that the future application of these agile elements can be supported more effectively. The Scrum Guide advocates for each individual element to be executed in the same manner (Sutherland and Schwaber 2020). While this may be valid in terms of intended purpose, the proclamation of absoluteness in this statement is untenable. Rather, it becomes imperative for companies in the manufacturing industry to comprehend the distinct purpose-oriented perspectives, thereby facilitating effective adaptation to the specific contextual and developmental conditions of the enterprise. Even following the passage of numerous years, the persistent and pronounced existence of the transitional domain in terms of application and adaptation underscores the notion that Scrum may not be viable as a universally applicable, one-size-fits-all solution. Overall, the sole plausible inference drawn from the accrued findings thus far suggests that the derived benefits from the utilization of agile methods and frameworks, such as Scrum, prevail despite the substantial need for adaptation and the attendant effort expended in making such adaptations. Each instance was scrutinized for its alignment with the Scrum framework. It was observed that not all organizations have fully incorporated every facet of Scrum; each entity opted to incorporate roles, implement Scrum events, and create Scrum artifacts according to their own unique manner (Ovesen and Sommer 2015). However, this should clearly be owed to the purpose and benefit. This is further congruent with the findings of (Orejuela et al. 2023), even though it incorporates additional elements pertaining to values such as trust, and allowed the interviewees of their paper to highlight these elements. This contribution focused on the stipulated elements of the Scrum Guide, and moreover, provided a generalization independent of the Scrum framework. Regarding the limitations, it is imperative to note that the gathered data originates from the DACH region, thus rendering these findings non-generalizable. Additional limitations arise from the analysis, contingent upon the researcher's interpretation of respondent's answers. Furthermore, it is worth mentioning that a qualitative validation of these data has not yet been conducted, as the focus was on a cross-sectional view of the companies. In the subsequent phase, it becomes necessary to validate these interpretations within the manufacturing industry companies. Moreover, future research should focus on advancing a more comprehensive exploration of the agile elements and their interactions within the system, both at the technical and organizational levels. These insights have the potential to enhance the comprehension of the scalability of agile development and the procedural models employed therein. Due to obstacles and challenges, these procedural models are also subjected to changes and adaptations dictated by practical circumstances (Michalides et al. 2023a; Michalides et al. 2023b).

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