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Towards agile automotive development: benefits, challenges and organizational changes

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Abstract

Agile methods are increasingly being used in automotive development. This research delves into the current state of agile transformation in the automotive industry regarding benefits, challenges, organizational adaptations, and successful measures to establish the agile approach. The results of an online survey reveal that benefits are already evident after 6 months and that challenges are mainly organizational in nature and organizational structures need to be adapted. Main drivers of success are pilot projects on a small scale and top management support as well as training managers.

Keywords: agile development, automotive industry, engineering design, product development

1. Introduction

Volatile, Uncertain, Complex and Ambiguous - commonly referred to as VUCA: organizations across all industries are increasingly tasked with executing development projects under these conditions (Schmidt *et al.*, 2019). Manufacturing companies, including those in the automotive industry, face a significant challenge in efficiently developing innovative hardware products due to ever-changing customer demands and shortened product lifecycles in today's market environments (Gartzen *et al.*, 2016). That's why being able to quickly respond and adapt to changes becomes highly relevant. Agile hardware development is seen as particularly advantageous in such VUCA environments, where its potential lies in transparent, reactive, and flexible processes (Schmidt *et al.*, 2018).

Michalides *et al.* (2022) and Nicklas *et al.* (2021) noted in their research that agile methods in physical product development are increasingly being implemented, particularly in the automotive industry. The benefits of using agile methods are also evident in their work. Alongside the benefits of agile development, there are also challenges associated with using this approach. Ovesen (2012) claims that these challenges include education and maturation, paradigm perplexity, designer's dissent, team distribution dilemma, as well as constraints of physicality.

In the automotive context, Scharold *et al.* (2023) have already demonstrated that agile physical product development is beneficial in terms of the quality of collaboration at team level. However, the automotive industry lacks a comprehensive view of the benefits of agile product development beyond the team level. The literature also lacks a comprehensive study that considers the aforementioned aspects of benefits, challenges, organizational aspects and enablers for an agile transformation in relation to automotive with a focus on mechatronics. The presented study represents a first approach towards the investigation of this set of topics. This paper aims to provide a first data-based insight into the perspective of benefits, both in absolute and relative terms. The **research question** of the paper at hand is therefore: What are the current advantages, challenges, organizational adjustments, and measures for successfully transitioning to agile development within the automotive industry? The work contributes to the research concerning agile automotive development by highlighting aspects regarding benefits, hurdles, and important factors to consider during an agile transformation in physical product development.

2. State of the art

According Böhmer *et al.* (2015) agility is perceived as the ability to constantly and rapidly respond to and adapt to unexpected and expected changes in a dynamic environment; and to turn these changes (where possible) to advantage. Conboy (2009) illustrates agility as a multifaceted concept. He claims more precisely that in many cases, it refers to an organization's, project's, or team's ability to respond to change. The readiness to react, create, embrace and learn from change to improve customer value are the key characteristics of agility in product development (Conboy, 2009). The Agile Manifesto serves as the foundation of agile development, while it outlines the practices and principles that need to be followed in agile methodology (Beck *et al.*, 2001). The methodology has replaced heavy and traditional processes in software development as a popular set of practices. The core concepts of agility are incremental and iterative development, collaboration in teams, inspect and adapt cycles, as well as continuous customer involvement (Baham and Hirschheim, 2022).

Currently, there are various agile methods in use (Edison *et al.*, 2022), of which Scrum (Schwaber and Sutherland, 2020) is the most popular (Komus and Kuberg, 2020). Weiss *et al.* (2023), Michalides *et al.* (2022) and Komus and Kuberg (2020) note that agile methods are also being applied in areas of physical product development such as automotive. In the study by Michalides *et al.* (2022), participants from a variety of industries estimated the benefits of agile physical product development in a quantitative survey. The improved communication within the team, the increased responsiveness, the increased transparency within the organization and the increased flexibility to be able to react to changes proved to be particularly advantageous. Scharold *et al.* (2023) also highlighted **beneficial aspects** regarding the quality of collaboration at team level in automotive industry.

In addition to the benefits, the study from Michalides *et al.* (2022) also analysed the **challenges** associated with implementing agile development. In particular, social challenges were identified, such as the loss of power and control by managers. When scaling agile, they found that synchronization, interdependencies in collaborating and coordinating are the biggest challenges. Researchers such as Hohl *et al.* (2016), Katumba and Knauss (2014) have focused on occurring challenges in agile automotive development but their research primarily centred on the software domain. Challenges they identified include process dependencies, long communication chains, task switching, hierarchy in the organization, and limited acceptance for organizational restructuring are challenging. Steghöfer *et al.* (2019) confirm that the **organization** can also be perceived as a barrier. They mention organizational flexibility as a factor that affects ecosystems, change management, and way of working. When encountering challenges, it is important to consider how to enable a successful agile transformation. Stelzmann *et al.* (2010) analysed factors that help projects succeed in becoming agile. The study identified 15 **success criteria** such as team and inter-team organisation, synchronisation of sprint cycles with general organisation control cycles and software and hardware development coordination and collaboration.

3. Research design

We collected empirical data by conducting an online survey, covering qualitative data collection and analysis methods only. The investigation was based on our overarching survey (see Weiss *et al.* (2023)), which deals with agile development of physical products in mechatronics. Relevant topics of the study were the exploration of benefits, barriers to adoption and impact of the transformation, measurability of success, and the application of Scrum.

However, the data presented here relates solely to the automotive industry and especially large companies were among the participants. Three questions out of the overarching survey (Weiss *et al.*, 2023) matter for the paper at hand:

1. Question: #14: "In what time frame were the following benefits achieved through the use of agile methods?"

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2. Question: #12: "Looking back, how challenging was it for your company to implement agile product development?"
3. Question: #24: "To what extent do you agree with the following statements regarding your organization (-al structure)?"
4. Question: #29: "When implementing agile development in your organization, to what extent have the following measures been successful?"

For question 1, we had a set of eleven partial values which can be found in Fig. 1, whereas the six partial values for question 2 are shown in Fig. 2. The four partial values for the third question are visualised in Fig. 3. Six partial values we asked for the last question are shown in Fig. 4.

The German-speaking region was the study's area of interest and in total, 53 practitioners from the automotive realm participated. We also requested demographical data in terms of the respondent's position, firm size, and the progress in using agile methods in hardware development (see Table 1).

Table 1. Sample demographics

Company size (number of employees)	***n***	***%***
1.000 - 4.999	2	4
5.000 - 9.999	3	6
10.000 - 49.999	22	41
> 50.000	26	49
Position		
Developer	6	11
Department Lead	13	25
Team Lead	13	25
Agile Coach	21	39
Progress of agile transformation		
Started	36	68
Advanced	15	28
Completed	2	4

We drew on the extensive preliminary work of Rohrmann (1978) and Bühner (2021) in order to present response scales that are as equidistant and unambiguous as possible with regard to the assessment of intensity, probability and agreement. For minimizing our influence on the participants' answers, we randomized the order of partial values for each participant. The participants should evaluate the first question based on different time spans, namely: "6 months"; "1 year"; "2-3 years"; "4-5 years"; ">5 years" and "no benefit". The challenges in question two could be ranked as "no challenge"; "low"; "medium"; "high" and "very high". Concerning question three and four, the participants were able to claim their agreement based on a 5-point Likert scale. Each question also had an N/A answer option which were used by some participants for only some values. We removed those single ratings and adapted the total number of participants for the corresponding partial value. The survey was published via different channels. The link to the survey was distributed via VDI newsletter. The VDI (Verein Deutscher Ingenieure) represents the interests of engineers in Germany. The link was also posted and shared on LinkedIn and emailed to personal contacts.

4. Findings

In Figure 1 to 4 the questions presented in section 3 can be found in chronological order. The time periods in which the success of agile methods can be expected in different categories are shown in Figure 1.

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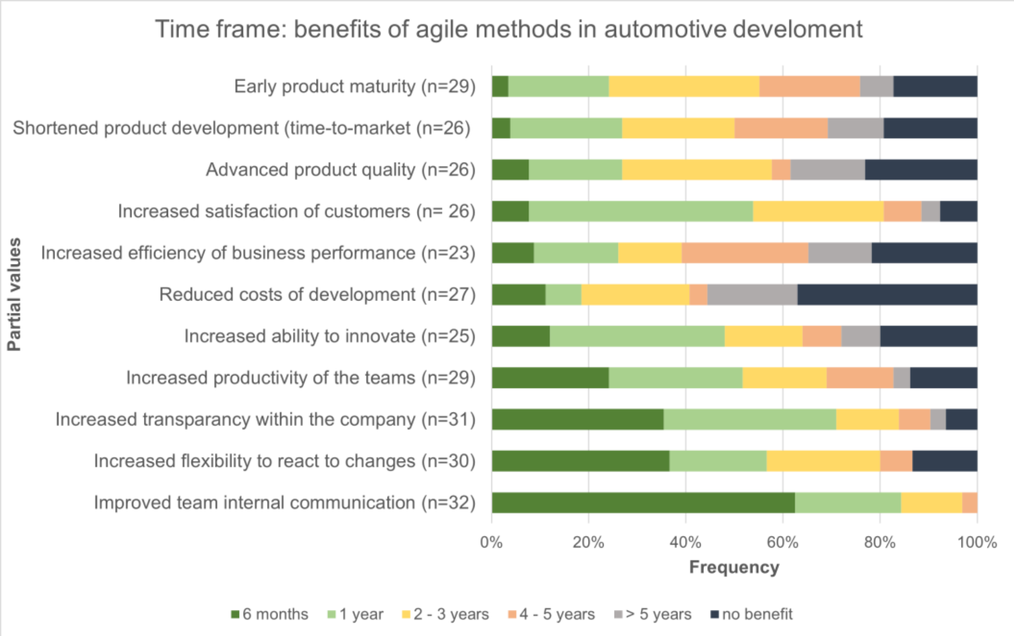

Figure 1. Benefits and their time frame in agile automotive development

Nearly 63% of respondents agree that their team internal communication improves within 6 months. All respondents acknowledge a benefit in this aspect, despite variations in ratings up to a maximum period of 5 years. Some voices disagree with the benefit for all other partial values. After 6 months, increased flexibility in reacting to changes is also observed (37%), as well as an increase in transparency throughout the company. There is no clear trend as to whether the latter is the case after 6 months (35%) or a year (35%). Primarily, increased productivity of the teams (28%) and an increased ability to innovate (36%) are to be expected after about a year. The idea that a benefit will be realized with reduced development costs is rejected by a majority of respondents (37%) or is considered to be the case only after more than 5 years. Increased efficiency of business performance can typically be expected after 4 to 5 years, while increased customer satisfaction can often be seen after just one year. Ultimately, improved product quality (31%), a shorter time-to-market (23%), and earlier product maturity (31%) can be expected around 2 to 3 years, with some respondents noting a benefit in time-to-market after just one year.

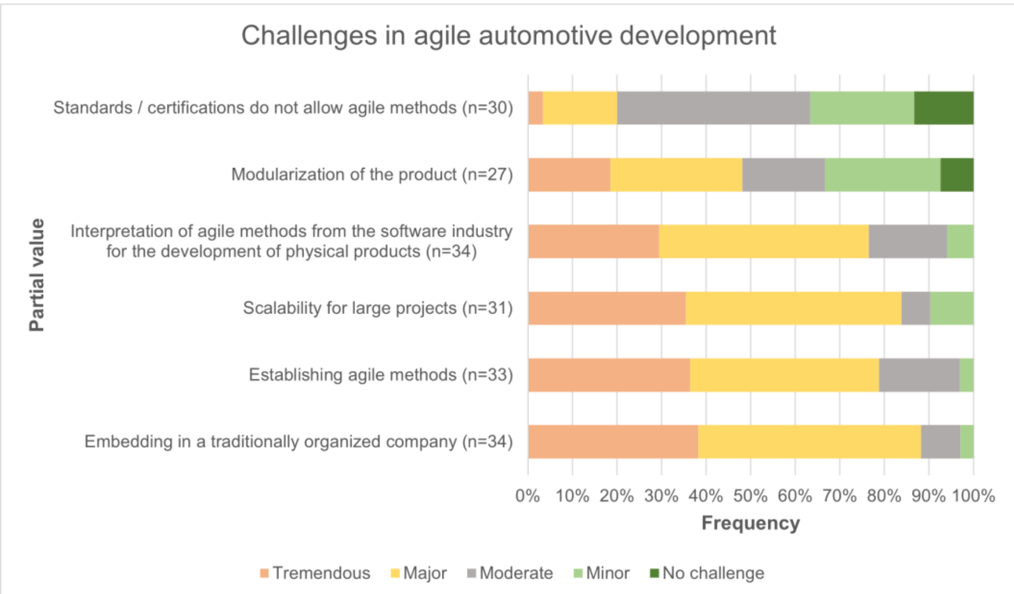

Figure 2. Challenges in agile automotive development

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Figure 2 displays the challenges examined in agile development in the automotive sector. Except for the aspect that standards / certifications do not allow agile working methods, the respondents see a major challenge in the areas of embedding in a traditionally organized company (50%), establishing agile methods (42%), scalability for large projects (48%), modularization of the product (30%), and interpreting agile practices from the software industry for the development of physical products (47%). Standards and certifications are commonly seen as moderately challenging. It is noteworthy that the aforementioned aspect (13%) and the modularization of the product (7%) do not represent a challenge for a small proportion of respondents.

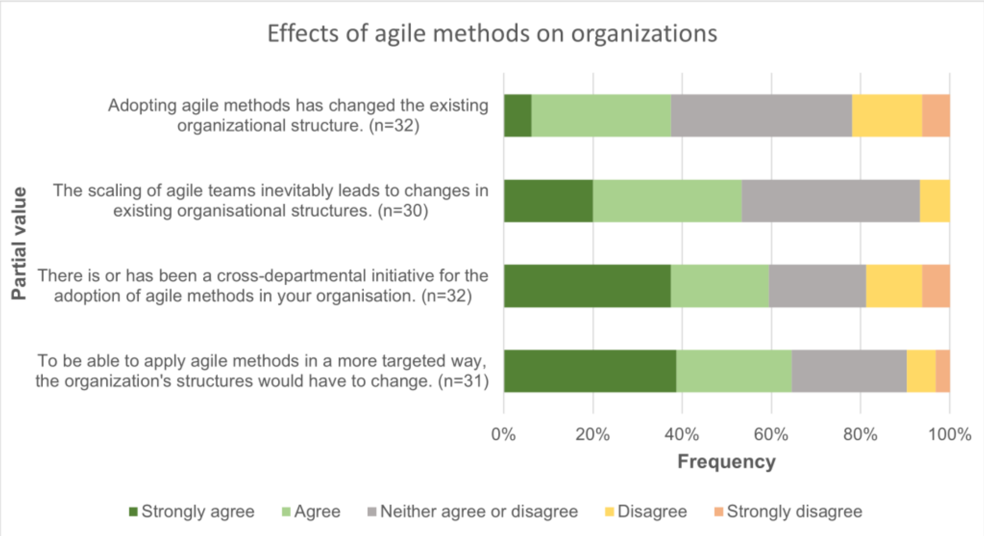

Figure 3. Effect of agile methods on organizations

39% of participants strongly agree that organizational structures would have to be changed in order to apply agile methods more effectively. Additionally, 38% of respondents in the online survey reported a current or past cross-departmental initiative to adopt agile methods within their organization. In general, 53% of participants agree that scaling agile teams inevitably leads to changes in the organizational structure, with 40% neither agreeing nor disagreeing. 41% of respondents are neutral about whether the adoption of agile methods has led to changes in the existing organizational structure. Nevertheless, a total of 37% agree with this aspect.

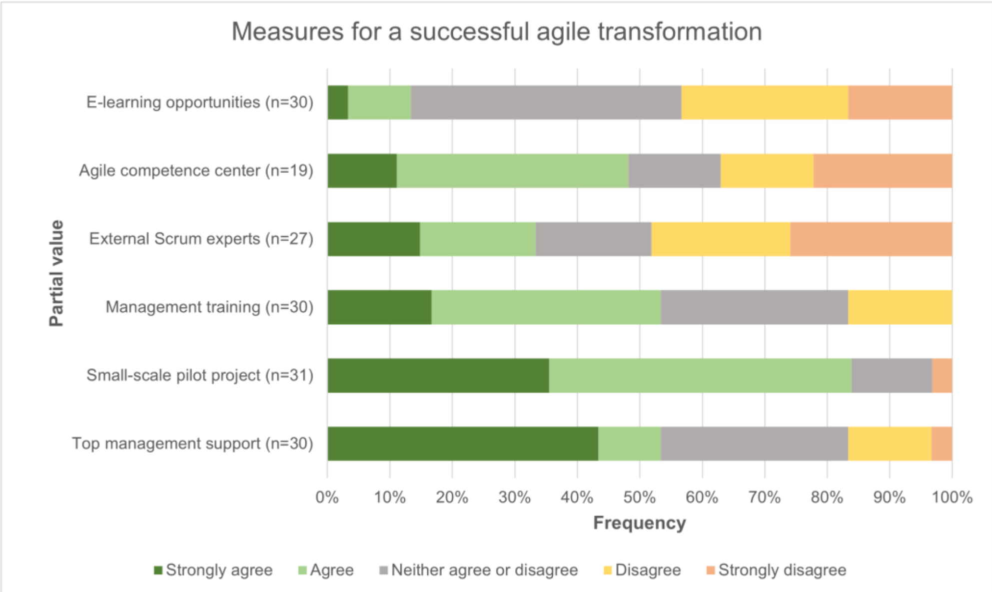

Figure 4. Measures for a successful agile transformation in automotive development

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Figure 4 illustrates whether the assessed aspects have proven to be successful measures for the implementation of agile development. The survey results indicate that top management support is particularly important, with 43% of respondents agreeing with this statement. Small-scale pilot projects received an 83% strong agreement. Additionally, management training appears to be a successful measure as the combined agreement rate for it stands at 54%. The results for external Scrum experts display a range of differences without definite patterns. Regarding the agile competence center, 48% of survey participants agree or strongly agree that this measure is beneficial. However, e-learning opportunities are typically rejected (44%) or seen as neutral (43%).

5. Discussion

Figure 1 demonstrates the short-term advantages of agile automotive development, specifically in terms of collaboration. Improvement can be observed in team internal communication, productivity, and transparency within the company. These advantages provide a foundation for other beneficial effects. Nevertheless, certain aspects reveal a more nuanced perspective, such as the increased efficiency within the company. However, the study specific to agile at automotive by Vollus *et al.* (2020) indicates that agility positively impacts business performance. The findings of their research show that benefit perspectives cannot all be realized simultaneously. Instead, a staggered time sequence emerges, leading to means-ends relationships between the individual aspects. Although Schmidt *et al.* (2018) and Stelzmann's (2011) work primarily focuses on agile physical product development, it also highlights the presence of means-ends relationships. It remains uncertain whether benefits will occur at all or only after a certain period of time for individual respondents. Notably, some respondents described the beginning of agile transformation within their companies (see Table 1), making it premature to offer well-founded statements regarding the timelines for potential benefits. Additionally, assessments were conducted by different groups of individuals such as developers and agile coaches.

Several challenges arise in agile vehicle development. The paper explores these challenges, which are primarily of an organizational nature. Embedding agile methods in organizations that follow the stage-gate or waterfall model is particularly difficult. This also is true for the establishment and sustainable implementation of agile development. The successful implementation of agile methods is closely tied to the organizational structure; however, the employees' mindset plays a pivotal role. The way agile practices are interpreted within the software environment is directly linked to this factor. Notably, users acknowledge that agile methods must be tailored when applied beyond software development and that the scalability for large projects is intrinsically connected. Overall, this highlights the pervasive nature of agile development. If the aspects considered are applied to the agile development of physical products without reference to a specific industry, Weiss *et al.* (2023) come to the same conclusion. The challenges of agile physical development were first explored by Ovesen (2012). The problem of paradigm perplexity is the focus of the organizational aspect. The aforementioned challenges persist as obstacles for the past 12 years and don't seem to have been resolved.

In terms of the organization, most respondents agreed that a more specific adaptation of agile methods would require a restructuring of their organizations. This future-oriented statement highlights both the organizational challenges and the need to break down traditional structures. As stated in section 2, organizational flexibility becomes crucial (Steghöfer *et al.*, 2019). Furthermore, the interviewees reported retrospective changes in the pre-existing organizational structures due to scaling agile teams, which inevitably causes a change in structures. Accordingly, the dissolution of paradigm perplexity (Ovesen, 2012) currently appears to be an important topic in the automotive industry. This is particularly true as most respondents reported implementing or planning to implement cross-departmental initiatives to introduce agile methods in their organizations.

Top management support and training for managers have proven to be especially helpful in successfully implementing agile methods. The introduction of new roles, such as Agile Master or Product Owner, has caused the interpretation of responsibility to shift. As a result, the decision-making structures have moved away from a command-and-control model to one in which teams organize themselves. A mindset shift is vital in this regard as well. Moreover, pilot projects have been shown to be particularly effective on a small scale, while e-learning opportunities have tended to be rejected. The results demonstrate that both top-down and bottom-up approaches are equally beneficial for successfully introducing agile methods.

6. Conclusion, limitations, and future work

The paper at hand explores the current advantages, challenges, organizational adjustments, and measures for successfully transitioning to agile development within the automotive industry.

In terms of the timeframe for reaping the benefits of agile automotive development, it was found that soft factors, such as improved communication within the team, increased flexibility in responding to changes, and increased transparency within the organization, were evident after just 6 months. In the intermediate term, benefits in terms of improved customer satisfaction may be observed within 3 years. It may take a minimum of 5 years to observe a boost in business performance efficiency. Time, cost, and quality are contributing factors that need to be differentiated. With agile methods, the majority of respondents do not see a benefit for reducing development costs for more than 5 years, and some do not see a benefit at all. There is significant uncertainty about the timing of benefits for reducing time-to-market and improving product quality. The findings of this research show that there are dependencies in the benefits of agile automotive development that need to be further explored.

Respondents considered the greatest challenges to be embedding agile methods in traditionally organized companies and establishing agile methods in general. The respondents also viewed comprehending methodologies derived from the software industry as a difficulty. It is therefore not surprising that scalability to large-scale projects was also seen as a challenging aspect. Accordingly, the challenges primarily relate to organizational adjustments and are also based on the employee's mindset.

The study also analysed the impact of agile development on organizations. The results indicate: To effectively implement agile methods, the majority of respondents believe that organizational structures need to be restructured. The scaling of teams also necessitates adjustments. Certain companies are already making the transition to agile development across departments and have already adapted their organizational structures. None of the organizational aspects were disagreed with, suggesting that the adoption of agile methods is having an impact on the structure of organizations in the automotive sector, both retrospectively and in the future.

The most effective measure for implementing agile development was small-scale pilot projects. Furthermore, top management support and management training also received a high level of agreement. These measures are therefore identified as key enablers for the implementation of agile automotive development. Agile competence centers provided valuable assistance as well, while external Scrum experts or e-learning courses were not found to be helpful.

There are limitations to this study that need to be acknowledged. Firstly, despite the wide distribution of the survey, only a limited number of people responded. Secondly, only German companies in the automotive industry were surveyed, hence there are cultural limitations. Additionally, the sample is limited in that the respondents were primarily managers and agile coaches. Therefore, it is recommended that future research focus on a larger and an international sample. Furthermore, the assumed means-ends relationships in the realm of benefits need to be evaluated in more depth, as well as aspects of mindset. In terms of challenges, the other challenges of Ovesen (2012) should also be further explored in the context of automotive development, and the impact on the organization should be better understood.

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