Navigating the Hybrid Landscape: A Literature Study on Hybrid Development Approaches for Physical Products

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Abstract: Hybrid development approaches promise to entail the advantages of both agile and traditional techniques. Still there is no consensus on how a combination can look like and therefore a lot of variants and interpretations of hybrid can be found in literature. This paper presents a list of 23 development approaches and suggests criteria for categorizing the findings. This should enable a proper discussion on defining hybrid and how a combination of agile and traditional techniques can look like in the future.

Keywords: Product Development, Hybrid Development Approaches, Hybrid Models, Agile Development

1 Introduction

In order to respond to today's demand for more flexibility and innovation companies must be able to balance the specific characteristics of their environment and projects (Copola Azenha *et al.*, 2021). Ambiguities, uncertainties, interdependencies among activities, results, people and tools, which all make the development process complex and challenging have to be considered (Browning and Ramasesh, 2007; Kline, 1985). Project execution is affected by the size of a company and its level of maturity in project management, technological uncertainty, the degree of innovation, the scope of the system and the size of the development team (Boehm, 2004; Project Management Institute, 2013; Shenhar and Dvir, 1996; Turner and Ledwith, 2018). As every project is unique, they still share common features and elements, which are picked up by researchers and formed into different kinds of practices to support project management and the process of developing a product (Smith and Morrow, 1999). Those practices can appear for example in the shape of a process model, a development method or a tool for project management that can be assigned to an agile or traditional paradigm. Depending on the context and a projects environment, a company and/or a project manager has to decide, whether a project should be executed following the agile or the traditional paradigm. But study cases show that the adaption of pure agility outside the context of software development have reached their limits. Reasons are the peculiarities and needs of the organization, the lack of necessary documents and difficulties in measuring progress (Bianchi *et al.*, 2022; Heimicke *et al.*, 2020). Some researchers and companies have realized that adopting agile methods does not necessarily mean to abandon traditional development techniques and combining the two is a feasible way to overcome current challenges (Heimicke *et al.*, 2020; Žužek *et al.*, 2020). A hybrid approach would be able to promote flexibility and productivity while satisfying corporate policies and procedures and would therefore be very beneficial to overcome challenges by combining the advantages (Binder *et al.*, 2014; Cooper, 2016). Traditional aspects provide an overview over the projects main phases and guide developers and managers by recommending required activities and expected deliverables for each phase. Agility is used to motivate teams by enabling them with more influence. Deliverables are leaner and more flexible and are physical prototypes rather than reports or slide presentations (Garzaniti and Golkar, 2020). However, there are several challenges that have to be addressed proposing and applying hybrid developing approaches. One Challenge is to find the right balance between agility and discipline. Then there is the challenge of choosing and adapting the right model, because of the high number of existing propositions (Bianchi *et al.*, 2022; Boehm, 2004). There is literature that can be found administering the problem of gathering and organizing existing hybrid approaches. Heimicke *et al.* (2020) present a list of hybrid approaches, where they outlined main characteristics and benefits. The list contains of 25 different approaches while most of the findings can be located in the field of software development. Cocchi *et al.* (2023) analyzed iterative methodologies that were integrated into the stage-gate process and propose a set of categories to classify the found approaches.

The aim of this paper is to display, compare and categorize existing proposals for hybrid approaches in the field of physical product development in order to enable a proper discussion as to how a combination of agile and traditional practices can look like and to fill the gap that is left between the research of the above mentioned literature.
This leads to the following research questions:

RQ1: Which hybrid approaches for the development of physical products exist in the literature?

RQ2: How can the approaches be categorized?

2 Study Design

In order to answer the research questions, a literature survey was performed by scanning the online database Scopus. The search for relevant literature was focussed on Scopus as this database covers the majority of relevant publication organs in the relevant thematic area. The aim was to identify papers that propose a method combining agile with traditional development methods, or the integration of an agile approach in the plan-driven development process. Figure 1 illustrates the selection process using the PRISMA flow diagram (Page *et al.*, 2022). Only English and peer-reviewed papers were included, book chapters were excluded. The search strings used were 'agile hybrid product development' (111 documents), 'agile hybrid project management' (108 documents) and 'agile hybrid process model' (143 documents). The results were limited to the topics 'engineering and management'. It is also important to note that the focus lay on the development of physical, hardware and mechatronic products and therefore any research concerning software development was also excluded. After reading the abstracts 54 research papers were identified as relevant for this study and were analyzed in detail to answer the research question.
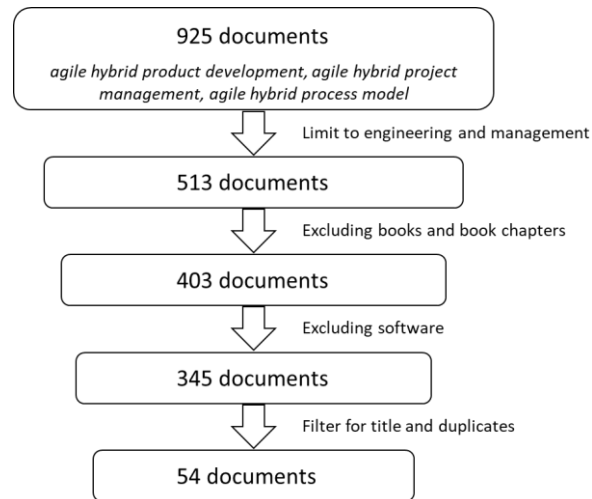

Figure 1. Selection process of the cunducted systematic literature review

3 Findings

Based on the 54 documents revealed through the systematic literature review, a total number of 23 hybrid development approaches were found to be described in the analyzed research papers. They have been published between 2014 and 2023 and can be organized into five groups: (1) Organizational structure, (2) Framework for modelling or choosing an individual hybrid process model, (3) Situational Agility, (4) Agility in specific project phases and (5) Hybrid process models.

3.1 Organizational structure

Agile methods and techniques cannot simply be implemented into a company from one day to the other. For example, one of the core agile principles are dedicated teams. Traditionally, developers and project managers are involved in several projects at the same time. So in order to allow team members to be 100% dedicated to just one project and enable agile ways of working in general, the overall organizational structure has to be reorganized.

Brandl *et al.* (2018) suggests a Hybrid Framework for MIM (Manufacturing Innovation Management) which shows a structure of prerequisites to enable a more agile project management approach. It demonstrates available possibilities and supports decision making. The framework works as an agility assessment system. It evaluates whether a new development project should rather be managed traditionally or if an agile procedure is more reasonable (Brandl *et al.*, 2018).

Atzberger and Dethloff (2023) introduce the Hotdog Model, which presents a possibility to organize teams. The system facilitates organizing teams that consist of experts from different disciplines (e.g. mechanical engineering, electronic engineering,…) with the support of product owners and „Agile Masters" (Atzberger and Dethloff, 2023).

3.2 Framework for modelling or choosing an individual hybrid process model

The approaches belonging to the category framework for modelling or choosing an individual hybrid process model address practitioners' need for assistance in choosing the right hybrid process model for their specific organization or even for a single project considering the project environment and characteristics.

Klein and Reinhart (2016) propose a vertical agile approach where mechanics are developed following mainly a traditional approach while software and electronics are developed simultaneously and agile. The mechatronic reference model by Drescher et al., 2014 serves as the universal development process consisting of a broad set of engineering tasks, which are then selected, prioritized and executed by the engineering team. A domain mapping matrix supports designers by presenting possible combinations and assists in choosing the right techniques for specific planning steps (Klein and Reinhart, 2016).

The Adamo Modeller by Schmidtner et al. (2020) supports companies creating an individual hybrid process model based on different context parameters (Schmidtner et al., 2020).

The framework for the construction and tailoring of engineering development process model (FELICS) assists the development of an individual process models incorporating functional elements, collaborational elements and support elements (methods and tools). It is limited to a combination of PMBoK of the PMI, ICB 4.0 of the International Project Management Association, PRINCE2, International Standard ISO 21500 Guidance on Project Management, Scrum and Kanban (Timinger et al., 2022).

Based in the SIMOC method Konigbauer proposes an adaptive reference model for the creation of an individual process model by choosing from a range of methods. The methods are building blocks that make up the process model which are ranked and therefore proposed for different phases and process steps (Konigbauer, 2021).

The hybrid model radar by Cocchi et al. (2023) compares variables across several hybrid models. Radar supports managers in evaluating the proposed dimensions and in choosing the best suited hybrid model. It also highlights the need to adopt the model to the project based on contingencies (Cocchi et al., 2023).

3.3 Situational agility

Four methods that propose agile working techniques in specific situations during the development process were found in the analyzed papers.

Schuh et al. (2018) present a list of guidelines for the application of traditional and agile methods. They differentiate between a macro perspective (organization level) and a micro perspective (team level). They suggest approaches to overcome challenges during designing and managing a project, e.g. alignment and collaboration between traditional and agile teams. Practitioners are enabled to come up with the right tools and measures to successfully design and execute hybrid projects (Schuh et al., 2018).

Scrum++ by Plateaux et al. (2020) proposes agile working techniques in different aspects of the process, e.g. requirements management (Plateaux et al., 2020).

Zasa et al. (2020) suggest possible corrective actions to address challenges that come up when integrating agile into stage-gate (Zasa et al., 2020).

Gabriel et al. (2021) present an agile toolbox that consists of 50 agile practices (roles, artefacts, events, values and techniques). First, an initial situation is being analyzed that reveals specific challenges. After that, agile practices from the toolbox are selected and matched to the challenges detected. The agile practices are then integrated into the existing development process (Gabriel et al., 2021).

3.4 Agility in specific project phases

The ACPM model (Agile Crisis Management) can be integrated into a traditional development process and sets in when needed. It is characterized by an active inclusion of key external and internal stakeholders, small steps and visible results and intensive communication. It is an adaption of the agile concept with regard to its effects and enables fast and efficient handling of changes in late project phases. The economic owner functions as the actual owner and a successful cooperation of the key stakeholders has a great impact the success of the programme (Čelesnik et al., 2018).

The MUD method (misalignments users-designers) aims at overcoming misalignments between the designers' and the users' perspective. It integrates the discipline, rigor and linearity of traditional (stage-gate) methods with the hierarchical structure of the means end chain approach to gain analytical insights which are derived by analyzing, comparing and identifying (mis)alignments between the designers' top down incorporation and the users' bottom up abstraction process. The proactive, reflective and learning-oriented perspective that can be found in agility is used to gain strategic insight (Granato et al., 2022).

3.5 Hybrid Process Models

3.5.1 Vertical Process Models

One example for a vertical hybrid process model is the Industrial Scrum Framework, which is organized into three levels of project management. The first level covers product portfolio management and the steering committee where a strategic project management with consideration of company specific stages and gates is proposed. The second level is the tactical planning level between product development teams and the operational organization where value chains and the project portfolio are coordinated. On this level, stakeholders from across the organization meet periodically to coordinate resources using a visual method. The third level inhibits project execution and the development teams which are supported by a project manager using Scrum methods (Sommer *et al.*, 2015).

Feldmuller (2018) proposes a vertical model that integrates different disciplines each following different approaches, e.g. software aspects are managed agile and mechatronic components are managed traditional. Synchronisation across the different layers in this model is foreseen before each quality gate, by exchanging information between disciplines (Feldmuller, 2018).

The Hybrid Agile Product Development Process is also a kind of vertical approach with a three-layer architecture. There are multiple project participants that are operating with their own product development process, which can be agile or traditional. It is divided into a consortium layer which is most likely managed traditionally, an organization layer which is agile and in between there is a coordination interface. Each organization defines their work packages and minimum viable products autonomously (Garzaniti *et al.*, 2019).

3.5.2 Horizontal Process Models

Horizontal process models can further be grouped into four categories. The four categories presented here are based on research by Cocchi *et al.* (2023) who separated nested hybridization from handed-over hybridization. Nested hybridization (agility within) results out of the prevalent perception of traditional approaches being most useful on a macro level whereas agile working techniques are more suitable on a micro level (Bianchi *et al.*, 2020; Conforto and Amaral, 2016; Cooper and Sommer, 2016; de Vasconcelos Gomes *et al.*, 2021). The respective hybrid approaches consist of agile techniques that are embedded into a traditional framework. Handed-over hybridization represents approaches where certain phases of a development process are executed *either* agile *or* traditional. Cocchi *et al.* (2023) distinguish between developing iteratively before transferring into traditional development and the other way around. This research revealed a third strategy where pure agile proceeding takes place in between traditional development. The categories are presented in Figure 2.
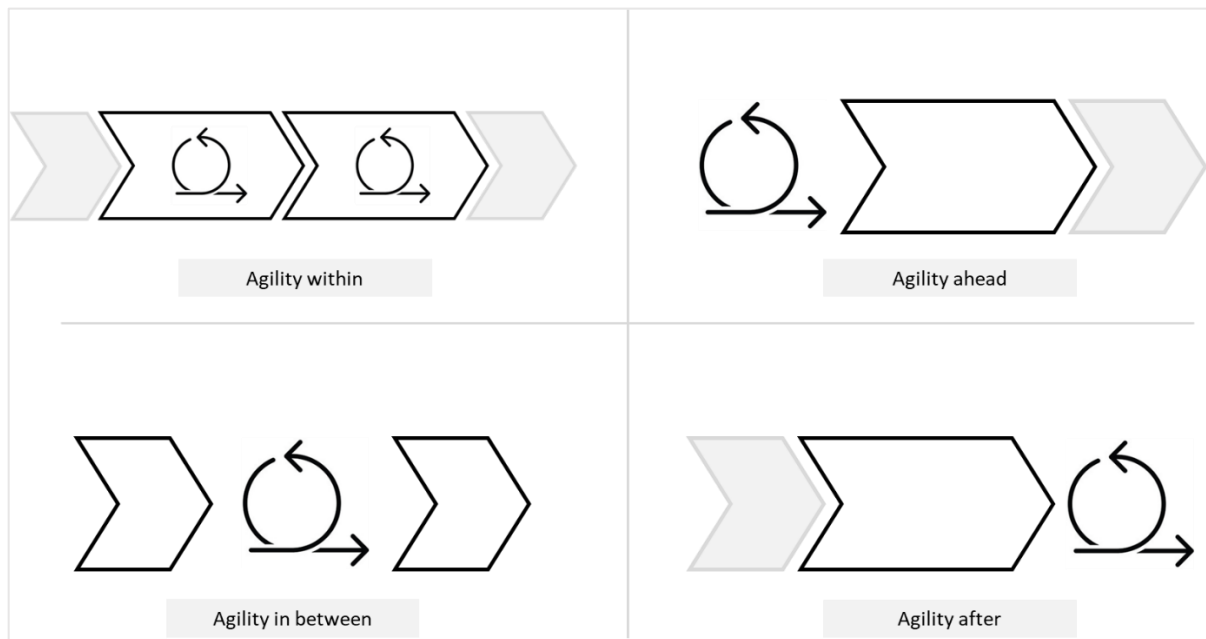

Figure 2. Horizontal hybrid process models, based on *(Cocchi* et al.*, 2023)*

The greatest number of hybrid process models falls into the category agility within.

The Cocktail-Model (Binder *et al.*, 2014) suggests how agile principles can be integrated into the ISO 21500. Agile principles are used to adapt the ISO process and similarities are highlighted. The result is a simplified process where unnecessary aspects are left out and other processes are merged.

Another hybrid process model is the Triple A or Agile-Stage-Gate Model (Cooper, 2014). The model incorporates spiral or iterative development and represents a fast-track version of a process for lower-risk projects. It is characterized by context-based stage definitions and activities, flexible go/kill criteria and dedicated teams. The improved version (Cooper and Sommer, 2018) proposes an agile way of working within stages while the highest intensity of agility is supposedly during development and testing. Traditional management tools like Gantt-charts, milestones and critical path planning are replaced with agile tools and processes.

IVPM2 (iterative and visual project management method) combines different concepts from new product development and agile project management. It comprises of five dimensions, seven stages and three levels. The five dimensions are a phase and project deliverable model, project planning and controlling, weekly activity planning, project management and a performance indicator system. The three levels are stage-gate, sprints (iterative development) and an iteration plan that is carried out on a weekly or daily basis. The seven stages cover (1) the beginning of a project, where main phases and deliverables are defined, (2) definition of iterations and length, (3) registration of deliverables, (4) detailing deliverables into activities and tasks (5) stand-ups, (6) performance reports and (7) decisions to improve the process and discussion of upcoming risks (Conforto and Amaral, 2016).

Žužek *et al.* (2020) recommend an agile-concurrent hybrid process model where scrum is integrated into the concurrent development model in order to increase flexibility and responsiveness to changes. The concurrent development model remains unchanged and provides a formal structure of the process. The track-and-loop principle is applied to overlapping stages while a changing team composition adjusted to the loop is preserved (Žužek *et al.*, 2020).

Conforto (2009) proposes a model for companies that intend to scale agile to large projects. In this model, agility is considered as a microplanning technique and combines processes, techniques, and practices of traditional and agile approaches, such as personas and the product backlog. It contains robust documentation while planning is precise. The focus of control lies in initial and final phases of the project (Conforto, 2009; Copola Azenha *et al.*, 2021).

Mabrouk *et al.* (2018) present a way to integrate Scrum into the MBSE methodology (model based systems engineering). Their model covers three main aspects, which are the black box analysis, the physical prototype increment and a white box analysis. The black box analysis results in a complete and coherent set of requirements, which represents the product backlog. The white box analysis enables building a physical architecture of the system. All the activities in between are carried out using Scrum and at the end of each sprint a physical prototype shall be realized (Mabrouk *et al.*, 2018).

One example for "Agility ahead" is a hybrid development process from Mule *et al.* (2021), where Scrum dominates the first half of the V-Model. The product development process is divided into the three phases product architecture design, module design and prototyping with testing. The first two phases are carried out iteratively, the third traditionally and the output of one phase is the input for the next phase (Mule *et al.*, 2021).

Up to this point there were no hybrid process models found in the field of physical product development that proposed a model according to the category "Agility after". Still there are companies implementing such a development process which can be seen in case studies, e.g. (Rehder *et al.*, 2023).

4 Discussion and Conclusion

This paper presents a systematic literature review on hybrid development approaches in the physical product development industry. 54 papers were selected from a list of 362 contributions. The analyzed papers were published between 2014 and 2023 and a total number of 23 concepts for hybrid approaches were identified. The main characteristics of the hybrid approaches were investigated in order to find a way to categorize and compare them.

First of all, what can be retrieved from the literature study is a broad spectrum of methods, frameworks and models that all run under the term "hybrid" approach. The high number of variations show that there is still no general consensus as to how a combination of traditional and agile product development can look like and that research is still in its an early stage. It can also mean that the term "hybrid" is formulated too broadly and needs further specification in order to form a common basis for discussion to avoid misunderstandings.

While not being consensual, the approaches still have similarities. The similarities and differences made it possible to organize the proposed hybrid approaches into five categories reaching from the organizational structure of a company to detailed plans for modelling the product development process. The latter can further be subdivided into vertical and four variations of horizontal process models, which fits well into the findings by Cocchi *et al.* (2023).

There are hybrid approaches that address project management as well as approaches that administer product development whereas product development is represented more often. The majority of the analysed proposals use a traditional approach as a framework and "fill the gaps" using agile techniques. Agility is used to improve certain aspects of the development process, to find solutions for specific problems or to enable a quicker and more flexible development. This is an evident strategy, because traditional approaches are more prevalent in companies and there is still some reluctance towards agility because of its divergent philosophy and disciplinary barriers (Cocchi *et al.*, 2023).

Within this research no hybrid concept was found where an agile approach was used to serve as the framework with only selected traditional aspects for an improvement. The most frequently represented traditional approach is the stage-gate process model by Cooper and selected aspects of the Scrum framework were used to enable agility, because Scrum is said to inherit the greatest potential affecting physical product development (Cooper and Sommer, 2018). Still there are other concepts that are based on other traditional methodologies such as the V-Model (VDI2206, 2006) or the mechatronic reference model by Drescher *et al.* (2014).

The hybrid variations differ from each other in their degree of maturity. Some are very detailed, validated through case studies and further developed into revised versions (e.g. (Cooper, 2014)) while others are just an idea of a concept (e.g. (Zasa *et al.*, 2020)). In between there are approaches with only partial statements as to which projects are suited best or which context factors foster a hybrid approach. Some contain benefits and possible obstacles when using the proposed approach and only some support their statements with study cases.

No matter the level of maturity the hybrid approaches have, project managers still need to decide whether it is suited for a certain project and need to adapt it to the project's context and environment. Only some of the propositions offer recommendations what circumstances encourage a hybrid approach and suggest necessary adjustments. This literature study shows a way for combining different approaches with the help of the proposed categories. It also shows that hybrid product development is multidimensional. It occurs on different levels and addresses different facets. As a result, companies must identify the drivers that indicate the facet of product development they want to redesign to then use the categorization as a first step to choose the appropriate hybrid approach.

During this research paper inclusion and exclusion criteria were listed to ensure transparency and validation of the study, because despite most diligent research, this paper is not without limitations. Potentially relevant studies may have been neglected that propose a hybrid approach without explicitly naming them as such.

Future research should further concentrate on case studies evaluating the hybrid approaches found in the literature to emphasise their benefits and to pave the way for companies integrating hybrid methods and process models into their organization.

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