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Agile versus Waterfall Project Management: Decision Model for Selecting the Appropriate Approach to a Project

Theo Thesing[a], Carsten Feldmann[a]*, Martin Burchardt[b]

[a]*University of Applied Sciences Munster, Corrensstr. 25, 48149, Germany*
[b]*evonade GmbH, Seestrasse 40,6442 Gersau, Switzerland*

Abstract

Procedural models for project management can be differentiated into plan-driven methods which follow a classical waterfall process and agile methods which follow an iterative, test-driven approach. This paper answers the following research questions: What are the differences, benefits, and constraints of these two approaches from a practitioner's point of view? How can a decision model be set up to select the most appropriate approach for a concrete project? This study develops a decision model for the selection of a procedural model for project management which is based on the modelling process described by Adam (1996). The research gap was identified based on a systematic and comprehensive analysis of the literature following Vom Brocke et al. (2009), which reflects the state-of-research. Insights gained were compared with empirical data from 15 expert interviews across different industries in Germany. The presented model systematically supports the selection of an appropriate procedural model for a concrete project based on 15 criteria subsumed under the following categories: scope, time, costs, organization context, and project-team characteristics. It closes a relevant research gap, both from a scientific perspective and from the practitioners' view. Expert interviews ensure practical relevance and significantly expand the state-of-research with regards to decision support on the project-management approach.

* Corresponding author. Tel.: +49 251-83-65404
E-mail address: carsten.feldmann@fh-muenster.de

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1. Introduction

Rapidly changing market conditions, new technologies, short time-to-market cycles and many other factors of the social and business world influence how projects are managed [1]. Different types of projects require different procedural models for successful execution. A *procedural model* organizes the methods and tools of project management into project phases or processes in a standardized manner. Procedural models for project management can be roughly divided into (1) plan-driven methods. which follow a classical waterfall process; and (2) agile methods (such as Scrum and Kanban), which follow an iterative, test-driven approach [2, 3, 4]. In *classical project management* following a *"waterfall" process* of planning and execution, expected results are communicated relatively clearly by the client at the beginning of the project [5, 6]. So that the project can be "worked through" in a goal- and plan-oriented manner, it is planned holistically, from kick-off to completion, with work packages, responsibilities, and deadlines. The focus is on implementing the initial plan as precisely as possible. This provides stability and structure, predictable resources, and documented planning [2, 6, 7].

Having originated in software development [8], *agile project management* is used in a growing number of industries [9, 10]. Agile methods such as Scrum or Kanban do not focus on comprehensive advanced planning and the linear, exact "execution" of a plan [11, 12]. Instead, a project team develops a solution step by step and coordinates respective interim results with the customer in very short cycles [1, 2, 3, 4]. One reason for adopting this method is that the customer or user of the project result specifies general requirements but cannot specify these in detail in early project phases. On the other hand, the steps required to achieve the objectives may be unclear. The agile approach also defines goals or a vision for the project, but it does so at a relatively low level of detail and with a shorter planning horizon (e.g., two to four weeks) and less commitment. Flexibility in the case of change requests is more important than rigid adherence to the initial plan, as expectations regarding the result are concretized during project implementation [2, 3]. The project process is not linear in successive phases, as in the classical waterfall process. Rather, multiple iterations may be used to approach the desired result in a test-driven manner. Agile project-management methods provide flexibility in project management, thereby enabling companies to react quickly to changing customer requirements [3, 13].

Hybrid approaches are used to enrich the plan-driven process model with agile principles, thereby combining the advantages of both methods: The "big picture" is planned by means of a plan-driven waterfall process, but suitable subprojects are managed in an agile manner [2, 4, 9, 10, 14, 15]. Using high-frequency communication and short feedback cycles, subprojects take advantage of agile characteristics such as transparency and adaptability but follow the overall structure of a higher-level, classical project plan. The selection of a suitable procedural model to a project is often a major challenge for practitioners.

The aims of this paper can be summarized as follows: From a practitioners' point of view, what are the differences, advantages, and disadvantages of agile approaches versus plan-driven methods which are based on a classical waterfall process? How can a decision model be set up to select the most appropriate approach to a concrete project, given the insights provided by a comprehensive literature analysis and empirical primary data? Section 2 documents the literature-review process, provides an overview of the state-of-research, and points out the research gap to be closed. Next, Section 3 spells out the research methodology. Subsequently, Section 4 presents the empirical findings. Section 5 introduces the decision model. In the concluding section, Section 6, findings are summarized, implications are discussed for research and practice, and an outlook on future research opportunities is given.

2. State-of-research

Literature analysis was based on the approach of [16]. Six scientific databases (EBSCO, Emerald Insight, Disco, Google Scholar, ScienceDirect, Web of Science) were searched with a key-word matrix. Fifty-two relevant sources were selected based on the following criteria: currency, relevance, authority, accuracy, and purpose. The present studies are characterized by wide heterogeneity in terms of the applied analyses, the empirical database, and the

presentation of the results, so the findings are not strictly comparable. The practice-oriented research focuses primarily on the benefits and constraints of procedural models [17, 18, 19]. There are various studies on the dissemination and benefit of certain methods [20, 21]. Some provide general hints regarding the suitability of a procedural model based on general characteristics of a project [2, 3, 4] and give advice on the selection of methods and tools within a procedure model [22, 23], as choosing the appropriate procedural model significantly impacts the success of the project [24, 25]. Only one of the studies identified presents a model for decision-making and evaluation of advantages [26]. However, the empirical database remains unclear, and the result is only a list of criteria with which to support decision making.

The research gap can be summarized as follows: There is no decision model for practitioners that is based on desk research and primary data-collection and that supports the selection of an appropriate procedural model for a concrete project. Accordingly, two research questions were addressed:

RQ1: From a practitioners' point of view, what are the differentiating characteristics, advantages, and disadvantages of an agile approach (such as Scrum) versus plan-driven methods which are based on a classical waterfall process?

RQ2: Which procedural model fits which project: How can a decision model be set up to select the most appropriate approach to a concrete project?

3. Research methodology

3.1. Modeling process

The development of the decision model followed the modeling process developed by [27], as presented in Figure 1. First, an overall process model was created.

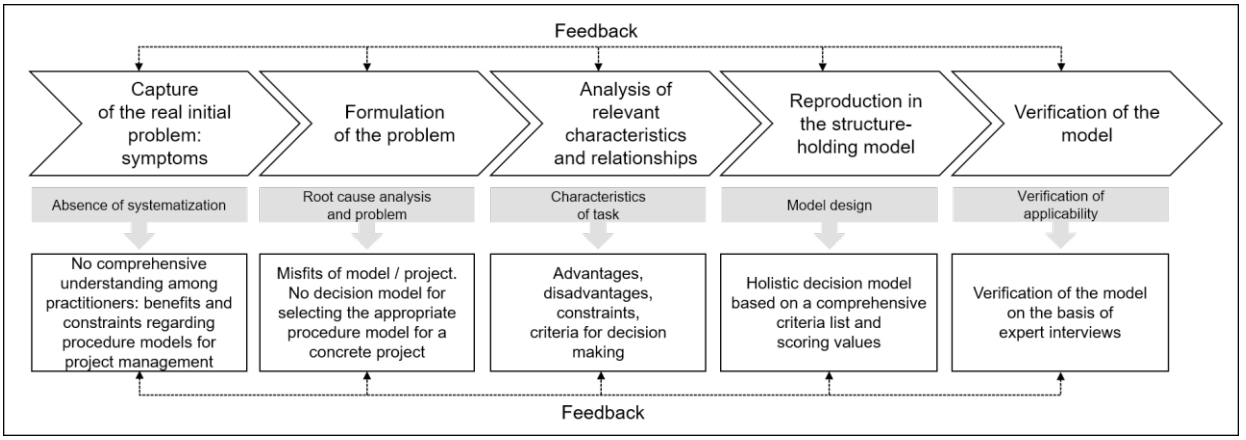

Fig. 1. Overall modeling process

In a second step, a decision model was provisionally established based on desk research and then further developed in a second step on the basis of 15 expert interviews. Modeling is a design process in which designers build a model according to user's needs [28]. The model should be suitable as a framework for decision-making in a suitable project approach by program and project managers. Prerequisites for applicability by the aforementioned target group are comprehensibility, simple applicability, and practical relevance.

The quality of a model shall be ensured by following the six *principles of proper modelling* developed by [29]. These principles are guidelines for the modelling of information systems which can be transferred to the modelling of the decision model as a methodological framework. The principles aim at clarity, consistency assurance, and quality. The principle of correctness requires that the model depicts the real world in its essential features. According to the principle of relevance, a model should not represent all facts but only those that are relevant to the purpose of the

model. Insignificant facts are to be abstracted from. The principle of economic efficiency means that the effort required to create the model should not exceed its benefit. The principle of clarity requires that models are easy to read, understand, and illustrate. The principle of comparability aims to ensure that models based on different modeling procedures can be compared with each other. The principle of systematic structure requires consistency across views when modeling different views, such as organizational and process views.

3.2. Design of the empirical survey

To ensure that the results can be generalized, expert interviews were carried out as semi-structured, guided interviews with interview partners drawn from various sectors, company sizes, and age groups. Eight of these experts work as external project management consultants in various industries: Two work in the automotive industry, two in the information and communication industry, and the remaining experts work in the financial, construction, and chemical industries; mechanical engineering; and in the public sector. The companies vary from small companies with fewer than 50 employees and less than 10 million Euros in revenue per year to publicly listed companies with large workforces and billions in yearly revenue. Four of the 15 interview partners were females, and 11 were males. Regarding the age structure, four interview partners were between 20 and 29 years old, six between 30 and 39, two between 44 and 49, two between 50 and 59, and one interviewee was over 60. Concerning the professional background in project management, five experts had fewer than five years, nine had more than five years, and six had more than 10 years of experience in projects. The answers were transcribed, and a qualitative content analysis was performed afterwards following the approach of [30].

4. Findings of the empirical survey

First, the differences between classical waterfall-model versus agile methods were discussed with the interview partners, who rated the six domains with regards to their significance from no difference (0) to high difference (3) and provided a rationale for their rankings (see Figure 2).

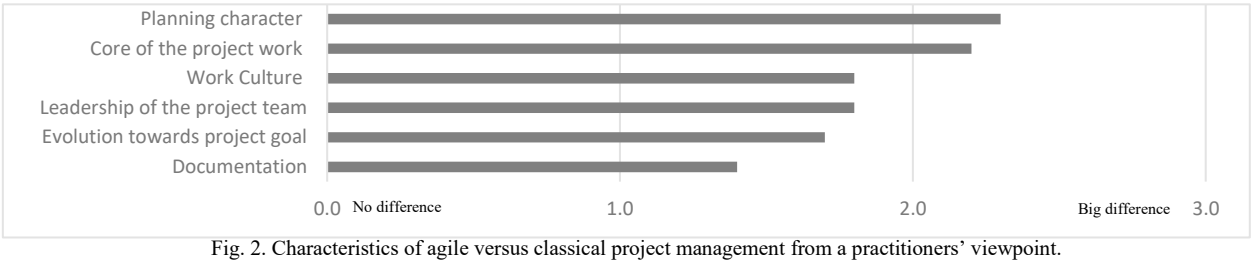

Fig. 2. Characteristics of agile versus classical project management from a practitioners' viewpoint.

From the viewpoints of the project managers, the main differences between the two approaches are in their planning character (see Figure 2). Classical project management is characterized by holistic planning in advance, stability, a long-term perspective. Furthermore, the scope of a classical project is clear, possibly with a foreseeable evolution. In contrast, planning in agile project management is incremental, continuous, step-by-step, flexible, short-term oriented in detail, and based on a long-term vision. These findings confirm those reported in the literature [2, 31].

The working structure of a team is also perceived as a relevant difference. While in classical projects, the execution of the initial project plan is the backbone of the project work, in agile projects, it is the working process with transparent communication, short and frequent feedback cycles from the customer or user, and a high level of flexibility. Other differentiators seem to be less significant. From a practitioners' viewpoint, the amount of documentation, the required capacity, the quality, and the importance of documentation are the least important factors in differentiating the two approaches. However, the interviewees all shared the opinion that the requirements for documentation and the compilation of high-quality documentation are very important for a successful project, despite the procedural model chosen. Second, to compare the findings with the literature [1, 2, 7, 31, 32, 33], the project managers were questioned about the advantages of the two procedural models. The experts were asked to evaluate them from not important (0) to very important (3) and to provide a rationale (see Figures 3, 4).

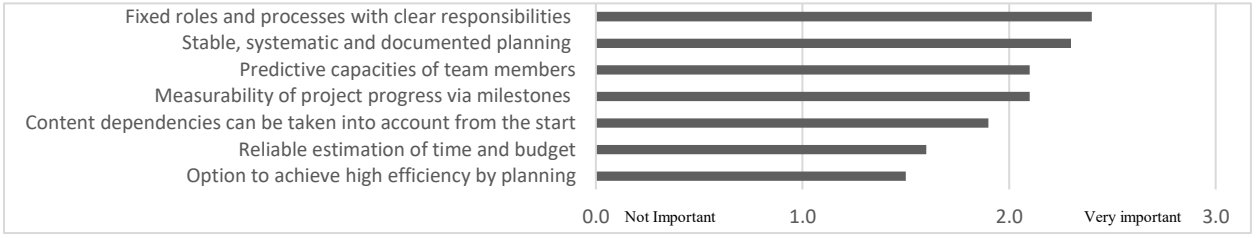

Fig. 3. Advantages of classical project management from a practitioners' viewpoint.

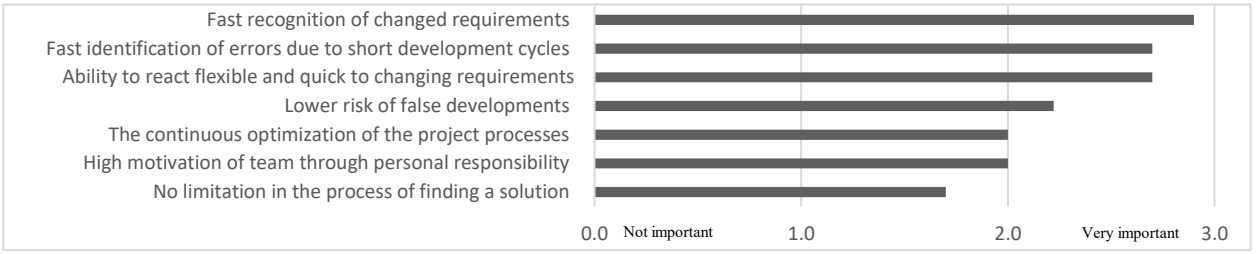

Fig. 4. Advantages of agile management from a practitioners' viewpoint.

It is noteworthy that the important advantages of both procedural models can be linked to the areas where the approaches exhibit significant differences. The key advantages of classical project management are the fixed processes with clear roles and responsibilities, and stable, systematic, and documented planning (see Figure 3). This is consistent with findings reported in the literature [5, 7, 31, 34]. Also, the ability to predict the capacities of the team members (based on the planning) and the measurability of the project progress (by planned milestones) are perceived as beneficial. According to the experts, the greatest advantage of agile project management is the ability to recognize changed requirements in a very short time due to regular feedback from the customer. Also, the benefit of quickly identifying errors based on the short feedback-and-development cycles is considered a major advantage. This goes hand-in-hand with the third great advantage: the ability to react flexibly and quickly to dynamically changing customer requirements with regards to project scope [1, 35].

Third, the interviewees were questioned about the disadvantages of the two process models (see Figures 5, 6) and were asked to explain their rating to facilitate comparison of their views with the literature [7, 32, 36].

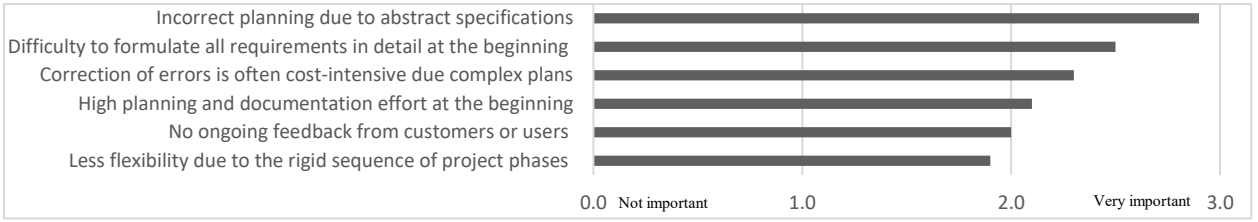

Fig. 5. Disadvantages of classical project management from a practitioners' viewpoint.

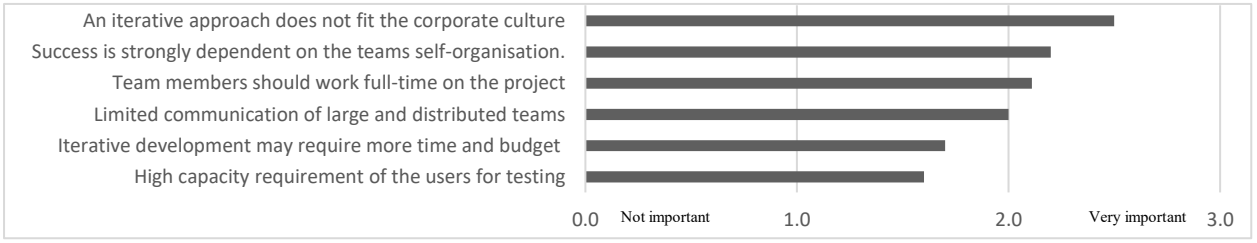

Fig. 6. Disadvantages of agile project management from a practitioners' viewpoint.

For the expert panel, the largest disadvantages of classical project management are abstract and misinterpreted initial requirements which lead to mistaken assumptions in the planning process, as these can have a great impact on future project process (see Figure 5). This shortcoming is closely related to the equally significant disadvantage that customers are often overburdened with the need to specify all requirements clearly and in detail at the very beginning of the project, which means that planning is fraught with uncertainty.

The most important constraint of an agile approach is that the iterative approach may not fit the corporate culture, in terms, for example, of planning, reporting, hierarchical structures, and leadership (see Figure 6). Furthermore, project success depends strongly on the team's skills and its members' ability to organize. Although the data base of 15 interviewed experts is relatively small, the findings are consistent with the results of other studies [37, 38, 39].

5. Decision model for selecting an appropriate procedure model

How to select the appropriate approach to a concrete project? The decision-model to be presented meets the requirements of practitioners with regards to comprehensibility, simple applicability, and practical relevance. Simplicity is ensured by the structure of the decision model that can be applied to a specific situation with less effort than the approaches of [40] and [41]. The authors of [42] focus on the process of implementing agile methods, but do not provide detailed information on how to choose the appropriate procedural model for a specific project. Instead, they refer to the work of [43] and to other authors in the field, which are mainly related to the field of software development [44]. The decision model presented in this paper follows a similar approach to the model of [45]. But in contrast to [45] it does not divide projects into four categories and derives recommendations per category, but allows even finer customization of the methodology, since the results are specific to the five important project dimensions. To ensure efficiency, the decision-making process is divided into two steps. In the first step, exclusion criteria are used for a rough assessment; in a second step, a detailed catalogue of criteria is used for a thorough evaluation of the project to be analyzed. Thereby it follows the idea of [46] to customize the procedural model for a specific project situation, which ensures that the methodology is aligned with the existing processes of the company, which is considered as a key success factor [47, 48, 49]. *Exclusion criteria* are characteristics of projects that serve as "knockout criteria" against using an agile methodology as an overarching procedural model for the overall project. These exclusion criteria can be structured according to the nature of the project and the nature of the organization or project sponsor, and follows established findings, for example of [38]. A project is not suitable for agile methods if the following project properties apply (see Appendix):

- *Lack of decomposability* of the overall result into separate deliverables.
- *One-shot game:* Frequent changes or a step-by-step, iterative approach to the solution are not possible from a legal or technical point of view or are associated with unreasonable costs. Examples include the construction of a house (adding a cellar in an ongoing project after the first two floors have already been built) or the geographical relocation of a production facility.
- *Criticality of the project:* Operational risks prevent an iterative, agile approach. Examples include solutions in the field of process control or real-time applications and safety-critical systems.

Likewise, the *nature of an organization* or the *characteristics of a project sponsor* may preclude the suitability of an agile approach if the following characteristics apply: The sponsor and management do not understand or accept the agile philosophy, or the organization is not able to deal with the frequent delivery of partial results or increments due to capacity or mindset.

If one or more of the exclusion criteria mentioned above apply, project success with agile methods is unlikely. Thus, a classical waterfall approach is recommended, and the decision process will be abandoned. However, even with a waterfall approach, individual sub-modules may well be suitable for agile methods.

Provided that an agile approach has not been excluded in the first step, the 15 detailed criteria—in the categories of scope [15], time [50], costs [51], organizational context [2, 50], and project team characteristics [1, 7, 9]—are scored in the second step (see Appendix). The criteria are phrased in a manner that represents the suitability for a classical project-management approach. Scoring is based on the following scale: (4) characteristic is fully applicable, (3) characteristic applies to a large extent, (2) characteristic is partially applicable, (1) characteristic applies only to a very limited extent, and (0) characteristic does not apply. A high score indicates a good fit of the project's characteristics for a classical waterfall approach, while a low score indicates that agile methods are better suited.

Both the weights of the categories and the weights of the single criteria can be adjusted based on the project context. Adjustments should be made by the project manager on a project-specific basis. However, to derive a trend for a potential weighting, the weighting of the categories was discussed in the interviews (see Figure 7).

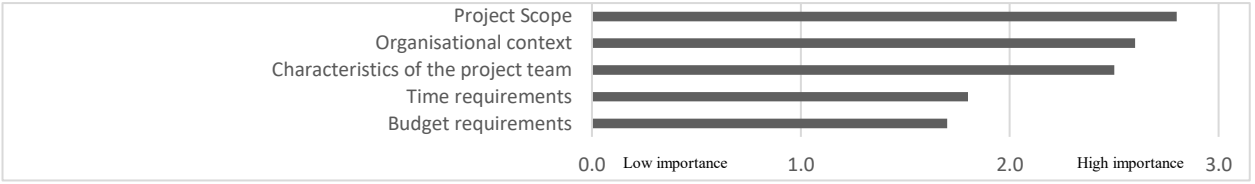

Fig. 7. Potential weighing of categories in the decision model from a practitioners' viewpoint.

The most important decision category seems to be the project scope, which is closely followed by organizational context and project-team characteristics. Criteria regarding time and budget requirements are significantly less important in selecting a procedural model. This is consistent with our findings regarding the differences, advantages, and disadvantages of the approaches (see above) and is in line with [46, 47, 48, 49].

Characteristics of the project scope, such as the dynamics and uncertainty of the customer requirements, are said to have the strongest influence on selecting the procedural model. If there is little uncertainty regarding the project scope, and if the requirements are described transparently and in detail, a classical project procedure has a high probability of project success: responsibilities, roles, and processes can be clearly assigned and documented in a systematic, structured plan from the beginning [5]. The largest disadvantage of classical project management, that incorrect planning is caused by wrong assumptions, would be marginal in this case. However, given rapidly changing customer requirements, the resulting uncertainty is high. In this case, agile project management shows its advantages: e.g., the rapid identification of changing customer requirements and the ability to react quickly and flexibly to errors in implementation [4, 35].

6. Conclusions

This paper makes two principal contributions. The first contribution is to provide a simple and comprehensible decision model which can help project management practitioners select an appropriate procedural model for a concrete project based on the following dimensions: scope, time, costs, organization, and project team (RQ2). If a hybrid approach is considered, the model will provide reliable information about which elements of the various approaches should be combined or which model is the best choice. This addresses the fact that the problem is often no longer in the range of methods available but also in the adequate use of existing methods [36]. The second contribution is to provide insights regarding how practitioners perceive the differences in the two approaches discussed and which benefits and constraints they experience in practice (RQ1).

The present explorative study has pursued the goal of generating inductively derived findings and developing a new theoretical concept from them. This was accomplished based on comprehensive desk research and an empirical survey with the result of the decision model, thus expanding the state-of-research. However, some limitations of the methodology should be mentioned. The results of the expert interviews are not representative and can be related only to some industries, as the qualitative research with 15 experts represents a limited database. The framework is to be interpreted in the view of the specific context of a project. The cause-and-effect relationships which govern the selection of the procedural model and project success have not been empirically quantified, and they depend on the companies' context. As the decision model presented is based on qualitative research and a limited number of expert interviews, further quantitative research may refine and validate the findings by a broader database. For future research, the decision model must be applied to facilitate the development of further iterations and improvements. Detailed case studies which focus on specific project types and industries are desirable, using the presented framework for systematic analysis. In addition, other domains can be integrated into the model.

No procedural model is a "silver bullet" for all types of projects. Each procedural model is particularly well suited for certain project types with defined criteria. If these project criteria are not met or are met only to a limited extent, the approach is likely to fail.

Appendix A. Decision Model

Step 1: Exclusion criteria	
1.1	**Nature of project** - *Decomposability:* Solution cannot be implemented in increments. The technology used is not suitable for prototyping. - *"One-shot game":* Frequent changes are not possible from a legal/technical perspective or are associated with unacceptable costs. Examples: building a house, transferring a manufacturing plant. - *Criticality of project:* Operation risks prohibit an iterative, agile approach. Examples: process control/real time applications, safety-critical applications. Obligation of proof in the sense of a traceability requirement.
1.2	**Nature of sponsoring organization** - *Sponsor and management* do not support or accept agile philosophy. - *Organization* is not able to accomodate frequent delivery of increments.
Step 2: Selection Criteria	
2.1 Project constraints – "magic triangle"	
Average	**2.1.1 Scope, quality and risks**
Score	**Low dynamics and low uncertainty of customer requirements** *Scope and quality requirements* are complete, detailed, stable, and provided at an early stage of the project. *Novelty level/level of innovation* is low. The project does not require very creative work, necessitating frequent changes in scope. Level of customer involvement/engagement needed is low. *Level of complexity* is fully understood by the project team. Risks are fully captured at an early stage of the project.
Score	**High visibility of customer requirements** *Customer and user requirements* are available in a written form and signed at an early stage. *Requirements* can be clearly prioritized by customers, e.g. in categories "must have," "could have," and "will not have." There is *no highly demonstrable user interface* available. *Documentation* of approach and results is important.
Score	**Large size and high complexity of the end product** *High complexity of the end product,* especially with regards to interconnections between sub-projects/parts of the overall solution. *Interdependencies of deliverables:* Against the background of the project contents, each phase can be started only once the preceding phase has been completed. *Solution cannot be implemented by increments* due to the nature of the project. Solution is aimed at *delivering re-usable components. Approved documentation is required.*
Average	**2.1.2 Time**
Score	**Critical time-to-market** needed for a minimum viable product or go-live date. Timescale is fixed: Planned end date must be strictly adhered to.
Score	**Reliable and detailed prediction** of project duration is required.
Score	**Long project duration** or length of release cycle is relatively long.
Average	**2.1.3 Budget**
Score	**Detailed and reliable estimation** of effort and cost are required. Fixed cost estimate is demanded by customer (cost cap).
Score	**Outsourcing of project activities** at fixed prices is planned to reduce the risk of miscalculation.
Score	**Easy estimation of effort/costs**. Potential future changes of scope do not result in high costs.
2.2 People and Culture	

Average	2.2.1 Organization
Score	**Organization type and culture** Characterized by hierarchical, central control (in contrast to a collaborative matrix organization/no central control). *Team* is not empowered by the product owner to make decisions.
Score	**Level of stakeholder involvement** Low level of *stakeholder engagement* as it contrasts with the culture of the organization. Low level of *customer collaboration*, commitment, and domain knowledge: A quick and valid feedback cycle from stakeholders cannot be guaranteed on a constant basis. There is no clear *ownership* of the projects' outcome. *Senior users* are not committed to providing end user involvement. Organization cannot accommodate the frequent delivery of increments.
Score	**Cultural values of the organization** *Focus* on monetary success. *Structure and order* are given a high value of their own. Adherence to milestones and gate reviews are assigned a high significance. *High necessity of documentation* of deliverables. People feel comfortable and empowered by having their roles defined by clear policies and procedures. Subordinate values include *communication, collaboration, self-organization* / many degrees of freedom, feedback, and courage for innovative solutions.
Average	**2.2.2 Project team**
Score	**Personality characteristics** *Low flexibility* towards scope (ability, willingness). Team is not capable of *self-organization*. Low level of collaboration, communication, adaptation, testing, and learning. Not willing to validate their work to the best of their ability and improve their processes. Focus is on *communication via documents* in contrast to direct communication via meetings, working in one room.
Score	**Knowledge and experience** Low average *technical/functional/domain skill and experience level* with regards to project scope. Team members' tenure on the project is short. Low *skill level regarding agile methods*. Non-acceptance and low motivation to apply/learn agile methods.
Score	**Size and geographic distribution** *Size of the team* is large (> 10), and team members work in geographically dispersed locations (across offices, sites, countries, and cultures), thereby resulting in many interfaces and high coordination effort. *Team-internal personal relationships* are weakly developed. Effectiveness of communication is low.

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