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Project management approaches and their selection in the digital age: Overview, challenges and decision models

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C H R O N I C L E

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A B S T R A C T

Digital transformation is a challenge that also impacts the selection of tools for implementing projects. Which tools are suitable for handling complex digital twins? Project management must respond to this with suitable approaches. The challenge for decision-makers is to choose the right one. Based on literature research and a case study, influencing factors are derived and practice-relevant project management approaches are collected. Furthermore, a decision model is developed that, on the one hand, supports the decision-maker in selecting tools before and during the project, and on the other hand makes empirical values from past projects usable for future decisions. The results show that the number of influencing factors is large, and the approaches are di-verse. In complex projects, this can lead to complex decision-making situations that require appropriate decision models. The developed "Supervised Decision Model – L5" is based on five levels (L): (L1) Building a database; (L2) Derivation of algorithms; (L3) Initial approach selection; (L4) Review of the initial selection; (L5) Using experiences for future decisions. In practice it turns out that complex projects – like Digital Twins - often fail. Modified decision models for selecting suitable approaches should therefore take the following as-pects into account: (a) decision-makers are actively supported in the initial decision phase; (b) initial decisions once made are checked in the early phase of the project and corrected if necessary; (c) the lessons learned are recorded in the database as empirical value and used for future decisions.

1. Introduction

Use The constant need for individualized, inexpensive products generally puts manufacturers under pressure to constantly adapt and design innovative products and processes. Digital twins (DT) can make an important contribution to this by subjecting these products or processes to a digital test (Dassault Systèmes, 2023). Dassault Systèmes, a major provider of digital solutions, describes the potential of DT as follows:

> The use of the Digital Twin opens up opportunities in all phases of manufacturing organization and processes, from the planning of systems, processes and production to the actual production. This approach begins exclusively in the virtual world and once production is started; data is fed back to establish a system of continuous improvements in all areas of the manufacturing processes. (Dassault Systèmes, 2023)

There are various process models in the literature that deal with the implementation of digital twins. These include, for example, the Digital Twin-Driven Product Design Framework (Tao et al., 2019), FA3ST Approach (Stojanovic et al., 2021), DT Lifecycle (Moyne et al., 2020) or the roadmap for the implementation of Digital Twins (Reinhart et al., 2019). The development of such process models is a challenge that is still the subject of intensive discussion. Another challenge in the context of the implementation of digital twins is the practical implementation of the process models in the sense of project

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management. For this purpose, the following project management approaches are available in practice (Špundak, 2014): (a) Traditional approach; (b) Agile approach; (c) Hybrid/Mixed approach. This study addresses the question of what requirements are placed on successful project management (PM) or project management approaches and their selection in the context of a project to implement digital twins. Special requirements could result, among other things, from the complexity of the digital twin being examined (e.g. depiction of a simple or complex process) as well as the area of application (e.g. production, energy, buildings). The basics and areas of application of digital twins as well as their special requirements for project management are discussed below.

2. Digital Twins

In the age of digitalization, topics such as automation, smart products, digital talents (Sommer, 2023b), optimization of process chains are becoming increasingly important for companies: "...what can be meaningfully digitized, networked and automated is being digitized, networked and automated" (Göckel & Müller, 2020). Digital twins can play a relevant role here, although - from a historical perspective - they are not a novelty, as their origin dates to the 1970s (Yu et al., 2022). The concept of the digital twin achieved greater relevance with Grieves (2003), who presented his first concept, consisting of the components "reality, virtual space and the data or data exchange" (Singh et al., 2021; Yu et al., 2022). In 2010, NASA introduced the term "digital twin" for the first time and used it for simulations (Göckel & Müller, 2020; Yu et al., 2022). An important component is the data that is subsequently analyzed to be able to make relevant decisions in an early product or process phase (Yu et al., 2022). In this respect, they represent the connection between the real and virtual world (Göckel & Müller, 2020). The areas of application are diverse, as a study by Capgemini (2022) shows (Gya et al., 2022). These range from Energy and Utilities, Automotive, Aviation, Manufacturing, Smart Buildings / Cities to Healthcare (Gya et al., 2022). Important areas of application are briefly presented below. As mentioned above, digital twins are used in buildings, for example, as this could result in relevant advantages in terms of the creation and operation of the buildings (Huber, 2018). However, the ideas extend beyond individual buildings, i.e. the topic of smart cities is also considered (Fuller et al., 2020). The idea that digital twins of smart cities could evaluate the available amounts of data and learn from them represents an interesting option for the further development of modern cities (Fuller et al., 2020). Another interesting area is automobility or the automobile sector (Wohlfeld, 2019). The aim is, among other things, to minimize the maintenance of vehicles and their breakdowns, which requires the systems to be networked (Singh et al., 2021). However, there is still a need for development here, as the question of compatibility of the systems and thus data transfer is not yet guaranteed, and the evaluation of the data still causes problems (Wohlfeld, 2019). Digital twins are also becoming increasingly important in relation to the topic of "production and energy efficiency". Energy costs are now a relevant challenge for companies. Already in the first quarter of 2022, medium-sized companies recorded an increase in energy prices of up to 40% compared to 2021 (Schwartz et al., 2022a).

The reason why the increase still had little impact on German medium-sized companies was, among other things, because, on the one hand, many medium-sized companies have rather low energy costs, and on the other hand, they passed on the additional costs to their customers (Schwartz et al., 2022a). However, practice shows that the ongoing price increase on the energy exchanges will soon have consequences for all companies. In other words, the expiring contracts with energy suppliers will inevitably increase costs in companies (Schwartz et al., 2022b). Great opportunities for solving the problem are attributed, among other things, to digitalization, i.e. the use of digital technologies that could contribute to a reduction in energy consumption in relation to products, production, and buildings (Bertschek et al., 2020). These tools were already available in the past, but were only used to a limited extent, although various sources of information existed (Bertschek et al., 2020; Huber, 2018). Among the various instruments, the digital twin is also available, which represents a connection between the virtual and real world. Since the definitions are different, the definition from Siemens, a large provider of digital solutions, should be used (Siemens, 2023):

> Digital twins are virtual images of products, machines, processes, or even entire production systems that contain all relevant data and simulation models - be it for an electronic circuit, a factory, rail vehicles or buildings. Digital twins not only allow products to be designed, simulated, and manufactured more quickly, they also make it possible to make them particularly cheap, powerful, robust or environmentally friendly, depending on your wishes. (Siemens, 2023)

A special manifestation of digital twins is the "Digital Energy Twin" or "Energy Digital Twin", which is defined as follows (DET, 2023):

> The objective of Digital Energy Twin is to support the industry with the development of a methodology and software tool to optimize the operation and design of industrial energy systems. By applying the methodology of the digital twin, detailed energy system modelling will be developed for selected processes (energy relevant) and renewable energy supply technologies, validated and simplified. (DET, 2023)

The possibilities for using digital energy twins or energy digital twins can be divided into the following phases (Yu et al., 2022): (a) Design Phase - Virtual Testing and Optimisation; (b) Processing Phase - Process Optimisation, Process Prediction, Process Monitoring, Production control and Process training; (c) Service Phase - Fault detection and diagnosis. Through continuous data analysis, the transparency of an energy system can be significantly improved, and the energetic efficiency of real objects can be estimated via digital twins (e.g. machines), which can then lead to minimizing lifecycle costs and energy consumption (Yu et al., 2022). Finally, it should be noted that the technologies/tools used not only contribute to reducing energy costs, but additional energy requirements or their implementation may also cause additional costs (Bertschek et al., 2020).

3. Implementation Digital Twins

The scope of application areas for digital twins is large. This inevitably means that implementation in practice can become very complex - depending on the area of application. In other words, a suitable process model for implementing digital twins must be chosen that meets the respective challenges. There are various options when selecting, e.g. data models with integrated project management (Follath et al., 2022) or the combination of several individual models. In other words, process models for the implementation of digital twins can consist of several models, e.g. a data model and a model for software development. In this constellation, project management can be found as an independent or integrated component in the respective models - here the data and software model. If the process model consists of a combination of several models, there are special requirements for handling the implementation of a digital twin. In practice, these are solved, among other things, by the so-called program management or program manager (Null et al., 2020): "Program management combines several projects that are interdependent. In this case, all projects serve to achieve an overarching goal. According to our definition, a program is, in short, a main project with many sub-projects" (Strasser & Schmidt-Sibeth, 2023).

4. Research Question and Hypothesis

The above explanations make it clear that the successful implementation of digital twins not only depends on the chosen process model, but also, to the relevant extent, on the project management approach. At this point, however, the question must be asked as to whether project management – alongside various other influencing factors in relation to the implementation of a digital twin – is a relevant factor? In this regard, the results of Waqar et al. (2023) can be used in relation to the implementation of a digital twin for smart city development, who examined four constructs - personalization, standardization, knowledge and operational - and 13 variables as part of their study (Waqar et al., 2023). The results of the structural model documented a value >= 0.3 with a p-value of < 0.001 for all four constructs about the ß value (Waqar et al., 2023). In other words, the "Operational and Personalization" constructs, which are linked to project management to the relevant extent, play an important role in the implementation of digital twins alongside the other factors. This leads to a second important question: Which of the various possible project management approaches is actually suitable for implementing a digital twin and what other influencing factors may play a role in the selection? Research into possible influencing factors for the selection of project management approaches provides the following overview, which does not claim to be complete: (a) 12x success factors for "digitization projects", derived from the experiences of companies (Block, 2022); (b) 9x trends in project management that are becoming more important in the digital age (Strasser & Pauels, 2023); (c) 43x trends in project management, based on the period 2000 to 2019 (Wawak & Woźniak, 2020); (d) 16x project parameters and their influence on project success (Ciric et al., 2022; Ciric et al., 2021); (e) "Traditional, Agile or Hybrid" – Which model is suitable? (Thesing et al., 2021; Gemino et al., 2021).

This overview shows how complex the decision regarding the project management approach can become. In this respect, increasingly complex decision-making situations may also require more complex decision-making tools. Simple AI tools, such as decision trees as well as more complex tools, could be a useful tool today due to their widespread use (Scikit-Learn.org, 2023). For the present study, for example, a decision tree or random forest could be used, for which prefabricated low coding Python codes already exist (Scikit-Learn.org, 2023) or node coding software packages - such as RapidMiner - with a drap-and-drop Surface exist (RapidMiner, 2023). Based on the above, the question arises as to whether the degree of complexity when deciding on suitable project management approaches to implement DT is so great that the use of complex decision-making processes or AI algorithms is necessary. The following research question (RQ) can be derived from this:

> RQ: For complex projects, such as the implementation of a digital twin, do you have to limit the number of suitable project management approaches and influencing factors to be able to make the decision with a reasonable amount of effort?

In other words, in certain decision-making situations there could be so many influencing factors that the resulting level of complexity increases disproportionately, as shown below as an example of a digital twin:

- Influencing factor A: General requirements for project management, such as trends or success factors

- Influencing factor B: Specific requirements of digital twins that require special consideration when selecting project management approaches
- Project management approaches: The number of potentially relevant approaches also inevitably contributes to increasing complexity.

This results in the following hypothesis (H):

> H: When implementing complex projects, such as an industrial digital twin, a decision model can be derived to select a suitable project management approach that, using AI algorithms, enables decision-making without significantly limiting the decision alternatives with a reasonable amount of effort.

5. Materials and methods

The study is initially implemented on the basis of a literature search, which is methodologically based on the approach of Nordhausen and Hirt (2022). The aim is to summarize the most important approaches to project management (PM) as well as the relevant influencing factors. The following structure was chosen (Nordhausen & Hirt, 2022):

Table 1
Procedure – Systematic Literature Research

Step-by-step procedure - Systematic literature research	Implementation of the procedure – Systematic literature search
1. Establishing the research principle	A sensitive principle was chosen that enables many hits to the question.
2. Determination of search components	Digital twin, production, energy efficiency, process model, project management
3. Databases	DBIS, e-library, EZB, Scopus, Web of Science, Google Scholar, EBSCO, ProQuest, DOAJ, BASE
4. Determination of keywords	Project Management, Framework, Process Model, Design, Management, Planning, Implementation, Methodology, Practical Guide, Management, Project, Project Management, Requirements, Success Factors, Influencing Factors, Trends
5. Conducting the research	Implementation according to steps 1 – 4
6. Documentation of results	Implementation of the documentation

Note: Procedure model for literature research according to Nordhausen & Hirt (2022)

In the second step, empirical data is collected, including complexity requirements and project characteristics. The use case is the implementation of the digital twin as part of the EU research project Flex4Fact (2023). The survey takes place in the form of a qualitative study via interviews and observations (Hussy et al., 2010). In addition, literature sources are also used. Finally, the complexity is assessed, and it is checked whether there is a need to use different AI algorithms (KDnuggets, 2023). The structure of the study can be summarized as follows:

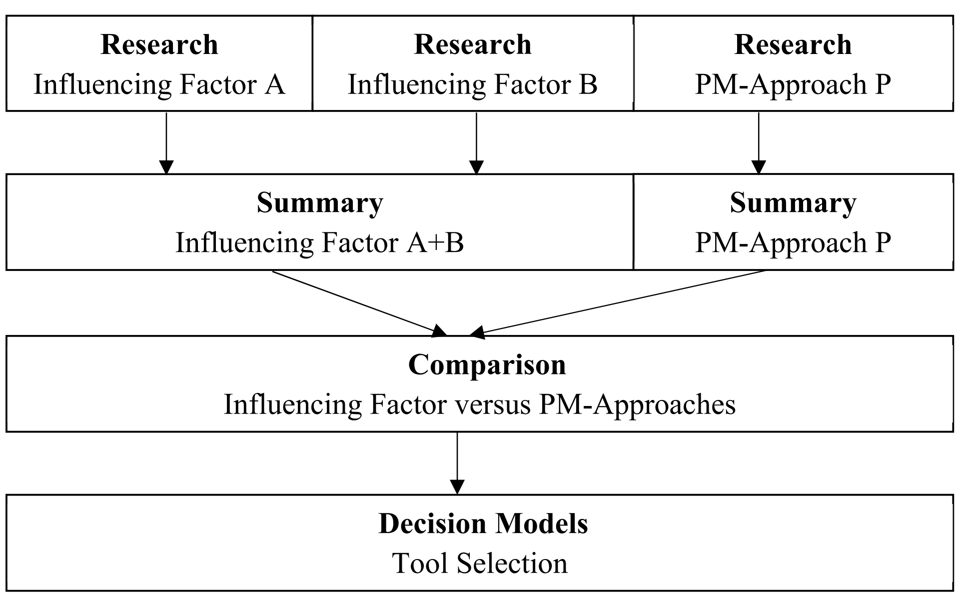

Fig. 1. Structure of the Study

6. Results

Results According to the structure of the study, research is first carried out on the influencing factors A and B and PM approaches, then a framework for decision-making is derived.

Research – General Influencing Factor A

The general influencing factors (A) in relation to the selection of a suitable project management approach also include negative experiences. The renowned American business magazine Forbes (2022) has summarized negative experiences regarding the implementation of digitalization projects in an article (Block, 2022). Here are 12 reasons (R1-R12) why digital transformation projects can fail:

- A-R1: “Lack of alignment to business outcomes: … If you want to get your CFOs onboard, you need to be producing a net present value (NPV) …” (Block, 2022)
- A-R2: “Lack of awareness within the organization: Humans by default fear what they don’t understand…” (Block, 2022)
- A-R3: “Micromanagement/mismanagement of agile teams” (Block, 2022)
- A-R4: “Distraction by the minutia” (Block, 2022)
- A-R5: “Shiny toy syndrome: Stop buying cool things that don’t have a solid business case for implementation! Stop it!” (Block, 2022)
- A-R6: “Inability to translate into executive language: … Drop your IT vocabulary and start telling compelling user experience …” (Block, 2022)
- A-R7: “Lack of control over external vendors: Clear timelines, owners and deliverables keep everyone working at the same pace on the same problems” (Block, 2022)
- A-R8: ”Lack of training for internal users” (Block, 2022)
- A-R9: “Loss of talent to competitors” (Block, 2022)
- A-R10: “Resistance for fear of being replaced: … internal saboteurs who fear losing their jobs …doing everything …” (Block, 2022)
- A-R11: “Slow decision-making processes: … executives don’t have any sense of urgency because you didn’t bother with the delay cost calculations …” (Block, 2022)
- A-R12: “Poor prioritization of development: You’re using politics in development prioritization, instead of profitability and business outcomes” (Block, 2022)

In summary, it can be said that the human factor can be a major reason for the failure of digitalization projects. The early reflection of the above experiences in relation to your own project can therefore be an important influencing factor in the selection of the project management approach. Furthermore, 9x project management trends (T1-T9) are also possible influencing factors. These include the following trends (Strasser & Pauels, 2023):

- A-T1: “Artificial intelligence in project management is increasing”
- A-T2: “Self-determined work in flexible environments”
- A-T3: “Resource planning is becoming increasingly important”
- A-T4: “More focus on the use of results”
- A-T5: “The sharing of knowledge continues to increase”
- A-T6: “Agile and hybrid methods continue to gain in importance”
- A-T7: “Change management is becoming more important”
- A-T8: “The Project Management Office (MBO) is becoming more strategic”
- A-T9: “PM tools and automated data use”

Taking these trends into account can also have a significant influence on the choice of project management approach, as topics such as AI, change management or results orientation are taken into account to different degrees in the respective approaches.

Research – Special Influencing Factor B

The specific factors are the requirements that are characteristic of the respective project. They are usually recorded in the form of a requirement specification (Silva, 2014). This is very important in practice, including in software development: “Requirements specification is a core activity in the requirements engineering phase of a software development project” (Franch et al., 2023). With regard to the complexity of a project, San Cristóbal et al. (2018) identified the following main influencing factors: B1-“Size”; B2-“Interdependence and interrelations”; B3-“Goals and Objectives”; B4 “stakeholders”;

B5-“Management Practices”; B6-“Division of labor”; B7 “Technology”; B8-“Concurrent Engineering”; B9-“Globalization and context dependency”; B10 “Diversity”; B11-“Ambiguity”; B12 “flux” (San Cristóbal et al., 2018). In the context of this article, the main influencing factors for the complexity of a project will be examined using the example of the case study “Digital Energy Twin – Flex4Fact” (Flex4Fact, 2023). The subject is, among other things, “energy efficiency in production” which is of high practical relevance: “…a third of companies have implemented digital twins to understand and predict energy consumption and emissions throughout the entire value chain” (Gya et al., 2022). The following project-specific influencing factors (B1-B12) can be derived for this project (San Cristóbal et al.,2018):

- B1: “Size” factor - The project includes 23x industrial and research institutions from five countries. As a result, the organizational structure is correspondingly complex.
- B2: Factor “Interdependence and Interrelations” - The development of the digital twin causes a high degree of dependency between the research and industrial partners, as the tasks are divided between the partners, i.e. software development, data determination, setting up IoT solutions or analyzes are the responsibility of the partners Research partners and implementation with industry and research partners. The implementation of DT can therefore be seen as a complex task, as the real and virtual world - including data transfer - have to be connected. However, such complex projects in particular often fail, as a survey by the renowned management consultancy BearingPoint confirms: “… depending on type, size and complexity, at least one in six projects fails” (Wachs & Tiefenbeck, 2022). Projects in the area of digital transformation even fail with an averagely high percentage. Forbes magazine (2022) reports that projects in the area of digital transformation processes fail with a risk of 70 - 95% (Block, 2022).
- B3: Factor “Goals and Objectives” - The objective is clearly defined: “… aims to develop an end-to-end ecosystem based on a modular and multi-level architecture to enable flexible manufacturing in industries and create the conditions for the necessary energy transition in energy intensive industrial sectors” (Flex4Fact, 2023)
- B4: “Stakeholders” factor - The project partners and stakeholders are defined, and reporting is installed.
- B5: Factor “Management Practices” - The relationships between the participants and suppliers are defined. But a generally accepted process model/methodology for implementing digital twins does not yet exist. Rather, various process models - with or without an integrated project management approach - are currently being tested or further developed (Singh et al., 2021). In addition, according to a study of 1,000x companies with sales between USD 1 and 50 billion, the proportion of companies with significant experience with digital twins was only around a third (Gya et al., 2022). This means that empirical values or successful use cases are rarely or not at all available to SMEs and larger companies, which also makes handling these projects more difficult. This also applies to the industrial partners of the Flex4Fact project.
- B6: Factor “Division of labor” - the personnel structure of the project is defined; the selection process for personnel is in place; The objectives are known to the employees
- B7: “Technology” factor - although the scope and variety of tasks is known, the technological requirements in relation to the implementation of digital twins in terms of real time, APIs, cloud solutions, data modeling and mapping as well as data security are high, which is a requires extensive coordination (Gya et al., 2022).
- B8: Factor “Concurrent Engineering” - The integration of project members into different areas is sometimes problematic due to the international orientation. A balance is sought through digital technologies.
- B9: Factor “Globalization and context dependency” - The international orientation of the Flex4Fact project is a real challenge that can only be partially covered by digital communication technologies.
- B10: “Diversity” factor - The number of participants, tasks and technologies is high.
- B11: Factor “Ambiguity” - The scope for interpretation within the project is limited by the specific task.
- B12: “Flux” factor – Constant changes / adjustments are generally part of development projects, including the Flex4Fact project. What is special about this project is that different sub-projects with possibly different project management approaches come together, e.g. the software department with an “agile focus” and the technology department with a “traditional focus”. This raises the question of a methodology that possibly combines several approaches. This challenge is also controversially discussed in literature (Steyn, 2020).

Research – Project Management Approaches P

The general or specific influencing factors may affect various potentially suitable project management approaches (P), which makes the decision-making process about the appropriate approach complex. This raises the question; how many approaches are potentially relevant and can be included in the investigation? For this purpose, relevant websites are searched for that advertise a “list of the most important project management approaches” without carrying out a ranking. This particularly included portals from software providers and project management experts, which are frequently visited by Internet users. The aim of this approach was to depict relevant project management approaches from the user's perspective. According to research, 28x project management approaches were identified that were classified as relevant on 20x relevant websites (see appendix). Various studies show that there are other approaches and that the discussion about the suitability of the individual approaches continues to be controversial (Gemino et al., 2021; Thesing et al., 2021). The following table provides an overview of the researched approaches (P1-P28), divided according to the following methods:

- Traditional models: These exist when there is a "...separate sequence of project phases initiation, planning, monitoring and control as well as completion" (Angermeier, 2023).
- Agile models: These are methods that "…do not focus on comprehensive advanced planning and the linear, exact execution of a plan" (Thesing et al., 2021). Furthermore, in agile projects "…work must be iterative, incremental and also prototype-based" (Baez & Schuster, 2017).
- Hybrid models: In the narrower sense, they represent an extension of the traditional approach to include agile elements" (Thesing et al., 2021). It is therefore possible to use "...e.g. a sequential, parallel, iterative or agile approach" in the implementation phase (Frerichs & Hilmer, 2017). In the "broader sense" they are simply combinations of several approaches (Angermeier, 2023).
- Not Assigned: i.e. no clear assignment was available on the website

Table 2
Overview of the researched Project Management Approaches (PMA)

No.	PMA	Method	Description	Source
P1	Waterfall / Waterfall Scrum / Waterfall Agile	Traditional / Hybrid / Hybrid	„The waterfall model is a traditional, linear project management methodology … includes five or six independent phases, and each phase relies on the deliverables of the previous phase. You need to complete each before you can move onto the next"	(Miranda & Hardy, 2023) (Reiff & Schlegel, 2022)
P2	Lean Project Management	Agile	"… lean project management is focused on delivering value and eliminating waste …"	(Miranda & Hardy, 2023)
P3	Kanban	Agile	"…Kanban is a method of lean project management that gives a visual overview of the process from start to finish, which helps manage workflow by showing exactly who is working on what and where resources are needed most"	(Miranda & Hardy, 2023)
P4	Agile PM / Agile-Stage-Gate	Agile / Hybrid	"Agile project management methodologies developed as a response to the rigidity of the waterfall model … intentionally iterative and collaborative, and they put emphasis on creating good products for customers"	(Miranda & Hardy, 2023): (Cooper & Sommer, 2016)
P5	Scrum	Agile	"Designed for small teams, a scrum framework guides a simple process of communication, planning, execution and feedback"	(Miranda & Hardy, 2023)
P6	Scrumban	Hybrid - Broader Sense	"Scrumban is a hybrid of Scrum and Kanban methods. It follows a scrum workflow and visualizes work on a Kanban board with 7three columns: To Do, Doing and Done"	(Miranda & Hardy, 2023)
P7	Extreme Programming (XP)	Agile	"Focused squarely on software development, … emphasizes communication and simplicity. It relies on "feedback loops," where coding is happening continuously—without waiting for comprehensive design or planning upfront …"	(Miranda & Hardy, 2023)
P8	Crystal Method	Agile	"Crystal is an agile method that focuses on one core value: individuals and interactions over processes and tools. It lets teams optimize their own workflows and adjust them per project"	(Miranda & Hardy, 2023)
P9	Dynamic Systems Development Method (DSDM)	Agile	"… is the most structured of the agile methodologies and an example of a hybrid methodology. It was developed to add discipline to unstructured methodologies while retaining the adaptability of agile"	(Miranda & Hardy, 2023)
P10	Feature-Driven Development (FDD)	Agile	"Addressing the complexities larger projects might pose by developing fast, repeatable processes"	(Brecher, 2023); (Lynn, 2023)
P11	Critical Path Method (CPM)	Traditional	"It is focused on maximizing project activities and finding the shortest path (timeline) to task and project success using a work-breakdown structure (WBS) and a timeline to complete, as well as dependencies, milestones, and deliverables"	(Brecher, 2023)
P12	Critical Chain Project Management (CCPM)	Not assigned	"CCPM differs from CPM in that it focuses on the use of resources within a project instead of project activities"	(Brecher, 2023); (Critical-Chain- Projects.com, 2023)
P13	Lean Six Sigma	Hybrid – Broader Sense	"This hybrid of Lean and Six Sigma focuses on the customer with the goal of improving business efficiency and effectiveness in identifying and understanding how the work gets done (the value stream)"	(Brecher, 2023)
P14	Rapid Application Development (RAD)	Agile	"… focuses on the user's input based on testing, and how well a product is working compared to its intended goals … identifies the requirements, quickly builds prototypes and garners user input"	(Brecher, 2023); (Microsoft, 2023)

Table 2
Overview of the researched Project Management Approaches (PMA) (Continued)

P15	Spiral Model	Agile* vs. Hybrid*	"Combines waterfall and an iterative mode to make it easier for teams to adapt … divided into four stages: analysis, risk evaluation, execution, and planning. It works best for long-term and higher-risk projects"	(Brecher, 2023) / (Matthew, 2023)
P16	Rational Unified Process (RUP)	Agile	"… similar to Waterfall, but RUP has four iterative phases: inception, elaboration, construction, and transition. Each stage involves regular and frequent stakeholder feedback …"	(Brecher, 2023)
P17	Hybrid Model	Hybrid	"… hybrid project management methodology solution, one in which the planning and requirements phase is undertaken under a waterfall approach and the design, develop, implement, and evaluate phases follow the agile methodology"	(Brecher, 2023)
P18	V-Model / V-SCRUM Model	Traditional / Hybrid	"The V-Model can be considered an extension and improvement of the Waterfall model. The « V » reflects the graphical representation of this method, which considers that for each development stage there is always a corresponding validation phase"	(tuleap, 2023); (Ghnaimat & Hudaib, 2022)
P19	Program Evaluation and Review Technique (PERT)	Traditional	"… is a useful graphical representation to define the sequencing of specific project phases. More precisely, it is a network chart that represents all the tasks and milestones involved to effectively get your project across the finish line"	(tuleap, 2023)
P20	Scaled Agile Framework (SAFe®)	Agile	"…embodying a mindset and a framework for teams to be aligned with the overall business strategy. The core principle is to split work into smaller tasks to be framed and scheduled within teams, making sure that each one of them stays focused on the ultimate goal to achieve"	(tuleap, 2023)
P21	PRINCE2 / PRINCE2 Agile	Traditional / Hybrid	"… a project life cycle is divided into stages which have a strong degree of dependencies on one another. There are six main aspects … are project scope, timescale, risk, quality, benefits and cost"	(Scheiner, 2022); (PRINCE2 Agile, 2023)
P22	Projects Integrating Sustainable Methods (PRiSM)	Not assigned	"… methodology that values sustainability over all else. The goal of PRiSM projects is to reduce the environmental impact of a project and drive meaningful social impact"	(Smartsheet, 2023); (Daniels, 2017)
P23	Adaptive Project Framework (APF)	Hybrid	"… is an iterative, client-focused, and adaptive approach to project planning … most IT projects can't be managed using traditional PM methods and was designed to help project managers respond to unexpected changes effectively.	(actiTIME, 2023); (Kanjilal, 2023)
P24	Event Chain Methodology	Not assigned	"… is an uncertainty modeling approach. It's based on identifying relationships between project events and focuses on events that may affect project schedules"	(actiTIME, 2023)
P25	Extreme Project Management (XPM)	Agile	"… is a methodology that aims to tackle complex and high-risk projects. It takes a more flexible and adaptive approach to managing projects than traditional methodologies.	(actiTIME, 2023)
P26	Project Management Body of Knowledge (PMBOK)	Not assigned	"… describes a structured approach to managing time, projects, resources, schedules, risks, and other business aspects. It includes the following five stages: Initiating – Planning – Executing - Controlling - Closing	(actiTIME, 2023)
P27	New Product Introduction (NPI)	Not assigned	"…refers to the process of planning, developing, producing, and introducing a new product, service, or technology …it relies on six stages or gates …"	(Brooke, 2019)
P28	Integrated Project Management (IPM)	Not assigned	"This strategy makes way for clarity across the board by having employees across departments follow the same structure. It simplifies progress communication, as all teams operate on a similar agenda"	(Pinegar, 2023)

Note. Summary of project management approaches that were most frequently mentioned on 20x relevant internet platforms. The platforms examined are listed in the appendix

7. Comparison – Influencing Factors and Project Management Approaches

The results document that it is not simply a matter of choosing between "traditional, agile and hybrid approaches", but that there are various variants of these manifestations (e.g. Prince2 vs Prince2 Agile), which further increase the complexity of the decision for an approach. It can also be seen that certain approaches can be found on almost all websites examined. These TOP 5 approaches include Scrum, Waterfall Model, Kanban, Agile Project Management and Lean Development, as the following figure shows:

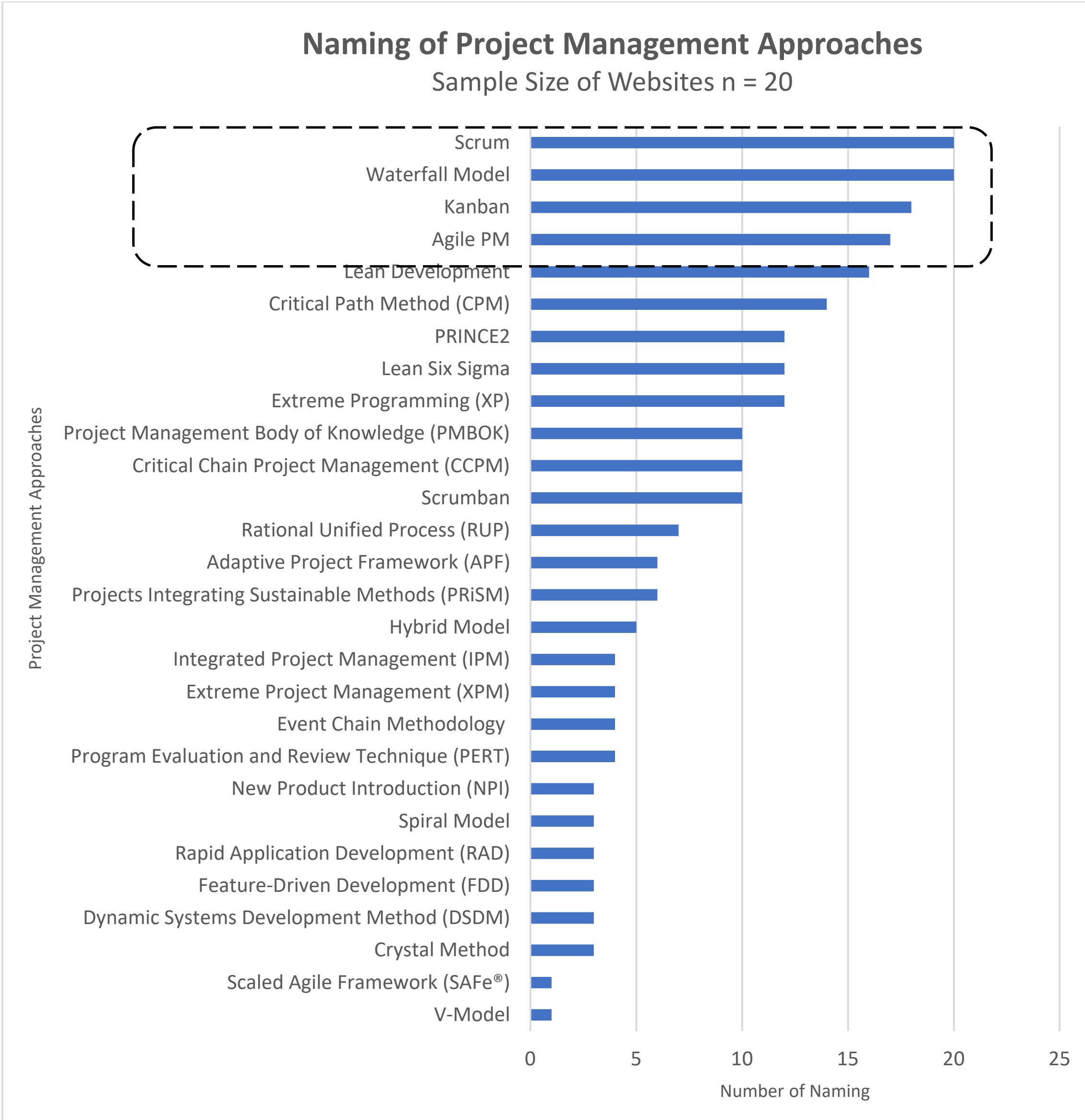

Fig. 2. Listing of the Project Management Approaches (PMA) according to the 20x examined internet platforms (see appendix)

It is also noticeable that almost 50% of all mentions on the websites refer to "agile methods". In other words, this methodology is very present on websites. The following figure summarizes the results for all methods:

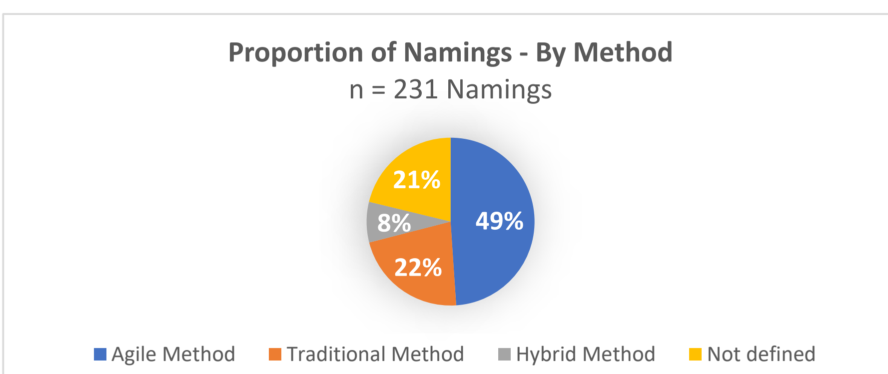

Fig. 3. Frequency of Naming - Agile vs Traditional vs Hybrid Method based on 20x examined internet platforms (see appendix)

If you summarize the influencing factors A and B as well as the researched project management approaches P, it becomes clear that selecting a suitable project management approach is a complex challenge for projects in general and for the implementation of a digital twin in particular:

Table 3
Complexity of Project Management – Measured by Variables

Factor	Variable	Number
(1) General Influencing Factor	A-R + A-T	12 + 9
(2) Special Influencing Factor	B	12
(3) Project Management Approach	P	28
Total Number of Variables		*61*

Note: Reasons for project failure (A-R) and current trends (A-T) as well as specific project influencing factors (B) represent in total 33 factors; Project Management Approaches represent in total 28 factors

Derivation of a decision model

The "Complexity-Predictability Project Diagnosis Model" is a model to support the selection of suitable approaches, according to which the decision depends on the situational dimensions of the project (Boonstra & Reezigt, 2019). According to the model, a distinction is made between the following dimensions:

- Dimensions 1 – Degree of predictability: Projects of this type are characterized by content and an environment that is stable. Projects with high predictability are usually characterized by clearly defined project goals, available resources and technology, i.e. surprises are not to be expected (Boonstra & Reezigt, 2019).
- Dimension 2 – Degree of complexity: Projects of this type are of low complexity if, for example, the content of the project can be solved on a simple problem with little expert knowledge and resources using a few disciplines. Furthermore, the environment is only involved to a limited extent (Boonstra & Reezigt, 2019).

Based on the above-mentioned dimensions, the authors derived four project types, according to the Complexity-Predictability Project Diagnosis Model by Boonstra & Reezigt (2019):

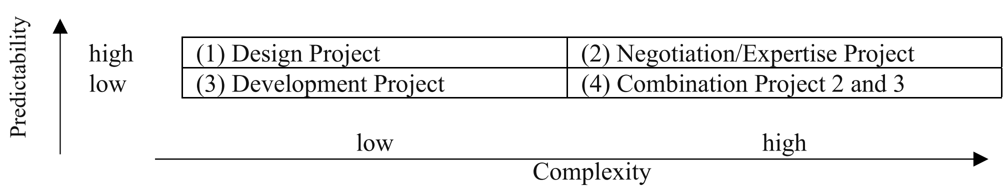

Fig. 4. Overview – Project Types - Modified illustration, based on the Complexity-Predictability Project Diagnosis Model (Boonstra & Reezigt, 2019)

The four project types can be characterized as follows (Boonstra & Reezigt, 2019):

- **Design Project:** High predictability, low disagreement with stakeholders, enough resources, competent project staff, manageable technologies
- **Negotiation / Expertise Project:** Although the ability to plan is high, the technical complexity as well as the differences of opinion among those involved are also high. In other words, there are different objectives and use of resources.
- **Development Project:** The low predictability and complexity allow the project team to work together harmoniously - often in an agile manner - with the goals being openly formulated.
- **Combination of Negotiation / Expertise Project / Development:** This type of project is highly complex and difficult to predict, i.e. those involved do not agree, it is technically a challenge, and the distribution of resources is unclear.

The next logical steps are based on the creation of a diagnostic questionnaire that questions, among other things, the goals, scope and project resources as well as the development of a toolbox for selecting an approach (Boonstra & Reezigt, 2019). The authors Thesing et al. (2020) have taken up the ideas and modified them from their perspective by, in the first step, exclusion criteria - so-called. Knockout criteria – defined: "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" (Thesing et al., 2021). In other words, projects are excluded from further investigation in this step, i.e. the “classical waterfall approach” is recommended (Thesing et al., 2021). In the second, a catalog of criteria/questions including a decision model - based on the dimensions "scope, time, costs, organization and project team" - was developed to assess the remaining projects and care was taken to ensure that the model was adapted to the project situation (Thesing et al., 2021). Overall, this further developed decision-making process can be seen as a further step towards practical use in companies. In this context, the question arises to what extent can one build on the above research work? The following extensions are available for this:

- Extension A - Include more PM approaches: If you look at the 28x project management approaches presented alone, it becomes clear that, in addition to traditional and agile approaches, hybrid forms now play a relevant role (Copola Azenha et al., 2021; Gemino et al., 2021). A more comprehensive consideration of relevant models should therefore be given priority over a simplified decision model.
- Extension B – Include hybrid PM approaches in a broader sense: These are combinations of PM approaches without necessarily consisting of agile and traditional models (Reiff & Schlegel, 2022), e.g. the combinations of Scrum and Kanban or Lean and Six Sigma.
- Extension C – Include more influencing factors: The 21x general and 12x specific influencing factors derived in this study show that the decision-making process is complex. The authors Thesing et al. (2020) deliberately focused on the simplicity of the decision. Alternatively, there is also the possibility of taking significantly more influencing factors into account and foregoing early simplification.
- Extension D – Use of AI tools: The progressive use of AI tools and the accompanying development of corresponding easy-to-use tools (Sommer, 2023a) enable decision-makers to make decisions even under more complex conditions.
- Extension E – Use project success as a correction factor: The decision in favor of a project management approach does not necessarily mean that this approach must be used unchanged over the entire duration of the project. Changing or modifying the approach should not be a “no-go”. For example, the waterfall approach can be supplemented with agile elements, or, in the case of hybrid approaches, the procedure can be changed in the implementation phase (Frerichs & Hilmer, 2017) without having to cancel the entire project. In this respect, the success of the project would have to be continuously measured and controlled to make appropriate changes to the procedure during the project. For example, control loops that are widely used in both technology and management (Laudan & Mauritz, 2006) are suitable for this purpose. Possible “dimensions of project success” such as “… project efficiency, impact on the team, impact on the customer, business success and preparation for the future” (Ciric et al., 2021) could be used to realign the approach.
- Extension F – Actively use lessons learned: Using experience from completed projects for the next decision-making process and just as important as using the experience from implementation. This model offers the opportunity to utilize the lessons learned in two ways.

Based on the above extensions, an AI-oriented decision model (Mahdi et al., 2021) can now be derived about the selection of project management approaches for various projects: “…artificial intelligence that provides systems to learn and improve from experience without being explicitly programmed automatically …. “The primary aim of ML is to allow the computers to learn automatically without human intervention or help and then adjust actions accordingly” (Mahdi et al., 2021). The following considerations underlie the decision model:

- A five-stage model is developed in which, in the initial step, a database of relevant project management approaches is built or existing experiences are used (stage 1), followed by the development and testing of an AI algorithm (stage 2) and the collection of data about the projects to be completed and decision on the PM approach (stage 3), the review of the decision within the project via project success factors and, if necessary, revision (stage 4) with final integration of the “lessons learned” from the current project (stage 5) in relation to the algorithm and the database (extension A - F)
- There is no larger pre-selection of PM approaches in order to take the diversity of approaches into account during the selection (extension A - B)
- The influencing factors are checked using AI algorithms for patterns that allow a prediction regarding the suitability of one of the 28x PM approaches. For this purpose, a supervised learning algorithm (e.g. Decision Trees, Linear Regression or Support Vector Machines) is used (Bonaccorso, 2017), which is based on training data (extension C - D)
- The decision about the project management approach is checked over the course of the project via “Project Success Dimensions” and, if necessary, flexibly adjusted because the initial framework conditions of the project may have proven to be incorrect (extension E).
- The project ends with a lesson learned regarding the project management approach, which is entered into the decision model database.

Below is the illustration of the "Supervised Decision Model – L5" with five decision levels (L5) for selecting suitable project management approaches (PMA), based on supervised learning algorithms on the one hand and Bonaccorso (2017) on the other:

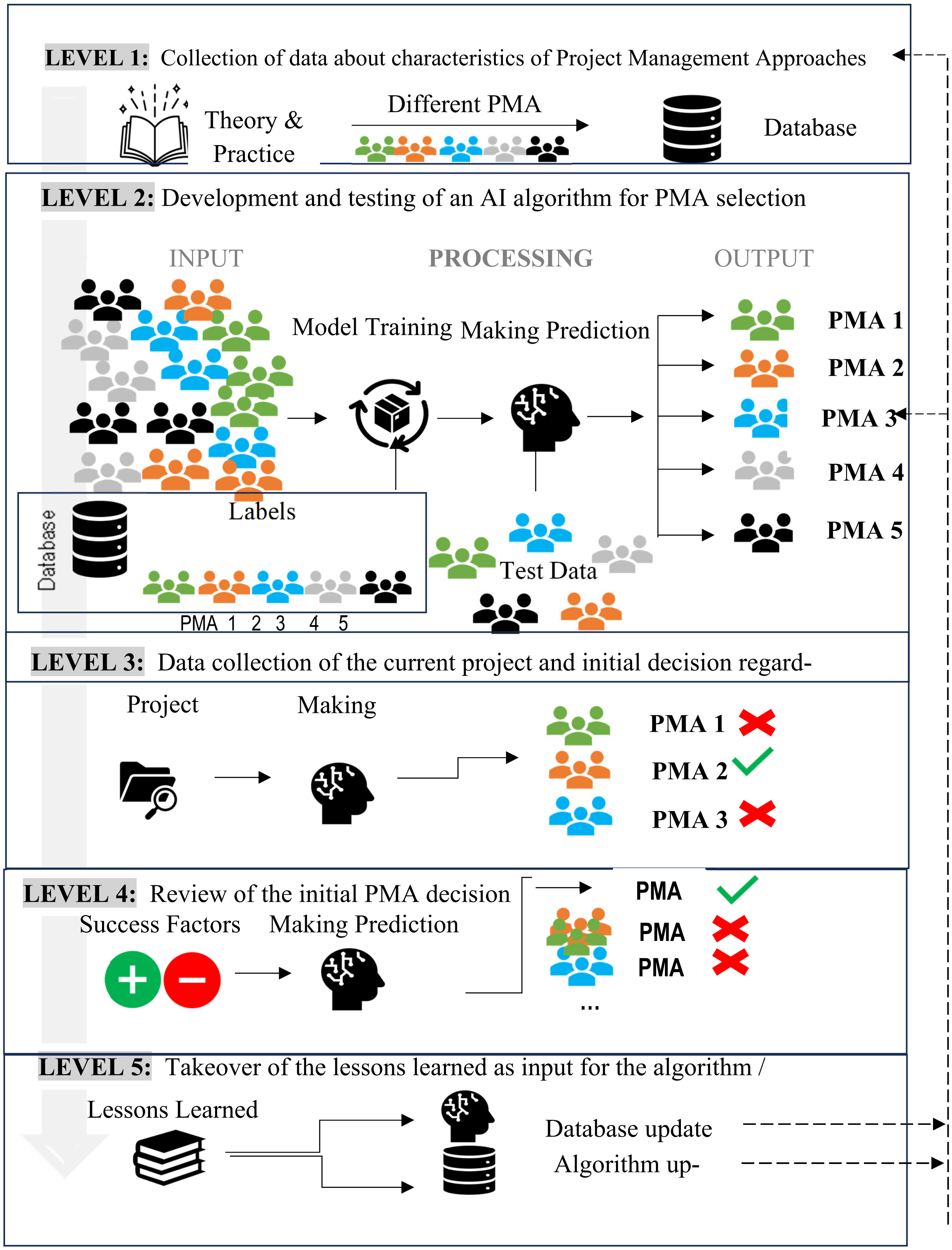

Fig. 5. "Supervised Decision Model – L5" for PMA Selection - Flowchart for the AI-supported decision-making process based on supervised learning algorithms and Bonaccorso (2017)

8. Discussions

8.1 Hypothesis Test

The results show that it is possible to derive a decision model for complex projects such as digital twins that can actively support decision-makers in the selection of project management approaches via AI algorithms and database, without reducing the number of decision parameters (= general and specific influencing factors or . Number of project management approaches) to the detriment of decision quality. In the present work, a decision model was derived that expands existing decision models (Thesing et al., 2021), among other things, by including more influencing factors, the use of AI algorithms for optimized decision-making, and the possibility of correcting decisions made of project success factors and the active use of lessons learned from existing projects for the selection of future projects in the form of integration into the AI algorithm. In summary, the decision model - in the sense of a control loop - is characterized by the following aspects: (a) decision-makers are actively supported in the initial selection by empirical values from a database; (b) Initial decisions once made are checked in the early phase of the project and corrected if necessary; (c) At the end of the project, the lessons learned are recorded in the database as empirical value and used for future decisions. This confirms the hypothesis.

8.2 Implication for Theory and Practice

The benefits of this work can be presented as follows:

- From a theoretical perspective, this decision model can be used to document that AI algorithms can make a significant contribution to the selection of project management approaches, provided that the available data on the characteristics of different project management approaches are consistently developed and stored in a database.
- Information about project management approaches is available in both science and practice. These could be stored in a database as needed.
- Furthermore, the present work documents that the complexity of the decision has grown significantly, e.g. taking into account the growing variety of project management approaches. Approaches to reduce decision complexity in the sense of pre-selection, e.g. between agile and traditional approaches, no longer meet practical requirements.
- In addition, the present decision model extends existing models with three components: (a) a detailed initial selection using a database for project management approaches; (b) the evaluation of the chosen approach in the ongoing project with the option to modify the approach (e.g. additional use of agile elements); (c) the integration of lessons learned for the selection of future approaches. The latter serves to actively use experiences from past projects and thus acts in the sense of a control loop.
- With regard to hybrid approaches, this work documents that the number of combined approaches is constantly increasing, i.e. the decision “Agile or Classic Approach” is only one of various options.
- From the perspective of practitioners, it can be stated that they are overwhelmed by the diversity when selecting the project management approach. It is not to be expected that the decision-maker will make a trade-off between 28 project management approaches, taking into account current project management trends and his or her individual wishes regarding his or her project. As a result, the selection is not well-founded or is based on experience or company specifications. The consequences can be significant if you look at Forbes' results, according to which 70 - 95% of projects with a focus on digital transformation fail (Block, 2022). The right choice of the project management approach and the willingness to review success during the project - with the option to adapt the approach - could contribute to improving the success rate.

9. Limitations

The application of this approach is aimed at larger, complex projects, as only in these cases the ratio between effort and benefit is justified. The effort for implementation lies, on the one hand, in developing a tool that makes the relevant project management approaches available as a database and, on the other hand, in entering influencing parameters and empirical values from the lessons learned. It would therefore be desirable to develop a corresponding company-specific tool with low-code applications for internal use or to develop a commercial tool. The present decision model is a theoretical approach that has yet to be implemented and tested in practice. Even if appropriate low coding tools are available for implementation, there are still significant challenges to be solved in practice. It should also be noted at this point that the database, in relation to the different project management approaches, represents a challenge. In the literature as well as in practice, there are always different assessments regarding the application requirements of the individual approaches and their classification into the categories “Agile, Traditional or Hybrid”. Furthermore, there is no publicly available and generally accepted database that comprehensively presents the essential project management approaches. Another limitation lies in the ability of those responsible for the project to correctly assess their own requirements. The best AI algorithm will fail if the decision-makers do not know the criteria for assessment or the effort required to collect data becomes so complex that it is carried out very incompletely or incorrectly. Appropriate instructions are required here.

10. Conclusions

Projects are an integral part of the corporate world these days. The selection of the associated project management approach is therefore an important success factor for companies in general. With the "Supervised Decision Model – L5", this work presents a decision model that could improve the quality of decisions in relation to the selection of project management approaches in complex projects (e.g. a digital twin). Decision-makers are supported both in choosing the approach at the beginning of the project and during the project duration in terms of evaluating the decision using project success factors. At the end of the project, the lessons learned provide feedback for future decisions, i.e. the algorithm learns from each project. Future work should be aimed at creating appropriate prototypes and testing them on the market in order to gather experience for a comprehensive implementation in the form of an app.

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Conflict of interests

The author declares no conflict of interest.

Author Contributions

Conceptualization, L.S.; Resources, L.S.; Methodology, L.S.; Investigation, L.S.; Formal Analysis, L.S.; Writing – original draft, L.S.; Writing, review and editing, L.S.

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Appendix

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