A Project Management Decision Support Tool for Keeping Pace with the Dynamics of Corporate Innovation Projects

Karolin Gebhardt[1,2(✉)], Tom Maes[2(✉)], and Andreas Riel[1(✉)]

[1] Institute of Engineering, University Grenoble Alpes, G-SCOP, 38000 Grenoble, France
karolin.gebhardt@gmail.com, andreas.riel@grenoble-inp.fr
[2] Bayer AG, 51373 Leverkusen, Germany
tom.maes@bayer.com

Abstract. Corporate innovation projects are typically characterized by a high dynamics of needs, insights and related solution approaches. In particular, the continuously increasing need complexity of innovation projects requires an approach to identify the project methodologies that are appropriate for a particular project, sub-project and their context, as well as to apply them correctly. This article proposes a practical decision support model for innovation project managers to select the management mode and method according to the current and evolving needs of an innovation project. This model has strongly been inspired by the experiential learning model of Kolb. This model is validated within the industrial environment of a German global key player in the pharmaceutical and chemical industry based on four selected innovation projects.

Keywords: Innovation project management · Agile project management
Corporate entrepreneurship · Leadership

1 Introduction

Innovation projects in huge and complex organizations are typically challenged by a balancing act of continuously changing needs [1, 2]. In practically every industry sector, innovation projects have to deal with an increasingly complex and uncertain business environment. Embedded in their corporate context, innovation projects have to assert their position in the middle of routine processes and standards and compete with business projects for dedicated resources. Just the sheer number of innovation project management approaches (IPMA) next to the traditional project management approaches highlights that the relevance of corporate innovation for organizational competiveness is scientifically acknowledged [3, 4]. The huge number of project management methodologies shows that project needs differ. This is supported by the common understanding that there is no one fits all methodology. The Project Management Institute (2018) diagnosed that despite the existence of various methodologies, about 15% of projects fail (12% with high maturity level and 21% with low maturity level) [5]. Furthermore, the PMI emphasizes in [5] that projects are more likely to succeed when they use various different project management approaches. This leads to

© Springer Nature Switzerland AG 2018
X. Larrucea et al. (Eds.): EuroSPI 2018, CCIS 896, pp. 619–630, 2018.
https://doi.org/10.1007/978-3-319-97925-0_52

the assumption that either the chosen methodology does not fit to the project's needs and/or that the methodology is not used in the right way. In particular, the continuously increasing and changing innovation project and sub project need complexity requires an approach to identify the project methodologies that are appropriate for a particular project and context [6], as well as to apply them correctly [7].

This article proposes a systematic and practical model-based tool that is based on the experiential learning model [8] and the established project management concepts. This tool helps to manage innovation projects depending on their particular temporary context and maturity and to select the appropriate fitting project management approach. Section 2 introduces our hypotheses related to innovation project dynamics. Section 3 investigates related work in agile, lean and traditional project management. Section 4 proposes our model built upon the hypothesis and the findings of the state of the art. Section 5 validates this model in the specific Bayer context based on four concrete innovation projects, two of which based in the information technology (IT) domain. Section 6 points out the implications of our proposed model on the selection of relevant innovation project management methods. Section 7 concludes with a summary of the key contributions and an outlook to our future research.

2 Objectives and Methodology

The objective of this research is to elaborate a systematic and actionable approach that helps to manage innovation projects depending on their particular context and maturity and to select the project management method that fits best to the project´s current context and maturity [9]. In order to address these challenges we want to propose an approach that allows characterizing the current needs of an innovation project and is sub projects as well as to capture the evolution of these needs over time and maturity. Furthermore, the intended approach allows associating the required management approaches with these needs, as well as to derive guidelines for innovation project managers. Ultimately, our research objective is to create a basis for a measurement framework for innovation project management.

With regard to the complexity and dynamics of changes of innovation project needs, our fundamental hypothesis is that successful innovation projects in corporate organizations make flexible use of four central methodical approaches dependent on the project phase or sub-project specific context:

- Experiment: Project phases that are confronted with complex and not well-defined needs, as well as not clearly defined solution, tend to be solved by experimentation.
- Iterate: Project phases that are confronted with complicated and not well-defined needs, but a clearly defined solution, tend to be solved by iteration.
- Plan: Project phases that are confronted with complicated and well-defined needs, but a not well defined solution, tend to be solved by planning.
- Execute: Project phases that are confronted with simple and well-defined needs as well as a clearly defined solution tend to be executed directly.

Based on this hypothesis we propose a model as decision aid for innovation project managers. We derive this model from the previous research result and project experience in a grounded theory approach and validate it in four innovation projects in a corporate context.

3 State of the Art

Traditional project management follows a linear, sequential and relatively predictable problem-solving-process, which can be organized in hierarchical tasks, like e.g. stage-gate-process [10]. The theoretical planning of the project is based on existing knowledge and takes place isolated from the later execution [9]. Thereby, the main objective is to stick to the project plan regarding time, costs and quality to reach the intended outcome [2, 11].

Because today´s project needs are in many cases more complex and dynamic, the traditional project management reaches its limits recognizing and articulating all relevant variables and their functional relationships). In this context, research and practice have put forth agile project management approaches, which are more flexible e.g. with regard to timing, resources or task completion [12]. The various agile approaches support the iterative and incremental development of the project, which is not predetermined by a project plan [13] Rapid and continuous consumer or user feedback enables an improved needs understanding and an ongoing according project adjustment [12].

A further approach to project management is based on exploration and experimentation. Experimentation, in particular design thinking, is described as a human-centered practice and learn process (experiment) that recommends collaboration and observation, allow rapid learning, and fast execution of ideas via building of prototypes [14]. In comparison to agile project management approaches, which analyze and address in particular existing (conscious) needs and possibilities, experiments explore both new needs (knowledge) and new solution concepts [15]. Based on experiments it allows to design an imaginable, potential solution and the search for a problem instead of planning and sequentially solving a problem or iteratively developing a solution. It can be described as system of spaces that frame solution and problem rather than a goal-oriented spiral or a predefined order of discrete steps [16]. Experiments are used to test derived hypotheses related to the problem and the solution and help to explore this spaces. Thereby, the main objective is on learning and knowledge acquisition to reduce uncertainty [17], which include the potential and frequent reformulation of the problem statement and project objectives. Both agile and design thinking not only describe a project management approach, but also a mindset [18].

In the innovation context, several scientists consider traditional project management as obsolete and redundant [19]. In contrast, supporters criticize the lack of agile management methods and progress assessment of agile approaches [20]. They regard traditional project management as a general standard to develop, control and assess projects without losing track by continuously defining new objectives [21]. Further approaches try to link the advantages of traditional and modern approaches and investigate in hybrid approaches like agile-stage-gate processes [10]. There is a growing understanding that the project method has to be tailor-made: individually selected, customized and implemented [22]. First approaches investigate in project parameters like project size, team size, and expertise of project manager to identify the best methodology [7]. Nevertheless, context and project needs change during the project lifecycle, and few insights have been published on how to tackle these changing needs appropriately [9].

4 A Decision Aid Model for Innovation Project Management

In order to investigate our hypothesis expressed in Sect. 2, we define a simple model that help situate the current management needs of innovation projects, dependent on the type of uncertainty they are confronted with. Our 2-by-2 innovation project management model is spanned on two axes representing the uncertainty regarding the problem, and the uncertainty regarding the solution, respectively. Both axes are binary, i.e. the model differentiates between uncertainty regarding the problem and the solution (high/high), uncertainty regarding the problem (high/low), uncertainty regarding the solution (high/low), and no uncertainty (low/low). Following Ashby's law of requisite variety (1957), which states that to control a situation with certain variety, an approach with the same degree of variety is required [23]; we assigned the four innovation project management approaches (IPMA) proposed in Sect. 2 to the four spaces as shown in Fig. 1.

4.1 Experimentation

If defining the problem and developing a solution is the challenge, the project team has to focus on experimentation to gain a clearer picture of the current situation as quickly as possible. Hence, the current central focus is on experience-based learning and less on the outcome of the project. Based on the experiential learning model of Kolb (1984) project teams learn through "the process whereby knowledge is created through the transformation of experience", which necessitates the four steps of observing and feedback, reflecting insights, synthesizing ideas, and building prototypes.

Experimentation within innovation projects means gaining a deep understanding of the context, the scope and the needs by analyzing the potential users or customers e.g. by observation or feedback. Thus, new ideas can be synthesized and corresponding hypotheses derived and tested. Exploring these ideas by building prototypes allows testing the hypotheses. This experiential learning circle can be repeated multiple times until the project teams eliminate uncertainty regarding the needs or the solution and should move to a more target-oriented approach. Thus, driving an innovation project by experimentation means to fluidly move back and forth between the concrete and abstract perspective as well as between the reflective and active mode. Order and time spent in each mode don´t follow an established standard [24]. In case of a high level of uncertainty (solution and problem uncertainty) this methodical approach of experimentation allows rapid and unrestricted learning from the environment. This explains why this approach is of high relevance in the context of radical innovation.

Experimentation is not based on key performance indicators, it is rather focused on the learning progress which makes it difficult to measure and evaluate the performance of a project team. With this approach managers delegate the definition of the scope and

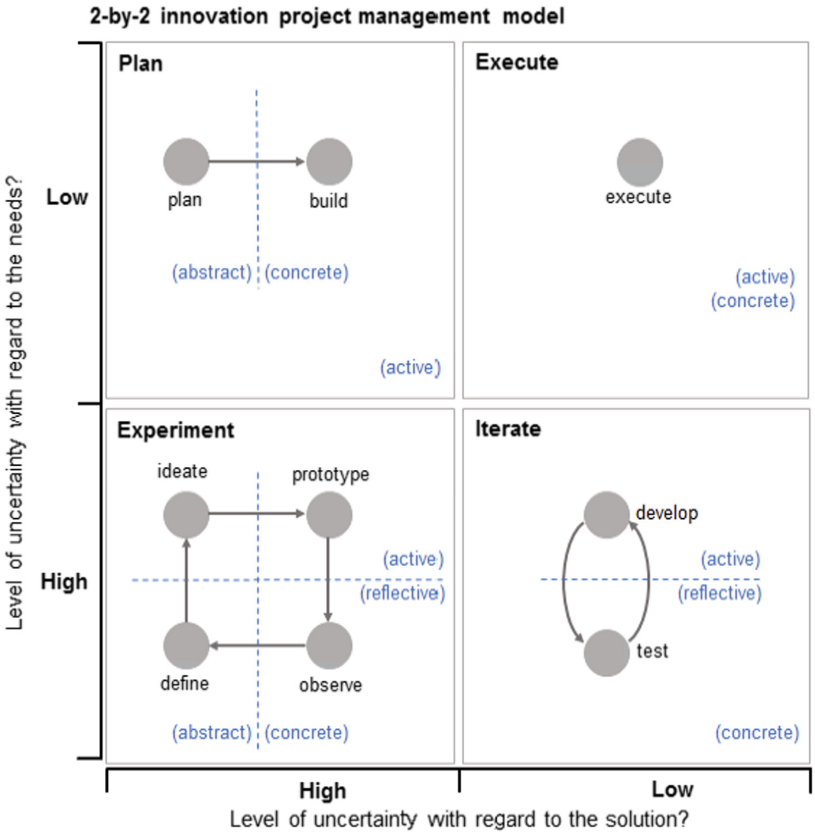

Fig. 1. 2-by-2 model: methodical innovation project management approaches

the problem (allow teams to pivot) as well as the development of a solution to the project teams. To guide teams under these conditions as well as to gain insights about their performance, managers have to make sure that teams always start with the most critical assumption. Furthermore, teams need to move fast and in small steps. This can be ensured by providing short timeframes and a shoestring budget, and/or by the engagement of a coach. Managers can organize frequent feedback sessions or demonstrations in order to ensure that teams don´t remain isolated. Managers have to guide teams as they are moving fluidly between active and reflective mode as well as abstract and real mode (e.g. by placing requirements regarding user exchange intensity). In particular in innovation projects performance is driven by team diversity, which can be presumed by team composition conditions. Basically, the manager has to keep on the sideline to avoid limiting or influencing the possibility space. The key players within experimentation are the project team and the users/ customers.

4.2 Iteration

Iterating within innovation projects means to focus on understanding and defining the needs of the customer to execute the defined solution. As the solution is already well defined there is no focus needed on synthesizing further ideas. In comparison to experiential learning, the learning process through *iteration* is only solution-oriented. To learn as effectively as possible, teams should invest time and resources in building a solution (active mode) and testing their solution through customer feedback and observation (reflective mode). Doing so teams iterate more rapidly in the "express test cycle" between the active and reflective mode and stay in the concrete mode to continuously improve their solution and problem understanding. With regard to the lack of problem understanding, changes within the project are inevitable. Thus, adaptability to change based on learning is a central characteristic of iteration [25–27]. Moving between feedback and solution is often the case of technology push: a new technology is pushed in the organization, whereas the related need still needs to be identified [28].

Iteration like experimentation is focused on learning as it is difficult to measure and evaluate project team performance. In case of iterating the manager delegates how to define the problem. By defining the solution in advance, restricting the budget as well as joint prioritization of features that should be taken into account, the manager is able to provide guidance. Feedback meetings with customers or users ensure the learning progress with regard to the problem understanding. To evaluate the learning progress, dialogues with the team should be focused on the functioning of the solution. In this case, project manager, users and/or customers are key players close to the project team.

4.3 Planning

Planning within innovation projects means to focus on the coordination and prioritization of tasks to develop a solution when the problem is clearly known. Departing from a clearly defined problem, the project team has to link and structure various data to schedule related tasks. Based on experience through preceding and similar tasks, teams are able to abstract the available information and identify patterns. Through the structuring of data, different solution opportunities can be identified. The learning process can be reduced to the active mode: project teams abstract patterns from the available information base to synthesize a plan for the development of solutions.

Planning is focused on the abstraction of given information regarding problem understanding. The manager delegates the development of the solution and project deliverables. Demanding for a specific degree of detail with respect to the project plan or a clear budget restriction, managers are able to provide guidance to the project team. The manager is able to monitor the progress by evaluating if project deliverables have been achieved on time. Optionally the manager is able to summon a steering committee to guide the project. The manager as well as the project team play key roles.

4.4 Execution

Execution means making use of the knowledge about the defined problem and known solution without further learning or planning. Based on a clear understanding coming from available information, prior experience or e.g. a clearly defined guideline, performance is no coincidence. If, for example, an IT expert has to set up a 100 web sites under same conditions, the implementation is a pure execution without further planning (for how to implement each web site) or further feedback loops. In case of a clear understanding of what is needed and how to solve the problem, any experimenting, iterating or planning is considered waste.

Execution can therefore be completely delegated by the manager. Guidance is given by established routine processes and standards. Face-to-face meetings or team meetings can be used as a framework for discussing irregularities. The key players are the operating experts/team members.

In a typical innovation project, these four generic IPMAs have to be applied dynamically at different project stages to strategically tackle uncertainty. The main objective of an innovation project is the outcome, the customer value, which can only delivered by execution. To achieve the intended outcome in an innovation project requires dealing with different sources of uncertainty (regarding problem or solution definition or both), whereas each of the presented approaches is able to deal with one specific source of uncertainty. Due to the continuously changing project needs, managers can neither stick to one single approach nor to a standardized order of approaches. Instead, managers have to ensure that the approach is flexible adapted to the relating subprojects′ needs to drive the project successfully to execution. Further flexibility is required to adapt the basis to assess, guide the project team and their way of communication depending on the selected project management approach.

5 Corporate Innovation Case Study

We applied the 2-by-2 innovation project management model in the context of a German major corporation in the pharmaceutical and chemical industry. In order to analyze the methodical procedure of the teams related the project maturity and context we developed a quantitative questionnaire and a supplementary interview guideline based on qualitative questions. The questionnaire consists of 45 questions, subdivided in questions that address (1) the project charter (2) project maturity (3) project context, and (4) project management approach. The majority of the questions were scored on a 5-item-Likert-scale (strongly agree (1) – strongly disagree (5)) and were reviewed by colleagues and survey experts regarding practical understanding, logic errors, etc. To evaluate the results, we defined an “ideal” answer for each question to develop stereotype context and project management approach profiles (as defined by our model). Based on the ideal answer we calculated the distance of the answer to the ideal answer for each IPMA. For the visualization we plot the inverted results in a network diagram, whereas a value of 0 means a maximum distance (no IPMA characteristic) and a value of 4 means no distance (maximum IPMA characteristic).

The four selected innovation projects analyzed in this present paper have been ongoing for about seven months (A, B, D; 30 months for C) and have reached different technology maturity levels (TRL) [29]: 4 (A), 5 (B), 9 (C), and 7 (D). Two of which are based in the IT domain (C, D). Each of the projects is supported by a corporate innovation initiative with funding and/or consultancy. The projects were intended to be implemented at one individual location (A), at many locations in one county (B, C) and globally (D). The project team size varies between 2 (A, B) and 4 (C, D) team members, which are by the majority located in different departments but similar business units and functions (A, B, D). Only one project (D) consists of 2 external and 2 internal partners located in different business units. All projects were supported by an innovation coach in the beginning (A, B) or throughout the complete duration so far (C, D). Together with the project leaders, we identified 3 (A, B, D) and 5 (C) crucial project phases based on important milestones and turning points. Each project leader and further project team members were asked to evaluate each phase by sequentially using the developed questionnaire.

Team A started their project with a defined problem. The team differentiates three phases derived from central turning points that characterize the project (need definition, ideation & prototyping). In phase 1 the context results state a relatively high and balanced approach of plan, iteration and experimentation and less execution, whereas the results of the used IPMA only state a high level of experimentation and iteration. In phase 2 the results of context and used IPMA are overlapping and balanced at medium level in all four IPMAs. In phase 3 the context results stay on the same extension level, whereas the results of experimentation and iteration state a moderate increase and decrease of experimentation.

Team B started their project with a defined solution to which they originally tried to identify a relating problem. Up to the time of interviewing the team differentiates three phases derived from central turning points during the project (problem definition, development, and prototyping). Starting from balanced values in experimentation, iteration, and planning and a lower value in execution, the characteristics of the results change during the named project phases. Therefore, the importance of experimentation and iteration continuously decreases (context and approach related questions) during the project. On the other hand the importance of execution and planning continuously increases.

Team C started their project based on an identified business problem which the team tried to address by a fitting solution respectively a fitting technology. The team differentiated five project phases (problem definition, ideation, experimentation, developing a working solution, piloting). In the phase 1 the team tried to frame the problem based on different stakeholder definitions. At the same time they were focused on identifying a technical solution. The results in this phase are characterized by a high discrepancy between the context and the used IPMA (see Fig. 2). Whereas the context scores the highest value in experimentation, the team focused mainly on execute and plan, In phase 2 and 3 the team started to involve customers to ensure that the focused technology (solution) fits to the customer needs. In the course of the project phase two to five the values of context and approach results are largely overlapping. In total, the values of experimentation and iteration increase, whereas the values of execution and planning decrease.

Team D had no clear understanding of the user needs neither of the solution at the start of the project. The team differentiates three project phases (experimentation, prototyping/funding, developing a working solution). In the phase 1 the questionnaire results regarding the context state a high level of experimentation, iteration, and relatively high level of plan and a low level of execution. This is in contrast with the

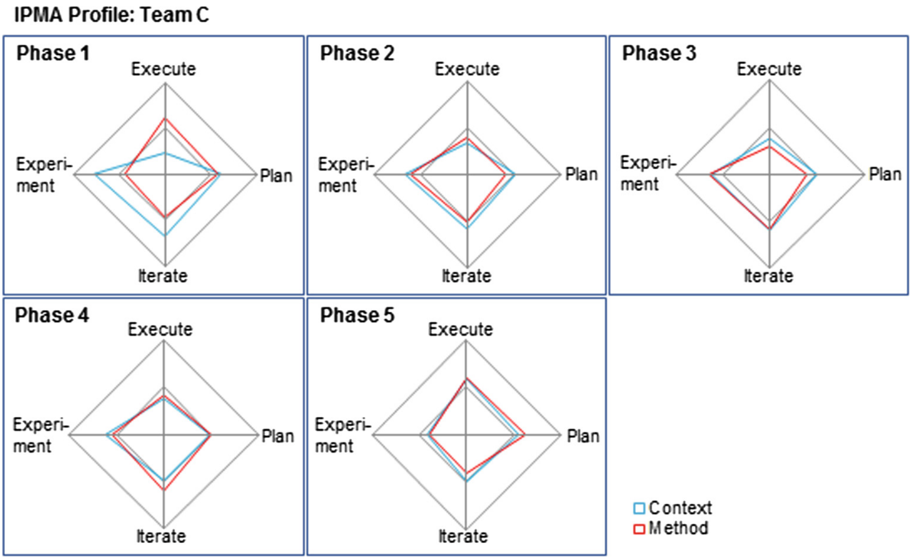

Fig. 2. Results - IPMA Profile: Team C

results of the used approach which indicates a lower level of planning and iteration, whereas the values of experimentation are overlapping. In the course of the project the values of execution, planning and iteration are overlapping, whereas the context results consistently state a higher level of experimentation than the team really used. In sum the values of experimentation and iteration decrease, whereas the values of planning and execution first decrease and later increase.

Summarizing the results of all teams allows comparing the distance of the really used approach to the context stated approach of each IPMA. This indicates a value of 0.42, for execution, 0.40 for planning, 0.34 for iteration, and 0.37 for experimentation with a maximum deviation of 4. In the course of the projects, the outlier values diminish in each IPMA.

Comparing the four innovation projects, there are several patterns that support our hypothesis: (a) the level of experimentation decreases continuously with increasing project maturity; (b) the level of iteration is higher at the beginning of the project than at the last measuring point but can increase during the project; (c) the level of planning is relatively balanced during the project; (d) the level of execution increases continuously with increasing project maturity. The IPMA development of team B, which discarded their first idea, represents one of several events in which a team makes flexible use of IPMAs. In addition to that, the results point out that the teams make use of all four IPMAs in each phase, varying only the strength and focus of the respective IPMA.

6 Implication on Project Management Method Application

The 2-by-2 IPMA serves as a decision making tool for innovation project managers, as their projects moving from one phase to another, and their context change dynamically. In order to provide guidance for the selection of the appropriate IPMA, we provide a mapping of IPMA characteristics and examples to each of the four model areas in Fig. 3.

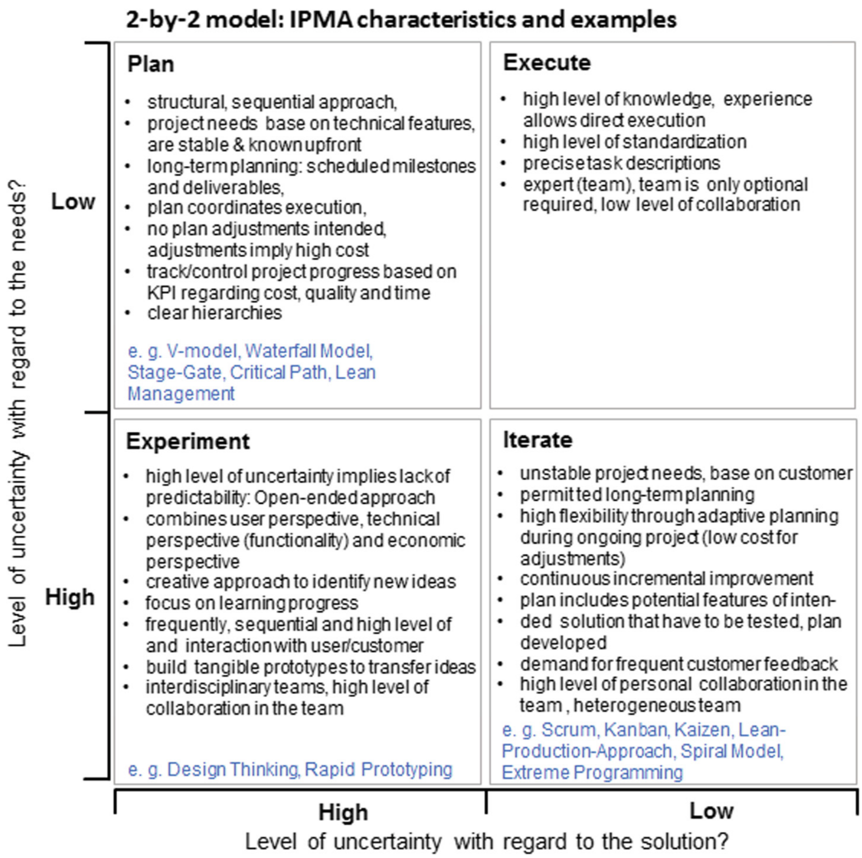

Fig. 3. IPMA characteristics and examples

The 2-by-2 model classifies the IPMA on two axes that characterize the degree and type of uncertainty and, hence, risk in an innovation project. In principle, innovation projects have to deal with uncertainties, whereas each of the four IPMAs represents a portfolio of methodologies that are in particular efficient in dealing with one specific type and level of uncertainty. In other words, the choice and starting point of an IPMA depends on the characteristic of uncertainty. Moreover, the "exit point" of the IPMAs creates a further intersection. Starting from a low level of uncertainty, the IPMA executions starts and ends in executing in the active and concrete mode. Planning also ends in the active and concrete mode by translating the plan to building. Additionally, iteration and experimentation imply the continuously developing or building of a solution/prototype in the active and concrete mode. With decreasing uncertainty the focus in this mode increases. At the end the successful implementation of a project as requirement of creating added value can only become true on the real market with a working solution in the active and concrete mode. When choosing the IPMA, managers have to assess uncertainty which has to be efficiently reduced by fitting IPMA. With decreasing uncertainty the mangers have to ensure an IPMA shift to a more execution-focused IPMA.

7 Conclusion and Outlook

We have proposed a model that supports innovation project managers in selecting an IPMA that fits to the current temporary innovation project needs. The central elements of our model are four fundamental IPMAs *Experiment*, *Iterate*, *Plan*, and *Execute* differing by their level of uncertainty regarding the project´s needs and the solution. The model is complemented by a question catalogue to identify the fitting IPMA derived from the current context and maturity level of the project and its subprojects. We applied our model in a corporate context that is representative for huge and complex organizations. It has to be noted that our results are based on a small sample size and on interviews that underlie subjective interpretations. Our further research will therefore investigate a larger sample of both successful and failed projects in several companies and industries. We will also relate the model to uncertainty and risk management in order to further enlarge its usefulness and applicability as decision aid tool.

References

1. Williams, T.: Assessing and moving on from the dominant project management discourse in the light of project overruns. IEEE Trans. Eng. Manag. **52**(4), 497–508 (2005)
2. Wysocki, R.K.: Effective Project Management, 4th edn. Wiley, Hoboken (2007)
3. Crawford, G.C., Kreiser, P.M.: Corporate entrepreneurship strategy: extending the integrative framework through the lens of complexity science. Small Bus. Econ. **45**(2), 403–423 (2015)
4. Ireland, R.D., Covin, J.G., Kuratko, D.F.: Conceptualizing corporate entrepreneurship strategy. Entrepreneurship Theory Pract. **33**(1), 19–46 (2009)
5. PMI: https://www.pmi.org/-/media/pmi/documents/public/pdf/learning/thought-leadership/pulse/pulse-of-the-profession-2018.pdf. Accessed 01 Apr 2018
6. Cheema, A., Shahid, A.A.: Customizing project management methodology. In: 9th International Multitopic Conference, IEEE INMIC 2005, pp. 1–6. IEEE (2005)
7. Cockburn, A.: Selecting a project's methodology. IEEE Softw. **17**(4), 64–71 (2000)
8. Kolb, D.A.: Experiential Learning: Experience as the Source of Learning and Development. Prentice-Hall, New Jersey (1984)

9. Špundak, M.: Mixed agile/traditional project management methodology – reality or illusion? Procedia - Soc. Behav. Sci. **119**, 939–948 (2014)
10. Cooper, R.G., Sommer, A.F.: Agile-Stage-Gate: new idea-to-launch method for manufactured new products is faster, more responsive. Ind. Market. Manag. **59**, 167–180 (2016)
11. de Carvalho, M.M., Patah, L.A., de Souza Bido, D.: Project management and its effects on project success: cross-country and cross-industry comparisons. Int. J. Proj. Manag. **33**(7), 1509–1522 (2015)
12. Cooper, R.G.: The stage-gates idea-to-launch process: update, what's new, and NexGen systems. J. Prod. Innov. Manag. **25**(3), 213–232 (2008)
13. Lindvall, M., et al.: Empirical Findings in Agile Methods. In: Wells, D., Williams, L. (eds.) XP/Agile Universe 2002. LNCS, vol. 2418, pp. 197–207. Springer, Heidelberg (2002). https://doi.org/10.1007/3-540-45672-4_19
14. Lockwood, T.: Design Thinking: Integrating Innovation, Customer Experience, and Brand Value, 3rd edn. Allworth Press, New York (2009)
15. Sage, D., Dainty, A., Brookes, N.: A critical argument in favor of theoretical pluralism: project failure and the many and varied limitations of project management. Int. J. Proj. Manag. **32**(4), 544–555 (2014)
16. Brown, T.: Design thinking. Harv. Bus. Rev. **86**(6), 84 (2008)
17. Liedtka, J.: Innovative ways companies are using design thinking. Strateg. Leadersh. **42**(2), 40–45 (2014)
18. Serrador, P., Pinto, J.K.: Does Agile work? A quantitative analysis of agile project success. Int. J. Proj. Manag. **33**(5), 1040–1051 (2015)
19. Lenfle, S., Loch, C.: Lost roots: how project management came to emphasize control over flexibility and novelty. Calif. Manag. Rev. **53**(1), 32–55 (2010)
20. Lenfle, S.: Floating in space? On the strangeness of exploratory projects. Proj. Manag. J. **47** (2), 47–61 (2016)
21. Gillier, T., Hooge, S., Piat, G.: Framing value management for creative projects: an expansive perspective. Int. J. Proj. Manag. **33**(4), 947–960 (2014)
22. Charvat, J.: Project Management Methodologies: Selecting, Implementing, and Supporting Methodologies and Processes for Projects. Wiley, New Jersey (2003)
23. Ashby, W.R.: An Introduction to Cybernetics. Chapman & Hall Ltd., New York (1957)
24. Beckman, S.L., Barry, M.: Innovation as a learning process: embedding design thinking. Calif. Manag. Rev. **50**(1), 25–56 (2007)
25. Heck, J., Rittiner, F., Steinert, M., Meboldt, M.: Iteration-based performance measurement in the fuzzy front end of PDPs. Procedia CIRP **50**, 14–19 (2016)
26. de Weck, O.L., Eckert, C.: A classification of uncertainty for early product and system design. In: International Conference on Engineering Design, ICED 2007, 28–31 August 2007, Cite des Sciences et de l'industrie, Paris (2007)
27. McManus, H., Hastings, D.: A framework for understanding uncertainty and its mitigation and exploitation in complex systems. In: INCOSE International Symposium, Rochester, NY, vol. 15, no. 1, pp. 484–503 (2005)
28. Åstebro, T., Dahlin, K.: Effects of expected demand, technological opportunity, appropriability and competitive conditions on invention commercialization. In: DRUID Summer Conference 2003, Copenhagen, pp. 12–14 (2003)
29. Mankins, J.C.: Technology readiness assessments: a retrospective. Acta Astronaut. **65**(9-10), 1216–1223 (2009)