Project Management Development – Practice and Perspectives
International Scientific Conference on Project Management in the Baltic Countries

# JOURNAL

# Project Management Development – Practice and Perspectives

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# PREFACE
# Professionalization and further development of project management

During the last year we continued to deal with the new challenges as during pandemic many projects and project managers faced problems what we all did not expect to happen. However, project management has always been a field what is flexible to changes and risk mittigations as those are cruical processes in any project.

That is why this publication features experts experience with the use of agile methods, techniques, and formats in project development. They will review the agile project management practice in IT, services, construction, and other projects. The new formats additionally concentrate on the development of their standards of use and the problems arising in their practical application.

The current global economy and growing digitalization require ever new solutions for cooperation between economy and society. In these terms, project management serves as a key discipline ensuring technically innovative and fast satisfaction of clients' demands. The classical project management methods are faced with certain changes in such circumstances. The new factors of success are agile and hybrid project management, as well as social competence and interactivity. The time of choosing between agile and traditional project management has already passed. Today, the tools to use for project management combine both agile and traditional elements. Pandemic thought as that risk management is still crucial in every project and right risk management actions should be impelemented. Proper risk management also requires proper risk management methodologies.

Now agile methodology has its roots in the IT world. It has recently been adopted by other industries for more tangible projects and just larger projects overall. It is particularly useful in situations where there is a lot of unknowns, where project specs can change frequently and we can see that happening a lot when you have got your teams distributed over a wide geography or, some are remote, some are having to come in.

Leveraging technology is crucial. Advanced technologies now, such as artificial intelligence can play a very important role in helping teams organize their work. This year will be challenging for every insitution and particulary for project managers. I hope there will be good leasons learned and new approaches and best practices will be discussed next year in the international conference, here in Riga, Latvia!

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# Chatbot-Supported Retrospective

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## Abstract

Retrospectives are not just a part of agile projects, but also the driver that keeps the entire project, from initiation to successful completion, on track. By conducting them regularly, a project team can analyze and, if necessary, align the agile practices at the team level. In practice, however, conducting a retrospective as part of an agile project to generate qualitative benefit is a complex process that is significantly influenced by personal behaviour. Particularly for newly formed teams, the retrospective is often not fully successful at the beginning. A chatbot-supported retrospective helps novice Scrum Masters and newly formed teams to provide new stimuli for reflection during a stagnating retrospective. The chatbot, as the team's electronic coach, purposefully steers the retrospective by addressing critical issues from a neutral perspective. The chatbot is mainly placed at the situation for evaluating the current state. In addition to a set of standard questions, the Scrum Master can deposit additional questions as needed. The evaluation of the requirements and the solution concept took place within the Co-Innovation Lab (Günzel at al 2019) of the Munich University of Applied Sciences.


**Key words:** *Agile Project management, Retrospective, Chatbot*
**JEL code:** O31

## Introduction

The retrospective is a central element in agile project management, as the team repeatedly evaluates its own approach during the project and can take corrective actions in the case of deviations. The statement by Soichiro Honda "Success can only be achieved through repeated failure and introspection." (Atkinson et al 2014) expresses the basic framework of the retrospective, in that through *Inspect and Adapt* procedural errors of the team can be identified and eliminated by the team itself. Retrospectives serve as an occasion to take a look at the past - in detail at the last sprint - and to reflect on which aspects are good, but also which topics can still be improved.  Thus, a basis for continuous improvement can be achieved (Kerth 2001).

According to Luckner and Nadler's (1997) comfort zone model, a distinction is made between the learning, comfort, and panic zones, which are crucial for learning and further development. Normally, team members are in the comfort zone because they feel comfortable with familiar tasks and situations. Nevertheless, learning psychology assumes that learning in the comfort zone is sparse to impossible (Michl 2020).  The goal of the retrospective must be to get the team members to leave their personal comfort zone and enter the learning zone during the execution. This only works based on an appropriate framework, which on the one hand depends on the trust-inspiring environment (Sutherland 2015). On the other hand, entering the learning zone depends on the use of a framework of rules to achieve the establishment of privacy (Andresen 2017). Specifically, the way participants' contributions are handled is responsible for the success of the retrospective. Interest and attention must be given to team members' contributions, as well as an appreciation for their participation back. This ensures and encourages long-term engagement of the individual parts of the group (Timinger 2017). However, the retrospective should not only be a space to lift individual members out of the comfort zone and into the learning zone, but much more to encourage the whole team to improve. For this, it is important to create a framework in which constructive criticism and suggestions for improvement are not seen as personal attacks (Dräther 2014).

The step into the learning zone represents a classic change process, which is accompanied by the Scrum Master. He/ she ensures that an atmosphere free of fear is created. In addition, there must be enough room for creativity so that the participants can develop their ideas. The selected methodologies should aim to ensure that all participants are able and willing to actively participate to jointly conduct a root cause analysis of the obstacles in the team and in the project (Hanschke 2017).

Especially with newly formed teams and untrained team processes, there is a risk that conducting a retrospective will have a negative impact and that individual team members will slip into the panic zone. Since the Scrum Master is also an active part of the team, the basis for a successful cooperation of the team must be created at the beginning to exploit the full potential.

In various projects in the context of courses at the university, it has been shown again and again that in newly formed teams the retrospective was not carried out or only performed on the surface. These projects are conducted via the Co-Innovation Lab platform (Günzel at al 2019) to obtain as real situations as possible with genuine challenges and companies as clients. It was shown that the students were theoretically aware of the procedure of a retrospective but did not generate any added value due to the lack of practical experience, due to the new situation and due to the avoidance of critical questions.

Based on the problem definition, the following research questions can be stated for the paper: What is the basic acceptance and application of the retrospective by newly formed teams using the example of the Co-Innovation Lab? Why is the usefulness and necessity of retrospective questioned? How do interpersonal and personal factors influence the implementation of the retrospective? To what extent can the use of virtual assistance increase the acceptance and application rate of the retrospective?

## Unsuccessful execution of retrospectives in new teams

As part of the execution of several projects in the Co-Innovation Lab in the winter semester 2020/2021, the acceptance and application of the retrospective was surveyed among the participating students. With the help of an online survey, 24 responses were generated from 62 surveyed students. The respondents were students of a bachelor's and master's program in business administration as well as a bachelor's program in IT, all of whom already had a theoretical background on agile project management and the importance and execution of the retrospective. The survey took place in the first days of the project phase to record the status quo.

One question related to the planned frequency of execution. 35% of the participants answered that they planned to conduct a periodic retrospective at the end of each sprint, 35% planned to conduct a one-time retrospective at the end of the project, and 30% did not plan to conduct any retrospective.

The following question refers to causes of sporadic or missing execution. In addition to the answer options unnecessary (22%), no improvement recognizable (7%) and waste of time (35%), the participants could give their own answer options (42%). Here different answers resulted; from the statement, that the importance of the Retrospective is underestimated as unawareness of its importance or not at all recognized as lack of importance given to it, in addition, on the fact that a bad planning prevents the execution (Simply often not thought of it; lack of time).

Furthermore, they were asked where they see failure or the greatest potential for error and problems within the individual procedural steps of a retrospective (e.g., according to Esther Derby). The biggest challenges are seen in the collection of data (Gather data) with 37% and the determination of measures (Decide what to do) with 44%. However, many respondents also found generating insights (Generate insights) a problem at 6%. Other participants (12%) also criticized a lack of ability for self and team reflection and the obstacle of implementing the derived actions.

When asked what problems prevented, plagued, or hindered the implementation of the retrospective in the past, respondents found many different explanations. Without exception, these can be traced back to interpersonal and personal characteristics (shyness; dishonesty; no respectful interaction, actively putting obstacles in the way). However, planning errors described at the beginning also caused problems (too time-consuming; no one felt responsible).

The question based on this referred the interviewees to a requirement for the retrospective from the literature. The focus was on openly addressing problems and the virtues of honesty and constructive communication. Interestingly, these problems were already independently posed by respondents in the previous question. Answers included "people often have barriers to being honest and don't want to hurt team members" as well as "problems were not addressed directly because people also knew each other personally, the personal relationship took precedence over the professional work." Only one response generated an opposite result ("We communicated clearly and honestly and therefore had no difficulties").

In summary, the basic acceptance of retrospective and its recognition among students in newly formed teams is very low. The survey reinforced the hypothesis made at the beginning of the research of students questioning the meaningfulness and relevance. The problems and causes of this are manifold. However, despite prior knowledge, many participants fail to recognize the added value of the retrospective. Meanwhile, the retrospective tends to be described as a waste of time and unnecessary. Also, the reflection of the entire survey generates the assumption that the students are overwhelmed with the self-organized planning and the agile way of working, respectively, reach their limits. Therefore, agile methodologies of the Scrum process, such as the retrospective, fall by the wayside due to temporal misplanning.  Often, the retrospective is not done by choice, but because a retrospective at the end of the project is part of the exam performance (or as part of the project completion). Students therefore see the retrospective as a constraint and a requirement, but not as an aid to optimizing their own and their team's work. The power of the retrospective is simply underestimated, and its potential is not exploited.

**Related Work**

According to the Scrum Guide (Schwaber & Sutherland 2020), the retrospective is used to find and plan "ways to increase quality and effectiveness." The Scrum team inspects the last sprint in terms of people, interactions, processes, tools. In addition to the issues that went well or problematic, ways to solve these problems are identified. In the literature, a variety of approaches can be found, which are further presented from a classification into question-based, emotion-analytical, big-picture, prioritizing and creative retrospective.

- Question-based retrospective: Basically, methods in this category such as Asking Questions (Goncalves & Linders 2014), Starfish Retrospective (Stein 2015), Sailboat Method (Goncalves 2019a) or the Each One Meets All Method (Fatjak 2013) pursue a long-term improvement idea by initiating discussion in the team through questions. This aim to ensure that continuous improvement of the team, each individual, and the project is driven through execution. Precisely because these formats are adapted to the entry into the agile world and retrospective, an attempt is made to create a trusting environment, which, however, does not immediately result in constructive execution. Rather, teams in these methodologies make the mistake of dealing with feedback and criticism too personally due to their inexperience. This cannot or can only partially be reduced by these approaches. The formats have a fixed schedule, which restricts creativity and freedom of thought or makes them disappear. On the positive side, however, the participation of each individual is encouraged by the concrete specifications of the methodologies.
- Emotion-analytical retrospectives: This category is suitable for teams facing fluctuating emotional difficulties. The Happiness Index (Goncalves 2019b), One-Word Retrospective (Linders 2013), the Appreciative Retrospective (Retrospectivewiki 2013) or Strengths-Based Retrospective (Linders 2013) try to score with a special focus on the psychological level and specially to create trust and space for constructive criticism, openness and feedback.

Furthermore, the idea of continuous improvement is also followed and lived. The emotion-analytical retrospectives try by their structure to motivate the participants to take part in the execution but seem mostly very unchangeable and leave little room for creative and innovative approaches. The templates found in the literature always try to fulfill the points of root cause analysis and action planning in order to add value to the further course of the project.

- Big Picture Retrospectives: This category aims to create a Big Picture. This type of retrospective, such as the Fly High Retrospective (Linders 2014), the Spider Web Retrospective/Team Radar (Derby et al 2006), or the Amazon Customer Review (Baldauf 2020), scores particularly well with the overarching planning, execution, and follow-up of root cause analysis and subsequent action planning. Teams that choose this form of retrospective generate very helpful documents and problem maps during the exercise, which can be integrated in the next Sprint Planning. The rather open execution of the retrospective exercises allows the participants to incorporate their own ideas, ways of thinking and views and has a positive effect on the motivation to participate. The team finds a trusting environment that invites open discussion with a healthy feedback culture and honesty.
- Prioritizing Retrospectives: The focus is on generating and prioritizing actions. This line of business scores particularly well in terms of root cause justification, analysis, and the associated derivation of actions that result in optimal improvement at the team or organizational level. Typical representatives are the Plan of Action Retrospective (Caroli & Coimbra 2020), Top 5 Retrospective (Bowley 2013) or the Deep Tissue Massage Retrospective (Mamoli 2015). The constant drive for improvement can cause the team's motivation, desire, and commitment to participate in the retrospective session to suffer. In addition, in certain cases, the setting of the retrospective can be more like a tense meeting and create anxiety and closed-mindedness among participants. This ultimately risks participants ceasing participation out of self-protection or becoming too personal and attacking with their statements.
- Creative Retrospectives: In this category, retrospectives are conducted in a playful, off-topic manner that brings out creativity and personal responsibility. Nevertheless, the trust-building and constructive atmosphere can often suffer from the lack of seriousness of the methodology. In the end, the implementation of such a methodology as the Giphy Retrospective (Müller 2020), Card Game (Dellnitz), or Retro Game (Stoll 2017) only partially aims to generate useful output. Depending on the often-missing striving for improvement, the aspects of root cause analysis and action planning are only partially implemented. The focus is on creating variety and increasing the fun factor in often deadlocked projects and teams.

## Chatbot-supported Retrospective

From the research conducted within the framework of the study, it has been shown that the steps of information gathering, analysis and measures derivation are the biggest issues of retrospective in the phase of team formation. All existing methods are unable to reduce the risk of unsuccessful implementation in the constellation of new and inexperienced teams. Therefore, the goal of improvement is not to improve the pre- or post-processing of retrospective meetings, but to focus on the integration into the meeting itself.

Initial articles and research integrating chatbots into retrospecktive execution show the potential. Matthies et al. (Matthies et al 2019) focused on integrating a chatbot into the retrospective communication and tracking process. Remy Sharp (2019) addressed the integration of a chatbot into virtual communication using the tool Slack. Here, the chatbot initially acts a collector of retrospective input from developers, who sent it to the chatbot via message. The

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chatbot then presented this information for prioritization in the development team's communication channel with the goal of highlighting the top three areas for improvement.

The chatbot presented in the following should not only structure and guide the retrospective, but also collect and evaluate data from the team to intervene and derive actions with the help of this data. Optimization through a chatbot is to be based on the ideal-typical process of Derby et al in that the integration of a chatbot supports these phases as a neutral third party to focus the team in the first phases of team building.

*Basic framework of the chatbot-supported retrospective*

The chatbot-supported approach uses Ester Derby's (Derby et al 2006) flow as the basic framework of retrospective (see figure 1). Analogously as described by Goncalves & Linders (2014), "learning by doing" will produce the version appropriate for the team.

1. Set the Stage: Retrospective participants are mentally picked up and prepared for the main part of the retrospective. The content can be introductory questions, which are either off-topic or aimed at inquiring about the general well-being of the members. Here, the literature likes to refer to the visualization of the personal feeling of the participants. Another way to make the start of the retrospective successful is to consciously ask the developers about the process and content of the last sprint to revive what happened. It is also important in this phase to create the aforementioned framework or the required atmosphere (Derby et al 2006).
2. Gather Data: information is gathered about what happened in the last sprint. Even if the sprints are managed together by the developers and are characterized by daily exchanges, this does not mean that every member of the group shares the same impression and perspective on the past. Pooling information in the form of views, opinions and experiences expands everyones views and creates a holistic picture. This is the only way to advance to the next stage (Derby et al 2006).
3. Generate Insights: The goal in this step is to optimize the work of the developers in terms of a better cost-benefit ratio. A central role here is to rethink the concrete processes and not to draw hasty conclusions. Here a sustainable thinking and consideration of the problems is more advantageous than only solution-oriented thinking (Derby et al 2006).
4. Decide What to Do: The main focus is on prioritizing the suggestions for improvement. A too comprehensive list of changes for the next sprint would only lead to disillusionment in the next retrospective and affect it adversely. It is important to keep the right balance between feasible improvement potentials and too utopian ones. Finally, a concrete overview should be created during this phase to incorporate these points in the next Sprint Planning (Derby et al 2006).
5. Close the Retrospective: Like the beginning of the meeting, concrete questions should round off the session and record what added value the invested time enables. To exaggerate, one could even conduct a separate retrospective session to analyze whether the actual retrospective went according to plan and achieved a usable output (Derby et al 2006).

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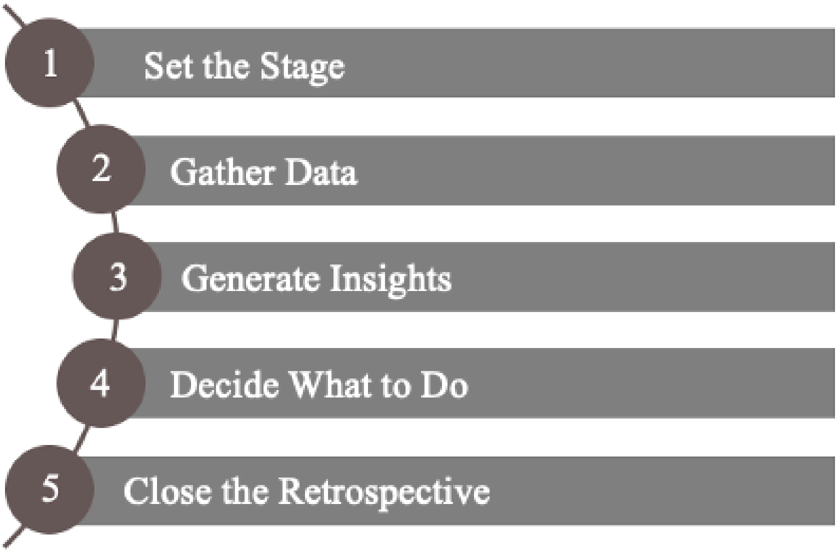


Fig. 1. ***Structure of a Retrospective (Own representation based on Derby et al 2006)***

*Support by the chatbot*

The approach is based on the concept of "Asking Questions" according to Goncalves & Linders (2014), which is adapted to support the Scrum Master and Developer. In general, the idea is that by asking questions of the chatbot (figure 2), developers generate answers to these questions. These results are processed, documented, and integrated in the next sprint to improve the processes. The questions are not permanently fixed, but can be adapted, deepened or made more complex depending on the knowledge level of the Scrum Master and the developers.

Starting with Norman Kerth's four core questions (Goncalves & Linders 2014): 1. What did we do well as a team and is important to discuss? 2. What have we learned as a team? 3. What should we change as a team in the next sprint? 4. What is still unclear? Just the open posing of the questions challenges the group members to think logically and ends naturally in a discussion, moderated by the Scrum Master. These introductory questions are initialized with open-ended questions about collaboration, technical set-up, or perspective expectation, and are supplemented with more detailed questions over the duration of the project. Follow-up questions can also help achieve the desired outcome of the retrospective.

The chatbot not only enables operational support through appropriate questions during the retrospective. Rather, it can control and shape the further course of the session by recording and processing the team's answers.

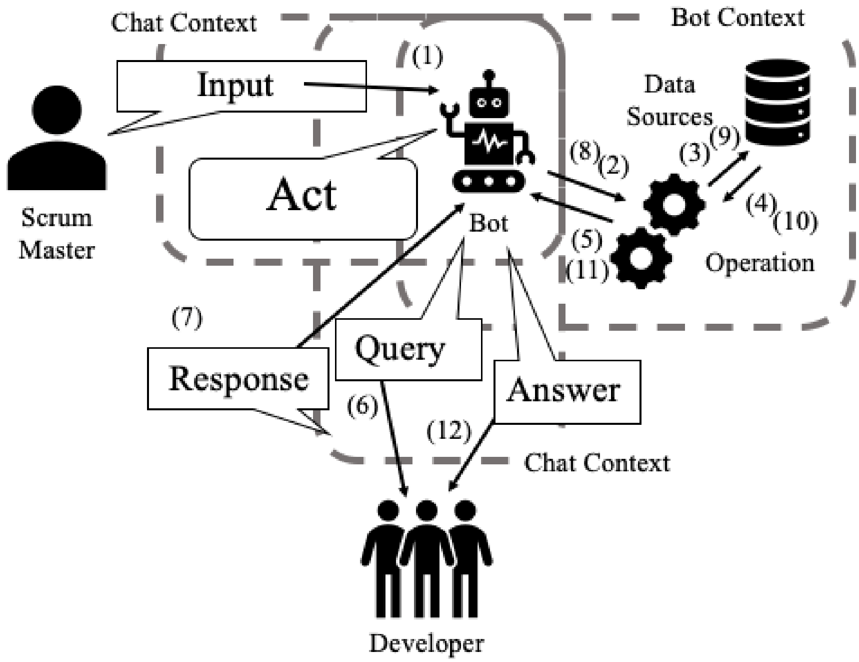


Fig. 2. ***Architecture of the support (adapted from Inukuchi et al 2016)***

*Execution with the chatbot*

Developer and the Scrum Master start the retrospective in the process according to Derby (see figure 3). In the preparation of the retrospective, the Scrum Master plans the chatbot's approach based on the findings of the past collaboration by means of targeted feeding of questions (1) from a predefined question collection, which originates from the Scrum Master, from past retrospectives, and from the developers, to carry out the data collection phase with fitting precision.

Already at the beginning (2), the "Set the Stage", the chatbot introduces the retrospective with an opening by presenting its own functions and way of working (3). The interaction of the chatbot shows up visualized by pressing a play button in the online retrospective appears.

In the second step, the chatbot supports in the critical phase of collecting data. Especially the generation of positive as well as negative insights is a key task of the retrospective. The chatbot intervenes by means of selected questions (4), which are intended to provide new food for thoughts. The questions help the developers to think about topics that have not yet been considered and to optimize the generation of contributions.

The answers of the developers (5) are stored in variables by the chatbot to output them consolidated as a list in the next step (6). Since current chatbots cannot be expected to perform sufficient independent analysis, the team must structure, analyze, and perform root cause research and prioritization by importance on the basis. After the root cause question, the team enters the responses (7). Based on stored heuristics (8), the chatbot suggests potential actions that need to be expanded, discussed, and fixed by the team. When asked by the chatbot for the three highest priority activities (9), the team enters the answer. In the last phase (10), the chatbot concludes the retrospective.

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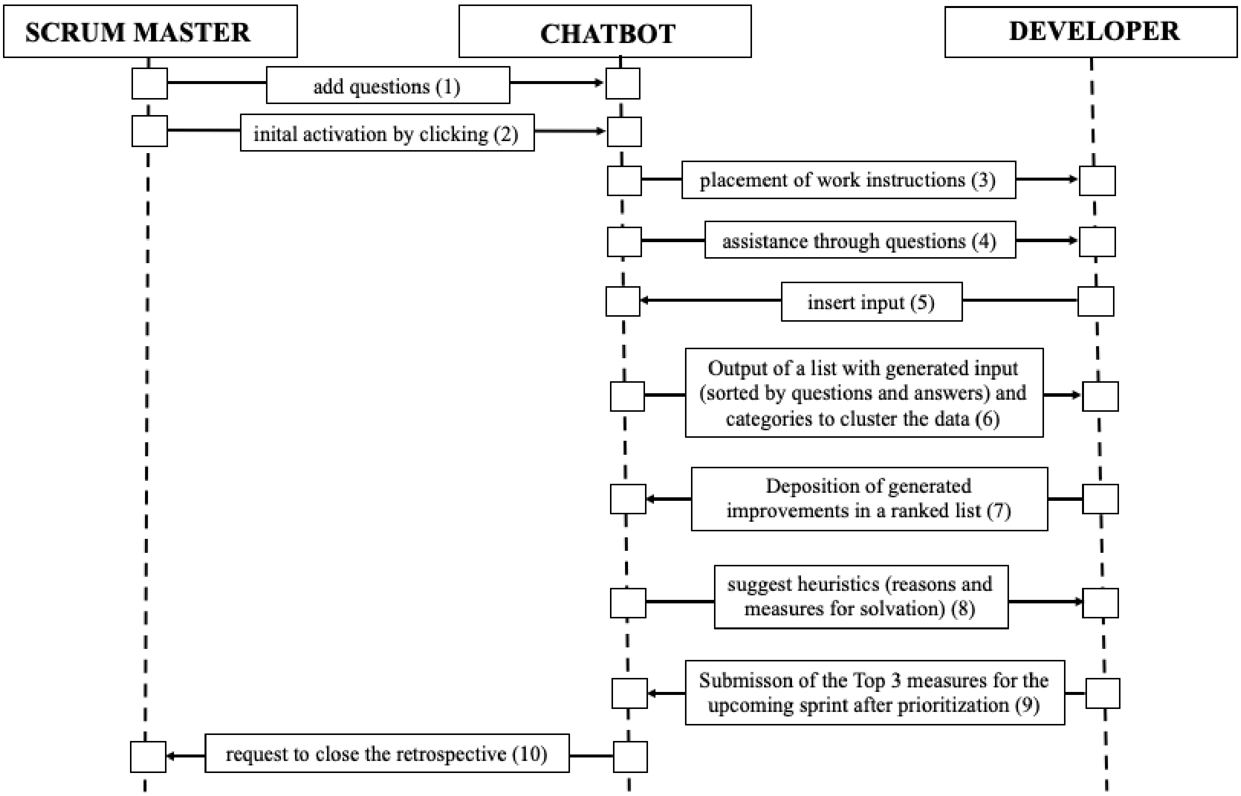


Fig. 3. ***Interactions between Scrum Master, Chatbot and Developers***

## Evaluation of the concept

In addition to the qualitative research method used, the results in the test groups are discussed below.

*Scientific Method*

The research design used is based on a model approach that can be traced back to Jan Recker (Recker 2013). This three-phase way of thinking builds on the pillars of rationalization, validation, and exploration, determined by conducting inductions, deductions, and observations. Here, exploration revolves around what is determined in the execution of the retrospective in the Co-Innovation Lab. Care is taken to ensure that the research is always concrete, reliable, and authentic. By observing the retrospective, a basic understanding of the status quo and requirements is established in the first instance. The next building block is rationalization. The focus in terms of the work is to classify the observations made and to generate and make sense of generally applicable theories regarding the research questions. Finally, the validation follows. This is about deriving a conclusion from hypotheses. This is done by testing the hypothesized theory by conducting surveys.

In this work, both quantitative strategies and design science methods can be found (Recker 2013). These are on the one hand two surveys, which in the first run reflect the current situation in the Co-Innovation Lab and in the second run the experiences directly after conducting an experiment on a possible future retrospective approach. By means of a Wizard Of Experiment the participants were confronted with a non-existing system for testing. The goal was to generate meaningful research results in the short time available by simulating a real system (Bernsen et al. 2016).

*Results*

A total of 14 student volunteers from four different teams participated in the test of the chatbot-supported retrospective as part of the Wizard-of-Oz experiment and associated survey to gain insight into the applicability of the chatbot-supported retrospective. In the wrap-up of the projects, it was found out that participating teams tended to perform in general better, although the participation was not known to the evaluating instructors.

A total of eight evaluation criteria (figure 4) were considered, among which were the points of participation and interaction, the quality and quantity of contributions, and the general output for the project. In addition, the participants considered factors such as the relationship between time and benefit, as well as usability, comprehensibility, and the structure of the retrospective. The categories of participation, output, and quality scored only average across all survey groups before the chatbot-supported retrospective was applied. The chatbot demonstrably generated better discourse by increasing qualitative and quantitative contributions within each group. In addition, participants recognized a positive impact on the overall output of the project. Collectively, all groups realized a jump from 3 to an average of 4.5 out of 5 points in these categories. This trend was also seen in the remaining four criteria. The criteria usability, comprehensibility and structure recorded a jump to the maximum in almost all groups and even the ratio between time and benefit could be raised in all teams by at least one evaluation point. The chosen concept made it possible to increase the acceptance of the retrospective in such a way that due to the reliability on the different features and the certainty of the formation of an added value for the retrospective, an integration was possible without any problems and will be in the future. The retrospective generated demonstrable usable output for implementation in current or future projects in many of the groups surveyed.

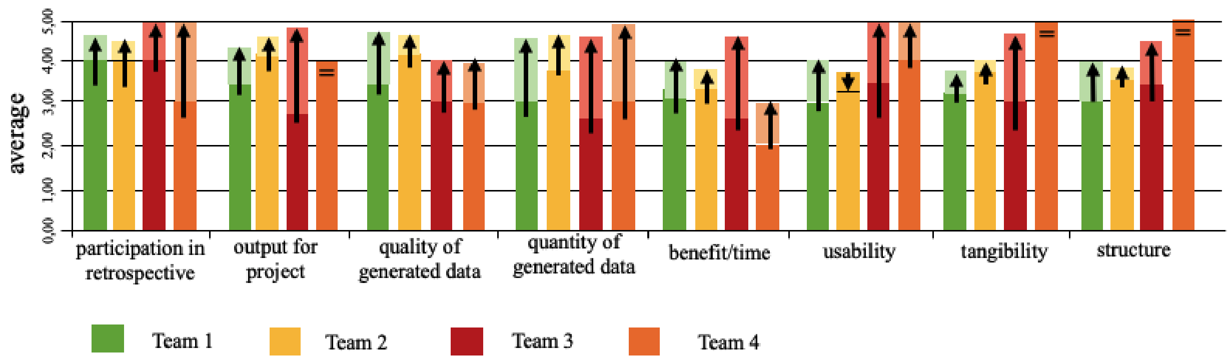


Fig. 4. ***Evaluation of the chatbot-supported Retrospective***

**Conclusions**

This paper aimed to analyze and evaluate retrospective in newly formed teams in agile projects. Using the university environment Co-Innovation Lab, where students solve challenges with companies, the concept of a chatbot-supported retrospective was developed and tested in addition to the root cause analysis.

Those who are responsible for the Co-Innovation Lab have been aware for some time of the problem that participants do not approach the retrospective with the necessary seriousness or even eliminate it from the scope of the agile project. Using an online survey, 62 students were asked about this issue, which confirmed the hypothesis. Only 35% of all respondents chose the ideal-typical course of conducting retrospectives at the end of each sprint; 30% of students eliminated retrospectives entirely. Arguments such as unnecessary, no discernible improvement, time wasted, or problems in execution were cited. General templates and procedures could not help in the specific project situations; the Scrum Master lacked the experience and assertiveness to collect usable data and derive actions.

The chatbot-supported retrospective allows to minimize the team's problems in connection with the retrospective by adding a virtual, external coach. Tests and surveys showed that the methodology performed positively in both objective and subjective criteria. Not only did the applicability rate increase, but also the reputation of the retrospective in terms of its importance to the overall project. After conducting the experiment and the online survey, the chatbot-supported retrospective approach was confirmed as a workable approach to implement retrospective and sustainably increased the applicability rate in the surveyed teams. The next step is to implement the concept with a chatbot framework and test it with other projects in the Co-Innovation Lab to extend the previous results.

The integration of artificial intelligence could be further supportive in the future. Through the targeted use of a chatbot, the retrospective in agile projects will experience a significant improvement. In the future, it remains to be seen to what extent artificial avatars will be able to independently take responsibility for meetings such as a retrospective.

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# Utilization of Elements of Digital Transformation in Project Management: A comparative study

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## Abstract

Improving effectiveness and efficiency in project management (PM) in today's world with digital transformation (DT) being omnipresent is a serious and important challenge for today's organizations.
The motivation for this study stems from the fact that organizations are increasingly project-based and require performant and effective PM, however, the possible impact of DT elements has not been investigated yet. The purpose of this paper is to provide academia and practitioners with appreciation of DT elements as useful factors that help project managers to execute their work more efficiently. As part of a larger research project (doctoral thesis), this paper suggests disassembling the phenomenon of DT in elements and analyze their role in the realm of PM. The previous research stage identified DT elements that may have the ability to impact project success. On this basis, an online questionnaire was conducted to examine different aspects of the relationship between DT elements and PM.
With more than 400 answers from project managers, clients and other stakeholders, a rich empirical data basis for various analyses emerged. First analysis shows that the choice DT elements can be efficaciously utilized either on project level, or on the level of project environment (typically organization level). This paper presents exemplary the relationship between utilization of DT elements and PM depending on project success criteria, the respondent's role in PM and the geographical region via comparative analysis.
The research makes its contribution to the body of academic knowledge by suggesting a structured basis of DT elements and revealing their role in project management practices. For practitioners, the study offers an overview and a better understanding of DT elements that may help during project execution.

**Keywords:** *digital transformation, elements of digital transformation, project management, project success*

**JEL code:** H43, O22, O33.

## Introduction

Digital transformation is on everyone's lips and increasingly gaining speed. At the same time, increasing projectification (Midler, 1995) makes organizations become increasingly project-based (Kwak, Sadatsafavi, Walewski, & Williams, 2015; Miterev, Mancini, & Turner, 2016; Packendorff & Lindgren, 2014). In project-based organizations "the majority of products made or services supplied are against bespoke designs for customers" (Turner, & Keegan, 2001, p. 256) which requires performant project management (PM). With the ongoing development of digital tools and methods, and thus increasing of organizations' digital maturity, the way of working and co-working continues to change incrementally and leaves organizations and project managers with the question how to benefit from digitalization in practice (Parviainen, Tihinen, Kääriäinen, & Teppola, 2017).
In the realm of PM there is a growing need to understand how to exploit elements of digital transformation (DT) to increase PM efficiency (Project Management Institute, 2018). PM performance, as a combination of effectiveness and efficiency (Kerzner, 2011) and a relevant contributor to project

success (Turner, 2009), is crucial for the achievement of organizational goals and their ability to survive and successfully compete. Despite this importance, the possible impact of DT on PM success has not yet been elucidated in the academic literature.
The present research is targeting at bridging this research gap. As a part of a larger research project, namely a doctoral thesis, this paper sheds light on DT elements (EDTs) in the realm of PM. To begin with, it explores the body of literature to derive and categorize DT elements that may have the ability to increase PM success. Later, the relationship of EDTs and PM is closer analyzed based on data collected through an online questionnaire.
The research questions (RQ) are the following:
***RQ1****: What elements of digital transformation exist and could be relevant for project management?*
***RQ2****: How utilization of elements of digital transformation impacts project management?*
***RG3:*** *What factors can moderate this impact?*
The RQ 1 was already answered in the earlier paper (Nemirovski, & Kaul, 2020).
The present paper answers the research questions 2 and 3.
The subsequent research will attempt to further discover the impact of EDTs on project success.

## Literature review

The contemporary business world is highly projectified. Project-oriented and project-based organizations are becoming increasingly popular in the recent time (Turner & Miterev, 2019).
The tendency to projectification of value creation has emerged with an expectation of increasing growth (Liang, 2011) and faster time to impact (Svejvig, Geraldi, Grex, 2019). Also, PMI (Project Management Institute) has recently affirmed that the nature of work is changing from “job for life” to “portfolio of projects” (PMI, 2019, p.3). In-depth studies in Germany, Norway and Iceland show that the national projectification levels were between 25% and 29,3% in the years 2009/2010 of these countries’ GDP and are expected between 31,5 and 41,3% in the years 2019/2020 (Schoper, Wald, Ingason, & Fridgeirsson, 2018). This strongly growing trend will presumably continue in the future.
These insights underpin the suggestion that the value creation in each organization relates to and depending on success of projects conducted in this organization.

Project success is a sophisticated and multidimensional variable. Since decades, academic minds keep arguing about how it can be measured. In the last decades, the overall recognition has been reached those different types of projects require different approaches to their management (Müller, & Turner, 2007; Crawford et al., 2005). Furthermore, it seems to be a general agreement that success of different types of projects can be assessed with different success criteria. Though, it is still not clear whether different types of projects perform differently in terms of different success criteria (Müller, & Turner, 2007).

Although projects are generally expected to increase the shareholder value, many projects remain rated as unsuccessful, even though the academic field of PM has been experienced intensive research for over 50 years. With introduction and development of Project Management Methodologies (PMM) as well as establishing of project management offices (PMO), it became possible to improve the PM quality.

Nevertheless, a considerable and sustainable increase of project success rates has not yet arrived. The PMI issue "Pulse of the profession - 2019" stated that "Yet despite all the talk, project performance isn't getting any better" (PMI, 2019, p. 2). After approximately 10% of waste rate of project investments in 2018 (PMI, 2018), it increased to 12% in 2019 (PMI, 2019).

Thereby, PMI has admitted that it is high time for the global PM community to understand possible implications of digital age and take advantage of its opportunities to improve PM practices. The first steps have already been undertaken with the development and application of agile methods. "Agility" means the ability of an organization to quickly adapt and change according to their surroundings (Rynus, 2018). Implementing and improving agile methods, organizations can raise transparency in processes, enhance value creation and achieve project excellence (PWC, 2018).
Starting with agilizing their IT-departments, organizations would lay the cornerstone for the further digital transformation (Sambamurthy, Bharadwaj, & Grover, 2003; Röglinger, Römer, Schmidl, Venus, Linhart, & Utz, 2017).

But what does digital transformation (DT) actually mean?
DT is not just about the installation of robots or introduction of new technologies, but also about the emergence and development of novel ("digital") business models and working forms. All businesses – a bakery around the corner, or a multinational corporation – must ask themselves if their business model is future-proof, and thus has henceforth chances of survival in the digital era.
With the emerging of IT as first digital technologies and their implementing in organizations in the 1960-s, the question arose whether they were worth investing and how they impact the organization. At early stages, this impact could not be understood easily and was found ambiguous. IT business value research in the 1990-s and early 2000-s showed that implementing information technology in organizations may contribute to the performance improvement (Sambamurthy et al., 2003; Melville, Kraemer, & Gurbaxani, 2004).

The question in the theoretical frameworks has been then changed from "if" to "how and why" IT investments enhance firm value (Sambamurthy et al., 2003). In the recent years, the research has become more specific and focusing on single aspects of organization's performance which is increasingly projectified.

Bayo-Moriones, Billón, & Lera-Lopez (2013) explored whether information and communication technologies (ICT) and innovative work practices have an impact on organizational performance, both directly and indirectly as well as in short- and long-term ranges. They found a positive relationship between ICT adoption and different aspects of perceived performance. Also, advanced using of ICT improves external and internal communication and indirectly impacts performance.
Digital technologies are predestined to improve processes in an organization which should lead to more added value. Harvard Business Review states that digital technologies do not automatically lead to increasing performance but create possibilities for it (Tabrizi, Lam, Girard, & Irvin, 2019).
In a recent study on DT, the research question "What is the impact of DT on performance?" is considered one of the most relevant ones in the next future (Verhoef, Broekhuizen, Bart, Bhattacharya, Qi Dong, Fabian, & Haenlein, M., 2019).

The grade of DT achieved by a given organization can be described by means of its "*digital maturity*". Since its introduction in early 1990s (Paulk, Curtis, Chrissis, & Weber, 1993), the concept of maturity model has been becoming popular in different areas (Becker, Niehaves, Pöppelbuß, & Simons, 2010). Commonly, maturity models are put in place to assess the as-is situation of an organization from the chosen perspective, then to define improvement actions and afterwards to monitor their implementations and results achieved (Pöppelbuß, & Röglinger, 2011).

While Vejseli, Proba, Rossmann, & Reinhard (2018) recognize that some aspects of digital maturity could have an impact on some criteria of project success, this possible effect has not yet been explicitly elucidated in the academic literature. Management is often unsure not only about how improve processes but also regarding choice of the right digital technology (Denner, Püschel, & Röglinger, 2017). The currently existing approaches on measuring of how a given organization is doing on DT focus merely on digital maturity. Assessment results and recommendations usually contain general guidelines how to improve the state of maturity whilst performance improvement stays in the shadow.

Implementing the research lens of Mathur, G., Jugdev, K., & Shing Fung, T. (2013) as well as referring to Radujkovic, & Sjekavica (2017), who laid the focus on tools and techniques used in project management, this research suggests changing the perspective and to disassemble digital transformation in *elements* (in analogy to "project management elements" of Jugdev, & Mathur, 2006) which are then to be individually analyzed.

As already reported in the previous paper (Nemirovski, & Kaul, 2020), Elements of Digital Transformation for Project Management (EDT4PM for short) was identified from which two lists were composed:

- one list with 14 elements relevant by utilization directly in PM – EDT_PM; and
- one list with 36 elements relevant by utilization in the project environment (organization) – EDT_Org.

Both lists are enclosed in Appendices 3 and 4.

This way, the RQ1 was already entirely answered in advance. The question remains, <u>how</u> utilization of the identified EDTs impacts PM? This constitutes the RQ2 which is dealt with in the present paper.

Every project is unique like every human being is individual. Even if major similarities between two different projects may be found, some other characteristics will probably distinguish. Therefore, an additional question arises in the present research, namely whether project characteristics can change (moderate) the relationship between the utilized EDTs and PM (RQ3).

## Research Design

The figure 1 outlines the research model. Utilization of EDTs plays the role of independent variables (IV) which is supposed to have impact on project management as dependent variable (DV). There are different factors (Moderators) that may reinforce or reduce this impact.

The research investigates first what is the relationship between IV and DV (RQ2), and then what factors can be the moderators (RQ3).

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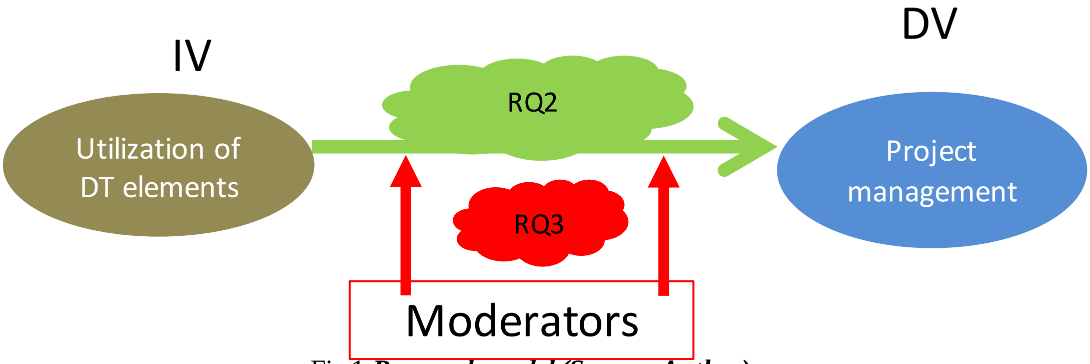


Fig.1 ***Research model (Source: Author)***

A survey was conducted online between August 2020 and April 2021 and brought more than 400 answers of project managers and other participant or stakeholders of projects.
The data sets were analyzed using SPSS as well as Sphinx software resulting in findings that will be discussed below.

Following kinds of analysis were provided:

- Factor analysis
- Regression analysis
- Comparative analysis
- Textual and sentiment analysis

In this paper, only preliminary results of comparative analysis are presented to concentrate on discovering moderators in the research model and describing their influence on the relationship between IV and DV.

## Results

The respondents were first asked about their general perception of the impact of DT on PM. Generally, most respondents (95 %) perceive that project management is already impacted by digital transformation while about 80% say that this impact is significant or even radical (s. figure 2).

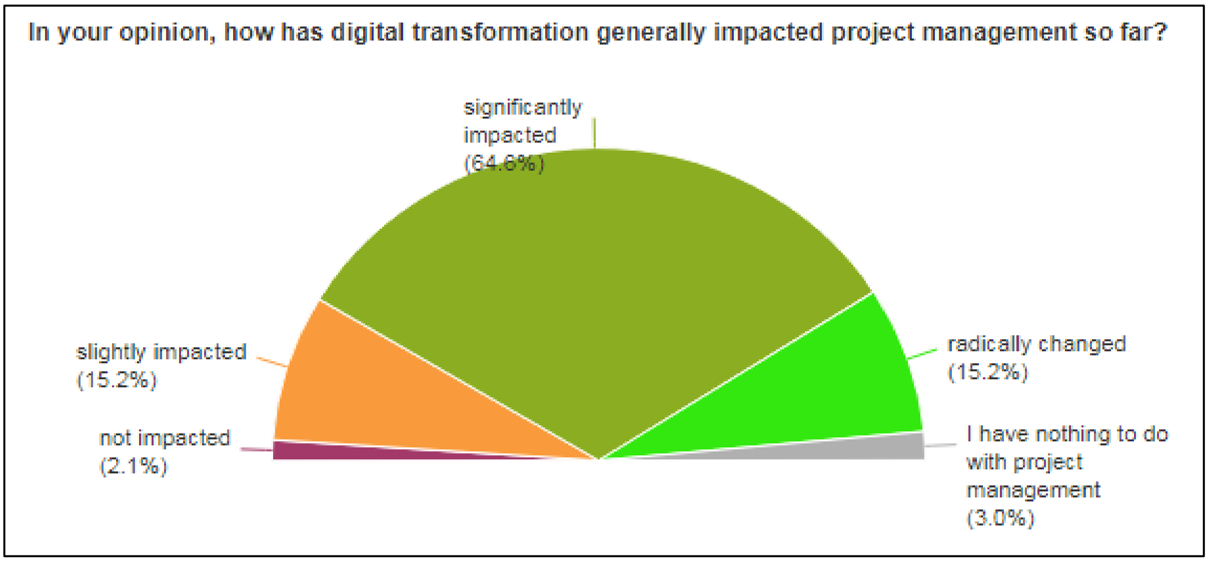


Fig.2 ***Perceived impact of DT on PM (Source: Author based on survey data)***

To evaluate the impact on project management more precisely, following project success criteria were chosen:

- *meeting project time schedule,*
- *meeting project cost budget,*
- *scope and quality of project outputs,*
- *client's/users' satisfaction,*
- *satisfaction of project team, and*
- *satisfaction of senior management.*

Respective survey questions were formulated as follows:

*Please choose from the following elements of digital transformation those being able - in your opinion - to improve project success in terms of* ***meeting project time schedule*** *and arrange them beginning with the highest relevance (1) towards lower relevance (2/3/4/5/…).*

During the evaluation phase, a mean of given numbers was calculated as 5.3 (answers with all possibilities chosen were excluded). Then, the EDTs were weighted by 5 for the highest place, by 4 for the second place, … and by 1 for the 5th place. This way, a relevance scales for each criterion were constructed and depicted in figure 3.

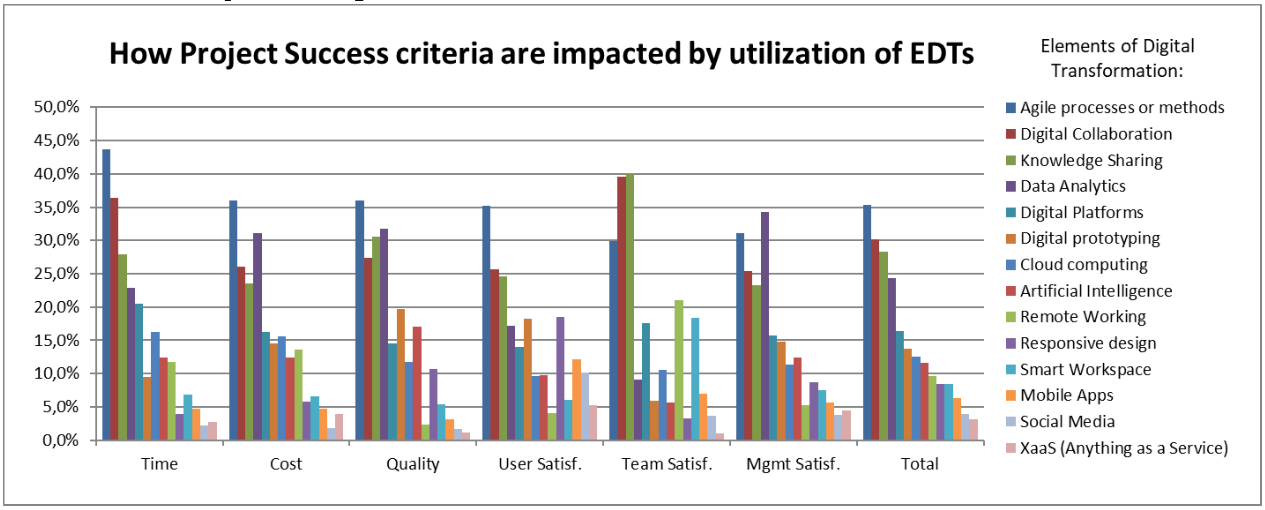


***Fig.3 Relevance of utilized EDTs on project success criteria (Source: Author based on survey data)***

The results disclose *Agile processes or methods* as the most important driver for the overall Project success as well as regarding the criteria *Time*, *Cost*, *Quality*, and *User Satisfaction*. Besides, *Knowledge Sharing* and *Digital Collaboration* are most important for *Team Satisfaction* while *Management Satisfaction* is mainly impacted by *Data Analytics*. *Social Media* and *Mobile Apps* managed to score 10% only regarding User Satisfaction whereas *Remote Working* and *Smart Workplace* are solely relevant for *Team Satisfaction*. *Responsive Design* has the strongest correlation with *User Satisfaction*. *XaaS* is not seen to play any important role for project success.

These discovering answers the RQ2.

To continue, the following questions were asked:

*In your opinion, how do the following digital transformation elements, being utilized in project management, influence project success (broadly speaking)?*
and
*In your opinion, how do the following digital transformation elements, being utilized in project environment (an organization where the project is conducted), influence project success (broadly speaking)?*

To elucidate the RQ3 "*What factors can moderate the impact of EDTs on project management?"*, the respondents were asked to make statements regarding the country of activity and their role in project management.

The figures 4 and 5 portray how the perceptions vary depending on regional differences. The countries were aggregated in regions for sake of readability.

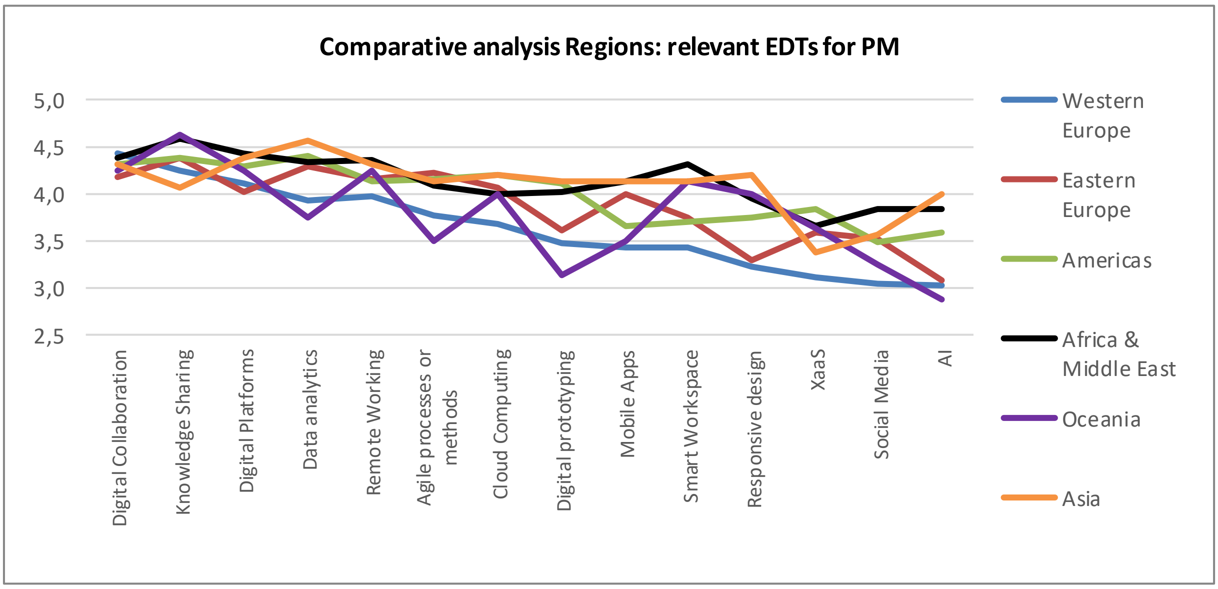


Fig.4 ***Comparative analysis Regions: relevant EDTs for PM (Source: Author based on survey data)***

While the Western Europeans marked the relevance of the most EDTs for PM as relatively moderate, the respondents from Asia and MEA (Middle East & Africa) were more generous.

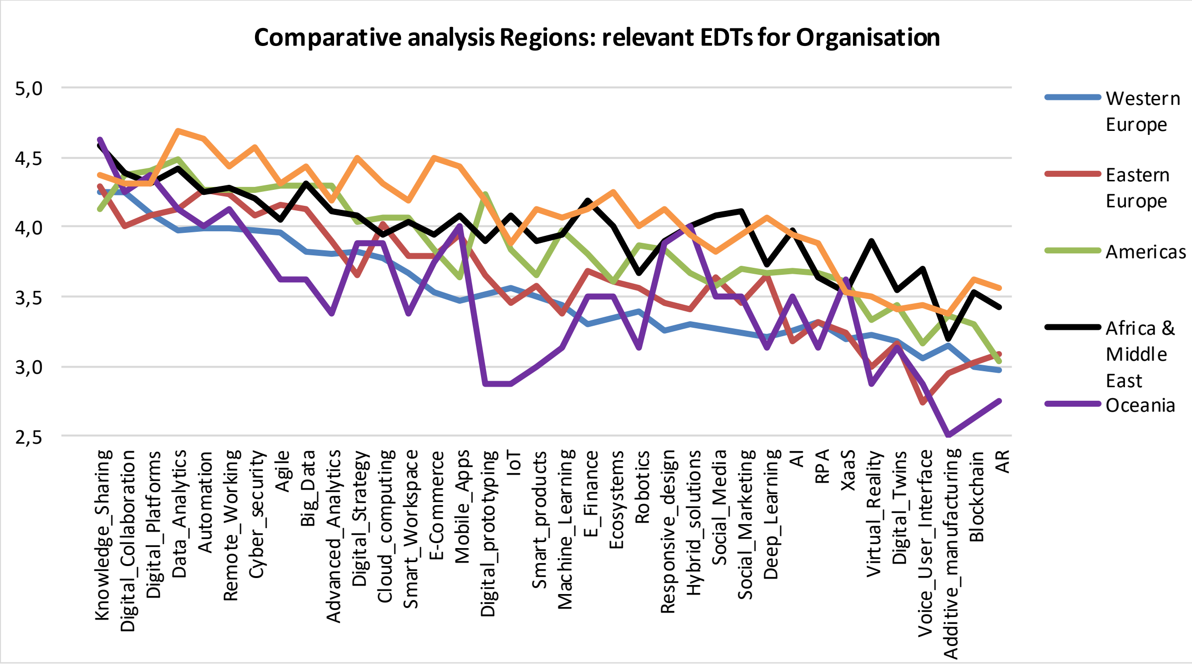


*Fig.5* ***Comparative analysis Regions: relevant EDTs for Organization (Source: Author based on survey data)***

*Social Media* und *AI* are seen least important as being utilized in PM. *Smart workspace* is not very successful for PM but much more popular for Organization. *Digital Collaboration*, *Knowledge Sharing*, *Digital Platforms* and *Data Analytics* are unquestionable leaders on both graphs. *Agile Methods* and *Remote Working* remain some behind them.

Considering the importance of EDTs for organizations as project environment, Oceania gave the worst marks, especially for *Digital prototyping*, *IoT*, *Additive manufacturing*, *Blockchain* and *AR*. It can be well observed that the lines crisscross each other and don't join together to a spot. In the "point of mutual consensus", the score range only melts once to 0.2 (*Digital Collaboration)* staying higher in other cases and growing up to 1.1 (*AI = Artificial Intelligence*) in case of the PM graph, On the organization graph, the score range oscillates between 0.3 (*Digital Platforms)* and 1.4 (*Digital Prototyping*).

Like the geographical analysis, a comparative analysis regarding the respondent's role in PM was conducted. The figures 6 and 7 illustrate this type of variances.

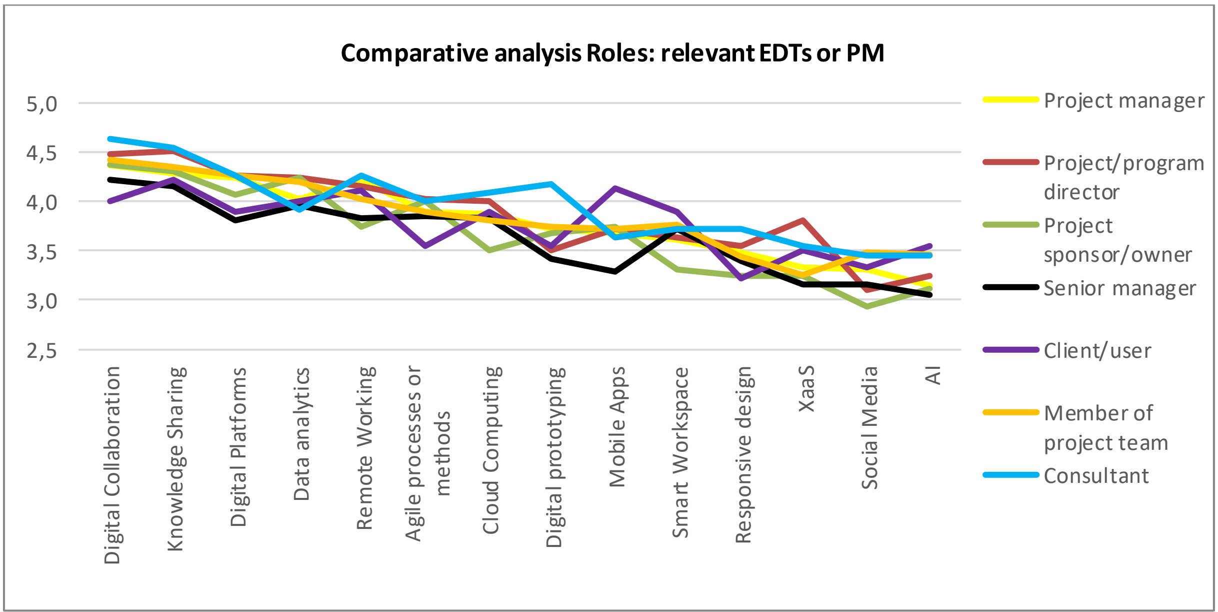


Fig.6 ***Comparative analysis Roles: relevant EDTs for PM (Source: Author based on survey data)***

Senior managers show the highest skepticism while consultants are more generous for the most EDTs.

Also, here, the lines do not run parallelly but rather differentiate from each other in the pattern. In the "point of mutual consensus", the score range melts to 0.2 (*Data Analytics*), but in other cases grow up to 0.7 (*Mobile Apps*) in case of the PM graph, respectively to 0.9 (*Responsive design*) in case of the organization graph.

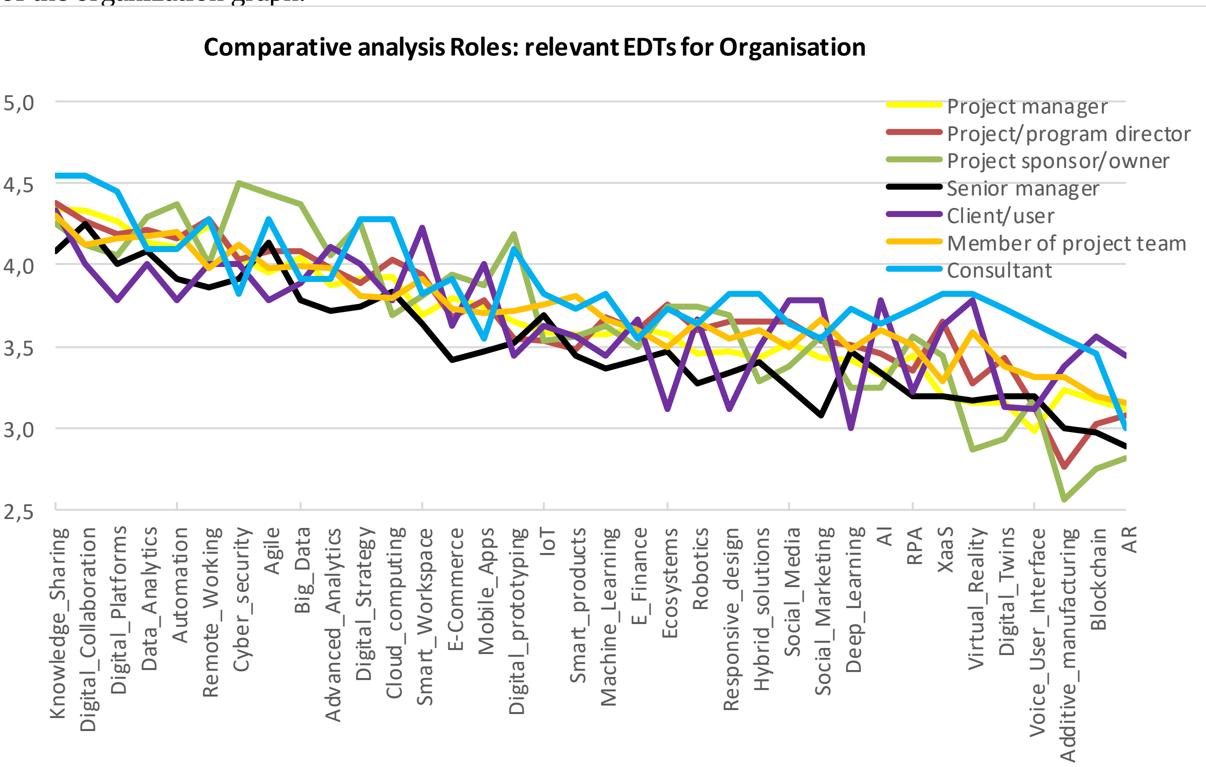


Fig.7 ***Comparative analysis Roles: relevant EDTs for Organization (Source: Author based on survey data)***

Thus, for each Respondent's Role as well as region, a unique line course is given. This fact proves that these two factors work as moderator in the relationship between Utilization of EDTs and PM.
This way, the RQ 3 "*What factors can moderate the impact of utilization of EDTs on PM"* is answered.

## Conclusions

The present paper is the second part of a broader research on DT elements and their possible impact on PM and project success. Based on findings from the first part, this paper sheds light on how a survey was conducted and reveals some of its preliminary findings.
These shows that DTEs can impact PM either directly being utilized in PM process, or indirectly, through utilization in project environment (organization).
It was illustrated that different project success criteria are differently impacted by different EDTs utilized in PM.

To describe variety of this impact, several comparative analyses were presented. Against this background, two factors were identified as moderators, namely the region of respondent's activity and his/her role in project management.
Alongside that, several other analyses were provided on the survey data. The results will be presented in the subsequent papers and in the doctoral thesis.

The implication for academia consists of description of DT elements and their relevance for both PM process and PM environment.

For practitioners, this study's results offer new and deeper insights into existing DT elements. The relevance and importance of EDTs utilized in PM and organizations is not equal under different conditions. Being aware of this, project manager, clients, consultants, and other PM stakeholders will be better equipped to find the optimal way for organizing project management.

This study has its limitations. The literature studied was comprehensive but limited and may not always represent the most recent state of the art. The composed list of DT elements may not consider the whole variety of existing elements. The author's opinion may be biased, and definitions may not be always appropriate. The respondents were asked for their opinion and experience so that the data collected can be biased.

Along with the announced subsequent part of this research, further investigations in the presented topic may be highly promising. Future studies could contribute to consequent developing of the EDT4PM-Glossary to enhance it and kept it up to date. Also, researchers are encouraged to use the excavated data sets for other analytical studies.

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## Appendix 1.

***List of Elements of Digital Transformation that may be utilized in Project Management (Source: Author)***

Agile Processes or Methods
Artificial Intelligence (AI)
Cloud Computing
Deep Learning
Digital Collaboration
Digital Platforms
Digital Prototyping
Knowledge Sharing
Mobile Apps
Remote Working
Responsive Design
Smart Workspace
Social Media
XaaS (Anything as a Service)

## Appendix 2.

***List of Elements of Digital Transformation that may be utilized in Organizations. (Source: Author)***

Additive Manufacturing (3D printing)
Advanced Analytics
Agile Processes or Methods
Artificial Intelligence (AI)
Augmented Reality
Automation
Big Data
Block chain
Cloud Computing
Cyber Security
Data Analytics
Deep Learning
Digital Collaboration
Digital Platforms
Digital Prototyping
Digital Strategy
Digital Twins
E-Commerce
Ecosystems
E-Finance
Hybrid solutions
Internet of Things (IoT)
Knowledge Sharing
Machine Learning
Mobile Apps
Remote Working
Responsive Design
Robotic Process Automation (RPA)
Robotics
Smart Products
Smart Workspace
Social Marketing
Social Media
Virtual Reality
Voice User Interface
XaaS (Anything as a Service)

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# Applicability of Multivariant Linear Optimization for Project Process Relevance Modeling

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## Abstract

This article evaluates the applicability of linear regression method for optimization of PMBOK project process relevance factors.

In a first step, published in the article "Relevance of PMBOK v6 Processes for Tailored Agile Project Categories" [ROS19] published at IEEE 13th International Symposium on Applied Computational Intelligence in Timisoara Romania May 29-30, initial relevance factors of all PMBOK version 6 project processes have been postulated, based on scientific literature coverage. These presented relevance factors presented themselves as highly heterogenic. In other words, some project processes seemed to be more critical and complex to manage then others.

Nevertheless, the distribution of these factors is highly individual and until today only based on scientific literature and not on real project management practice. As next step, statistically and mathematically modelling needs to follow, enabling IT project managers to evaluate their own process relevance experience and therefore delivering input data sets for a mathematical optimization model increasing overall project health and success. As a first step towards this goal, this article evaluates the suitability of multivariate linear regression methods for such modelling purposes. Based on a dimensionally reduced example set of data it is proven, that linear models are not usable in this system. They do not reflect the needed balance in covariance of all PMBOK project processes for project success. In addition to this proven result of non-applicability of linear optimization models, the article proposes non-parametric kernel-based optimization as a possible non-linear solution. Furthermore, the requirements of using neuronal network-based modelling and optimization are discussed.

**Key words:** *SCRUM, IT-Project Management, Agile, PMBOK*
**JEL code**: M15 (IT-Management)

## Introduction

Professional project managers try to standardize and optimize their work by applying project management frameworks in their projects. These frameworks and certifications like the project management body of knowledge (PMBOK) of PMI Organization [PMI17] or PRINCE2 framework of AXELOS [PRI17] Organization provide structure and a collection of project processes to be performed by project managers. Often, these frames give an indication about what to do in a project, but at the same time, do not indicate how much to do certain activities in a project. This factor can make management of agile developed IT project challenging. [PIC07] PMBOK certification just mentions, that it is the responsibility of an experienced project manager to choose the right processes and where to focus on, while often integrating agile practices [WEN16 ]. PMI organization structures the 49 project processes in different ways like knowledge areas or project phases and thereby gives an indication, which processes to use when in the project, but lacks a clear indication about a specific distribution of relevance. Of course, one could argue,

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that every project is different and unique and therefore relevance of project processes is unique in every project but providing an average value for indication could provide a valuable indication for project managers. In a nutshell: Project frameworks may be well defined regarding what to do but lack information regarding how much to do which activities. This lack of information where to focus on, defines the underlying problem for this research project, of which testing of linear optimization, although only part of the problem-solving process, is the focus of this article.

## Basis and approach for this research

Discovering "how much to do" certain activities to optimize project success is the overall goal of this research approach. To achieve this goal a combination of data collection and mathematical optimization will be applied.

### Data Collection:

Currently in development, a slim android app will collect data from IT project managers. These practitioners will be asked about their distribution of process relevance in their specific project phases. For example: Do you spend 80% of your focus and work in the project on the PMBOK process "Risk Management Execution"? And the rest on "Planning Stakeholder Management"? Ignoring all other processes? If not, which seems likely, how do you distribute your work and focus in the project? And how successful and healthy is your current project right now?

By asking project managers about their project process specific relevance factors and asking about their current project health, we will get data sets of project process relevance in relation to overall project success. These data sets will have the following form (Note: The data values in bellows table are just dummy data values)

| Dataset Upload Number | ProcessNo1 | ProcessNo2 | ProcessNo3 | ... | ... | ProcessNo46 | ProcessNo47 | ProcessNo48 | ProcessNo49 | Project Health Indicator |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 14,8 | 6,6 | 2,2 | ... | ... | 2,2 | 0,4 | 0,4 | 0,4 | 2,8 |
| 2 | 15,05 | 6,1 | 3,3 | ... | ... | 2,0 | 0,2 | 1,0 | 1,0 | 2,3 |
| 3 | 14,02 | 8,4 | 3,3 | ... | ... | 5,6 | 1,5 | 2,0 | 1,0 | 2,2 |
| 4 | 0,3 | 14,8 | 8,1 | ... | ... | 2,1 | 0,3 | 0,4 | 0,3 | 2,0 |
| 5 | 14,2 | 6,8 | 1,9 | ... | ... | 3,5 | 0,1 | 2,2 | 0,1 | 2,8 |
| 6 | 0,1 | 0,1 | 2,5 | ... | ... | 4,4 | 0,8 | 1,3 | 1,3 | 2,6 |
| 7 | 8,7 | 2,5 | 1,0 | ... | ... | 0,7 | 0,6 | 1,3 | 3,6 | 2,8 |
| 8 | 2,2 | 14,8 | 6,6 | ... | ... | 2,2 | 0,4 | 0,4 | 0,4 | 2,1 |
| 9 | 14,1 | 6,1 | 2,0 | ... | ... | 2,0 | 0,2 | 1,0 | 0,9 | 2,9 |
| 10 | 13,95 | 8,4 | 1,0 | ... | ... | 5,6 | 1,5 | 2,0 | 1,0 | 2,1 |
| 11 | 14,8 | 8,1 | 2,1 | ... | ... | 2,1 | 0,3 | 0,3 | 0,4 | 2,4 |
| 12 | 14,25 | 6,8 | 1,9 | ... | ... | 3,5 | 0,1 | 2,2 | 5,0 | 2,7 |
| 13 | 12,52 | 7,7 | 1,9 | ... | ... | 4,4 | 0,8 | 1,3 | 2,0 | 2,1 |
| 14 | 8,7 | 2,5 | 3,0 | ... | ... | 7,0 | 5,8 | 7,2 | 2,7 | 3,2 |
| 15 | 12,0 | 0,4 | 0,4 | ... | ... | 2,2 | 0,4 | 0,4 | 2,2 | 1,7 |
| 16 | 0,2 | 0,2 | 0,2 | ... | ... | 2,7 | 0,2 | 0,2 | 2,0 | 2,4 |
| 17 | 0,0 | 0,0 | 0,0 | ... | ... | 3,0 | 0,0 | 0,0 | 0,8 | 2,6 |
| 18 | 0,3 | 0,3 | 2,1 | ... | ... | 0,3 | 1,2 | 0,3 | 2,1 | 3,1 |
| 19 | 0,1 | 0,1 | 0,1 | ... | ... | 1,0 | 1,2 | 0,7 | 1,9 | 2,4 |

Table 1: ***Dummy data set for optimization***

Basic conditions for data collection:

- Sum of process factors No.1 to No.49 = 100
- Project Health Indicator <= 4
- Minimal value of each process shall be 0,5
- All values >=0
- One single process <=76

Collected data sets can then be used to mathematically define an optimally distributed process relevance solution. An initial proposal of such a process relevance distribution is already proposed in the IEEE article "Suitability of PMBOK 6$^{th}$ edition for agile-developed IT Projects" [ROS18] . We shall now assume that the data collection has already been finalised and the optimization can be started. Goal of this current research step and focus of this article is to answer the question, whether linear least square optimization method [ALE10] is generally applicable to optimize the dummy data of table 1. To answer this question a three-step approach is applied. After a brief introduction to least square regression method and optimization, three optimization attempts with increasing complexity will demonstrate the applicability of the optimization method.

**Introduction to multivariate regression.**

The multivariate linear regression approach can be described mathematically the following way:

Equation of linear regression:

$$\mathbf{y = m{*}x + c} \qquad [1.]$$

where:

- y is the output of the model
- x is the independent variable
- m is the slope of the regression line
- c is the intercept

**x** and **y** values now get measured by data collection and we try to estimate m and c as best as possible to predict **y** for any given input **x**.

As we use multiple dependent variables, a matrix representation of linear regression is needed to describe the model more compact.

Using matrix notation the equation for linear regression looks like that:

$$\mathbf{Y = X\beta + e} \qquad [2.]$$

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where:

- β is the matrix of parameters
- X is the matrix of measured values of these parameters
- e is a factor of predicted error for each measurement in contrast to the the predicted value (we want to minimize that!)

Changing the equation for e results in this equation:

**e = Y – Xβ** [3.]

so **e** is a function of parameters **β.** Now we want to get the mean square error (MSE) in Matrix form as basis for optimization.

We get MSE be adding all squares of e from all measurements and divide them by the number of observations. In mathematical notation:

$$\sum_{i=1}^{i=n} e_i^2 = e_1^2 + e_2^2 + e_3^2 + e_4^2 + \dots + e_n^2$$

$$MSE = \frac{1}{n}\sum_{i=1}^{i=n} e_i^2 \qquad = [e_1\ e_2\ e_3\ e_4\ \dots\ e_n] \times \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \\ . \\ . \\ . \\ e_n \end{bmatrix} = e^T e \qquad [4.]$$

Now, we can replace **e** with the equation **Y — Xβ** giving us MSE in such a form:

$$\boldsymbol{MSE = \frac{1}{n}(Y - X\beta)^T(Y - X\beta)} \qquad [5.]$$

After some expansion and replacing of that equation, we get for MSE the following equation:

$$MSE = \frac{1}{n}(Y^T Y - 2\beta^T X^T Y + \beta^T X^T X\beta) \qquad [6.]$$

This function is used as objective function in the optimization problem. Most algorithms will then, minimize this function. To get the best parameters in the model. To do this, gradients need to be estimated for gradient descent optimization.

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The gradient of MSE is noted as such:

$$\nabla MSE = \frac{1}{n}(\nabla Y^T Y - 2\nabla\beta^T X^T Y + \nabla\beta^T X^T X\beta) \quad [7.]$$

where ∇ is the differential operator for the gradient.

By applying matrix differentiation, we get the following two equations for optimization:

$$= \frac{1}{n}(0 - 2X^T Y + 2X^T X\beta)$$

$$= \frac{2}{n}(X^T X\beta - X^T Y) \quad [8.]$$

The second equation is called Jacobian matrix and is used together with a learning rate (**lr**) to gradually update model parameter.

$$J(\beta) = \frac{2}{n}(X^T X\beta - X^T Y) \quad [9.]$$

The gradient descent method now iteratively updates model parameters by applying the Jacobian matrix and the learning rate:

$$\beta new = \beta old - lr \times J(\beta) \quad [10.]$$

**βold** is an initial starting point, that needs to be defined to start. This initial vector then gets updated with each iteration. This happens again and again until the **MSE** value gets reduced and becomes flat. **lr**, the learning rate can be seen as the step size for each iteration and shall help to prevent "shooting over the optimum " in other words, the lowest point of the error curve/surface. So by a minimization of the error and collecting new **β** values, we can define a optimum regression solution. [PRA19]

As the basic approach for least square regression and optimization is now clarified, we can apply the method to dummy data in three solution proposals with increasing complexity.

### Solution proposal 1: Single variable application of LSQ

As a first, most simple step we use linear regression method with only one single input and output variable.

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**Data:**

Table 2: ***Single Input Data Set***

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input Variable | 0,35 | 0,95 | 1,00 | 0,30 | 0,10 | 1,25 | 3,60 | 0,35 | 0,90 | 1,00 | 0,40 | 5,00 | 2,00 | 2,70 | 2,17 |
| Output Variable | 0.80 | 0.50 | 0.70 | 0.60 | 0.70 | 0.50 | 0.20 | 0.50 | 0.70 | 0.50 | 0.50 | 0.70 | 0.60 | 0.70 | 0.40 |

**Linearization of data:**

The Matlab function "polyfit" is linearizing the data points.

[11.]

```
>> p=polyfit(x,y,1)
|
p =

   -0.0221    0.6398
```

**x** is the input, **y** is the output and **1** for the digit of the polynome, which is linear and therefore 1. As a result, we get the k value of the linear function with -0.0221 and the d value with 0.6398.

Using the plot command shows the linear function: >> plot(x,y,'o',x,y1,'-')

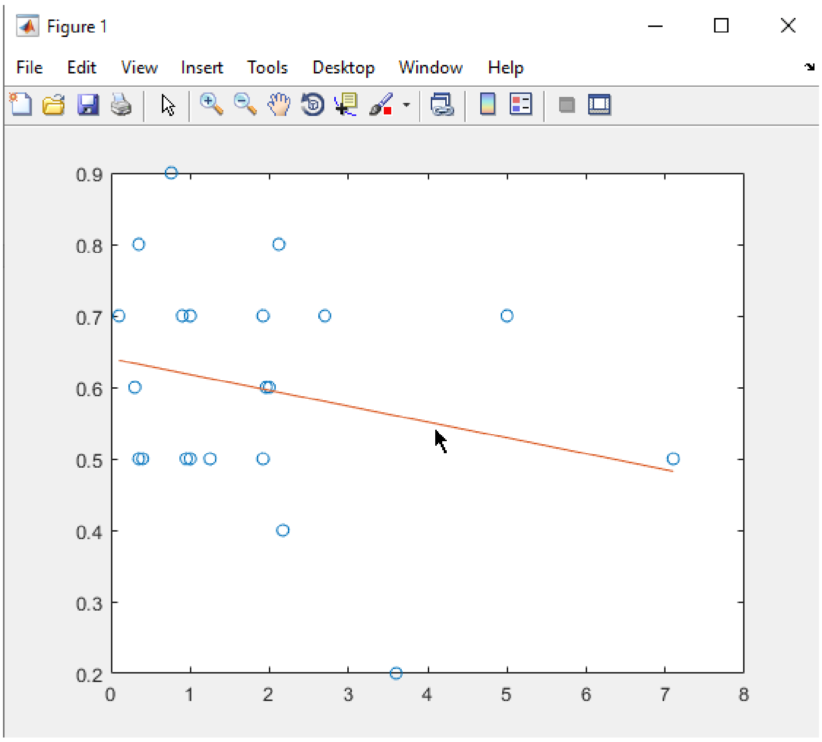


Fig. 1: ***Linear function***
*Source: author's construction*

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**Result:**

Linear regression works well with a single variable. The optimized solution equals in that dummy data set x = 0.

**Solution proposal 2: Multiple variable application of LSQ**

As a next step, we increase complexity by applying regression to two input and one output variable:

**Data:**

Table 3: ***Double Input Data Set***

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input Variable 1 | 0,40 | 1,00 | 2,00 | 0,40 | 2,20 | 1,30 | 1,30 | 0,40 | 1,00 | 2,00 | 0,30 | 2,20 | 1,30 | 7,20 | 0,40 | 0,20 | 0,00 | 0,30 | 0,70 | 1,80 | 0,76 |
| Input Variable 2 | 0,35 | 0,95 | 1,00 | 0,30 | 0,10 | 1,25 | 3,60 | 0,35 | 0,90 | 1,00 | 0,40 | 5,00 | 2,00 | 2,70 | 2,17 | 1,96 | 0,76 | 2,12 | 1,92 | 1,92 | 7,10 |
| Output Variable | 0,80 | 0,50 | 0,70 | 0,60 | 0,70 | 0,50 | 0,20 | 0,50 | 0,70 | 0,50 | 0,50 | 0,70 | 0,60 | 0,70 | 0,40 | 0,60 | 0,90 | 0,80 | 0,70 | 0,50 | 0,50 |

Based on these variables, a coefficient matrix using: X=[ones(size(x)) x y x.*y] can be created:

```
>> X=[ones(size(x)) x y x.*y]

X =

    1.0000    0.4000    0.3500    0.1400
    1.0000    1.0000    0.9500    0.9500
    1.0000    2.0000    1.0000    2.0000
    1.0000    0.4000    0.3000    0.1200
    1.0000    2.2000    0.1000    0.2200
    1.0000    1.3000    1.2500    1.6250
    1.0000    1.3000    3.6000    4.6800
    1.0000    0.4000    0.3500    0.1400
    1.0000    1.0000    0.9000    0.9000
    1.0000    2.0000    1.0000    2.0000
    1.0000    0.3000    0.4000    0.1200
    1.0000    2.2000    5.0000   11.0000
    1.0000    1.3000    2.0000    2.6000
    1.0000    7.2000    2.7000   19.4400
    1.0000    0.4000    2.1700    0.8680
    1.0000    0.2000    1.9600    0.3920
    1.0000         0    0.7600         0
    1.0000    0.3000    2.1200    0.6360
    1.0000    0.7000    1.9200    1.3440
    1.0000    1.8000    1.9200    3.4560
    1.0000    0.7600    7.1000    5.3960
```

Then, the regress function can be created as such:

```
>> regress(z,X)

ans =

    0.6857
   -0.0490
   -0.0505
    0.0248

>> z=0.6857-0.0490*x-0.0505*y+0.0248
```

Using the CFToolbox in MATLAB, the regress function can be visualized as such:

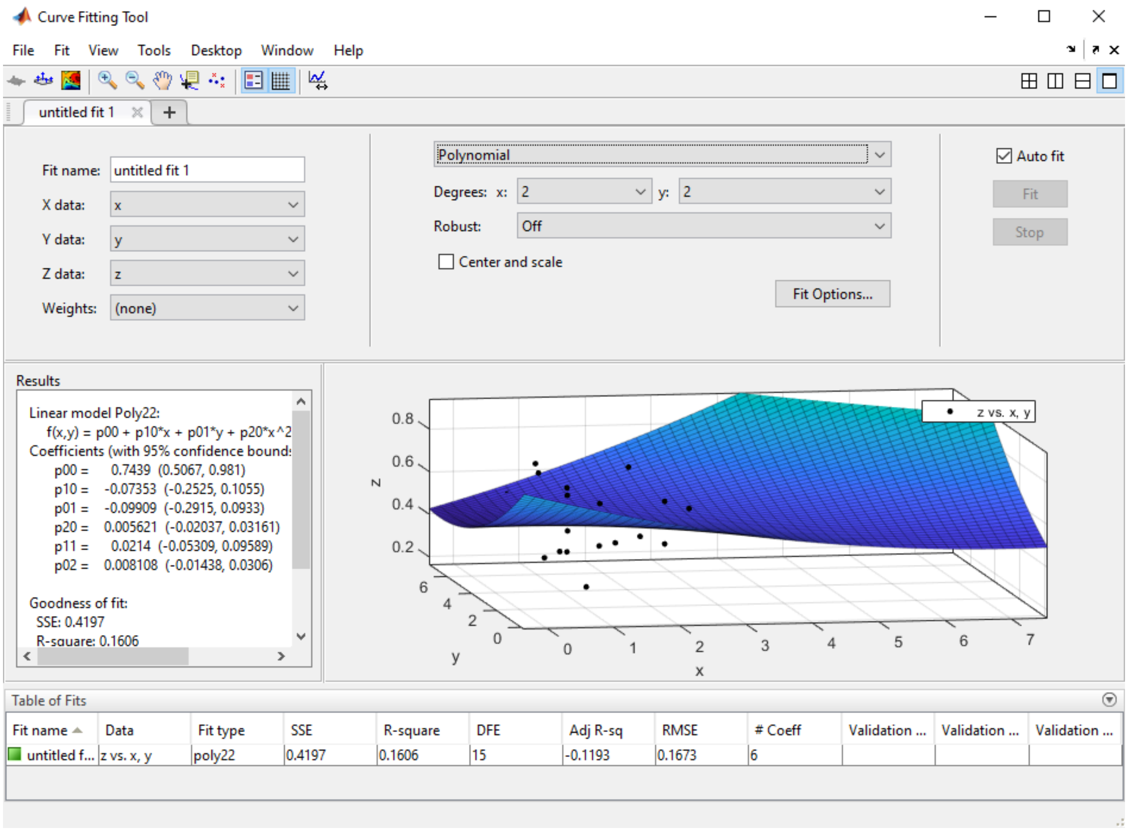


Fig. 2: ***Double input regression***
*Source: author's construction*

**Result:**

The graphic clearly shows the regression plane in the three-dimensional system. The maximum is in a corner of the system with a max y value and an x value between 4 and 5. So the maximum of this system is maximizing one input variable as much as possible. Interpreting this result with the goal of the process relevance optimization, the solution found here would not be applicable.

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It would mean, that one process of project management should be done as much as possible, based on the existing data. In the practice of project management, focusing on just one process as much as possible would rarely be a good approach. However, this specific interpretation cannot be done, before the actual data of project managers is available. Only then can the results have interpreted correctly.

**Solution proposal 3: Multiple variable application of LSQ**

As a last step, we use linear regression method with four input and one output variable.

As we have 49 independent variables, we cannot visualize the curves anymore. To get the parameter P of a regression function in form of. Y=P1*x1+P2*x2+…….+Pn*xn we can use the fitlm command in Matlab.

Therefore, inputting the data and defining the variables x1 to x49 by using x1=data(:,1);x2=data(:,2);x3=data(:,3);x4=data(:,4);o=data(:,50); (here only with 4 variables for testing) and o the output, is not necessary. Matlab automatically defines each column as a parameter and the last column as output. Just importing the data and then input the command: mdl=fitlm(data) is enough to get this result:

```
Command Window
>> mdl=fitlm(data)

mdl =


Linear regression model:
    SumofOutputs ~ [Linear formula with 50 terms in 49 predictors]

Estimated Coefficients:
                    Estimate       SE         tStat      pValue
                   _________    ________    ________    _______

    (Intercept)       6.4036      4.2216      1.5169    0.13423
    ProcessNo1     -0.054538     0.04335     -1.2581    0.21294
    ProcessNo2     -0.074031    0.049765     -1.4876    0.14177
    ProcessNo3     -0.037776    0.058033    -0.65094    0.51742
    ProcessNo4      -0.12503    0.089346     -1.3994    0.16651
    ProcessNo5     -0.079918     0.05903     -1.3539    0.18054
    ProcessNo6     -0.024255    0.047506    -0.51057    0.61141
    ProcessNo7      0.019212     0.04586     0.41894    0.67666
    ProcessNo8     -0.048475    0.052277    -0.92726    0.35727
    ProcessNo9     -0.041543    0.049123    -0.84568    0.40088
```

Fig.3: ***Result of multiple regression in MATLAB***
*Source: author's construction*

As a next step we can use these parameters to define a function, which then needs to be optimized.

Based on the result of the regression, we can use the parameter of the "Estimate column" to create our objective function for the maximization operation (in our case we use the minimization operation *fmincon* of MATLAB and just invert the output goals to achieve the maximization.

The function for optimization is reduced to 4 processes for a proof of concept.

```
objective = @(x) -0.054538*x(1)-0.074031*x(2)-0.03776*x(3)-0.12503*x(4);
```

The constraints of the function are:

- The sum of all x factors has to be 100
- Each x value has to be between 0 and 100.
- We want to start at an initial "estimation point" we use here the values of our initial process relevance defined by literature research. (in the case below, we randomly chose the values 1,5,5 and 1 for the x values to start.

This optimization can be implemented in MATLAB as follows:

```
objective = @(x) -0.054538*x(1)-0.074031*x(2)-0.03776*x(3)-0.12503*x(4);
% initial guess
x0 = [1,5,5,1];
% variable bounds
lb = 0.0 * ones(4);
ub = 100.0 * ones(4);
% show initial objective
disp(['Initial Objective: ' num2str(objective(x0))])
% linear constraints
A = [1 1 1 1];
b = 100;
Aeq = [];
beq = [];
% optimize with fmincon
%[X,FVAL,EXITFLAG,OUTPUT,LAMBDA,GRAD,HESSIAN]
% = fmincon(FUN,X0,A,B,Aeq,Beq,LB,UB,NONLCON,OPTIONS)
x = fmincon(objective,x0,A,b,Aeq,beq,lb,ub);
% show final objective
disp(['Final Objective: ' num2str(objective(x))])
% print solution
disp('Solution')
disp(['x1 = ' num2str(x(1))])
disp(['x2 = ' num2str(x(2))])
disp(['x3 = ' num2str(x(3))])
disp(['x4 = ' num2str(x(4))])
```

Running this script presents us values for x. therefore optimized process relevance. In our proof of concept all values x1 until x3 are 0 and x4 is 100.

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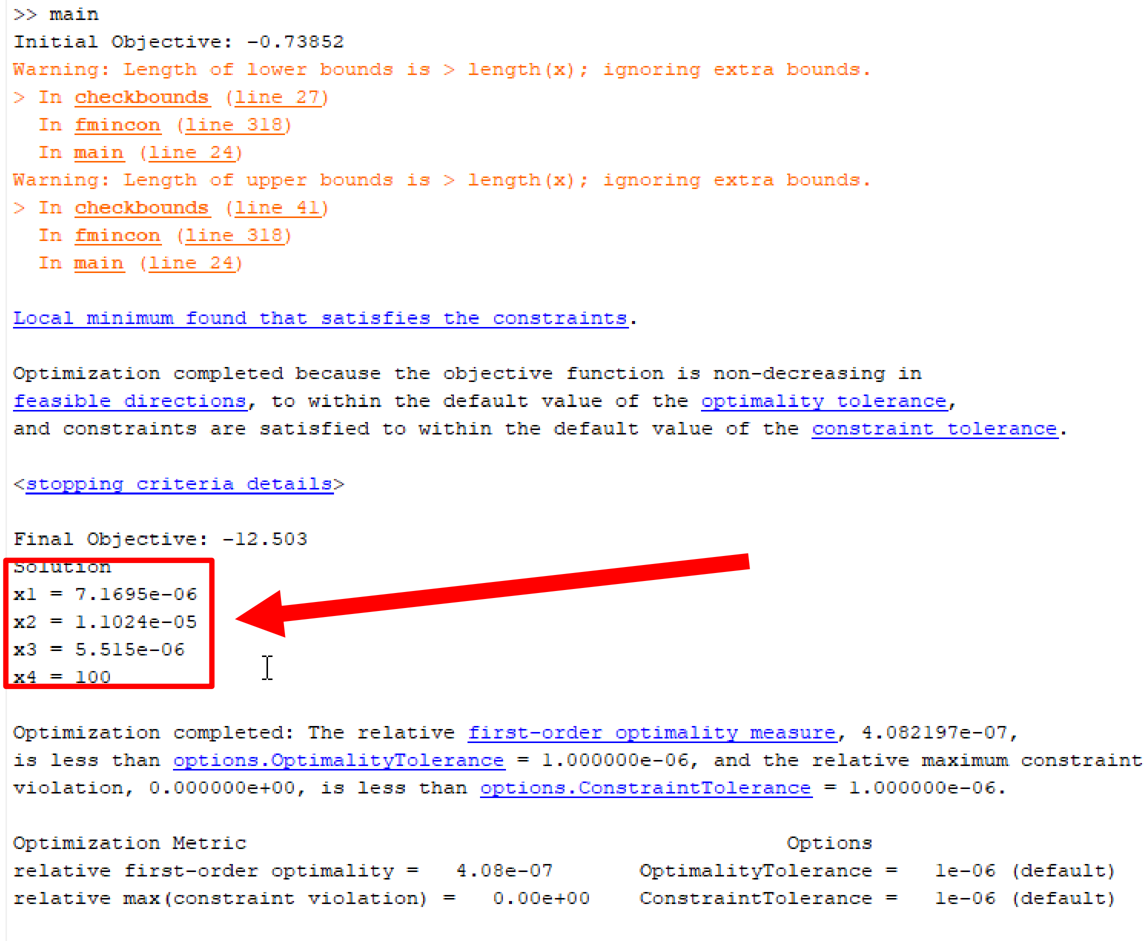

```
>> main
Initial Objective: -0.73852
Warning: Length of lower bounds is > length(x); ignoring extra bounds.
> In checkbounds (line 27)
  In fmincon (line 318)
  In main (line 24)
Warning: Length of upper bounds is > length(x); ignoring extra bounds.
> In checkbounds (line 41)
  In fmincon (line 318)
  In main (line 24)

Local minimum found that satisfies the constraints.

Optimization completed because the objective function is non-decreasing in
feasible directions, to within the default value of the optimality tolerance,
and constraints are satisfied to within the default value of the constraint tolerance.

<stopping criteria details>

Final Objective: -12.503
Solution
x1 = 7.1695e-06
x2 = 1.1024e-05
x3 = 5.515e-06
x4 = 100

Optimization completed: The relative first-order optimality measure, 4.082197e-07,
is less than options.OptimalityTolerance = 1.000000e-06, and the relative maximum constraint
violation, 0.000000e+00, is less than options.ConstraintTolerance = 1.000000e-06.

Optimization Metric                                         Options
relative first-order optimality =    4.08e-07       OptimalityTolerance =    1e-06 (default)
relative max(constraint violation) =    0.00e+00    ConstraintTolerance =    1e-06 (default)
```

Fig.4: **Result of multiple regression optimization in MATLAB**
*Source: author's construction*

**Result:**

We only need the operations "fitlm" and "fmincon" of MATLAB to optimize our process relevance factors with linear regression if we summarize the 4 health indicators to a single output value. The actual values of the input variables from our dummy data set are as useless as in solution 2. Again, the optimization maximizes only one single input variable, and minimizes all others.

## Conclusion

Based on the used dummy data set, the optimization works, but would not be useful for process relevance optimization, which is the overall goal to this research project. The optimum of the used data sets will always be in a corner of our "hyper-plane" and therefor always have one of the 49 processes at 100% and the others at 0%. Of course, this result is based only on the dummy data, which itself is randomly developed. So non- significant behavior was to be expected.

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In the future, when a large data set of project management practitioners is available, the optimization approach must be repeated, and the results analyzed again. Only then can a deliberate decision in choosing the best optimization method be made.

## Outlook to different optimization algorithms

As the linearity of least square optimization method causes maxima to appear in “corners”, nonlinear models could offer better fitting to the actual data. The most promising methods could be non-parametric multivariate models like kernel-based and spline-based regression methods. [WEN19]

Especially because kernel-based models apply smoothing to nonlinear data as shown in a graphic example below. [CAO08]

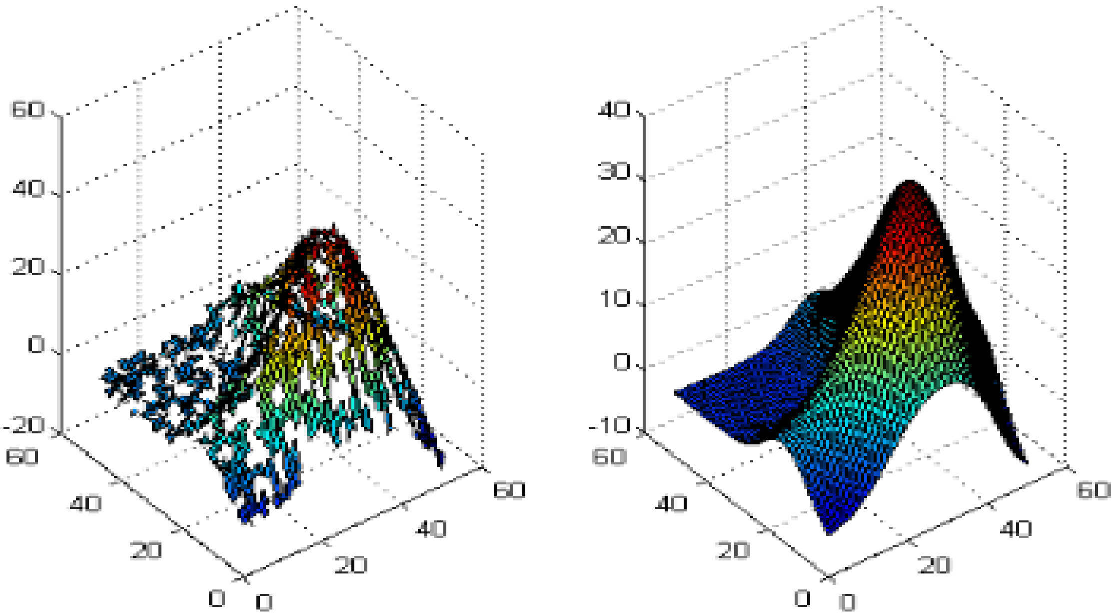


Fig.5: ***Kernel-based smoothing of nonlinear distributions***
*Source: author’s construction*

Another approach to decrease the complexity and co-variance between all 49 processes would be splitting the processes into project phases and applying only project phase specific optimizations with decreased number of processes in each phase.

All these decisions will be finally made when the data from project practitioners is available. For now, it is only obvious, that least square optimization fundamentally works for multiple inputs, but is most likely optimize one single input parameter, which does not fit to the modeled system of project management practice.

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# Agile Development and Open Innovation: Challenges and Trade-offs in Virtually Enlarging Innovation Sources

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## Abstract

Ever faster changing business and technological environments and increased competition urge companies to look for new sources of information to increase and speed up their innovation process. Open Innovation addresses this need through integrating knowledge and ideas from a company's ecosystem. On the other side, companies applying Agile Development base their innovation strategy on close cooperation with customers and on-site collaboration but tend to leave the innovation potential of a broader range of outside-stakeholders unused. In this context, the paper contributes to the research on the application of Open Innovation in Agile Development. Also addressing the pressure enforced by the recent pandemic for virtualisation of almost any collaboration, it identifies which challenges arise and which trade-offs to decide on when agile companies utilize the Open Innovation approach to integrate the knowledge of external stakeholders particularly by means of virtual communities.

A literature analysis following the principles of systematic mapping studies is applied to the topics of *Open Innovation* and *Agile Development*, but also related areas that can provide examples of virtual collaboration and openness. The overall goal of the research is to contribute to adapting an innovation system customization framework to the context of Open Innovation in Agile Development.

The findings indicate several challenges counteracting a straightforward application of Open Innovation concepts in Agile Development and point out the need for companies to thoroughly evaluate adaptations of either agile principles or Open Innovation elements. Solution approaches indicate a trend towards re-shifting to rather classical approaches where stability, planning, and documentation play an important role. The insights from identifying these challenges and trade-offs are used to derive design decisions for adapting an innovation system customization approach to the given context.

**Key words:** *agile development, open innovation, virtual communities, stakeholder collaboration, innovation system customization.*
**JEL code:** O22, 036, L17, L22

## Introduction

Emerging from the software industry, agile development in contrast to traditional development approaches focuses on streamlining procedures, direct communication, self-organization, and close collaboration with the customer (Beck et al., 2001). Particularly in information technology, agile approaches and methods proofed to raise productivity and quality as well as employee and customer satisfaction (Dybå & Dingsøyr, 2008). The move away from an 'introverted' development by integrating customers throughout the whole development endeavour is a major advantage of Agile Development and particularly small companies and teams benefit from the reduction in time-to-market and early customer feedback (Conboy & Morgan, 2011). On the other hand, limiting the cooperation only to customers or customer representatives could compromise the innovation potential of a company as new ideas and respective proposals for implementation often emerge from the end-users of a product or service or from external experts (Reichwald & Piller, 2009).

The Open Innovation approach in consequence, strives for exploiting the innovation potential of the various stakeholders of the whole ecosystem of a company to augment the company-internal innovation capabilities (Chesbrough, 2011). As innovations typically emerge

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from the collaboration of several involved people rather than from the work of an individual, a special focus of the Open Innovation approach relates to virtual communities. Their facilitator role and importance for the Open Innovation approach is underpinned by the steady growth of the internet and continuously emerging new or improved means of virtual collaboration. Consequently, Open Source Software Development and applications in the context of Software Ecosystems can be analysed as examples of how to use virtual communities to encourage user innovation (Reichwald & Piller, 2009).

In general, innovations tend to disturb well-established routines in an organization and bear the inherent potential for conflicts (Hauschildt, Salomo, Schultz, & Kock, 2016). Therefore, an organization must determine rules on how to handle innovations. Typical elements of such innovation management systems are identified by Davila, Epstein, and Shelton (2013) and comprise amongst others *innovation strategy*, *organizational structure*, *innovation process*, and *innovation culture*. Due to different business characteristics, each organization must develop or at least customize its own innovation management system. For the context of software businesses pursuing a Software Product Line Engineering approach Stallinger, Neumann, and Schossleitner (2014) proposed a business characteristics-driven approach for systematically customizing an organization's innovation management system.

The research presented here addresses the challenges that arise when organizations applying Agile Development decide to apply the concept of Open Innovation by integrating potential external stakeholders via virtual communities. In a longer-term step, it is envisioned to provide an innovation management system customization framework for the context of Agile Development and Open Innovation, capturing the main issues and practices identified. The research questions underlying the work in this paper are thus threefold: Firstly, which challenges emerge when agile companies use the Open Innovation approach to integrate external stakeholders via virtual communities? Secondly, based on the results of Research Question 1, how could an existing framework for innovation management system customization be conceptually adapted to support innovation system customization at the intersection of Agile Development, Open Innovation, and virtual stakeholder integration? Thirdly, but out of the core scope of this paper, which practices for virtual stakeholder integration applicable in the context of Open Innovation and Agile Development can be identified for integration in the framework? Research question 1 comprises the focus of this paper and is addressed by literature search and analysis following the guidelines for systematic mapping studies as proposed by Petersen, Feldt, Mujtaba, and Mattsson (2008) and Kitchenham, Budgen, and Pearl Brereton (2011). Research question 2 addresses particularly step 3 of a six-step design science-based approach (cf. Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) to develop the innovation management system customization approach comprising the steps of problem identification and motivation, objectives for a solution, design and development, demonstration, evaluation, and communication, with the first two steps and the design part of step 3 covered within this paper.

Several related works address Open Innovation in the context of Requirements Engineering, e.g. (Alspaugh & Scacchi, 2013), (Knauss, Damian, Knauss, & Borici, 2014), (Linåker, Rempel, Regnell, & Mäder, 2016), or (Wnuk, Pfahl, Callele, & Karlsson, 2012), but overall, these studies do not explicitly address the management of external stakeholders. According a research agenda for Requirements Engineering in Open Innovation by Linåker, Regnell, and Munir (2015) stakeholder management in open systems needs to be further investigated, particularly with respect to the mode of approaching external stakeholders, the way to use existing requirements artifacts, or the integration of processes and methods from the Open Source Software Development. In their research in the context of software development Conboy

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and Morgan (2011) conclude that "there is a lack of understanding of what constitutes innovation in software development in general and to what extent agile methods actually facilitate this process". Accordning Munir, Wnuk, and Runeson (2016) the combination of Agile Development and Open Innovation "seems to create barriers in transferring the ideas outside the team's boundaries". In a bachelor thesis supervised by the author, Kordon (2017) distilled four problem areas hindering the integration of external stakeholders in agile systems: the need for transition to online artifacts, issues of knowledge sharing and long-term knowledge retention, increased planning insecurity for both the agile company and the external stakeholders, and reaching a network's critical mass given the small agile team size.

The remainder of the paper is structured as follows: Section 2 summarizes relevant background on requirements and innovation in Agile Development, Open Innovation, stakeholder integration via virtual communities, and innovation system customization. Section 3 summarizes the challenges and trade-offs identified for the combination of Open Innovation and Agile Development. Section 4 consolidates the insights from section 3 into basic design decisions for an innovation system customization framework. Section 5 concludes the paper.

## Background

### Innovation and Requirements in Agile Development

Agile approaches typically address the issue of frequent changes and the ongoing demand for innovation by maintaining a constant exchange with the customer and thereby focus on close interpersonal collaboration (Beck et al., 2001; Dybå & Dingsøyr, 2008). It is consequently the involved people who represent the most significant bottleneck in the innovation process. Further, from the viewpoint of the influence of developers on the innovation process Hevner and Green (2000) observe in the context of software development that with more perceived control by and more involvement of developers particularly technical innovations get adapted more quickly and effectively. Moreover, a growth of a company might negatively affect the innovation potential of developers as scaling up typically implies moving away from interdisciplinary task fields to rather specialized ones with less responsibilities and space for creativity (Moe et al., 2012). Overall, since a close relationship to the customer constitutes a significant and human resources-intensive part of Agile Development, it seems to rather prevent a company from applying a broader and more open approach to innovation (Conboy & Morgan, 2011).

To better integrate real end-users into the innovation process, the combination of user-driven approaches with Agile Development is proposed by several authors (e.g. Chamberlain, Sharp, & Maiden, 2006; P. Näkki, K. Koskela, & M. Pikkarainen, 2011). According Chamberlain et al. (2006) – for the case of *User Centered Design* – five dimensions can be identified showing a direct correlation with Agile Development. These comprise direct user involvement into the development process; collaboration and culture stimulating active communication and collaboration with users; prototyping enabling users to provide feedback; a project lifecycle giving enough time to early identify user needs and requirements; a way of project management guiding the interplay of Agile Development and User Centered Design without too strict rules. Particularly, the fourth dimension here might contradict to the agile claim for short iteration cycles if additional time must be spent on elicitation and communication of user needs and requirements.

Agile methods generally view requirements as information that is subject to quick change and that cannot be elicited at once prior to development (Sillitti & Succi, 2005). With respect to agile requirements engineering practices, several principles can be identified (cf. Cao & Ramesh, 2008): requirements elicitation via on-site communication between developers and customers and documentation in only high-level descriptions; iterative negotiation of requirements with

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increasing level of detail as development progresses; extensive and repeated prioritizing of requirements together with the customer; constant planning to maintain flexibility when dealing with changes; delivery of prototypes and mock-ups to the customer for early requirements validation; regular meetings to evaluate the requirements to keep track of project status and validate the match of the requirements with customer's need. – Overall, the outlined practices pose the need for high-qualified staff due to an inherent lack of documentation and rigor and the high amount of transfer tasks with the customer (Savolainen, Kuusela, & Vilavaara, 2010).

The artifacts used in requirements engineering in Agile Development correspond to the focus on on-site communication and emphasize simple methods that can easily be performed with pens and paper (Sillitti & Succi, 2005). Particularly, the physical character of such artifacts (like e.g., user stories) is regarded a key promotor of collaboration, communication, and self-organization. On the other hand, the trend to virtual teams and the use of information sharing systems causes issues with maintaining this promotor (Sharp & Robinson, 2008). Similarly other artifacts like e.g. a product backlog lack detailed specifications, underlie high dynamics and reprioritization and do not provide a sound basis for differentiating between user requirements and system requirements (Savolainen et al., 2010).

## Innovations and Open Innovation

From a terminological perspective, 'innovation' is not restricted to a new idea or invention, but also encompasses its exploitation and successful introduction in a market. Consequently, the term 'innovation' only applies if there is some novel combination of – in broad sense – "tools" and "purpose" and such innovations generally can be categorized according various criteria, like content (e.g. process innovation or product innovation), intensity/novelty (e.g. incremental or radical innovations), or subjectivity (different perception of novelty by different actors) (Hauschildt et al., 2016).

The innovation process is a central element of innovation management, and many process models are proposed in literature. Generally, an innovation passes through a series of phases, activities and decisions. While many of the models are based on rather sequential stage-and-review concepts, more recent models explicitly comprise parallel and iterative activities. Although the number and properties of the involved phases varies between sources, the generation and gathering of ideas and their commercial exploitation typically represent fixed starts and ends in such processes (Herzog, 2008). Figure 1 shows an ideal-typical model extending the mentioned two phases with a decision-oriented idea acceptance phase.

| 1. Idea generation | 2. Idea acceptance | 3. Idea realization |
|---|---|---|
| 1.1 Determination of search area | 2.1 Evaluation of the ideas | 3.1 Concrete implementation of the novel idea |
| 1.2 Idea finding | 2.2 Preparation of realization schedules | 3.2 Sales in desired market |
| 1.3 Proposal of ideas | 2.3 Decision on a plan to realize | 3.3 Check on acceptance |

*Source: author's construction adapted from (Thom, 1980)*

Fig. 1. **Three-phase innovation process**

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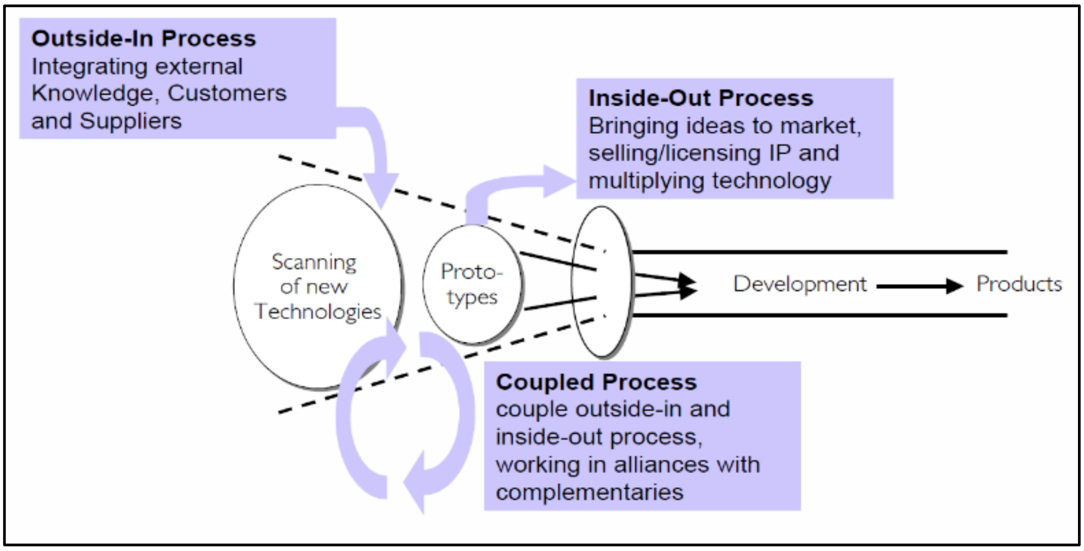
In classical 'closed innovation', novel ideas are generated through knowledge within the company without being shared with others in the same application domain or market. Being further developed, they are typically regarded as intellectual property and competitive advantage, secured by patents and exploited through existing business models without allowing other potential contributors to consider further applications or uses (Chesbrough, 2011).

On the other side, to enlarge innovation capability, companies could leverage innovation potentials across their boundaries following the idea of 'collective invention' where free exchange of information allows companies to identify and follow the most relevant and promising technical developments (Allen, 1983). The concept of Open Innovation therefore tries to weaken the company's boundaries by involving external actors and utilizing the surroundings of a company through externalizing ideas which do not fit current internal business models, and by internalizing ideas and knowledge from the outside and using these within the company's innovation process (Chesbrough, 2011). Reichwald and Piller (2009) extend this concept by networks of experts and other value-creation partners and actively integrating users and their needs in all phases of the innovation process, particularly the earlier phases of idea generation and concept development. Such an Open Innovation approach can be conceptually structured into three cores 'archetypes' of innovation processes (cf. Figure 2).




*Source: (Gassmann & Enkel, 2004)*

Fig. 2. **Archetype processes of Open Innovation**

For the outside-in process, users and customers are of high importance as they are directly linked to the market of the company or the technology (Slaughter, 1993). A key factor for the success of this process is the ability of a company to develop competence in identifying the relevant external information carriers, to integrate them, and to assimilate the respective knowledge. Cohen and Levinthal (1990) denote this as 'absorptive capacity'. However, this capability might conflict with the 'Not Invited Here'-syndrome denoting the resistance of long-tenured internal groups against outside events and technological developments (Katz & Allen, 1982). For the case that a company's business model does not allow the integration of an idea emerging from the company's innovation process, the company can externalize this idea via the inside-out process and leverage technological multiplication and commercialization e.g. through licenses (Gassmann & Enkel, 2004). The coupled process, finally, combines both previous processes into a collaborative ecosystem of companies, users, and experts and provides ways for finding the best purposes and markets for existing technologies and for developing novel tools and technologies to fulfil a given market's needs (Gassmann & Enkel, 2004).

**Stakeholder Integration in Virtual Communities**

Open Source Software Development is regarded as one of the most popular examples of collaborative networks driving innovation in terms of openness of process as well as of out-comes (Huizingh, 2011). Several factors like high numbers of ideas generated and programmers involved as well as the selection mechanisms and criteria for new features favour the transfer of principles to Open Innovation. Two basic approaches can be identified: 1) the user-based approach in form of a collaborative development of features, and 2) the vendor-based approach organized by a company managing feature and requirement selection and prioritization with involvement of users (Laurent & Cleland-Huang, 2009). Particularly this second approach highly overlaps with the context of Open Innovation and is further analysed hereafter.

Requirements in Open-Source Software Development ecosystems are quite different compared to requirements in closed systems. They are dispersed across and evolve within a plethora of different artifacts, online conversations, and repositories, and further include requirements-like artifacts like feature-requests. Most such artifacts describe a desired behaviour or feature rather in the solution than in the problem space (Alspaugh/Scacchi, 2013). This online and dispersed nature of requirements causes a series of challenges and problems, comprising among others: insufficient exploitation of stakeholder collaboration due to deficiencies of online tools in matching stakeholders with similar ideas; insufficient user-side mechanisms for prioritization resulting in users unsatisfied with the vendor-side handling of their effort and input; insufficient vendor-to-user communication, not satisfactorily allowing to keep track of user needs and including users into requirements elicitation; insufficient feedback and status updates on requests leading to contributors perceiving their input unnoticed or ignored (cf. Laurent & Cleland-Huang, 2009).

These challenges require a company to set up adequate and transparent decision making tools and processes for identifying innovation critical information in order not to get overwhelmed with a plethora of ideas and suggestions (Dahlander & Magnusson, 2008). Processing all ideas and requests with universally applicable processes could lead to discarding innovative ideas, as these are often immature and incalculable in their early stages. Wnuk et al. (2012) therefore recommend a segregation of requirements processes and refinement of prioritization methods as countermeasures as the plethora of requirements artifacts forms a comprehensive network of distributed knowledge and it is crucial for a company to know these artefacts and related communication structures.

To determine appropriate collaboration and communication strategies for virtual communities, the basic Open Innovation strategies to integrate external actors must be analysed. According Dahlander and Magnusson (2008) three basic strategies to integrate Open Source Software Development communities into business models can be identified:

- ***Accessing***: integration of new or existing communities to enlarge a company's innovation potential,
- ***Aligning***: alignment of deferring intentions of the community and the company regarding free availability or commercialization of the development or product, e.g., by means of licensing policies or incentives to influence the community's development,

- ***Assimilating***: after successful integration (i.e. accessing) and alignment, active pushing of the integration of the community's outputs, but also in return the provision of content to the community in order to leverage legitimacy.

The combination of these strategies can lead to hybrid structures within a company, encompassing proprietary as well as open parts or to structures with varying degrees of community involvement. Overall, a company that takes into account to open its boundaries, but also wants to maintain its competitiveness has to identify the appropriate degree of openness, sometimes by giving priority to control and limiting openness (Dahlander & Magnusson, 2008).

Following the concept of vendor-based Open Source Software Development, so-called Software Ecosystems form a reference of how a collaboration-based approach can be integrated into a company's business model. Jansen, Brinkkemper, and Finkelstein (2013) define a Software Ecosystem as "a set of actors functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. These relationships are frequently underpinned by a common technological platform or market and operate through the exchange of information, resources and artifacts".

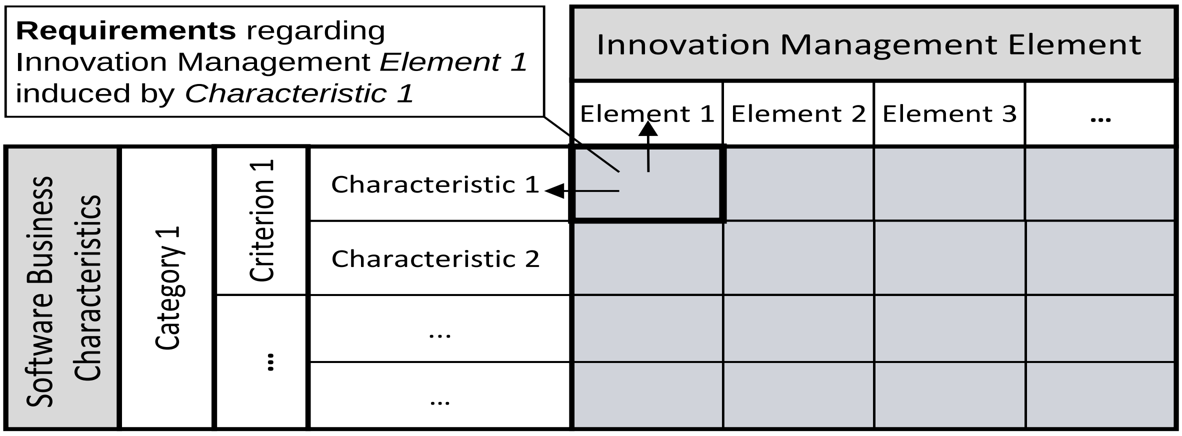
Exemplary studies of such Software Ecosystems allow drawing basic conclusions and illustrating behavioural patterns in the respective virtual communities. The study of Linåker et al. (2016) on an open source ecosystem showed a core team of stakeholders of platform users as well as platform providers with quite stable influence and collaborative behaviour to be the main drivers for ongoing development. In contrast, the study of Knauss et al. (2014) on a commercial ecosystem revealed a need for key players (platform providers, etc.) to ensure ecosystem stability. As these players have the power to change the direction of an ecosystem, niche players might get ignored or even forced to leave.

Similarly, to Open-Source Software Development systems, the representation of knowledge is crucial for the health of the ecosystem. Although consumers can rather easily provide feedback or request requirements, this information is typically only represented on a quite specific and narrow abstraction level, which requires experienced and skilled staff to derive appropriate interpretations using in turn their closest network, thus tending to lead to very close links and encapsulation of knowledge (Knauss et al., 2014).

**Innovation System Customization**

The management of innovations in a systematic way has been a subject to research for a long time and mainly driven by product and service businesses in consumer or business-to-business markets. Software Product Line Engineering as primarily an engineering approach emphasises a systematic and widely prescriptive management of product variability and proactive planning. Potential innovations to a Software Product Line may thus be hindered if they require changes to these pre-planned models and structures. (Stallinger & Neumann, 2013)

To help organizations that apply a Software Product Line Engineering approach to systematically and better exploit their innovation potential, Stallinger and Neumann (2013) present a conceptual framework for innovation system customization in the set context, which is further extended by Stallinger et al. (2014) with the proposal of an assessment-based innovation system evaluation and adaptation method. The framework captures and prescribes generic innovation management system requirements for the context of Software Product Line Engineering across two dimensions (cf. Figure 3): firstly, innovation management elements, like innovation strategy or innovation process, that must be considered in defining an innovation system; secondly, software business characteristics, that differentiate businesses or organizations. The requirements are then defined at the intersection of a specific software business characteristic with an innovation management element (Stallinger & Neumann, 2013).




*Source: (Stallinger & Neumann, 2013)*

Fig. 3. **Conceptual framework for innovation system customization**

According Davila et al. (2013) the following innovation system elements require consideration: *Innovation Strategy, Organizational Structure, Innovation Process, Innovation Culture, Innovation Measurement, Incentives and Rewards,* and *Learning*. Their adoption and interpretation for use in the framework is described in more depth in (Stallinger & Neumann, 2013). The criteria used to characterize and differentiate software businesses are organized into the following categories (cf. (Stallinger et al., 2014) for more details): *Customers and Market* (e.g. anonymity of customers, strength of customer-relationships), *Products and Services* (e.g. typical product life-span, degree of customization), *Engineering and Production* (e.g. repeatability of the process, number of involved engineering disciplines), and *Organization* (e.g. position in the value chain, structure of supplier networks). For each criterion in the software business characteristics dimension a set of typical characteristics or values the criterion could take for a specific organization is foreseen.

## Open Innovation via Virtual Communities in Agile Development: Challenges & Trade-offs

This section tries to distil and structure the main results and insights from literature as summarized in subsections 1 to 3 under 'Background' above. The focus is on identifying major potential challenges and issues that arise when companies try to combine Agile Development with Open Innovation by integrating external stakeholders via virtual communities (cf. Research Question 1). The results are presented in Table 1 clustered into three categories according to the interplay of the involved approaches. Pointers to literature sources elaborating on the respective item or its underlying assumptions are provided where possible, as well as an indication which innovation system elements (cf. subsection 4 of 'Background' above) might be appropriate to address the respective item.

With respect to the effects between Agile Development and Open Innovation, basic agile principles and practices like small team sizes, minimization of documentation and reliance on the knowledge of individuals limit the potential of a company to fully exploit the three basic Open Innovation processes of out-side in, inside-out, and coupled. Minimization of documentation and

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the resource-intensive communication with stakeholders results in humans turning out as the bottleneck for open knowledge sharing within a broader network.

Table 1

**Challenges and issues when opening up Agile Development via virtual communities**

| Challenge/Issue | ISE [1)] |
|---|---|
| **Agile Development vs. Open Innovation** | |
| Minimization of documentation and focus on individuals as knowledge carriers limit inside-out/coupled processes (cf. Cao & Ramesh, 2008; Gassmann & Enkel, 2004; Munir et al., 2016) | S, P |
| Small team sizes limit absorptive capacity and outside-in process (cf. Cao & Ramesh, 2008; Cohen & Levinthal, 1990; Gassmann & Enkel, 2004; Munir et al., 2016) | S, P, O |
| Minimization of documentation causes human bottlenecks in knowledge sharing as main principle of Open Innovation (cf. Conboy & Morgan, 2011; Savolainen et al., 2010) | S, P |
| Increasing instability through extensive requirements changes and reprioritizations caused by early integration of end-users in outside-in-process (cf. Cohen & Levinthal, 1990; Daneva & Pastor, 2016; Reichwald & Piller, 2009) | P |
| NIH-Syndrome counteracts absorptive capacity and outside-in process (cf. Cohen & Levinthal, 1990; Katz & Allen, 1982) | C |
| **Virtual Communities vs. Agile Development** | |
| Move to online artifacts counteracts focus on physical artifacts as major agile practice (cf. Sillitti & Succi, 2005) | P |
| Move to online, time-/location independent communication counteracts on-site and local communication as major agile practices (cf. Sharp & Robinson, 2008; Sillitti & Succi, 2005) | P |
| Growing, distributed knowledge base challenges agile principle of knowledge sharing in small teams (cf. Knauss et al., 2014; Munir et al., 2016) | P |
| Solely/increasing use of online artifacts for requirements limits exploitation of stakeholder collaboration (cf. Laurent & Cleland-Huang, 2009) | P |
| Solely/increasing use of online artifacts for requirements limits support for user-side feature prioritization (cf. Laurent & Cleland-Huang, 2009) | P |
| Small agile team size creates tendency to join existing instead of creating new communities (cf. Dahlander & Magnusson, 2008) | S |
| Community growth reduces importance of customer as main agile principle (cf. Conboy & Morgan, 2011) | S, P, C |
| Community growth diminishes developer innovation as an effect of scaling-up (cf. Moe et al., 2012) | S, O |
| **Virtual Communities vs. Open Innovation** | |
| Measures to maintain community stability compromise the network's ability to rapidly adapt to environmental changes (cf. Knauss et al., 2014; Linåker et al., 2016) | S, O |
| Attracting/maintaining community requires appropriate management of intellectual property (cf. Dahlander & Magnusson, 2008) | S |
| Solely online artifacts for requirements limit vendor-user communication and user inclusion in requirements elicitation (cf. Laurent & Cleland-Huang, 2009) | P, O |
| Solely online artifacts for requirements limit feedback and status updates to contributors (cf. Laurent & Cleland-Huang, 2009) | P,O |
| Low abstraction level of information representation leads to knowledge encapsulation in experts' closer networks (cf. Knauss et al., 2014) | P, O |

[1)] Innovation System Elements: S(trategy), P(rocess), O(rganization), C(ulture), L(earning), M(easures), I(ncentives)

*Source: Own compilation*

With the Open Innovation approach to gain momentum, the huge number of requirements emerging from consumers, end-users and other network players could lead to increasing instability for all players, because of increased change and re-prioritization efforts. Further, independently from the specifics of Agile Development, psychological factors like the 'Not-Invented-here'-syndrome might hinder the company to fully exploit input from the outside.

Regarding the relationships and effects between virtual communities and Agile Development, the dominance of online artifacts and online communication limit the advantages of fundamental agile principles and practices like physical artifacts and onsite, personal communication. Further, the growing, spread and only virtually represented knowledge might overwhelm a small agile team. The move to online artifacts also limits collaboration with and among stakeholders and lacks provision of support for consolidation and joint prioritization of feature and requirements requests among the external stakeholders. Weighting the envisioned efforts for reaching and maintaining a virtual community's critical mass against the possibilities of small agile teams often results in a decision to join an existing community instead of creating a new one specific to the company's business objectives. Assuming the opening-up to be successful, the increasing number of new stakeholders and stakeholder types to deal with might decrease the customer focus inherent to agile principles and, if the company reacts with scaling-up, developer innovation as one of the drivers of agile innovation might decrease.

Concerning potential effects between the use of virtual communities and Open Innovation, the analysis of virtual networks shows that there is a certain need for key players to provide direction and stability. However, such players have the potential to compromise the ability of the network to adapt quickly to changes in the environment. In addition, the appropriate management of intellectual property with respect to the community plays an important role. The move to online artifacts, limits from a vendor perspective the communication with users and their inclusion in requirements elicitation, while on the other side contributors within the network might not get the expected feedback, updates, or recognition. Finally, the quality and abstraction level of information and its dispersed online representation might result in the need of experts to interpret and differentiate such information, which creates a tendency of accumulation and encapsulation of the respective knowledge by these experts and their closest network contacts, compromising the core ideas underlying truly Open Innovation.

Analysing the above-identified relationships and effects, one can derive that applying the concept of Open Innovation to Agile Development and using virtual communities as a basic means for realization is not a self-enforcing combination, but requires decisions with respect to several trade-offs with the following appearing to be most important ones:

(1) Defining the appropriate degree of openness to increase a company's innovation potential vs. losing competitive advantages.
(2) Balancing the degree of agility vs. the innovation potential resulting from Open Innovation.
(3) Managing the appropriate mix of sources for requirements and ideas by balancing the influence from key players and the contributions from a broader stakeholder network.
(4) Identifying the appropriate level of detail and abstraction of documentation and overall knowledge representation to balance the effectiveness of internal agile processes with efficient and effective community communication and collaboration.

## Innovation System Customization Approach

Above insights into potential challenges and trade-offs when applying the Open Innovation approach to Agile Development by virtually integrating stakeholders allow drawing basic decisions along the first three of six steps of a design science-based approach for the development of an innovation system customization approach (cf. Research question 2).

Regarding the first step of *problem identification and motivation*, the analysis of challenges and trade-offs provides essential insights into the problem to be solved. While the main motivation is to support companies applying Agile Development with a structured approach to customize their innovation management system when opening, the underlying problem turns out as quite challenging and complex. While Open Innovation is generally expected to foster innovation in Agile Development, the detailed view on Table 1 shows several particularly negative cause-effect relationships in both directions between the elements of Open Innovation, Agile Development, and virtual communities. Customizing an innovation system in this context is thus much more about identifying and evaluating respective trade-offs than a straightforward decision-making exercise and involves strategic decisions by the company.

With respect to the second step of defining the *objectives for a solution* the overall objective can be set as supporting companies applying Agile Development with a structured approach to customize Open Innovation based on virtual stakeholder integration according to their business objectives and business environment. More detailed objectives comprise efficient and effective applicability of the framework and respective methods, ease of understanding and applicability by non-innovation management experts, and coverage of a wide range of business types and business sizes in the domain of product and/or service development.

Concerning the third step of *design and development* the insights from the analysis carried out in the previous section suggest several key design decisions:

(1) Simply enhancing the existing innovation system customization framework for Software Product Line Engineering by e.g., including Agile Development characteristics appears no longer a meaningful option. The perceived complexity added by virtual collaboration and the substantial differences between the concepts of classical innovation and Open Innovation suggest the provision of a dedicated framework.

(2) The evaluation of several trade-offs and respective decision-making appears to clearly exceed the scope and responsibilities of core innovation management and affect the overall business model and strategy of a company. Therefore, the enhancement of the method for the application of the customization framework as laid out by Stallinger et al. (2014) by an up-front method for trade-off determination and strategic decision-making is suggested.

(3) An extension of the innovation management elements dimension (cf. Figure 3) comprising e.g., Innovation Strategy, Organizational Structure, and Innovation Process by a further element to capture requirements on the collaboration and communication infrastructure and particularly respective knowledge representation appears necessary.

(4) With respect to the criteria used to characterize and differentiate businesses no extensions at the level of categories appear necessary, but extension of the characteristics within certain categories, e.g., an extension in the Customers and Market category to cover ecosystem and respective stakeholder characteristics, or an extension in the Engineering and Production category to cover properties of the agile process.

(5) A subset of these business characteristics or respectively the values they can take has to serve to systematically link the results of the method for trade-off determination and strategic decision-making (cf. (2)) to the core customization framework.

The proper step of developing the framework (cf. Research question 3) exceeds the scope of the present paper and comprises systematically gathering ‘good practices’ at the intersection of Open Innovation, Agile Development, and virtual communities for abstraction and inclusion as innovation system requirements in the framework. Part of these practices can serve as input for the method for trade-off determination and strategic decision-making, e.g.:

- analysis of the basic Open Innovation strategies (i.e. accessing, aligning assimilating) in order to determine an adequate combination of these strategies and appropriate collaboration and communication strategies (cf. Dahlander & Magnusson, 2008), or
- opening-up only partly to lead users to limit the number of stakeholders an agile team has to collaborate with at the cost of a reduction of innovation potential (cf. P. Näkki et al., 2011).

Other practices can serve as requirements on innovation system elements for the core customization framework, e.g.:

- set up adequate and transparent decision making tools and processes for identifying innovation critical information in order not to get overwhelmed with ideas and suggestions (cf. Dahlander & Magnusson, 2008), or
- segregate requirements processes and refine prioritization methods in order not to get overwhelmed with ideas and to understand the multiple types of requirements artefacts and communication structures in the network of distributed knowledge (cf. Wnuk et al. (2012).

Particularly the innovation system requirements part of the framework is envisioned as a living artefact, to reflect best practices increasingly and continuously.

**Conclusions**

The research presented in this paper addresses the challenges that organizations applying Agile Development face when applying the concept of Open Innovation to lift limitations on their innovation potential resulting from a mere customer focus. The Open Innovation approach strives for exploiting the innovation potential of the whole ecosystem of a company and puts a special focus to virtual communities as a facilitator for Open Innovation.

Based on an analysis of requirements practices and innovation in Agile Development, the concept of Open Innovation, and of stakeholder integration via virtual communities in the fields of Open-Source Software Development and of Software Ecosystems, major challenges for opening-up Agile Development via virtual communities are identified. A deeper analysis of these challenges shows that beyond ‘simple’ challenges it is particularly the interplay of these challenges in the triangle of Open Innovation principles, Agile Development principles and practices, and virtual community and virtual collaboration peculiarities that creates a series of trade-offs. These trade-offs must be carefully evaluated, and respective strategic decisions made. Sample trade-offs relate e.g., to defining the appropriate degree of openness without losing competitive advantages, to balancing the degree of agility vs. the potential resulting from Open Innovation, or to balancing the influence of key players and community leaders against that of a broader user and stakeholder network while maintaining network health.

The results obtained are used to derive basic design decisions for the adaptation of an innovation system customization framework for Software Engineering Product Line Businesses to the context of Open Innovation via virtual communities in Agile Development, particularly for the context of product and/or service development. A basic decision is suggested to provide a separate and dedicated framework for the combination of Open Innovation with Agile development via virtual communities. Beyond that, major conceptual adaptations suggested referring to the need for provision of an up-front method for trade-off determination and strategic decision-making and to an extension of the innovation management elements dimension by a further element to capture requirements on the collaboration and communication infrastructure and knowledge representation. Further, several extensions of the business characteristics within certain characteristic categories appear necessary, e.g., extensions to cover ecosystem and respective stakeholder characteristics, or to cover properties of the applied agile process.

With respect to limitations, the paper mainly follows the claim by Conboy and Morgan (2011) that in order to understand the relationship between Agile Development and Open Innovation particularly the requirements practices of both worlds have to be analysed and understood. In turn, this might imply that the findings presented here apply more to the concept of incremental than of radical innovations. Further, the implicit assumption underlying the paper with respect to Agile Development is 'agile in the small'. Further research would be necessary to elaborate the interplay of Open Innovation with Scaled Agile settings.

As an outlook to the proper step of developing the framework by systematically capturing good practices, examples of practices and strategic decision making are provided as identified in course of the literature work. These examples indicate a tendency towards rather traditional and classical approaches where stability, planning, and documentation play an important role.

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# Defining the Set of Criteria for Establishing and Evaluating the Project Risk Register

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## Abstract

The project risk register is an important part of project management and one of risk management documents. The process of creating project risk registers is described and coincides in most theoretical sources. However, the outcome of the process is different. Among the project risk registers used in practice, there are ones of various size and content.

The author has used the results of his previous studies, especially the study where the criteria for establishing and evaluating the project risk register were developed. To achieve the aims of this study, the author chose one source, A Guide to the Project Management Body of Knowledge.

The size, structure and content of the risk register may vary from small to large, with different volumes of content and number of columns. The study is limited by the number of publicly available quality registers that contain a description of the risk management process or registers are part of other documents with a process description.

**Key words**: *project, risk, risk register, process, set of criteria.*
**JEL code**: M00, M10, M190

## The aim and framework of the research

The aim of the research is to study the register development process to find out whether it is possible to develop the risk register evaluation criteria according to the chosen project management methodology. One source was used to develop the set of criteria – A Guide to the Project Management Body of Knowledge.

## Theoretical justification of the study

The author believes that in the theory of project management there are no possible criteria for determining the truth. There is no single and generally accepted set of project management knowledge and no studies with sufficient results to confirm or reject judgements based on management theories. Without answering the question of what is true, it is possible that a set of criteria can be developed against which the process, content and scope of project risk registers can be assessed. The set of criteria would correspond to the chosen project management theory, or a certain body of knowledge.

A Guide to the Project Management Body of Knowledge (PMBoK) is the sixth edition, the book's publisher is the Project Management Institute (PMI). The first edition was in 1996. The PMI has also published The Standard for Risk Management in Portfolios, Programs, and Projects. However, PMBoK provides more information on risk registers than The Standard for Risk Management in Portfolios, Programs, and Projects.

The choice of the PMBoK was determined by the following factors:

1. Sufficient information on the risk register, the term "risk register" is used 168 times in the source;
2. In the PMBoiK, there are definitions of risk and risk register;

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3. The PMBoK presents a process-oriented theoretical model of project management with the interaction of processes, process start conditions and end results and tools and techniques applied in the process;
4. There are five process groups and ten knowledge areas in the PMBoK, including risk management;
5. Risk management is an integral part of all processes and several areas of knowledge.

According to publicly available information on the Internet, the seventh edition, scheduled for August 2021, will differ from all previous editions. However, the impact of the content will be gradual, and the author believes that the impact of the previous edition management concept will remain even after the release of the new edition.

According to the PMBoK, Project risk management processes are as follows: Plan risk management, identify risks, perform qualitative risk analysis, perform quantitative risk analysis, Plan risk responses, Implement risk responses, and Monitor risks. The risk register is an integral part of all the processes. Distinguished are two types of risks – the individual project risk and overall project risk. Risk is defined as "An uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives" (PMBoK, 2017). The risk register contains individual project risks. The Project Risk Management processes must comply with the project size, complexity, importance, and development approach (PMBoK, 2017). The Project Risk Management process must be appropriate to the size, complexity importance, and development approach of the project. In a situation where there are high-variability environments and the project is managed using adaptive approaches, risks will also be identified, analyzed, and managed during each iteration (PMBoK, 2017).

**Theoretical substantiation of criteria**

In the processes of the project Initiating and Planning, the creation of a risk register is started with risk categories, risk statement templates, probability and impact definitions, probability, and impact matrices (PMBoK, 2017). The establishment of a risk register is a risk management process. Project Initiating and Planning processes include Identify Risk, Perform Qualitative Risk Analysis, Perform Quantitative Risk Analysis, Plan Risk Responses. The risk register is updated within the Executing, Monitoring, and Controlling processes. During the closing process, the risk register collects the information on the risks that existed during the life of the project. All risk management processes have an input and output. Table 1 summarizes the information on the risk register in accordance with the risk management processes.

Table 1.

**The risk register in accordance with the risk management processes.**

| Process | Input | Activities | Output |
|---|---|---|---|
| Plan Risk Management | Risk register template | Defining how to conduct risk management activities for a project | Risk categories, stakeholder risk appetite, definitions of risk probability and impacts, probability and impact matrix, and reporting formats |
| Identify Risks process | | Identifying individual project risks | Risk register, with risks, potential risk owners, and list of potential risk responses, also with a risk title, risk category, current risk status, one or more causes, one or more effects on objectives, risk triggers, as well as the WBS reference of affected activities, and timing information |
| Perform Qualitative | Risk register | Prioritizing individual project risks for further analysis or action | Assessments of probability and impacts for each individual project risk, its priority level or risk score, the nominated risk owner, risk |

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| | | | |
|---|---|---|---|
| Risk Analysis | | | urgency information or risk categorization, and a watch list for low-priority risks or risks requiring further analysis |
| Perform Quantitative Risk Analysis | Risk register | Numerical analysis of the combined effect of the identified individual project risks and other sources of uncertainty on overall project objectives | Prioritized list of individual project risks, trends in quantitative risk analysis results, recommended risk responses |
| Plan Risk Responses | Risk register | Developing options, selecting strategies, and agreeing on actions to address the overall project risk exposure, as well as to treat individual project risks | Updated risk register with appropriate risk responses, trigger conditions, symptoms, and warning signs of a risk occurrence, risk responses budget and schedule, contingency plans, fallback plans, residual risks, and secondary risks, as a direct outcome of implementing a risk response |
| Implement Risk Responses | Risk register | Implementing agreed-upon risk response plans | Risk register may be updated to reflect any changes to the previously agreed-upon risk responses for individual project risks that are subsequently made as a result of the Implement risk responses process |
| Monitor Risks | Risk register | Monitoring the implementation of the agreed-upon risk response plans, tracking identified risks, identifying and analyzing new risks, and evaluating risk process effectiveness throughout the project | Updated with information on individual project risks generated during the Monitor risks process |

*Source: Compiled by the author from PMBoK*

The process of creating a risk register in the risk management process is shown in Figure 1.

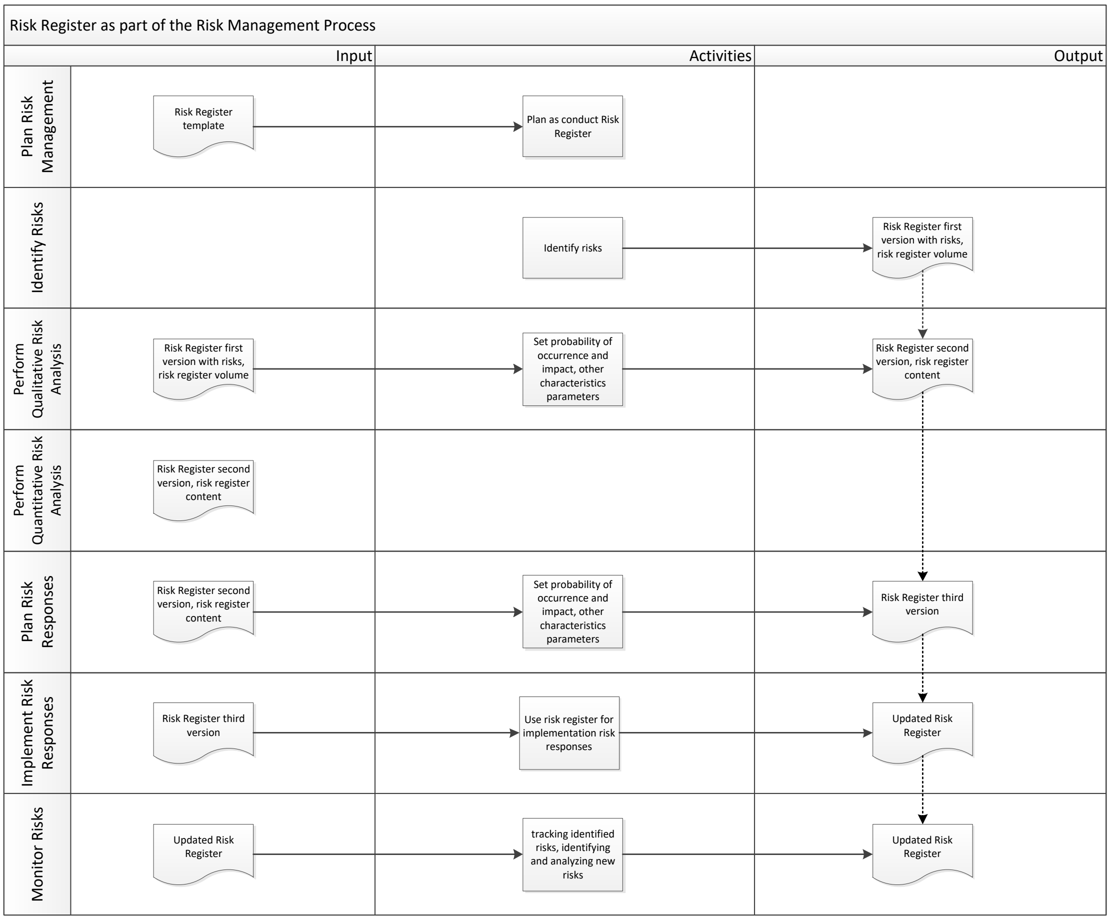


**Fig 1.:** ***The process of creating a risk register in the risk management process***
*Source: Compiled by the author from PMBoK*

The risk register is created and supplemented in other processes as well, see Table 2.

Table 2.

**The risk register in other processes**

| Process | How to use or inputs | How to change or outputs |
|---|---|---|
| | Project integration management | |
| Direct and Manage Project Work | Risk register provides information on threats and opportunities that may impact project execution | Risk register updates, new risks may be identified and existing risks may be updated during this process |
| Monitor and control project work | Risk register provides information on threats and opportunities that have occurred during project execution | New risks identified during this process are recorded in the risk register and managed using the risk management processes |
| Close project or phase | The risk register provides information on risks that have occurred throughout the project | |
| | Project scope management | |

| | | |
|---|---|---|
| Define scope | The risk register contains response strategies that may affect the project scope, such as reducing or changing project and product scope to avoid or mitigate a risk | |
| Project schedule management | | |
| Estimate activity duration | Individual project risks may impact resource selection and availability | |
| Develop schedule | The risk register provides the details of all identified risks, and their characteristics, that affect the schedule model | The risk register may need to be updated to reflect opportunities or threats perceived through scheduling assumptions |
| Control schedule | | The risk register and risk response plans within it; may be updated based on the risks that may arise due to schedule compression techniques |
| Project cost management | | |
| Estimate costs | The risk register provides detailed information that can be used to estimate costs | The risk register may be updated when appropriate risk responses are chosen and agreed upon during the Estimate Cost process |
| Determine budget | The risk register should be reviewed to consider how to aggregate the risk response costs | New risks identified during this process are recorded in the risk register and managed using the risk management processes |
| Control costs | | The risk register may be updated if the cost variances have crossed, or are likely to cross, the cost threshold |
| Project quality management | | |
| Plan quality management | The risk register contains information on threats and opportunities that may impact quality requirements | New risks identified during this process are recorded in the risk register and managed using the risk management processes |
| Manage quality | | The new risks identified during this process are recorded in the risk register and managed using the risk management processes |
| Control quality | | The new risks identified during this process are recorded in the risk register and managed using the risk management processes |
| Project resource management | | |
| Plan resource management | The risk register contains information on threats and opportunities that may impact resource planning | The risk register is updated with the risks associated with team and physical |

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| | | |
|---|---|---|
| | | resource availability or other known resource-related risks |
| Estimate activity resources | The risk register describes the individual risks that can impact resource selection and availability | |
| Acquire resources | | New risks identified during this process are recorded in the risk register and managed using the risk management processes |
| Control resources | The risk register identifies individual risks that can impact equipment, materials, or supplies | The risk register is updated with any new risks associated with resource availability, utilization, or other physical resource risks |
| Project communications management | | |
| Manage communications | | The risk register is updated to capture the risks associated with managing communications |
| Project procurement management | | |
| Plan procurement management | Some risks are transferred via a procurement agreement | Each approved seller comes with its own unique set of risks |
| Conduct procurements | Each approved seller comes with its own unique set of risks | Changes are made to the risk register during the contracting process, which reflect the specific risks of each seller |
| Control procurements | Each approved seller comes with its own unique set of risks | Changes are made to the risk register during the execution of the project, as early risks may no longer be applicable and new risks occur |
| Project stakeholder management | | |
| Plan stakeholder engagement | The risk register contains the identified risks of the project and usually links them to the specific stakeholders as either risk owners or as subject to risk impact | |
| Monitor stakeholder engagement | The risk register contains the identified risks for the project, including those related to stakeholder engagement and interactions, their categorization, and list of potential responses | The risk register may need to be updated with responses to stakeholder risks |

*Source: Compiled by the author from PMBoK*

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The risk register is also created and supplemented in other processes, see Figure 2.

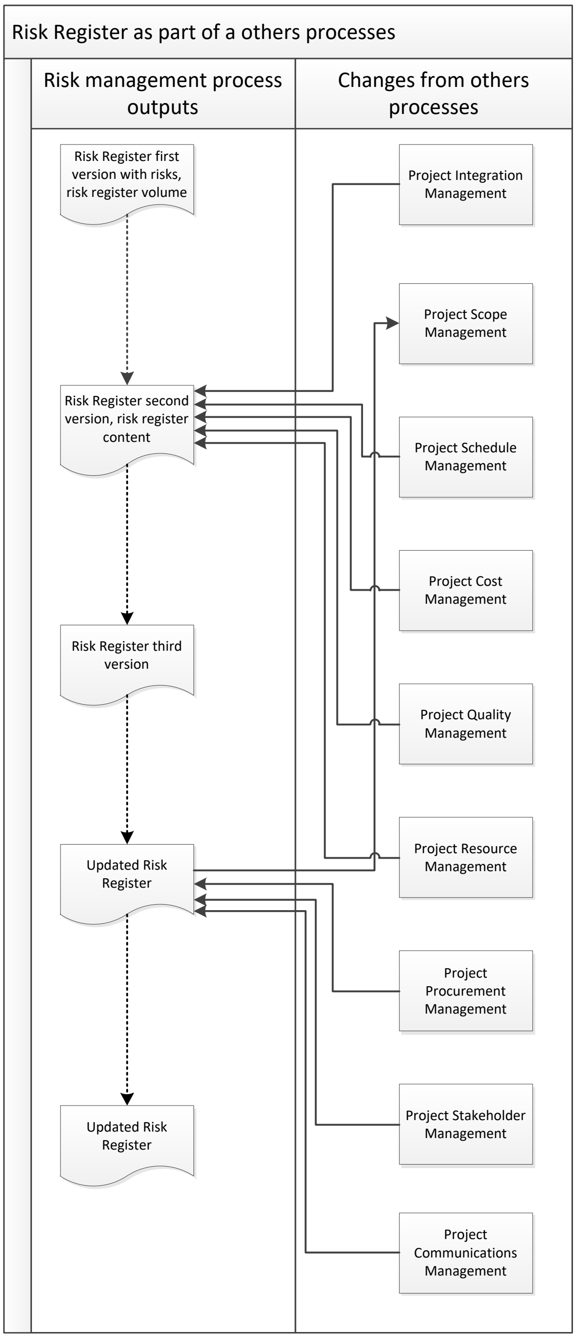


Fig 2.: ***The risk register in other processes***
*Source: Compiled by the author from PMBoK*

**The set of criteria**

The volume of the risk register is created in the project risk management process by planning risk management. The risk identification process in PMBoK is one of the project risk management processes. Risk identification involves not only the participants of the risk management process, but also participants in other processes, and the identification process is an iterative process, as risk identification takes place throughout the life of the project.

After analyzing the PMBoK risk register development processes, it can be concluded that 3 types of criteria are possible. The first group of criteria are the criteria that can be used to assess the size of the risk register by assessing what and how many columns or fields the risk register has, for example, there may be risk registers with 3 or 25 columns (Uzulans, 2019, 2020). However, the volume criteria are insufficient because the number of columns or fields can be the same, even if the columns or fields contain different amounts of information (Uzulans, 2019, 2020). The second group of criteria are the criteria that can be used to assess the information in the risk register, or content criteria. The third group of criteria is the criteria for the information on the changes in the risk register. The three types of criteria are summarized in Table 3.

Table 3.

| Type of criteria | Criteria | | Source | How to use |
|---|---|---|---|---|
| Volume | Compliance with risk management processes | Yes/No | PMBoK project risk management process, all processes | To assess if the information in the risk register complies with the risk management processes |
| | Compliance with other management processes | Yes/No | PMBoK project processes, all processes where risk register is presented | To assess if the information in the risk register complies with the risk management processes |
| | Completeness of the risk management process | Full/Partly/Not presented | PMBoK project risk management process, all processes | To assess if the information in the risk register complies with the risk management processes |
| | Non-controversial in relation to the risk management process | Compatible/Partly compatible/ Incompatible | PMBoK project risk management process | To assess if the information in the risk register complies with the risk management processes |
| Content | Compliance with risk management process input | Yes/No | PMBoK project risk management process | To assess that the content of the information corresponds to in the risk register complies with the risk management processes |
| | Compliance with risk management process output | Yes/No | PMBoK project risk management process | To assess that the content of the information corresponds to in the risk register complies with the risk management processes |

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| | | | | |
|---|---|---|---|---|
| | Completeness of the content | Full/Partly/Not | PMBoK project risk management process, all processes | To assess that the content of the information corresponds to in the risk register complies with the risk management processes |
| Change | Information about the change | Is/Is not | PMBoK project risk management process, all processes | Assess whether the risk register is changing during the life of the project |
| | Justification for the change | Is/Is not | PMBoK project risk management process, all processes | Assess whether the risk register is changing during the life of the project |

*Source: Compiled by the author from PMBoK*

## Conclusions

It can be concluded that the goal of the study - whether it is possible to develop the risk register evaluation criteria according to the chosen project management methodology is at least partially achieved. Development of criteria in accordance with the project management methodology is possible. However, the study cannot be considered complete as only one source for the selection of criteria was selected - A Guide to the Project Management Body of Knowledge. The next step would be to select other criteria for the selection of criteria and compare the sets of criteria to assess whether a universal set of criteria is possible. A set of criteria based on several project management methodologies could be used to assess risk registers according to different project management methodologies.

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