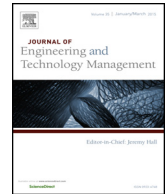




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Agile project management and stage-gate model—A hybrid framework for technology-based companies

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ABSTRACT

This study reports an empirical analysis of a hybrid management framework combining agile project management and stage-gate model implemented in a technology-driven project. The results indicate positive impact on the project and product development performance and suggest that combining these two approaches to balance stability with flexibility is a potential solution for managing innovation projects in high technology-based companies. The evidence indicated critical aspects to be considered, such as the proper diagnosis of organizational factors and implementation of practices, and the alignment of agile project tools (e.g., visual boards) with traditional information systems used in the stage-gate process.

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1. Introduction

New product development (NPD) theory has evolved considerably since 1990 (Brown and Eisenhardt, 1995; Griffin, 1997; Barczak et al., 2009) with distinct practices, tools, techniques, and management frameworks. In recent years, a new and disruptive innovation environment has challenged NPD theory and practice with the emergence of, for example, digital creative industries (Parmentier and Mangematin, 2014), co-creation (Rayna et al., 2015), 3D printing, fast prototyping (Elverum and Welo, 2015), and the demand for radical innovation-oriented capabilities (Salomo et al., 2007).

The challenges and changes in these industries require NPD strategies and frameworks that combine simplicity, velocity, and flexibility as never before. Consequently, the search for NPD models and approaches has become a new and emergent topic for both scholars and practitioners. Cooper (2008), for example, emphasized the importance of exploring different approaches, including practices from so-called “agile methods”, in order to cope with the innovation and dynamism of certain industries and project types. In addition, Cooper (2008) pointed out the need to adapt stage-gate models to achieve higher levels of flexibility and “agility”.

Agile project management (APM) methods have been disseminated widely in the software development industry. These methods gained momentum since a group of practitioners from the software development field (Beck et al., 2001) conceived a manifesto (*Manifesto for Agile Software Development*), which presents basic principles and values to assist project managers in dealing with issues related to software development projects. APM is focused primarily on managing customer needs and evolving requirements by using short development cycles (iterations) and continuous change and adaptation all the way through the project life cycle (Barlow et al., 2011).

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Product complexity and technology innovation may affect the use of these practices for NPD environments. According to Kim and Wilemon (2003), NPD complexity can originate from several sources, for example, technology uncertainty, number of components, systems and subsystems, and number of organizations involved. These characteristics undermine the project team's ability to deal with evolving requirements. The recommended approach then is to detail the product requirements and specifications in the early stages. This results in reduced flexibility to absorb changes (Nerur et al., 2005) and to disrupt the information and communication process among teams, and, consequently, the coordination and decision-making during the NPD life cycle (Laanti, 2008 *apud* Mishra and Mishra, 2011).

These challenges make the adoption of APM as a pure approach risky when compared with traditional NPD stage-gate models, which assume a great deal of effort dedicated to the initial planning phase to identify and detail requirements and product specifications (Vinekar et al., 2006). The APM can generate rework, failures, and cost overruns in highly integrated products with interdependent components and systems (Turk et al., 2009).

Despite these considerations, other authors have argued the opposite by stating that APM is more suitable for small projects, and small and collocated teams, as opposed to traditional NPD practices, which are suited to large and complex programs (Lee et al., 2006). In this respect, the agile management approach could be a reasonable solution for small and technology-based companies.

Nonetheless, this dilemma could be resolved by properly combining both stage-gate and agile management approaches. Since the initial development of the agile approach, Boehm and Turner (2004) have argued that the challenge is to find the balance between agility and discipline. The result is a recent set of studies focused on understanding and exploring hybrid product development approaches (Fernandez and Fernandez, 2008; Port and Bui, 2009; Batra et al., 2010; Zaki and Moawad, 2010; Barlow et al., 2011; Cobb, 2011; Spundak, 2014). Despite the evolution of this literature, there is a lack of empirical studies showing if the combination of stage-gate and APM contribute to agility and better project and product development performance.

In 2010, Conforto and Amaral (2010) proposed a management framework titled Iterative and Visual Project Management Method (IVPM2), which combines APM practices and techniques with stage-gate concepts in a hybrid management model. The stage-gate model presents an overall and unified vision, which facilitates communication between team members. Combined with APM practices, it supports the use of agile principles, such as promoting a team's self-discipline and process flexibility to allow experimentation and iterative development, using multiple planning and execution levels.

This study evaluates the implementation of the IVPM2 in a single case, a project that aimed to develop a new product, conducted in a small technology-based company. Based on the project team members' perceptions, we attempted to answer three main research questions, as follows. (RQ1) Did the company use stage-gate model combined with agile practices? (RQ2) Did the framework contribute to the agility principle? (RQ3) Did the framework improve overall performance of the project and product development? To address these questions, we applied a combination of research techniques (e.g., interviews, questionnaire application, and observation) with an in-depth case study approach involving all team members that worked on the project.

2. APM combined with stage-gate as a solution for technology-based companies

Recent studies have shed some light on the investigation of the use of structured and flexible product development processes in different industries and project contexts (Marion et al., 2012; Högman and Johannesson, 2013). Despite the potential paradox between structured and flexible approaches and the evolving literature about NPD frameworks, there is still a lack of studies focused on understanding the benefits and limitations of combining different practices from distinct approaches to meet the current state of technology and product development in fast-changing and competitive business environments.

Small technology-based companies or high-tech firms (Olausson and Berggren, 2010) share characteristics, such as focus on R&D activities, innovation, entrepreneurial behavior, and high levels of interaction among collaborators (Grinstein and Goldman, 2006). These organizations are driven to create innovative products and services, and therefore, need to be responsive to changes and opportunities, while dealing with uncertainty, risks, and complexity of NPD projects (Olausson and Berggren, 2010).

A study of NPD practices adopted in two early-stage firms conducted by Marion et al. (2012) identified challenges for this type of company in the use of well-disseminated NPD practices, especially in detailed and well-structured processes with systematic milestones, and phase evaluation guided by a linear ("waterfall") development approach. Very often, the lack of resources (financial and human) limits the use of these practices commonly adopted by large organizations (Marion et al., 2012).

The characteristics and limitations of this type of organization represent an opportunity for developing and testing hybrid management frameworks, combining NPD practices and project management concepts, which are specifically designed for this environment, as highlighted by Olausson and Berggren (2010). Recently, other authors have debated the idea of developing hybrid approaches as a potential solution to improve the performance of innovation projects (Fernandez and Fernandez, 2008; Port and Bui, 2009; Batra et al., 2010; Zaki and Moawad, 2010; Barlow et al., 2011; Cobb, 2011; Spundak, 2014; Carvalho and Rabechini, 2015).

One solution might be the integration of the APM approach with stage-gate process and practices. This focus is considered a relevant research agenda, mainly because APM is still seen as a management approach designed for software development companies (see Conforto et al., 2014), but with great potential to be customized for other industries and projects. Furthermore, recent studies have shown the importance of adapting and combining APM practices with more traditional NPD processes (e.g., stage-gates) to improve flexibility and response to changes in uncertain and dynamic project environments (Cooper, 2008; Högman and Johannesson, 2013); in addition, recent studies have indicated the potential impact of agile practices in project performance, as discussed by Serrador and Pinto (2015, p. 1049) based on a survey with 1002 respondents from different industries.

APM focuses on dealing with constant changes by enhancing interactions with customers, developing people's specific competencies, and planning and controlling projects through short iterative cycles so as to cope with the challenges of dynamic project environments in the software development industry (Highsmith, 2004; Schwaber, 2004; Augustine, 2005, among others).

Agile methods are focused on flexibility by using a minimal set of rules and eliminating activities that do not add value to the product development process. They are based on series of iterative development cycles and promote self-management and self-discipline attitudes in order to help the team be more responsive to changes (Beck, 1999; Boehm and Turner, 2004; Cockburn, 2004; Cohn, 2005; Highsmith, 2004; Schwaber, 2004).

Discussion about integrating agile practices with traditional NPD processes is not new. According to Cooper (2008), managers should consider different approaches, such as "iterative development", to deal with different types of projects. This evidence was confirmed in a recent study by Högman and Johannesson (2013) in six hardware development companies. From this perspective, APM combined with the stage-gate approach could be explored as an alternative to deal with the challenges of managing product development projects in highly dynamic business environments.

Conforto and Amaral (2010) proposed a hybrid framework that combines APM with stage-gate process, the IVP2. The framework combines stage-gate model elements, such as phase definition, standardized documents and deliverables, milestones and phase checkpoint reviews with iterative development (e.g., 2-week development cycles or "sprints"), multiple levels of planning and controlling, visual boards (e.g., Kanban), and frequent informal meetings. The IVP2 is an example of how to implement Cooper's (2008) insights by combining iterative development with stage gates, and it is aligned with the demand for hybrid models to meet the needs of some specific types of organizations (Högman and Johannesson, 2013; Marion et al., 2012).

3. The hybrid framework: iterative and visual project management method

This section presents a synthesis of the hybrid framework, IVP2 (Conforto and Amaral, 2010), which was adapted to the project under analysis. The sole purpose of this study is to present empirical data regarding the use and effect of the framework in the project and product process and overall performance.

The IVP2 combines different concepts from the NPD and APM literature (e.g., Cooper, 2001, 2008; Boehm and Turner, 2004; Highsmith, 2004; Schwaber, 2004; Augustine, 2005; Cohn, 2005; Shenhar and Dvir, 2007). The framework (IVP2) implemented in this project comprises five dimensions and a seven-stage iterative cycle. The five dimensions are: (1) phase and project deliverable model (PPDM); (2) project planning and controlling whiteboard (PPCW); (3) weekly activity planning whiteboard (WAPW); (4) project management software (PMS); and (5) simplified performance indicator system (SPIS). The seven-stage cycle represents an iterative development approach throughout a phase-oriented development process (stage-gate); each project phase can have as many iterations as necessary in order to satisfy the requirements for each phase-review milestone (or phase gate) of the product development process.

Fig. 1 illustrates the IVP2. One of the key concepts used in the IVP2 is multiple planning and controlling levels, which are supported by some authors in the APM literature (Boehm and Turner, 2004; Cohn, 2005). IVP2 has three levels. The first level is the stage-gate model represented by the PPDM, its phases, milestones, and macro-deliverables for the entire project. These deliverables are related to the product and technology development phases.

The second level is related to iterative development, also named "sprints" in the Scrum agile method (Schwaber, 2004), in which the team breaks down the deliverables from the product backlog into tasks or small deliverables, and prioritizes and defines the order of development during the iterative planning meeting (or sprint planning). These tasks are performed in time-boxed iterations (on average a 15-day length). The PPCW represents the general set of deliverables and tasks to be performed in each phase. It is a physical visual board that evolves throughout the project life cycle and could be compared with the product backlog described in the Scrum agile method (Schwaber, 2004).

The third level is on a weekly or daily basis. It is similar to the iteration plan or sprint backlog (Schwaber, 2004). The WAPW is related to the tasks to be performed on a weekly or daily basis during the iteration. The IVP2 deliberately recommends these three levels. The information generated on all three levels can be registered in the PMS.

Once a new project begins, the iteration cycle starts with the definition of the main phases and project deliverables, guided by the PPDM (Stage 1). This element of the IVP2 is important because its purpose is to guide the team into the main phases of the product development process. Therefore, the PPDM includes all main deliverables and documents which are key outputs related to the product and project being executed, and these elements are specific to the type of project and industry sector.

Once the PPDM is defined and the team has a broader view of the macro-deliverables for the project, the project manager and team members collaboratively define the iterations and place the deliverables related to the product on a visual

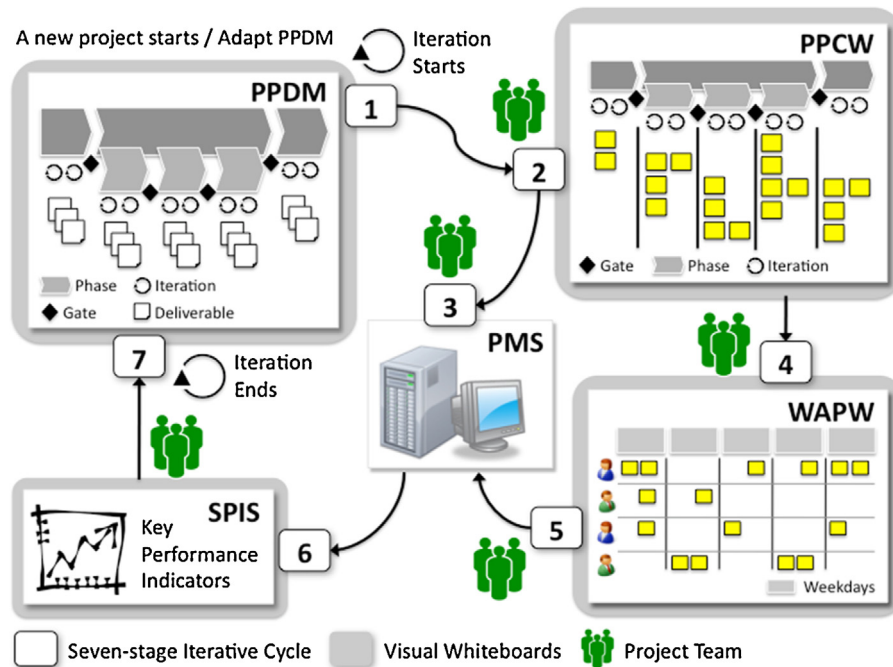


Fig. 1. IVPM2 combining APM and NPD process. Source: Conforto and Amaral (2010).

whiteboard (PPCW) using sticky notes (Stage 2). At this stage, the team defines the iteration length (e.g., usually 2 weeks, 15 days). However, this length may be dependent on the type of project. According to the IVPM2 framework, the phase length is usually longer compared to the iteration length, and it reflects the characteristics of the project type and industry sector.

At Stage 3, the deliverables placed on the PPCW (product backlog) are registered in the project management software. In the project studied, the team used an open-source software that has the most common features of commercial project management software. The PMS is used in the IVPM2 to document and register project data and information regarding cost, schedule, and progress to help the team generate progress reports to be used in the evaluation of the phase review meeting as well as the iteration performance. The PMS also helps the team create different views of planning and scheduling, for example, the Gantt chart, along with the visual board used to illustrate the iterative development cycles, the WAPW and PPCW.

After being fed into the PMS (Stage 3), the deliverables must be detailed into activities and tasks to be executed during the iteration (or sprint) and placed in the WAPW (Stage 4) to illustrate the work to be performed on a weekly basis. Project team members perform the tasks related to one or more PPCW-defined deliverables, and once these tasks are complete, members need to update the information and project plan in the PMS as well as the visual whiteboards (Stage 5).

At Stage 5, the development is on a weekly and sometimes daily basis, supported by rapid and focused team meetings called “stand-ups” or “daily Scrum” (Schwaber, 2004). In other words, the team regularly discusses what members need to deliver, and what the issues or challenges are, so the project manager can proactively address these problems. At Stage 6, using the PMS, the project manager generates performance reports and provides an overview of the project progress to the team. At the end of the iteration, the project team and project manager use the information to make decisions, to improve the process, and to discuss upcoming risks or obstacles in order to plan for the next iteration cycle (Stage 7).

The IVPM2 relies on an iterative planning–exploring–delivering approach. It combines key elements from the stage-gate model and APM literature, as recognized by Gonzalez (2014, p. 9). The primary goal of having a phase-oriented model combined with iterative development is to allow multiple levels of planning and execution in a hybrid management approach, allowing a balance of discipline and flexibility for highly dynamic and innovative project environments, such as the case reported in this paper.

4. Research approach and methods

4.1. Case description

This study is based on a case study approach (Eisenhardt, 1989; Yin, 1993; Voss et al., 2002) and primarily focuses on collecting perceptions about the usefulness and contributions of the IVPM2 framework for the project and product development process performance as well as its adherence to some of the key APM principles found in the literature.

Based on a single and holistic case study, a technology-based company is considered in order to explore the combination of stage-gate and agile models in this context. Its product development environment has many characteristics that qualify for application of APM combined with the traditional product development processes to find the right balance between formalization and flexibility. Technology-based companies are good examples of organizations that continually face uncertainty when developing innovative products and new technologies under limited structures and resources.

The use of a single case approach is supported based on its unique characteristics, for example, (i) the type of project analyzed, which involved both hardware and software development and was considered innovative and complex for the project team; and (ii) the willingness to adopt new management approaches that may result in high risks, resistance from team members, and poor performance in the product development process.

The organization studied was founded in 2003 with the main goal of developing high-technology products involving hardware and software for education, research, and entertainment. At the time this study was conducted, the company had 25 employees, including graduate engineers, masters-degree graduates, and PhD graduates, working in a projectized organizational structure. Based on such characteristics, this organization was considered a technology-based company, according to Heydebreck et al. (2000).

The goal of the product development project analyzed in this study was to develop a robot to support researching and teaching activities in educational institutions and for entertainment purposes. The project had a 24-month timeframe and the team that participated in this study comprised a project coordinator and five team members, including software, mechanical, electrical, and electronic engineers. This project was considered innovative and complex according to the team members because it was the first of its kind in the company and there were no similar products in the market at that time.

The researchers identified some of the key challenges to manage the project, as summarized by the company's CEO: "We are looking for simple and practical techniques and methods that meet our needs, avoiding any waste of time so as to become competitive and capable of dealing with the uncertainty and turbulence inherent to our business environment and types of projects we are used to deal with".

In addition, the project team pointed out some specific challenges, such as the difficulty in planning and controlling the project due to several uncertainties regarding the technology, systems, and sub-systems of the product, and the absence of an adapted methodology to their project environment. Therefore, the team struggled to deal with frequent changes and uncertainties in the product development process.

4.2. Data collection and analysis techniques

The IVPM2 implementation in the project studied was carried out before the evaluation phase. The implementation phase started with an extensive diagnosis of the challenges and problems related to project and product development management in the organization. This diagnosis involved semi-structured interviews with two project managers, one technical coordinator, and one team member (electronic engineer). In this phase, each interview lasted around 3 h.

The diagnosis process comprised four main steps: (1) interview and data collection; (2) synthesis and development of the cause-and-effect tree (adapted from Goldratt's Theory); (3) feedback and validation with the organization stakeholders using multiple meetings; and (4) identification of the main challenges and problems to improve project and product development processes. This process took roughly 3 months to complete. At the end, this diagnosis helped the organization to adapt the IVPM2 for their characteristics and needs. As one of the project managers declared: "We realized that we don't have a management method that helps us to deliver the projects properly, on time, and with the right specifications."

The customized IVPM2 included a simplified stage-gate model, specially adapted for the organization and the project under analysis, and the visual artifacts (PPCW and WAPW), as illustrated in Subsection 5.1. After the customization of the

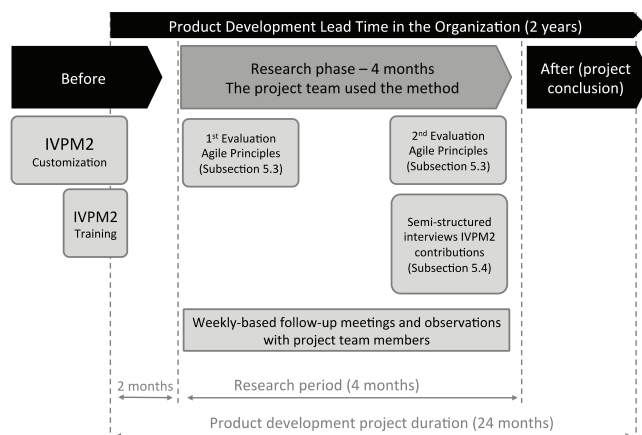


Fig. 2. Summary of the research events. Source: authors.

IVPM2, all project team members, including the CEO and project manager, participated in a full-day training (8 h) focused on the presentation and use of the IVPM2.

In order to improve the internal validity of the research findings (Gibbert and Ruigrok, 2010, p. 713), we adopted some key techniques. First, we applied a triangulation strategy, which resulted in the collection and comparison of data from multiple sources or “angles”, as suggested in the case study literature (Gibbert and Ruigrok, 2010). Using multiple sources and data analysis techniques, we looked for potential counter-evidence to corroborate or question previous insights, patterns, or conclusions. These different techniques are summarized in Fig. 2 and Table 1.

The project team used the IVPM2 for a couple of months before the first evaluation was applied. This first evaluation was focused on the analysis of its adherence to some agile principles, as discussed in Subsection 5.3. After the first evaluation, the researchers observed and monitored the team using the framework for about 4 months, using a direct observation technique based on an anthropological approach in which the observer registered all relevant data in a research notebook. After this period, the researchers carried out the second evaluation and the semi-structured interviews focused on collecting participants’ perceptions about the benefits of the IVPM2 for the project and product performance. Combined, these two points of evaluation in time resulted in a longitudinal analysis of the perception of the team regarding the adherence of the method to some agile principles. These research events are summarized in Fig. 2.

For the purpose of the longitudinal analysis (Subsection 5.3), we adopted a simplified set of criteria that were used to evaluate the adherence of the IVPM2 to some agile principles. This set of criteria was developed based on the APM literature (Boehm and Turner, 2004; Highsmith, 2004; Augustine, 2005; Cohn, 2005):

- Criterion 1 (C1): The framework requires a team’s self-discipline and self-management;
- Criterion 2 (C2): The framework is simple to use and easily adapted (simplicity);
- Criterion 3 (C3): The framework is flexible enough to absorb project changes (flexibility);
- Criterion 4 (C4): The framework promotes visual communication.

These criteria were chosen intentionally because they represent the general perception of the APM’s authors regarding key principles commonly found in the literature. Due to the abstraction of these criteria and the time in which the team was exposed to the framework, we decided to apply this questionnaire twice in a period of 4 months (see Fig. 2). We attempted to identify any divergence in the team members’ perceptions about the IVPM2 to answer properly RQ2: did the framework contribute to the agility principle? This procedure contributed to increasing the internal validity of the results as well as the level of confidence of the responses collected from the participants regarding the framework’s adherence to some APM principles.

Table 1

Summary of data collection and analysis techniques.

Data collection procedure	Description	Research period	Participants	Data analysis techniques
First-round APM principles adherence test	Questionnaire (paper-based) containing four criteria based on the APM principles to capture the framework’s adherence to some APM principles.	Beginning of the implementation of the IVPM2	7 people All team members who were involved in the project and the CEO	After collecting data from both evaluations, we applied descriptive statistics combined with a comparison of means considering the 1st versus 2nd rounds
Second-round APM principles adherence test		After the team used the framework for 4 months	6 people, including all project team members. At this stage of the research, one team member left the organization.	
23 closed-ended questions combined with individual interviews after the questionnaire completion	Protocol containing 23 closed-ended questions to identify contributions to project and product development performance. After collecting responses for this questionnaire, we conducted informal individual interviews with the research participants	After the second evaluation of the APM adherence, almost 5 months after the team started using the framework	6 people, including all project team members and the company CEO	Quantitative and qualitative approach. Descriptive statistics combined with comparison of means. Content analysis of the responses and comments from the interviews. Cross analyses comparing these results with the findings from the first evaluation.
Observations and informal conversations with research participants, carried out by the same researcher, recorded on a research notebook	We used observations and collected qualitative data and perceptions from the study participants about their work environment and daily work routine while they were using the framework.	Throughout the research period and the use of the framework. These observations occurred twice a week, resulting on approximately 256 h of interaction.	All project participants, including the one that left the company, and the interactions of the CEO with the project team	All relevant quotes from the participants were used to look for counter-evidence and to compare results from the first and second evaluations. Both co-authors of this paper participated in the content analysis.

Product Development Phases and Main Deliverables

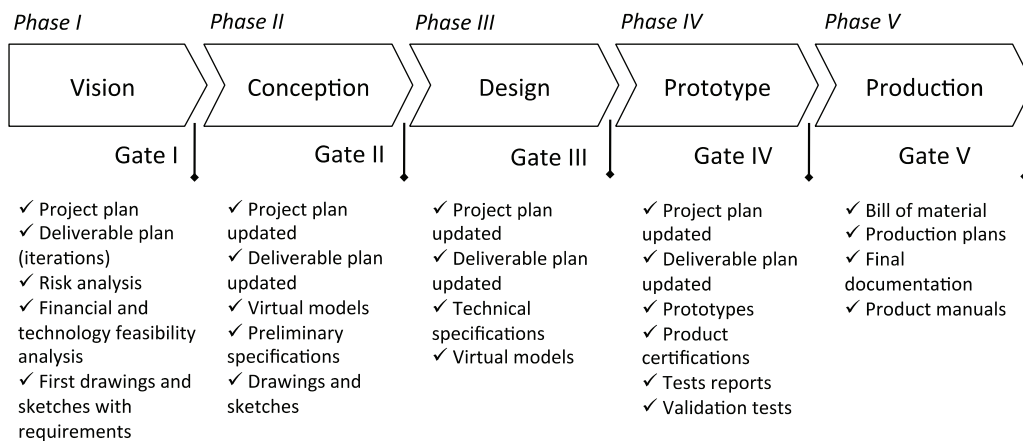


Fig. 3. Illustration of the PPDM adapted for the project.

After the second round evaluation regarding the framework adherence to some agile principles (Fig. 2), we applied a research protocol containing 23 closed-ended questions in order to capture the participants' perceptions regarding the overall benefits of using the framework for the project and product performance (RQ3). All team members that participated in the project under analysis completely answered the questionnaire without the help of the researchers. This approach helped the researchers to avoid any influence in the results or bias regarding specific elements of the IVP2. After the questionnaire applications, we held an informal meeting to talk with the project team members, project coordinator, and CEO individually and to collect additional feedback about the use of the IVP2.

We complemented this process with direct observations and informal interviews and conversations with team members throughout the research period to collect relevant perceptions and feedback about the use of the framework. These informal observation sessions occurred twice a week, in which the researcher usually spent an entire working day at the organization for four months. This represents roughly 64 h per month, and an estimated 256 h of interaction over 4 months. During this period of interaction (direct observation), the researcher used a notebook to register some of the key events and gather data about the context and daily routine of the project team and all activities related to the use of the IVP2. The organization was aware of the scientific experiment but did not know about the research questions, any specific detail about methods used, or the analysis and elements in which we were interested.

Table 1 summarizes data collection and analysis techniques adopted.

5. Results

5.1. Adapted IVP2 implemented in the case study

Fig. 3 illustrates the PPDM adapted and implemented in the project studied. It comprises five phases and the set of documents and deliverables that guided the team in the execution of the product development activities. A formal phase review milestone was defined using a stage-gate concept, as proposed by Cooper (2001), in which the team used a set of criteria to perform an overall assessment of the product development phases and project progress.

The deliverables, shown in Fig. 3, served as a reference for each phase of the product development process. As described in Section 3, each phase of the PPDM could have multiple iterations. All iterations have well-defined goals and expected results aligned with the phase objectives.

Fig. 4 shows the PPCW, as used by the project team members. It contains the main set of deliverables of the project and was designed to represent the phases, as described in the PPDM. The WAPW is on the right side of the PPCW. Right below the WAPW, there is a picture illustrating the "product structure" containing its main systems and subsystems.

One key aspect of the IVP2 is the multiple planning-execution level. In the case studied, the PPDM defines the first level (the stage-gate approach), which describes macro-deliverables, key milestones, and phases of the product development (Fig. 3). In this level, the team defines the "big picture" of the process, which is described in a more linear perspective, from the idea and concept to the production and launch (as proposed by Cooper, 2001).

The second and third levels were performed through the iterative development approach. The second level is represented by the PPCW (Fig. 4). It contains the phases defined in the PPDM. The team defines the number of iterations and breaks down the macro-deliverables into a set of deliverables, so that the team is able to define activities to be performed according to the iteration goal and phase objectives. On average, the iteration lasted for 2 weeks in the project studied.

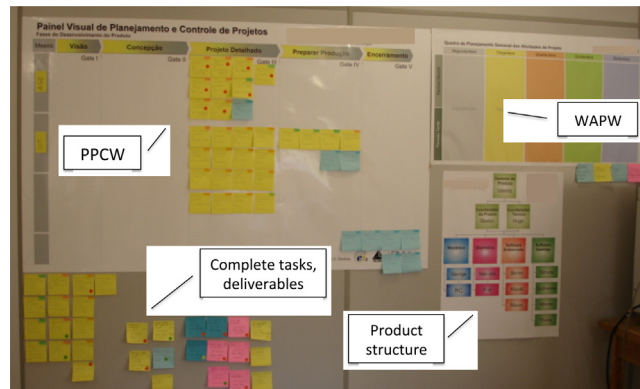


Fig. 4. Pictures of the PPCW and WAPW used in the project.

In the case studied, the third level is based on the WAPW (Fig. 4) in which the team defined the tasks to be performed considering a 5-day timeframe, based on the deliverables placed in the PPCW. The planning and controlling activities required the team's autonomy, self-management, and self-organizing competencies to keep the tasks on track and aligned with the second and first levels of the framework.

In addition to formal phase-review and milestone meetings, the team had informal and quick daily meetings and more formal weekly meetings to discuss the iteration progress, remaining work to be performed, challenges, and decisions to be made. These informal meetings usually occurred in front of the PPCW board.

5.2. Stage-gate and agile practice integration in the project studied

The first research question aimed to identify what elements of the IPVM2 the team actively used during the project development. The results showed that five out of six team members used the PPDM and PPCW. This evidence supports that the adapted stage-gate model and iterative development process were both applied together. The research participants would break down the deliverables from the PPDM into tasks or small deliverables and place them in the PPCW based on the phase of execution, their priorities, and iteration to be executed. This is relevant evidence of the hybrid management approach using a phase-gate model with multiple iterations for each phase.

The PMS, which was used to register data related to the project deliverables, received the highest score, and all research participants, excluding the company's CEO, agreed that this component was useful. The WAPW received no votes, and the SPIS received only one vote. The research participants argued that the WAPW was replaced by the PMS. They used the software to plan their activities on a weekly basis, and so, there was no great contribution by the WAPW component to the management process from the team's perspective.

One of the reasons identified during the interviews for the uselessness of the WAPW pointed to the duplicate effort required to keep it up to date, since all the information placed on the whiteboard should also be reflected in the PMS. Even though the team did not use the WAPW, its members argued that the idea of having a weekly planning level was very useful, and so, they applied the concept of multiple planning and execution levels: a phase-planning level, iteration planning (every 2 weeks), and weekly planning. In addition, the participants highlighted the importance of investigating ways to integrate the use of physical boards within the PMS to improve the visual management aspect as well as controlling and monitoring activities.

The SPIS component was used mostly by the project coordinator. The research team members declared that they monitored the progress of the deliverables and tasks using the PPCW board and the PMS.

5.3. Alignment with some APM principles

The aim of this test was to verify to what extent the adapted framework adhered to some of the key principles of the APM literature. In addition, this test aimed to identify the participants' awareness of the presence of these principles, as per RQ2 (see details in Subsection 4.2). For each criterion, we applied a closed-ended question based on a 5-point Likert scale (1 = totally disagree; 5 = totally agree). Table 2 summarizes the results.

In the first criterion (C1), the respondents declared that the framework demanded self-discipline and self-management behavior ($\mu = 4,7$) on both evaluations. All project participants mentioned "both aspects were necessary during the planning and controlling activities, especially due to the use of an iterative development approach with multiple management levels".

The IPVM2 stated that the team members were co-responsible for defining, prioritizing, planning, and controlling the execution of all project deliverables and activities. Each team member was responsible for updating the progress of the tasks on the visual boards as well as inserting additional information in the PMS when necessary. Furthermore, the team was

Table 2
Longitudinal analysis for RQ2, ($n = 7$, 100% of research participants).

#	Evaluationcriteria	Mean		Median		S.D.	
		1st	2nd	1st	2nd	1st	2nd
C1	Theframework requires team self-discipline and self-management	4.7	4.7	5	5	0.49	0.49
C2	Theframework is simple to use and easily adapted (simplicity)	4.1	4.1	4	4	0.90	0.90
C3	Theframework is flexible enough to absorb project changes (flexibility)	4.4	4.1	5	4	0.79	0.90
C4	Theframework promotes visual communication	4.6	3.7	5	4	0.53	0.76

co-responsible and actively involved in the decision-making process and had active participation in the daily and weekly meetings.

In the APM approach, these two characteristics are important in order to have full involvement and participation of the team, to be co-responsible for the planning and controlling process, and to be more self-directed and to respond quickly to the uncertainties of the project environment. Agile methods clearly emphasize continual learning and focus on people development throughout the project life cycle as one of the key aspects for successful implementation (Beck, 1999; Palmer and Felsing, 2002; Boehm and Turner, 2004; Cockburn, 2004; Highsmith, 2004; Schwaber, 2004; Augustine, 2005).

In the second criterion (C2), data show the same score for both evaluations ($\mu = 4.1$), being positively evaluated by 71% of the study participants. Simplicity is essential in the APM approach. According to the Manifesto for Agile Software Development, simplicity is defined as “the art of maximizing the amount of work not done” (Beck et al., 2001). Simplicity means few rules and a clear definition of roles, practices, tools, and techniques but emphasizes the need for customization according to the project type and business environment (Stapleton, 1997; Beck, 1999; Palmer and Felsing, 2002; Cockburn, 2004; Highsmith, 2004; Schwaber, 2004).

Along with simplicity, the third criterion (C3), flexibility, is considered a critical aspect, according to the APM literature. This criterion scored a mean of 4.4 and 4.1 in the first and second evaluations, respectively. Agile methods designed for software development projects are based on the premise that changes are inevitable. Therefore, they are designed intentionally to accommodate constant changes triggered by different sources (e.g., client, market, technology), and so, flexibility is considered critical (Boehm and Turner, 2004; Highsmith, 2004; Augustine, 2005; Cohn, 2005).

According to the study participants, both simplicity and flexibility aspects were more visible during the iteration execution in which the team was able to adapt the planning easily by adding or excluding tasks/deliverables according to changes in requirements, specifications, market, or technology. Such evidence resonates with the criticism of some authors opposing the use of traditional methods in technologically innovative project environments (Maylor, 2001; Dvir and Lechler, 2004; Highsmith, 2004; Cohn, 2005; Suikki et al., 2006).

Simplicity and flexibility of the process are especially relevant for technology development projects, such as the case presented in this study. This evidence corroborates the results found by Högman and Johannesson (2013), which support the use of strategies, such as short iterations and continuous feedback loops, to improve flexibility and accommodate changes during the development process.

The fourth criterion (C4) is related to the promotion of visual communication as one of the key aspects related to agile management tools. It scored a mean of 4.6 in the first evaluation compared to 3.7 in the second evaluation. This evidence might indicate some difficulties in the use of visual boards as proposed in the IVPM2, their design and layout, or even some challenges related to the integration of these elements to the whole management process, which is discussed in Section 6. Nevertheless, the APM literature supports the use of “visual tools” to support more interactive and collaborative planning and controlling activities (Boehm and Turner, 2004; Cockburn, 2004; Highsmith, 2004; Schwaber, 2004; Augustine, 2005).

In the case under analysis, despite potential contradictory perceptions collected during the interviews, we noticed two important facts: (1) visual boards were used to support face-to-face interactions between team members during the daily and weekly meetings; and (2) the team used the visual boards as a guideline to discuss project progress and issues related to delays of deliverables and activities to be executed during the iteration cycle (as illustrated in Fig. 4, where it is visible in the PPCW as red marks in the deliverables cards).

Based on the longitudinal analysis, the overall result indicates that the adapted IVPM2 seems to be aligned with at least three of the four APM principles analyzed (C1, C2, and C3), as described in the agile project management literature (Boehm and Turner, 2004; Highsmith, 2004; Augustine, 2005; Cohn, 2005).

5.4. Contributions and benefits to NPD and PM processes

Of the 23 questions, 13 scored a mean of at least 4.0 (Table 3). In the following paragraphs, we discuss some of the more relevant results of this evaluation. Regarding Q1, five respondents (83%) agreed that the framework contributed to delivering value to the team and customers ($\mu = 4.33$). In addition, regarding Q2, five respondents (83%) acknowledged that the framework contributed to product development using iterative cycles combined with an incremental deliverable plan ($\mu = 3.83$), and all respondents agreed or totally agreed that it contributed to absorbing project changes more effectively, promoting flexibility during the project life cycle (Q4).

Table 3Third evaluation ($n=6$, 100% of research participants).

Question	Mean	Median	S.D.
Q1. Contributed to delivering value to the team and customers	4.33 ^a	4.50	0.82
Q2. Contributed to product development using iterative cycles combined with an incremental deliverable plan	3.83a	4.00	1.47
Q3. Contributed to improving project results (time, cost, quality)	3.67	4.50	1.75
Q4. Contributed to absorbing project changes more effectively (flexibility)	4.33 ^a	4.00	0.52
Q5. Contributed to creating a project environment that promotes development of self-organized and self-disciplined teams	4.67 ^a	5.00	0.52
Q6. Contributed to improving communication with customers	3.83 ^a	4.00	1.47
Q7. Contributed to creating a participative decision process among team members and project coordinator	4.17 ^a	4.00	0.41
Q8. Contributed visually to project management and progress monitoring	3.67	3.50	0.82
Q9. Time spent in management activities was low	3.67	4.00	1.51
Q10. Improved the project's information accuracy	4.50 ^a	4.50	0.55
Q11. IVP2 requires low investment in resources and tools	3.33	3.00	1.51
Q12. Contributed to projects' documentation standardization	4.50 ^a	4.50	0.55
Q13. Contributed to speeding up and simplifying the project's information retrieval	4.00 ^a	4.00	1.10
Q14. Contributed to enhancing the project team members' commitment to results	4.50 ^a	4.50	0.55
Q15. Contributed to making project planning activities agile and simple	4.00 ^a	4.00	1.10
Q16. Contributed to speeding up replanning project activities	3.67 ^a	4.00	0.82
Q17. Contributed to simplifying the project progress monitoring	4.17 ^a	4.50	1.17
Q18. Contributed to alignment of project goals and strategic plan	3.83 ^a	4.00	1.47
Q19. Contributed to enhancing the leadership aspects of project team members	4.50 ^a	4.50	0.55
Q20. Contributed to creating a standard NPD process, including applied terms and templates	4.00 ^a	4.00	0.63
Q21. Contributed to reducing conflicts among team members	3.00	3.50	1.67
Q22. Contributed to reducing conflicts among customers and project team	4.33 ^a	4.50	0.82
Q23. Integration of APM into NPD using PMS, and contributed to improving project documentation and progress report	3.17	3.00	0.98

^a At least five out of six respondents positively agreed with the aspect evaluated ($n=6$).

Adding value through iterative development cycles is one of the critical characteristics of the APM, according to some authors (Highsmith, 2004; Schwaber, 2004), and the combination with the stage-gate approach is highlighted by Cooper (2008), who argues in favor of exploring agile approaches to improve integrated phase-gate models. These results reinforce the evidence that the right level of “flexibility” could result from combining different NPD practices with an iterative process to obtain multiple levels of planning and execution, as per findings documented in Högman and Johannesson (2013).

In the project studied in the present research, the NPD process was a combination of stage-gate concepts, for example, phase and criteria definitions, clear milestones with iterative development, and fast development cycles with frequent informal meetings and feedback. This process was supported by a simple visual management board, which resulted in a more hybrid approach that was aligned with the project needs and challenges.

According to the company's CEO

“iterative development is very critical to absorb changes . . . we cannot define in detail what is going to happen during the whole project life cycle, so it is important to have a master plan in which the team will be able to advance in the development cycle and break down macro-deliverables into more specific deliverables and tasks throughout a series of iterations”.

A predictable execution based on a detailed plan defined upfront is seen to be essential for better performance, albeit in a more stable environment. In a more unstable project environment, such as the case presented, the ability to learn quickly and respond effectively to changes is more relevant. Thus, the results corroborate the findings of Marion et al. (2012).

In addition, the respondents confirmed the importance of having frequent project planning sessions in a collaborative and participative approach, using an iterative development technique through the IVP2's seven stages. In this sense, flexibility in the different project planning levels and flexibility of the product design and specifications seems to be correlated and further research is encouraged to explore the causal link with project performance, as indicated by Candi et al. (2013).

Another positive aspect of the framework is the contribution to create a project environment that promotes the development of self-organized and self-disciplined teams (Q5). All respondents agreed with this aspect ($\mu = 4.67$). Moreover, the respondents agreed that the IVP2 contributed to create a more participative decision-making process among team members and the project coordinator (Q7) $\mu = 4.17$, and to enhance the leadership aspects of project team members (Q19, $\mu = 4.50$).

In this sense, during the interviews, the project coordinator declared: “In order to adopt the IVP2, one of the key aspects is to have a lower turnover in the team, which means that they will work together for a long time to accumulate experience to deal with uncertainty, project challenges, and complexity”. As discussed in Subsection 5.3 (Criterion C1, Table 2), there is consensus that self-organized and self-disciplined teams are critical to apply the APM approach properly.

With regard to Q7, the APM literature emphasizes the importance of promoting leadership toward a participatory decision-making process, and process ownership, in which all team members are encouraged to contribute their ideas to improve the project, solve problems, as well as “process tailoring” (Boehm and Turner, 2004; Highsmith, 2004; Schwaber, 2004; Augustine, 2005). Therefore, simplicity should be a key characteristic of the framework (C2, Table 2).

Regarding Q15 ($\mu = 4.00$), Q16 ($\mu = 3.67$) and Q17 ($\mu = 4.17$), five out of six respondents (83%) agreed with these aspects. The IVPM2's contribution to make planning activities and progress monitoring (Q15 and Q17) agile and simple is also aligned with criterion C2 (Table 2). One of the main characteristics of the APM approach is constant iterations within the involvement and feedback from real customers or market representatives (e.g., Highsmith, 2004; Schwaber, 2004).

As discussed in Subsection 5.3, the simplicity and flexibility applied to the project planning and controlling activities were critical for the project under study because the team had to “learn on the fly” due to multiple changes that occurred during the product development life cycle. “The IVPM2 contributed to define and identify main deliverables and the replanning cycle on every iteration”, stated the project coordinator. These aspects helped the team revise and improve the project plan in such a way that it continuously reflected the changes and opportunities related to the technology, customer, and market requirements.

Sharing the responsibility of planning and controlling activities, in addition to using simple techniques, helped the team to keep the overall time spent on management activities low (Q9, $\mu = 3.67$), which four out of six respondents agreed with (67%). For the company studied, the entire project team was focused on the product development activities and the project coordinator also worked on the development; hence, time allocated to these activities was considered critical and was to be invested in the use of complex management processes, practices, tools, and techniques.

The use of visual tools may also have contributed to simplify the framework; however, although half of the respondents agreed that the IVPM2 contributed to the visual management of the project and progress monitoring (Q8, $\mu = 3.67$), the CEO commented: “the visual boards have not been used properly, especially the WAPW. I think they are just illustrating the project tasks.” In addition, a project team member made the following comment regarding the PPCW: “There are many cards on the board, so visualization can be very challenging, sometimes I struggle to read the information on the cards”.

Another interesting comment from a team member is related to the duplication of information and the additional effort to keep the PMS, PPCW, and WAPW updated. He said: “The concepts underlying the visual boards are very relevant, for example, the visual communication; however, due to the duplicated information inserted in these tools, if the software could be integrated or at least have the same characteristics of a visual board, the updating process would be much simpler”.

There is also the “exposure effect” caused by the visual management tools, which could be interpreted as positive or negative in some organizational cultures. Another team member did not feel comfortable using the boards because they would expose any delay or problem related to his tasks, which, from the project coordinator's perspective, is something very useful to help team members with potential issues. However, this evidence could raise some questions regarding the proper use of visual tools, their purpose, and potential relationship with hidden factors, such as team and organizational culture.

6. Managerial implications

The proposed hybrid management framework demonstrates the importance of combining stage-gate models with agile management practices for innovative projects as a potential solution for small technology-based companies. Project teams with similar product development environments could benefit from the insights and implications identified in this study.

Project teams interested in adopting this hybrid approach should gradually adopt some of the key elements of the IVPM2, such as the stage-gate component (PPDM) and move to the visual boards (PPCW and WAPW), the iteration development approach, and then the software for project management and performance indicator system, with just a few metrics to start. It is important to consider that the PPDM may be unique for each type of project or company, since it should reflect the product development phases, key deliverables, templates, milestones, and gate evaluation criteria.

This study shows that the use of visual boards may present some challenges, and therefore, use of such boards requires the team to understand clearly the purpose of visual management. In order to improve the benefits of using such tools, one key action would be to involve all team members in the implementation and customization of these components, so they could contribute ideas and suggestions and provide feedback about the expected benefit of each IVPM2 component.

The correct implementation of the IVPM2 components may require specific knowledge about agile management practices, especially iterative development, the use of frequent informal meetings, and other specific metrics and techniques. We provided training to present the IVPM2 and show how to use its components for all research participants. This training also contributed to help the team members understand key concepts and principles that support agile methods. In addition, we noticed the need to develop additional competencies and attitudes. This study shows evidence of the need to develop team's self-management and self-discipline. In addition, more proactive involvement of the team in the management process is required, including daily planning and controlling activities as well as decision-making.

Finally, there is a need to understand the characteristics of the project environment that are more suitable for using some of the tools and techniques presented in this study, such as the following: use of small and co-located teams fully dedicated to the project, which would contribute to having frequent face-to-face meetings using visual boards; and frequent interaction with decision-makers, for example, the project manager or, as in this case study, the CEO of the company.

7. Conclusions, limitations and future work

This research combines stage-gate model and APM practices in a technology-based product development project. The contribution relies on empirical evidence that supports the current debate regarding the benefits of combining different

management approaches, for example, stage gates and agile management, to create a hybrid framework for some specific types of projects.

Regarding RQ1, the evidence collected in this case points to the possibility of combining stage-gate models with agile management practices. Moreover, according to the research participants, the adapted framework adhered to some of the key principles from the APM literature, which is positive evidence to answer RQ2. This is relevant to support the development of hybrid models combining stage-gate and APM practices, tools, and techniques to expand the use of agile methods beyond the software industry.

The results demonstrated that the hybrid framework contributed to several aspects of project and product development performance, that is, information accuracy, commitment, and leadership (RQ3). We believe that similar project environments and organizations could experience similar improvements by properly adapting and combining stage-gate models with agile practices. However, although there are positive results in the overall project and product performance, some critical questions arose. For instance, what are the critical factors/characteristics of the team, project environment, and organization that will favor the use of APM practices, tools, and techniques? Some of these critical factors may include team characteristics, people competencies, organizational culture, structure, and available resources, technology uncertainty, and market characteristics.

Some “critical factors” or potential “enablers” cannot be overestimated. We believe that one of the challenges in developing hybrid frameworks and adopting agile practices in other industries is to properly diagnose and understand the critical conditions in the organization, project, and team characteristics in order to define the “sweet spot” to adapt these practices properly for different types of projects in the portfolio, as discussed in Conforto et al. (2014). Since this study is limited to a single case, one of the major limitations is the lack of evidence to test the external validity of the findings (Gibbert and Ruigrok, 2010). For those critical factors in particular, we strongly recommend additional investigation considering multiple cases to identify, first, the importance of these factors, and second, which factors might affect the adoption of hybrid frameworks in different organizational and project conditions.

In addition, researchers could focus on investigating how to combine multiple concepts and approaches, such as design thinking, systems engineering, and lean development concepts to meet other industries’ needs and challenges.

Another piece of relevant evidence from this study is the use of visual boards that might not be critical for some types of projects in order to achieve the same level of performance. The research participants questioned the WAPW’s usefulness. They argued that this component was not integrated automatically in the PMS, and so, they experienced duplicated effort to keep both components updated, which could be considered a negative aspect and a waste of time for team members and the project manager.

In the APM literature, the use of visual boards is recognized as critical to communicating and supporting the team in planning and controlling tasks. Product complexity and team organization with distinct disciplines (i.e., software, engineering, etc.) prevent the exclusive use of visual controls. Project management software is a necessary tool to ensure that relevant information is properly registered and communicated, and so, multiple tools (virtual and physical) must be combined. For this reason, there is an opportunity to explore the positive and negative aspects of using software rather than visual boards, and how to merge them in a more effective way.

Another research stream might focus on investigation of the potential use of touch-screen devices and big displays to replace physical boards with sticky notes. This suggests the opportunity to explore different tools for creating visual boards to meet the needs of hybrid applications in similar cases to the one in this study.

As a single and holistic case study, this research has several limitations. First, we had to prioritize internal over external validity of the findings because of how the case study was developed and access to the daily routine of the organization investigated. For this reason, generalizability of the results and implications is limited. According to Gibbert and Ruigrok (2010), this focus on internal validity, even for studies with multiple cases, is very common in qualitative research due to the emphasis on the need to first resolve the internal validity of the findings, and then, to look for generalization with complementary research approaches and techniques.

One way to address external validity in future studies and crosscheck current findings would be to focus on collecting and analyzing data from multiple projects. This could be achieved by replicating this study in several projects in one single organization. Multiple projects from different organizations in different industry sectors should be considered to allow more in-depth analysis and multiple comparisons.

Second, the authors observed, interviewed, and talked with the participants. We provided training in the use of the IVPM2 at the beginning of the implementation although we attempted to keep a safe distance from the participants to avoid biased interpretations. Nonetheless, we cannot ensure that some interpretations and participants’ responses were not biased, because of the presence of the researchers in day-to-day work, and because of participants’ awareness that the work was part of a research experiment. To reduce these impacts, we collected data from multiple sources (triangulation strategy), for example, questionnaires, research notes, observations, and informal conversations. Then, we compared the final results with the research notes and discussed the implications with the participants to develop an accurate interpretation of the facts and evidence.

Third, there is a potential limitation regarding the length of the experiment and the broad focus on the implementation of the whole framework. Some types of case study may require a longer period of observation and analysis, especially when the object of the study is implementation of a new framework. In this study, we did not have time to explore each specific component of the IVPM2 in detail, for example, the use of visual tools or cultural and behavioral aspects that might be

relevant to the use of the framework and its implementation. Therefore, we suggest a longer period of data collection and analysis in future studies.

Fourth, the fact that the company did not have a structured management method in place before implementing the IVP2 may affect the ability to make comparisons and really identify the contributions from some of the elements of the IVP2. In addition, there are some restrictions regarding the approach used to evaluate the results. For instance, although we focused on interviewing all research participants and applied multiple data collection techniques, the project team was small and worked on a single project. Due to the lack of documented cases similar to the one presented herein, it is necessary to implement this approach in more than one project in the same organization or multiple organizations in order to make additional comparisons possible, as well as to improve the evaluation instruments applied.

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