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Project Management Practices for Collaborative University-Industry R&D: A Hybrid Approach

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Abstract

This paper aims to help stakeholders involved in collaborative university-industry R&D initiatives by presenting a hybrid project management (PM) approach, with a set of key distinct PM practices for this particular context.
Collaborative university-industry R&D initiatives are usually organized as programs with a set of related projects associated. Therefore, a hybrid PM approach was developed based on a case study research strategy. During the large case study analysis two research methods were applied: participant observation and document analysis.
The hybrid management approach was developed based on the contingency theory, which identifies a set of 24 Must Have PM practices, and that are transversal to all projects in the program as the program governance must have to be assured. Additionally, it identifies three different sets of Nice to Have PM practices, which are optional and are dependent on the particular project context and PM approach adopted by each project team: waterfall or agile. Overall 32 Nice to Have PM practices were identified, being 15 of them agile, 3 waterfall and the 14 remaining transversal to both agile and waterfall approaches.

Keywords: Project management practices; waterfall; agile; contingency theory; university-industry collaborations; R&D projects

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1. Introduction

Since the 80's, with the rise of market competition and the fast technological change, collaborative university-industry research and development (R&D) has been actively stimulated, as a way of increasing economic and social wealth [1]. R&D is increasingly viewed as an important input to innovation [2] and it has been given an important focus on government policies due to its unique characteristics [3]. Frascati Manual [4, p. 44] defines R&D as "…creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge."

Collaborative university-industry R&D initiatives are usually funded and named as projects by the funding entities, but often are organized by partners as programs. A program is a set of projects that are somehow related and aimed at achieving a set of major benefits that are more than just the sum of the projects they consist of [5]. A collaborative university-industry R&D program is here defined as a temporary organization with a collaborative work environment, within a specific context, with heterogeneous partners, collective responsibilities and, in most cases, with public funding support [6].

Formal management mechanisms, suitable for the context of collaborative university-industry R&D, should be implemented in order to increase the efficacy and efficiency of this type of collaborations [7]. These mechanisms can be defined as a monitoring and control process that allows inter-organizational relationships to be replicated and maintained. These relationships involve the commitment between universities and companies to exchange tangible resources (funds, materials and equipment) and intangible resources (technology and data) [8].

However, the understanding of how to manage collaborative university-industry R&D projects and their specific issues seems to be limited [9]. Several studies show that the PM practices are highly dependent on the project context (e.g., Besner and Hobbs [10,11]; Engwall [12]).

PM practices are the mechanisms by which PM processes in the organization are delivered and supported. This includes PM techniques (e.g., work breakdown structure or earned value management), various guidelines in which organizational processes are defined, including the use of procedure documents, checklists, job aids, and templates, as well as the use of software packages and various databases [13].

Searching for tools and techniques is a tangible way to study PM practices because they represent the means by which project managers execute PM processes, and are also concrete and specific ways to apply rules and principles that must be chosen according to the context of the organization where they fit [14].

This research has as main objective to find and adjust the PM practices to adopt in projects under a collaborative university-industry R&D program, in order to increase the probability of its success. As such it aims at answering the following research question: What are the key PM practices for managing collaborative university-industry R&D?

This research involved the analysis of a large collaborative university-industry R&D program, comprising 30 projects, between University of Minho and Bosch Car Multimedia, named as Innovative Car HMI (IC-HMI). The IC-HMI program adopted the Program and Project Management (PgPM) approach, developed from an exploratory study [15,16] dedicated especially in supporting R&D projects and programs on university-industry collaborations. This approach integrates the program management life cycle with the PM life cycle. The project life cycle is divided into four phases: Project Initiation; Project Initial Planning; Project Execution, Monitoring/ Controlling and Replanning and Project Closure [15], detailed in Section 4.

The research involves the analysis of the most useful PM practices (tools and techniques), taking into account two different management approaches: predictive (waterfall) and adaptive (agile). The predictive approach (waterfall) can be applied to any project environment, but in situations where projects involve requirements volatility, high degree of uncertainty of change, ambiguity (unknown cause and effect interdependencies) and when dealing with complexity in project environment, this waterfall approach presents difficulties in responding quickly. In these situations it may sometimes lead to conflicting relationships with clients or partners when pursuing compliance with the deadline [17]. In this scenario the adaptive (agile) approach can and should be considered, since agile development has proved to be adequate to dominate the presented situations and to capitalize the changes as opportunities [18].

The following paper presents a commonly used structure. In Section 2 we discuss the PM practices, as well as the different existing PM approaches - predictive (waterfall) or adaptive (agile). Section 3 describes the applied research methodology, including the case study background and the research methods applied to the IC-HMI case study. In Section 4 the hybrid PM approach, with the key PM practices proposed for managing collaborative university-industry R&D projects under a program, are presented and discussed. Finally, the last section addresses the conclusions and final considerations about this study, as well as suggestions for future research work.

2. Project management approaches and practices

PM approaches can be predictive or adaptive [19]. In a predictive approach, usually referred as waterfall, the project scope, time, and cost are determined in the early phases of the life cycle. Any changes to the scope are carefully managed. In an adaptive approach, usually referred as agile, the detailed scope is defined and approved before the start of each iteration. The agile approach is based on the Agile Manifesto values [19] for software development and has been expanding for all segments that require a more agile perspective of PM. The Agile Manifesto (in February 2001) have identified four values [19]: (1) individuals and interactions more important than processes and tools; (2) software in operation rather than in-depth documentation; (3) customer collaboration over contract negotiation, and (4) responding to changes more than following a plan. A hybrid approach is a combination of a predictive and an adaptive approach. Where those elements of the project that are well known follow a predictive life cycle (waterfall), and those elements that are still evolving follow an adaptive life cycle (agile) [19]. Hybrid life cycles might be adjusted to the context of collaborative university-industry R&D.

Sometimes, project teams feel they need to use more than one approach, since the objective is to achieve the best outcome regardless of the approach used [19]. Therefore, organizations should select and practice an appropriate PM approach [20], as well as introduce and adjust the practices so that organizations can obtain more benefits, and comply with the established objectives, since each project is unique and each organization has its own strategy.

Over time, several investigations were done on the most used and useful PM practices (tools and techniques). Some investigations refer to tools and techniques in general as Besner and Hobbs [10,11,14,21] and Fernandes, Ward, and Araújo [13], while others refer a specific context such as the study by Perrotta, Fernandes, Araújo and Tereso [22], as PM practice is highly dependent on the organizational context [10,11].

Besner and Hobbs [14] in 2006 identified 70 tools and techniques in descending order of usage, that they grouped into: "from limited to extensive use", "from very limited to limited use" and "less than very limited use". However, the most commonly used tools and techniques do not necessarily mean that they are the best. In this way the authors created another variable to perceive the tools and techniques intrinsic value, and thus it was possible to identify the most useful tools and techniques. In 2008, Besner and Hobbs [21], based on questionnaire responses of 750 PM professionals, identified common practices in most contexts, as well as those that vary significantly depending on the context and typology of projects. Later, in 2012, Besner and Hobbs [10] investigated whether the PM tools and techniques are used in groups or clusters and if / how the practice varies depending on the project type. Besner and Hobbs [11] based on the toolsets identified in their previous study from 2012 [10] identified the contextual differences in project practice, considering five contexts related to the project and organization size, performance-maturity and activity sector.

A more recent study by Fernandes, Ward and Araújo [13], using a mixed methodology approach, of 30 semi-structured interviews and 793 questionnaire responses, identified the most useful PM practices. 15 of the 20 most useful PM practices are coincident with the tools and techniques of higher intrinsic value identified in the Besner and Hobbs study [14]. The study of Perrotta et al. [22] had as main objective to identify the professionals' perceptions about the most useful PM practices also in a particular context, through a company case study in the automotive sector, thus highlighting the differences in PM inherent in the context of industrialization projects.

There has been an emergence of multiple PM Bodies of Knowledges (BoKs)/ standards, such as PMBoK® [19]. The attempts by the BoKs to systematize the knowledge required to manage projects are largely based on the underlying assumption that there are identifiable patterns and generalizations, from which rules, controls and guidelines for 'best practice' can be established that are replicable, even if not on absolutely every circumstance. This research gives a greater emphasis to PMBoK® [19] which has a more tightly defined scope that might be seen more accessible than the wider range of the other existent standards, and addresses various approaches, such as, predictive (waterfall) and adaptive (agile). O PM² Project Management Methodology Guide [23] is another guide that has a prominent position in this study, as it was developed by the European Commission considering the environment and need of European Union institutions and projects that usually are focused on R&D performed in a collaborative environment between industries and research institutions.

Regarding the agile practices two studies appear very relevant, the study of Fernandes and Almeida [24] which addresses frameworks such as eXtreme Programming (XP) and Scrum and the study of Flora and Chande [25] in which they explain the values and principles of various agile frameworks and methods that are becoming increasingly dominant in the software development industry, but can also be used in other contexts.

3. Research methodology

An exploratory research was carried out, aiming to learn from the experience of the program and project stakeholders of one large case study, in order to identify the key PM practices, in the particular context of collaborative university-industry R&D.

3.1 Case study background

The partnership between University of Minho (UMinho) and Bosch Car Multimedia Portugal, S.A. (Bosch) had its beginning in July 2012. The HMIExcel program, which included 14 R&D projects, started in May 2013 and ended up in June 2015. The success achieved with this program led to the reinforcement of the partnership and, in the same year, another R&D program, designated by IC-HMI program, was started. This partnership made possible the development of highly innovative technologies based on knowledge with high value to the multimedia automotive sector.

The University of Minho positioned in the top 150 of the youngest higher education institutions (aged 50 and under) worldwide, in the 2017 ranking of Times Higher Education (THE) and stands out for the high level of collaboration with industry, with around 250 R&D contracts signed annually with industry players. Bosch has become one of the largest suppliers in the automotive industry, producing a broad portfolio of products such as navigation systems, instrumentation systems, automotive radios, steering angle sensors and electronic controllers. Bosch employs about 12% of sales volume to R&D activities.

The IC-HMI program is the result of two funding applications, INNOVCAR and iFACTORY, which are understood as projects by the funding entity. However, the size and complexity of INNOVCAR and iFACTORY projects led the two partners, UMinho and Bosch, to operate them as a single R&D program, which comprises 30 R&D projects. The IC-HMI program involves an investment of 54.7 million euros, between July 2015 and June 2018, and aims to create new design solutions and systems while achieving a high level of flexibility and quality in the main operations related to the different industrialization project phases. The carried-out works are going to contribute to the design and development of new products and technologies. The IC-HMI program has planned 417 deliverables and the submission of 22 patent applications until June 2018 and 72 publications until June 2021.

3.2 Research methods

This research followed a qualitative multimethod, where the chosen research methods applied to the case study were participant observation and document analysis [26].

Observation is a complex research method and played an important role in the context of this research by driving the researchers to have a closer contact with the object of study in its native environment [26]. Observation is characterized by being participative, since the researchers are inserted in the group and participate in the observed activities [26]. Researchers observed IC-HMI stakeholders, since the beginning of program (July 2015), in naturally occurring situations, namely during regular management and technical meetings. Therefore, through participative and systematic observation, it was possible to realize and perceive the collaborative university-industry R&D context and identify the key PM practices for this particular context.

The analysis of several IC-HMI documents was conducted in order to better understand the case study context, namely the case study efforts on improving PM practices, and the most useful PM practices adopted. Among the most relevant documents analysed we can point out the established governance model for the IC-HMI program, the detailed roles of the Program and Project Management Office reported in Fernandes, Pinto, Araújo and Machado [27], as well as several documents that supported the management of the program and its constituent projects (e.g., project charters, project plans, program plan, risk and lessons learned register, progress reports, and technical and financial progress reports to the funding entity).

4. Hybrid project management approach for collaborative university-industry R&D

4.1 Hybrid approach conceptualization

This research was based on the contingency theory, which is being applied in the PM area in the last two decades [28]. The contingency approach in PM investigates the extent of fit or misfit between project characteristics and PM approach adopted [28]. Engwall [12] emphasizes the importance of a contingency approach and defends that projects are open systems dependent on history and organizational context. All different project types would benefit from a contingency theory perspective. However, a study developed by Hanisch and Wald [29] shows that construction projects are the dominant project type in project contingency research, followed by R&D and IT.

Organizations and project managers should choose the set of PM practices (tools and techniques) according to the context of the projects and organization, in order to integrate them as a mean to build a strategic asset [14]. So, in order to identify the most useful PM practices for collaborative university-industry R&D context, it was essential to understand the IC-HMI context, as well as the context at the program level itself to adjust the PM practices.

As such, a hybrid management approach, grounded on the contingency theory, is proposed (see Fig. 1). The approach identifies a set of transversal or common PM practices for all projects in the program, as the program management level must have to be assured, named Must Have PM practices. Its application is standardized in any project of the R&D program in this university-industry context regardless of the approach, waterfall or agile, adopted by each project in the program. As argued by Fernandes, Ward and Araújo [30] the standardization and tailoring of PM tools and techniques is one the most important key PM improvement initiatives to improve PM practice in organizations.

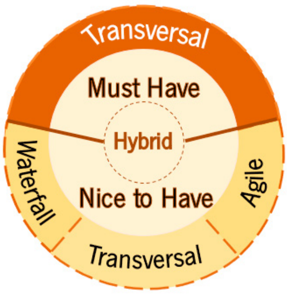

Fig. 1. Hybrid approach for managing collaborative university-industry R&D.

The hybrid approach presents separately Nice to Have PM practices, which are optional useful PM practices that can be adopted by project teams, divided into waterfall, agile and transversal, with the latter referring to the practices which can be used either in waterfall or agile approaches.

The Must Have PM practices are presented by the phases of the PM life cycle adopted by IC-HMI, which follows the PgPM approach developed by Fernandes et al. [15,16], in which the project life cycle is composed of four phases [15]: (1) Project Initiation, which consists on the official project start and occurs only after the formalization of the program initiation; (2) Project Initial Planning, which aims to reach an initial compromise between scope, time, quality and budget of the project; (3) Project Execution, Monitoring/ Controlling and Replanning, which follows the works' execution, performs the monitoring and control of the project, as well as the project's own replanning; and (4) Project Closure, which aims to elaborate the project closure report, to achieve the formal acceptance of the project results, and to handover the results of the project. The Nice to Have PM practices, depending on the ones which are used, are integrated into the PM life cycle phases of the project.

Each project team needs to understand the differences between waterfall and agile approaches and analyze the project context in order to understand which one better fits and serves the project context. The specificities of each one must be valued and, if necessary, work with the two simultaneously, since each one adds value in its own way. When applied together, they can counteract the weaknesses of each other.

As such, this research proposes, based on document analysis and participant observation within the IC-HMI program case study, as well as on an extensive literature review, mainly on the publications by Besner and Hobbs [10,11,14,21], Fernandes et al. [13], Perrotta et al. [22], Fernandes and Almeida [24], Flora and Chande [25], among other bibliographic references such as PMBoK® [19] and PM² Project Management Methodology Guide [23], a set of PM practices (tools and techniques) to be adopted by collaborative university-industry R&D, divided into Must Have PM practices (see Table 1) and Nice to Have PM practices (see Table 2).

Some of the practices found in the literature, although very useful and common in several contexts, were understood as optional in this context (e.g., requirements analysis, work breakdown structure, Gantt chart). On the other hand, the deep analysis of the case study allowed the identification of more specific PM practices for this particular context of university-industry R&D collaborations (e.g., project idea paper, new project ideas log, audits) and the confirmation of others (e.g., project charter, kick-off meeting, milestone list), referred as the most useful in literature. Concerning the agile PM practices, no studies were found in the literature identifying the most useful agile PM tools and techniques; therefore, these were identified based on the best known agile practices.

4.2 Must Have project management practices

Table 1 presents the proposed Must Have PM practices according to the PM life cycle [15,16] and discloses the research method used to reach them in the case study analysis, as well as the literature references where they are identified. For example, the PM practice transition plan was not found in the case study analysis, however the literature and the researchers' experience in this type of projects led to its inclusion as Must Have PM practices.

Table 1. Must Have PM practices (transversal) for collaborative university-industry R&D.

Phase	PM practice	Research Methods	References
Project Initiation	Project idea paper	Document analysis	[13,14,19,21]
	Project charter	Document analysis	[10,13,14,19,21–23,31]
	Kick-off meeting	Participant observation	[10,13,14,19,21–23]
	Stakeholder register	Document analysis	[10,13,14,19,21,23]
Project Initial Planning	High level project scope plan	Document analysis	[10,13,14,19,21,23]
	Project procurement plan	Document analysis	[19]
	Project staff plan	Document analysis	[19]
	Dissemination and communication plan	-	[10,13,14,19,21–23]
	Milestone list	Document analysis	[10,13,14,19,21,22]
	Responsibility assignment matrix	Document analysis	[10,13,14,19,21–23]
	Risk register	Document analysis	[10,13,14,19,21,22]
Project Execution, Monitoring/Controlling and Replanning	Project issue log	Document analysis	[13,19]
	Benefits log	Document analysis	[19,32]
	New project ideas log	Document analysis	[19]
	Quality inspection (level of fulfillment of deliverables)	Document analysis	[10,14,21,22]
	Progress report	Document analysis	[10,13,14,19,21]
	Progress meetings	Participant observation	[13,19]
	Change log	Document analysis	[10,13,14,19,21,22]
	Re-baselining	Document analysis	[10,13,14,19,21,23]
	Audits	Participant observation	[19,23]
	Lesson learned register	Document analysis	[10,13,14,19,21,22]
Project Closure	Project closure report	Document analysis	[19,22,23]
	Project closure meeting	-	[19,23]
	Transition plan	-	[19,23]

Twenty four Must Have PM practices are identified, being most of them in the top twenty most useful PM practices presented by one or both studies of Besner and Hobbs [14] and Fernandes et al. [13]. Although, some practices have slightly different designations than the ones attributed by the referred authors, they can be considered equivalent to those twenty most useful practices. The terminology here adopted follow Fernandes et al. [13] study, being common to the worldwide recognized PM body of knowledge, the PMBoK® guide from Project Management Institute [19].

4.3 Nice to Have project management practices

Nice to Have PM practices means that project teams might or not adopt them. Its adoption depends on the PM approach embraced, waterfall or agile, and is also dependent on the PM knowledge of the project teams involved in each project, since the value of the use of PM tools and techniques is also dependent on the organization PM maturity [33].

Table 2 presents the selected Nice to Have PM practices, as referred above, divided into waterfall, agile and transversal PM practices (which can be used by both, waterfall or agile approaches). As presented in Table 1, the research methods used during the case study analysis and the literature references are also identified. Many of the PM practices here presented in Table 2 are mentioned by different authors with other similar terminologies.

Table 2. Nice to Have PM practices in collaborative university-industry R&D.

Approach	PM practice	Research Methods	References
Waterfall approach	Work breakdown structure - WBS (Scope baseline)	Participant observation	[10,13,14,19,21,22]
	Gantt chart - project schedule	-	[10,13,14,19,21,22]
	PM software for monitoring schedule	-	[10,13,14,19,21]
Agile approach	Planning for iteration-based agile	Participant observation	[19,24,25]
	Product backlog - Backlog preparation, Backlog refinement	Participant observation	[19,20,31,34]
	Release planning schedule	-	[19,20,23]
	Daily standups (meetings)	-	[19,20,31,35]
	Sprint backlog	Participant observation	[19,20,24,25,34]
	Sprint reviews (meeting)	Participant observation	[19,20]
	Sprintr retrospective (meeting)	-	[19,20,31]
	Continuous integration	Participant observation	[19,24,25,31]
	Self-directed work teams	Participant observation	[10,13,14,19,21]
	Burn charts - burndown or burnup charts	-	[19,24,25,31,35]
	Kanban board	-	[19,25,31,36]
	Simple design	-	[24, 25,31]
	Process miniature	-	[35]
	Essential interaction design	-	[25,35]
	System metaphor	-	[24,25]
Transversal (either waterfall or agile)	Requirement analysis	Participant observation	[13,14,19,21]
	Activity list	-	[13,14,19,21]
	Effort estimation	-	[24,25,34]
	Meeting minutes	Document analysis	[23]
	Project communication room	Participant observation	[10,13,14,19,21,31]
	Social media	Document analysis	[19,37,38]
	Team-building event	Participant observation	[10,13,14,19,21]
	Information radiator	-	[31,39]
	Decision log	-	[19,23]
	Earned value management (EVM, AgileEVM)	-	[10,13,14,19,21,23,40]
	MoSCoW method for prioritization	-	[34,41]
	Modelling	-	[41]
	Demonstrations	Participant observation	[19]
	Testings (Test plan, Test driven development, Independent testing, Test at all levels)	Participant observation	[19,23–25,41]

Within the set of Nice to Have – Waterfall PM practices, only three were identified: WBS; Gantt chart and PM software for monitoring schedule. Although, Besner and Hobbs [14] and Fernandes et al. [13] had identified them as among the twenty most important tools and techniques, in the collaborative university-industry R&D context they were identified as optional. It was observed that a few IC-HMI projects used the WBS, and only at the internal project team. If a project team decided to make use of the WBS (a more detailed planning), the PM software for monitoring is an important tool for supporting schedule management.

Within the set of Nice to Have – Agile PM practices, 15 practices were identified. However, most of the agile practices here presented are not used in the majority of the IC-HMI projects, since only four IC-HMI project teams have adopted an agile approach at some point in their projects, more specifically the Scrum framework. The 15 practices identified are based on different agile frameworks like Dynamic Systems Development Model (DSDM) [41], eXtreme Programming (XP) [24,25], Scrum [20,34], Crystal [35] and Kanban [25,36]. Most of the agile PM practices identified in Table 2 are linked to the Scrum framework.

Lastly, a set of 14 Nice to Have – Transversal PM practices are proposed, which can be used independently of the approach adopted, since they fit both, as the use of a project communication room subsequently described, exemplifies. During the analysis of the IC-HMI case study, one of the greatest difficulties in managing both program and project levels is communication (the management of interpersonal relations), since it is a collaboration between two entities with distinct objectives (an industrial company focused on product development and a university focused on the development and production of knowledge), hence the existence of a "war room" was important. A specific space was created in University of Minho dedicated to Bosch and UMinho partnership, to guarantee the project teams co-allocation. There several team-building events were also developed to bring people together, in order to establish good relationships, trust and to create a collaborative and cooperative working environment and to address the difficulties presented above.

The project teams should carefully evaluate their project context before following the agile approach, since their adoption can constitute a series of challenges, such as the project manager to relinquish the authority he/she previously enjoyed [42]. Therefore, it is important that the project teams select and practice an appropriate PM approach [20], as well as introduce and adjust the PM practices, so that the projects can meet the established objectives and benefits, since each project is unique and has its own strategy.

5. Conclusions

The main contribution of this research is the proposed hybrid PM approach to manage university-industry R&D collaborations itself. The hybrid PM approach gathers current knowledge on key PM practices (tools and techniques) for the particular context of collaborative university-industry R&D, which can provide guidance to universities and industries interested in increasing their performance in the management of their collaborative R&D initiatives.

The development of the proposed hybrid PM approach was based on an extensive literature review, in order to identify the most useful PM practices perceived from different organizational contexts, as well as those used by different PM approaches (waterfall and agile), and a deep analysis of the IC-HMI case study, through the researchers' participant observation since the beginning of the program, in July 2015 (expected closure of the program is in June 2018), as well as the analysis of several documents of the program and its constituent set of projects was also performed. The deep understanding of the university-industry R&D collaborations context through the deep case study analysis was crucial to achieve the proposed hybrid PM approach with the sets of key PM practices identified.

The hybrid PM approach, based on the contingency theory, proposes a set of Must Have 24 well-known PM practices, which are transversal to all projects in the program, in order to assure the program governance. These PM practices are presented by the PM life cycle, divided into four phases: project initiation, project initial planning, execution, monitoring and control and re-planning, and, lastly, project closure.

There are three other sets of PM practices, called as Nice to Have, which are optional and dependent on the PM approach adopted. In R&D projects, the use of waterfall and agile approaches is common. However, in the IC-HMI case study, the waterfall approach was the most common. It was perceived during the case analysis that the agile approach would be better implemented when the research problem is well understood. The set of PM practices for the project teams that follow an agile approach is composed by 15 tools and techniques, while the waterfall set of Nice to Have PM practices is composed by only 3 PM practices. Finally, there are a set of 14 Nice to Have tools and techniques that are identified as common for both approaches, agile or waterfall.

For future research, a confirmatory study, through a questionnaire survey, would be useful in order to identify the perceptions of academics and industry collaborators involved in this particular typology of initiatives using the hybrid management approach containing the different set of PM practices here proposed. Additionally, research could also be conducted on the value of the application of this hybrid PM approach to measure the success of collaborative university-industry R&D projects, by using for example the method proposed by Fernandes, Pinto, Magalhães, Araújo, Machado [43], by comparing cases that applied this hybrid approach versus initiatives that did not adopt it.

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