A Framework for the Management of Research and Innovation Projects in Academic Settings

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Abstract: *The contemporary complex settings under which research and innovation (R&I) activities are executed in academic institutions calls for the definition of suitable management and administration approaches. To this end, (1) the existing literature on the management of R&I projects in the academia is reviewed; (2) major specificities of R&I projects are discussed; (3) recent trends in project management are addressed; and (4) a specific framework for the management of R&I projects in higher education is proposed. The proposed management framework is defined in eight pillars, namely: (i) clarification of scope and goals; (ii) use of standards; (iii) scalability and flexibility; (iv) workflow modelling; (v) use of tools, techniques and templates; (vi) existence of a "project board" or similar; (vii) adequate risk management; and (viii) organizational learning. The authors argue that it should be seen as a practical tool for university managers and administrators to apply a structured and comprehensive overview of key action areas that will increase the effectiveness, efficiency and impact of R&I project management and administration in academic contexts.*

Keywords: *higher education; third mission; research and innovation administration; project management; management framework*

Introduction

Besides the functions of teaching and research, higher education institutions (HEIs) are required to contribute to society through the creation, transfer, and exchange of knowledge and technologies, i.e. fulfill their "third mission", in close interaction with key societal stakeholders such as enterprises and local communities. The associated shift from discipline-based research ("mode 1") to interdisciplinary knowledge production, involving industry or service partnerships and increased social accountability ("mode 2") has led to deep changes in the organizational structure of research and innovation (R&I) ecosystems (Rajaeian et al., 2018; Wilts, 2000), and particularly of academic institutions (Emmert & Crow, 1989), namely in terms of project management practices (Wedekind & Philbin, 2018). Public research-performing organizations in general have been re-shaping their management and organizational structures towards a more market-oriented approach, with a strong executive control approach also known as 'new public managerialism' (Shattock, 2010; Deem, 2017). In this new environment, public, academic, and private agents and their consortia seek to achieve innovative results across disciplinary, organizational, and national boundaries (Lippe & Vom Brocke, 2016). Also, HEIs, in particular, have taken on collaborative projects, seeking to increasingly secure funds from regional, national and supranational sources, and to access complementary knowledge and competencies.

In R&I activities, goals are ambitious by definition, the aims uncertain, and partners often have heterogeneous interests (academic-, business-, or policy-oriented). Consequently, the application of "standard" or "mode 1" management approaches tends to be displaced, since the setting of such multi-stakeholder R&I projects, "mode 2", is inherently different from "regular" new product development carried out by individual companies or public research labs (European Commission, 2014). In the latter, pre-specified product or service descriptions or requirements are provided by the "customer". In the former, a high level of creativity to produce novel outcomes is required. Often, the results are intangible, such as knowledge not yet incorporated into new products or services by the end of the project. Under "mode 2" R&I projects, managers must integrate individual and small-team research activities that demand high levels of creativity and innovation. However, funding bodies and institutions require clear work plans, perfectly defined and assigned responsibilities, and strict schedules, deliverables and milestones. This apparent contradiction calls for flexible and adaptable project management approaches.

Success or failure of contemporary R&I endeavors is, therefore, strongly linked to the project management practices adopted by institutions and teams along a collaborative and "open" context (as in open science, open innovation), under which new knowledge and technologies are developed and transferred to the society at large. Although the use of professional managers is increasing, on many collaborative projects a scientist is given the project management role in addition to scientific responsibilities. Unfortunately, this added responsibility is typically not accompanied by the necessary training or tools to fulfil the role. The result is an increased risk of missed performance targets and of inefficiently managed resources (Procca, 2008). Also, the acceptance of project management methodologies may not be the same in the academic institutions compared to industry mainly because generally university researchers lack the skills in managing and planning research projects (Ali Qalati et al., 2019; Chin et al., 2012). To try to mitigate this, Johnson et al. (2020) report the development and implementation of a project management community of practice at a university aimed at sharing best practices, tools, and resources among research project managers. Actually, academics tend to disregard the importance of project management elements and functions in the management of collaborative projects (Gist & Langley, 2007). Moreover, researchers may have competing obligations on their time, e.g. teaching, administration or other projects.

Thus, the management of R&I projects in academic settings requires different frameworks than those typically applied in "traditional" projects. The research question forming the basis of this study is: "Which should be the basic components of a project management framework adequate to the R&I endeavor in the academic sector?"

To answer this question, the research methodology used is based on documented action and participatory observation. To that end, use is made of a case study: the *ValorNatural* project. This is one of the main multi-stakeholder research projects in Portugal dealing with the contentious topic of new natural ingredients for the agribusiness industry, funded by the Portuguese government under the country's Framework Programme 2014-2020 (Portugal 2020) within the European Structural and Investment Funds (ESIF) of the European Union (EU).

Literature Review

The application of project management tools to R&I activities is not new. Anderson (1967) addressed the adaptation of the program evaluation and review technique (PERT) for coordinating interdisciplinary manpower research in university setting. The research was developed to determine (a) the effect of PERT scheduling on researchers, (b) the familiarity of researchers with PERT and the extensiveness of its use, and (c) researchers′ attitude toward interdisciplinary research. It was found that (1) reaction to PERT was favorable, (2) approximately 50% of researchers were familiar with PERT, and (3) researchers were in favor of interdisciplinary manpower. The author concluded that PERT assists researchers in valuable and realistic planning for their projects. Liberatore and Titus (1983) developed an empirical study on the usage of quantitative techniques for R&I in "Fortune 500" industrial firms. The authors concluded that managers missed a thorough understanding of the budgeting techniques used by their organizations. Also, the authors noted that the initial training for research managers in project management should provide a broad-based introduction to the available methods and techniques, while emphasizing organizational "fit" considerations. These examples illustrate that early research on R&I project management essentially focused on planning and compliance with schedules, costs and budgeting. The work of Liberatore and Titus (1983) does nevertheless point out the need for adequate training of managers and for alignment of research management with the organizational culture and setting. Both issues are still relevant today, and require further research, as evidenced by the case study addressed herein in the context of the development of a new management framework for R&I projects.

Following the consolidation of the shift from "mode 1" to "mode 2" research setting, the focus of research on R&I project management has moved to a higher concern with conciliating academic and industrial approaches. This is mainly due to: (a) the need to align R&I with business needs in the increasingly common academia-industry collaborative projects, and (b) the fact that increased accountability of the use of public funds has led to the need for "standardized" project management practices.

Gist and Langley (2007) reported the use of PRINCE2 (a structured project management methodology, originally developed as a UK government standard for information systems projects) in a multi-national clinical trial. The authors addressed the challenge of ensuring that the project management tools add value to the project overall and are not perceived as an overly administrative burden. The paper takes into account the wider costs and benefits to researchers and funders of taking this approach and explores implications for research administrators and managers at institutions involved in large, complex collaborative research projects, whether clinical or not. A framework for research projects management based on three success-based pillars was developed by Powers and Kerr (2009). The three pillars comprise: (a) a credible and recognizable definition of the desired state; (b) a credible and compelling measure of deviation from the desired state; and (3) a way to bring the project back on track. This approach focuses on reducing uncertainty in the early phases of research projects by developing short-term tasks with limited resources and restricting scope accordingly. This is clearly in line with industry standard agile project management methodologies. For this framework to succeed the authors highlight the need for a "functioning feedback mechanism, including the capacity to change the behavior of the researchers".

Chin et al. (2012) proposed a project management methodology to be applied in a university-industry collaborative research environment in Malaysia using reference industrial standards such as the Project Management Body of Knowledge (PMBOK), PRINCE2, Association of Project Management Body of Knowledge (APMBOK) and British Standard BS6079-1:2002. The primary outcome of Chin's study was a project management methodology guidebook for the initiation, planning, execution, monitoring and closing of research projects.

Binder et al. (2014) reported a combination of agile approaches with the international standard ISO 21500:2012 ("Guidance on Project Management"). The authors proposed a new "cocktail" system to complement waterfall-based project management models (such as PMBOK, where you complete a project as a step-by-step—linear or sequential—process) with flexible approaches (such as Scrum). It was found that the utilization of agile principles may struggle with business processes like knowledge and procurement management.

Philbin (2017) reported on the results of an exploratory study based on a systematic literature review, which was carried out in order to improve the understanding of the key features and issues arising from the application of project management principles to research projects. The dimensions analyzed were process, structure, people and technology. The paper included a synthesis of a proposed research agenda in order to advance the knowledge base on the management of research projects. The author pointed out that there is a need for empirical data on the management of research projects. The data reported herein on the management of the *ValorNatural* project contributes to the fulfilment of this identified need.

Wedekind and Philbin (2018) addressed the challenges of managing R&I projects in academic settings, in the context of a case study related to a European Union funded initiative, and the key role that project management offices (PMO) using PRINCE2 principles can play in this regard. The authors concluded by recommending an increase to the number of cases under investigation on this topic.

Pirro et al. (2019) developed a project management methodology specific for use in doctoral research projects, based on agile management practices.

These examples illustrate that in what concerns the use of formal project management for R&I projects, no ideal methodology exists and, often, a combination of concepts and approaches from different standards are needed to efficiently and effectively translate best practices from "traditional" project management to R&I endeavors.

In conclusion, there is a need for more holistic approaches to project management that account for the complexity of contemporary R&I endeavors. Therefore, this research paper aims at contributing to this topic by identifying common "pillars" of formal project management approaches that should be considered when developing management models for "traditional" projects and, in particular, R&I initiatives. Thereafter, the authors propose a R&I project management framework that facilitates structuring of project management methodologies and their practical application to planning, conducting and assessing of management activities for academic R&I projects.

Methodology

A two-stage methodology was adopted. The first stage reviewed the literature on R&I processes and on project management. For this, the Scopus database (Elsevier's abstract and citation database, covering approximately 36,377 titles from 11,678 publishers) was used employing search terms such as "research and innovation" and "project management". The following exclusion criteria were applied: 1) publications that did not include sufficient coverage of both topics, 2) publications that did not use any form of formal research methodology, 3) publications repeating concepts or analyses, and 4) publications not addressing academic contexts. The results presented herein are representative of the major findings. In the second stage, the authors conducted documented action and participatory observation, based on the main author's experience in working with the project *ValorNatural*.

The sources of empirical evidence used in this exploratory case study were documented action and participatory observation (primary sources) as well as documents and materials (secondary sources). The case study approach was selected as it is a form of qualitative research that analyses a phenomenon in its real environment, based on multiple sources of evidence, being recommended when the social and personal context is fundamental in understanding and interpreting the phenomenon (Franco & Haase, 2015). The research corresponds to a single case study. This method facilitates the exploration and capture of common characteristics and conditions of similar "projects" within the case (Yin, 2009).

The *ValorNatural* project was selected as an adequate and representative case study because it involved partners from industry, academia and interface organizations dedicated to technology and knowledge transfer. The consortium consisted of nine companies, two higher education/research organizations, two research organizations and one interface organization (not performing research). The disciplines involved included biotechnology, chemical engineering, mechanical engineering, electro-technical engineering, food science and materials science. The project was led by a company and coordinated by a higher education/research organization. Thus, its heterogeneous consortium composition, multidisciplinary and market-driven nature provided an adequate case study in the context of our research. The case study results validated the logical structure of the framework and showed its utility.

The Management of Research and Innovation Endeavors

In this section, key specific characteristics of R&I endeavors are discussed, in particular in HIEs. It is argued that these characteristics are those that make R&I projects differ from "standard" projects. Four main areas are addressed: (1) project preparation; (2) project context; (3) project uncertainty and (4) project human factor. Each one of these areas will be addressed in detail in the following subsections.

R&I Project Preparation: Where it All Starts

Every R&I endeavor begins with the identification of problems and/or opportunities, set in a particular context. Eventually, these needs will have to be evaluated and prioritized in the light of specific criteria such as urgency and opportunity windows. Inevitably, a research project proposal has to be developed. This involves the preparation of a document, more or less succinct, mentioning the need, goals, objectives, contextual benefits, high-level estimates of schedules, resources and financial requirements. Also, a preliminary risk analysis ought to be provided. This information will allow an informed priority setting among various competing projects that are being pursued at a given point in time. With regard to eventual benefits resulting from the project execution, these can actually be quite varied and could range from an increase of the image/visibility of the HEI to the development of some scientific expertise in a particular area. The relative importance given to each benefit should be clear in the project proposal. Also, though it may not be possible to do a detailed cost-benefit analysis for each and every project, it is nevertheless useful to have an idea of the total cost and benefits, including those at the utilization stage.

Often a R&I project needs external funding to be executed. This is increasingly the case in academic settings, namely in HEIs, and competition over resources made available by both public and private entities has been increasing steadily. The project may require a volume of resources not available at the host organization, or a set of skills and competencies that demand joint ventures with other organizations. Funders may be public, private or a combination of both. Their mission includes (but may not be restricted to) facilitating availability of funds and resources for R&I activities that are consistent with defined policies and priorities, which may not coincide with the researchers' interests and ideas.

Funders do expect a well-defined timeframe and budget for project implementation. This is often influenced by increasing accountability on the use of public funds (in the public sectors) and by the existence of "opportunity windows'" beyond which the sought novelty may vanish (in commercially or privately funded projects). Research is therefore implicitly delivered through projects that have a well-defined life expectancy timeline and resources pool that are used to provide deliverables within specifications and a predefined set of quality criteria. Thus, project management is particularly relevant when researchers compete for external resources, with donors requiring clear information on research plans and results.

The Project Context

The context of a R&I project includes the social, economic, political and technical conditions that surround any research endeavor. The impact of these, and other dimensions should be evaluated beforehand (ex-ante), but also monitored during implementation (real-time), and assessed again after its conclusion (ex-post evaluation), including reasons for deviations from the expected initial impact.

A R&I institution ought to make sure that results of basic and applied research projects are accessible to a wider range of stakeholders, namely those that can implement and exploit the created knowledge and technology into new processes, products, services, etc. Usually, the success of these organizations is measured by the intellectual output, e.g. scientific papers, patents, and by successful transfer of knowledge and technology to the community, namely the enterprise sector. However, a R&I project should be a part of a wider institutional program and also address national, regional and/or supranational science policy priorities. These may include projects aimed at solving societal challenges (such as an unexpected pandemic), without clear and direct economic return to the organization itself. Therefore, priorities for research set by policy-making bodies (often themselves research funders) and host institutions must be taken into account in publicly funded projects. Actually, if the project is not aligned with high-level priorities and strategies, the chances to be funded in the first place are dim.

The needs of customers and end-users must be accounted for. Indeed, increasingly, R&I projects are framed in "end-user based" development contexts. So, in the first place, one must critically acknowledge and evaluate the real needs of those who will use the new knowledge or technology. This may seem obvious, but the fact is that traditionally R&I projects are created around what a researcher perceives to be a specific need or opportunity, seldom validated by the actual end users. Researchers and users' interests are potentially divergent. The researchers, often, tend to work on the scientifically most interesting problems. Consequently, the technologies emanating from such research may not be very relevant to the actual end users.

Every project must also consider the state of the art of the knowledge in the relevant scientific fields. Often researchers focus on scientific literature, not paying due attention to other sources such as patent and commercial databases. Technology available from such external sources is often overlooked, thereby resulting in missed opportunities for translational technology implementation.

The project manager has to acquaint him/herself with the institutional context under which the project will be implemented. Namely, a good knowledge and practice of administrative procedures is recommended. Also, who are the key institutional stakeholders? Would they "buy" the project's main idea? If so, the prospects of a smooth project execution may be higher. Moreover, R&I institutions use project portfolios to fulfil their strategic plans. So, how well aligned is the project idea with existing portfolios?

Finally, research projects are often inter-organizational, multinational and multidisciplinary. In these projects there are challenges associated with different national languages and cultures but also different professional and institutional languages and cultures. Under such circumstances, the manager needs to become a kind of "knowledge translator" with the responsibility of facilitating processes that make it possible for project participants to discuss and communicate about research created outside their own academic and institutional fields (European Commission, 2014). This may be particularly challenging for early-stage researchers based in the academy.

Uncertainty

Quoting Albert Einstein: "If we knew what we were doing, it would not be called research, would it?". This summarizes perfectly one of the main characteristics of R&I projects: uncertainty.

The ambiguous nature of goals in many large R&I projects, namely if curiosity-driven, represents a particular challenge when managing a project of this nature (European Commission, 2014). Also, it is commonly stated that the outputs of research projects are difficult to convert into quantifiable measures. This is usually the case in basic research projects, which produce mainly knowledge, be it concepts, ideas or frameworks. Funders and peers often struggle to identify clearly associated benefits. This is not the case with applied research as quantifiable deliverables are usually more plausible.

The implementation of innovative R&I projects is usually accompanied by high risk (Biscola et al., 2017; Ernø-Kjølhede, 2000; Huljenic et al., 2005). Particularly in applied research, a major source of risk is the uncertainty in relation to the development of the concept, of the solution, and to the verification of the conformity of deliverables. Uncertainty may arise from the lack of exact knowledge about costs, duration, or quality of planned activities. The uncertainty in the project design phase can also arise as a result of the usual heterogeneity in teams. Different views may arise regarding specific objectives, solution performance levels, stakeholder motivation and expectations, data quality issues (e.g. needs identification), and issues with the perceived skills of available team members. Often, uncertainty is actually created by a lack of clarity among the project stakeholders regarding desired outcomes. This can in fact be remarkably difficult to achieve, namely when groups of people that have not worked together before are set up. In this case, even differing terminology, not to mention cultural aspects, may hinder agreement. The development of an interdisciplinary culture is generally limited in the sense that researchers are primarily concerned with their own organizations' research questions and, therefore, may contribute to conflicts in multi-partner projects (Wiesmann et al., 2008). Moreover, researchers may prefer not to share their detailed objectives with their own institutions or colleagues if they feel constrained e.g. by their organizations' policies on intellectual property. In such cases, some members of the team intentionally stay vague to keep from attracting notice from their own research offices (Powers & Kerr, 2009).

In order to obtain innovative results, researchers should have a risk-taking behavior, increasing the probability of failure. But then, how to cope with uncertainty? An approach based on alternative solutions, and an analytical search for optimal solutions using multicriteria methods could help. Also, adequate risk management methods should be used. For example, Bodea and Dascalu (2009) proposed a risk evaluation model for research projects based on fuzzy inference. It should be noted, however, that R&I project managers tend to focus on scientific and technical risks, neglecting other potential sources related e.g. with context changes (e.g. a need that is no longer) or stakeholder management (e.g. someone that changes from supporting to confronting). This is usually a source of significant impacts on the success of a R&I project, and can be mitigated by incorporating project management best practices during the project definition stage.

The Human Factor

If there is a single critical aspect in R&I projects that is the human factor. This has consequences at several dimensions, namely at the project leadership, team and stakeholders' levels. These aspects will be individually discussed in the following subsections.

Project Leadership

Leadership is a significant challenge for research managers (Amollo & Omwenga, 2017). Besides technical and scientific skills, a leader of R&I projects has to have strong transversal skills (e.g. negotiation, conflict resolution and communication skills) and complementary hard skills such as those related to entrepreneurship. The achievement of a balance among these sets of skills is notably difficult. Usually, the project leader tends to be more of a technical-scientific expert. This raises challenges for managers as well as those that are managed, that increase because of the intrinsic uncertainty in research projects (European Commission, 2014). Such uncertainty requires a high level of autonomy of project participants with specific expertise in specialist domains. Thus, one of the first challenges for a research manager is to find the right balance between controlling participants (e.g. steering and instructing) and facilitating individual participants (e.g. informing and assisting).

Finally, project managers face an additional challenge imposed by the high-level hierarchy of management structures of R&I institutions that might impose restrictions in terms of leadership of research projects.

The Team

R&I project managers in HEIs have only very little formal authority over project participants. Usually, they are not their subordinates but peers. Furthermore, not only does the project manager not have authority over the project participants but also many of these may only be working part time on the project and have many other constraints on their time, making it even harder for the project manager to obtain commitment from participants. Also, usually, the specialty of researchers' individual knowledge requires the enrolment of team elements with complementary and interdisciplinary skills and knowledge. However, there are intrinsic dilemmas with this. On the one hand, as mentioned before, the researchers' desire for a large degree of autonomy in their work and democracy in decision making must be conciliated with the need for strict project control (e.g., adherence to budget and time limits). On the other hand, the fact that researchers both co-operate and compete with each other in the project (for recognition that might influence positions, grants, etc.) may lead to conflict between the joint goals of the consortium and individual goals of researchers. Additionally, the knowledge asymmetry between the project manager and the individual researchers may also be a cause of tension.

Lippe and Vom Brocke (2016) estimated the amount of time spent on partner management at 20–50%, based on interviews of project managers in collaborative research projects. The European Commission (2014) found that the composition of the consortium may change along the way in about one third of the projects, based on an analysis of EU's FP6 and FP7 projects.

Thus, team-building is particularly important in research projects (Cristina & Mihaela, 2008). For example, Ernø-Kjølhede (2000) found that successful EUREKA projects (a private-public European R&I association) are often characterized by the development of strong social relations between participants.

In projects with a high performance rating, the coordinator shares information with other consortium members in a timely fashion, trusting them to deliver as needed, and discussing any issues person to person (European Commission, 2014). Thus, a R&I project manager who wants to be successful should consider managing by continuously building relationships and high trust levels and invest in one-to-one communication. He/she should favor a consensus-based decision-making model, rather than a hierarchical or formal management style. This should be complemented with an all-inclusive approach. These activities serve to align consortium partners' interests and contribute to the project success.

In short, R&I projects′ management is more associated with concepts such as team building, treating people as peers and personal charisma/knowledge than it is with authority, subordination and issuing orders. Moreover, adequate team reward and recognition mechanisms, tailored to each institutional context (e.g., project performance as criteria incorporated in assessment frameworks) should be used to promote the team members′ commitment to the project.

Stakeholders

The critical factor of a successful project is often related with management of challenges and opportunities, and with how project attained outcomes are perceived by researchers, funding bodies, governmental agencies, potential end users of the new knowledge and technology, and other key people. Thus, R&I projects′ management performance is enabled by a high frequency of contact and involvement of key partners (i.e. stakeholders) in substantial decision making.

Formally, stakeholders are people, groups or institutions that may influence, or be influenced by, the project. They are those ultimately affected, either positively or negatively by the project performance. This definition of stakeholder includes both winners and losers and those involved or excluded from decision-making processes. Key stakeholders are those who can significantly influence or are important to the success of the project. This wide definition clearly includes researchers along with other categories such as policymakers, extension officers, and relevant government and non-governmental organizations (Biscola et al., 2017). For example, the DRUSSA ("Development Research Uptake in Sub Saharan Africa"), project, led by the Association of Commonwealth Universities (2012), specifically addressed the effective use of evidence-based research by policymakers and practitioners.

Mention should also be made to the stakeholders represented by the administrative structures that support the execution of R&I projects. Often, there is an "us and them" perspective that adds difficulty to everyday project management tasks. Many scientists view administrators as unimaginative and not helpful, bureaucratic, "lovers of red tape", and bound by inflexible rules and regulations. On the other hand, many administrators view scientists as highly critical, allergic to paperwork and red tape, and breakers of rules and procedures. However, the increasing recognition of research managers and administrators as “interface professionals” (Agostinho et al., 2020) ought to fade away the border line among these two views.

Adequate stakeholder analysis can help organizations to identify which institutional and individual actors are likely to favor and press for particular kinds of actions. It helps to identify appropriate forms of stakeholder participation in a R&I project. As evidenced in the previous paragraphs, R&I projects´ management is a people business.

The Management of Projects

Projects are regarded as temporary endeavors undertaken to create unique products, services or results (Project Management Institute [PMI], 2017). The essence of project management is to support the execution of an organization’s competitive strategy to move towards its goals and deliver a desired outcome. Put simply, project management is a road map to get you from where you are to where you want to be.

Project management methodologies include a wide range of knowledge areas, provide a means of identifying the threats and opportunities associated with the project, and involve controlling costs, time, risks, scope, and quality through specific processes, tools and techniques. The scope of project management goes from conceptualization to closing with one objective in mind: to meet the requirements of stakeholders within budget and the given timeline. By using the right methodology, a project manager is able to identify and minimize risks, satisfy stakeholders’ expectations, optimize resources and time usage, and internalize learning from the process.

However, project management does not provide a one-fits-all solution. Many effective project management paradigms, methods, tools, techniques and standards have been developed, from “classical” project management, represented primarily by PMBOK (by the Project Management Institute) and PRINCE2 (currently owned by AXELOS Ltd.), to flexible iterative and incremental agile methods (e.g., Scrum, Lean, Kanban). Other techniques and frameworks include the Logical Framework Approach (developed in 1969 for the U.S. Agency for International Development) and the standards developed by APMBOK and the International Project Management Association (IPMA), the ISO 21500:2012 standard for project management (based on PMBOK principles) and the British Standard BS6079-1:2002.

The approach to “traditional” project management can generally be expressed by the grouping of specific management high-level processes. For example, PMBOK is developed around five groups of management processes (Initiating, Planning, Executing, Monitoring and Controlling, and Closing) and ten areas of knowledge (Project Integration Management, Project Scope Management, Project Schedule Management, Project Cost Management, Project Quality Management, Project Resource Management, Project Communications Management, Project Risk Management, Project Procurement Management, and Project Stakeholder Management). These are usually considered to be “waterfall” methodologies with clearly defined sequential steps, although this observation is still controversial. On the other hand, “agile” methodologies are composed of several iterations or incremental steps and focused on life cycle management stages (Plan, Sprint, Ship, Repeat). They are less formalized and allow the absence of an explicit description of a number of processes. As illustrated in the literature review section, hybrid methodologies combining aspects of each of the approaches have also been developed.

Which approach is better? It depends on the specific context of each project, namely from the organizational (e.g. nature of the partners), scientific discipline(s) and goals (e.g. market-driven or curiosity-driven) points of view. Table 1 highlights example advantages and disadvantages of major methodologies ("waterfall"—PMBOK, PRINCE2) and development approaches (Agile—Scrum), and example alternative frameworks (namely the Logical Framework).

As far as frameworks are concerned, the Logical Framework is a tool for the design, monitoring and evaluation of projects. It gives an overview of the objectives, activities and resources of a project. It also provides information about external elements that may influence the project (assumptions) and includes information on how the project will be monitored. A hierarchy of objectives in the form of short narrative descriptions is mapped to components of key management activities for evaluation, performance measurement and external conditions. Therefore, it presents the key items of the project in a manner which enables an effective visualization of connections between them. The logic of the project is, thus, exposed to scrutiny. It allows project managers to make the management objectives explicit from the beginning of the project. Moreover, it identifies critical assumptions which will influence the project success. A distinctive feature is that it helps to identify the sustainability of the project outcomes once the project has ended. In face of the above, the Logical Framework is definitely not a universal approach to all types of projects (namely development initiatives), but it does create conditions to understand what the project intends to do and how and what are the conditions for failure and success.

Table 1. Example Advantages and Disadvantages of Major Project Management Approaches

Project Management Approach	**Advantages**	**Disadvantages**
PMBOK	Collection of best practices from the industry. Templates and checklists available.	Heavy administrative load. May hinder creativity.
PRINCE2	Highly standardized. Templates and checklists available.	Heavy administrative load. Lack of flexibility. Does not cover all subjects relevant to project management.
Agile	Flexibility in scope and procedures. Low administrative load. Focus on team working.	Low predictability of resource usage. Difficulties in scaling up to large, complex projects. Insufficient knowledge management.
Logical Framework	Highly graphic. Transparency of management.	Lack of operational detail. Not applicable to every type of project, namely R&I.

A Proposed Development Framework

In this section, a framework for R&I project management is established. For this, based on the information presented previously, key features that should be observed when managing any type of project are collated. It then follows the formulation of a management framework specifically for R&I projects, based on the information presented before on key specificities of this type of projects, and on the information collected by the participatory observation carried out in the context of the ValorNatural project as a case study.

Whatever methodologies, approaches or frameworks are implemented for project management, eight key characteristics should emerge (Table 2). Their identification is based on the analysis of main characteristics of major project management approaches described previously. Thus, any project management approach should: 1) facilitate the clarification of the project´s scope and goals; 2) model the expected project workflow; 3) include adequate tools, techniques and templates to efficiently and effectively plan and manage the project activities; 4) consider a project "board" (or similar role) to supervise and evaluate the project progression by the use of a set of relevant indicators; 5) facilitate the identification, management and mitigation of risks; 6) allow for project scalability and flexibility to account for varied sizes and formats; 7) adapt projects to industry or governmental specific standards, but simultaneously to each organization's culture; and 8) facilitate organizational learning and maturity. Also, as discussed and justified above, it is argued that key characteristics should be considered when managing R&I projects, namely their 1) specific origin, 2) complex context, 3) high uncertainty and 4) complex human factor setting. Together, these guidelines form a proposal for a "R&I project management framework", illustrated in Figure 1.

Table 2. Key Characteristics of "Standard" Project Management Approaches

	PMBOK	**PRINCE2**	**Agile**	**Logical Framework**
Facilitate clarity of project scope and goals	Project charter	Business case	Flexible project scope	Short and medium term outputs, long term goal
Based on standards but adaptable	Yes	Yes	Yes	Yes
Scalable, flexible	Yes, but need to be implemented at higher levels of the work breakdown structure in large, complex projects	Yes, but need to be implemented at higher levels of the work breakdown structure in large, complex projects	Yes, but need to be implemented at lower levels of the work breakdown structure in large, complex projects	Scalable, but difficulties when adapting to high uncertainty projects (e.g. variable outputs)
Model the project workflow	Standardized: Initiating, Planning, Executing, Monitoring and Controlling, and Closing	Standardized: Starting Up, Directing, Initiating, Controlling a Stage, Managing Product Delivery, Managing Stage Boundaries, Closing a Project	Flexible, Iterative: Plan, Sprint, Ship, Repeat	Standardized: "Logframe"
Provide tools, techniques, templates	Templates and checklist available	Templates and checklist available	Available, although kept to a minimum	"Logframe"
Provide a project "board" or similar role	Specific knowledge area for project integration management	Specific processes group for directing a project	Self-organizing project team	Graphic nature implies transparency of management
Ensure adequate risk management	Specific knowledge area for risk	Management of risks is a key element	Specific tools and techniques (e.g. "Risk Burndown Chart")	Identifies critical assumptions and risks
Facilitate organizational maturity, learning	Specific processes in the "closing" phase	Specific processes in the "closing a project" phase	Extensive communication, focused on teamwork, although weak formal knowledge management	Documented "Logframes"

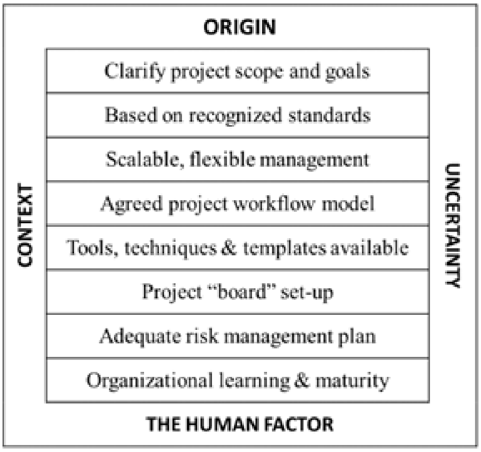

Figure 1. Proposed R&I Project Management Framework

Case Study of Use of Framework

The proposed framework was developed and tested in the context of the *ValorNatural* project as a case study. Table 3 illustrates how the proposed framework applies to *ValorNatural*, namely how this R&I project deals with the eight pillars—plus four specificities included in the general framework proposed for R&I project management. This is further expanded in the following subsections.

Table 3. Application of the Proposed R&I Project Management Framework to *ValorNatural*

Key Characteristic	How it is Addressed in the Case Study
At the R&I activity level	
Origin	Industry-driven, multi-stakeholder project, sponsored by P2020.
Context	Set at the Project Charter, managed at the Project Management Board and at the Advisory Board level.
Human factor	The project leader is an industrialist and the scientific coordinator is a leading scientist; the project manager is a certified project management professional. Stakeholders are involved in the Advisory Board.
Uncertainty	A Risk Register is used and managed at the Project Management Board and at the Advisory Board level. Formal procedures kept to a minimum.
At the project management level	
Based on standards	PMBOK®
Scalable, adaptable	Formal procedures kept to a minimum.
Project workflow model	Detailed in the "Procedures Manual".
Tools, techniques, templates	Detailed in the "Procedures Manual".
Project "board"	A Project Management Board was set up.
Risk management	A Risk Register was implemented.
Organizational maturity, learning	Meetings and lessons learned are documented.

Specificities Identified as Key R&I Project Characteristics

Its Origin

The *ValorNatural* R&I project is coordinated by the Polytechnic Institute of Bragança (Portugal) and deals with the development of new additives and ingredients for the food and drink industry, based namely on by-products and side-products of the agrifood industry itself, and on new extraction and preserving technologies. It is a "large scale" project, as defined by the Portuguese Innovation Agency, that involves nine companies from varied sectors (food industry, biotechnology industry, processing equipment industry), four research performing organizations and a dedicated technology/knowledge transfer organization. The consortium is therefore quite heterogeneous, gathering organizations with different aims and cultures. The project´s duration is three years, concluding in August 2022, and the partners are geographically scattered in the north region of Portugal. The global investment reaches € 3.25 million. The project is co-funded by the Portuguese Government under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (ERDF), namely by the North Regional Operational Programme (NORTE2020). The approved project proposal defines the main goals, objectives, activities, deliverables, milestones, schedule, and cost over time. The development of the activities, achievement of deliverables and milestones, and compliance with the predicted schedule and costs are monitored every six months by the Portuguese Innovation Agency.

The Context

The valorization of bio-based organic wastes and by-products has become an issue of great public and scientific concern, namely since the European Commission presented its Circular Economy Strategy and the related Action Plan "Closing the loop" (Carus & Dammer, 2018). The project is being developed in the context of the biorefinery concept (Clark & Deswarte, 2014). This valorization approach has been considered as one of the most promising pathways to attaining a resource-efficient circular bioeconomy since it is a way of decreasing human-induced environmental impacts, generate new market opportunities and use resources more efficiently (Nizami et al., 2017).

In order to ensure a common understanding across the partnership, the overall context is detailed at the project charter, and any changes are addressed at the Project Management Board and at the Advisory Board. The latter was set up specifically to provide independent, external feedback on the scientific, technological, economic and societal impacts of the project activities and results. The Project Management Board and the Advisory Board interact once per year.

The Human Factor

The consortium involves public and private entities, industry and academia, research performing organizations, higher education institutions, and "interface" organizations. Therefore, the profile of the 35 (in average) team members is quite varied, from the background, experience and activity points of view. In order to account for the inherently different perspectives, a management model was adopted where the project leader is an industrialist, the scientific coordinator is a leading scientist, and the project manager is a certified project management professional. Also, a "Project Management Board" was set up that includes representatives of all the involved organizations. Moreover, external stakeholders are involved as members of the "Advisory Board".

Uncertainty

The project foresees the development of new processing technologies that will lead to the production of new food/drink additives and ingredients. The associated risk is significant, not just from the scientific and technological points of view but also from the market point of view. In fact, competition in this sector is fierce and alternative products may be launched in the market before the project ends. The scientific and technological routes being pursued involve the development of new concepts and equipment, amenable to inherent difficulties. Moreover, compliance with regulatory legislation must be ensured for a successful market launch. Therefore, risk management is a key issue and a dynamic "risk register" has been implemented, that is managed at the Project Management Board and at the Advisory Board. Formal management procedures have been kept to a minimum, in order not to hinder creativity, needed to help to cope with the uncertainty associated with the foreseen scientific and technological developments.

The Eight Pillars Identified as Key Project Management Features

Clarification of Project Scope and Goals

The project scope and goals are summarized in a "project charter", developed at the project kickoff. It details the scope, general and individual goals and objectives. It is contained in several other documents such as periodic reports, so as to ensure a common understanding by all the partners involved in the project.

Based on Standards but Adaptable

The methodology adopted for project management is based on the PMBOK standard. Thus, an approach following the project management life cycle (initiation, planning, execution, monitoring and controlling, closing) is used. This was driven by the fact that the project manager is a certified project management professional (by the Project Management Institute). However, bearing in mind the widely different organizational and project management cultures existing in the consortium, a simplified approach was used to develop a "Procedures Manual" that could easily be incorporated in each organization's culture and practices. This is critical to ensure a common ground in terms of practices and rules involving such a heterogeneous consortium.

Be Scalable, Flexible

The project management model is implemented at higher levels of the work breakdown structure. At the activity level, the corresponding leaders can use the approach that the team agrees to best suit the purpose. Thus, for example, different activity leaders implement more or less formal practices.

Model the Project Workflow

The "Procedures Manual" details the project workflow inputs, tools, techniques, and outputs. It includes the templates needed to support key management and operational areas: project integration (including changes, issues and intellectual property management, and day-to-day project management tasks); scope, time and cost management (including resource and time usage reporting, project activities progress reporting and corresponding indicators); communication management and risk management. In order not to restrict undesirably the "freedom" of action needed to promote creativity at the scientific level, the "formal" procedures are kept to what is strictly needed to comply with the accountability and funding rules by the funder and at each organization level.

Project "Board" or Similar Role

A "Project Management Board" was set up to supervise and regularly evaluate the project progress, according to a set of metrics/indicators detailed in the project proposal (some determined by the project sponsor and the remaining defined by the involved scientific team). It is headed by one of the participating companies (the project leader) so as to keep the focus on the innovation side of the project. The project scientific coordinator comes from one of the participating scientific organizations and is a leading world-class scientist. As mentioned, the project manager, a scientist himself, is a trained, certified professional project manager. An external, international "Advisory Board", working as a stakeholder forum, was implemented in order to ensure the compliance of the project with the established objectives from the scientific, technological and societal points of view. This board ensures that the project management is aligned with the contextual setting and that, this way, delivers the projected added value for this R&I initiative. Regular meetings gathering the individual scientific teams are held in order to promote communication, team spirit and work synergies.

Adequate Risk Management

Due to the high uncertainty associated with the R&I plan, particular attention is paid to risk management. This involves the use of a "dynamic" risk register (including mitigation measures) regularly updated by the individual teams and evaluated by the "Project Management Board".

Organizational Maturity, Learning

Organizational learning and maturity is promoted by the shared use of templates and dissemination of best practices to be adopted by other projects. The implementation of the described project management model has been shown to be both efficient and practical in the case study addressed herein.

However, it is acknowledged that for it to be successfully implemented in R&I projects, training in project management tools and techniques should be provided to scientific projects managers. Project management of R&I activities is in fact a particularly complex and difficult decision-making process, where adequate qualifications and competencies of the project manager are required. A project manager should manage the 'Five Ms': men, material, machine, money and motivating factors. But the duality between technical management and scientific management increases the challenges for a R&I project manager as typically their background is academic and technical project management skills may be lacking. Often this is not readily perceived due to a "halo effect", under which the team perceives the project manager to be as competent a manager as a scientist. In the *ValorNatural* project, it was observed that the allocation of a dedicated "scientific coordinator" and of a dedicated "project manager" can be utilized to mitigate this issue. Nevertheless, it was also observed that providing short training courses on project management to the scientific coordinator and activity leaders would have contributed to a more rapid understanding and adoption of the devised management model.

An additional lesson learnt from this case study concerns the efficiency and efficacy of communication internal to the consortium. The specific tools and techniques used included both "offline" and "online" mechanisms such as meetings at the consortium level every six months, an intranet as information repository and ad-hoc meetings at the activity level. This strategy was adopted as researchers initially perceived that in-person meetings should be limited to a minimum, and more time should be dedicated to scientific work. However, as the project progressed, it was clear that communication among the project partners wasn´t as fluid as desirable. Therefore, more agile communication strategies, such as closer and more regular contact between activity leaders, was adopted as a means to balance the communication need perceived by the project management structure and by the scientific team. This issue derived from the typical "aversion" that scientists have in relation to formal and administrative practices. Usually, the time spent on such tasks is regarded as "lost time" that could otherwise be dedicated to scientific work. While initially the project management approach complied accordingly, the scientific team gradually acknowledged that more agile communication strategies not bonded to fixed meeting schedules should be adopted. This illustrated the need to balance structured project management approaches with more "fluid" and flexible approaches (as depicted in the proposed framework), in order to account for specificities of R&I projects.

Implications for Research Administrators

The roles and functions of research managers and administrators in academic settings include support to project proposal development (pre-award), project management and knowledge and technology transfer (post-award) (Schofield, 2013; Wedekind & Philbin, 2018). The proposed framework can support their role in R&I project management by providing a structured guide to key aspects that may influence decisively the success or failure of this specific type of projects.

Conclusions and Future Work

Contemporary "mode 2" knowledge production paradigm, including increased social accountability by higher education institutions, inherently requires interdisciplinary R&I projects to often engage different types of stakeholders, such as industry, governmental organizations, user's associations, and non-governmental organizations, with varied cultures and practices. R&I projects are characterized by uncertainty, creativity and complexity, elements that distinguish them from "traditional" and "standard" projects, to which the classical theory of project management is generally applied. Therefore, a fine balance is needed between implementing management approaches to support the efficient and effective delivery of projects while not compromising accountability, creativity and innovation. Managers and administrators at higher education should support a critical balance among major stakeholder needs, creative but unstructured processes, free ruling (even chaotic) and intensive knowledge-based activities. But, at the same time, in order to mitigate the uncertainty associated with R&I endeavors, there is a requirement for tight management.

This paper provides a systematic discussion on key aspects of the specificities of R&I projects management in academic settings and, based on documented action and participatory observation in managing the *ValorNatural* project, a framework is suggested that should be considered when managing R&I projects in a sound, efficient and enabling manner. Accordingly, the management model for R&I projects in academic settings should consider the following "pillars": 1) define scope and goals as clearly as possible; 2) be based on standards but flexible; 3) be scalable and adaptable; 4) a project workflow model must be developed; 5) tools, techniques, templates should be provided; 6) a project "board" should be in place; 7) appropriate risk management strategies must be implemented; and 8) organizational maturity and learning should be promoted.

In addition, the project manager should deal adequately with the specific areas where R&I projects clearly diverge from "traditional" projects, namely its origin, context, uncertainty and the human factor. In particular, the leadership function must be focused on integration management roles, and on a participatory and collaborative approach. Adequate time and resources that support improved communication between project team members, partners and stakeholders are essential in order to minimize eventual conflicting views that may compromise the project. Also, the management of R&I projects, namely in higher education, is ultimately facilitated by adequate involvement of key partners in substantial decision-making.

The proposed framework can be implemented by university managers and administrators in a straightforward fashion, as illustrated for the *ValorNatural* project.

The main limitations observed in this research are related to its use of a single case study for the development and validation of the project management model. Thus, future avenues for research include the validation of the proposed framework by increasing (a) the number and diversity of case studies, namely R&I projects from different subject areas (e.g. humanities, life sciences, social sciences); (b) implementation contexts (e.g. basic research vs applied research); and (c) locations (e.g. other continents) exposed to different cultures, practices and perceptions. This will enrich the framework by making it useful for a broader range of R&I project types and contexts. Moreover, it is intended to develop a survey to identify best practices in terms of specific tools and techniques perceived by practitioners as a key contribution to the success of R&I projects. This will complement the proposed framework with a toolset of practical artifacts that facilitate its implementation.

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