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Structuring inter-organizational R&D projects: Towards a better understanding of the project architecture as an interplay between activity coordination and knowledge integration

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ABSTRACT

The architects of inter-organizational R&D projects organize collaboration by structuring the activities and the knowledge base of the project. How do these two dimensions interplay and what are the implications on the project execution? The paper aims at developing new perspectives on inter-organizational multi-actor R&D projects using an exploratory inductive multi-case study of projects funded by the European Union's Research and Innovation Programmes. The projects have been studied *simultaneously* in terms of activity coordination and knowledge integration as well as the implications of their interplay on collaboration, project resilience and project management. The paper provides empirical evidence about six patterns of project architecture. The workflow-integrated architecture disintegrates the knowledge base, provides a lower collaboration potential and may require high management efforts, while a workflow-decomposed architecture makes project management easy but provides little added value from the inter-organizational setting. Nearly decomposable architectures offer the highest collaboration potential under contingent conditions.

1. Introduction

Society has taken the 'projectification' path (Lundin et al., 2015; Midler, 1995): organizations increasingly engage into inter-organizational projects (Stjerne, Söderlund & Minbaeva, 2019). Research, development and innovation (R&D) are affected by this trend: over the last decades, they have become more collaborative (Chesbrough, 2005) and more project-organized (Kim, Kim & Lee, 2015). Multi-actor publicly funded inter-organizational R&D projects are a propitious setting for the generation of new knowledge, thanks to the diversity of the knowledge base of the actors and the possibilities for knowledge combination (Nahapiet & Ghoshal, 1998). These projects have characteristic properties which are different from other inter-organizational projects: autonomy and equality of the organizational actors (Bor, 2014) and bottom-up self-organization in response to competitive calls, considerable numbers of heterogeneous actors, collective responsibilities, significant public funding, and lack of structural project flexibility (vom Brocke & Lippe, 2015). These projects address problems which are ambiguous, uncertain and complex *at the same time* (König, Diehl, Tscherning & Helming, 2013). Inter-organizational R&D projects are difficult to manage (Lin, Müller, Zhu & Liu, 2019; Söderlund & Tell, 2011), especially in the multi-actor setting.

The project *structure* defines the way how the tasks are decomposed and coordinated (Mintzberg, 1979), it significantly contributes to the organization of the collaboration (Calamel, Defelix, Picq & Retour, 2012) and to the success of the project (Caniëls, Chiocchio & van Loon, 2019; Dietrich, Eskerod, Dalcher & Sandhawalia, 2010). In the presence of multiple actors, the way in which the collaboration is arranged (Fjeldstad, Snow, Miles & Lettl, 2012), or the structure of interdependencies between actors in an organizational setting (Capaldo, 2007), is often called *architecture*, defined in terms of strength and intensity of links, or couplings, between the nodes in the network, or actors (Orton & Weick, 1990). Couplings are often studied using social network theory, which suggests that the structure and the strengths of relationships or couplings between the actors in the network explain differences in outcomes for these actors (Borgatti, Mehra, Brass & Labianca, 2009; Coleman, 1988; Granovetter, 1973). In the context of collaborative research and innovation, dynamic knowledge integration leading into creation of new knowledge has become increasingly important (Berggren, Bergek, Bengtsson & Söderlund, 2011); and the project structure provides a framework to organize knowledge integration (Lin et al.,

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2019). Abundant literature on inter-organizational projects, ecosystems and networks mostly focuses on inter-firm collaboration, in most cases with one focal actor, but it is not well understood how to best set up inter-organizational R&D projects (vom Brocke & Lippe, 2015) where the both activity coordination and knowledge integration are required. Their interplay defines the core architectural collaborative patterns in inter-organizational R&D projects, called "project architecture" in this paper.

The present study addresses this research gap, using a theoretical framework which builds on literature on project management and additionally takes into account literature on innovation management. This is in line with the call of scholars for a better connection between the project management and innovation research streams (Davies, Manning & Söderlund, 2018; Geraldi & Söderlund, 2018; Sydow & Braun, 2018), especially when the focus is on projects aiming at knowledge integration to generate new knowledge (Berggren, 2019). We pose two related research questions: (1) How do activity coordination and knowledge integration interplay to define the architecture of inter-organizational R&D projects with multiple actors? (2) How does the project architecture favor (or disfavor) collaboration and how does it affect the resilience of the project and the requirements for project management? In order to provide answers to these questions, an empirical inductive multi-case study (Eisenhardt, 1989) has been put in place on inter-organizational R&D projects funded by the latest European Union's Research and Innovation Framework Programmes. The on-going Horizon 2020 Programme has provided 27,55B€ to fund 5147 such projects in 2014–2019, with 13.7 partners per project on average (European Commission, 2020).

In the first stage of the study, 11 projects were selected and studied using the project documentation *simultaneously* from two angles: the angle of the activity coordination and the angle of the knowledge integration. In the second part, the set of projects was narrowed to 6 projects with different architectures. 43 semi-structured interviews were organized, coded and analyzed in terms of activity coordination and knowledge integration. The study provides empirical evidence about the interplay between activity coordination and knowledge integration, led to the identification of typologies of architectures with different implications on collaboration, project resilience and project management, and offers heuristics for project managers on how to structure inter-organizational R&D projects with multiple actors.

The study enhances the understanding of complex inter-organizational R&D projects with multiple actors and contributes to the literature on the management of inter-organizational projects and to the connection of project and innovation studies (Berggren, 2019; Davies et al., 2018; Geraldi & Söderlund, 2018; Sydow & Braun, 2018). From a practical point of view, the study provides suggestions to the project managers and funding agencies on how to adequately organize inter-organizational R&D projects with multiple partners.

The remainder of the paper is organized as follows. Firstly, the theoretical framework that guided the study is provided. Then the research setting and the research design of the study are explained, followed by the presentation of results, discussion and limitations of the research. The paper concludes with a summary of the theoretical contributions as well as the practical implications of the study, and future research directions.

2. Theoretical framework

2.1. Structuring inter-organizational R&D projects: Project management perspective

2.1.1. Inter-organizational projects: Structuring for activity coordination

Society is characterized by "projectification" (Lundin et al., 2015; Simard, Aubry & Laberge, 2018): more and more resources are allocated to projects, "a unique, novel and transient endeavor managing the inherent uncertainty and need for integration in order to deliver beneficial objectives of change" (Turner & Müller, 2003, p. 7). Organizations increasingly engage into inter-organizational projects (Lundin et al., 2015; Stjerne et al., 2019), which are "so alike yet so different" (Ahola, 2018, p. 1007); all of them require efficient collaboration (Caniëls et al., 2019).

The structure significantly contributes to the success of the collaboration in multi-actor projects (Dietrich et al., 2010). Together with the term structure, the terms '*organizational design*' or '*architecture*' are largely synonymously used in the literature (Aubry & Lavoie-Tremblay, 2018) . ***Structure*** is "the sum total of the ways in which (an organization) divides its labor into distinct tasks and then achieves coordination among them" (Mintzberg, 1979, p. 2). Architecture can be defined as the way in which a system is arranged (Fjeldstad et al., 2012) and in an organizational setting the focus often is on the patterns of interdependencies (Capaldo, 2007). *Organizational design* explains "what should be the design, structure, or architecture of the organization" (Burton & Obel, 2011, p. 1198), referring to both the *thing*, i.e. the resulting organization, and the *process* to perform the design (Aubry & Lavoie-Tremblay, 2018). Often scholars do not address the organizational design/structure/architecture of the projects, taking it 'for granted' (Aubry & Lavoie-Tremblay, 2018). Still, literature points out that structure stabilizes patterns of interactions between participants in projects and reduces the uncertainty for the involved actors (Raab, Soeters, van Fenema & de Waard, 2009; Söderlund & Sydow, 2019), supports governance mechanisms (Miterev, Mancini & Turner, 2017; Van de Ven, Ganco & Hinings, 2013), helps to organize the integration of outcomes of different activities (Srikanth & Puranam, 2011; Zerjav, Edkins & Davies, 2018), and influences organizational efficiency and performance (e.g. Burton & Obel, 2018, Englmaier, Foss, Knudsen & Kretschmer, 2018, Yi, Stieglitz & Knudsen, 2018). Structure also influences project resilience, or capacity to maintain project viability during times of disruptive change; an important research issue is how structures should be designed to provide resilience of the inter-organizational settings (Linnenluecke, 2017).

Sydow and Braun (2018) pointed out that most project theories focus on actors; this includes their interrelated activities. Extant literature explains decomposition and integration of activities, using e.g. process architecture framework, process flow diagrams, workflow (Bakker, Wang, Bosch-Rekveldt & Eykelenboom, 2018; Browning, 2014; Shi & Blomquist, 2012). Activities can be organized parallelly, sequentially and with partial overlapping (Eppinger & Browning, 2012). The choice of an appropriate structure of activities in a project is a big challenge: there are multiple ways to organize interactions, and as a consequence there may be a reduction or an increase of uncertainty and ambiguity (Lin, Qian, Cui & Goh, 2015; Yang, Lu, Yao & Zhang, 2014). This challenge is even more salient in large inter-organizational R&D projects which offer even more options to structure human resources, interactions and thus collaboration between actors (Calamel et al., 2012), but organizational setting and processes in inter-organizational R&D projects with multiple actors are yet not well understood (vom Brocke & Lippe, 2015).

2.1.2. Inter-organizational R&D projects: Structuring for knowledge integration

Over the last decades, organizations face an increasingly challenging environment: innovation becomes more complex, the time to market is shorter, the competition on the market harder. In response to these challenges, research and innovation have become more open and more collaborative (Berggren et al., 2011; Chesbrough, 2005; Lundin et al., 2015) and often take place within inter-organizational R&D projects setting (Kim et al., 2015; Tiwana, 2008).

Inter-organizational R&D projects with multiple actors are a specific category of inter-organizational projects: their common purpose, *raison d'être,* is the generation of new knowledge (Manning, 2017) as the result of knowledge integration (Berggren et al., 2011). Such projects operate in contexts of simultaneous complexity, ambiguity, and uncertainty (König et al., 2013) and exhibit particular properties: autonomy and equality of partners (Bor, 2014), large numbers of partners-organizations (Pandza, Wilkins & Alfoldi, 2011; Pinheiro, Serôdio, Pinho & Lucas, 2016), heterogeneity of organizational actors, usually from academia and industry, collective responsibilities, significant public funding and lack of structural project flexibility (vom Brocke & Lippe, 2015).

Efficient collaboration, or joint work to achieve a common purpose (new knowledge generation) significantly contribute to the project success. Joint work in early project stages, communication, coordination, and aligned efforts favor collaboration quality in multi-actor projects (Calamel et al., 2012; Caniëls et al., 2019; Dietrich et al., 2010). Historic experience and project context are other important aspects contributing to collaboration quality: "no project is an island" (Engwall, 2003, p. 789). Project management practice influences collaboration dynamics and needs to be adapted to the different types of projects (Kapsali, 2011).

The project structure in inter-organizational R&D projects with multiple actors exhibits the same characteristics as the structure of other inter-organizational projects; in addition, it has to facilitate knowledge integration and to reduce uncertainties (Lin et al., 2019). While there are several possible terms to describe the project structure, as explained in Section 2.1.1, the authors of this paper prefer the term 'architecture' which emphasizes the patterns of interactions between the multiple actors in the project.

Project management scholars pointed out that inter-organizational R&D projects with multiple actors experience three main management paradoxes (vom Brocke & Lippe, 2015): requirement for freedom due to research uncertainties versus requirements for tight management and structure that reduce uncertainty and help to achieve project outputs; requirement for integration of different research views versus the resulting heterogeneity of partners and inter-disciplinarily challenges; limited management authority versus requirement for integration of results and commitment of all partners. The literature also points out that the project actors may depend on each other in terms of workflow (activities) or in terms of knowledge flow (Clement & Puranam, 2018); not only workflows but also knowledge flows shall be structured to improve performance of the organizations (Rauniar, Rawski, Morgan & Mishra, 2019). This suggests that the managers of multi-actor inter-organizational R&D projects shall structure both activities and knowledge to facilitate collaboration. How to structure such projects is however not well understood (vom Brocke & Lippe, 2015), but very important, as the consequences of structuring usually persist until the project end.

To address this research gap, we pose two related research questions: (1) How do activity coordination and knowledge integration interplay to define the architecture of inter-organizational R&D projects with multiple actors? (2) How does the project architecture favor (or disfavor) collaboration and how does it affect the resilience of the project and the requirements for project management?

To fill this gap, scholars call for a better connection between the research streams of project studies and innovation studies (Davies et al., 2018; Geraldi & Söderlund, 2018; Sydow & Braun, 2018), especially when studying projects that focus on knowledge generation (Berggren, 2019). In line with these calls, the theoretical framework contributes to better linkages between both streams of studies and builds upon the project management literature (Section 2.1), and also on the innovation management literature (Section 2.2).

2.2. *Structuring inter-organizational R&D projects: An innovation management perspective*

2.2.1. *Knowledge integration*

Knowledge is often created using the mechanisms of *exchange and combination* (Nahapiet & Ghoshal, 1998); the activation of these mechanisms is conditioned by the *opportunity for exchange or combination*, the *anticipation of valuable collaborative outcome*, the *motivation* to be engaged, and the *combinatory capability* (Moran & Ghoshal, 1996). However, the combinatory mechanisms are activated only when certain pre-conditions take place, such as reasonable cognitive technological distance (Nooteboom, Vanhaverbeke, Duysters, Gilsing & van den Oord, 2007) and existence of collaborative links and social relations, influencing the creation of social capital (Burt, 2004; Nahapiet & Ghoshal, 1998).

Combinatorial innovation (Obstfeld, 2005) requires knowledge integration. Scholars defined knowledge integration "as a process of collaborative and purposeful combination of complementary knowledge, underpinned by specific and focused personal, team and organizational capabilities, a process that usually involves significant element of new knowledge generation" (Berggren et al., 2011, p. 7). The more specialized the knowledge becomes, the more there is a need for dynamic knowledge integration for innovation: this is particularly critical in inter-organizational settings (Tell et al., 2017). Knowledge integration depends on the characteristics of knowledge being integrated (Brusoni & Prencipe, 2013; Johansson, Axelson, Enberg & Tell, 2011), and requires strong internal capabilities for exploiting external knowledge and adequate knowledge integration mechanisms (Berggren et al., 2011) such as rules, sequencing activities, organizational routines, group problem-solving, formal and informal interactions (Grant, 1996, Berggren et al., 2017, Canonico, De Nito, Esposito, Martinez & Iacono, 2017). Knowledge integration is goal-oriented process: in the project context, the goal is to create new knowledge in order to obtain the project outcome. Enberg (2012) pointed out that among two dominant approaches in literature on knowledge integration, one puts accent on the need for knowledge integration mechanisms based on frequent interactions and knowledge sharing, and another one emphasizes structural mechanisms, attaching lower importance to shared knowledge and joint understanding. Project structuring supports knowledge integration: it helps to deal with interdependencies between activities and components, to organize interactions, to stimulate exchanges when required, or put constraints on them, for example in case of coopetition in the project (Enberg, 2012).

2.2.2. *Modularity for knowledge integration*

The literature on innovation and modularity often studies knowledge base and knowledge flows through the network lens (Steen, DeFillippi, Sydow, Pryke & Michelfelder, 2018), putting the focus on the *architecture* of the network (e.g. Capaldo, 2007, Michelfelder & Kratzer, 2013, Rost, 2011, Yayavaram & Ahuja, 2008). Scholars conceptualized the architecture of networks in terms of the nodes that make up the network, the couplings between the nodes, and the resulting pattern of interconnections (Ahuja, Soda & Zaheer, 2012). In the context of inter-organizational R&D projects with multiple actors, the interconnections are in terms of patterns of coordinated activities and in terms of patterns of knowledge integration; interconnections of knowledge and activities may be partially independent (Brusoni & Prencipe, 2006; Tell, 2011). The interplay of these patterns defines the project architecture.

Architecture of a complex organizational setting is rooted in the concept of modularity, or decomposability (Simon, 1969). Simon's seminal theory of complex system and near decomposability puts in evidence that the structure influences the performance of a system: complex systems with nearly decomposable configurations adapt themselves to the demands of their environment more easily than non-decomposable systems; the level of decomposition depends on the necessity of interactions between components that is necessary to achieve the intended results (Simon, 1969). Modularity describes the degree of independence and interdependence between the components of a system (Baldwin & Clark, 1997), which can also be conceptualized as the presence or absence of couplings (Orton & Weick, 1990). Couplings are often studied using social network theory (Coleman, 1988; Granovetter, 1973), which suggests that the variations in the properties of the networks, such as the structure and the strengths of relationships or couplings between the nodes in the network "account for differences in outcomes for the networks (or nodes)" (Borgatti et al., 2009, p. 895). Orton and Weick (1990) described couplings in terms of distinctiveness and responsiveness: "if there is responsiveness without distinctiveness, the system is tightly coupled. If there is distinctiveness without responsiveness, the system is decoupled. If there is both distinctiveness and responsiveness, the system is loosely coupled" (Orton & Weick, 1990, p. 205). In the project context, distinctiveness is about setting up distinct modules, while responsiveness is about maintenance of the coherence between the modules.

A modular structure facilitates coordination, helps to organize the knowledge base and the interdependencies (Brusoni & Prencipe, 2013; Yayavaram & Ahuja, 2008), helps to manage complexity (Tee, Davies & Whyte, 2019), it also may help to achieve efficiency in integration of specialized knowledge (Grant, 1996). However, too high modularity has downside effects, e.g. it encourages specialization within modules, thus creating barriers to collaboration: this is the reason why modularity is often counterbalanced by integration (Tee et al., 2019), through the couplings between the modules, which – especially when they are not precisely defined initially - require dynamic management to ensure coherence of the system (Brusoni & Prencipe, 2013).

2.2.3. *Modularity for knowledge integration in inter-organizational structures*

Previous research has investigated the characteristics of actors, knowledge, degree of modularity and relevant knowledge integration mechanisms in different inter-organizational settings and contexts. Below, some main findings of prominent scholars about several inter-organizational structures are provided.

Inter-firm R&D projects are characterized by a relatively limited number of involved autonomous organizations and by a limited (usually up to several years) duration of the project. In such settings, analysis of the interplay between *coordination*, or alignment of the knowledge of the firms, and *cooperation*, or alignment of the interests of the firms and their relationship, is needed for better understanding of knowledge integration: the problems of coordination are related to knowledge characteristics - multi-disciplinarity, interdependence, degree of tacitness…, and thus call for adequate knowledge integration mechanisms, and both coordination and cooperation call for appropriate governance mechanisms (Johansson et al., 2011). Rotating leadership is an example of a governance mechanism that helps to diversify the access to different knowledge in different phases of the project and to facilitate knowledge integration (Davis & Eisenhardt, 2011).

R&D *business ecosystems* are characterized by the presence of a focal, orchestrating firm, multiple partners and relative stability of relationships without fixed durations. Brusoni and Prencipe (2013) studied coupling and knowledge in such settings, and demonstrated how different types of couplings between the actors are influenced by the features of the problems that require to be addressed, how types of couplings relate to the degree of specific knowledge characteristics, such as uncertainty, complexity, and ambiguity, and how types of couplings may have to evolve over time: "ambiguous problems call for tightly coupled ecosystems; complex problems call for loosely coupled ecosystems; and uncertain problems call for decoupled business ecosystems" (Brusoni & Prencipe, 2013, p. 167). The level of ambiguity also depends on the historic collaboration and the context of project preparation (Engwall, 2003), and it echoes the degree of tacitness of knowledge being integrated (Johansson et al., 2011): the higher the ambiguity, the higher the tacitness of knowledge, the more couplings and interactions are required.

In *innovation collaboration networks*, scholars studied the decomposability of the knowledge base with different strengths and density of couplings, and pointed out a continuum of different types of architectures (Yayavaram & Ahuja, 2008): in *highly decomposable* knowledge structures**,** dense couplings exist within modules but not between modules; in *nearly decomposable* structures**,** there are dense couplings within modules and loose coupling between modules; in *integrated* (non-modular) structures, there are strong and pervasive couplings between groups of elements which are in interactions and interdependent. It was also found that there is no optimum architecture, as it depends on the objectives of the actors (Ahuja, 2000), but the nearly-decomposable architecture combining strong and weak couplings is considered beneficial in terms of the performance of inter-organizational collaborations (Michelfelder & Kratzer, 2013; Rost, 2011; Yayavaram & Ahuja, 2008).

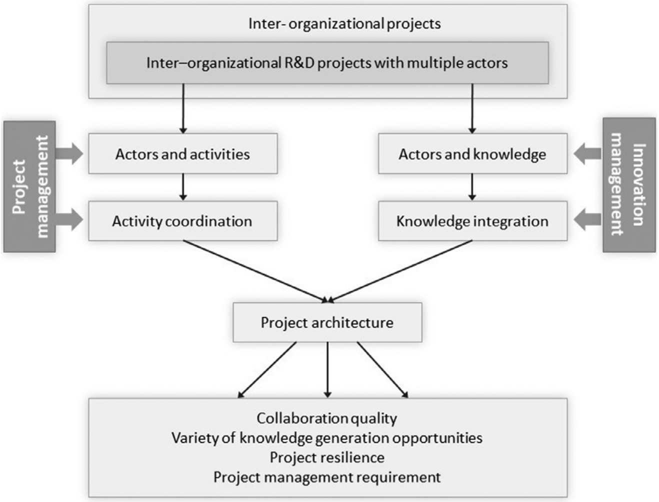

Fig. 1. Conceptual framework: the interplay between activity coordination and knowledge integration.

Extant literature mostly deals with inter-firm project and networks, often with one orchestrating firm: although the findings presented above provide directions, they do not provide an answer to the research questions in the context of inter-organizational R&D projects with multiple actors. First, as mentioned before, these projects operate in contexts which are characterized by complexity, ambiguity and uncertainty *at the same time*: this requires tight coupling to deal with ambiguity, but also loose coupling to deal with complexity and uncertainty (Brusoni & Prencipe, 2013), and it is not clear how to combine different types of couplings. In addition, there is no focal firm. Second, there are multiple options of couplings because of many organizational actors. Rotating leadership (Davis & Eisenhardt, 2011) is hardly feasible at the project level due to the contractual arrangements with the funding agency. Third, to the best of knowledge of the authors, the architecture of couplings and its implications in inter-organizational R&D projects with multiple actors were not studied yet.

2.3. *Towards a conceptual framework*

Our understanding of the differences amongst inter-organizational R&D projects is still limited (Ahola, 2018) and it is of interest to analyse different settings of collaborative R&D projects with multiple actors, as these projects offer multiple options to structure activities and knowledge, with different implications which are yet not well understood. Sydow and Braun (2018) pointed out that most project theories put the accent on the actors, and most network theories put the accent on the pattern of interdependencies, while none of them shall be put first: both are related and both shall be analyzed together. This duality of patterns is not well studied (Pinheiro et al., 2016). The proposed conceptual framework (see Fig. 1) takes the duality of patterns into account, grounds the research study in theoretical constructs and provides a foundation to investigate the research questions defined in Section 2.1.2: how do activity coordination and knowledge integration interplay to define the architecture of inter-organizational R&D projects with multiple actors? How does the project architecture favor (or disfavor) collaboration and how does it affect the resilience of the project and the requirements for project management?

In projects, a dynamic layer of processes is required in addition to the structure (Lundin & Söderholm, 1995) and both, the architecture and the processes, should be analyzed (Aubry & Lavoie-Tremblay, 2018). This paper puts in focus the project architecture, because the interplay between activity coordination and knowledge integration as well as its implications are not well understood in structurally inflexible projects with multiple actors. The scope of both architecture and processes would be too broad for a single paper.

3. Research setting

The research setting is defined as inter-organizational R&D projects with multiple actors, that are funded through competitive open calls by the European Commission (EC) through its latest Framework Programmes of Research and Innovation: the 7th Framework Programme (2007–2013) and Horizon 2020 (2014–2020). Although the topic of each project is specific, their setting is similar. The EC calls define the topic, the challenge, and the scope of the projects. The goal of the projects is pre-competitive R&D, the intended outputs is generation of new knowledge which is translated into innovations. The on-going Programme uses the term “research and innovation action” or “innovation action” for these projects, to highlight innovation beyond knowledge generation. The projects usually last three to four years and they are managed (coordinated, in the EU terminology) by a coordinator (project manager in this paper) which can be from industry, from a research organization or from a consultancy. During the proposal preparation, the applicants agree on the way to organize their collaboration patterns, and they must demonstrate in the proposal why the project requires a joint effort and the presence of each partner. The projects have a well-defined architecture in terms of workflow: they are decomposed into work packages and tasks which provide the logical structure of the project activities. The proposal also describes the collaborative links between the partners, thus identifying the knowledge integration pattern. The project architecture is chosen based on the previous experiences of participants. At the proposal stage, time and available resources usually put tight restrictions on the exchange of information. There is a great deal of tacit knowledge involved in the projects.

There are three main reasons that make this setting particularly interesting for management research. First, because the field is large and important: inter-organizational R&D projects with multiple actors have become an important instrument of R&D funding, and the number of such projects is steadily growing; the on-going Horizon 2020 Programme has already provided 27,55B€ to fund 5147 such projects involving over 70,000 participants (organizations) all over the world. Second, the number of partners in such projects is quite high, over 13 on average (European Commission, 2020). Third, the projects lack structural flexibility, it is difficult to change partners or to drastically revise the workplan. Thus, the consequences of the architectural choices mostly persist until the project end.

The field is difficult to access: consultation of internal project documents by external organizations is possible only with unanimous authorization from all project partners because of confidentiality reasons. As the project work is reviewed by the funding agency, the partners of on-going projects are reluctant to share their concerns other than in interviews with someone they know and trust, with anonymity guaranteed. In addition, partners are geographically distributed across Europe and beyond. Given these difficulties, it is not surprising that this field so far remained largely outside the focus of management research. Our study was enabled by the fact that the first author was either known by the informants or was introduced to them through a co-author or a common contact, and got access to data, the second author guided the research process and challenged the findings, and the third author has participated in many EU-funded multi-actor inter-organizational R&D projects.

4. Research design

We have adopted the exploratory inductive multiple case study method (Eisenhardt, 1989). Multiple case studies usually provide a stronger base to build theory (Eisenhardt & Graebner, 2007; Yin, 1994), enable comparison and demonstration of replication (Eisenhardt, 1991) and provide a deep understanding of the investigated phenomena and processes (Bakker, De Fillippi, Schwab & Sydow, 2016). A detailed case study protocol was developed with two phases, including specifications of the quantity and variety of data collection (Avenier & Thomas, 2015).

4.1. Case selection and data collection

4.1.1. Phase one. Identification of project architectures

For this phase, 11 projects were selected, using three selection criteria: *homogeneity, variety and availability of data. Homogeneity*: The selected projects (1) are inter-organizational R&D projects with multiple actors; (2) have durations from 3 to 4 years; (3) have a considerable number of partners, between 10 and 21. *Variety*: the projects vary in terms of (1) technology maturity (European Commission, 2014); (2) project advancement: completed or on-going; and (3) their thematic. We selected projects where it was possible to have *access to project data*. Each of these 11 projects is unique, but the whole sample enabled us to recognize and compare architectural patterns and to analyze their influence on the project execution.

Names of celestial constellations were given to the projects for their anonymization. The projects were firstly studied in terms of their characteristics, using content analysis of over 1500 pages of project documentation: 624 pages of project proposals, over 900 pages of public and internal project reports, and approx. 50 pages of agendas of plenary meetings.

Following the literature, we conceptualize *modularity* as the degree of (inter)dependence, or couplings, between the project actors, in terms of knowledge flow or/and workflow. We studied modularity by capturing the couplings (working links) between partners in the project as well as the strength of these couplings and dependencies (activities or knowledge). For example, if academic and industrial actors collaborate throughout a project, they form a module of knowledge and activities with tight couplings. Loose couplings describe weak, punctual or irregular collaborative links: this is, for example, review by one partner of a work done by another partner.

Based on the literature, we adopted the following definitions. A *project* combines different *elements*: actors, activities, knowledge, organized into *components*, which in turn may form *modules*, i.e. sets of activities organized in a thread of work for a common purpose, to produce specific outputs. Modules are characterized by a strong integration of the activities and of the knowledge of the participating partners. *Integrative module(s)* receive input from two or more other modules, and/or provide input to other modules, and produce own output(s). A *coupling* defines a connection between the elements or groups of elements of the project. The strength of a coupling, *weak or strong*, defines the degree of inter-dependence between the elements. A *project output* is an element of the finality of the project. The *resilience* of a project architecture describes to which extent the project is affected if an element is encountering problems, e.g. not performed or not performed satisfactorily. Previously, scholars conceptualized also *interacting* activities between partners, such as plenary project meetings, as weak couplings (e.g. Michelfelder & Kratzer, 2013, Pinheiro et al., 2016). These activities facilitate knowledge integration, and meetings may be part of the project architecture, however regular plenary meetings are mandatory in all projects in the research setting, and they are not specific to the types of architecture. Thus, for theoretical clarity, this paper focuses on working relations between partners as elements of the architecture*;* interactive activities are considered as part of the knowledge integration mechanisms.

Table 1
Overview of informants and number of interviews.

Profile	Total	Informants (number) incl. those participated in two or more projects under study	Interviews (number)
Research/university	11	2	17
Industry	22	5	24
incl. large industry	10	4	12
incl. tech SMEs	12	1	12
Consultancy	2	0	2
TOTAL	**35**	**7**	**43**

We used three criteria to identify the project architectures: the *finality* (how many project outputs are planned or obtained), the *decomposition* of the project (how many modules are planned, are they running in parallel or sequentially, are they dependent), and the *coordination* (*connectedness* between modules, density and strength of integrative modules). We asked at least one core project actor, usually the project manager, to verify the identification of the project architecture: the use of both primary and secondary sources enables triangulation of the collected information in order to avoid potential interpretation biases (Eisenhardt, 1989). Appendix 1 provides an overview of the projects and their architectures.

4.1.2. Phase two. Understanding the effect of the project architecture

For this second, explicative phase of the study, following Eisenhardt (1989), we selected projects that are *comparable* and applied two additional criteria to narrow down the knowledge base from 11 to 6 cases that (1) represent *all types and sub-types of architectures* identified in the first phase, and (2) are at an advanced project stage or already *completed*. In all selected projects, about half of the partners had historical experience of joint work. We conducted 43 semi-structured interviews in 2018–2019: 39 interviews of about one hour duration each, and 4 complementary shorter interviews, that focused on specific issues that required additional investigations. The interviews involved 35 informants; in each project, representatives of between 35 and 65% of the participating organizations were interviewed. We used theoretical sampling (Eisenhardt, 1989) to select the informants, using three criteria: different profiles of the partner-organizations (large industry, technological SMEs, research organization), different roles of the persons in the projects (project manager, workpackage leader, contributor), different levels of participation of the persons in EC-funded multi-actor projects (multiple projects or newcomer). In order to have comparable data, we selected experienced informants: over 80% of the informants were CEOs of technological SMEs, team leaders within large multinational corporations, university professors and research directors. These informants allocated only part of their activities to the studied projects and thus they were able to see the project in a larger context. 7 informants participated in more than one project from our sample and thus interviews included comparative elements, adding to this research a comparative multiple-case dimension. An overview of the informants is provided in Table 1.

The interview protocol included 8 groups of questions related to (1) project preparation and context; (2) motivation of organizations to participate in the project; (3) project overview and outputs; (4) project architecture; (5) inter-organizational collaboration and its evolution over time; (6) new knowledge generation; (7) involvement of external parties, their influence; and (8) project management. A detailed interview guide was developed, and all interviews were recorded. Before the interviews, information was provided to the informants according to European General Data Protection Regulations, and their consent was obtained about the recording. The fact that the informants knew one or more of the co-authors, either directly or through a colleague, supported establishing of trust since the beginning of the interview and resulted in the collection of a wealth of information.

The interviews resulted into 45.02 h of recording and 791.2 pages of materials transcribed verbatim (Table 2). The results of the interviews were compared with the findings of Phase 1 and confirmed the classification of the project architectures.

4.2. Data analysis

The data analysis in phase two is based on the abstractive process of open coding (Strauss & Corbin, 1998, adapted by Gioia, Corley & Hamilton, 2013). The interviews transcripts were firstly coded using the NVivo 12.1 software: a data structure has been built by grouping 31 concepts of 1st order into 13 aggregate and more abstract themes of the 2nd order, which were combined into 6 aggregate dimensions (Appendix 2). Then each dimension was matched with different types of architectures identified during the documentary analysis. Coding and analysis were done for each of the 6 cases, and then the results of the analysis were compared across cases. During the research process, reflections on the theoretical foundations were performed and some new elements were added to the interviews in response to these reflections, e.g. on historic experience (Engwall, 2003).

5. Results

The findings are presented below in two parts: firstly, the typology of the identified project architectures is presented, with their characteristics and sub-types. Then, the analysis of the implications of different types of architecture is provided.

5.1. Identification of three main types and six sub-types of project architectures

To facilitate the explanations, a conceptual representation of the project architecture is shown in Fig. 2. It provides an example of a project with four modules: three parallel modules, with small groups of contributing organizational actors following three main consecutive stages of activities (workflow), and one integrative module (green color) going throughout the project, where the whole group of actors contribute.

The results of the first phase put in evidence three main types of project architecture (Table 3): *workflow-integrated* (3 projects)*, nearly decomposable* (6 projects), and *decomposed* (2 projects). The project architecture is not easily recognizable in the proposals: the workflow and the knowledge flow are often “hidden” in the formal structure of the workpackages and only became visible thanks to the analysis of internal project documents.

The *workflow-integrated* architecture is sequential*;* its defining features are a dominating collaborative finality and the absence of modularity.[1] It has two sub-types, *sequential* and *converging*. The *sequential* sub-type is in fact one big module that runs through the project: output from one stage is a prerequisite for the work at the next stage, the groups of activities (components) are strongly interdependent. Strong couplings exist within the components where two or more partner contribute. In the *converging* sub-type, the work is organized in several parallel components; work starts with a joint, integrative activity where most partners contribute, such as the development of specifications for a software platform. However, this integrative activity is only a first step in the process, and the result of this activity does not have its “own life” after the end of the project.

The *nearly decomposable architecture* comprises three sub-types: weakly coupled, grid, and waterfall. They all consist of modules with

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[1] Isolated work of partners which does not have important consequences on the project in case of their failure, does not count as a module.

Table 2
Overview of interviews per case study.

Anonymous Name	Partners-organizations (number)	Interviewed organizations per case		Interviews, including compar. (number)	Interviews per profile of informants (number)				Recording (minutes)	Trans-cripts (pages)	Type / sub-type of project architecture (de facto)
		number	%		Research	Industry: Large	Industry: SME	Consultant			
GEMINI	13	6	46	6	1	1	3	1	410	118,1	workflow-integrated, sequentual
SCORPIUS	14	5	35	5	1	1	2	1	298	87,6	workflow-integrated, converging
HERCULES	10	4	40	6	3	2	1	0	443	130,3	waterfall
ORION	17	11	65	11	4	3	4	0	639	201,1	grid
PERSEUS	15	7	47	8	5	2	1	0	527	145	decomposed
PEGASUS	12	6	50	7	3	3	1	0	384	109,1	weakly coupled
TOTAL				**43**	**17**	**12**	**12**	**2**	**2701 (45,02 h)**	**791,2**	

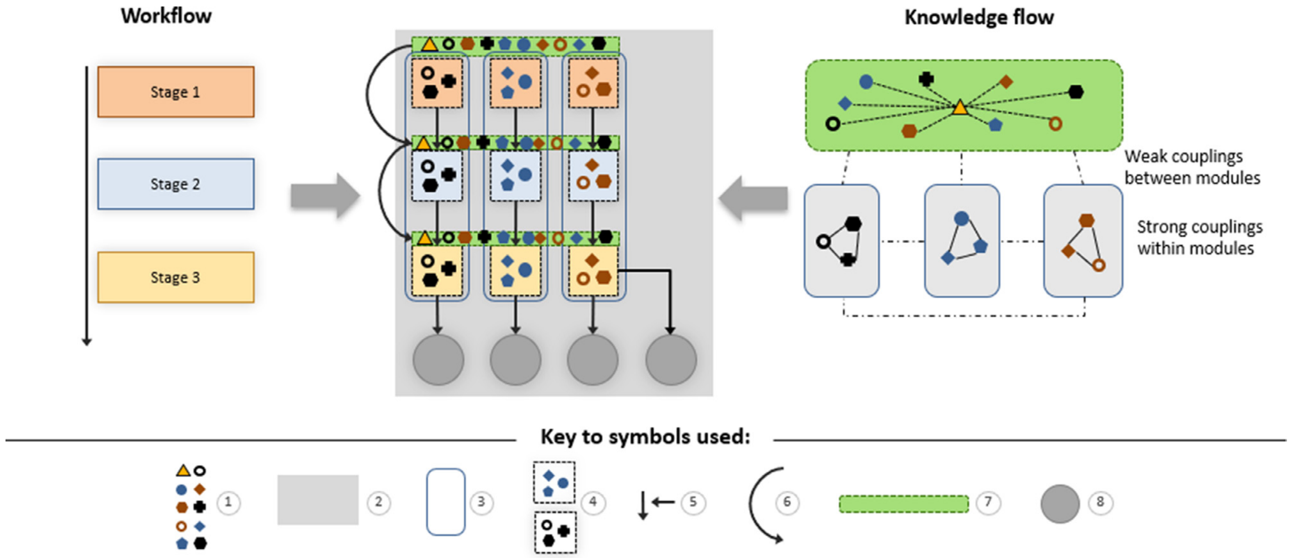

Fig. 2. Conceptual representation of the project architecture (example of a project with three parallel modules and one integrative module). Key to symbols used: 1: set of partners (organizations); 2: project boundary; 3: module; 4: components (with collaborating partners); 5, 6: dependencies; 7: integrative module; 8: main project output. Couplings within the components and intermediary project outputs have been removed for clarity.

Table 3
Three main types of architecture in inter-organizational R&D projects.

Type of project architecture	Sub-types of project architecture	Number of main outputs	Structure of activities		Knowledge base
			Decomposition of activities	*Integration of activities*	
Decomposed (highly decomposable)	N/A	Several (at least one per module)	Decomposed into independent modules, with dense couplings within modules	No couplings between modules	Strongly integrated within modules, no coupling between modules
Nearly decomposable	Three: weakly coupled, grid, waterfall	Several (at least one per module)	Decomposed into independent modules, with dense couplings within modules	Couplings between modules are not pronounced but relevant	Integrated within modules, nearly decomposable in integrative module
Workflow-integrated	Two: sequential converging	One	Integrated, with strong couplings between groups of activities	Integrated, elements are sequentially dependent	Decomposed; integration only happens at the inter-faces and on a lower level if the group of partners works together

Table 4
Main characteristics of the sub-types of architectures.

Type of architecture	Organization of workflow			Strengths of couplings	Stage of the project when integrative activities happen (if applicable)			Strength of integrative activity (if applicable)	
	Sequential	Parallel	Integrative		Early stage	Mid-term	End stage	Strong	Weak
Workflow-integrated									
Sequential	X			Strong between interconnected components		Between interconnected components			
Converging	X	X	X	Strong between interconnected components	X		X	X (end stage)	X (early stage)
Nearly decomposable									
Weakly coupled		X	X	Strong within modules, weak between modules		X			X
Grid		X	X	Strong within modules, vary between modules	X	X	X		X
Waterfall		X	X	Strong within modules, strong in the first phase (integrative module), weak between modules	X			X (starts early)	
Decomposed		X		Strong within modules					X

strong couplings within them and resulting sets of collaborative outputs. The defining feature of this type of architecture is the presence of some degree of connectedness between parallel modules, *integrative module(s)* of different intensity, with their own output(s). The knowledge base is strongly integrated in the modules and loosely coupled between the modules. The workflow couplings are sequential in modules and loose between modules. The *weakly coupled* sub-type is composed of independent sequential modules where a limited number of partners collaborate, combining complementary knowledge bases within each module, and at least one finality per module. The *grid* sub-type includes integrative module(s) that interact with other modules regularly at various stages: they are intended to bring actors together at regular intervals to work together throughout the project. The *waterfall* sub-type includes one important integrative activity which starts at the beginning of the project, then the output of this module is used in a “waterfall” of parallel modules. For the purposes of triangulation, the strength of the integrative module was not only estimated during the interviews, but also measured quantitatively, calculating reported person-month inputs of all partners in the integrative modules comparing to the overall volume of person-months in the project: it was 3.5% in PEGAGUS (weakly coupled), approx. 10% in ORION (grid), and approx. 20% in HERCULES (waterfall). This quantitative data thus confirmed the qualitative feedback that was collected during the interviews.

The *decomposed* architecture follows a completely modular pattern: similarly to the weakly coupled architecture, the project is decomposed into parallel modules, or sub-projects, often running throughout the project, but there is very little connectedness between modules. Table 4 summarizes the main characteristics of the six sub-types of the project architecture.

The typology of architectures is conceptually presented in Fig. 3. When the project is driven by a well defined main technological output, then it is similar to product development projects, and the project architecture is workflow-integrated. When the outputs are ambiguously defined and numerous, there are several options to structure the project but a nearly decomposable architecture is advantageous, with different strengths of the integrative module(s). In the studied projects, nearly decomposable type of architecture was chosen when several industrial actors wished to develop innovative solutions for their specific needs, or when several scientific actors wished to develop, compare and validate different approaches to similar fundamental problems. In the former case, the relatively strong integrative module provided opportunities to develop the concept and implement it in the modules, allowing for regular feedback loop. In the latter case, the weak integrative module provided opportunities for scientific interactions, linking the modules.

5.2. Implications of the types of architectures

During the second phase, we performed a deeper analysis of the effects of the architecture on project resilience, project management requirements and *planned* collaboration and knowledge integration. The findings show that most partners planned collaborations at the proposal stage, both by planning couplings with known actors, to continue historic collaborations, and by putting forward couplings with new collaborators:

> *“I prefer to follow something like a 70/30 strategy, okay so taking 70% partners you have worked with already or whom you know reasonably well to be relatively sure, and you add 30% you want. Otherwise it gets too boring… If you continue for too long you need a bit of new ideas and you have a new topic and it is better to look for the right people for the topic” (ID5_ORION_res). “To meet new partners, this is another motivation, okay… to meet new partners with new ideas…” (ID34_ORION_res)*

The project architecture is crucial for the realization of collaborations:

> *“The design is everything, the design provides the framework, what you don’t have in the design does usually not happen a lot. It pushes, it defines where to work together on what to work together” (ID36_HERCULES_compar_res).*

The projects that were studied during the second phase are highlighted in boldface in Appendix 1. A summary of the implications of the different types and sub-types of architectures is presented in Table 5, then the following sections explain the table.

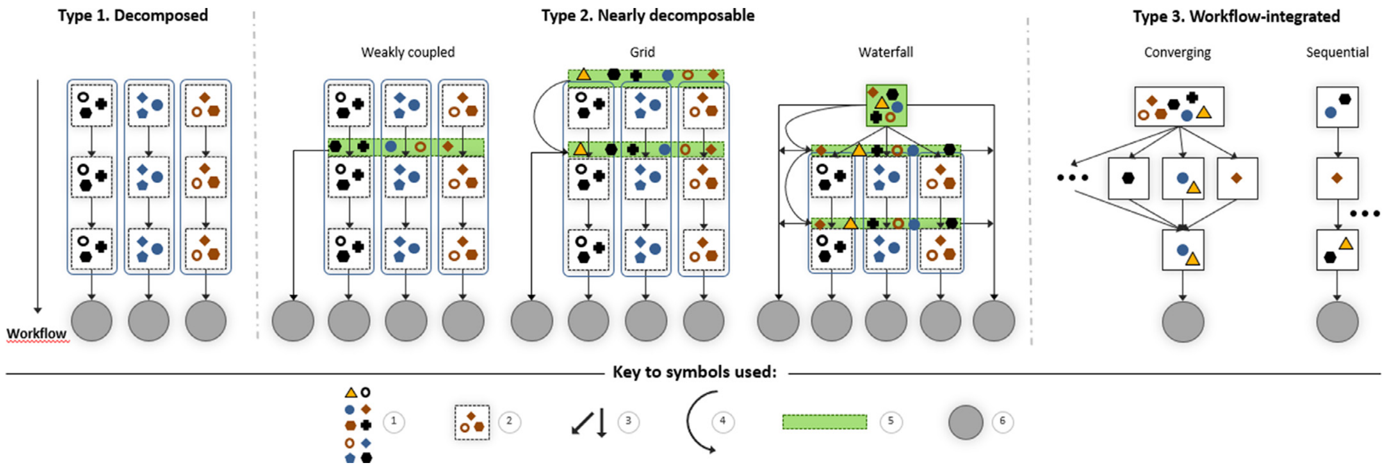

Fig. 3. Types and sub-types of architectures of the projects included in the study. Key to symbols used: 1: set of project partners (organizations); 2: component (group of collaborating partners), 3, 4: dependencies, 5: integrative module, 6: main project output. Links at lower level and intermediary project outputs have been removed for illustration clarity.

Table 5
Implications of the types of project architectures on knowledge integration, collaboration, project resilience and project management.

Type of architecture	Variety of potential knowledge integration	Collaboration quality / difficulties in terms of collaboration and knowledge integration	Project resilience	Project management cost		Scientific/technical skills of project manager required?
				Coordination of activities; delivery of project outputs	Knowledge integration	
Workflow-integrated						
Sequential	Low	Easy within components, difficult between not connected components with different partners	Low	High	Low	No
Converging	Low to medium	Same as above, but additionally difficult integration	Low	High	Low, then high at the last stage	Preferably
Nearly decomposable						
Weakly coupled	Low to medium	Easy within the modules, more difficult at the weak couplings across modules	High	Low	Low to medium	Preferably
Grid	High	Easy within modules, difficult otherwise	High	Low	Medium to high	Yes
Waterfall	Medium	Easy within modules, the first integrative phase is demanding	High	Low	High	Yes
Decomposed	Low	Easy within modules, no collaboration between modules	High	Low	Low	No

5.2.1. *Workflow-integrated architecture: Knowledge-disintegration but a collaborative final output, requiring high managerial effort and strong managerial skills*

The *workflow-integrated* architecture (GEMINI, sequential, and SCORPIUS, converging) disintegrate knowledge: the partners contribute what they know best, this results mainly in isolated work at the organizational level with occasional synchronization. Some partners may contribute only to very specific tasks, often also limited in time, such as testing of a software. The architecture facilitates collaboration within the components and between tightly interconnected components. The partners deepen their technical /scientific skills in their domain of specialization; individual work of partners may be used by them after the project end, separately from the main project output. The variety of knowledge integration opportunities is low.

> *"We firstly discussed about the specification document, this deliverable was done together. And then all partners worked on their side, just to develop things" (ID12_SCORPIUS_cons)*

The architecture enforces collaboration of the whole team in terms of finality, in the sense that contributions of different partners are required to produce the main output, which is the result of the joint work. When an output of one group of partners is taken as an input by another partner, then there is strong workflow coupling, but there is no or little knowledge flow coupling. The resilience of the project is low: delay or failure in one of the major sequential components result in a major project shock.

> *"At the proposal stage, you are concerned about your own workpackage, you are pressed, well you do not pay a lot of attention to another work package. Then the project started, the deliverable of the first step was there, but the responsible for the next step looked at it and said 'okay this is fine but how am I supposed to start my work?'. Then we realized something is missing, there was the gap, the output of the first workpackage did not become the input of the second workpackage" (ID1_GEMINI_coord).*

The converging sub-type is even more risky: there is a high probability that all deficiencies in the previous stages of the project will ultimately harm at the final integrative stage. Thus, workflow-integrated projects require a high managerial effort with very competent monitoring of the work to ensure its timing and quality and, above all, to ensure that it matches with the needs of the subsequent stages. Such projects are suitable for coordination by consultants with strong managerial skills, but require a skilled and recognized technical development leader, usually the one who is behind the project idea. This type of architecture requires particular management attention during the proposal preparation: in case of failure of one partner with important tasks, as happened in one of the studied projects, another partner will have to assume the workload, otherwise the project would fail. The architecture is adapted for less complex projects when there is one main project output; it is similar to product development projects and the study found this type of architecture only in the projects which aims at the development of specific technology, such as new software platform.

Cutting just one essential coupling in a workflow-integrated project presents a major risk for the implementation of the project and puts strong pressure on the project management: continuation of collaboration is required even at high cost for management and for partners. Thus, workflow-integrated projects are not resilient from the point of view of workflow, but they are resilient in terms of collaboration.

5.2.2. Nearly decomposable architecture: Several modules with variety of collaborative outputs; the intensity of integrative module sets requirements for strong scientific/technical competences of the project manager

In the initial sample of 11 projects, the nearly decomposable structure was found in 6 projects. The modules in all *nearly decomposable architectures* in the projects studied during the second phase (PEGASUS – weakly coupled, ORION – grid, and HERCULES – waterfall) involve small groups of partners with complementary knowledge.

The *weakly coupled* architecture is beneficial to those participants who understand the topics dealt with in other modules without being involved in them, i.e. those with more experience and broad foundations:

> *"They did a lot of really hard research which I never understood in their presentations… this sounds good but whatever they are doing, I had no idea (smiles)…" (ID8_PEGASUS_ind). "The gluing part there were the universities. Companies always talked with universities. They were not linked between each others in general (ID23_PEGASUS_res).*

The *grid* sub-type, thanks to planned elements of joint work, provides *regular* opportunities for exchange and knowledge integration, these elements help to get cross-fertilization between the modules, and act as a glue: their loss would drive the project towards full decomposition into independent modules.

The integrative activity in *waterfall* sub-type of architecture starts at the beginning of the project and deals with a "challenge", e.g. a development of a new concept with planned contributions of all or most partners. It helps to deal with ambiguity and requires frequent interactions, especially at the beginning. New knowledge is then further deepened throughout the project thanks to the feedback from specialized modules, where partners work on e.g. new technologies and applications, and the integrative activity leads to a project output that has a "life on its own" after the project end. Thus, the waterfall architecture offers a variety of knowledge integration opportunities and especially favors the development of joint understanding between partners.

> "*There was from the very beginning a common theme and a common idea that we wanted to pursue. That helped a lot to draw the different ideas together. Some things have to brew for a while, and then all of a sudden the ideas are there and you can implement the ideas" (ID6_HERCULES_ind).*

> *"There was a bigger block of work where an unknown problem had to be solved, a problem where a solution was not known had to be solved by the consortium as a whole. It was a core part of the design. We had to develop this thing, and create a joint understanding. That was an aspect which I have not seen too often in projects, that virtually all partners had to get involved in the creation of something, and this is the creation of concepts and ideas brainstorming about them…And it went through the project from day one to day final" (ID36_HERCULES_compar_res)*

Comparing with the waterfall, the weakly coupled and grid architecture did not require knowledge integration at the project level at the beginning, as the concepts used in the projects were known and clear to the actors.

The resilience of weakly coupled and grid sub-types of architecture is relatively high from the point of view of the overall project viability: cutting of one module still allows the project to achieve the larger part of its objectives. But collaboration is much less resilient. For example, competition between actors working in one module suddenly appeared during the course of the ORION project: planned collaboration broke and the planned module disappeared.

> *The setup of the project was one reason why it was strongly suggested that we should step out. … And (a partner) becoming a competitor, that was something that… I really had no influence on. (ID33_ORION_ind)*

However, although the break in collaboration was regretful, it did not have major influence on the overall project outputs: the module in question was one of many project modules.

The waterfall architecture is more vulnerable at the initial stage than other nearly decomposable architectures, because of the strong links between the initial integrative module and the "waterfall" of further modules: in the studied project, the initial integrative module did not comprise tasks with a high technical risk. Some deficiencies of contributions to the integrative module (e.g. some non-contributing partners) did not prevent the module to continue.

In all studied nearly decomposable projects, the integrative module provided planned knowledge integration opportunities (of different intensity) for different project partners, and strengthened the collaboration in the project in several ways: it brought partners closer together that otherwise would only work in small groups, it widened the horizon of the partners by forcing them to unify concepts and ideas of an overarching nature systematically, and, because of joint work requirement, it 'pushed' for integration of knowledge coming from various backgrounds and applications.

> *"Most deliverables were not produced just by one partner, but by a group of partners, even* if *one partner coordinated the deliverable. We contributed to the deliverable, criticized them, gave them ideas, and the other way around, we have got very good input from other academic partners." (ID23_PERSEUS_res).*

> *"It (integrative activity) forces partners to really do something together, not just sit and listen. With the meetings as such, there is a certain randomness and arbitrariness of these interactions. When there are tasks when partners have to work together, the exchanges are much more deeper, richer… If there is a task that you have to do, it is easier to mobilize people."(ID43_ORION_res).*

Collaboration and management in weakly coupled projects are easy, as the modules mostly run throughout the project and they have their own leader. The grid and especially the waterfall sub-types require higher managerial efforts and strong scientific or technical competence of the project manager, to keep the project on track. This role is more adequate for an academic or industrial partner who is an expert in the project topic, with strong leadership skills. Significant efforts from the partners are required too to "keep alive" the integrative module.

> "*Work between partners and across components, this requires quite a bit of effort and coordination, so that it doesn't fall apart. That effort sometimes may be underestimated, managerial efforts but also efforts of the partners." (ID7_ORION_compar_ind).*

5.2.3. Decomposed architecture: Knowledge-integration within modules but workflow-disintegration between the modules; easy project management but little added value from the large inter-organizational setting

The decomposed architecture significantly limits the collaboration across modules, but it provides a setting for strong collaboration of small groups within specialized modules:

> *"We did not have scientific partners who could exchange over the boundaries of the modules because the modules were very specialized" (ID15_PERSEUS_res). "The topics of the projects were too far apart, people do not have much in common" (ID28_PERSEUS_ind). "It was work on our own, nobody understood what we are doing and nobody was interested in it. It was just for interest of us and our partner" (ID43_PERSEUS_res)*

When one partner organization, usually a research organization, provides input to several parallel modules, it may seem that this will help to make the project more integrated. However, this is not always true: the study found several examples when a research lab employs several staff, each of them working in different modules of the project with different partners on independent topics and with little interaction.

The decomposed architecture is highly resilient at the project level: in case of disruption, only one module will be affected, the other modules continue as planned. However, the modules by themselves are not resilient: the collaboration partners, usually from academia and industry with complementary knowledge, are interdependent during the whole project, and the success of the module critically depends on collaboration quality and on sufficient inputs of all partners involved. The leaders of the disintegrated modules manage the work in their modules. If the manager is a consultant not experienced in the technical domain of the project, then a decomposed project is the easiest type of project to manage.

> *"It's a very convenient way to run projects because then each industrial partner, each end-user, each technology developer can do what they want to do and that's basically it." (ID4_PEGASUS_res).*

The added value of the large inter-organizational setting is low in projects with decomposed architecture:

> *"If I was a reviewer for proposal, a proposal like this, I would always reject. Because that's not the idea of an EU project.… If you organize the project directly in modules, it is obviously not designed for collaboration" (ID7_ORION_compar_ind).*

Perhaps for this reason, the study uncovered that the fact that the project work is done in largely disconnected modules is often hidden in the proposals, by the introduction of "horizontal" workpackages in which "slices" of the modules are formally integrated under a common umbrella. The projects look integrated on paper and there were intentions to integrate knowledge, but the integration did not happen.

6. Discussion

The study has collected and analyzed rare and rich field data to contribute to project studies (Geraldi & Söderlund, 2018) and to bridge between the management and innovation literature (Berggren, 2019; Davies et al., 2018; Sydow & Braun, 2018), as discussed next.

First, the research provided evidence that the interplay between activity coordination and knowledge integration has a structuring effect and defines the architecture of inter-organizational R&D projects with multiple actors: both knowledge and activity flow shall be structured (Rauniar et al., 2019), both shape patterns of interactions in the project and decrease uncertainties (Raab et al., 2009; Söderlund & Sydow, 2019), and both actors (with their activities) and structures shall be considered in a duality in order to better understand inter-organizational R&D projects, none shall be put first (Sydow & Braun, 2018). For the first time, different architectures of inter-organizational R&D projects were identified and light was shed on the setting of inter-organizational R&D projects with multiple actors (vom Brocke & Lippe, 2015), using a network lens (Steen et al., 2018). Research explaining the differences between inter-organizational projects is still at its early stage (Ahola, 2018); the study has proposed a typology of project architectures, consisting of three main types and six sub-types. The identified architectures do not depend on the number of partners or the domain of the project.

Second, the study shows that although the optimum architecture depends on the intended innovations and the interests of the partners (Ahuja, 2000), for projects with specific characteristics there may be optimum structure. Two elements especially play a role: the characteristics of the final outputs, in terms of their number and the degree of their ambiguity, and the degree of ambiguity of the problem addressed in the project. If there is one main finality, it is well defined and the ambiguity is low, then the workflow-integrated architecture is suitable. If the ambiguity of the outputs is high and the outputs are diverse within an overarching setting, potentially driven by the interests of groups of partners, then the modular architecture (nearly decomposable or decomposed) is suitable, and there are more options to structure the project. If there is high degree of ambiguity at the beginning of the project and joint work is required initially (Calamel et al., 2012) to reduce it, then the waterfall architecture is the most adequate one. If the ambiguity is low at the beginning of the project, then direct division into distinct modules (e.g. weakly coupled or grid architectures) is possible, with different degree of connectedness, depending on the required level of knowledge integration between modules and knowledge sharing constraints (Enberg, 2012). If there is no need for shared knowledge between the modules, e.g. if the outputs of the projects fall under a common theme but are not related, then the decomposed architecture is suitable. In the sample of 11 projects analyzed in this paper, the nearly decomposable structure is represented strongly, and most projects are modular: this is not accidental but reflects the needs and the constraints of inter-organizational R&D projects with multiple actors from industry and academia. Extant literature argues that if the uniqueness of projects is *low*, many elements of the project architectures can be used from one project to another (Ahola, 2018). This study went a step further to show that even when the uniqueness of projects is *high*, there are typical project architectures which can be used from one project to another. Thus, the study provides heuristics to structure inter-organizational R&D projects.

Brusoni and Prencipe (2013) have shown that different levels of complexity, uncertainty, and ambiguity of knowledge call for different types of couplings within an inter-organizational structure and that the couplings may evolve over time. The present study extends the findings in the complex, ambiguous and uncertain context of the projects with rigid structures, where interconnections of knowledge and activities may be partially independent (Tell, 2011): it has been shown that the project architecture can enable the evolution of couplings and it can help to cope with the low structural flexibility.

Third, the study provided insights into the implications of the project architectures. Some of them favor collaboration within the project through integration of workflow, others favor collaboration through integration of knowledge; the waterfall structure help in creating a common base of understanding at the very beginning. The workflow-integrated projects, where partners work for the same finality, provides considerably less opportunities for collaboration than other types of architectures, while decomposed projects consist of largely isolated clusters of knowledge and activities, and the value of the large inter-organizational setting for collaboration is low. Historic experience helps to facilitate collaboration (Engwall, 2003) but may conflict with the R&D nature of the projects, which calls for opening them towards new actors to look for new ideas and approaches, as the study shows. Different types of architecture put different requirements in terms of the role and cost of project management, and the need for scientific or technical skills of the project manager. As previous studies have shown in other contexts (Michelfelder & Kratzer, 2013; Yayavaram & Ahuja, 2008), the nearly-decomposable architecture is beneficial for the innovation performance of inter-organizational settings. However, this architecture is demanding in terms of management efforts and requires not only management skills, but also specific scientific or technical skills, depending on the strength of the integrative modules. It is difficult to maintain the coupling via the integrative module and to make knowledge integration happen (Brusoni & Prencipe, 2013; Tiwana, 2008), but if the integrative module is maintained, it adds a lot of value to the project, as the study shows. The research has also contributed to a better understanding of how inter-organizational structures should be designed for resilience (Linnenluecke, 2017). Disturbances in workflow-integrated project presents a major risk and this puts strong pressure on the project management to find adequate solutions and practices (Kapsali, 2011).

The research presented here has certain inherent limitations. The empirical evidence is limited to multi-actor inter-organizational R&D projects funded by the European Union Research and Innovation Framework Programmes, which have specificities such as a large number of organizations working together and a rather inflexible structure. It does not include projects of smaller size funded by the national programs. The study covers a certain selection of themes and projects; thus, it is possible that there are additional types of interplay between workflow and knowledge flow, leading to other types of project architectures that have not been found in this study. The paper focused on the project architecture and does not discuss the types of knowledge that is generated in the projects or the knowledge integration processes that operate within the projects. The collaboration quality also depends on the historic experience of the partners, the project context and the dynamics of the participating organizations (Engwall, 2003). However, these factors play a limited role in the definition of the project architecture and therefore were not included in the analysis.

7. Conclusion

7.1. Contributions

The study aims at developing new perspectives on inter-organizational R&D projects with multiple actors by means of an empirical qualitative analysis of selected projects from the latest European Research and Innovation Framework Programmes. Making use of and bridging the research streams of project management and innovation studies, the study focuses on the interplay between activity coordination and knowledge integration. It suggests a typology of architectures and discusses the implications of each type of architecture on the execution of the projects. The findings show that the workflow-integrated architecture disintegrates the knowledge base, provides a lower collaboration potential and may require high management efforts, while a workflow-decomposed architecture allows easy project management but provides little added value from the inter-organizational setting. Nearly decomposable architectures offer the highest collaboration potential under contingent conditions.

The study provides contributions for theory and practice of project management. On the theoretical level, it leads to a better comprehension of how activity coordination and knowledge integration simultaneously influence the project execution and set requirements for project management. On the practical level, the study provides heuristics on the choice of the architecture and helps to understand the implications of the choice of the architecture. It provides guidance to the project managers, as well as to the funding agencies, about how to adequately structure collaborative R&D projects with multiple partners. Overall, the results of the study enhance the understanding about complex inter-organizational R&D projects with multiple actors, which are *networked projects*: the *network* of organizational actors collaborates in the framework of a *project* with the goal to integrate knowledge and develop innovations.

7.2. Future research directions

The findings of the study point to several exciting and relevant questions for future research. To better understand inter-organizational R&D projects with many actors, it would be of interest to study in more detail the processes that operate within the projects. Couplings can be studied as a structure and as a process (Brusoni & Prencipe, 2013), and future research could also help to better understand the processes and mechanisms that influence knowledge integration in this empirical context. Also the historic experience of the actors, the project context, the dynamics of the participating organizations (Engwall, 2003), the coordination and cooperation processes as well as the governance mechanisms (Johansson et al., 2011) shall be taken into account.

The study found that some connections and knowledge integration were planned but did not happen, resulting in a reconfiguration of the couplings. Thus why and how dynamic reconfiguration happens in structurally inflexible multi-actor projects, and what the consequences of this are on new knowledge generation should be investigated. The project size regularly increases: for instance, it has more than doubled in the European Research and Innovation Programmes during the last 20 years, from 6.1 to 13.7 partners per R&D project on average.[2] Whether larger inter-organizational settings, which are not easy to structure, are beneficial for knowledge generation and how the project management and knowledge integration mechanisms should be adapted to this trend is another promising research direction, which also could be useful for the designers of the research programmes.

Declaration of Competing Interest

None.

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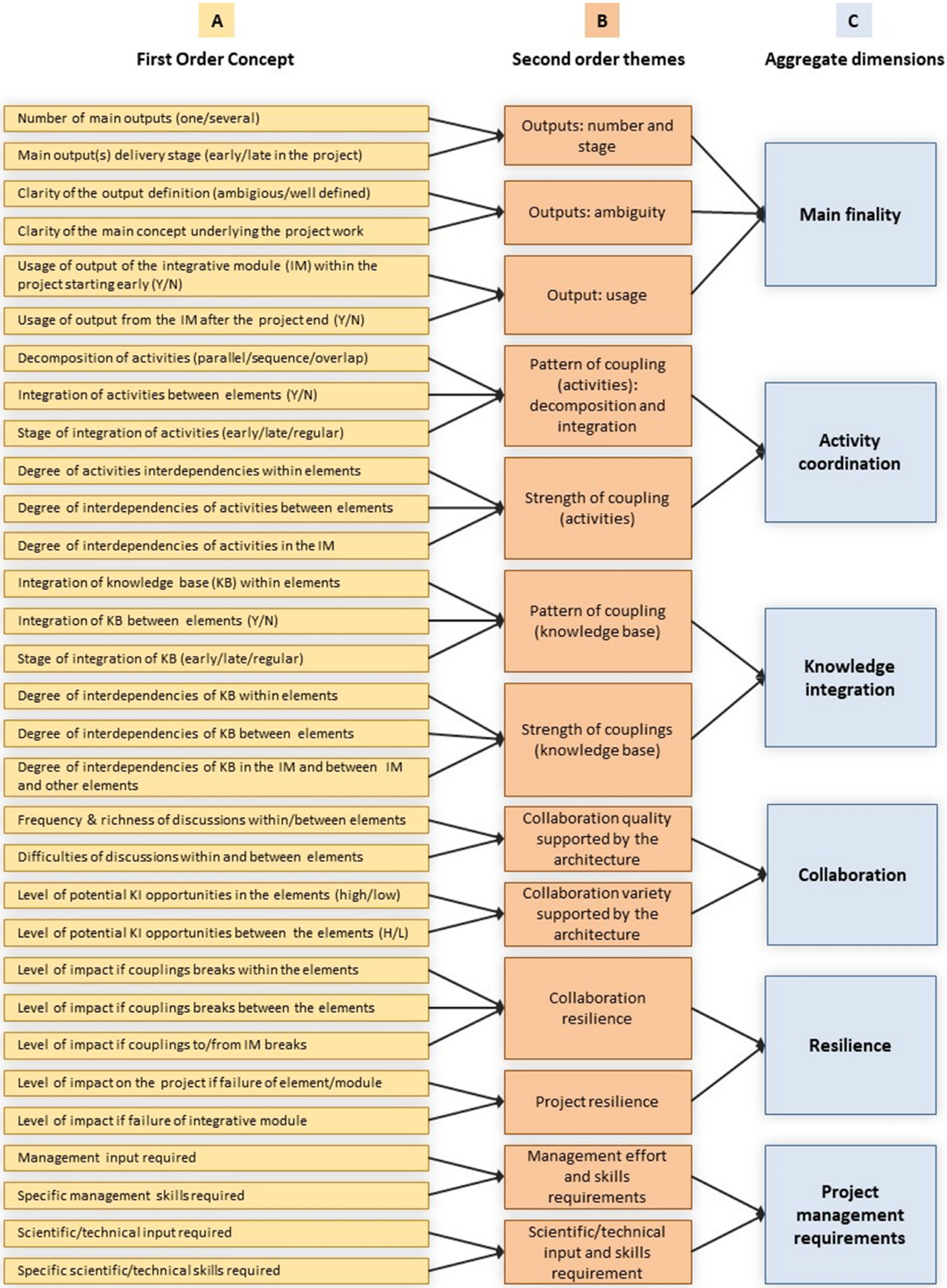
[2] Authors' calculation based on the data provided by the European Commission (2010, 2020).

Appendix 1
Overview of studied inter-organizational R&D projects (the projects in boldface were selected for the second phase).

	Name	*Objective*	*N of main results*	*EC Programme*	*Thematic*	*Project stage*	*N° of partners*	*Type / sub-type of architecture (de facto)*
1	**PEGASUS**	**New methods and software**	**Several**	**FP7**	**ICT**	**Ended**	**12**	**Weakly coupled**
2	**HERCULES**	**New methods and software**	**Several**	**FP7**	**Production, ICT**	**Ended**	**10**	**Waterfall**
3	**PERSEUS**	**New hardware, methods and software**	**Several**	**H2020**	**Production, ICT**	**Ended**	**15**	**Decomposed**
4	**ORION**	**New methods and software**	**Several**	**H2020**	**Production, ICT**	**Close to the end**	**17**	**Grid**
5	**SCORPIUS**	**New software**	**One**	**H2020**	**ICT**	**Ended**	**14**	**Workflow-integrated, converging**
6	**GEMINI**	**New software**	**One**	**H2020**	**ICT**	**On-going**	**13**	**Workflow-integrated, sequential**
7	ANDROMEDA	New hardware, methods and software	Several	H2020	Environment, ICT	On-going	21	Waterfall
8	LIBRA	New software	One	FP7	ICT	Ended	16	Workflow-integrated, converging
9	CAPRICOR-NUS	New matetials, methods and software	Several	H2020	Production	On-going	12	Decomposed
10	CYGNUS	New software and hardware	Several	FP7	Energy	Ended	12	Grid
11	LEO	New technologies, products and processes	Several	FP7	Production	Ended	15	Waterfall



Appendix 2. Data structure: Overview.

References

Ahola, T. (2018). So alike yet so different: A typology of interorganizational projects. *International Journal of Project Management, 36*, 1007–1018.

Ahuja, G. (2000). Collaboration networks, structural holes, and innovation: A longitudinal study (2000). *Administrative Science Quarterly, 45*(3), 425–455.

Ahuja, G., Soda, G., & Zaheer, A. (2012). The genesis and dynamics of organizational networks. *Organization Science, 23*(4), 1211 -1211.

Aubry, M., & Lavoie-Tremblay, M. (2018). Rethinking organizational design for managing multiple projects. *International Journal of Project Management, 36*, 12–26.

Avenier, M., & Thomas, C. (2015). Finding one's way around various methodological guidelines for doing rigorous case studies: A comparison of four epistemological frameworks. *ESKA. Systèmes d'information et management, 1*(20), 61–98.

Bakker, H., Wang, F., Bosch-Rekveldt, M., & Eykelenboom, M. G. (2018). Organizational effectiveness: Collaboration in an integrated project team. *Civil Engineering Research Journal, 4*(3). 10.19080/CERJ.2018.04.555637.

Bakker, R. M., De Fillippi, R. J., Schwab, A., & Sydow, J. (2016). Temporary organizing: Promises, processes, problems. *Organization Studies, 37*(12), 1703–1719.

Baldwin, C., & Clark, K. (1997). Managing in an age of modularity. *Harvard Business Review, Sept-Oct 1997*, 84–93.

Berggren, C. (2019). The cumulative power of incremental innovation and the role of project sequence management. *International Journal of Project Management, 37*, 461–472.

Berggren, C., Bergek, A., Bengtsson, L., & Söderlund, J. (2011). Exploring Knowledge Integration and Innovation. In C. Berggren, A. Bergek, L. Bengtsson, M. Hobday, & J. Söderlund (Eds.). In *Knowledge integration and innovation: Critical challenges facing international technology-based firms: 2011* (pp. 3–19). Oxford: OUP.

Bor, S. (2014). A theory of meta-organisation: An analysis of steering processes in European Commission-funded R&D "Network of Excellence" consortia. Publications of the Hanken School of Economics Nr 285.

Borgatti, S., Mehra, A., Brass, D., & Labianca, G. (2009). Network analysis in the social sciences. *Science (New York, N.Y.), 323*, 892–895.

Browning, T. (2014). Managing complex project process models with a process architecture framework. *International Journal of Project Management, 32*, 229–241.

Brusoni, S., & Prencipe, A. (2006). Making design rules: A multidomain perspective. *Organization Science, 17*(2), 179–189.

Brusoni, S., & Prencipe, A. (2013). The organization of innovation in ecosystems: Problem framing, problem solving and patterns of coupling. *Advances in Strategic Management, 30*, 167–194.

Burt, R. (2004). Structural holes and good ideas. *American Journal of Sociology, 110*(2), 349–399.

Burton, R., & Obel, B. (2011). Computational Modeling for what-is, what-might-be, and what-should-be studies—And triangulation. *Organization Science, 22*(5), 1195–1202.

Burton, R., & Obel, B. (2018). The science of organizational design: Fit between structure and coordination. *Journal of Organization Design, 7*(5).

Calamel, L., Defelix, C., Picq, T., & Retour, D. (2012). Inter-organisational projects in French innovation clusters: The construction of collaboration. *International Journal of Project Management, 30*, 48–59.

Caniëls, M., Chiocchio, F., & van Loon, N. (2019). Collaboration in project teams: The role of mastery and performance climates. *International Journal of Project Management, 37*, 1–13.

Canonico, P., De Nito, E., Esposito, V., Martinez, M., & Iacono, M. (2017). The adoption of knowledge integration mechanisms in an interdisciplinary research project. *Management Research Review, 40*(5), 604–622.

Capaldo, A. (2007). Network structure and innovation: The leveraging of a dual network as a distinctive relational capability. *Strategic Management Journal, 28*(6), 585–608.

Chesbrough, H. W. (2005). Open innovation: The new imperative for creating and profiting from technology (1st Trade Paper edition). Harvard Business School Press.

Clement, J., & Puranam, P. (2018). Searching for structure: Formal organization design as a guide to network evolution. *Management Science, 64*(8), 3469–3970.

Coleman, J. (1988). Social capital in the creation of human capital. *American Journal of Sociology, 94*, 95–120.

Davies, A., Manning, S., & Söderlund, J. (2018). When neighboring disciplines fail to learn from each other: The case of innovation and project management research. *Research Policy, 47*, 965–979.

Davis, J., & Eisenhardt, K. (2011). Rotating leadership and collaborative innovation: Recombination processes in symbiotic relationships. *Administrative Science Quarterly, 56*(2), 159–201.

Dietrich, P., Eskerod, P., Dalcher, D., & Sandhawalia, B. (2010). The dynamics of collaboration in multipartner projects. *Project Management Journal, 41*(4), 59–78.

Eisenhardt, K. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532–550.

Eisenhardt, K. (1991). Better stories and better constructs: The case for rigor and comparative logic. *Academy of Management Review, 16*(3), 620–627.

Eisenhardt, K. M., & Graebner, M. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal, 50*(1), 25–32.

Enberg, C. (2012). Enabling knowledge integration in coopetitive R&D projects—The management of conflicting logics. *International Journal of Project Management, 30*, 771–780.

Englmaier, F., Foss, N., Knudsen, T., & Kretschmer, T. (2018). Organization design and firm heterogeneity: towards an integrated research agenda for strategy (May 15, 2018). Available at SSRN:Https://ssrn.com/abstract=3179196

Engwall, M. (2003). No project is an island: Linking projects to history and context. *Research Policy, 32*, 789–808.

Eppinger, S., & Browning, T. (2012). *Design structure matrix methods and applications* (p. 334). MIT Press.

European Commission (2010). Evaluation of the Sixth Framework Programmes for Research and Technological Development 2002-2006 (p. 90). 10.2777/84968.

European Commission (2014). Horizon 2020 Work Programme 2014-2015, General Annexes, Annex G, Technology Readiness Levels, Retried from https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf, Accessed on March 20, 2020.

European Commission (2020). Horizon 2020 Interactive Dashboard. Data Retrieved from https://webgate.ec.europa.eu/dashboard/hub/, accessed on January 2, 2020.

Fjeldstad, Ø., Snow, C., Miles, R., & Lettl, C. (2012). The architecture of collaboration. *Strategic Management Journal, 33*, 734–750.

Geraldi, J., & Söderlund, J. (2018). Project studies: What it is, where it is going. *International Journal of Project Management, 36*(1), 55–70.

Gioia, D., Corley, K., & Hamilton, A. (2013). Seeking qualitative rigor in inductive research. *Organizational Research Methods, 16*(1), 15–31.

Granovetter, M. (1973). The strength of weak ties. *The American Journal of Sociology, 78*(6), 1360–1380.

Grant, R. (1996). Towards a knowledge-based theory of the firm. *Strategic Management Journal, 17*(S2), 109–122.

Johansson, M., Axelson, M., Enberg, C., & Tell, F. (2011). Knowledge integration in inter–firm R&D collaboration: How do firms manage problems of coordination and cooperation? In C. Berggren, A. Bergek, L. Bengtsson, M. Hobday, & J. Söderlund (Eds.), Knowledge integration and innovation: Critical challenges facing international technology-based firms Oxford: OUP.

Kapsali, M. (2011). Systems thinking in innovation project management: A match that works. *International Journal of Project Management, 29*, 396–407.

Kim, N., Kim, D. J., & Lee, S. (2015). Antecedents of open innovation at the project level: Empirical analysis of Korean firms. *R&D Management, 45*(5), 411–439.

König, B., Diehl, K., Tscherning, K., & Helming, K. (2013). A framework for structuring interdisciplinary research management. *Research Policy, 42*, 261–272.

Lin, J., Qian, Y., Cui, W., & Goh, T. (2015). An effective approach for scheduling coupled activities in development projects. *European Journal of Operational Research, 243*(1), 97–108.

Lin, L., Müller, R., Zhu, F., & Liu, H. (2019). Choosing suitable project control modes to improve the knowledge integration under different uncertainties. *International Journal of Project Management, 37*, 896–911.

Linnenluecke, M. (2017). Resilience in business and management research: A review of influential publications and a research agenda. *International Journal of Management Reviews, 19*(1), 4–30.

Lundin, R., Arvidsson, N., Brady, T., Ekstedt, E., Midler, C., & Sydow, J. (2015). Managing and working in project society: Institutional challenges of temporary organizations. Cambridge, England: Cambridge University Press.

Lundin, R., & Söderholm, A. (1995). A theory of the temporary organization. *Scandinavian Journal of Management, 11*(4), 437–455.

Manning, S. (2017). The rise of project network organizations: Building core teams and flexible partner pools for interorganizational projects. *Research Policy, 46*, 1399–1415.

Michelfelder, I., & Kratzer, J. (2013). Why and how combining strong and weak ties within a single interorganizational R&D collaboration outperforms other collaboration structures. *Journal of Product Innovation Management, 30*(6), 1159–1177.

Midler, C. (1995). Projectification of the Firm: The Renault Case. *Scandinavian Journal of Management, 11*(4), 363–375.

Mintzberg, H. (1979). *The structuring of organizations*. Englewood Cliffs, NJ: Prentice Hall.

Miterev, M., Mancini, M., & Turner, R. (2017). Towards a design for the project-based organization. *International Journal of Project Management, 35*, 479–491.

Moran, P., & Ghoshal, S. (1996). Theories of economic organization: The case for realism and balance. *Academy of Management Review, 21*(1), 58–72.

Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review, 23*(2), 242–266.

Nooteboom, B., Vanhaverbeke, W., Duysters, G., Gilsing, V., & van den Oord, A. (2007). Optimal cognitive distance and absorptive capacity. *Research Policy, 36*(2007), 1016–1034.

Obstfeld, D. (2005). Social networks, the tertius lungens orientation, and involvement in innovation. *Administrative Science Quarterly, 50*, 100–130.

Orton, J., & Weick, K. (1990). Loosely coupled systems: A reconceptualization. *Academy of Management Review, 15*, 203–223.

Pandza, K., Wilkins, T., & Alfoldi, E. (2011). Collaborative diversity in a nanotechnology innovation system: Evidence from the EU Framework Programme. *Technovation, 31*, 476–489.

Pinheiro, M., Serôdio, P., Pinho, J., & Lucas, C. (2016). The role of social capital towards resource sharing in collaborative R&D projects: Evidences from the 7th Framework Programme. *International Journal of Project Management, 34*, 1519–1536.

Raab, J., Soeters, J., van Fenema, P., & de Waard, E. (2009). Structure in temporary organizations. In P. Kenis, M. Janowicz-Panjaitan, & B. Cambré (Eds.), Temporary organizations: Prevalence, logic and effectiveness (pp. 171–200). London: Edward Elgar Pub..

Rauniar, R., Rawski, G., Morgan, S., & Mishra, S. (2019). Knowledge integration in IPPD project: Role of shared project mission, mutual trust, and mutual influence. *International Journal of Project Management, 37*, 239–258.

Rost, K. (2011). The strength of strong ties in the creation of innovation. *Research Policy, 40*, 588–604.

Shi, Q., & Blomquist, T. (2012). A new approach for project scheduling using fuzzy dependency structure matrix. *International Journal of Project Management, 30*, 503–510.

Simard, M., Aubry, M., & Laberge, D. (2018). The utopia of order versus chaos: A conceptual framework for governance, organizational design and governmentality in projects. *International Journal of Project Management, 36*, 460–473.

Simon, H. (1969). *The science of the artificial*. MIT Press.

Söderlund, J., & Sydow, J. (2019). Projects and institutions: Towards understanding their mutual constitution and dynamics. *International Journal of Project Management, 37*, 259–268.

Söderlund, J., & Tell, F. (2011). Strategy and capabilities in the p-form corporation: linking strategic direction with organizational capabilities. In G. Cattani, S. Ferriani, L. Frederiksen, & F. Täube (Eds.), Project-Based organizing and strategic management *(Advances in strategic management, vol. 28)* (pp. 235–262). Bingley: Emerald Group Publishing Limited.

Srikanth, K., & Puranam, P. (2011). Integrating distributed work: Comparing task design, communication, and tacit coordination mechanisms. *Strategic Management Journal, 32*(8), 849–875.

Steen, J., DeFillippi, R., Sydow, J., Pryke, S., & Michelfelder, I. (2018). Projects and networks: Understanding resource flows and governance of temporary organizations with quantitative and qualitative research methods. *Project Management Journal, 49*(2), 3–17.

Stjerne, I., Söderlund, J., & Minbaeva, D. (2019). Crossing times: Temporal boundary-spanning practices in interorganizational projects. *International Journal of Project Management, 37*, 344–362.

Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Techniques and procedures for developing grounded theory. Thousand Oaks, CA: Sage.

Sydow, J., & Braun, T. (2018). Projects as temporary organizations: An agenda for further theorizing the interorganizational dimension. *International Journal of Project Management, 36*, 4–11.

Tee, R., Davies, A., & Whyte, J. (2019). Modular designs and integrating practices: Managing collaboration through coordination and cooperation. *Research Policy, 48*, 51–61.

Tell, F. (2011). Knowledge Integration and Innovation: A Survey of the Field. In C. Berggren, A. Bergek, L. Bengtsson, M. Hobday, & J. Söderlund (Eds.). In *Knowledge integration and innovation: Critical challenges facing international technology-based firms: 2011* (pp. 20–58). Oxford: OUP.

(2017). In Tell, F., Berggren, C., Brusoni, S., & Van de Ven, A. (Eds.). In *Managing knowledge integration across boundaries: 2017* (p. 336). Oxford: OUP.

Tiwana, A. (2008). Do bridging ties complement strong ties? An empirical examination of alliance ambidexterity. *Strategic Management Journal, 29*(3), 251–272.

Turner, R., & Müller, R. (2003). On the nature of the project as a temporary organisation. *International Journal of Project Management, 21*(7), 1–8.

Van de Ven, A., Ganco, M., & Hinings, C. (2013). Returning to the frontier of contingency theory of organizational and institutional designs. *Academy of Management Annals, 7*(1), 393–440.

vom Brocke, J., & Lippe, S. (2015). Managing collaborative research projects: A synthesis of project management literature and directives for future research. *International Journal of Project Management, 33*, 1022–1039.

Yang, Q., Lu, T., Yao, T., & Zhang, B. (2014). The impact of uncertainty and ambiguity related to iteration and overlapping on schedule of product development projects. *International Journal of Project Management, 32*(5), 827–837.

Yayavaram, S., & Ahuja, G. (2008). Decomposability in knowledge structures and its impact on the usefulness of inventions and knowledge-base malleability. *Administrative Science Quarterly, 53*, 333–362.

Yi, S., Stieglitz, N., & Knudsen, T. (2018). Differentiation and integration in organizational learning: A garbage can model. In *Organization design (Advances in strategic management, vol. 40)* (pp. 177–204). Emerald Publishing Limited.

Yin, R. (1994). Discovering the future of the case study. method in evaluation research. *American Journal of Evaluation, 15*(3), 283–290.

Zerjav, V., Edkins, A., & Davies, A. (2018). Project capabilities for operational outcomes in inter-organisational settings: The case of London Heathrow Terminal 2. *International Journal of Project Management, 36*(3), 444–459.