JULIO CEZAR FONSECA DE MELO

Radicalizing innovation in mature firms: a process-based investigation

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Radicalizing innovation in mature firms: a process-based investigation

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Supervisor: Mario Sergio Salerno

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To my mother, Maria Margareth Fonseca de Melo (in memoriam).

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RESUMO

Gerenciar inovações radicais é fundamentalmente diferente da gestão de inovações incrementais, especialmente pelo desafio de lidar com incertezas ao invés de riscos mensuráveis. A literatura desenvolveu modelos para o que deveria ser um sistema de gestão para inovações radicais com respectivos elementos constituintes (por exemplo, processos, mandato, governança, mecanismos de ligação, habilidades) para garantir uma capacidade de inovação radical completa em empresas maduras - a habilidade de criar e lançar inovações radicais repetidamente. No entanto, esses modelos são predominantemente estáticos, falhando em fornecer gradualmente um caminho claro para as empresas atingirem essa capacidade. Além disso, mesmo os estudos com abordagem processual não fornecem procedimentos analíticos para explicar os fenômenos estudados numa abordagem mecanicista causal. Para preencher as lacunas teóricas anteriores, esta tese apresenta um conjunto de três artigos para responder à questão de pesquisa: como as empresas maduras constroem capacidade para gerenciar inovações radicais sistematicamente? O Artigo #1 defende que a capacidade de inovação radical pode emergir progressivamente da ação de alguns indivíduos até a formação de um time dedicado, a partir do acúmulo progressivo de habilidades especializadas e do alcance de resultados intermediários em projetos de inovação. O Artigo #2 fundamenta-se em teorias de inovação aberta e gerenciamento de projetos para apresentar um processo de quatro estágios (*closed mode; open driver; vanguard project; project-to-organization*) para a construção de capacidade de inovação. O Artigo #3 traz insights sobre os principais agentes responsáveis pelo processo de construção desta capacitação (por exemplo, indivíduos internos, alta administração e a própria empresa) e também oferece avanços metodológicos no método “Análise da Estrutura de Eventos” (ESA) - um método qualitativo formal para pesquisa de processos. As principais contribuições da tese incluem uma explicação profunda e robusta (baseada em mecanismos causais) sobre a construção de capacidade de inovação radical em empresas maduras, melhorias nos modelos de construção de capacidade tanto da literatura de inovação aberta quanto da de gerenciamento de projetos, e também contribuições metodológicas, fornecendo artigos que incorporam, modificam ou mesmo avançam estratégias distintas de pesquisa de processos.

ABSTRACT

Radical innovation management is entirely different from incremental innovation management, primarily because of the challenge to handle uncertainties instead of measurable risks. Literature developed models to what should be an ideal radical innovation management system and respective constituent elements (e.g., processes, mandate, governance, linking mechanisms, skills) to ensure a full radical innovation capability in mature companies - the ability to create and launch radical innovations repeatedly. However, these models are predominantly static, failing to gradually provide a clear path to companies to reach such capability. Besides that, even the studies with a processual approach do not provide analytical procedures to explain the studied phenomena in a causal mechanistic sense. To the previous gaps, this thesis presents a set of three articles to answer the research question: how do mature firms build capabilities to manage radical innovations systematically? Paper #1 advocates that radical innovation capability can emerge progressively from individual action to teams, accumulating specialized skills and achieving intermediate results by innovation projects. Paper #2 relies on open innovation and project management theories to present a four-stage process (closed mode; open driver; vanguard project; project-to-organization) for innovation capability building. Paper #3 brings insights about the main agents responsible for this capability process (e.g., internal individuals, top management, and the company itself) and delivers methodological improvements in Event Structure Analysis (ESA) – a formal qualitative process research method. The thesis main contributions include an in-depth and robust (causal mechanistic based) explanation about radical innovation capability building in mature companies, improvements on previous open innovation and project management capability building models, and also methodological contributions by providing articles that incorporate, modify, or even improve distinct process-research strategies.

FIGURES

TABLES

CONTENT

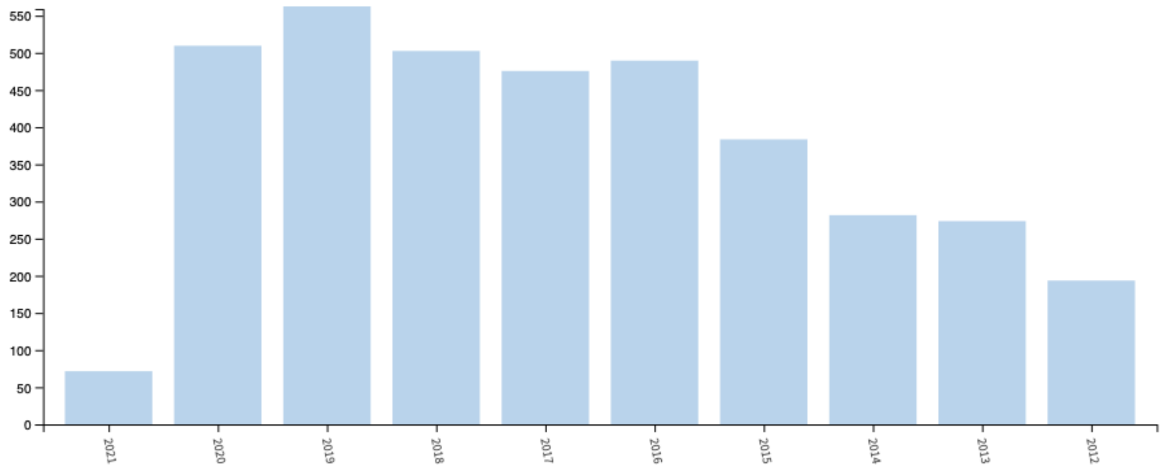
1. INTRODUCTION

1.1. Context and justification

Literature suggests that management systems for Radical Innovation (RI) should be different when compared to incremental ones (Bagno, Salerno, & Silva, 2017; O'Connor, 2012; O'Connor et al., 2008, 2018). The establishment of an innovation process (like stage-gates) is appropriate when there is a high volume of projects with similar characteristics (Salerno & Gomes, 2018). As RI projects inherently possess extreme uncertainties (Pich et al., 2002), organizations must develop dedicated capabilities to manage them, which encompass specific aspects such as mandate and governance definition, processes, metrics and reward systems, lateral linkages, among others (O'Connor, 2008). As it is the best mechanism for the accumulation of specialized skills, an organizational function (i.e., the Innovation Function - IF) would be the ideal alternative to manage radical innovations (O'Connor et al., 2008; Salerno & Gomes, 2018). Besides, as a unit dedicated to this mission (i.e., manage radical innovations) and recognized in the organizational environment, the IF works to guarantee that radical innovations will be not evaluated under the same assumptions established for incremental ones, as the tendency is to discard then due to the lack of return estimates for the business by its nature (i.e., the presence of uncertainties).

The management of radical innovation (RI) has been gaining considerable preeminence in innovation studies – in a quick search by "topic" in ISI – Web of Science (March/2021) combining "Radical innovation*" OR "Breakthrough innovation*" OR "Disruptive innovation*" OR "Strategic innovation*" OR "Major innovation*" terms, 5283 articles returned. As shown in Figure 1, publications increased over time, especially in "Management" and "Business" categories. Gina O'Connor appeared at the top of the publication's list in this search with 27 registers. In this sense, the theoretical foundations of this thesis are highly influenced by O'Connor's works, particularly the discussions about capabilities held by a dedicated Innovation Function (O'Connor, 2008, 2012; O'Connor et al., 2008) as the best strategy for organizations to generate radical innovations regularly and systematically (Bagno, Salerno, & Dias, 2017; Salerno & Gomes, 2018).

Figure 1: Web of Science (March/2021) – publications per year about radical innovation and related concepts



Leifer et al. (2000) conceptualize radical innovation as a fivefold performance improvement along with customer needs (5-10 times) or significant cost reduction (30-50%). Over time, beyond so many terminologies which were used to conceptualize innovations with the high level of innovativeness such as "radical", "major", "disruptive", "game-changing", "transformational", "discontinuous", "breakthrough", and recently, "strategic innovation" (O'Connor et al., 2018). Strategic innovation consists in the development of "new platforms of growth through major market impact, to create new business for the company, not new products within a current platform" (O'Connor et al., 2018). The common point among these terms is that these innovation types pursue a high level of uncertainties (i.e., the results cannot be predicted or estimated during a planning phase (Pich et al., 2002). For this reason, we generalize the construct "radical innovation" over this thesis but have been careful to include all the previously cited constructs during the definition of keywords in the literature search process.

Over the years, extensive academic research was built about the establishment of a management system for radical innovation (Bagno, Salerno, & Silva, 2017; Colombo et al., 2017; O'Connor, 2008; O'Connor et al., 2008; O'Connor & DeMartino, 2006; Salerno & Gomes, 2018; Slater et al., 2014). Although insightful, there are essential gaps in previous studies. First, debates were concentrated on the experience of large multinational corporates with various distinct business units spread over the globe. There is a considerable challenge in translating these insights into smaller mature companies, especially those found in Brazil (c.f., Bagno et al., 2017a). Second, scholars have focused on presenting management systems for innovation (Bagno, Salerno, & Silva, 2017; O'Connor, 2008; Slater et al., 2014) as a static model, with a little emphasis on the process by which companies reach this maturity (i.e., more focus on photos rather than films). In this sense, literature provides little insights for companies initiating the journey to be more innovative, especially those who face resource limitations to build innovation capabilities. Third, in a broader sense, Kouamé and Langley (2018) claim for studies that explain how lower-level processes and practices engaged in by individuals and groups connect to broader organizational-level processes and outcomes, including strategy, organizational capabilities, and performance. Some examples about innovation capability building at the firm-level studies present cases through a macro-level lens of analysis (e.g., new business unit and R&D centers creation), with little attention to actions taken at the micro-level (e.g., the role of individuals and their relationship, team building and daily activities, processes, and routines) - (Börjesson et al., 2014; Börjesson & Elmquist, 2012; Chiaroni et al., 2011). Finally, even generating strong conceptual models, process research studies are frequently criticized due to the difficulty to quantify and test the generated results, mainly due the lack of formal analytical procedures (Beach, 2020; Cloutier & Langley, 2020; Kouamé & Langley, 2018; Perks & Roberts, 2013).

In sum, the literature presented a quite number of theoretical models for mature companies to manage radical innovations over the years with little emphasis on the processes by which firms achieve this condition and also neglecting the mechanisms linking causes in a micro-level (e.g., individuals, projects) to the desired macro-outcome (i.e., the capability establishment).

1.2. Research problem and objectives

In order to fulfill the previous gaps, this research intends to answer the general research question: *how do mature firms build capabilities to manage radical innovations systematically?* More specifically, the general objective of this thesis is to trace causal mechanisms beneath the emergence of a dedicated organizational function to manage radical innovations in mature firms. This research is process and single case oriented, anchored on process-tracing approaches (Beach, 2020; Beach & Pedersen, 2019; Mahoney, 2012) which allows the exploration of cases in-depth to make inferences about the operation of causal mechanisms that link causes to outcomes.

To reach the general objective, three specific objectives are placed:

- SO1: to comprehend how organizational context and the organization external environment may influence or even shape the radical innovation capability building process.

- SO2: to elucidate the role of open innovation projects for the radical innovation capability building, emphasizing the role of vanguard projects.
- SO3: to identify the underlying causal mechanisms connecting specific causes to the desired macro-outcome (i.e., the radical innovation capability in the form of the dedicated innovation function).

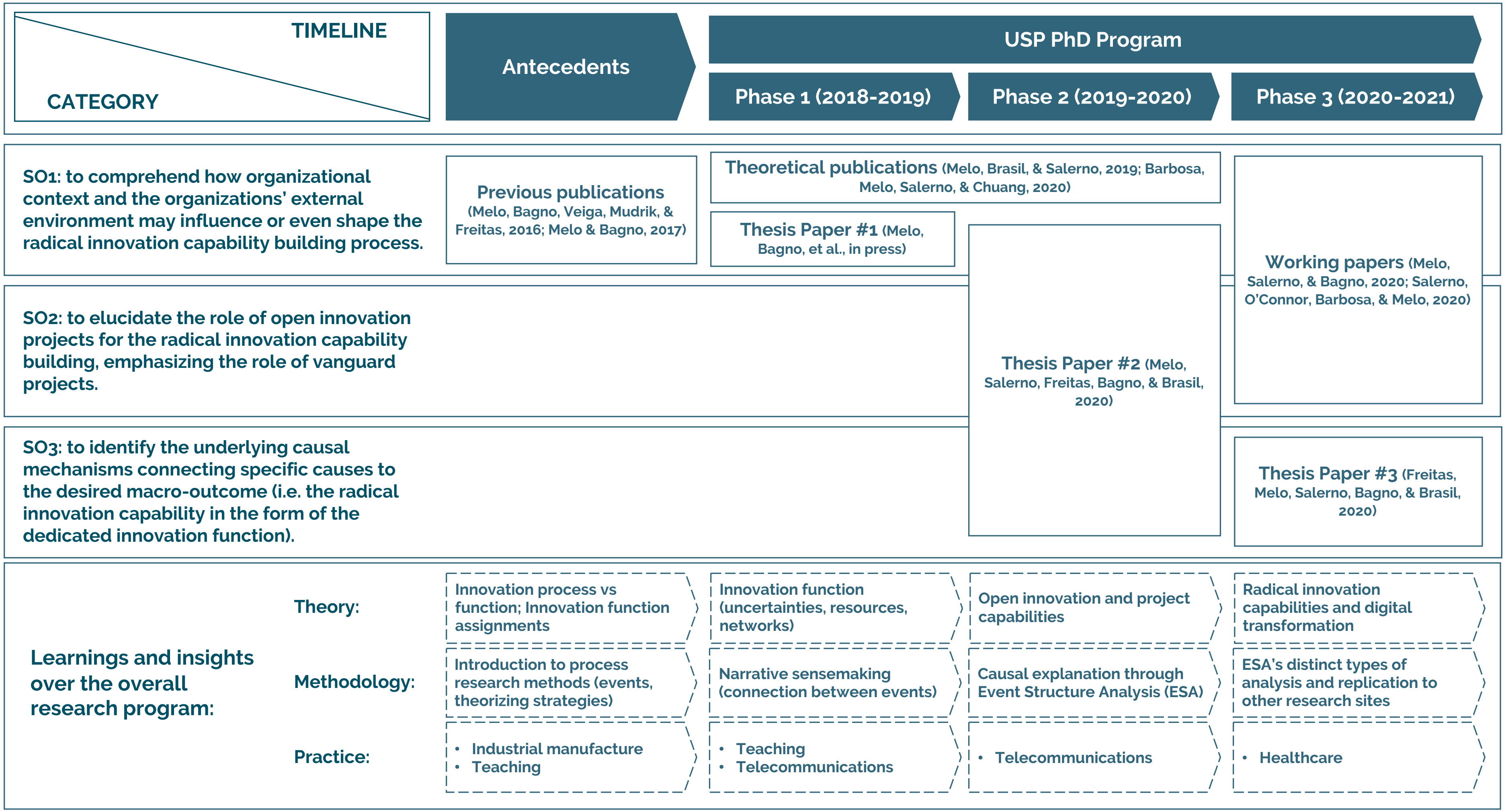
1.3. Thesis structure

This thesis encompasses six sections, including this Introduction. Section 2 presents my pathway during PhD Program, highlighting publications over the period, both thesis papers and also adjacent publications, which helped to advance in theoretical and methodological foundations. Section 2.1 initiates with theoretical discussions about radical and innovation management. In sequence, there is a debate about capability building for radical innovation and the selected theories (e.g., open innovation, project management) to strengthen thesis contributions. Section 3 brings methodological assumptions for this work, with an emphasis on a process research stream and Event Structure Analysis (ESA) method. Research results based on thesis papers – i.e., Paper #1 (Melo et al., 2021) – P#1, Paper #2 (Melo et al., 2020) – P#2, and Paper #3 (Freitas et al., 2021) – P#3, are presented in Section 4. Each of them extends the research question with distinct goals and methodological strategies. Section 5 summarizes the main contributions of this thesis and suggestions for future studies. Finally, thesis papers are fully available in the appendix (Section 6).

2. THESIS INTEGRATED VISION

This thesis is a result of a cumulative research program over the last years. Figure 2 presents in detail the research process at distinct points of time (antecedents and phases 1, 2, and 3 over the Ph.D. Program) where some publications were developed to accomplish the objectives of the thesis (i.e., SO1, SO2, SO3). Figure 2 also highlights principal learnings and insights about theoretical discussions, methodological approaches, and practical experiences, which served as the basis for the research evolution.

Figure 2: The overall research view and article integration



The research started near 2013 when I was responsible for an innovation area in an industrial company (ORTENG). During this period, Prof Raoni Bagno (a Ph.D. Candidate in Poli-USP at that moment, oriented by Prof Mario Salerno) was mapping some Brazilian companies in order to characterize the “Innovation Function”, inspired in O’Connor’s research (O’Connor, 2012; O’Connor et al., 2008; O’Connor & DeMartino, 2006), and interviewed me. From this moment, I realized that the work we were doing to structure the innovation department could be significant for theorizing at innovation management field. In 2014 I left ORTENG and returned to “Núcleo de Tecnologia da Qualidade e da Inovação” (NTQI) Lab at UFMG to engage in a research project oriented by Prof Jonathan Freitas. He introduced me to process research methods, especially Langley (1999)’s publication. In 2014 I engaged in the “Faculdade de Administração” (FACE) mastering program at UFMG. My research was oriented to the comprehension of internal and external influences for the Innovation Function’s consolidation (SO1), using Bagno, Salerno, and Dias (2017) and O’Connor et al. (2008) as the primary theoretical basis and process research strategies (Langley, 1999) like narratives and visual maps in a single case study of an industrial organization. From my dissertation (finished in 2016), we published related articles (Melo et al., 2016; Melo & Bagno, 2017) discussing how the Innovation Function’s assignments (Bagno, Salerno, & Dias, 2017) gradually emerged over time in a single case, identifying, for example, the impact of governmental funding incentives at the beginning of the process to legitimize the new area. Prof Mario Salerno was invited to participate in my final dissertation exam and questioned me if I was interested in continuing the research in a doctoral program. From 2016-2017 I engaged in teaching and academic initiatives (at UFMG, PUC-MG, UniBH), mostly involving new product development and innovation subjects. At this moment, Prof Jonathan Freitas introduced me Event Structure Analysis (ESA) method, which was used in his Ph.D. thesis. We started to refine my dissertation database to apply ESA in the future. During this period, I matured the doctoral program idea and was accepted in the Poli-USP Program at the end of 2017.

During my first year at the doctoral program (2018), I engaged in theoretical debates about radical innovation management, supervised by Prof Mario Salerno. During the discipline (“Gestão Estratégica da Inovação”), I deepened in discussions between radical and innovation management (i.e., uncertainties vs. risk; function vs. process), which helped to structure the theoretical basis of an article (the final delivery of this course) submitted and approved “Gestão e Produção” (Thesis Paper #1). This paper (Melo et al., 2020) presents an in-depth case study with a narrative approach to explain the Innovation Function evolution. In this study, it became clear the importance of intermediate results (i.e., projects) to legitimize innovation capabilities (in the form of a dedicated function) and the accumulation of competencies from these initiatives. These insights were imperative (later) to develop Thesis Paper #2 (Melo et al., 2020). Another insight from this publication was the importance of internal networks (i.e., horizontal linkages) for the Innovation Function operation. At this time, influenced by Prof Mario Salerno current research (Salerno & Gomes, 2018), we started to study "how the Innovation Function gets resources from other organizational departments to manage radical innovation projects". This immersion culminated in a publication of a theoretical essay (Melo et al., 2019) discussed with Gina O'Connor and Professor Mario Salerno at the PDMA JPIM Conference entitled "Competitive Edge: Disruption by Design Conference" (https://www.pdma.org/mpage/2019-Conference-schedule).

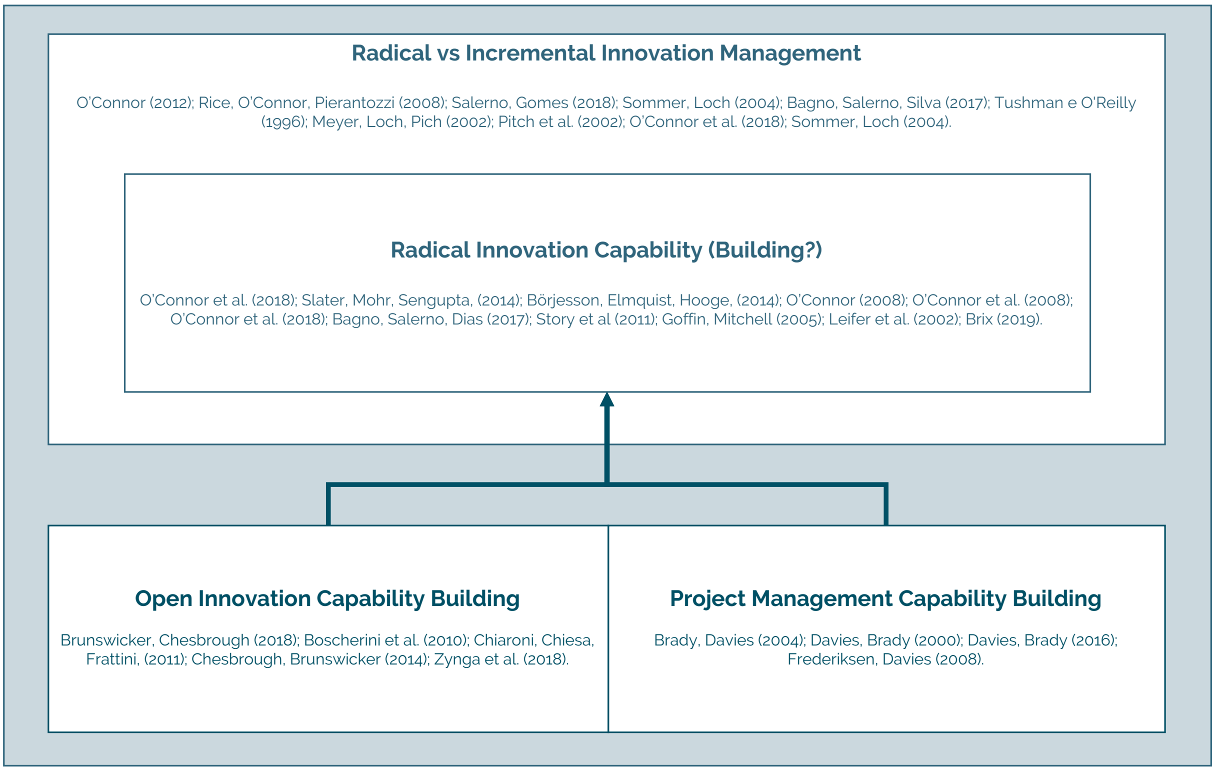
At the end of 2018, the International Journal of Project Management (IJPM) launched a call for papers about "managing open and user innovation by projects", with a specific question about "how can experiences form initial projects evolve into practices and routines". We decided to structure a new research paper starting from previous studies (Melo et al., 2021; Melo & Bagno, 2017), exploring the same case dataset. However, this time, we would need to overcome some gaps appointed in previous publications like the absence of causal explanation linkages between the events of the case and seek new theoretical lenses to address the Journal's call (i.e., open innovation and project capabilities). In this sense, we applied ESA to explain "how do organizations use the experience from projects to build a systematic capability to manage open innovation projects?" from an in-depth single case study (ORTENG's case). For more than two years, we engaged in the revision process of this paper, which helps to advance with our research to SO2 and SO3 by including new capability theoretical frameworks, both from open innovation (Chiaroni et al., 2011; Zynga et al., 2018) and project management (Brady & Davies, 2004; Davies & Brady, 2000) literatures and evidenced, from the application of ESA, the crucial role of vanguard projects for the innovation capability building process. It is important to note that these studies have a notable practical application – form these insights, I have been supporting other mature companies (e.g., Telecommunications, Healthcare) to create and establish their radical innovation management dedicated functions. The settlement of a vanguard project in the first steps of this journey, for example, has proven itself a prominent practice.

Recognizing the potential contribution of ESA to the Business/Management research field, the IJPM's Editor invited us to submit a methodological paper to MethodsX Journal - Thesis Paper #3 (Freitas et al., 2021). This paper (already published) presents some improvements made on the original version of the method (e.g., robust event coding, process-tracing tests to link events, network analyses), exemplified from the same case studied in previous publications. In parallel, we continued to explore the interplay between "social networks" and "radical innovation" (Barbosa et al., 2020; Salerno et al., 2020). We also started to investigate new theoretical arenas (i.e., digital transformation) to foster the comprehension of radical innovation capability building in mature companies. In this sense, we are working on a paper (Melo, Salerno, & Bagno, 2020) which captures pandemic COVID-19 crisis effect to this capability building process, from a single case process-oriented study in a health company (MIL).

2.1. THEORETICAL BASIS

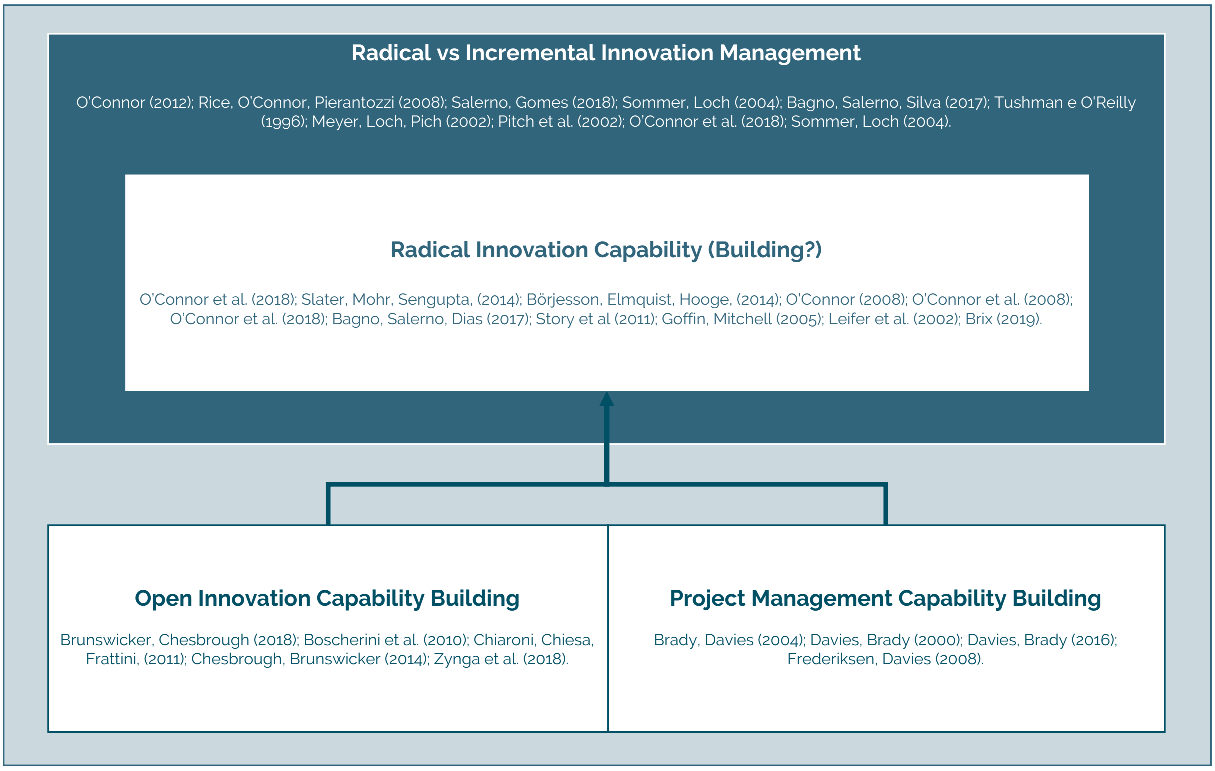
This section concisely presents the focal theoretical constructs which support this thesis (Figure 3). Subsection 2.2 presents a discussion about the differences between radical and incremental innovations in nature, which reflects directly in the approach needed to manage them. Subsection 2.3 argues that radical innovation capability can be associated to the construction of a dedicated management system and the creation of a dedicated organizational function (Innovation Function) to keep this system operating. This debate was the main pilar to the results found in Paper #1. During the maturation of this PhD thesis – i.e., for the preparation of Paper #2 and Paper #3, it was necessary to bring new theoretical basis to answer this thesis research question and also to accomplish the stated specific objectives (SOs). In this sense, Subsection 2.4 briefly presents selected organizational capability building approaches from open innovation and project management literatures, respectively.

Figure 3: Thesis theoretical framework



2.2. Radical vs incremental innovation management

Figure 4: Thesis theoretical framework - radical vs incremental innovation management

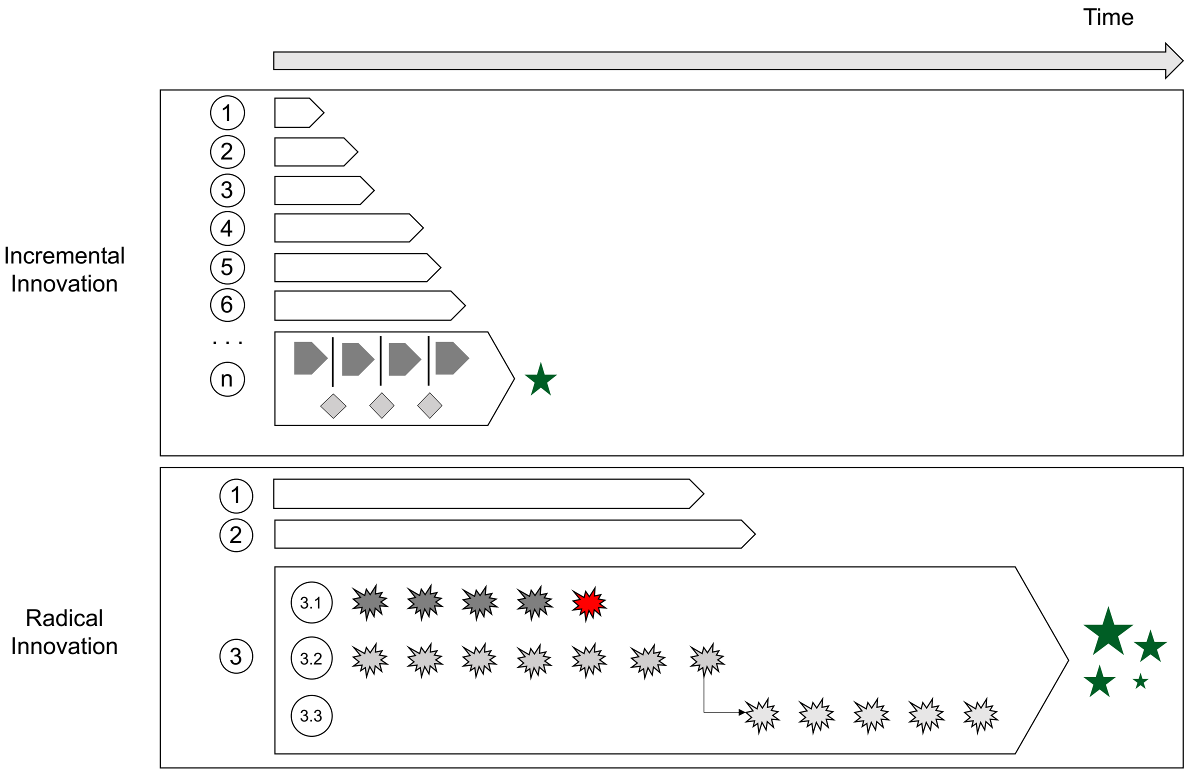


As pointed by Tushman and O'Reilly (1996), "all successful organizations evolve through long periods of incremental changes interrupted by environmental shifts and revolutionary change". In this sense, firms need to reorient their strategy and structure to face these changing conditions. In this sense, organizations should be ambidextrous, that is, they must create the ability to simultaneously pursue incremental and discontinuous innovation and change results from hosting multiple contradictory structure, processes, and culture. Raisch and Birkinshaw (2008) define ambidextrous organizations are those capable of simultaneously exploiting existing competencies and exploring new opportunities (i.e., exploration vs exploitation). March (1991), recognized as one of the foundations in this research stream, exploration and exploitation are central concepts for organization's adaptative processes. Exploration involves issues captured by search, variation, risk, experimentation, play, flexibility, discovery, innovation. Exploitation includes issues such as refinement, choice, production, efficiency, selection, implementation, execution (March, 1991). Maintaining a balance between the two is a primary factor for the system's survival and prosperity. Benner and Tushman (2003) state that ambidextrous organizations are composed of multiple tightly coupled subunits that are, by themselves, loosely coupled from each other. Exploration and exploitation require different structures, processes, strategies, capabilities and cultures and can have different impacts on the firm's adaptation and performance.

Following these perspectives, this thesis reinforces that incremental and radical innovation management should be treated differently, particularly because of their nature. Incremental innovations can be associated with risk, which in turn is considered a simpler form of uncertainty, or a set of possibilities for results for a situation, each with a probability of occurrence that can be measured (Pich et al., 2002). Meyer et al. (2002) highlight that risk can be calculated by methods such as “decision trees” and can be contingence by the creation of project buffers (i.e., additional resources expected from the beginning of the project). Thus, for incremental innovation management, procedural approaches with well-defined steps and decision points (i.e., stage-gates) are efficient, usually involving the development of a product or process or improvement in existing products and processes (Bagno, Salerno, & Silva, 2017).

In radical innovations (RI), on the other side, the levels of uncertainty are high. It is impossible to perform calculations in advance in relation to the desired result and the consistency between the established assumptions is questionable (Meyer et al., 2002). Sommer and Loch (2004) define uncertainty (*unforeseeable*) as the lack of ability to recognize the relevant influencing variables and the functional relationship between them. In this context, it is necessary (managerial) approaches that favor interaction, repetition of problem solving and test cycles since the variables that influence a project definition may not be defined a priori (i.e., at the planning phase). According Rice et al. (2008), uncertainty manifests in four ways: (i) *technical* - by advancing scientific knowledge, number of product specifications that can be implemented, reliability of manufacturing processes; (ii) *market* - customer needs, customer interaction with the product, sales and distribution methods, revenue models; (iii) *organizational* - as the most radical innovations have a long life cycle, the dynamism and the probable changes of the organization over time generate uncertainties; (iv) *resources* - sources of financing and support are unstable over time. As RI consists of the development of new business platforms (O’Connor et al., 2018) rather than simple projects, the portfolio of incremental innovations tends to be larger than that of radicals (considering the number of projects), with shorter-term projects when compared to radicals (Figure 5).

Figure 5: Differences between radical and incremental innovation management



Notes: (i) coded items (e.g., 1, 2, 3) with their associated horizontal bar-arrow represent one innovation project; (ii) stars represent an outcome of an innovation project (e.g., product, service, process); (iii) the image inside "n" in the "incremental innovation" layer is an allusion to the stage-gate® model; (iv) Sub-coded items (e.g., 3.1, 3.2, 3.3) represent distinct technological routes at the same project; (v) gray "explosions/clouds" are an allusion to the idea of Garud et al., (2017) fortuitous events over a radical innovation project (or even a learning cycle in Rice, O'Connor, and Pierantozzi (2008)'s sense); (vi) red "explosions/clouds" represent the closure of a technological route; (vii) the arrow connecting the gray "explosions/clouds" 3.2 to 3.3 represents a transition from one technological route to another.
Source: the author

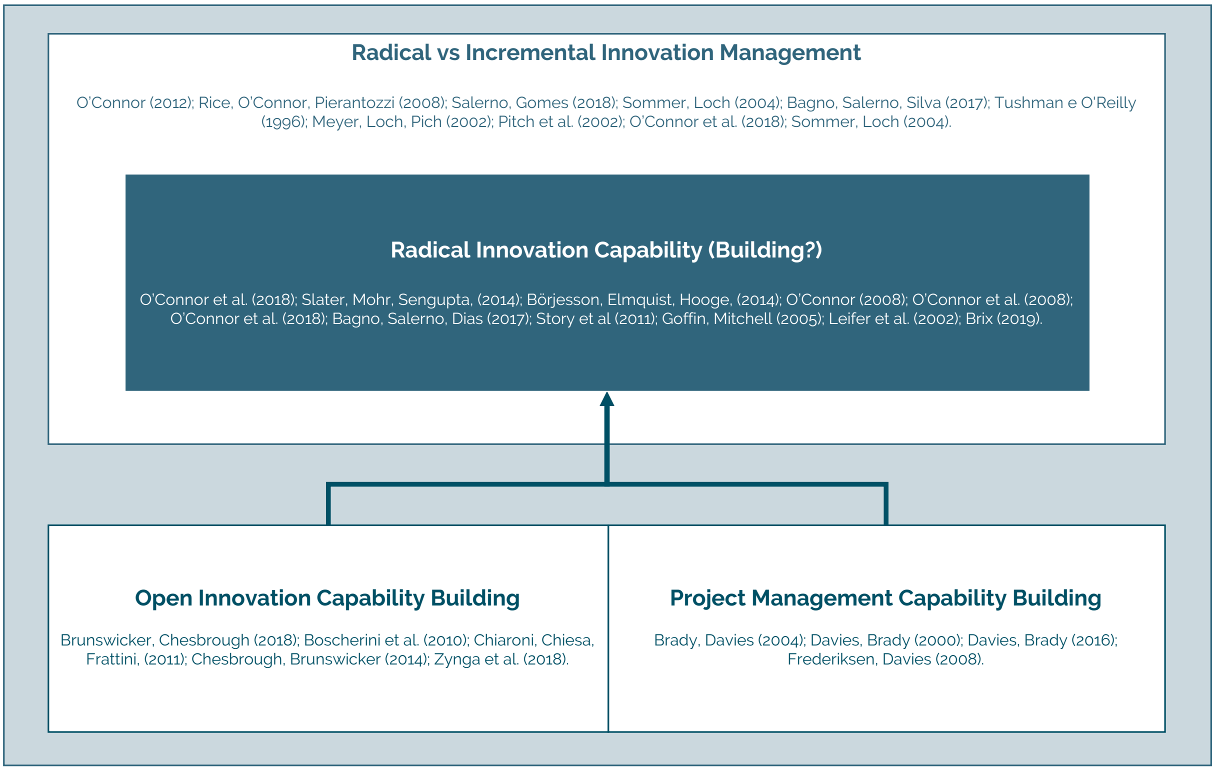
One of the strategies to deal with uncertainties in radical innovation projects is "selectionism" in which the company starts the innovation project from several possible technological routes at the beginning (items 3.1, 3.2, 3.3 in Figure 5 so that at least one proves to achieve the desired result (Sommer & Loch, 2004). Over time, some routes are aborted ("explosions" in Figure 5), or new routes may emerge from discoveries throughout the project (arrow linking route 3.2 to 3.3 in Figure 5 example). Each of the "explosions" in Figure 5 refers to the idea of Garud et al. (2017) in which the emergence of radical innovation is the result of an accumulated synthesis process marked by accidental or fortuitous events, in which multiple agents come together in specific local arrangements to make sense and transform the materials at their disposal. In this perspective ("innovation as a process" instead of the traditional "innovation process"), the actors actively contextualize their initiatives, continually redrawing their relationship boundaries, reinforcing or redesigning the existing ties. The beginning, middle and end of this process are mobilized and modified by the authors to form innovation journeys during the execution (i.e., in-the-making). In general, the vision of "innovation as a process" is guided by non-linear interpretations during the progress between multiple social and material elements. This view has fundamental principles similar to the learning logic of Sommer and Loch (2004) for the treatment of uncertainties in which the actors are continually attentive to the information that comes from the environment and judge when a change should be made in the course of the project (i.e., active incorporation of information).

Over the years, literature provided a lot of theoretical contributions to radical innovation management in mature companies. There is so much debate regarding organizational ambidexterity (Tushman & O'Reilly III, 1996), reinforcing the structural separation of the teams dedicated to radical and incremental innovation management in large companies (Simsek et al., 2009). Bagno, Salerno, and Silva (2017) deeply explores New Product Development (NPD) literature to discuss some innovation management models and argue that the analytic tools used for radical innovation are fundamentally different from the ones used to lead with incremental innovations. Ahuja and Morris Lampert (2001), for instance, connects the radical innovation discussion with entrepreneurship, emphasizing that large corporations must overcome some traps (e.g., familiarity, maturity, and propinquity) by experimenting technologies to create breakthrough innovations. O'Connor (2008) draws on systems theory, dynamic capability theory, and management theory to define a framework of seven elements (i.e., organizational structure, interface mechanisms, processes, skills, governance, metrics, culture) for the constitution of a complete system to manage major innovations. Important debates were carried out exploring connections between radical innovation and marketing disciplines, like (i) the introduction of radical innovations by incumbents (Chandy & Tellis, 2000), (ii) the importance of corporate culture as driver for radical innovation and the commercialization of innovations as a predictor of the financial performance of the company (Tellis et al., 2009), (iii) psychological processes underlying the individual consumer's adoption decision along with the diffusion of discontinuous innovations (Moreau et al., 2001), among others.

At the beginning of the radical innovation research stream, much attention was given to the champions' action in order to understanding how a radical innovation happens. The champion was the one who articulates projects throughout the company's internal and external network to accomplish its objectives (Dougherty & Hardy, 1996). However, recognizing that this approach was not sustainable for a company achieve systematic innovation by trusting on a talented individual, research evolved to a discussion of the capabilities that firms should develop to manage radical innovations (Leifer et al., 2000; O'Connor et al., 2008).

2.3. Radical innovation capability (building?)

Figure 6: Thesis theoretical framework - radical innovation capability (building?)



In this thesis, we rely on O'Connor et al. (2008)'s work to define an innovation capability as the (organizational) ability to generate innovations in a recurrent, systemic and wide-ranging way (and not as a result of individual brilliance or by chance). This capability can be considered dynamic in Eisenhardt and Martin (2000)'s sense as it depends on how managers alter their resource base (e.g., acquire and shed resources, integrate them together, and recombine them) to generate new value-creating strategies. For these authors, dynamic capabilities are often combinations of simpler capabilities and related routines, some of which may be foundational to others and so must be learned first. Exceptionally for product development, Slater, Mohr, Sengupta, (2014) define a radical product innovation capability as a dynamic capability, one that enables the organization to maintain alignment with rapidly evolving customer needs in high-velocity environments.

In this sense, the establishment of well-defined innovation process (like Stage-Gates®) does not fit to radical innovation management (i.e., enabling disruptive innovations several times) because this kind of innovation has an unpredictable and uncertain nature, and a smaller portfolio in number of projects (as discussed in Figure 5). Radical innovation is more about the construction of an organizational capability, usually associated to a specific management system (Bagno, Salerno, & Silva, 2017; Goffin & Mitchell, 2010; O'Connor, 2008; O'Connor et al., 2008). A management system can be considered the result of a learning process in which the company systematizes its competencies in routines and procedures to deal with specific problems (Fleury & Fleury, 2001). It involves a legitimate structure to continuously manage and improve an organization's policies, procedures and processes. Goffin and Mitchel (2010), for example, propose the pentathlon framework which extrapolate the stage-gate innovation process by adding the elements "strategy of innovation" and "people and organization". These elements appear as a way to support the repeated occurrence of the innovation process, guaranteeing that the behaviors will be oriented towards the achievement of the organization's objectives. For O'Connor et al. (2008), an innovation management system is formed by a set of elements necessary for an organization to function effectively, to guide its decisions, and to ensure that the behaviors will be oriented towards the achievement of the organization's objectives. These elements include: (i) Mandate and responsibilities - objectives and mission of the system; (ii) Structure and processes - ("Report to whom?; Hierarchical or flat organization?; Rigid or flexible?"); (iii) Resources and knowledge - ability to attract and develop staff with appropriate knowledge and skills; (iv) Leadership and governance (e.g., "How are decisions made?"; "Who takes them?"); (v) Metrics and reward systems.

Other management models for systematizing innovations are highlighted by Bagno, Salerno and da Silva (2017): (i) Kamm (1987), who relates organizational aspects to the phases of the Product Development Process (PDP); (ii) Jonash and Sommerlatte (2001), which points out how the different organizational functions of a corporation can be associated with the innovation process and its supporting elements (i.e., culture, leadership, among others); (iii) the pentathlon by Goffin and Mitchell (2005), which highlights the elements of strategy and organizational structure with fundamentals to guarantee the recurrence of the innovation process (i.e., idea, development, diffusion). In the vision of Slater, Mohr, Sengupta, (2014), a radical innovation capability comprises a set of organizational components: (i) senior leadership (i.e., to set an appropriate tone for innovation, articulate strategic intent and market vision, provide physical protection), (ii) organizational culture (i.e., adhocracy, customer and competitor orientation, technical and learning orientation, willingness to cannibalize), (iii) organizational architecture (i.e., cross-functional integration, reliance on partners, performance measurement), (iv) the radical product innovation development process (i.e., discovery, incubation, acceleration), and (v) the product launch strategy (i.e., guarantee focus, timing, marketing mix, bundling). Steiber and Alänge (2013) present Google's organization for continuous innovation which is characterized as a "dynamic and open corporate system for innovation, involving the entire organization, and supported by an innovation-oriented top management and board". These authors map seven organizational characteristics into four main building blocks: (i) *foundation* (e.g., innovation-oriented and change-prone top-management and board); (ii) *hygiene factors* (e.g., continuous learning, innovation-oriented performance and incentive system; semi-structured and ambidextrous organization); (iii) *facilitators* (e.g., empowering and coaching leaders removing obstacles for innovation); (iv) *key drivers* (e.g., innovation-oriented and change-prone culture; competent and committed individuals with a passion to innovate).

Although insightful, O'Connor (2008; 2012) argues that these management systems need to be held by a specific team, in this case (for radical innovation management), a dedicated organizational function - the "Innovation Function" (IF) (Bagno, Salerno, & Dias, 2017; O'Connor, 2012; O'Connor et al., 2008, 2018; Salerno & Gomes, 2018). O'Connor (2012) defines an organizational function as a group recognized in the organization, accountable for a specific mission within the organization. Lawrence & Lorsch (1967) argue that to be recognized in the organizational environment, an organizational function must differentiate itself from the others, but at the same time, it must be integrated with the mainstream to support the organization's central objective. Salerno and Gomes (2018) define an organizational function as "a perennial unit, formally recognized in the company, with responsibility for a specific assignment or mandate related to the company's mission, which implies having a central knowledge base (i.e., core base of knowledge.)". Salerno and Gomes (2018) remember that business processes cross-organizational functions in a transversal way orchestrating established knowledge (accumulated and owned by functions). In this sense, for the management of more radical innovations, an organization by function would be more appropriate, since it consolidates knowledge from a specific mandate on which it articulates its resources.

In the case of the Innovation Function (IF), the mission refers to radical innovation, one that creates opportunities (path-creating) instead of dependent (path-dependent) and offers new growth platforms for the company and benefits completely new to the market. The Innovation Function (IF) is considered emerging in organizations, but it has been gaining strength through formalizing positions and associated roles in large companies (O'Connor, 2012; O'Connor et al., 2018, 2008; Bagno et al., 2017). For O'Connor (2012), FI is responsible for the mission of creating opportunities and offering new growth platforms for companies and completely new benefits for the market. Salerno and Gomes (2018) define the IF's mission as "identifying, structuring, nurturing and managing a portfolio of radical innovations". Salerno & Gomes

(2018) argue that functional arrangement is adequate for systematizing the generation of radical innovations because it is the "best organizational mechanism for the accumulation of explicit and tacit knowledge regarding a theme." The function consolidates knowledge, since it has a specific mandate on which it articulates its own resources, independent from specific orders or clients - it is a reference for subjects related to its field of knowledge. Assuming Garud et al. (2017)'s perspective that radical innovation projects are marked by fortuitous events in which there is an articulation of multiple agents and resources, and that of Salerno and Gomes (2018) that the IF has the mandate to manage radical innovations, this organizational instance is the one who would assume the coordination of initiatives at those times. It should be noted that the IF takes on a more orchestrating role (O'Connor et al., 2008), and catalyzes the occurrence of innovations (Bagno, Salerno, & Dias, 2017) than in the participation of the project activities itself.

O'Connor et al. (2008) highlight three key competencies for the IF: discovery, incubation and acceleration (i.e., D-N-A model). The *discovery* involves the creation, recognition, elaboration and articulation of opportunities. It is not equivalent to the invention. The invention can occur outside the organization and be adapted to its own purposes, applications and capabilities. In *incubation*, ideas are transformed into business proposals, carrying out market analysis and establishing business models, for example. A prototype must be tested on the market in the case of the development of a goods. Among the necessary skills are experimentation, evaluation and review. Finally, the *acceleration* corresponds to the ramp-up (i.e., scaling) of incipient initiatives to a point where they can walk on their own in the final business unit. While the incubation seeks to mitigate technical and market uncertainties, the acceleration focuses on building businesses with a certain predictability of sales and operations. Its activities include investments in infrastructure, focus on responding to market opportunities, institutionalization of processes such as production and delivery orders, and contact with consumers. Once an innovation program generates profitable results, it is integrated into existing businesses or becomes an independent business unit. Specifically in Brazil, Bagno, Salerno and Dias, 2017) investigated 15 industries with a typical IF arrangement where a central team was in charge of certain assignments (e.g., finding tax and other funding opportunities, portfolio and project management, open innovation activities, knowledge development, among others) that characterizes the IF and make it identifiable in the organizational environment. Three instances would be associated with this team, supporting the work guidance, catalyzing internal connections or even assuming complementary responsibilities: (i) the strategic committee; (ii) focal points - people formally allocated in other functions, but working part-time as extensions of IF core team; (iii) and project teams - temporary structures working directly on the innovation projects. Following these perspectives, Melo and Bagno (2017) discuss how the development of the IF core team's assignments impacts the consolidation of IF in the organizational environment.

Previous paragraphs evidence that radical innovation management literature advanced over years in the definition of what should be an ideal management system to deal with radical innovations proficiently and also stated (by the proposition of the IF) how (or who) to operationalize this system. However, all the proposed models are essentially static – i.e., they present all the elements necessary to build a competence for radical innovation but fail to provide insights about the process by which mature companies can reach this goal (the capability building process).

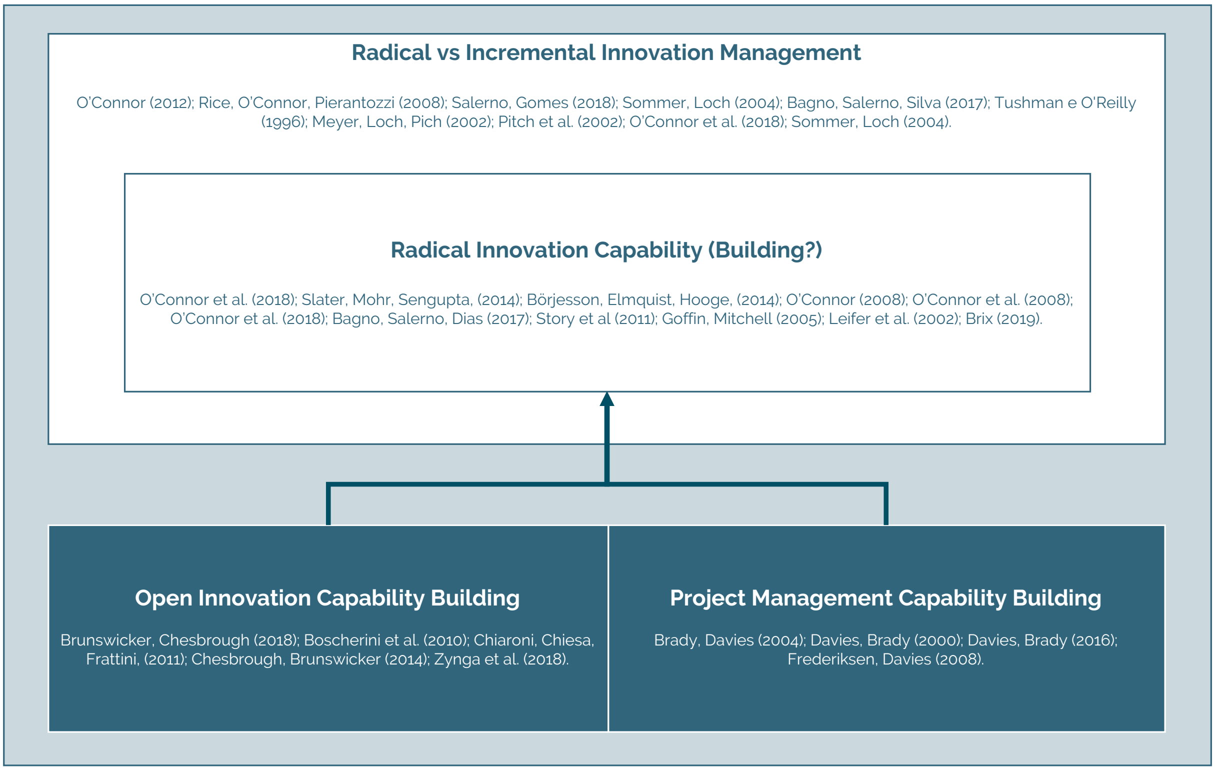
We found sporadic studies which tried to bring a more dynamic view of this capability building process. Brix (2019) proposes an innovation capability building framework based on a discussion about the local organizational context and interactions between management team and the employees. The author relies on a dual level approach (organizational and individual capacity building) to suggest that contextual ambidexterity (i.e., a bottom-up approach for ambidexterity, involving the capacity to simultaneously demonstrate alignment and adaptability across an entire business unit) can emerge in interaction between leaders and their team members and as a result of their dynamic interpretations of the environment and efforts to respond to perceived environmental changes. Based on a five-year longitudinal study, Börjesson et al. (2014) studied two initiatives for the development of innovation capabilities in firms in the automotive industry whose focus was on two missions: managing a portfolio of innovations and their subsequent activities and building capacities to innovate from a systemic perspective. Börjesson et al. (2014) brings important insights as the fact that the first mission became a tool to achieve managers' second objective. As working on an innovation portfolio is a concrete task that can be managed, communicated and evaluated, tangible results of this work can be used to create awareness of the need for innovation. Successful innovation projects can be identified as success stories, helping to convince managers and other employees of the value of developing innovative capacity. O'Connor et al. (2008) summarize the innovation capability building into main phases: setting the stage; initiation; and maturity. In the first phase, there is always a central motivation or a trigger event (e.g., strategic growth, financial return, technology strategy, need for skill development, product/business diversification and defense current business). Next, the whole management system is put into practice. There is a focus on the creation of an innovation-based culture, either by promoting workshops of ideation, by defining vocabulary for innovation and by seeking the people (leaders and staff) who will be involved in the new mission. The innovation management system only reaches maturity after the systematization of some processes like initiation, support and reward for its activities. The last stage (i.e., maturity) is achieved through the consolidation of the new organizational function (the Innovation Function), in a company. IF must be identifiable and measurable, in a way that it may be testified by rich interfaces and/or strong networks both internal and external, defined governance in project and portfolio levels, availability of appropriate metrics, and the rising of a culture / leadership that values innovation. Despite valuable insights, exemplified studies about innovation capability building (Börjesson et al., 2014; Brix, 2019; O'Connor et al., 2008) normally focus on a different level of analysis (e.g., the creation of new business units or R&D Centers) and pay little attention to the actions performed by individuals during innovation projects, from a micro perspective. Their insights do not provide specific guidelines for the capability implementation process. Finally, there is an encouragement for innovation studies that connect different levels of analysis (e.g., intra-organizational, organizational, extra-organizational) in multi-level perspectives, establishing, for example, linkages between projects and the firm's development of capabilities (Bogers et al., 2017; Kouamé & Langley, 2018; Perks & Roberts, 2013). In this sense, we included (presented in the next subsection) theoretical discussions about capability building both from Open Innovation (OI) and Project Management (PM) to address previous gaps about radical innovation capability building.

2.4. Selected theories about capability building

Open innovation (OI) has mainly been adopted, with firms engaging in a variety of practices, from bilateral to multiple parties' relationships (Brunswicker & Chesbrough, 2018; H. Chesbrough & Brunswicker, 2014). Despite its full application, OI has not been sufficiently formalized as a management practice by organizations (Brunswicker & Chesbrough, 2018; H. Chesbrough & Brunswicker, 2014; Mortara & Minshall, 2011). Scholars demand more theoretical approaches to manage open innovation initiatives as an organizational capability (Lichtenthaler & Lichtenthaler, 2009). In this sense, Project Management (PM) literature could be a valuable source to accomplish with the gaps identified in OI field, despite the focus on single and predicable megaprojects associated with existing customers and repeatable businesses (e.g., turnkey, outsourcing, public-private partnerships).

Deliberately in this thesis, as noted in Figure 7, our study was highly influenced by the "project-capability building" framework proposed by Brady and Davies (2004) and Zynga et al. (2018)'s model of the transition from closed to open innovation (i.e., unfreezing, moving, institutionalizing). The concepts of "project capabilities" (Davies & Brady, 2000) and "vanguard projects" (Brady & Davies, 2004; Davies & Brady, 2000; Frederiksen & Davies, 2008) were also central to our theoretical advancements. Moreover, some case studies about OI capability building (Boscherini et al., 2010; Chiaroni et al., 2011) served as inspiration to shape our causal case study (causal process linking a cause, or a set of causes, with an outcome – c.f., Beach & Pedersen, 2016; George & Bennett, 2005), gradually investigated in P#1, P#2 and P#3.

Figure 7: Thesis theoretical framework - selected theories about capability building

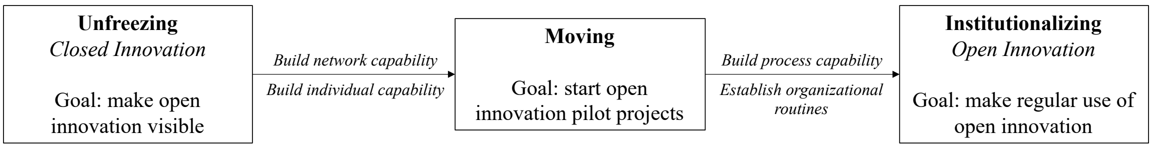


2.4.1. Open innovation

The open innovation (OI) paradigm, formally presented by Chesbrough (2003), assumes the principle that innovation should not be based only on firms' internal and isolated efforts. In this sense, partnerships with startups and research institutes, the involvement of customers and suppliers, and other partners can be a reasonable path to boost firms' innovative potential. However, from an organizational perspective, open innovation is often poorly formalized, and companies usually lack routines and metrics to manage it accordingly (Brunswicker & Chesbrough, 2018).

Boscherini et al. (2010) argue that organizational barriers and inertia need to be overcome in a transition from closed to Open Innovation. Highly inspired by studies on organizational change (Armenakis & Bedeian, 1999; Kotter, 1995; Lewin, 1947), these authors adopt the three-step process of unfreezing, moving, and institutionalizing to describe such a transition, an idea also present in Huizingh (2011). In this line, Zynga et al. (2018) proposes a process for open innovation adoption - (Figure 8). This model is centered in three categories of micro foundations: (i) individuals – dedicated ones (e.g., gatekeepers, scouts) to connect the organization to the external environment; (ii) processes – staged processes; (iii) structures – organizational structures to support open innovation. The authors argue that these micro foundations must be developed in a coordinated way to build an OI capability. During Phase 1 (unfreezing), innovations are more closed, and the firm develops more traditional connections (i.e., customers and suppliers) to transfer knowledge. In Phase 2 (moving), firms typically form clusters of micro foundations related to individuals and structure, and also start pilot projects. Phase 3 (institutionalizing) represents the moment of the full capability development, in which culture and mindset are considered established, and there is a formal structure to manage projects.

Figure 8: Process model of the transition from closed to open innovation



Source: adapted from Zynga et al. (2018)

Open innovation capability tends to be associated only as result of highly intentional and planned managerial efforts (Brunswicker & Chesbrough, 2018; Chesbrough & Brunswicker, 2014). Rarely this literature has treated the adoption of open innovation as the use of new practices, ignoring even the need for building a broader and complex organizational capability (like the radical innovation capability as an organizational function), as argued by Zynga et al. (2018). During this thesis, during the preparation of Paper #2, it was important to search for another level of analysis to explore the studied case from a more micro level of analysis. The choice was to focus on the "project-level" construct, especially the project management capabilities discussion and the "vanguard project" concept, presented in next subsection.

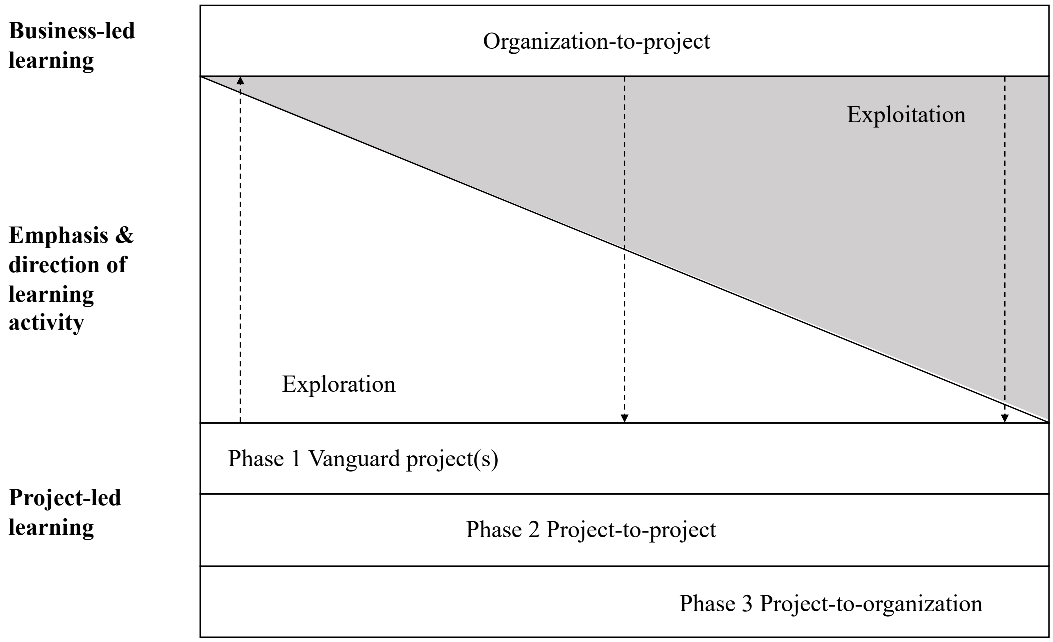
Project Management (PM) literature can be a valuable source to accomplish with the previous gaps identified in OI field. For instance, Worsnop, Miraglia, and Davies (2016) propose meaningful connections between OI and PM by discussing the relationship between open and closed innovation in civil engineering projects. However, their focus is on a single megaproject and does not cover capability development at the firm level. PM scholars notably offer substantial contributions about organizational capability building in mature companies (Brady & Davies, 2004; Davies et al., 2016; Davies & Brady, 2000; Söderlund, 2004; Söderlund & Tell, 2011).

2.4.2. Project management

Davies and Brady (2016) suggest that firms should establish distinct project management routines for exploration and exploitation. The project capabilities construct has been frequently debated in the literature (Brady & Davies, 2004; Davies & Brady, 2016). It "refers to the distinctive managerial knowledge, experience, and skills, which are located within a single organization (a firm) and required to establish, coordinate, and execute projects." (Davies & Brady, 2016, p. 314). Davies and Brady (2000) stated the concept of "project capabilities" where firms can use a first of its kind project - "vanguard project" - to explore new capabilities or domains of business. Frederiksen and Davies (2008, p. 489) define a vanguard project as a "new type of project organization developed specifically to experiment with and learn from new technology and to explore novel market opportunities".

A project capability sets routines, processes, and structures over time to guarantee the perennial ability to conduct projects by controlled and established flows. At a higher level of aggregation, project management capabilities can be dynamic capabilities (Teece et al., 1997), associated with organizational and strategy renewal (Davies & Brady, 2016). Brady and Davies (2004) proposed the "project capability-building" framework to explain how firms use vanguard projects to create a new organizational capability, based on two levels of learning: project-led and business-led. In this approach, Brady and Davies (2004) explain in a complete way the process by which companies build capabilities to deliver projects regularly after managing a vanguard project (i.e., the "project building-capability" framework – Figure 9). According to these authors, the establishment of a vanguard project can initiate an organizational cycle leading to changes in the capabilities and organization of the firm.

Figure 9: Project building-capability framework



Source: adapted from Brady and Davies (2004)

In phase 1 (Vanguard project), a new project is created in the organization to explore strategic opportunities (move technology/market bases or adapt to the environment) and vanguard projects help to gain experience over the new activity. In phase 2 (Project-to-project), the main goal is to transfer insights from the vanguard project(s) to subsequent project. Finally, in phase 3 (Project-to-organization), organizations have to grow in size, or new specialized units must be created to handle this new portfolio of projects of the same type. These project-led learning processes are embedded into the broader context of the firm (business-led learning). Several studies have shown that firms do achieve organizational learning through projects (Prencipe & Tell, 2001). In this thesis, our argument is that vanguard projects can serve as a trigger for mature organizations to build competences for radical innovation management – i.e., a typical "project-led learning" process in Brady and Davies (2004)'s sense where companies execute one new type of project and, from this experience, competencies are gradually incorporated and replicated in the following projects. Brady and Davies (2004) also demonstrate that the learning activity encompasses intertwined exploration and exploitation activities over the process (i.e., there are two interacting and co-evolving levels of learning). The "project-capability" model suggests a path to build project capabilities with a predefined sequence (i.e., from exploration to exploitation).

In sum, we advocate that project capabilities research stream, if combined with the open innovation capabilities discussion, can help to explain the process by which mature companies build an organizational capability to manage radical innovation systematically, as presented in the general thesis framework (Figure 3: Thesis theoretical framework). Next section presents the methodological approach of the thesis, characterizing process research theory, detailing some nuances (e.g., differences about process/variance theories, types of process research, strategies for data collection and analysis), and finishing with a discussion about Event Structure Analysis.

3. METHODOLOGICAL APPROACH

3.1. Process theory and research methods

In recent years, qualitative research gained substantial prominence in business and management fields, not only on quantity but also impact and contribution for theory development (Gehman et al., 2018). Gehman et al. (2018) take a vision of methods as tools that should be used for different purposes. These authors discuss the three main influential contributions on qualitative methods: Gioia's method, Eisenhardt's theory-building from cases, Langley's process research, each of them based on different ontologies and epistemologies which influence the nature of the proposed theory and its relationship with the methods.

Gioia's is considered a pure interpretivist method (c.f., Gioia et al., 2013). In this approach, people living, and experience are considered to systematically evaluate theoretical constructs built as the research is carried out (first and second-order labels). Eisenhardt's theory-testing method (c.f., Eisenhardt, 1989) relies on the combination of constructs, propositions, and theoretical arguments to explain a general phenomenon. This is a more inductive approach where researchers seek to produce testable and generalizable theories from multiple cases studies. Finally, Langley is one of the most representative authors of process research (Langley, 1999; Lerman et al., 2020). She defends "process" as a position about research (Gehman et al., 2018). Process theorists seek to explain the world in terms of interlinked events, activities, temporality, and flow (Langley et al., 2013). The notion of "process" implies a sequence of events, activities, and interactions over time-related to a strategy-relevant issue (Kouamé & Langley, 2018).

This thesis is essentially process oriented (i.e., all three papers use process methods). The "event" construct is central to this kind of research. It is associated with "what happened and who did what when" (Langley, 1999, p. 692). However, process theories are produced by understanding patterns in the event's sequence (Cloutier & Langley, 2020; Langley, 1999; Lerman et al., 2020), and not merely presenting a series of events in the form of narratives (Beach, 2020). Listing events were the starting point for this thesis data analysis. It helped both: (i) to prepare the causal narrative of Paper #1 which culminates in the model “competence accumulation - intermediate results - progressive legitimacy gain”, detailed in Subsection 4.1; (ii) and also to generate the causal network presented in Subsection 4.2 used in Paper #2 to reach the four-stage process about innovation capability building (i.e., “Closed-mode, Open-Driver, Vanguard-Project, Project-to-organization”). Paper #3 deepens on event construct by exploring an “event frame” with the main constituent elements of a typical event (e.g., agent, action, object), inspired in Heise and Durig (1997). These elements served to the “critical associations” analysis presented in Subsection 4.3, in which the relationships between agents during the construction of an open innovation project management capability for the studied case are modeled.

In process research, depth (e.g., cases, events, data sources, time period) is usually preferred over breadth (Beach, 2020; Bizzi & Langley, 2012). Process researchers prefer producing a rich understanding of specific contexts rather than performing a comparison provided by multiple case methodologies. Generalization in process research always relies on contributions to theory rather than statistical regularities (Kouamé and Langley, 2018). Kouamé and Langley (2018) argue that the notion of “transferability” stated by Lincoln and Guba (1985) is more relevant in this context by the fact that process research does not generate normative prescriptions. This form of “portability” of the results of a unique case is based on the analytical premise of "thin rationality" (Bengtsson & Hertting, 2014), according to which the social mechanisms found in a case can be carried over to other similar contexts, if conceived as ideal-typical expected patterns of action and interaction. In this sense, process research is suitable for long-term research strategies as long as it allows returning to old data (in the same case) and revising related contexts or theoretical foundations to possibly generate new theoretical contributions (Bizzi & Langley, 2012; Langley, 1999). In this sense, this thesis is based on a single case study of ORTENG, coded as “ORT” or “IEM” in the articles - an organization of the energy and automation systems sector. During the period of the study, this company had 3,000 direct employees and revenues of R$ 1bi / year. Its field of activity covered Energy, Refining and Sanitation, Metals and Cogeneration, Mining and Oil & Gas markets. As noted in Paper #2 (section “Method”, subsection “The Case”), the case was chosen (and proved to be a relevant context for this study) because: (i) it had the right criteria for state-of-art causal process-tracing research (Beach & Pedersen, 2018); (ii) the sector (engineering based company) and related products (technologically sophisticated modular ones) is a typical fruitful field to track innovation management capabilities; (iii) in large companies such ORTENG, establishing corporate-level capabilities from business-level projects is a strategic priority if the corporation is to properly manage its portfolio of multiple parallel innovation projects, whose leaders might be dispersed through its large organizational structure (Bahemia & Squire, 2010).

Another important distinction involves duality process-variance theories (Langley, 1999; Beach, 2020). In variance theories, the emphasis is placed on relationships between variables (Mohr, 1982). Process research involves studying how and why some significant temporally evolving phenomenon unfolds over time (Langley, 2009). This view carries a notion of progression, focusing on temporal and sequential relations among the studied phenomena (Kouamé and Langley, 2018). According to Bizzi and Langley (2012), “process research is preoccupied with appreciating and theorizing about their temporal patterning, rather than focusing on co-variation between independent and dependent variables as is the dominant approach in business studies”. For Gehman et al. (2018), using a variance thinking (e.g., A is better than B) does not capture the movement over time to move from A to B. In variance thinking, the outcome is always predefined. In contrast, time always goes on in a typical process research.

The last paragraph brings a vital discussion about the notion of process versus things (i.e., strong and weak process theories – c.f., Cloutier and Langley, 2020; Langley and Tsoukas, 2017). From the “weak” ontology view, the world is composed of things that maintain their identity over time (Bizzi & Langley, 2012) – this vein see processes as “happening to things” that retain their unique identity over time (Langley & Tsoukas, 2017). On the other side, a “strong” process ontology would imply focusing on how flows of activity continually reconstitute stable phenomena such as organizations, structures, cultures, identities. In this view, “a river is not an object but an ever-changing flow; the sun is not a thing, but a flaming fire”, as exemplified by Rescher (2013). In this perspective, “a process perspective would generally view outcomes at particular points in time as ephemeral way stations in the ongoing flow of activity” (Langley et al., 2013, p.10). This means that process data often have ambiguous boundaries that span multiple units and levels of analysis (Langley, 1999). Outcomes are no more than the starting point for subsequent actions and processes (Bizzi and Langley, 2012). For example, in this thesis (mainly Papers #1 and #2), we argue that a capability for radical innovation was set on the studied case more based on a status change (i.e., over the period, it developed organizational capabilities to nurture a radical innovation portfolio) than by determining a specific event over time (i.e., something like a turning point). Figure 11, presented in Section 4 clearly evidences this change (e.g., in number of team members, portfolio size).

Since process studies may vary on temporal orientation, data collection can be done by tracing back happening of the past (i.e., retrospective) or carried out in real-time. Real-time research can provide rich data about the phenomena as it emerges (Bizzi and Langley, 2012).

Retrospective studies depend on reliable data about crucial events and when they occurred. Gehman et al. (2018) emphasize that data must fit the project (e.g., interviews for events which occurred in the past; real-time observation to catch interpretations or cognitions). Bizzi and Langley (2012) recommend triangulating the "big three" (i.e., observation, interviewing and archival documents) data sources to guarantee rigor on qualitative research and to overcome weaknesses between them. Whereas observation is useful to comprehend behavior, interviews can be helpful to link temporal phenomena across time, and finally, documents may support key event chronologies construction. The dataset of this research was collected both in retrospective and real time. I guided a longitudinal participant observation (Langley et al., 2013) for approximately four years. In this period, supporting documents were collected to serve as a supplementary data source, including e-mails and administrative documents - e.g., proposals, reports, internal documents and meeting minutes, studies and evaluations, media publications, tables and budgets and personal records (journal entries and schedules. In a second moment, we added a retrospective approach to the data collection in order to understand the phenomenon before and after the participant observation. Accordingly, eight semi-structured interviews were conducted with key stakeholders who were involved in the process of building the new organizational function in ORTENG.

One of the most recognized papers about process studies is Langley's (1999) presentation about seven analytical strategies to generate useful insights from process data. The narrative strategy involves a detailed story ("thick description") and can be used in distinct phases of a given research – it served as the main strategy for theorization in Paper #1 and, in Papers #2 and #3 the narrative helped to prepare data for subsequent qualitative formal analysis (e.g., Event Structure Analysis). The quantification strategy works with large data sample codification respecting clear theoretical lenses. A grounded theory strategy encompasses the identification of key-categories to integrate theoretical constructs in a meaningful way. The synthetic strategy identifies regularities between events and global measures obtained from case comparison. Visual mapping allows process representation in various dimensions and is used to show precedence, parallelism, activities and outcomes relationships, among others. Alternate templates comprise different interpretations of the same event frame using distinct theories, in a deductive manner. Finally, temporal bracketing is the exercise to segregate a process into building blocks (i.e., stages) respecting some criteria – as an example, the four-stage process (i.e., closed mode, open-driver, vanguard project, project-to-organization) presented in Section 4.2 is a typical bracketing separation. Lerman et al. (2020) argue that these strategies are often used in combination. Lerman et al. (2020) reveal narrative strategy as the most dominant strategy among the selected studies, used for various purposes, including the description analytical procedures, to organize data offered by a chronology of events, and also a tool in the process of theory development (i.e., clarify sequences of analysis, establish causal links, and identify early themes) or the final research product/outcome. Despite widely used, Bizzi and Langley (2012) and Lerman et al. (2020) emphasizes that temporal bracketing has been applied in previous process studies merely to divide temporal sequences or periods without any theoretical significance (i.e., like phases of a predictable process). In this thesis, temporal bracketing was carefully used to separate the four-stage process presented in Figure 12, Section 4.2, where each transition between phases was justified as "turning points" in the story by a rigorous qualitative formal analysis (i.e., betweenness centrality calculation).

According to Cloutier and Langley (2020), there are five broad challenges (i.e., shifts in researchers' mindset) to generate relevant process theory: (i) from the "what" notion from concepts (variance thinking) to events, activities, and trajectories; (ii) from entities to entanglements – i.e., there are no static entities but a web of dynamic relationships; (iii) from the notion of the relation between constructs (i.e., more X, more Y) to process explanations (i.e., causality composed by chains of events that may not accomplish things over time; (iv) from outcomes to potentialities – i.e., to accept that there is no defined outcome but multiple process pathways; (v) from prediction to generative mechanisms – i.e., what constitutes a relevant theory is the "why", the explanatory story or narrative. Gehman et al. (2018) also point some typical problems (i.e., no theoretical contributions) in process research, notably: the generation of narratives without theorization, the "anti-theorizing" issue (i.e., fit the case in a received view), and what they call "illustrative theorizing" (i.e., labeling qualitative data to a preconceived theory). In process-tracing studies, Beach (2020) criticize what he called minimalist approaches in which the causal mechanisms are not unpacked (i.e., are typically in a high level of abstraction), and the parts of the process and causal logic that link parts of the process are not specified. In this author view, process studies should unpack a mechanism into constituent parts (i.e., entities engaging in activities) and test more rigorously when there is a strong evidence of causal relationship. In this thesis, we gave severe attention to this point by introducing the notion of mechanisms linking the most important events of the case (detailed in section "Example of application" - Paper #3) after a cautious step of establishing causal linkages (relationships) between events from optimization algorithm of the ETHNO Software, choosing the counterfactual question proposed by Mahoney (2012) for each pair of events in a process tracing logic.

Cloutier and Langley (2020) postulate four main styles to make significant contributions in process theory: linear, parallel, recursive, and conjunctive. In "linear studies", authors try to enrich previous staged process models by adding elements to explain dynamics between stages and outcomes. Paper #2 is an example of this linear style in which the four-stage process (i.e., closed mode, open-driver, vanguard project, project-to-organization - Figure 12, Section 4.2) was built inspired by previous capability building process models from open innovation (Zynga et al., 2018) and project management (Brady & Davies, 2004) literatures. The "parallel style" involves the evaluation of multiple processes which reinforces or affect each other (e.g., coevolution or bifurcation). On the other hand, the "recursive style" is based on different views of ongoing processes: interactive (i.e., accumulation of experiences between two entities over time); systemic (i.e., dynamics on stability or change, and the relationship with microprocesses); cyclical (i.e., amplification or diminishment provoked by repeated processes on outcomes); dialectical or evolutionary (i.e., phenomenon influenced by tensions among groups – c.f., Van de Ven and Poole, 1995). Regarding the connection between micro-processes to macro-outcomes, Kouamé and Langley (2018) highlight three genres of what is called "progression research": (i) flow matrix (e.g., Burgelman, 1983) which captures sequential and mutual influences between individual-level and corporate-level activities; (ii) recursive structuration (c.f., Barley, 1986) where the focus relies on the recursive link between micro-level activities and macro phenomena over time; (iii) outcome-driven narrative – aim to understand how a particular outcome emerged by searching the sources of explanations at the micro-level, usually taking historical forms of causal explanation expressed through chain of events and their interaction (e.g., Vuori and Huy, 2016). This thesis and related papers are inspired by this last category.

Bizzi and Langley (2012) state that some form of a valuable conceptual product (i.e., theoretical advances in relevant research questions) is essential in conducting successful process research. This means, for example, (i) "process patterns" (i.e., descriptive regularities in the evolution of phases of a process over time); (ii) "mechanisms" underlying the regularities about these processual patterns; and (iii) "meanings" about event's interpretation by research participants in a narrative or grounded theory. These mechanisms, in Gehman et al. (2018)'s sense is the set of driving forces that underlie and produce the patterns observed empirically. Some researchers abstract variance-based theoretical understandings from process-based empirical foundations to develop prediction models (c.f., Eisenhardt, 1989). Gehman et al. (2018) cite good examples of what can be considered good theoretical contributions to process research, for example, Monin et al. (2013) discussion about how dialectics and contradiction constitute a process motor, and Gehman et al. (2013), which explore the interaction between micro-processes and macro processes and how one grew out of the other, addressing Koumé and Langley (2018) claim for multi-level approaches in this research stream. More exemplars can be found at Langley, Smallman, Tsoukas, & Van de Ven (2013) collection of papers about the temporality, activity, and flow characteristics underpinning process studies. More recently, Lerman et al. (2020) investigated how ideas from Langley's (1999) seminal article have been used in practice, analyzing 176 articles from eight well-recognized management and organizational journals. The selected papers were classified as "exemplars" (i.e.,, articles that used Langley's process methods exemplary), "adaptions" (i.e., articles that extended Langley's ideas), and "considerations" (i.e., superficial citations or distortions).

3.2. A brief of Event Structure Analysis (ESA)

More specifically, this thesis is a representative of process-tracing (Beach, 2020; Beach & Pedersen, 2019; Mahoney, 2012), a method to explore in-depth cases to make within-case inferences about the operation of causal mechanisms that link causes to outcomes. Process-tracing studies seeks for mechanistic causal claims about the process that link a cause (or set of causes) with an outcome within a case (Beach, 2020; Beach & Pedersen, 2016). The concept of causal mechanisms is related to causes, but to the processes that are triggered by causes and that link them with outcomes in a productive relationship. Mechanisms can be imagined as "interlocking parts that transmit causal powers or forces between a cause (or set) to an outcome" (Beach & Pedersen, 2019).

In order to perform this kind of research, this thesis makes use of Event Structure Analysis (ESA) – c.f., Paper #2 and Paper #3. Event Structure Analysis (ESA) was proposed at the end of the 1980s by Heise (1989). It is a framework for computer-assisted analysis of event sequences containing analytic procedures to generate a qualitative model that graphically displays event logical relations. The author characterizes ESA as a "methodology for qualitative modeling of logical structures that guide action in concrete situations" (Heise, 1989, p. 2). ESA was created inspired in production system models in order to generate a unique sequence without outside interference where social experts use the language that experts use to talk about and think about their experiences (Heise, 1989). Corsaro and Heise (1990) this "production-system" inspiration is valuable as long as it states that events occur in a specific domain, logical relations define prerequisites for some events (i.e., events cannot occur until all its prerequisites have occurred), and other general rules (e.g., events do not repeat). Griffin and Korstad (1998) remember that ESA borrows features from formal social science like explicit deployment of theoretical concepts and hypotheses, application of causal generalizations, and use of replicable procedures of analysis. Given its originality and logical rigor, ESA contributed to establishing a new methodological category called "formal qualitative analysis" (Griffin & Ragin, 1994).

Corsaro and Heise (1990) application to model ethnographic descriptions in a study about approach-avoidance play in the peer culture of nursery school children. For these authors, ESA is useful for the analysis and interpretations of discourse processes and other cultural routines, like, for example, in medical, educational, and organizational settings. The benefits of the method include computer-assisted construction of explicit models, systematic consideration of logical relations, potential for revisiting formulations based on archival data, and to explore new scenarios through simulation analyses. Griffin (1993) was one of the first applications of ESA to evaluate historical narratives (i.e., a chronologically sequential order in a single coherent story). According to this author, narrative explanations, until that moment, were “merely descriptive” stories with poor causal explanations of social process – it was necessary to “unpack” narratives and analytically reconstitute them to build a replicable causal interpretation of a historical happening. Another formal qualitative analysis of narrative sequences already existed that time (e.g., “comparative narrative analysis”, unidimensional and multidimensional scaling - c.f., Abbott, 1992), but in the vision of Griffin (1993), they did not provide Weberian-type causal interpretations based on counterfactuals (i.e., what if questions). Griffin (1993) states that ESA is suitable for causal interpretations of historical happenings because: (i) it forces the analyst to replace temporal order with his judgement about causal connections; (ii) the method’s elicitation maintains fidelity with the interrogatory spirit; (iii) the logical foundations in production systems lead to the comprehension of historical events as configurational, contingent happenings; (iv) the obtained inferences are replicable. For Heise (1989) ESA has two main advantages: (i) it is a *systematic* methodology (i.e., generates a model that accounts fully for event sequences); it is *quantifiable* (i.e., directed graphs representing logical relations among events can be converted to a matrix format subject to mathematical analyses). In fundamental methodological reviews on the analysis of processes and narratives, Mahoney (2000) and Abell (2004) were unanimous in recognizing ESA as the main analytical approach for intra-case study of event causal chains.

According to Heise (1989), ESA has eligible methodological principles: *elicitation from experts* (i.e., listing the relevant events and pairing them in order to ask whether one event implies the other); *use of incidents* (i.e., focusing on events with relative significance/relevance); *dealing with local logic* (i.e., pairing all events in a system and ask about implications will result in a set of answers that might be logically inconsistent – the logical structure should have predominantly “yes” questions); *using obtained knowledge* (i.e., make use of implications already identified during the elicitation process); *fallibility of data* (i.e., the record can be changed selectively and thoughtfully during the analysis to achieve consistence between model and qualitative data); *prioritization by observation* (i.e., fiving a measure of priority to the event that happens-relative to the other events that were possible at that point). The release of the ETHNO software (https://cs.uwaterloo.ca/~jhoey/research/ACTBackup/ESA.html) in parallel with the first publications may have contributed to this diffusion (Abbott, 1995). Heise and Lewis (1988) detail ETHNO modeling. In sum, the program asks which prior events are prerequisites for the last event entered with relation questions about “something similar”. The program determines which events can initiate the series and then implements the next recorded events by revising, at each loop, which set of other events are now possible. Heise (1989) emphasizes that the resulted model can be tested and refined through analysis of additional data – simulations (i.e., generate other sequences that are logically correct but different to model priorities at some point) can be carried out to explore a variety of happenings within the system or to discover troublesome features of a model. According to Griffin and Korstad (1998), ESA is a “flexible analytical tool” as long it is capable to deal both with “theoretical” and “historical” purposes, it can be applied to singular happenings or systematic comparisons, and it can treat events from large blocks of space and time.

However, ESA was rarely applied in management-related fields (Stevenson & Greenberg, 2000, 1998; Valorinta et al., 2011). Also, in general, these applications only replicated the basic procedures of the initial proposal of the method. None of them, for example, adopted the robust system for coding events. Similarly, none of these papers explored the potential of the combination of ESA with network analyses, or with causal process tracing tests - which has been receiving a lot of attention in the field of comparative-historical methodologies in recent years (Bennett & Checkel, 2014; Blatter & Haverland, 2012; Kittel & Kuehn, 2013; Mahoney, 2012).

In the course of this thesis, we developed general improvements on ESA’s application (i.e., event codification, process tracing tests, combination with network analysis) and exemplify some analyses. Paper #3 focuses improvements on the original ESA method: (i) a robust system for coding events; (ii) the use of causal process tracing tests for inferring necessary connections; (iii) the combination of ESA with network analyses. We also presented five types of analysis for event network models (i.e., critical elements, critical associations, critical connections, critical specific happenings, and critical antecedents). One of this analysis types (i.e., critical specific happenings, based on degree index calculation), for example, was crucial to support the theoretical discussion of the role of vanguard projects to trigger the innovation capability in Paper #2 (Melo et al., 2020).

4. RESEARCH RESULTS

This section presents thesis results, summarizing the main findings of each article produced.

4.1. The *Competence accumulation - intermediate results - progressive legitimacy gain* loop

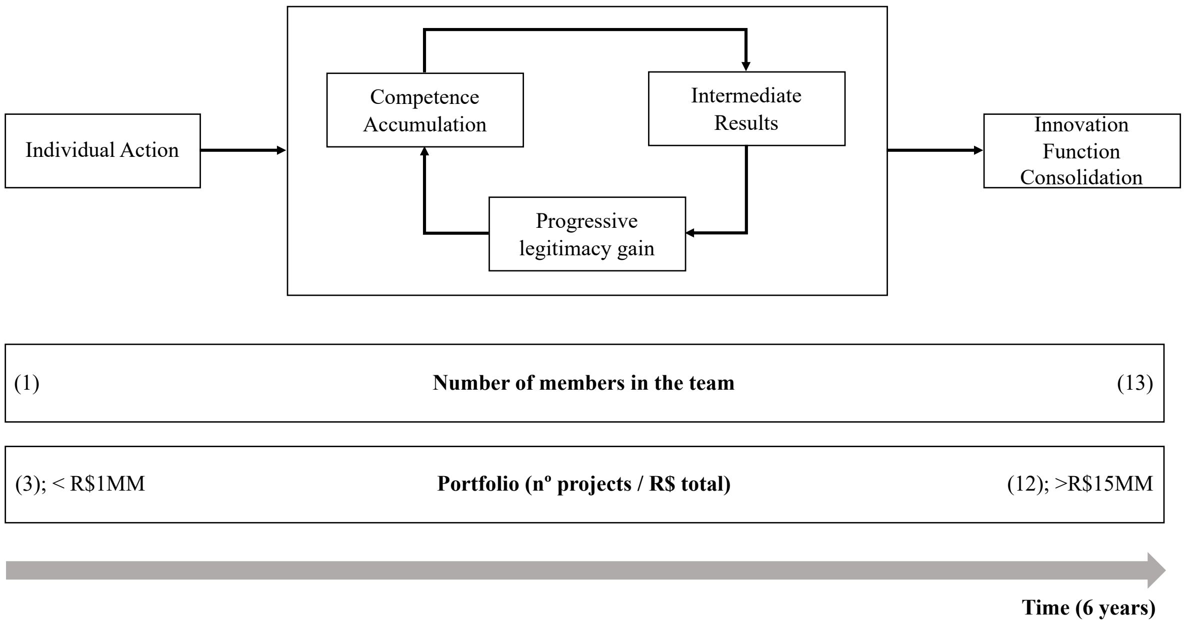
P#1 (Melo et al., 2020) addressed the specific question about "how do large industrial organizations build a dedicated function to the management of innovations?”. In order to answer the research question, a single in-depth case study was carried out in a large electro-electronic company (ORTENG), based on a procedural and retrospective approach. P#1 presents the history of this organization over six years in the construction of a dedicated function to the management of innovations, from the designation of a manager to assume such mission until the formalization of a department with more than 10 employees, responsible for a portfolio, at the end of the period, of 12 projects (total amount of approximately R$15 million budget).

The case narrative can be considered one of the results of this paper. It was divided into four subsections. The “Antecedents” summarizes the company history before the initial movements towards innovation initiatives and the direct influence of some governmental policies (e.g., P&D ANEEL, Innovation Law, “Lei do Bem”) for the company top management. In the subsection “Cycle 1 – Setting the stage”, the company allocated a dedicated person to manage the innovation portfolio and the first open innovation projects started. During “Cycle 2 - A new leadership”, important structural changes were made in the corporate governance (e.g., partners left executive roles to assume as board members; creation of strategic committees– on for the Research, Development and Innovation (R,D&I) theme; establishment of a new shared-services cross function to assist all business units, including IT, Law, Finance, Accounting) , and the organization accumulated competences (e.g., IP protection, project management controls, financial valuations, stage-gate® processes, new business process for resource control and status reports) to lead with more radical innovation projects. The final phase “Towards maturity” brings details about the last stage of maturity in the company, highlighting the structure and portfolio’s growth in terms of members, number of projects, and amount of investment, respectively. In this final moment, a change in the organizational structure of the company represented, for the first time, the creation of a formal department to handle with innovation activities. That department was responsible for both the execution of the projects and their management.

It’s important to note that the narrative concatenates all the collected data in a meaningful way (from theoretically informed reading), without losing their adherence to the case and language settings. The narrative strategy is recognized as an efficient strategy for analysis and not only as a mere step to prepare chronology (Langley, 1999). As pointed by Pentland (1999), narratives, if based on typical features (e.g., sequence in time, focal actors, identifiable voice, an evolutive frame of reference, context indicators), can be valuable to build process theories.

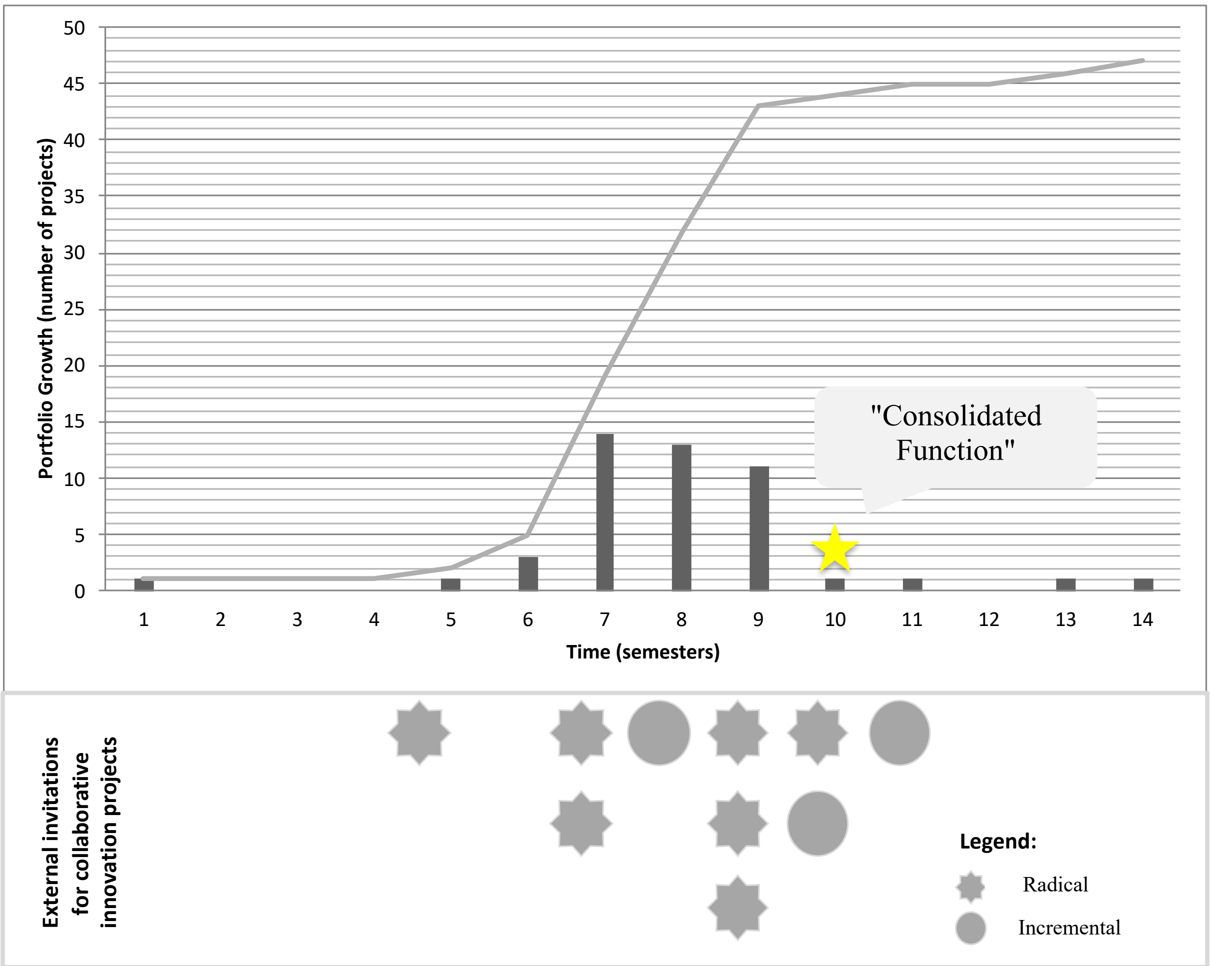
Figure 10 summarizes the IF building process from the narrative analysis, helping to elucidate some important findings of this paper: (i) the creation of a distinctive organizational unit dedicated to innovation management in Salerno and Gomes (2018)'s sense is presented in detail; (ii) the Innovation Function, in this specific case study, was built as a result from the individual action of central actors, acting as hunters (i.e., seeking for opportunities) and centralizers (i.e., focal points for other agents) serving as connecting points to the various parts of the organization (c.f., Leifer et al., 2000). (iii) the IF central team (or group) accumulates certain competences over time and establishes useful networks in the organization which credence them to handle with more uncertain projects as well as to manage a larger number of projects (portfolio increasing in size).

Figure 10: P#1 - The IF construction process



P#1 was also important to elucidate the direct influence of specific projects for the IF construction (Figure 10 "intermediate results"). Figure 11 indicates a direct relationship between projects and the established capability (in the form of a dedicated organizational function on period "10"). This insight was surely relevant for the sequence of the PhD as long as it provoked the deepening in "project" construct and Project Management literature, culminating in Paper #2 (Melo et al., 2020).

Figure 11: P#1 - The evolution of the innovation portfolio

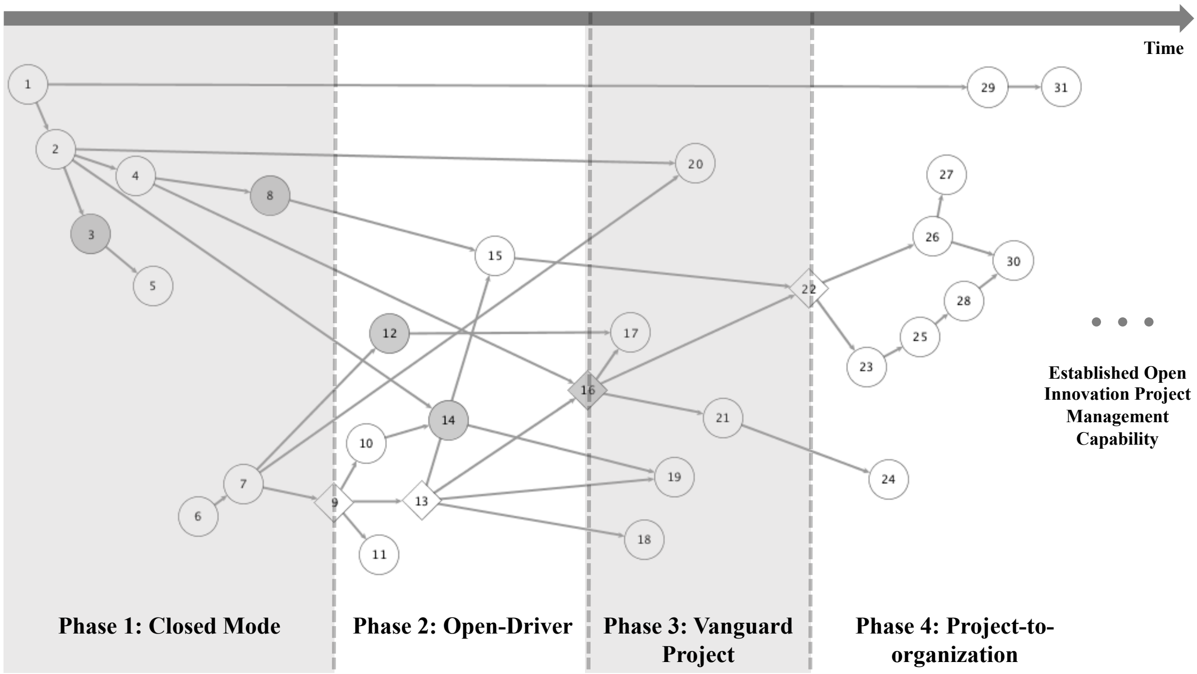


4.2. The *Closed-mode, Open-Driver, Vanguard-Project, Project-to-organization* process

P#2 (Melo et al., 2020) evolved from my previous works (Melo et al., 2016; Melo et al., 2021; Melo and Bagno, 2017). As pointed in Section 2.1, we intentionally chose Open Innovation and Project Management literatures about capability building to reinforce Radical Innovation Management literature and then, to answer the thesis main research question (i.e., how do mature firms build capabilities to manage radical innovations systematically?). Specifically in P#2, we noted that Open Innovation literature claims for more theoretical approaches concerning organizational capability building and Project Management literature offers valuable insights about capability building from projects, but with little attention to the domain of innovative, uncertain open projects. In this sense, P#2 explored *how can organizations use the experience from projects to build a systematic capability to manage open innovation projects?* We brought a new qualitative method (Event Structure Analysis - ESA) to deepen the case analysis combining two theoretical frameworks about capability building: (i) the "project-capability building" framework proposed by Brady and Davies (2004); and (ii) Zynga et al., (2018) unfreezing-moving-institutionalizing model of the transition from closed to open innovation.

After selecting the most important events for the case (a detailed explanation about data collection and analysis is presented in the "Method" section of Paper #2), a temporarily sequenced network was built, entitled "The Open Innovation Management Capability Building Process" (Figure 12). These events are listed in detail in Table 9. Events represented in circles are "typical events". Events symbolized in diamonds are considered "turning points" for the history, based on the betweenness centrality calculation – that means, if they are withdrawn from the network, the sequence of the history becomes broken. The events in gray represent the main innovation projects for the consolidation of the open innovation project management capability in the studied organization (ORTENG, here is coded as "Industrial Electronic Manufacturer – IEM"). The arrows linking the circles and the diamonds represent the causal connections between two distinct events.

Figure 12: P#2 - "The Open Innovation Management Capability Building Process"



Notes: (i) circles: typical events; (ii) diamonds: turning point events; (iii) gray circles/diamonds: events concerning main innovation projects; (iv) arrows: causal connections between events.

Our investigation showed that the process called "The Open-Project Capability Building" is grounded in four main phases: (i) closed mode; (ii) open driver; (iii) vanguard project; (iv) project-to-organization. This new process combines insights from both Project Management and Open Innovation strands, especially Brady and Davies (2004) and Zynga et al. (2018) theoretical frameworks. Brady and Davies (2004) project capability-building model start from the vanguard project, a highly valuable contribution, but neglects previous efforts, especially important in a context of high uncertainty, open innovation project portfolio. On the other hand, open innovation studies (e.g., Boscherini et al., 2010; Chiaroni et al., 2011; Zynga et al., 2018) recognize the importance of an initial phase ("unfreezing") where an organizational context is created to set up the new capability. In our model (Figure 12), two phases precede the vanguard project phase proposed by Brady and Davies (2004), namely "Closed Mode" and "Open Driver". Whereas these OI scholars simply refer to initial or "pilot" projects during the capability building process, PM introduced the importance of vanguard projects to explore new opportunities and to move into new technologies or market basis. However, as our case analysis shows, the vanguard project has a different purpose when compared to the way this concept emerges from PM literature – instead of the use of vanguard projects to create continuous products or experiences to the client, in our case, the vanguard project was not intentionally conceived to build the innovation capability.

Table 1 presents the main innovation projects (gray circles and diamonds in Figure 12 - events #3, #8, #12, #14, #16) developed over the three initial phases of the capability building process in studied organization. It also indicates the exact moment (i.e., year) where each project was initiated, the related phase in the four-stage process (Figure 12), a clear identification of its nature (i.e., open or closed project), the projects main characteristics as well as the key issues regarding each project development. These issues represent new management practices, routines or even competencies consolidated in the organization from the project's execution.

Table 1: P#2 - The distinguishing projects for the capability building

Event (#)	Event	Moment (year)	Phase	Open? (Y/N)	Main Characteristics	Key Issues
3	A Researcher (AGI-9) develops integrated digital supervision, protection, and control system (R&D-1)	1995	1	N	- Integrated digital supervision, protection, and control system - The first innovation relevant innovation project - Developed internally - The brand registered in the National Institute of Industrial Property	- Intellectual Property (IP) protection - Specific control for innovation projects (project charter)
8	The Automation	2008	1	N	- Equipment for systematic panel tests	- Financial evaluation for innovation projects

	Department develops “Test Gigas Project”- a device for automatization of panel’s final tests (R&D-3)				- Response to market demand (process improvement) - Developed internally - The first use of innovation tax incentives - Estimation of net present value to demonstrate innovation projects impact (retrospective)	- Expenditure traceability and cost control - The delimitation between development and scale-up phases to assign internal governance (*i.e.,* innovation vs operational departments)
12	IEM approves the development of a high-performance microprocessor rectifier prototype (R&D-2) with a state-owned energy company	2009	2	N	- Micro processed rectifier - improvement in an existing product (difficulty of internal approval) - The first innovation project to receive subsidized external financial resources (non-refundable) - Developed internally	- New processes (*e.g.,* specific bank accounts, financial resources transfer control, deliverables/milestones reports, status reports) - Accountability for external funding agencies
14	A Science and Technology Institute (ICT-2) makes a partnership with IEM for the development of software to increase the efficiency of hydroelectric generation (R&D-4) with a state-owned energy company	2011	2	Y	- Software to increase the efficiency of hydroelectric generation from computational intelligence techniques - new software development for a power plant delivered by IEM - External invitation from a Science and Technology Institute (STI) - Project led by the STI (~90% of the budget)	- Relationship University-Industry (co-development): multiple teams labor coordination and task distribution; knowledge transfer between teams; infrastructure sharing; new initiatives from outside the company
16	The Innovation Manager (AGI-6) makes a partnership with a Science	2011	3	Y	- Medium voltage panel - new product demanded by the commercial department - The "Vanguard Project":	- New processes (*e.g.,* collaborative purchasing, ERP specific reports) - New routines (*e.g.,*

	and Technology Institute (ICT-3) for the development of a medium voltage panel (36kV) with reduced dimensions (R&D-5)		cited by all interviewees; the causal structure of events (network structural indexes) - Partnership with an STI as a prerequisite for funding - Informal involvement of the STI in the initial phase - Multiple external funding sources	presentation and approval of innovation projects by the Innovation Committee and Administrative Council) - Budget allocation (project planning) - Growth of the structure of Innovation Center (members) and subsequent internal assignments division

As Table 1 shows, the company developed three relevant R&D projects before becoming involved in its first open innovation initiative. Moreover, more than a decade separates the first two projects, a period in which the same managerial mindset prevailed (closed innovation). The fourth project marked the beginning of a quick transition to an open innovation orientation, which would stabilize in the following phase and be consolidated by the so-called "vanguard" open innovation project (event #16). Indeed, just after the vanguard project the company showed a clear organizational shift, formally establishing a dedicated internal structure to manage innovation and presenting a wide breadth of open-oriented projects (see Table 2 for a list of over 40 projects that were launched in the following four years - approximately 75% of this portfolio is open in nature) – this statement reinforces the maturity of the company regarding open innovation practices following Brunswicker and Chesbrough (2018)'s statement: "a firm's approach to open innovation is reflected in its innovation project portfolio, which comprises all of the innovation projects within the firm or business unit."

Table 2: Detailed portfolio

PROJECT	DESCRIPTION	RADICAL (R) / INCREMENTAL (I)	INTERNAL (IN) / EXTERNAL (EX)
1	Integrated supervision, protection and digital control system.	R	IN
2	Equipment for the final inspection of electrical panels (cubicles or columns) and engine control center (CCMs).	R	IN
3	High performance microprocessor rectifier prototype.	R	IN
4	Software for increasing the efficiency of hydroelectric generation based on computational intelligence techniques.	R	EX
5	Medium voltage panel (36kV) with reduced dimensions.	R	IN

6	Transformers with electrical and physical variables online monitoring.	I	IN
7	Study of modernization of transmission substations with emphasis on the full digital integration of the functionalities and the construction of an unprecedented predictive maintenance system for all the assets.	R	IN
8	Software for real time management of production process, from the integration of corporate (ERP) and operational systems (SCADA, CLP, DCS).	I	IN
9	Transfer of knowledge in the area of Energy Efficiency in "Hot Rolling" steel processes.	I	IN
10	Platform of instrument transformers for high voltage (72.5 - 550kV).	R	IN
11	Stainless submersible transformer.	I	IN
12	Innovative computational system of load discharges capable of managing the distribution of power in the grid, by optimally and dynamically disconnecting parts of the system in an attempt to prevent failures due to overloads in the case of demand greater than capacity to a certain part of the power grid.	R	IN
13	Development, production and marketing of a 690V Engine Control Center (CCM).	R	IN
14	Prototype of Uninterruptible Power Supply (UPS), input and output three-phase, with power of 20kVA.	R	IN
15	Development of a methodology supported by computational tools for the choice of locations for the implementation of renewable energy generation plants (solar, wind, bioenergy and sources of cogeneration).	R	IN
16	Sharing of fiber optic networks for optical sensing (temperature, current and voltage) of transformers and data communication.	R	IN
17	Computational system for the management of medium and low voltage assets aiming at the optimal compromise between conflicting objectives of cost reduction, risk, performance increase and financial return.	R	IN
18	Optimization of heat exchange systems in power transformers.	R	EX
19	Planning and evaluation of the impact of distributed generation on electricity distribution systems.	R	EX
20	Incremental improvements in columns of CCMs and panels of low voltage (development of electric air deflectors, structural reinforcements in the duplication of shielding plates in strategic points of the structure, optimization of the	I	IN

	ways for the expansion of gases, optimization of the flaps in the pressure level) .		
21	Intelligent system based on the smart grid concept for the measurement and estimation of technical and commercial losses in cross-network circuits of spot-type distribution with economic feasibility for telemetry of small grouped consumers.	R	IN
22	Projects, analysis and construction of portfolio of Small Hydroelectric Power Plants (SHPs).	I	IN
23	Creation of models and applications for inspection of hydropower reservoirs with support of Unmanned Submersible Vehicle (VSNT).	I	EX
24	New generation of I-tubes annular space inspection tool for Oil & Gas offshore platforms.	I	IN
25	New generation of navigator robot and submarine creeper designed to perform continuous measurement (equipped with ultrasonic system) of thicknesses of submerged metallic structures, ship hulls and offshore platforms.	I	IN
26	New generation of the tool for inspection of vertical sections of flexible ducts with external diameters ranging from 250 to 450mm, in depth up to 2000m.	I	IN
27	New robotic system and remotely controlled to clean flexible lines up to 200m.	I	IN
28	Development of robotized tool with high productivity and remotely controlled for repair of flexible lines up to 2000m.	R	IN
29	New self-propelled vehicle to perform inspection and evaluation services for submarine equipment and pipelines, using state-of-the-art sensors and submarine robotics equipment.	R	IN
30	Panel class 24kV - 1250A.	I	IN
31	Incremental improvements in 17.5kV-50kA electrical panel for certification in NBR IEC 62271-200 standard for 50kA / 13.8kV.	I	IN
32	Incremental improvements in engine control center and low voltage panel for certification according to NBRIEC 60439- .	I	IN
33	New medium voltage grounding switch, genuinely national.	R	IN
34	Consists of promoting hardware and software changes in the previous object prototype.	I	IN
35	Waste processing plant via plasma technology, pyrolysis and gasification with the combined cycle electric power generation.	R	EX

36	Development of frequency inverters and measurement, control and supervision system for distributed generation.	R	IN
37	Development of product platforms standardized from the concept of Modularity.	I	IN
38	Manufacturing industry of photovoltaic panels, from the purification of Brazilian metallurgical silicon, through ingots, wafers, cells to complete modules.	R	IN
39	OES capacitation to provide turn-key solutions for isolated or grid-connected photovoltaic systems using its own inverter technology.	R	IN
40	Training to provide solutions for hydraulic, vertical and horizontal fracturing, as well as drilling of air drilling in "unconventional" natural gas basins.	R	IN
41	Development of new technologies with optical sensors in potential and current transformers - of measurement and protection - in the most diverse classes of voltage and current for detection of partial discharges and formation of gases in the oil.	R	EX
42	TCP / IP stack construction directly on the Remote Terminal Unit (RTU), thus enabling the emergence of IEEE 802.15.4 standard (typically telemetry) Wireless Sensor Network (WSN) capable of supporting in-band internet sharing wide by the same infrastructure that now serves the AMR (Automatic Metering Reading) services of power distributors.	R	EX
43	High power factor rectifier.	I	IN
44	Bus Rapid Transit (BRT) powered by electricity.	R	EX
45	Pilot installation of solar photovoltaic power plant.	I	EX
46	Medium voltage panel composed of 2 (two) circuit breakers per column.	R	IN
47	Underground camera project execution monitoring software.	I	EX
48	Feasibility study of hacks.	I	IN
49	Busbar temperature monitoring system.	I	IN

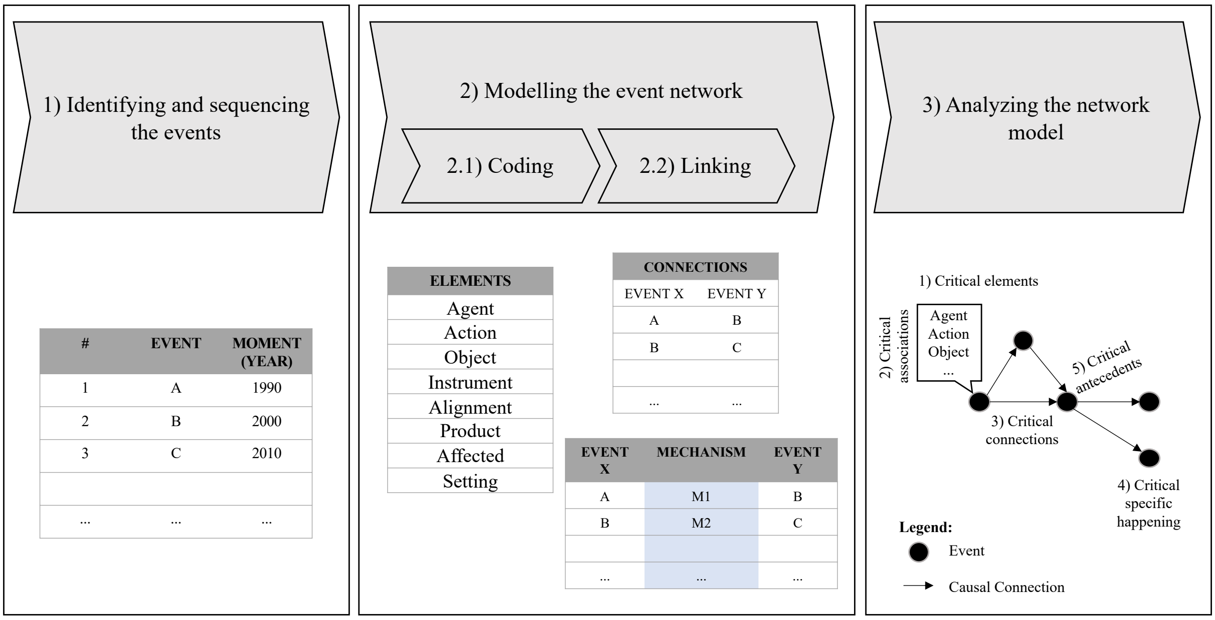
During P#2 revision process, we were invited to submit a methodological paper about ESA and its possible applications for engineering and management literatures, which culminated in P#3 (Freitas et al., 2021). In the next section, we present in detail the main results concerning this advancement, proposing five types of analysis for event network models (i.e.,, critical elements, critical associations, critical connections, critical specific happenings, and critical antecedents) and exemplifying some of them in the case study explored in P#1 and P#2.

4.3. Event network analysis and an illustrative application of *critical associations*

P#3 provides three important insights for the application of Event Structure Analysis (ESA) in organizational/management theory: (i) it can be combined with process-tracing tests to ground counterfactual causal inferences; (ii) it can be combined with network analysis to explore quantitative patterns in event structures; (iii) ESA is an outstanding method to conduct rigorous process research. Figure 13 summarizes our recommend approach for ESA's application and comprehend three main steps:

a) identifying and sequencing the events: events can be identified based on semi-structured interviews with key participants of the studied phenomena in order to elicit the narrative of each interviewee. Researchers must interpret these narratives and come to a consensus regarding the set of events that summarizes the story. Once the events have been properly identified and described, the researcher should sequence them in chronological order to be able to assess possible causal connections between them.
b) modeling the event network: this step initiates with event codification – i.e., theoretically conceptualization for the formal representation of events, using, for example, the set of eight elements proposed by Heise and Durig (1997) – e.g., Agent, Action, Object, Instrument, Alignment, Product, Affected; Setting. After that, events should be linked (i.e., inferring causal connections) – a causal interpretation of the chronological sequence obtained. The theoretical/conceptual frame suggested for coding causal connections between events relies on the notions of causal "necessity" and "sufficiency" (Goertz & Starr, 2003; Mahoney et al., 2009; Ragin, 2000).
c) Finally, it is important to analyze the network – we suggest the identification of critical (i) elements; (ii) associations; (iii) connections; (iv) specific happenings; (v) and antecedents of these happenings.

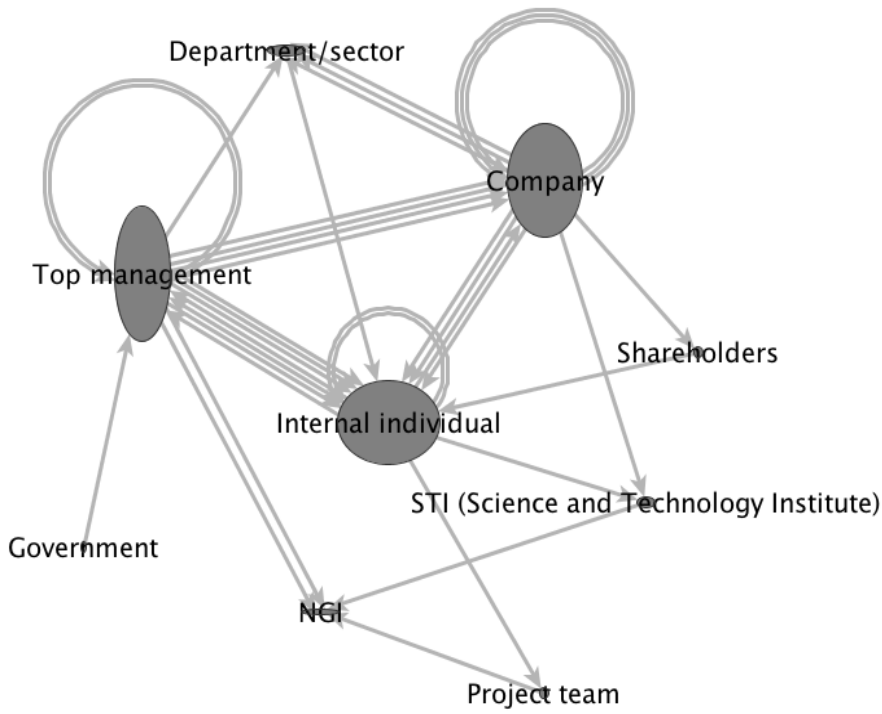
Figure 13: P#3 - Graphical abstract for ESA's application



In P#3, we briefly present one illustrative example of "critical associations" analysis representing a preliminary model of relationships between agents – i.e., the instigator of a happening (D. R. Heise & Durig, 1997) during the construction of an open innovation project management capability in the case studied. This model was constructed as follows. Firstly, we identified 9 types of agents involved in the 31 events of our causal structure shown in Figure 12. Each of the nine types of agents identified (Figure 14) was, then, connected to another type of agent by an arrow if - and only if - there was, in our original causal structure, an event instigated by an instance of the first type of agent that was inferred as causally necessary to another event instigated by an instance of the second type of agent under consideration. If there were more than one pair of connected events instigated by the corresponding pair of types of agents, this number of original causal connections in Figure 12 was represented by the number of arrows connecting the respective pair of agents in Figure 14. Thus, for instance, as shown in Figure 14, there was only one causal connection in our original event structure linking an event instigated by "top management" as a necessary cause of an event instigated by the "department/sector" type of agent. On the other hand, "top manager(s)" agents instigated four different events that were - each of them, individually - inferred as causally necessary to one of other four different events instigated by companies, respectively.

Therefore, in Figure 14, the number of arrows between two circles represents the frequency with which the two corresponding nodes were connected as agents of two causally related events. Thus, it visually highlights the most and least frequent causal connections in the historical process in question (i.e., the innovation capability building).

Figure 14: P#3 - The most relevant agents for the story



Notes: (i) circle – type of agent; (ii) circle height – outdegree; (iii) circle width – indegree; (iv) arrows: an event instigated by the type of agent represented in the node at the tail of the arrow was inferred as causally necessary to an event instigated by the other type of agent represented in the head of the arrow.

Figure 14 was modeled in Visone Software (www.visone.info) by imputing, for each event causal connection, the associated category of agents. For example, both event #1 ("IEM associates to a French Engineering Company") and event #2 ("IEM changes its business model to provide turn-key solutions") – see Table 9, has "IEM" as the agent, which were generally categorized as "company". In this sense, the causal connection between them (1-2) generates a "company"-"company" connection (i.e., feedback loop in the circle "company") in Figure 14. The causal connection between event #2 ("IEM changes its business model to provide turn-key solutions") and event #3 ("A Researcher (AGI-9) develops an integrated digital supervision, protection and control system (R&D-1)") generates a "company"-"internal individual" connection (represented as an arrow from the circle "company" to "internal individual" in Figure 14. Note the individuals like the Researcher AGI-9 were categorized as "internal individuals".

In sum, Figure 14 shows at the core of this structure a virtuous circle involving "Top Management", "Internal Individual" and "Company" - which can be considered the most influential actors in for the capability process in the studied case. In this graphical representation, circle's (nodes) width takes this information to represent the number of original events that led to the corresponding node, while node height represents the number of events that were caused by it. Hence, during the capability building process in the studied case, actions led by “Internal Individual” were more caused than causal while actions led by “Top Management” and “Company” were more causal than the opposite. Moreover, the relatively wide loop represented above the “Top Management”, “Company” and “Internal Individuals” nodes indicates that these agents frequently caused events initiated by other similar agents, pointing to some cumulative recursions in their interactions. It can also be noted that analyses such as these may highlight some important processual patterns and exceptions that might not be noticed without such a systematic methodological procedure for modeling and analyzing the event structure. These, in turn, may, of course, help discussing theoretical propositions, their adherence or not to the case in question, and, specially, the possibilities of advancing previous knowledge on the basis of such a detailed micro-processual tracing of a macro-outcome of interest.

5. CONCLUSION

This thesis explores how mature firms build capabilities to manage radical innovations. The findings, detailed in the Papers #1 and #2, suggest that this capability (in the form of a dedicated organizational function to manage radical innovations) can emerge progressively from individual action to groups, accumulating specialized skills and achieving intermediate results by innovation projects (Paper #1), and, more specifically, through a process of four phases: closed mode; open driver; vanguard project; project-to-organization (Paper #2). Paper #3 also brings insights about the main agents responsible for this process in the studied case (e.g., internal individuals, top management, and the company itself).

Regarding **SO1** (i.e., *to comprehend how organizational context and the organization external environment may influence or even shape the radical innovation capability building process*), Paper #1 evidences, from a detailed case narrative analysis, the influence of external entities to shape the Innovation Function. Government funding programs, for example, proved to have a huge impact on the selection of innovation projects and also in the structuration of the radical innovation capability itself (e.g., creation of new routines, committees, people hiring). In P#2, we highlight the impact caused by Brazilian National Policy on open innovation projects, stimulating the studied company to make partnerships with other agents of the ecosystem or fostering new markets for innovative technologies (e.g., energy generation and transmission).

We also *elucidate the role of open innovation projects for the radical innovation capability building, emphasizing the role of vanguard projects* (**SO2**) in Subsection 4.2, particularly with a discussion around the main innovation projects which helped to trigger the referred capability in the studied case. There is a presentation of how these projects triggered new organizational routines (i.e., “Key Issues”) involving, for example, IP protection, project management tools, project valuation, gates for the innovation process, governance rules for projects in partnership, among others. The causal event structure (including the four-stage process) of the open innovation management capability building process notably (and visually – i.e., gray circles/diamonds) reinforce this SO. Lastly, both P#1 and P#2 debate the hole performed by a specific project (event #16 - the “Panel 36kV” development) for the capability consolidation due distinct characteristics (i.e., top management interest, external funding, partner support, well-succeeded development).

Finally, P#2 and P#3 help to reach **SO3** (*to identify the underlying causal mechanisms connecting specific causes to the desired macro-outcome - i.e., the radical innovation capability in the form of the dedicated innovation function*). Each stage of the open innovation management capability building process (closed mode; open-driver; vanguard-project; project-to-organization) found in P#2 can be considered a causal mechanism in a more abstract sense as they act as “interlocking parts that transmit causal powers or forces between a cause (or set of causes) to an outcome” (Beach, 2020; Beach & Pedersen, 2019). Moreover, both in P#2 and P#3, the precaution in the network modelling, particularly the linkage between events by using process tracing logic (Mahoney, 2012) and the introduction of mechanisms to justify each event-event connection.

This thesis provides several theoretical contributions. First, it presents in detail the process for the creation of a distinctive organizational unit dedicated to radical innovation management (O’Connor, 2012; O’Connor et al., 2008; Salerno & Gomes, 2018). Additionally, it address an issue pointed by Kouamé and Langley (2018) as an “exemplar” case study of how lower-level practices performed by individuals connects to broader levels of analysis (organizational-level, including capabilities). Third, it fosters a bridge between Project Management and Open Innovation literatures because the four-stage process represents a combination of previous capability building frameworks (Boscherini et al., 2010; Brady & Davies, 2004; Chiaroni et al., 2011; Davies & Brady, 2000; Zynga et al., 2018). Precisely for open innovation theory, this thesis contributes to a pressing issue for academics and practitioners in Open Innovation field: how open innovation can be effectively implemented in organizations (Bogers et al., 2017; Brunswicker & Chesbrough, 2018; H. Chesbrough & Brunswicker, 2014; Gassmann, 2006; Mortara & Minshall, 2011; Zynga et al., 2018) and the reasons by which firms open up their innovation processes (Huizingh, 2011). In addition, there are some methodological contributions: the data analysis method and ESA’s application enables to tackle difficult “how” research questions by tracking the dynamic emergence of an outcome of interest over time; differently from other process studies, our approach distinguishes itself by its unique emphasis on the branched causal structure underlying an event sequence (Mahoney, 2000a); and to the best of our knowledge, this is the first application of Event Structure Analysis in innovation management research field. Finally, we also contributed to the evolution of Event Structure Analysis by incorporating a robust system for coding events, using causal process tracing tests for inferring necessary connections, and combining ESA with network analyses to suggest five types of analysis for event network models (i.e.,, critical elements, critical associations, critical connections, critical specific happenings, and critical antecedents).

From a practical point of view, this thesis: (i) provides specific insights for companies that aims to create a capability to generate more radical innovations (e.g., allocation of dedicated employees to conduct the mission, search for external resources to support the execution of projects, beginning of the construction of innovation portfolio by acting in projects more aligned to the business strategy); (ii) shows that the construction of an innovative capability may be a long and gradual process (in the case presented, it lasted more than four years) - this point is relevant for leveling expectations and reducing pressure on the dedicated innovation management team (i.e., Innovation Function) for short-term results; (iii) reinforces the importance of governmental support (financial and tax incentives) for the leverage of innovative projects in companies as well as a mechanism for the approximation between large companies and Universities / Research Centers; (iv) presents the four-stage process (closed mode; open driver; vanguard project; project-to-organization) which can be taken as a guide for new planned approaches to firms moving from closed to open innovation; (v) presents an innovative proposal on how to apply ESA may contribute to supplement and enrich knowledge sharing practices in disciplines dealing with inherently processual phenomena. Specifically, for the industrial engineering field, this adapted ESA method can support a wide range of organizational problems associated with complex engineering projects which may involve long causality chains within a project and/or high level of path-dependence among projects.

Notably, this thesis has limitations. The in-depth case study does not intend to provide a general pattern for the studied phenomena but to present a set of causal relationships relevant in itself. In sum, we are not arguing that our findings are replicable to any other situation but, if one can say that, if it occurred once, they could emerge in similar contexts. From a non-positivist paradigm, we are interested in the historical processes brought by the case and the insights they bring to theory, not to elaborate testable and replicable patterns. We chose not to listen to external agents within the scope of this work because they were not mentioned directly during the interviews.

The suggestions for future studies include: (i) to understand how Innovation Function (IF) changes itself from interaction with startups, as observed in recent forms of open innovation programs in large companies; (ii) to expand the understanding of the IF's organizational structure with an emphasis on roles, hierarchy and forms of coordination, a debate initiated by O'Connor et al. (2018); (iii) to comprehend differences between developing capabilities for non-open innovation projects and open innovation projects; (iv) to evaluate the critical associations between each event elements for the referred capability building process; (v) to applicate other process-based or historical (Beach, 2020; Cloutier & Langley, 2020) and compare to what ESA can offer for data analysis; (vi) and to test the four-stage process' applicability (closed mode, open-driver, vanguard project, project-to-organization) in other similar contexts.

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6. APPENDED PUBLICATIONS

6.1. PAPER 1 (#P1): From enthusiasts to systematic innovation: The journey of building the innovation function in a large industrial organization

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Figure 15: Paper #2 publication pre-print cover

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ORIGINAL ARTICLE

From enthusiasts to systematic innovation: the journey of building the innovation function in a large industrial organization

De entusiastas à inovação sistematizada: uma jornada da construção da função inovação em uma organização industrial de grande porte

Júlio Cézar Fonseca de Melo[1], Raoni Barros Bagno[2], Beatriz Costa Pinto Rio[2], Mario Sergio Salerno[1], Ana Valéria Carneiro Dias[2], Jonathan Simões Freitas[3]

[1]Universidade de São Paulo – USP, Departamento de Engenharia de Produção, Programa de Pós-graduação em Engenharia de Produção, Laboratório de Gestão da Inovação – LGI, São Paulo, SP, Brasil. E-mail: lgi@usp.br; juliocfmelo@gmail.com; msalerno@usp.br

[2]Universidade Federal de Minas Gerais – UFMG, Departamento de Engenharia de Produção, Belo Horizonte, MG, Brasil. E-mail: dep@dep.ufmg.br; rbagno@dep.ufmg.br; beatriz.cp.rio@hotmail.com; anaval@dep.ufmg.br

[3]Universidade Federal de Minas Gerais – UFMG, Faculdade de Ciências Econômicas – FACE, Belo Horizonte, MG, Brasil. E-mail: contato@face.ufmg.br; jonathansf@face.ufmg.br

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Abstract

The creation of a management system to systematically promote innovation is a great challenge for large companies. Some authors argue for the creation of a dedicated organizational function (the Innovation Function – IF) to guide this system. This paper aims to understand how a large company builds an Innovation Function from a longitudinal and retrospective case study. Some aspects regarding the emergence of the IF, its organizational structure evolution, and changes on its team's scope of action are discussed. The main results

highlight the importance of key actors for IF's recognition by the organization, serving as connecting mediators to other functions and external agents. Besides that, specific competence accumulation, gradual legitimacy acquisition, and project intermediary results enabled the team to deal with radical innovation projects over time.

Keywords: innovation, innovation management, innovation management system, innovation function.

6.1.1. Introduction

There is no single way for industries to organize to innovate given that the sources of opportunities are distinct, even for those belonging to the same industry or sector (Pavitt, 1984). Figueiredo (2002) highlights the cumulative paths of technology in which firms move from routine capabilities (i.e., to use or operate certain technologies and production systems) to innovative ones (i.e., to adapt and / or develop technological innovations). Bagno et al. (2017) emphasize the contribution of management models to achieve this goal, especially those considered "capability-focused", in which the focus is on radical innovations. Systems for the management of radical innovations would count on a set of underlying managerial elements (e.g., people and responsibilities, leadership, culture) that, if well concatenated, support the occurrence of radical innovations in a regular and systematic way (i.e., generation of ideas, development, launch) - (Goffin & Mitchell, 2010; O'Connor et al., 2008).

Despite the advances in the literature on the innovation management theme, some gaps stand out. First, relevant part of the studies presents what would be the constituent elements of an innovation management system, but they do not emphasize how to build such capability, in a processual way (Bagno, Salerno, & Silva, 2017). Second, studies considered to be more procedural (similar to this paper), such as Börjesson, Elmquist, & Hooge (2014), normally focus on a different level of analysis (e.g., the creation of new business units or R&D Centers) and pay little attention to the actions performed by individuals, from a micro perspective. Chiaroni, Chiesa, & Frattini (2011) report a process of organizational change in an Italian cement industry from dispersed efforts till institutionalized open innovation practices, but the study is strictly focused on open innovation. O'Connor et al. (2008) argue that building a system for managing radical innovations relies on three major stages: stage preparation, initiation, and maturation. However, this study offers few prescriptive guidelines for the implementation process. Bagno, Salerno, & Dias (2017), in turn, discuss the concept of the "Innovation Function" from the experience of 15 Brazilian companies, but do not present details about the construction process of IF in these companies. Finally, from a methodological point of view, Kouamé & Langley (2018) call for process-oriented research that explores the connections between organizations' macro (e.g., strategic aspects, organizational changes) and micro (e.g., individuals, projects) levels.

For O'Connor (2012), these radical innovation management systems in large companies should be driven by a recognized group in the organization, whose mission is to create new business platforms for the company - the "Innovation Function" (FI). Bagno, Salerno, & Dias (2017) point out that, in large Brazilian industrial companies, innovation management activities suffer from the lack of legitimacy within the organization and there is a constant dispute for resources against the current operational activities. In this sense, the central question of this research is: "How do large industrial organizations build a dedicated function to the management of innovations?".

In order to answer the research question, a single Case Study was carried out in a large electro-electronic company, based on a procedural and retrospective approach. We present the history of this organization over six years in the construction of a dedicated function to the management of innovations, from the designation of a collaborator to assume such mission until the formalization of a department with more than 10 employees, responsible for a portfolio, at the end of the period, of 12 projects (total amount of approximately R$15 million). The study supports the advancement of theory by evidencing the relationship between the role of key individuals and their gradual accumulation of skills (micro level) for the creation of a new organizational structure dedicated to innovation management (macro level). In addition, it is discussed how the gain of legitimacy from intermediary /marginal outcomes in the execution of innovation projects helps to reshape the management team's scope of work (i.e., from incremental innovations to more radical innovations).

6.1.2. Theoretical Framework

6.1.2.1. The Innovation Function (IF)

O'Connor et al. (2008) define an innovation management system through the following constituent elements: (i) Mandate and responsibilities - objectives and mission of the system; (ii) Structure and processes - (Report to whom?; location; Hierarchical or flat organization?; Rigid or flexible?"); (iii) Resources and knowledge - ability to attract and develop staff with appropriate knowledge and skills; (iv) Leadership and governance (e.g., "How are decisions made?"; "Who takes them?"); (v) Metrics and reward systems. To conduct this management system, O'Connor et al. (2018) propose the constitution of a specific team, with well-defined roles (e.g., from platform leaders to independent boards) - the Innovation Function (IF).

Lawrence & Lorsch (1967) argue that to be recognized in the organizational environment, an organizational function must differentiate itself from the others, but at the same time, it must be integrated with the mainstream to support the organization's central objective. Supported by this concept, Salerno & Gomes (2018) define an organizational function as a perennial entity, formally recognized in the company, with responsibility for a specific assignment or mandate related to the company's mission, which implies having a core base of knowledge.

The Innovation Function (IF) is considered to be in its early days, but it has been recognized in some organizations, especially through the increasing formalization of positions and roles for the management of innovation in mature companies (O'Connor, 2012; O'Connor et al., 2018, 2008). For O'Connor (2012), IF is responsible for creating new growth platforms in companies and for fostering completely new benefits for the market. Salerno & Gomes (2018) argue that functional arrangement is adequate for systematizing the generation of radical innovations because it is the "best organizational mechanism for the accumulation of explicit and tacit knowledge regarding a theme." The function consolidates knowledge, since it has a specific mandate on which it articulates its own resources, independent from specific orders or clients - it is a reference for subjects related to its field of knowledge.

For O'Connor et al. (2008), a specific person should take over the leadership role of the IF: the "Orchestrator". This agent would be responsible for monitoring the mandate, in order to guarantee that the system does not tend, under pressure, to gravitate towards opportunities that are more aligned to the current business or to short-term demands (i.e., incremental innovations). In addition, it would lead the projects transition during the development process so that, for example, initiatives with acceptable commercial results are not launched without proper preparation. In addition, the orchestrator should be responsible for managing the necessary interfaces within the organization as a whole (senior management, other corporate functions, project teams) in order to gain legitimacy and to ensure that resources are available for the IF core activities.

O'Connor et al. (2018) argues that the Orchestrator and the Chief Innovation Officer (CIO/CNO) work together to nurture and manage the company's innovation portfolio, but that other roles are critical to the Innovation Function (e.g., Opportunity Generator, Functional Manager, New Business Platforms Leader, Directors of Incubation and Acceleration, Innovation Council). Salerno & Gomes (2018) argue that the FI does not have all the resources needed to comply with its mission (i.e., to identify, structure, nurture and manage a radical innovation portfolio). In this sense, the IF should act in a network (i.e., "networked-function"), in that part of their activities come to be done by other people in the company (e.g., acceleration with the process engineering sector, experimentation together with the R&D team).

Bagno et al. (2017) investigated 15 Brazilian industries with a typical IF arrangement where a central team was in charge of certain assignments (e.g., finding tax and other funding opportunities, portfolio and project management, partnership building, knowledge development, among others) that characterizes the IF and make it identifiable in the organizational environment. Three instances would be associated with this team, supporting the work guidance, catalyzing internal connections or even assuming complementary responsibilities: (i) the strategic committee; (ii) focal points - people formally allocated in other functions, but working part-time as extensions of IF core team; (iii) and project teams - temporary structures working directly on the innovation projects. Specifically, Melo & Bagno (2017) discuss how the development of the IF core team's assignments impacts the consolidation of IF in the organizational environment.

6.1.2.2. The process of building an innovative capability

Companies begin employing their efforts in creating a capability to generate innovations systematically for diverse reasons. However, in the view of O'Connor, Leifer, Paulson, & Peters (2008), there is always a central motivation or a trigger event (e.g., strategic growth, financial return, technology strategy, need for skill development, product/business diversification and defense current business). In the case of Brazilian companies, Bagno, Salerno, & Dias (2017) suggest that IF origins from: previous projects or other initiatives related to innovation; facts around political and economic contexts (public policies, funding opportunities or existing infrastructure of Science and Technology); avoidance of commoditization and obsolescence; and business diversification to take advantage of the available technological assets.

At the beginning of the process of implementing an innovation management system, the company tends to seek for opportunities in close proximity to the current businesses, in order to apply available knowledge or to bring noble technologies to the current markets (O'Connor et al., 2008). This situation happened at Renault, where an "Innovation Logic" research department was created in 2004, involving academia to adapt governance rules, processes and innovation management tools. This initiative was carried out to optimize the range of existing products (Börjesson et al., 2014). These activities corresponded to what O'Connor et al. (2008) set as the first step of the process, the "stage preparation". At this stage, the mandate, scope and objectives of the new organizational function are clarified. Initially, groups start small and their perpetuity depends on top management support, even if the groups were not designed by them (Börjesson et al., 2014; O'Connor et al., 2008).

The challenge of building a capability for innovation is strongly related to change management and, therefore, to overcoming organizational resistance and the predominant mentality of some impacted individuals (Eisenhardt & Martin, 2000). Chiaroni et al. (2011) associate the first phase as an "unfreezing" exercise in which a sense of urgency for change is created. At this moment, in the case these authors discuss, social networks between the actors were created, the commitment of the top management was sought to support the change, and a committee of external experts was established to evaluate the innovation projects. Both companies studied by Börjesson et al. (2014) can be described as "restricted" in O'Connor et al. (2008)' perspective as they were under constant pressure for short-term results with economic outcomes.

Companies don't need to start by developing all their innovation competences at the same time (O'Connor et al., 2008). This choice should be based on specific organizational gaps. If there are no projects, the focus should be on discovery activities. But for example, if small businesses with some potential are already in place, more effort should be devoted to business acceleration. The successes in the management of innovation projects and their subsequent activities end up leading to a cultural change. Thus, they give legitimacy to the "need to work differently" (Börjesson et al., 2014).

Chiaroni et al. (2011) highlight that, after the initial stage, companies undergo a "moving" phase. In their specific case in a Cement company, external networks at the firm level were built to explore new ideas, and a dedicated department was set up to coordinate collaborative research projects. The studied company adopted formal procedures for the identification of external sources of knowledge as well as technical solutions developed by universities for projects. In O'Connor et al. (2008)'s point of view, after the "preparation of the terrain", an "initiation" phase is started, focusing on the construction of a capability (and not just a process) where the whole management system is put into practice. It focuses on the creation of an innovation-based culture, either by promoting workshops of ideation, by defining vocabulary for innovation and by seeking the people (leaders and staff) who will be involved in the new mission. Another point highlighted by the authors is that, at this moment, an internal infrastructure is defined (i.e., to whom the group reports, where it is physically located) and the group starts the search for an initial subset of projects, especially those in that the team already has some kind of experience.

Bagno, Salerno, & Dias (2017) point out that short-term results carried by the IF minimize internal friction as well as the diffusion of the IF's efforts to other areas of the company. In Börjesson et al. (2014)'s study, while projects were useful to evidence results, it was difficult to persuade the organization to adopt new ways of working. The study demonstrated that the direct operation of the portfolio has become a tool to achieve a second goal of the managers (i.e., to build the capability to innovate systemically).

The innovation management system only reaches maturity after the systematization of some processes like initiation, support and reward for its activities. For O'Connor et al. (2008), this maturity is achieved through the consolidation of the new organizational function (the Innovation Function), in a company. IF must be identifiable and measurable, in a way that it may be testified by rich interfaces and/or strong networks both internal and external, defined governance in project and portfolio levels, availability of appropriate metrics, and the rising of a culture / leadership that values innovation. In an analogous way, the changes in the organization as those presented by Chiaroni et al. (2011) get consolidated (i.e., the "institutionalization" phase) when: the company establishes formal long-term collaborations with universities and research centers; formal roles are created (e.g., gatekeeper, innovation champions for the main research areas); performance metrics are in place for project managers as well as a defined policy for Intellectual Property (IP) is implemented.

Figure 16 tries to articulate the concepts of the presented theoretical approaches in a framework that represents the macroprocess for the creation of a systematic innovation capability. It is organized in three main phases: the beginning; intermediary phase; and maturity. This framework will support the evaluation of the case in the "Discussions" topic.

Figure 16: Theoretical Framework

THE BEGINNING	→	INTERMEDIARY PHASE	→	MATURITY
• Triggers (O'Connor *et al*., 2008; Bagno et al., 2017); • Setting the stage (O'Connor *et al*, 2008); • Unfreezing (Chiaroni *et al.,* 2011).		• Iniciação (O'Connor *et al*., 2008); • Moving (Chiaroni *et al*., 2011); • Intermediate results (O'Connor *et al,* 2008; Borjesson *et a*l., 2014).		• Well-defined organizational function (O'Connor *et al*., 2008); • Institutionalizing (Chiaroni *et al*., 2011)

6.1.3. Methodology

We conducted a single case study, based on a process approach - i.e., taking seriously the temporal sequence between events (Langley, 1999). Events can be defined as actions of a given agent on a given object at a specific moment in time (Heise & Durig, 1997), and may include decisions, meetings, conversations, or even a simple handshake (Langley, 1999). The case selected for the study was considered a rare one (Yin, 2017) due the scarcity, in the Brazilian context, of large organizations adopting the IF perspective (Bagno et al., 2017). An in-depth intra-case analysis is more adequate when the object of the research refers to a processual phenomenon (Mahoney, 2000).

The case under analysis was an organization of the energy and automation systems sector - hereafter, the "ORT". During the period of the study, this company had 3,000 direct employees and revenues of R$ 1bi / year. Its field of activity covered Energy, Refining and Sanitation, Metals and Cogeneration, Mining and Oil & Gas markets. The list of ORT's business units is presented in Table 3.

Table 3: ORT's business units

Company	Description
OES	Turn-key solutions in power and automation systems, and electrical and electromechanical equipment manufacturing
BLT	Manufacturer of current transformers, potential transformers and measuring sets
MCT	Design and manufacture of power transformers
SPE	Solutions with complete EPC (Engineering, Procurement and Construction) design, electromechanical assembly, civil works, commissioning, start-up and assisted operation
MPN	Integrated solutions in multidisciplinary engineering
OAC	Cutting-edge technologies for the Oil & Gas market
ENR	Opportunity development in the area of electricity generation and transmission such as SHPPs (Small Hydroelectric Plants) and other renewable sources
CNP	Exploration and production of oil and gas.

Data were initially collected by one of the authors from a longitudinal participant observation (Langley, Smallman, Tsoukas, & Van de Ven, 2013) of approximately four years. In that period, supporting documents were collected to serve as a supplementary data source, including e-mails, administrative documents - e.g., proposals, reports, internal documents and meeting minutes, studies and evaluations, media publications, tables and budgets and personal records (journal entries and schedules). In order to understand the phenomenon before and after the participant observation, eight semi-structured interviews were conducted with ORT employees who were involved in the process of building the new organizational function. Table 4 shows the interviewed employees and the duration of their respective interviews.

Table 4: Duration of interviews and identification of respondents

Interviewee	Duration	Job Role	IF? (Y/N)

1	68 min 24 sec	Former R&D project analyst	Y
2	34 min 57 sec	Partner - Group Vice President	N
3	38 min 14 sec	R&D Coordinator	Y
4	72 min 34 sec	Quality, safety and environment manager	N
5	39 min 47 sec	Production Coordinator (Electrical Panel Factory)	N
6	56 min 57 sec	R&D Manager	Y
7	35 min 55 sec	Operations manager	N
8	52 min 07 sec	Engineering Director	N

The interviews were recorded, and the audios were transcribed. As a first step of analysis, researchers constructed, from data gathered during the participant observation, an ordered list of events associated to the process of IF consolidation. In order to justify both the occurrence and the timeframe of each happening, a specific supporting document was related to each event. At this stage, 121 events were identified, ordered by month and year. Subsequently, lists of events were elaborated from the discourse of each interviewee, by at least 2 collaborators, in isolation, as a way to allow for inter-coder cross-validation. In sum, 284 possible events were identified at this stage. After peer validation (i.e., between two researchers), a list was reached for each interviewee, with a sum of 185 events. During validation, researchers discussed: (i) the inclusion of an event identified by only one party; (i) the exclusion of a supposed event - when in fact it was a contextual or routine aspect, and not a specific event (i.e., no specific timeframe); (iii) and the granularity of events - merging (i.e., multiple events into one) or unlinking (i.e., one event into two or more of them).

In the possession of all supporting documents and chronologically ordered lists of events, a detailed narrative of the case was prepared, through cross-validation of all the collected evidence, expressing them in a meaningful way (from the point of view of a theoretically-informed reading), without losing their adherence to the particular case and language settings. Throughout the narrative (Section "4 Narrative of the Case"), patches of the transcriptions were used to enrich the story's presentation. Fictitious names (e.g., Luiz, Amanda, Marcos) were given to actors considered central for the narrative, to preserve anonymity.

During textual elaboration, the authors faced several doubts about the dynamics of the case and had to seek for additional clarifications with some interviewees in order to make sense of the story. The narrative allows the presentation of circumstances not initially pointed out during the interviews and the preparation of events' lists, mainly in what regards the participation of relevant actors and the sequences of actions. In addition, during this writing exercise, the research team inductively coded some entities that are recurrent and relevant to the case (e.g., internal employees, external personal agents, funding agencies, science and technology institutes - STIs). One of these entities are the “innovation projects” developed by ORT during the period (149 instances in total), which were used at the end of the article to foster the discussion of the evolution of the IF in order to manage more radical projects over time.

6.1.4. Case Narrative

Antecedents

The history of ORT begins with the creation of a unit (OES) for electrical panels manufacturing in 1977. Throughout the 1980s, the association of this company with a French engineering firm, specialist in supplying energy installations, transformed its business model. After all, the company started to provide complete solutions, ranging from products of their own manufacture to the installation in field, commissioning and assisted operation (i.e., turn-key systems).

The Brazilian National Electric Energy Agency (ANEEL), in order to encourage innovations in the electric sector, regulated the "P&D-ANEEL" Program. Electric power generation, transmission and distribution companies should invest at least a minimum percentage of their revenues in this program. Annually, these companies started to launch "Public Calls (or Calls)", releasing their priority lines of research, in order to hire interested companies, STIs or partnerships involving both of them.

Following this trend, in 2004, the Brazilian Federal Government issued a general innovation Law (10,973), which provided incentives for innovation and technological research in the productive environment, and regulated some entities of the National Innovation System, such as funding agencies, STIs (Institute of Science and Technology), innovation nuclei, support institutions, among others.

From this moment, Luiz, then Vice-President of ORT, started to encourage ORT employees to take part in these programs jointly promoted by local and federal government entities. In 2006, the Commercial Department of OES pointed to a demand for the development of a "Microprocessor Rectifier". An Operations Manager, due to his expertise in electronics, proposed a solution and sought the Minas Gerais Energy Company (CEMIG) for the presentation of his idea. Subsequently, he submitted the project to CEMIG's "P&D-ANEEL" call in that year.

In parallel, in 2007, OES won a competition to supply electric panels to PETROBRAS, which would increase its production capacity to about 100 electric panels per month. A production bottleneck was identified at that moment. The final inspection of these products was manually performed in the factory environment by employees (i.e., (individual measurement of various variables product interest), with customer follow-ups. There was a need for an automated equipment to systematize these tests, the so-called "Test Gigas" - developed over four years.

Management of innovation projects at that time was basically based on: (i) drawing up a preliminary project budget; (ii) approval by the board of executives; and (iii) registration in a corporate system to monitor purchases. As they were normally associated with a specific demand, previously identified by the Commercial Department, the amortization of these investments in innovations was allocated to the demanding business units.

> The first [prospection] is carried out by the Commercial Department itself, which often, due to the biddings that exist [related] to the quotation processes, maps, together with Product Engineering, the products that are not being provided [by the company]. Often, we are reactive because we are going to develop only when we have declined a proposal: "We are declining this proposal because we have no product" (Production Coordinator of the Electric Panel Factory).

At the end of 2007, due to the Brazilian context (i.e., incentive to innovative activities) and the incipient innovation activities at ORT, the need to formally allocate a collaborator for this task was perceived by the top management team.

Cycle 1 – Setting the stage

When asked about "what event marks the beginning of innovation management activities in ORT?", the interviewees were emphatic: "The hiring of Amanda." However, it should be noted that she was hired initially to work on other OES projects and later allocated to this mission by Luiz. The beginning of this work is registered by a partnership with the Euvaldo Lodi Institute (IEL) for the implementation of an "Innovation Management Methodology", creating the so-called "Innovation Management Center" or simply NGI.

> We did a job, which I remember, together with the IEL, which was bringing to Brazil a methodology for innovation management... And we implemented at the time the "NGI [Innovation Management Center]" (Luiz, Vice-President of ORT).

> This nucleus started with one person. This person tried to restructure and was adding, let's say, knowledge and expertise. At the beginning, it worked with a very small core of people [...] (Operations Manager).

It is clear by this last interview extract that this Center was created to be an instance to support R&D (c.f., Bagno et al., 2017), creating external connections to support R&D activities, rather than directly executing them. At the outset, cultural barriers hampered the progression of Amanda's work, as people were focused on their daily tasks and short-term results. Those who ventured into innovation initiatives made it out of their usual work schedule, with no expectation of recognition.

> You must imagine that this would lead to some problems. Why? Because those people who are so attached here to a particular department, they have their tasks, their obligations, and the development and innovation activities became an exception to their work. (Operations Manager).

At that moment, the attempt to frame projects in external funding calls began. An Engineering Director had been contacted by a former co-worker - at this time a professor at the Federal Center for Technological Education (CEFET-MG) - to discuss possible synergies between the institutions. OES was renovating the turbines of the Três Marias - MG hydroelectric power plant and a proposal was presented to CEMIG in the "P&D-ANEEL" for a software to increase hydroelectric generation efficiency based on computational intelligence techniques.

In this cycle, two initiatives involving the payment of scholarships for OES employees were also approved. Amanda complained about not getting internal support to promote innovation initiatives. A "Suggestions Box" was also implemented to collect ideas from internal collaborators. Some opportunities were identified, but the feeling was that this process would not work satisfactorily.

> We had a program of suggestions for improvements [...] we did not participate, but a world of information arrived. Some made sense, some less so. (Engineering Director).

At the end of this period, after approval, the "Microprocessor Rectifier" was started, in partnership with CEMIG. Amanda was approved in a public contest of a federal educational institution to become a full professor. She established an agreement with Luiz to transfer the activities and projects developed to the new person to be hired in order to assume the "Innovation Management Center", the NGI.

Cycle 2 - A new leadership

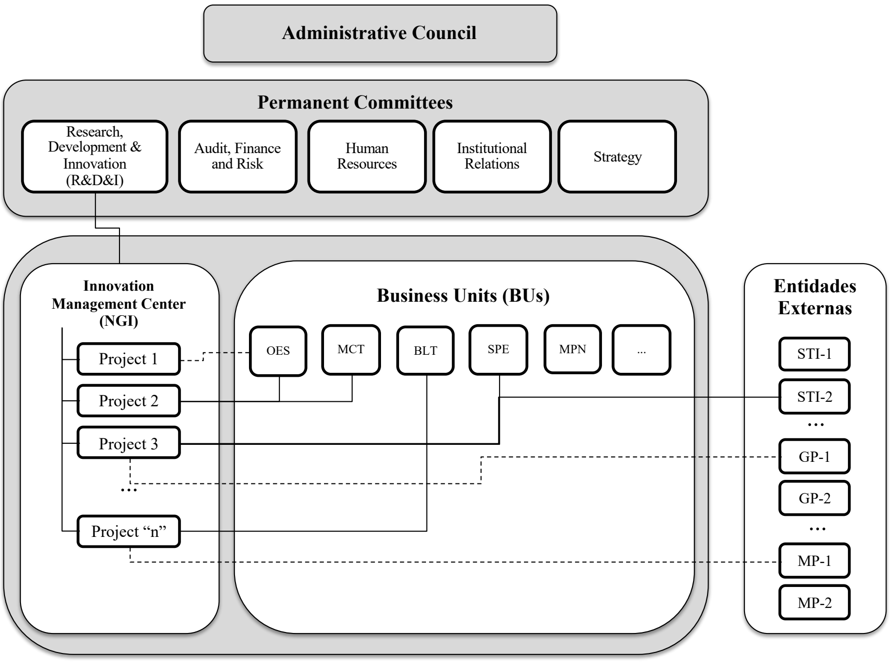
With the departure of Amanda, Luiz hired a trainee, Marcos, to take over the post of the NGI Orchestrator. The mission was clear, and the support of top management would also come deliberately and unrestrictedly. For Marcos, this mission should be converted into the creation of a portfolio of innovation projects so that these activities could be recognized and valued in the organization.

> It started, until Marcos came [...] there, yes, he started to have open innovation projects (R&D Coordinator).

> "Let's grow the cake and then adjust it, show that it [innovation] exists here. Let's make some noise!" (Innovation Analyst, repeating Marcos' speech at this time).

At the beginning of this Cycle, there was a restructuration of ORT through a corporate governance process – see Figure 17. "We made an internal change in the company, and it was redesigned in terms of high-level management practices" (Luiz, ORT’s Vice-President). The shareholders left their executive positions and would occupy the level of advisers (one president and two vice-presidents). Five permanent committees were set up for strategic matters and a new Direction (Shared Corporate Services) was created to serve all ORT's business units.

Figure 17: The Innovation Management Center (NGI) in the organizational structure



Luiz (Vice-President) was appointed to lead the "Research, Development & Innovation Committee" – R&D&I. Permanent members were appointed and, depending on the staff, other participants were also invited to attend the meetings.

> A stronger innovation committee was created, where we started to look (…) more formally: external partnerships, partnerships with state and federal institutions through government calls, to participate in these calls, showing what was our innovative idea, to try to obtain resources that would enable the execution of these ideas. (Product Engineering Coordinator).

At this moment, the mission of the Innovation Management Center (NGI), defined by Luiz, was the leadership of innovation initiatives in the ORT as a whole (Figure 17). The NGI was guided by the R&D&I Committee, but funded and accountable to OES (specifically to its CEO). For each innovation initiative approved to compose the project portfolio, a specific development team was formed. These teams had both internal and external members from Science and Technology Institutes (STIs), other Large Companies (GPs), and Micro and Small Enterprises or Startups (MPs).

Marcos, in his search for external funding for projects, attended an event at the Federal University of Minas Gerais (UFMG) regarding the Brazilian Law 11,196/05 ("Lei do Bem") which grants tax incentives to innovation projects, presented by an external consultant. After a first contact, Marcos and the Financial Manager met with the consultant at OES. This contact was motivated by a desire to return part of the investment on the "Test Gigas". The work was executed in cooperation between these agents, with a recovery of R$ 117,000 in taxes. At that time, the then CEO of OES stated: "Since we learned, next year we will do it by ourselves”.

At the same time, Luiz sent a message to Marcos requesting the follow-up of a proposal to develop a panel with 36kV nominal capacity (thirty-six thousand volts), already negotiated by the OES Commercial Department. At that moment, the "SENAI-SESI INNOVATION" call was launched, which promoted support through economic subsidy for projects in partnership with SENAI and / or SESI units. A few months after submission, the "36kV Panel" project was approved and the CEO of OES requested to use this project as a management model. As confirmed in the interviews, this project was, in fact, a "watershed" for the Group ORT:

> The "36kV Panel" allowed us to fight with these people. "Do you have a product? I also have! Mine, national. You pay royalties" (R&D Coordinator).

At the same time, NGI approved a financing in the "PRÓ-INOVAÇÃO" Program with the Development Bank of Minas Gerais (BDMG) for the counterparts involved in the "Microprocessor Rectifier", "36kV Panel" and the "Improvements in MCC columns of engines" projects. In addition, a new partnership with CEFET-MG was established for the development of the "System for management of distributed energy-network assets" in a public call for the electric sector involving CEMIG and the State of Minas Gerais Research Support Foundation (FAPEMIG). With the growing portfolio, Luiz, Marcos and the OES’s CEO established periodic meetings for project reporting. A channel was created, including for presentation and approval of projects by the Board of Directors.

ORT was in the process of implementing a new ERP (Enterprise Resource Planning). Based on the experience in the use of the tax incentives of "Lei do Bem", ORT attempted to incorporate it into this planning system, with specific reports to subsidize accountability in innovation projects. After a few months working with the IT Department, an ERP procedure was created for the automatic extraction of individual, specific values for any employee in the organization.

In this period, BLT decided to develop a "High Voltage Transformer Platform" and build a new plant to produce such equipment. The top management of the main competitor in the market was hired by BLT for this mission. Marcos stayed impressed with the magnitude of this initiative, the financial amount involved and the potential market entrance of such products. After a visit to the BLT, he returned to ORT headquarters determined to support this project.

Towards maturity

In the beginning of the following year, there was an opening of NGI's activities in relation to interaction with other ORT business units: (i) invitation from the Foundation for Technological Innovations (FITEC) to meet a demand from Companhia Paulista de Força and Luz (CPFL) in the development of an Unmanned Submersible Vehicle (VSNT), in a possible partnership with the OAC; and (ii) interaction with ENR, a company specialized in electricity generation and transmission, such as small hydropower plants and other renewable sources to seek for repayable financing for its innovation projects.

For the amount of financial resources in the "High Voltage Transformers Platform" development, Marcos engaged with BLT's technical team to prepare a proposal for the Brazilian Funder of Studies and Projects (FINEP) and the National Bank for Economic and Social Development (BNDES), which offered superior financial conditions compared to BDMG, despite greater complexity in submitting a proposal and merit evaluation. Proposals were submitted both to FINEP and BNDES. However, while FINEP approved the complete project, BNDES had only made its initial evaluation. In addition, the good relationship with an analyst recently hired by FINEP accelerated the process with this entity. Also, in that year, repayable financing was obtained for funding the counterparts of projects supported by economic subsidies (e.g., those supported by P&D-ANEEL) and were presented in the "Lei do Bem" report (i.e., three funding instruments were combined in one single project).

The "INOVA PETRO" was an unprecedented development program launched at that time by a cooperation between FINEP, BNDES and PETROBRAS. OAC had a track record in developing robotic solutions for the Oil & Gas market, in partnership with a French Business Group specialized in robotics and with the PETROBRAS Research Center (CENPES), but without commercial success. Marcos and the CEO of OAC structured a high-risk project proposal, including the development a new platform of tools for inspecting shells and submarine pipelines, with a total amount of R$ 96 million. All these tools would be developed by means of a France-Brazil technology transfer, with the commitment of 25% of local content.

Camila, then a NGI trainee, was hired as an R&D Analyst. At that moment, she and Marcos already divided the assignments of the NGI clearly, as put by Camila (one of the interviewees).

> In a way, it was already well divided: I was in charge of the projects, the management itself, and this is fine to talk about. At first, until he [Marcos] was able to get things right, we did all together, like this: he [Marcos] had a lot to do. Then, when I started taking care of this management on my own, I performed the internal [work], which was timing, accountability, knocking on everybody's door, collecting signatures [...] (Camila - Innovation Analyst).

Marcos was invited to participate in discussions involving ORT's Strategic Planning. In a meeting of the R&D&I Committee and subsequent presentation to the Board of Directors, a portfolio of projects was approved for the "INOVA ENERGIA" (a program similar to "INOVA PETRO", focused on the electricity sector): "System for discarding loads"; "Sensors for high voltage transformers"; "Industry of photovoltaic modules"; and "Photovoltaic solar power plant and own inverter technology". Due to the volume of projects in the pipeline and portfolio, NGI pressured the top management for additional resources to format and submit proposals for "INOVA PETRO" and "INOVA ENERGIA". Two different consulting firms were hired, and task-forces with internal collaborators were built to support each initiative. There was not enough time for the formation of a new team at NGI dedicated to such demands. Some tensions emerged between Marcos and the OES' CEO for the distributed attention of the NGI (i.e., attendance to all ORT's business units while its costs were hold only by OES).

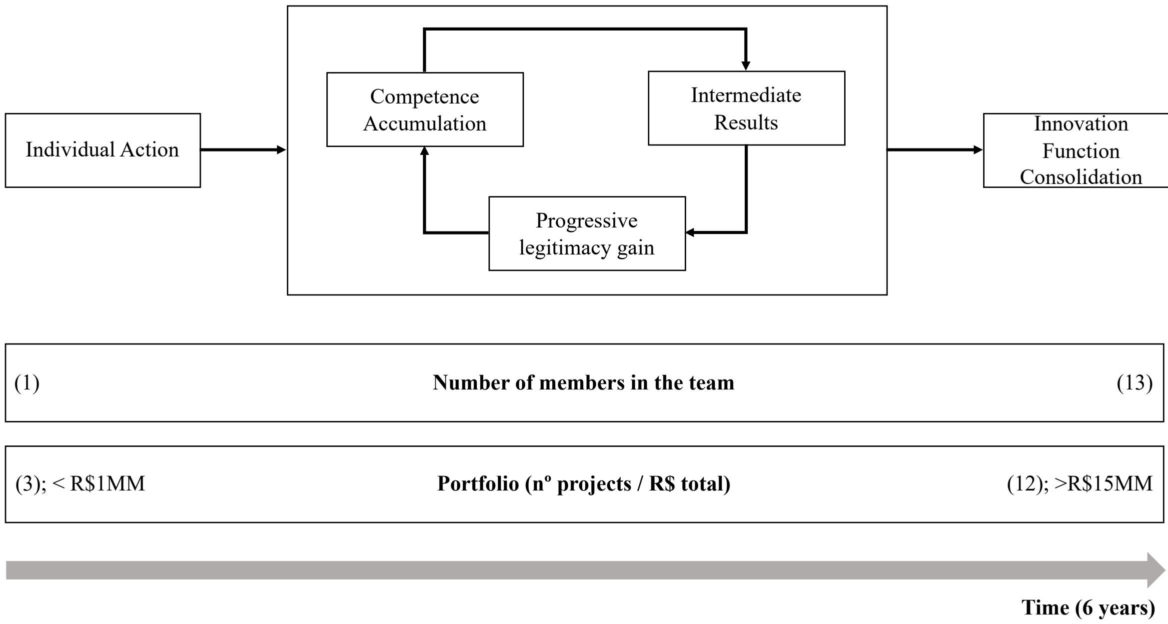
At the end of the Cycle, a change in the organizational structure of OES represented, for the first time, the creation of a formal department to deal with innovation activities. That department would be responsible for both the execution of the projects and their management. The NGI was incorporated into this structure. For the first time as well, OES recognized the unique dedication of some of its employees to R&D activities (e.g., Software, Electronics), which were incorporated into the new structure.

> That was a milestone. We did not have an innovation structure, despite having a R&D sector. [Until that] This was not, let's talk like that, widespread among people and was not a reference [for the company]. Today, anyone who has an idea of product innovation will seek the new department to make this idea viable (Engineering Coordinator).

6.1.5. Discussion

Figure 18 summarizes the IF's building process from the narrative analysis presented before. In the analyzed case, the IF gains legitimacy progressively from the individual action, the skills accumulated by the team (and consequent recognition of these skills by the organization), and the intermediate results obtained with the innovation projects. We also highlight the growth of the structure (i.e., number of members) as well as the portfolio of projects managed by the IF.

Figure 18: The IF's construction process.



Emergence and consolidation of the Innovation Function

From the Function concept proposed by Salerno & Gomes (2018), the narrative of the case presents in detail the creation of a distinctive organizational unit dedicated to innovation management. The case demonstrates the formalization of the team at ORT's at the business organization chart in the end of the investigated period with distinctive assignments when compared to other organizational instances, such as: the raising of resources from external Funding Agencies; the portfolio management; interface with external entities (e.g., Science and Technology Institutes, consultancies, among others) for issues involving innovation projects; and the accomplishment of R&D itself.

> Before, a single person was the whole department, and today we have a department with ten people [...] I have already hired three more trainees for software development. (R&D Coordinator).

The convergence of events for the constitution of a dedicated organizational function to innovation management is evidenced from different perspectives. In the described period, new procedures were created for project management (from planning to approval and monitoring -

by the R&D Committee and the Board of Directors). More than 50 new opportunities were articulated, and the team managed 12 innovation projects simultaneously at the end of the period. There was also an expansion in the team's activities regarding the establishment of formal partnerships (i.e., legal agreements) with Federal Government Funding Agencies, public and private investment banks, suppliers, clients, and universities. In addition, during the process narrated, the NGI discussed and formulated proposals for new projects with all seven ORT business units.

The articulation of teamwork from the individual action of central actors

The case highlights the relevance of individual action (especially, Amanda and Marcos) for the construction of IF. Respondents recognize the key performance of these managers throughout the process, who initially act as hunters (i.e., seeking for opportunities) and centralizers (i.e., focal points for other agents) serving as connecting points to the various parts of the organization (c.f., Leifer et al., 2000).

At the beginning, the instances involved in an innovative project were basically: Commercial Department - in identifying opportunities (most of the times, those were new normative requirements for the products); Board of Directors - in project approval; Engineering - in the product development itself. The projects were generally of an incremental nature, involving technical improvements in existing products to meet specific legislation, almost as a condition to continue competing in the respective markets. With the involvement of the IF's dedicated team, the number of connections made with other agents (internal and external to the company) is increased and also the diversity in the nature of the projects.

The IF establishes a point of reference in the organization for the discussion of subjects involving the theme "innovation" - many opportunities may have been left aside over the years by the lack of a channel to direct them. Over time, external agents started to search NGI to prepare project proposals. This is an important milestone, as the effort to build the portfolio is no longer just "inside out" of ORT. The companies' innovation process becomes more open (Chesbrough et al., 2006) as the IF consolidates itself in the organizational environment.

The projects carried out in partnership require new interactions with other organizational functions (Bagno et al., 2017). The Finance Department, for example, supports the financial resources management (e.g., project accountability) provided by external Funding Agencies. Partnering brings the discussion of intellectual property (IP) and, consequently, the involvement of the Legal Department. Another good example is the interaction of IF with the

Information Technology (IT) Department for the creation of reports in the company's ERP as a way of searching for specific information (e.g., salaries and social charges incurred with employee "X" in month "Y") in order to be accountable for Funding Agencies and the Science, Technology and Innovation Ministry (MCTIC), in the context of the “Lei do Bem”.

In addition, while the IF's performance is recognized in the organizational environment, new connections emerge, especially at the top management level. Throughout history, NGI has been invited to participate in meetings promoted by "Strategic Planning" and to discuss project proposals with the Board of Directors. Over time, ORT business units’ boards seek Marcos' support for the identification and search of external partners, structuration of innovation projects (e.g., deliveries, milestones, activities), raising of external funds, proposal preparation and submission to the R&D&I Committee and to the Board of Directors.

The accumulation of competences in the core group of the IF, the gain in complexity of the IF network and the increase in the radicality of innovation projects

The central group's role in monitoring innovation projects throughout the period is notably flexible and non-linear. Although there was, for example, a R&D&I Committee, there were no rules for approval or continuity of a project, a planned annual budget for the initiatives, or even a clear guideline concerning the participation of employees from other departments in the actions promoted by the NGI. Even so, one can note that there was an effort to protect innovation projects, either by seeking for external resources to reduce the perception of risk associated with them or by articulating partnerships as a way to raise sponsors for such initiatives in the context of the ORT.

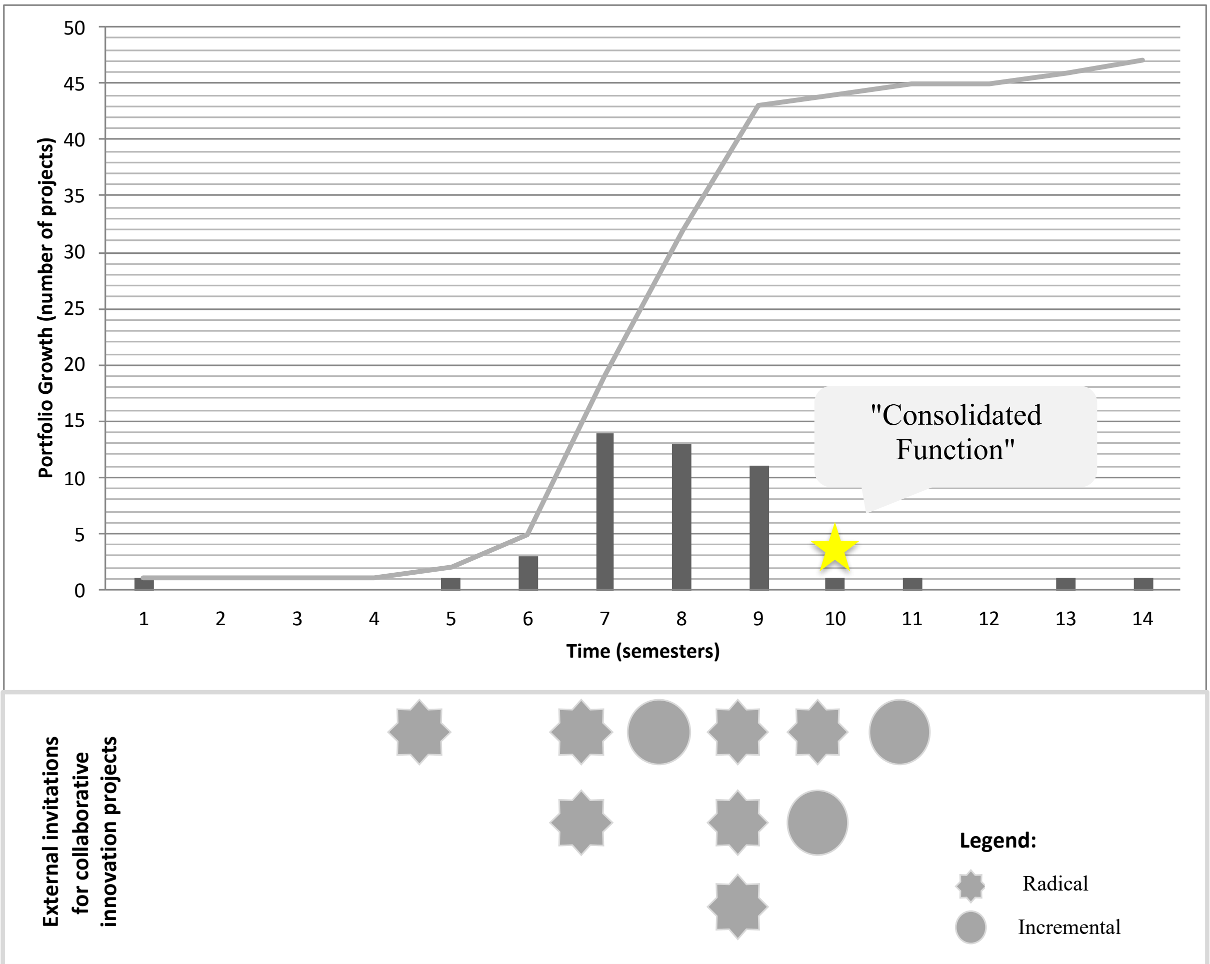
The work performed by the management team unfolded as the challenges emerged (recognized by the team) and were faced in a constant process of accumulation of skills to manage innovations. A good example is the use of the "Lei do Bem" incentives. After a first experience supported by an outside consultant, NGI built a series of routines together with other departments and internalizes that competence for subsequent demands. Another example concerns the evolution of the team's ability to manage financial resources of external agents by combining different types of instruments (e.g., repayable financing, economic subsidy and tax incentives) in a single project (e.g., "36kV Panel", "Microprocessor Rectifier").

Throughout history, NGI underwent a change in its way of acting. At the beginning, the team sought initiatives within the limits of the ORT (the use of tax incentives in the "Test Gigas" and the participation in the SENAI-SESI Program for the "36kV Panel" are some examples). Subsequently, there was a reversal in which other agents went for the NGI to contribute to their initiatives (e.g., invitation to Strategic Planning meetings). In addition, the team came to achieve greater budgetary autonomy (i.e., Camila's hiring, consultancy hiring to support the preparation of the proposals to "INOVA PETRO" and "INOVA ENERGIA", among others).

During the innovation management group maturation, the portfolio was raised with some projects with higher levels of uncertainty (i.e., cannot be foreseen during project planning) and complexity (i.e., number of parties with different specialties and amount of resources involved) - (Pich, Loch, & Meyer, 2002). The "Microprocessor Rectifier" (a variation of an existing product) was one of the first initiatives developed in partnership with external agents (CEMIG), involving an electronic engineer and two technicians of the company, with resources in the order of R$150.000,00. The "36kV Panel", which totalized R$1 million, was based on the development of a product for a new voltage class, not previously covered by OES. This project involved the Engineering and Quality Departments, external suppliers (in the development of some specific components of the new panel) and five SENAI professionals. At the end of the period presented, the NGI could already articulate opportunities involving unprecedented new business platforms for ORT, such as the OAC’s robot platform for off-shore structures inspection and the development of photovoltaic solar energy solutions by OES, estimated at R$96 million and R$1 billion, respectively. The latter involved international partnerships for technology transfer as well as government arrangements for the discussion on regulatory issues and tax immunities.

As the team developed competencies, the ability to manage a larger number of projects and projects with higher levels of uncertainty was expanded. New routines were created (e.g., project accountability and presentation of advances in projects), streamlining the execution of several processes associated to the generation of innovations. In addition, team members became able to find useful resources inside and outside of the organization more quickly, and relationships with other entities (i.e., people, groups, organizations) became stronger (i.e., through a successful shared experience) over time. In this sense, Figure 19 shows ORT's innovation portfolio evolution throughout history. It should be noted that in the two years preceding the consolidation of the IF (periods 6, 7, 8 and 9) there has been a large increase in companies’ projects, especially those executed in partnership and considered more radical.

Figure 19: The evolution of the innovation portfolio



This last analysis, in particular, reinforces the perspective that the management of innovation by the constitution of a dedicated function makes sense when innovations are more radical (O'Connor, 2012, O'Connor et al., 2008, Salerno & Gomes, 2018). Although NGI's work has also catalyzed the occurrence of incremental innovations, the case analyzed does not show evidence that this organizational instance would have been essential for the occurrence of these projects (although they may have occurred in greater numbers or have been conducted with better fluency). Incremental innovation projects may have been important in order to generate faster results for the IF, but the contribution of a dedicated team is mainly to protect the most radical innovations, searching for external support, partners or sponsors, in order to mitigate the uncertainties perceived by the top management.

6.1.6. Conclusion

This study deepens the discussions about how to build a dedicated function to innovation management in large organizations. The main contributions to the literature are: (i) deepening the understanding of the emergence of the IF (O'Connor, 2012; O'Connor et al., 2018, 2008) in large organizations, from a micro-analysis perspective, in which central individuals (e.g., Orchestrators), build the company's capability for innovation from the accumulation of competencies and from the legitimacy built with top management; (ii) the study presents in detail the gradual process of creating a managerial system for radical innovations, unlike previous works that deal with this implementation in a static way, from the definition of a set of pre-established organizational elements (Bagno, Salerno, & Silva, 2017; Goffin & Mitchell, 2010; O'Connor, 2008) – in sum, previous studies present a picture of the system and not the film to reach it; (iii) finally, this study presents how an organization starts from micro processes (i.e., individual interactions, team building and interpersonal relationship networks) to macro outputs (i.e., capability building from the constitution of a dedicated organizational entity) reinforcing Kouamé & Langley's (2018) clamor.

From a practical point of view, this study: (i) provides specific insights for companies that aims to create a capability to generate more radical innovations (e.g., allocation of dedicated employees to conduct the mission, search for external resources to support the execution of projects, beginning of the construction of innovation portfolio by acting in projects more adherent to the business as a way to obtain top management's visibility); (ii) shows that, for senior managers, the construction of an innovative capability is a long and gradual process (in the case presented, it lasted more than four years) - this point is relevant for leveling expectations and reducing pressure on the team for short-term results; (iii) reinforces the importance of governmental support (financial and tax incentives) for the leverage of innovative projects in companies as well as a mechanism for the approximation between large companies and Universities / Research Centers.

However, there are some limitations, especially from a methodological point of view. New interviews could strengthen the analysis of the case. The internal agent responsible for the IF during the first cycle of the narrative may have been the main gap in the interviewing stage. We chose not to listen to external agents within the scope of this work, based on the assumption that their visions would be restricted to projects that had been involved and because they were not mentioned directly during the interviews.

Suggestions for theoretical advances include: (i) how IF changes itself from interaction with startups, as observed in recent forms of open innovation programs in large companies; (ii) to study mature organizational functions, dedicated to radical innovation management, from a social network perspective (Granovetter, 1977; Scott, 1988; Wasserman & Faust, 1994) in order to understand how the IF articulates support from other functions to obtain necessary resources to fulfill its mission; and (iii) to expand the understanding of the IF's organizational structure with an emphasis on roles, hierarchy and forms of coordination, a debate initiated by O'Connor et al. (2018).

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6.2. PAPER 2 (#P2): From open innovation projects to open innovation project management capabilities: A process-based approach

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Figure 20: Paper #2 publication cover


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From open innovation projects to open innovation project management capabilities: A process-based approach

Júlio Cézar Fonseca de Melo[a,*], Mario Sergio Salerno[a], Jonathan Simões Freitas[b], Raoni Barros Bagno[b], Vinicius Chagas Brasil[a]

[a] Production Engineering Department Polytechnic School, University of São Paulo (USP), Av. Professor Luciano Gualberto, 1380, São Paulo, SP, Brazil
[b] Federal University of Minas Gerais (UFMG), Presidente Antônio Carlos Avenue, 6627 - Pampulha, Belo Horizonte, MG, Brazil

Abstract

How do organizations use the experience from projects to build a systematic capability to manage open innovation projects? Drawing upon Project Management and Open Innovation capability-building frameworks, we studied the crusade of an industrial company to create an open innovation capability. In that sense, we applied an Event Structure Analysis (ESA) to evaluate the event network, which evidenced a four-stage process: closed mode, open driver, vanguard project, project-to-organization. Results demonstrate, from causal connections, that the referred capability can be leveraged from the execution of key projects, especially from a vanguard project. Our study contributes to Project Management theory by reveling that previous experiences in both project and organizational levels offer a fertile ground for the emergence of a vanguard project. For the open innovation field, this paper provides a project-oriented approach to the discussion of open innovation's adoption in mature firms.

Keywords: open innovation; organizational capabilities; project capabilities; project capability-building; Event Structure Analysis; ESA.

6.2.1. Introduction

Open innovation (OI) has mainly been adopted, with firms engaging in a variety of practices, from bilateral to multiple parties' relationships (Brunswicker & Chesbrough, 2018; Henry Chesbrough & Brunswicker, 2014). However, despite its full application, OI has not been sufficiently formalized as a management practice by organizations (Brunswicker & Chesbrough, 2018; Henry Chesbrough & Brunswicker, 2014; Mortara & Minshall, 2011). In that vein, Bogers et al. (2017) advocate for studies that connect different levels of analysis (e.g., intra-organizational, organizational, extra-organizational) in multi-level perspectives, establishing, for example, linkages between projects and the firm's development of capabilities. Moreover, scholars demand more theoretical approaches to manage open innovation initiatives as an organizational capability (Lichtenthaler & Lichtenthaler, 2009). Additionally, Zynga et al. (2018), in a study of OI in 756 global organizations, argues that there is no sufficient research studying the processes by which organizations move from closed to open innovation. In this sense, research lacks the link between micro-level processes and organizational macro-level mechanisms towards the building of OI organizational capabilities.

In parallel, Project Management (PM) literature can be a valuable source to accomplish with the previous gaps identified in OI field. For instance, Worsnop, Miraglia, and Davies (2016) propose meaningful connections between OI and PM by discussing the relationship between open and closed innovation in civil engineering projects. However, their focus is on a single megaproject and does not cover capability development at the firm level. Nonetheless, PM scholars offer substantial contributions about organizational capability building in mature companies (Brady & Davies, 2004; Davies & Brady, 2000, 2016; Davies, Dodgson, & Gann, 2016; Söderlund, 2004; Söderlund & Tell, 2011). Jugdev, Mathur, and Fung (2007), for example, explore the management of intangible assets (i.e., knowledge-based) to build a capability for project management. On the other hand, Söderlund and Tell (2011) underline three main competencies associated with organizational capabilities in project-based organizations (P-form) (e.g., entrepreneurial – create projects; evaluative – evaluate projects; relational – form networks with partners and clients).

More specifically, Davies and Brady (2000) stated the concept of "project capabilities" where firms can use a first of its kind project - "vanguard project" - to explore new capabilities or domains of business. Subsequently, Brady and Davies (2004) proposed the "project capability-building" framework to explain how firms use vanguard projects to create a new organizational capability, based on two levels of learning: project-led and business-led. Although insightful, these concepts were developed in contexts of complex, but predictable projects, associated with existing customers and repeatable businesses (e.g., turnkey, outsourcing, public-private partnerships). Notwithstanding, Frederiksen and Davies (2008) connected the concept of vanguard projects to situations where there are no existing clients (innovative projects), concluding that a vanguard project can also be used as a path to a novel entrepreneurial venture. However, their focus was on innovative activities but not on the creation of a systematic capability to manage an innovation portfolio. The study of Boscherini, Chiaroni, Chiesa, and Frattini (2010) is one of the rare studies that bet on bridging PM and OI strands to find answers on how companies can implement open innovation from project experiences.

In sum, whereas OI literature claims for more theoretical approaches concerning organizational capability building, PM literature offers valuable insights about capability building from projects, but with little attention to the domain of innovative, uncertain open projects. We argue that these theoretical research streams can be brought together to explore the following research question: how can organizations use the experience from projects to build a systematic capability to manage open innovation projects?

In this sense, we applied Event Structure Analysis (ESA) to retrospectively approach the case of an industrial organization in its path to build an OI capability for three years. This study explores the micro-level aspects (i.e., specific actions conducted by a set of agents) regarding the building of a capability for open innovation project management, based on the "project-capability building" framework proposed by Brady and Davies (2004). The underlying assumption is that, although Brady and Davies (2004) framework was not conceived for innovation projects, it offers a comprehensive structure that, if associated with OI propositions (e.g., Zynga et al., 2018), may help to answer the stated research question.

The paper has five additional sections. In Section 6.2.2, we address a theoretical discussion about open innovation and project management capabilities, precisely the project-capability building approach. Then, in Section 6.2.3, we present the case selected for this study and procedures used for data collection/analysis, culminating in an ESA application. After that, the main results (e.g., the causal network structure and the key steps for the capability building) are presented in Section 6.2.4. Section 6.2.5 discusses the identified process to build an OI project management capability and its specificities, as well as implications for PM and OI strands. Finally, limitations and new directions for future research are offered in Section 6.2.6.

6.2.2. Literature Review

6.2.2.1. Open innovation as an organizational capability

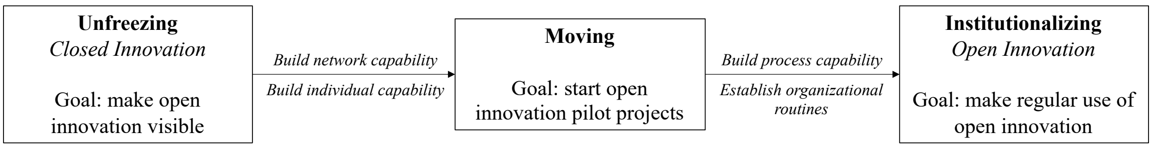
The open innovation paradigm, formally presented by Chesbrough (2003), assumes the principle that innovation should not be based only on firms' internal and isolated efforts. In this sense, partnerships with startups and research institutes, the involvement of customers and suppliers, and other partners can be a reasonable path to boost firms' innovative potential. An open approach may promote the company's innovation process at different phases through diverse forms such as spinning-off new ventures, intellectual property (IP) licensing of nondeveloped ideas, seeking for external funding from public or private sources, among others (Huizingh, 2011; Nambisan & Sawhney, 2007). Besides the potential benefits of these initiatives, particular challenges emerge from the complexity to deal with projects that involve the contribution of diverse external (Gomes, Facin, Salerno, & Ikenami, 2018). According to O'Connor, Leifer, Paulson, and Peters (2008), to face such challenges, large established firms need to develop (radical) innovation capabilities so that discoveries can be systematically sourced from internal/external parties and subsequently nurtured into business opportunities sooner.

However, from an organizational perspective, open innovation is often poorly formalized, and companies usually lack routines and metrics to manage it accordingly (Brunswicker & Chesbrough, 2018). Even though large firms bet on innovation projects, they have not built the supportive organizational infrastructure necessary to enable them, often relying just on maverick champions to push the project through a system tuned for incrementalism (O'Connor, 2006). Literature has focused on open innovation practices (Chesbrough & Brunswicker, 2014), as well as on an upper level of analysis (i.e., the firm), giving little attention to organizational enablers of an OI capability. Nevertheless, specific studies give us glimpses on how to build a capability to manage open innovation projects systematically. For instance, West and Bogers (2014) explore how firms leverage external sources of innovation, based on linear sequences of interactions with partners. By turn, Saebi and Foss (2015) discuss the adaptation of business models to equalize open innovation strategies and firms' current businesses.

Other studies emphasize the character of the establishment of such capabilities as an organizational transformation journey (e.g., Boscherini et al., 2010; Chiaroni, Chiesa, & Frattini, 2011). Focused on understanding the firm's path to open innovation, studies have emphasized, for instance, the different maturity levels in open innovation, based on elements as the climate for innovation, partnership capacity, and internal processes (Enkel, Bell, & Hogenkamp, 2011). Chiaroni et al. (2011) offer a model from a longitudinal study in a large manufacturing company to implement open innovation, based on managerial levers (e.g., knowledge management systems, evaluation processes, organizational structures, networks). Additionally, according to Mortara and Minshall (2011), the successful incorporation of Open Innovation into the organizational routines depends on the innovation needs, the timing of the implementation, and the corporate culture.

Boscherini, Chiaroni, and Chiesa (2010) argue that organizational barriers and inertia need to be overcomed in a transition from closed to Open Innovation. Highly inspired by studies on organizational change (Armenakis & Bedeian, 1999; Kotter, 1995; Lewin, 1947), these authors adopt the three-step process of unfreezing, moving, and institutionalizing to describe such a transition, an idea also present in Huizingh (2011) study. In this line, Zynga et al. (2018) proposes a process for OI adoption - (Figure 21). This model is centered in three categories of microfoundations: (i) individuals – dedicated ones (e.g., gatekeepers, scouts) to connect the organization to the external environment; (ii) processes – staged processes; (iii) structures – organizational structures to support open innovation. The authors argue that these microfoundations must be developed in a coordinated way to build an OI capability. During Phase 1 (unfreezing), innovations are more closed, and the firm develops more traditional connections (i.e., customers and suppliers) to transfer knowledge. In Phase 2 (moving), firms typically form clusters of microfoundations related to individuals and structure, and, also start pilot projects. Phase 3 (institutionalizing) represents the moment of the full capability development, in which culture and mindset are considered established, and there is a formal structure to manage projects.

Figure 21: Model of the transition from closed to open innovation



Source: adapted from Zynga et al. (2018)

Although the field is vast, the project-level, despite mentions (Chiaroni et al., 2011), has been largely neglected as the unit of analysis of the open innovation studies. Thus, OI capability tends to be associated only as result of highly intentional and planned managerial efforts (Brunswicker & Chesbrough, 2018; Chesbrough & Brunswicker, 2014). Yet, very often, this literature has treated the adoption of open innovation as the use of new practices, ignoring even the need for building a broader and complex organizational capability, as argued by Zynga et al. (2018). Moreover, most studies usually approach what OI consists (i.e., the interaction with external partners), but rarely undertake a process perspective to explore the path until the consolidation of an OI capability, and also what are the internal agents and the actions required to move this process forward. Finally, open innovation is essentially a relationship between multiple parts to reach an expected goal (i.e., share knowledge), usually formalized through projects. Therefore project management literature can be a fertile source to complement the open innovation field in those challenges, especially the subset of project capabilities.

6.2.2.2. Project capabilities

The project capabilities construct has been frequently debated in the literature (e.g., Brady & Davies, 2004; Davies & Brady, 2016). It “refers to the distinctive managerial knowledge, experience, and skills, which are located within a single organization (a firm) and required to establish, coordinate, and execute projects.” (Davies & Brady, 2016, p. 314). To pursue a project capability, in turn, an organization might develop a set of competences: project management, technical, entrepreneurial, evaluative, and relational. The relational dimension has a close link with open innovation, once it covers, among other aspects, the management of the relationships with clients, suppliers, and partners (Söderlund & Tell, 2011).

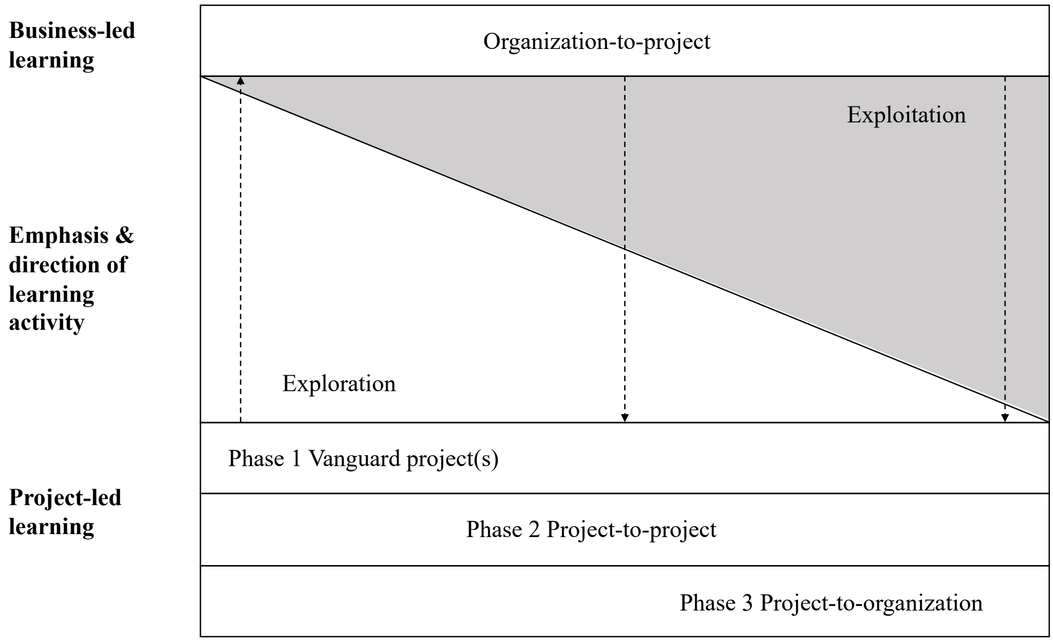
Thus, a project capability sets routines, processes, and structures over time to guarantee the perennial ability to conduct projects by controlled and established flows. At a higher level of aggregation, project management capabilities can be dynamic capabilities (Teece, Pisano, & Shuen, 1997), associated with organizational and strategy renewal (Brady & Davies, 2004; Davies & Brady, 2000, 2016).

Regarding the building of project capabilities, Davies and Brady (2016) suggest that firms should establish distinct project management routines for exploration and exploitation. This approach highlights the opportunity to conduct a specific initial project – a vanguard project (Davies & Brady, 2000, 2016; Frederiksen & Davies, 2008). Frederiksen and Davies (2008, p. 489) define a vanguard project as a “new type of project organization developed specifically to experiment with and learn from new technology and to explore novel market opportunities”.

Turner (2005), adopted the concept of “pilot study” as part of a larger project or program, intending to improve knowledge on the novelty the project/program delivers, which could reduce the risk and uncertainty associated with the change. Although this author explores several advantages in undertaken pilot studies in the context of projects, his insights do not spill over to clear implications for companies’ capabilities at the organizational level. On the other hand, Brady and Davies (2004) assume that, after the end of the vanguard project, individuals and teams empower themselves with the experience in managing new practices, routines, and processes to improve the project management system in the parent organization. Noteworthy that the literature extends the role of vanguard projects to other contexts. Frederiksen and Davies (2008), for instance, bridge project management and corporate entrepreneurship activities by affirming that vanguard projects represent a link between strategies for corporate entrepreneurship and its operationalization at the project level – also stating that literature has paid little attention to this issue.

Indeed, Brady and Davies (2004) explain in a complete way the process by which companies build capabilities to deliver projects regularly after managing a vanguard project (i.e., the "project building-capability" framework – Figure 22). According to these authors, the establishment of a vanguard project can initiate an organizational cycle leading to changes in the capabilities and organization of the firm.

Figure 22: Project building-capability framework

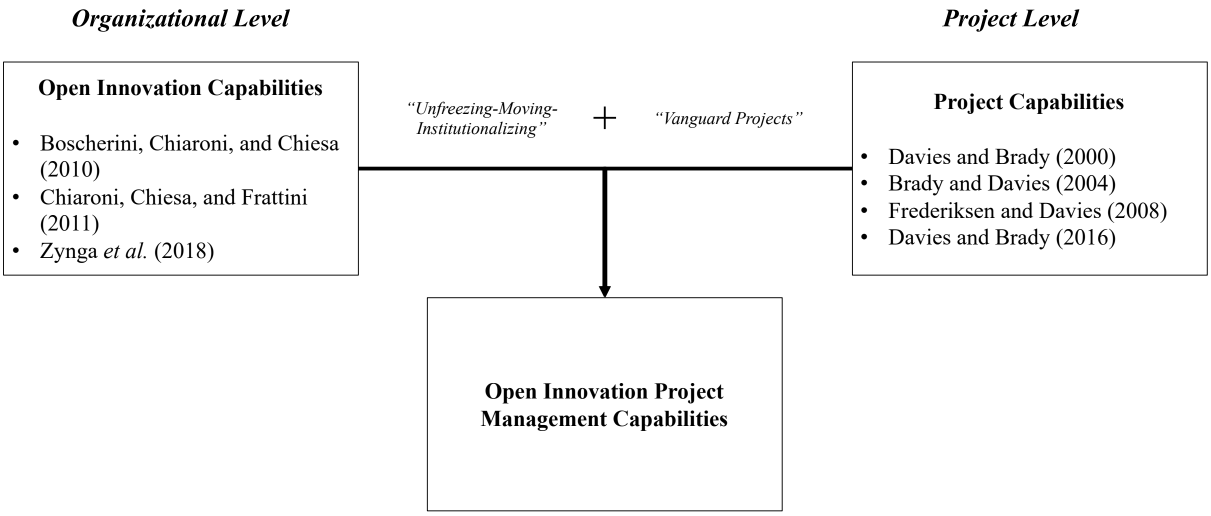


Source: adapted from Brady and Davies (2004)

In phase 1 (Vanguard project), a new project is created in the organization to explore strategic opportunities (move technology/market bases or adapt to the environment) and vanguard projects help to gain experience over the new activity. In phase 2 (Project-to-project), the main goal is to transfer insights from the vanguard project(s) to subsequent project teams. Finally, in phase 3 (Project-to-organization), the project business organizations have to grow in size, or new specialized units must be created to handle this new portfolio of projects of the same type. These project-led learning processes are embedded into a broader context of the firm (business-led learning). The model also demonstrates a change concerning the emphasis and direction of the learning activity and the intertwined exploration and exploitation activities over the process.

Therefore, we advocate that project capabilities research stream, if combined with the open innovation capabilities discussion, can help to explain the process by which mature companies build an organizational capability to manage open innovation projects systematically – Figure 23 presents this research theoretical framework.

Figure 23: Theoretical framework



6.2.3. Method

An in-depth causal case study (Beach & Pedersen, 2016) was carried out to identify causation patterns from a sequence of events, i.e., of specific spatio-temporal occurrences (c.f., Freitas, Gonçalves, Cheng, & Muniz, 2013). In this context, events can be defined as actions of a determined agent on a given object, at a specific moment in time (Heise & Durig, 1997). They may include decisions, meetings, conversations or even a simple, but explanatorily relevant, handshake (Langley, 1999).

Thus, causal case studies are within-case analyses that primarily aim to infer, mainly from the detailed historical development of a case, a causal structure that explains the outcome of interest (Rohlfing, 2012). According to Kouamé and Langley (2018, p. 569), this particular genre of processual research approaches, called "outcome-driven narrative", usually focus on a single case and "historical forms of causal explanation expressing causal chains of events and their interaction are inherent to this genre". Therefore, this specific kind of approach was chosen because we wanted, not only to thickly describe a case of capability building for open innovation project management, but to identify causal mechanisms underpinning this process from the historical analysis of a particularly prominent instance of this type of outcome. Thus, methodological emphasis relied on the historical explanation of an eventually remarkable outcome that emerged over time (i.e., the achievement of an open innovation project management capability). Hence, process-based logic played a vital role in this research, since variable relationships were not abstracted out from temporality (Langley, 1999, 2007). This processual approach was suitable to tackle our research objectives because they called for a focus on the progressive nature of capability building (c.f., Danneels, 2011).

6.2.3.1. The case

The research setting was an Industrial Electronic Manufacturer ("IEM") that had more than 3,000 employees and approximately US $500 million annual revenue during the period of our data collection. The IEM's main clients were mainly from the following sectors: energy (i.e., generation to distribution), sanitation, metals, cogeneration, mining, oil and gas, and cement. The study level of analysis was the building process of an open innovation project management capability. Of course, a couple of the holding's business units were more actively involved in this process than others, but, indeed, capability development was a corporate-level phenomenon that encompassed the relationship of events and projects from the IEM as a whole.

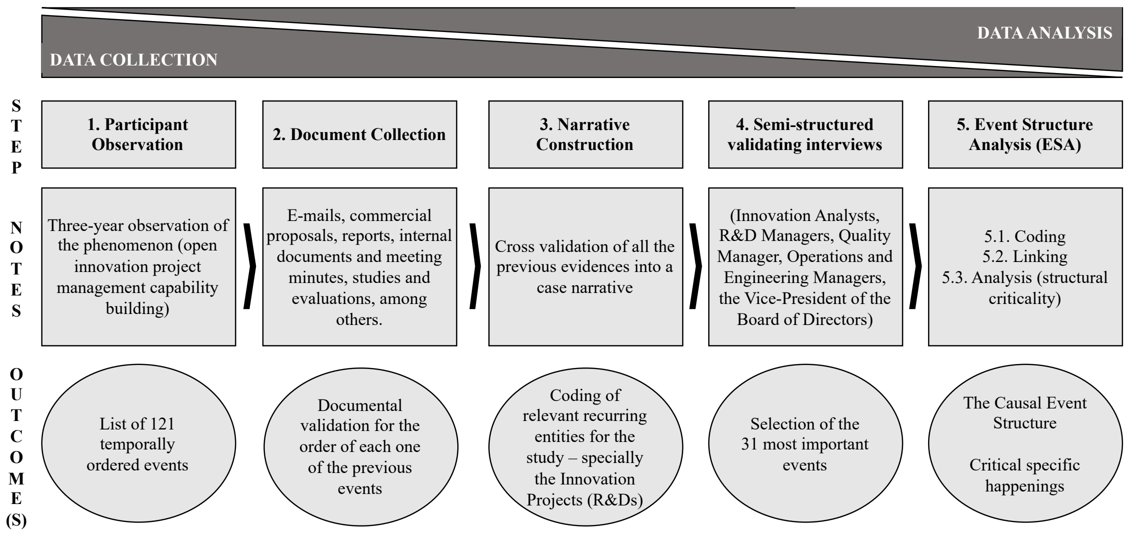
This case was chosen for several reasons. First, according to the state-of-the-art methodological guidelines for selecting cases in causal process-tracing research (Beach & Pedersen, 2018), IEM was a setting in which both the hypothesized root cause (i.e., vanguard project), the final effect of interest (i.e., open innovation project management capability), and literature-based requisite contextual conditions (e.g., top management strategic intent, dedicated individuals to accomplish the mission) were present. Second, engineering-based organizations such as IEM are particularly prone to be project-oriented in their organizational structures (Hobday, 2000; Kwak, Sadatsafavi, Walewski, & Williams, 2015; Thiry & Deguire, 2007), potentially providing an especially fruitful field to track project management capabilities. Third, the development of technologically sophisticated modular products, such as the ones tailor-made by IEM for its major clients, tends to provide a natural context for opening up the innovation process, and to cooperate with highly specialized third parties (Facin, Gomes, de Mesquita Spinola, & Salerno, 2016; Salerno, Camargo, & Lemos, 2008). Fourth, in large industrial firms as IEM, establishing corporate-level capabilities from business-level projects is a strategic priority if the corporation is to properly manage its portfolio of multiple parallel innovation projects, whose leaders might be dispersed through its large organizational structure (Bahemia & Squire, 2010).

Besides these theoretical sampling criteria (Eisenhardt, 1989; Eisenhardt & Graebner, 2007), there were also empirical reasons for selecting IEM, given our research objectives. First, IEM was notably engaged in a transformation process regarding its capability building for open innovation project management during the studied period. Hence, the phenomenon was unambiguously present and of genuine interest to strategic informants, favoring their motivated cooperation with this investigation (c.f., Martin & Eisenhardt, 2010). Second, the unusual privileged access to IEM's settings, people, and documents during a long period (i.e., three years) of direct participant observation guaranteed the richness of detail needed for a thorough case analysis (Eisenhardt, Graebner, & Sonenshein, 2016) enabled. This rare and thick longitudinal data provided unique insights into complex causal intricacies that would probably not have been noticed in other less-accessible contexts (c.f., Hetemi, Jerbrant, & Mere, 2020). Third and finally, the case came to represent a challenging major transformation in the project management capability of a large corporation, allowing one to observe in real-time how factors highlighted in the literature were playing out over time when the company faced a challenging learning process (c.f., Danneels, 2011).

6.2.3.2. Data collection and analysis

Figure 24 presents a summary of the data collection and analysis process, through five main steps: (i) participant observation; (ii) document collection; (iii) narrative construction; (iv) semi-structured validating interviews; (v) Event Structure Analysis. It is important to notice that collection and analysis were carried out in parallel, but with some level of overlapping. For example, while the authors observed the case, the first list of events was built. During the elaboration of the narrative, the authors eventually came back to the interviewees to adjust their understandings (i.e., collect additional data). The authors kept this iterative process until saturation point.

Figure 24: Data collection and analysis summary



Participant Observation

During this step, data were collected through longitudinal three-year participant observation (Langley, Smallman, Tsoukas, & Van de Ven, 2013). One of the authors followed IEM's innovation activities daily, including attendance at the "Research, Development and Innovation Committee" weekly workshop, project meetings, ideation sessions, prototype tests, and partnership negotiation episodes, among others. This period of observation was useful to the retrospective structuring of the first list of 121 temporally ordered events related to the consolidation of the open innovation project management capability at IEM (available for consultation in the supplementary material – "Events_Observation").

Document Collection

Over time, documents were collected to serve as an additional data source, including e-mails, commercial proposals, reports, internal documents and meeting minutes, studies, and evaluations, media publications and budgets. Semi-structured interviews and hallmark conversations were frequently held with key actors. Moreover, throughout the period, personal research notes were taken in journal entries and schedules. This bundle of multifaceted data served to justify the timescale and occurrence of each of the 121 listed events – i.e., a specific supporting (dated) document was associated with each event and is available for consultation in the supplementary material – "Events_Observation_Supporting Documents").

Narrative Construction

In the possession of this list of events and of all its supporting documents and notes, a detailed case narrative was carefully composed by cross validating all the evidence and expressing them in theoretically meaningful ways without losing its adherence to the local IEM's particular settings and language. The result is presented in Section "4 – Results and Discussion", and its complete version ("Full Narrative") is available in the supplementary material. While writing the narrative, the research team started to inductively encode relevant recurring entities, such as internal employees (AGIs), external personal agents (AGEs), government funding agencies (FOMs), science and technology institutes (ICTs) and research and development projects (R&Ds), among others. This step was conducted by at least two researchers (pair-validation) to select relevant constructs for subsequent theoretical discussion.

Table 5 presents the entities's codification. Thus, an "AGI", for instance, is an internal agent that was relevant to the outcome's historical background. The numbers after the codes (e.g., "AGI-1", "AGI-2") differentiate entities of the same category. Therefore, "AGI-1" is the Vice-President of the IEM and "AGI-6" one of the innovation managers during the period (and so on). The complete identification of the entities (“Codes”) is also provided as supplementary material.

Table 5: Summary of codes

CODE	DESCRIPTION
AGI	Internal Agent (Employees)
ENERG	Power Distribution Companies
EP	IEM's Companies
FOM	Government Funding Agencies
GOV	Other Government Institutions
GP	Big Market Players
ICT	Science and Technology Institutes (Universities and Research Centers)
IEM	Industrial Electronic Manufacturer (The Case)
R&D	Research and Development Projects
PROG	Government National Programs for Innovation

Semi-structured validating interviews

At the end of the data collection period, eight final semi-structured validating interviews with key internal stakeholders (Innovation Analysts, R&D Managers, Quality Manager, Operations and Engineering Managers, the Vice-President of the Board of Directors) were conducted. These interviewees were chosen for this study due to their direct contribution to capability building over the period. The VP, for example, led the transformation in the company as the main interlocutor for innovation managers. R&D and engineering managers had a crucial involvement in innovation projects as project managers and also technical advisors. The Quality Manager was responsible for the whole prototype tests. All projects presented in the sequence were supported by an innovation analyst, acting directly in the management of the project (e.g., timeline updates, deliverables control, accountability for external partners). They were asked to, as freely as possible, recapitulate the history behind the open innovation project management capability building process. These interviews aimed to reduce the number of possibly relevant historical events (i.e., the previously listed chronology) to a more analytically tractable number. Thus, only those events that were mentioned directly by two or more interviewees were included in the final list, to be formally analyzed through ESA. Temporal boundaries between them were defined by consulting previously collected documents and punctual validating phone contacts with the interviewees. Appendix 1 presents the resulting 31 most important events, which were mentioned, in total, 97 times during these interviews. The interview's transcriptions ("Transcription001", "Transcription002"), and the event table extracted from these discourses ("Events_Interviews") were included in the supplementary material. These interviews were crucial for the research for two reasons: (i) to comprehend the studied phenomena by forming a big picture of it (i.e., to go beyond the detailed participant observation unstructured note-taking); and (ii) to avoid any possible bias of the authors in the study – i.e., as they were involved in particular activities during the process, their vision served only to refine data but never to define which kind of data should be used in the analysis (e.g., the final list of 31 events were strictly built based on the outputs of the interviews).

Event Structure Analysis (ESA)

While the narrative was used to consolidate the collected data and to present the story in a sequenced manner, the selection and discretization of specific events supported the usage of ESA, a formal analytical procedure for analyzing and interpreting temporal sequences that constitute a historical narrative (Griffin & Korstad, 1998). During its application, the logical (i.e., not only temporal) relations between the events can be arranged graphically and allows causal interpretations that relate the particularity of the case with theoretical generalities, supporting the proposition of generative mechanisms that may have a certain resonance with the logic of causation in other similar settings (Griffin, 1993). Heise (1989) presents a detailed step-by-step procedure for applying the method, from data input (i.e., a chronological list of events) to the analysis of the series of events for exploring processual patterns and exceptions.

The events from this final list were written (sub-step of "coding" – Figure 24) using three elements that people usually mention in describing an event (Heise & Durig, 1997): (i) agent - the instigator of a happening; (ii) agency - the fusing of event-frame elements into a happening, including the alignment between the object and the instrument of the action; (iii) outcome - an entity that comes into existence as a result of a happening and that enables or disables subsequent happenings.

In sequence, during the sub-step called "linking", the causal relationships between the events were assessed in terms of logical necessity. This logic associates to the reasoning that a particular outcome would not have happened without a previous occurrence of an event similar in nature to the focal event (Mahoney, Kimball, & Koivu, 2009). These relationships were inferred by using the questioning optimization algorithm of the ETHNO Software (http://www.indiana.edu/~socpsy/ESA/), choosing the counterfactual question for each pair of events prompted by the program (e.g., "Suppose that a similar event X doesn't occur. Can Y happen?"). To consistently respond to these questionings, however, it is necessary to corroborate the position taken (i.e., the answer to the question) in specific and general aspects that apply to the connection being assessed. In other words, researchers must base their answers on specificities of the case and the evidence of comparable cases, relevant theories or other common-sense generalizations (Griffin, 1993; Mahoney, 2012). This interaction between the particular and the general in the justification of causal interpretation is considered the essential component for the possibility of a compelling historical explanation (Griffin, 1993; Griffin & Korstad, 1998; Mahoney, 2012) and was, therefore, the focus of the authors in the attempt to respond to the counterfactual questions. Besides, causal mechanisms that justify the linkage between two events were identified in a process-tracing logic (Mahoney, 2012).

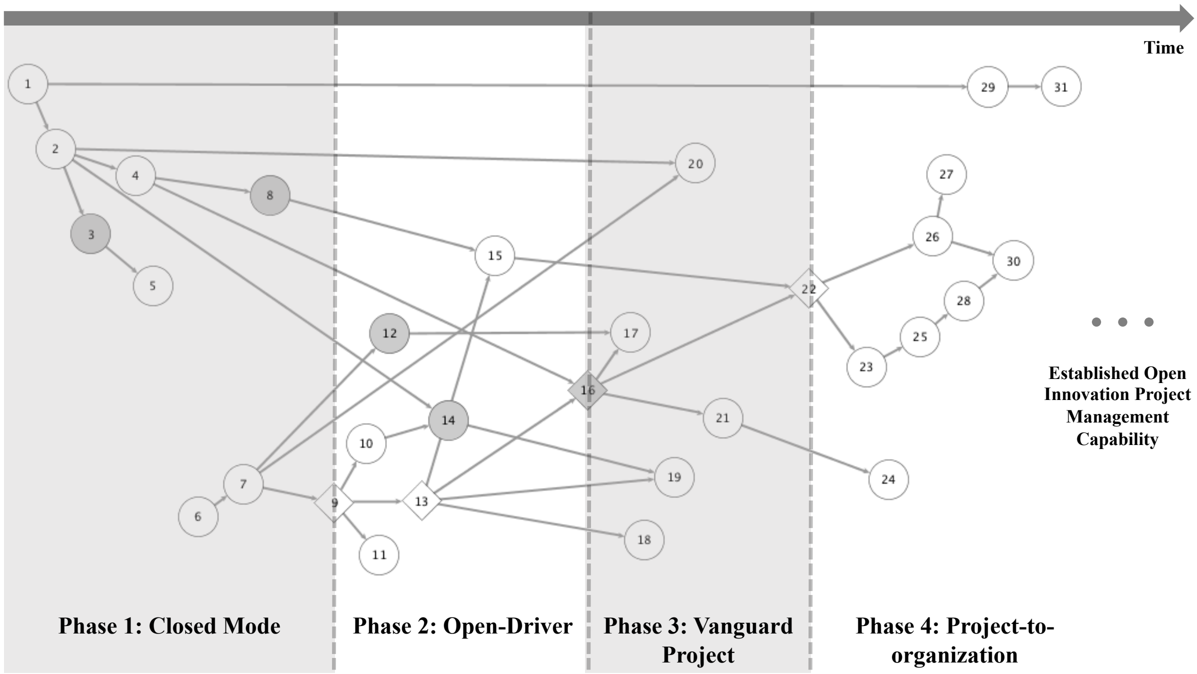
The resulting network was modeled and analyzed in Visone Software (www.visone.info), the final step of data analysis. The primary analysis of the final causal structure of events (named "structural criticality") were carried out to identify the events considered "critical specific happenings". These events were identified through the calculation of network structural indexes. In essence, events with high "outdegree" are those from which various causal paths have opened up, while "indegree" refers to events to which multiple causal paths have converged. Events with high "degree" (i.e., the sum of indegree and outdegree) are critical occurrences in terms of both convergence and divergence. Event "betweenness" indicates events that are more or less essential for connecting different paths (i.e., thus, they could be thought of as causal "bridges" in the network). The next section presents the results from all this data collection and analysis efforts.

6.2.4. Results

6.2.4.1. The Causal Event Structure

The network of 31 events considered the most important for the case, temporarily sequenced, is presented in Figure 25. These events are listed in detail in Appendix 1 – The most relevant events. Events represented in circles are "typical events". Events symbolized in diamonds are considered "turning points" for the history, based on the betweenness centrality calculation (see online supplementary material) – that means, if they are withdrawn from the network, the sequence of the history becomes broken. The events in grey represent the main innovation projects for the consolidation of the open innovation project management capability in IEM. The arrows linking the circles and the diamonds represent the causal connections between two distinct events. Other key issues (i.e., processes, routines, competences) accumulated by the organization through these projects over time are presented in Table 6, in the next subsection.

Figure 25: The Open Innovation Management Capability Building Process



Notes: (i) circles: typical events; (ii) diamonds: turning point events; (iii) grey circles/diamonds: events concerning main innovation projects; (iv) arrows: causal connections between events.

The process called “The Open-Project Capability Building” is grounded in four main phases: (i) closed mode; (ii) open driver; (iii) vanguard project; (iv) project-to-organization. This new process combines insights from both Project Management and Open Innovation strands, especially Brady and Davies (2004) and Zynga et al. (2018) theoretical frameworks.

Phase 1: Closed Mode

The main innovation projects developed in this phase, represented by event #3 and event #8 were developed internally. At the beginning of the process (1980’s), IEM merged with a French engineering company (event #1), specializing in energy supply solutions, which changed its business model to a turn-key systems provider (event #2). This association triggered the development of a product for power plants (event #3) whose brand was trademarked for IP protection (event #5). The 2000’s mark an exponential growth of IEM in terms of revenues, number of employees, and mergers and acquisitions. The productive capacity of the manufacturing sites was also boosted through equipment acquisition (event #4). Following this initiative, a new project, called “Test Gigas” (event #8), developed in four years a new device to automatize products’ final tests (R&D-3). During this initial period, the so-called "Innovation Law" was sanctioned in Brazil, which offered incentives (e.g., subsidized funding, scholarships, and mainly tax incentives) for tech-based innovations (event #6). In this context, IEM’s top managers started severe efforts to identify funding opportunities for innovation (event #7), deciding to assign for the first time a dedicated person for innovation management-related tasks (event #9) and subsequently, “NGI” (the Innovation Management Center) was created.

Phase 2: Open Driver

This phase marks the emergence of open innovation projects in the IEM. There were attempts to frame on-going projects into government funding programs (event #10) as well as the creation of mechanisms to involve the employees in innovation efforts (following the "suggestions box" model) to gather innovation ideas (event #11). In 2006, the Commercial Department identified a demand for a relevant improvement of an existing product (e.g., micro processed rectifier). Internal resistances to the project’s approval raised in contrast to the acceptance of the project by the state-owned Energy Company – both client and funding provider for the project – event #12. During this phase, the first innovation manager left the company, and a new person was hired to lead the NGI (event #13). One of the first actions of this new leader was to submit the “Test Gigas” as a pilot project to a governmental tax incentive program (event #15), which recovered about 20% of the total R&D expenditures.

> The first open innovation project (event #14), an invitation from a science and technology institute (ICT-2), consisted of a software development to support hydroelectric power generation (R&D-4).

Phase 3: Vanguard Project

In the meantime, also motivated by an on-going project concerning a new electric panel for high-voltage industrial applications – “Panel 36kV” (R&D-5), the innovation manager sought for a partnership (event #16) with another science and technology institute (ICT-3) in order to comply with the requirements of a new funding opportunity associated with an arm of the local Industry Federation. This project is considered, in fact, the vanguard for the IEM open innovation project management capability building. The event #16 (Panel 36kV development) was the only one mentioned by all interviewees and has the highest combination of betweenness and degree indexes among the 31 events of the network (see online supplementary material).

The vanguard project (36kV Panel) was considered a "watershed" for the IEM, as confirmed in the interviews:

> The "36kV Panel" allowed us to face our competitors. "Do you have a product? Me too! Mine, national. " (R&D Coordinator).

We understand that this is a successful project because we have already been able to sell several of such products in the market. This product is our "36kV Panel." (Operations Manager)
This project had remarkable characteristics. First, the demand was placed by the IEM commercial department as a market need and the outcome of the project (the panel) was, at that moment, an extension from the existing product line, reducing the top management risk perception about the project. Second, to receive external funding, the involvement of a science and technology institute in the scope of the project was a prerequisite. Therefore, this co-development did not start voluntarily by the company. Besides that, the Science and Technology Institute (ICT-3) engaged in the initial activities of the project (e.g., kick-off, technical specifications, virtual prototype modeling) even without a formal approval in the bidding. Third, after the authorization of this first external financial support (half of the project budget, non-refundable), the management team obtained another subsidized financing for the company counterpart as well as tax breaks relative to 10% of the total investment. In short, the amount effectively paid by the company in the project was approximately 30% of the initial expectations.

Finally, the project results were considered successful in terms of the certification tests, acceptance of the product, use of financial resources, and accountability (expenses report).
Several managerial issues were faced during the execution of the "36 kV Panel" and served to foster the OI innovation project management capability: (i) the IEM's purchasing processes had to be adapted to receive external resources from the Government; (ii) new reports were created in the ERP (enterprise resource planning) to guarantee the accountability of innovation projects; (iii) periodic project reports were included in the Innovation Committee and Administrative council agendas as well as the presentation of new projects in partnership with external entities; (iv) there were also problems concerning cost allocation in the prototyping phase (i.e., overtime of factory employees in the innovation project) which forced the Innovation Center to establish new mechanisms to control timesheet appointment; (v) this project helped to justify a separated budget in the company for innovation activates.

During this phase, more than 40 projects (see online supplementary material) were presented to diverse funding agencies and developed in partnership with external entities – e.g., events #17, #18 and #19. At this moment, the Innovation Center (NGI) also started to be regularly invited by universities and startups to collaborate in other innovation projects. In essence, this represents an inversion in the typical flow of open innovation project seeking until that moment (i.e., the NGI used to search for partnerships). From an initial state in which the projects were focused on technical improvements of current products, at this time the Innovation Center expanded its contribution to other IEM business units encompassing around-the-corner innovative projects (e.g., an unmanned submersible vehicle), gathering new collaborations with non-typical agents that held complementary competences, networks and technologies (e.g., energy transmission companies).

Phase 4: Project-to-organization

Over time, the Innovation Center accumulated competence to manage more complex innovation projects in yet more multifaceted network arrangements. One example was the development of a platform of robotic tools for the inspection of shells and submarine pipelines (R&D-24, R&D-25, R&D-26, R&D-27, R&D-28, R&D-29), with a total investment of US $20 million, involving international technology transferring and a partnership with a research center of a giant company of the oil & gas sector. Internally, the Innovation Center was growing both in size and organizational influence: new people were hired, a chair was assigned to NGI in IEM's strategic planning, and projects began to be presented directly to the Board of Directors. This final phase is marked by the formalization of an innovation management department (called "R&D Department"), with more than 20 employees (event #22). This new department was then responsible for both the execution of the innovative projects and their management, including the background tasks previously conducted by NGI at the organizational level (e.g., partnership prospection, project scope definition, intellectual property negotiation). Furthermore, it was the first time that IEM assigned technical researchers fully dedicated to R&D activities (e.g., software, electronics). Events #23, #25, #28, and #31 concern changes and staff turnovers during the initial period of the new department's implementation. Events #24, #27, and #30 evidence efforts and partnerships made to enhance open innovation management practices. The consolidation of such a department and its further influence on the organization's innovation path is the most imperative milestone for the open innovation project management capability consolidation in IEM during the time comprising the research.

6.2.4.2. The distinguishing projects for the capability building

Table 6 presents the main innovation projects (grey circles and diamonds in Figure 25 - events #3, #8, #12, #14, #16) developed over the three initial phases of the capability building process in IEM. It also indicates the exact moment (i.e., year) where each project was initiated, the related phase in the four-stage process (Figure 25), a clear identification of its nature (i.e., open or closed project), the project's main characteristics as well as the key issues regarding each project development. These issues represent new management practices, routines or even competencies consolidated in the organization from the project's execution.

As Table 6 shows, the company (IEM) developed three relevant R&D projects before becoming involved in its first open innovation initiative. Moreover, more than a decade separates the first two projects, a period in which the same managerial mindset prevailed (closed innovation). The fourth project marked the beginning of a quick transition to an open innovation orientation, which would stabilize in the following phase and be consolidated by the so-called "vanguard" open innovation project (event #16). Indeed, just after the vanguard project the company showed a clear organizational shift, formally establishing a dedicated internal structure to manage innovation and presenting a wide breadth of open-oriented projects (see online supplementary material for a list of over 40 projects that were launched in the following four years - approximately 75% of this portfolio is open in nature) – this statement reinforces the maturity of the company regarding OI practices following Brunswicker and Chesbrough (2018)'s statement: "a firm's approach to open innovation is reflected in its innovation project portfolio, which comprises all of the innovation projects within the firm or business unit."

Table 6: The distinguishing projects for the capability building

Event (#)	Event	Moment (year)	Phase	Open? (Y/N)	Main Characteristics	Key Issues
3	A Researcher (AGI-9) develops integrated digital supervision, protection, and control system (R&D-1)	1995	1	N	- Integrated digital supervision, protection, and control system - The first innovation relevant innovation project - Developed internally - The brand registered in the National Institute of Industrial Property	- Intellectual Property (IP) protection - Specific control for innovation projects (project charter)
8	The Automation Department develops "Test Gigas Project"- a device for automatization of panel's final tests (R&D-3)	2008	1	N	- Equipment for systematic panel tests - Response to market demand (process improvement) - Developed internally - The first use of innovation tax incentives - Estimation of net present value to demonstrate innovation projects impact (retrospective)	- Financial evaluation for innovation projects - Expenditure traceability and cost control - The delimitation between development and scale-up phases to assign internal governance (*i.e.,* innovation vs operational departments)

12	IEM approves the development of a high-performance microprocessor rectifier prototype (R&D-2) with a state-owned energy company	2009	2	N	- Micro processed rectifier - improvement in an existing product (difficulty of internal approval) - The first innovation project to receive subsidized external financial resources (non-refundable) - Developed internally	- New processes (*e.g.,* specific bank accounts, financial resources transfer control, deliverables/milestones reports, status reports) - Accountability for external funding agencies
14	A Science and Technology Institute (ICT-2) makes a partnership with IEM for the development of software to increase the efficiency of hydroelectric generation (R&D-4) with a state-owned energy company	2011	2	Y	- Software to increase the efficiency of hydroelectric generation from computational intelligence techniques - new software development for a power plant delivered by IEM - External invitation from a Science and Technology Institute (STI) - Project led by the STI (~90% of the budget)	- Relationship University-Industry (co-development): multiple teams labor coordination and task distribution; knowledge transfer between teams; infrastructure sharing; new initiatives from outside the company
16	The Innovation Manager (AGI-6) makes a partnership with a Science and Technology Institute (ICT-3) for the development of a medium voltage panel (36kV) with reduced dimensions (R&D-5)	2011	3	Y	- Medium voltage panel - new product demanded by the commercial department - The "Vanguard Project": cited by all interviewees; the causal structure of events (network structural indexes) - Partnership with an STI as a prerequisite for funding - Informal involvement of the STI in the initial phase - Multiple external funding sources	- New processes (*e.g.,* collaborative purchasing, ERP specific reports) - New routines (*e.g.,* presentation and approval of innovation projects by the Innovation Committee and Administrative Council) - Budget allocation (project planning) - Growth of the structure of Innovation Center (members) and

	subsequent internal assignments division

6.2.5. Discussion

This paper explores how organizations can use the experience from projects to build a systematic capability to manage open innovation projects. Our findings suggest that this capability can be built through a process of four phases: closed mode; open driver; vanguard project; project-to-organization. We argue that our study fosters a bridge between Project Management and Open Innovation strands because the four-stage process represents a combination of previous capability building frameworks. Brady and Davies (2004) project capability-building model starts from the vanguard project, a highly valuable contribution, but neglects previous efforts, especially important in a context of high uncertainty, open innovation project portfolio. On the other hand, open innovation studies (e.g., Boscherini et al., 2010; Chiaroni et al., 2011; Zynga et al., 2018) recognize the importance of an initial phase ("unfreezing") where an organizational context is created to set up the new capability. Whereas these OI scholars simply refer to initial or "pilot" projects during the capability building process, PM introduced the importance of vanguard projects to explore new opportunities and to move into new technologies or market basis. Finally, whereas both OI and PM capability strands emphasize the role of top management in creating a context to support the capability building, we offer a case where individuals played a crucial role in the creation of internal connections to legitimize open innovation activities through the implementation of prominent projects in a maturity scale - from the simple and closed setting to more complex arrangements in terms of collaborative partnerships. That is, the capability building for open innovation project management may be a complementarity of technicians and middle managers movement (as stated by Rodan and Galunic (2004), without the strong leadership of top manager "champion", at least in the first phases.

The case also reveals points of resistance to the new open approach for innovation projects from parts of the organization – the so-called innovation "antibodies" as termed by Davila, Epstein, and Shelton (2006). Counterbalancing resistances, the external linkages incurred by the open approach, viz, with science and technology institutes, funding agencies, or big companies of the energy sector, provided an anchorage to the innovation initiatives since the public commitment was usually needed to keep the company's reputation safe.

From an external perspective, it is remarkable the role played by the national innovation policy, whether conditioning the access to funding opportunities, stimulating the company to make partnerships with other agents of the ecosystem or fostering new markets for innovative technology through sectorial interventions (e.g., energy generation and transmission). As the narrative of the case shows, many managerial decisions to innovation efforts were a direct or indirect response to local regulations. They increased the pace of the organizational transformation towards the vanguard project.

Implications for Project Management Theory

It is noteworthy that Figure 25 shows no direct connection between projects, which suggests that the project-to-project spillovers were low for this through the period of analysis, contrasting with the study of Brady and Davies (2004). However, it is arguable that the relationships between these projects are strongly contextually mediated. Table 6 also highlights the increasing of management practices (organizational level), which supported the gradual accumulation of capabilities to conduct open innovation projects. Moreover, it is important to observe the extent to which the vanguard project (event #16) marks the beginning of a fertile period for projects associated with more complex networks and diversified funding providers.
In Davies and Brady (2004)'s study, the learning activities at the initial phases were primarily exploratory regarding the development of new areas of expertise and practices. After that, the emphasis is altered to what the authors call "exploitative learning", where firms develop the capability to manage a growing number of similar projects. Our case partially reverses this logic because the capability to manage open innovation projects is developed from simple (closed/incremental) innovation projects to more complex (open/radical) ones. This debate highlights a frequently overlooked issue in PM literature: the past trajectory of the organization in setting proper conditions (i.e., managerial and technological) upon which the vanguard project (event #16) will come to run. This observation corroborates with capability-building studies that emphasize the role of key events distributed along more extend periods as an explanatory basis for sudden-perceived transformations (Figueiredo, 2002). Freitas et al. (2019) provide an example in the field of retrospective roadmapping.

Thus, besides the argument of betweenness and degree indexes (see supplementary material), the so-called vanguard project is at the forefront of the narrative – as the term "vanguard" would suggest – but in the role of bringing together many (sometimes disconnected) organizational elements that made possible a successful open innovation approach from then on, and for inducing a new phase in which open innovation projects are conducted in a regular and systematic basis.

Hence, as Table 6 illustrates, while the first project led to learning on elementary innovation management capabilities (e.g., IP protection) as its central contribution to the overall capability building process, the second project evolved to analytical means to demonstrate the financial payoffs. By turn, the third project developed mechanisms to consolidate projects' traceability and accountability. The vanguard project takes advantage of this managerial apparatus, which reduces the uncertainty of dealing with external partners and brings confidence to bet on open innovation. As our case shows, the vanguard project has a different purpose when compared to the way this concept emerges from PM literature. Vanguard projects are first-of-their-kind base-moving projects to develop/adopt new technologies or to respond/create new markets (Brady & Davies, 2004; Davies & Brady, 2000). In PM literature (Brady & Davies, 2004; Frederiksen & Davies, 2008), vanguard projects are usually used to create continuous products or experiences to the client. In our case, the vanguard project was not intentionally conceived to build the capability. Still, it proved to be decisive for the process when evaluated a posteriori (i.e., high degree index in the network analysis).

In this sense, the vanguard project represented the primary trigger (see the causal connection in Figure 25 between events #16 and #22) to the implementation of a dedicated organizational function to manage innovation (in the terms employed by Bagno, Salerno and, Dias, 2017; Börjesson, Elmquist and Hooge, 2014; O'Connor et al., 2008) which represents a tangible milestone of OI capability building for the whole organization (event #22). From that time on, such an organizational function assumes the responsibility of a subsequent portfolio of open innovation projects (see supplementary material), supported by the corporation's top management team.

This debate expands and complements existent theory on PM capabilities not just due to the connection it establishes with the organizational level (necessary to understand the dynamics of a capability building), but also for introducing the context of high-uncertainty project portfolio, typical of large innovative companies, and that is brief addressed by the mainstream of PM capability field.

Implications for Open Innovation Theory

Our study contributes to a pressing issue for academics and practitioners in Open Innovation field: how open innovation can be effectively implemented in organizations (Bogers et al., 2017; Brunswicker & Chesbrough, 2018; Gassmann, 2006; Mortara & Minshall, 2011; Zynga et al., 2018) and the reasons by which firms open up their innovation processes (Huizingh, 2011). While most of OI studies focus on the adoption of OI at the organizational/firm-level (Brunswicker & Chesbrough; 2018; Zynga et al., 2018), our investigation applies a multi-level perspective (following the suggestion of Borgers et al., 2017). Our study sheds light on the actions carried out by individuals to move forward a set of open innovation projects in a coordinated way to legitimize an open innovation management capability. All these multiple elements of different levels of analysis were broken down and causally connected in our four-stage process framework (Figure 25).

Zynga et al. (2018)'s framework, as well as few other previous studies on OI capabilities, suggest an initial phase entitled "unfreezing" which would be generally dedicated to establishing a sense of urgency for change in the organization, and the delineation of the new vision about OI to the internal and external stakeholders (Boscherini et al., 2010, Zynga et al., 2018, Chiaroni et al. 2011). In general, as previously stated, the efforts in this phase are considered mainly from an organizational perspective and, besides the low amount of research on the process of building capabilities for open innovation, considerations on the role of projects in these dynamics are rare. Boscherini et al. (2010) mention the possibility of using pilot projects "to put into test, in an isolated and risk-free context, protected from the pressure of everyday business activities, a number of alternative practices". According to this study, a pilot project could be a tool to unfreeze the status quo and prepare the organization for further OI efforts. In our study, however, instead of designing a special environment for a pilot project to intentionally develop a group of OI-related practices in a lab-like protected context, our observations revealed an alternative description of how this phase may unfold unintentionally in a real-world setting– and, due to that, it may fit best to the current context of other companies.

In our model (Figure 25), two phases precede the vanguard project, namely "Closed Mode" and "Open Driver". Closed Mode was an essential phase for the company to develop necessary capabilities and skills associated with regular R&D projects as well as tools and organizational routines that enabled project management to establish as a discipline along over the organization. Following, the Open Driver takes advantage of ongoing projects to serve as platforms for simple practices of OI, and so paves the way to the attempts of getting external funding for the innovation portfolio. Moreover, it was an opportunity to get feedback from the organization about the first amount of running changes towards systematic OI project management capability.

Our study also establishes a link between the concept of "pilot project" (Chiaroni et al. 2011), from OI literature, and vanguard project (Davies & Brady, 2000; Brady & Davies, 2004), from PM literature. Moreover, we extend both views towards a model of how this kind of project can support an OI project management capability building. In this sense, as seen in Figure 25 (nodes 12 and 14), small and less complex projects are conducted during the Open Driver phase in our framework, stimulating the exposure to new challenges, as the need of new business processes (e.g., specific bank accounts creation for innovative projects, financial resources transferring, deliverables/milestones reports, status reports). Then, after having contact with the requirements imposed by initial projects and overcoming the challenges by implementing processes and developing competences, the firm moves into the "Vanguard Project" phase. The node 16 in our framework represents the vanguard project and, from this moment on, more complex issues are faced, as the implementation of new and more complex processes (e.g., collaborative purchasing, ERP specific reports, presentation and approval of innovation projects by the Innovation Committee and Administrative Council) and budget allocation governance (e.g., project planning).

The "Project-to-organization" phase of our framework carries similar aspects of the "Institutionalizing" step set by OI literature (e.g., Chiaroni et al., 2011, Boscherini, Chiaroni & Chiesa, 2010). According to Zynga et al. (2018), during this phase, all three categories of microfoundations (i.e., individuals, processes, and structures) are straightened. Our research corroborates with findings of this study as the gatekeeper role (played by the Innovation Manager in our case); regularly scheduled meetings (at the department and board levels); and the establishment of a formal project management structure to handle a large number of projects. However, contrary to Zynga et al. (2018), having a clearly defined innovation process (stage-gates) was not a major success factor in our case. Here, the capability building was developed upon pre-approved projects (without posterior decision gates) in which external partnerships were set up to access resources or competences, like an "R&D outsourcing" (Mortara & Minshall, 2011). Moreover, OI capability studies (Chiaroni et al., 2010; Chiaroni et al., 2011; Zynga et al., 2018) argue that companies usually start the relationship with the innovation ecosystem in the "immediate neighborhood" (i.e., customers and suppliers) and, in a second moment, with industry associations, government agencies, and universities. In our case, IEM's capability leaned, since the beginning, on the relationship with Government Funding Agencies (i.e., FOMs) and Universities or Science and Technology Institutes (i.e., ICTs) anchored on long-term collaboration agreements.

Methodological Implications

The data analysis method used in this paper also contributes to project management and open innovation research. First, it builds on the strengths of a processual approach to organizational phenomena (Gehman et al., 2018; Langley, 1999, 2007; Van de Ven & Poole, 2005). As such, it enables one to tackle difficult "how" questions in both strands by tracking the dynamic emergence of an outcome of interest over time, instead of inadvertently oversimplifying complex processes in typically reified variable relationships (Thompson, 2011).

Second, differently from other process studies that have been published in both fields (Berggren, 2019; Chiaroni et al., 2011; Hetemi et al., 2020; Horvat, Dreher, & Som, 2019; Niederman, Müller, & March, 2018), our approach distinguishes itself by its unique emphasis on the branched causal structure underlying an event sequence (c.f., Mahoney, 2000). Therefore, our analytical focus is not limited to the mere ordering of occurrences (i.e., temporality per se) nor the construction of linear stage models depicted in broad strokes. On the contrary, we combine the depth of historical detail with the breadth of explanatory propositions, without letting one subsume the other. This formal systematic integration of narrative and explanation is, thus, an attractive feature of our analysis in comparison to another process-based approaches recently adopted in project management and open innovation research.

Indeed, to the best of our knowledge, this is the first application of Event Structure Analysis in both strands (a search in Web of Science database for the sentences (i) "event structure analysis" AND “project” or (ii) "event structure analysis" AND “open innovation” doesn’t bring any results –march/2020). Apart from rare exceptions (Stevenson & Greenberg, 2000, 1998), the whole management academic community seems to remain virtually unaware of this longtime praised method in historical sociology (Abell, 2004; Mahoney, 2000). Hence, in a broader sense, this paper also contributes to the - unjustifiably late - introduction of ESA in our field, providing an exemplar to serve as a methodological reference for future process studies.

6.2.6. Conclusion

This article aimed to contribute to Open Innovation and Project Management theories by investigating how organizations can build an open innovation project management capability. We argue that our study bridges both theories. For OI field, it offers a project-oriented approach by presenting in detail the project’s dynamics over the studied period, the role of a vanguard project (construct derived from PM literature), and also the role of “key projects” to the capability establishment at the end of the process. On the other hand, for PM literature, we evidenced the importance of previous phases and organizational context for the emergence of a vanguard project, which proved to trigger the new capability. We also brought to PM field a discussion based on open, uncertain projects, shifting the usual focus on complex and predictable projects. To do so, we applied Event Structure Analysis (ESA), which made possible to elucidate a network of causally connected events (i.e., specifc happenings in the case) for the open innovation project management capability building.

Our study also contributes to practice. The ESA method is a powerful analytical tool for managers who want to identify the patterns by which their organizations are transformed over time. Besides that, the four phases evidenced for building an open innovation project management capability (closed mode; open driver; vanguard project; project-to-organization) can be taken as a guide for new planned approaches to firms moving from closed to open innovation. Finally, our study may serve to create awareness by top managers about the complexity inherent to this capability building process in order to attenuate short-term results' pressure.

It is undeniable that this work has limitations. The in-depth case study does not intend to provide a general pattern for the studied phenomena but to present a set of causal relationships relevant in itself. In sum, we are not arguing that our findings are replicable to any other situation but, if one can say that, if it occurred once, they could emerge in similar contexts. From a non-positivist paradigm, we are interested in the historical processes brought by the case and the insights they bring to theory, not to elaborate testable and replicable patterns.

We would appreciate listing avenues for future research. First, there are opportunities to understand better eventual differences between developing competences for non-open innovation projects and open innovation projects. Second, the critical associations between each agent (e.g., internal individuals) or actions performed by them could be analyzed on the referred capability building process. Third, the impact of governmental policies on the building of firms' innovation capabilities could be more deeply investigated. Finally, other process-based or historical approaches may be applied to be compared to what ESA can offer for data analysis.

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Appendix 1 – The most relevant events

Event (#)	Event (long name)
1	IEM associates to a French Engineering Company
2	IEM changes its business model to provide turn-key solutions
3	A Researcher (AGI-9) develops an integrated digital supervision, protection and control system (R&D-1)
4	IEM acquires a punching machine for the production process of electric panels
5	IEM register the integrated digital supervision, protection and control system (R&D-1)'s brand in the National Institute of Industrial Property (INPI)
6	Government sanctions an "Innovation Law" – a government tax incentives program
7	Top Management identifies funding opportunities for innovation

8	The Automation Department develops “Test Gigas Project”- a device for automatization of panel’s final tests (R&D-3)
9	Top management allocates an Innovation Manager (AGI-3) to lead the Innovation Center initiative (NGI)
10	The Innovation Manager (AGI-3) presents innovation projects to funding agencies
11	IEM implement "ideation boxes"
12	IEM approves the development of a high-performance microprocessor rectifier prototype (R&D-2) with a state-owned energy company
13	Top Management hires a new Innovation Manager (AGI-6) for innovation management (NGI)
14	A Science and Technology Institute (ICT-2) forms a partnership with IEM for the development of a software to increase the efficiency of hydroelectric generation (R&D-4) with a state-owned energy company
15	The Innovation Manager (AGI-6) perceives opportunity to frame “Test Gigas Project” (R&D-3) in the “Innovation Law” (PROG-5)
16	The Innovation Manager (AGI-6) forms a partnership with a Science and Technology Institute (ICT-3) for the development of a medium voltage panel (36kV) with reduced dimensions (R&D-5)
17	The Innovation Manager (AGI-6) approves new financial grants for the high performance microprocessor rectifier prototype (R&D-2), medium voltage panel (36kV) with reduced dimensions (R&D-5), and incremental improvements in columns of CCMs and panels of low voltage (R&D-10) projects
18	NGI approves financing for a platform of instrument transformers for high voltage (72.5 - 550kV) development (R&D-9)
19	NGI approves the development of a computational system for the management of medium and low voltage network assets (R&D-12) in partnership with a Science and Technology Institute (ICT-2)
20	IEM presents " solar photovoltaic energy generation" project
21	Project team tests the medium voltage panel (36kV) prototypes abroad
22	Top management restructures IEM - creation of an innovation management department
23	The Innovation Manager (AGI-6) leaves IEM
24	NGI prepares a proposal for the development of a medium voltage panel composed of 2 (two) circuit breakers per column (R&D-45) with a Science and Technology Institute (ICT-3)
25	The Innovation Manager (AGI-19) leaves IEM

26	IEM forms a partnership with a government agency to develop new innovation management capabilities
27	"R&D Department" implements "Visual management"
28	Top management allocates a new Innovation Manager (AGI-23) to lead "R&D Department"
29	Shareholders sell IEM to a French company
30	"R&D Department" implements "Supervision committee"
31	The Vice-President (AGI-1) leaves IEM

6.3. PAPER 3 (#P3): An innovative application of event structure analysis (ESA)

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Figure 26: Paper #3 publication cover


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Method Article

An innovative application of event structure analysis (ESA)

Jonathan Simões Freitas [a], Julio Cezar Fonseca de Melo [b], Mario Sergio Salerno [b], Raoni Barros Bagno [a], Vinicius Chagas Brasil [b]

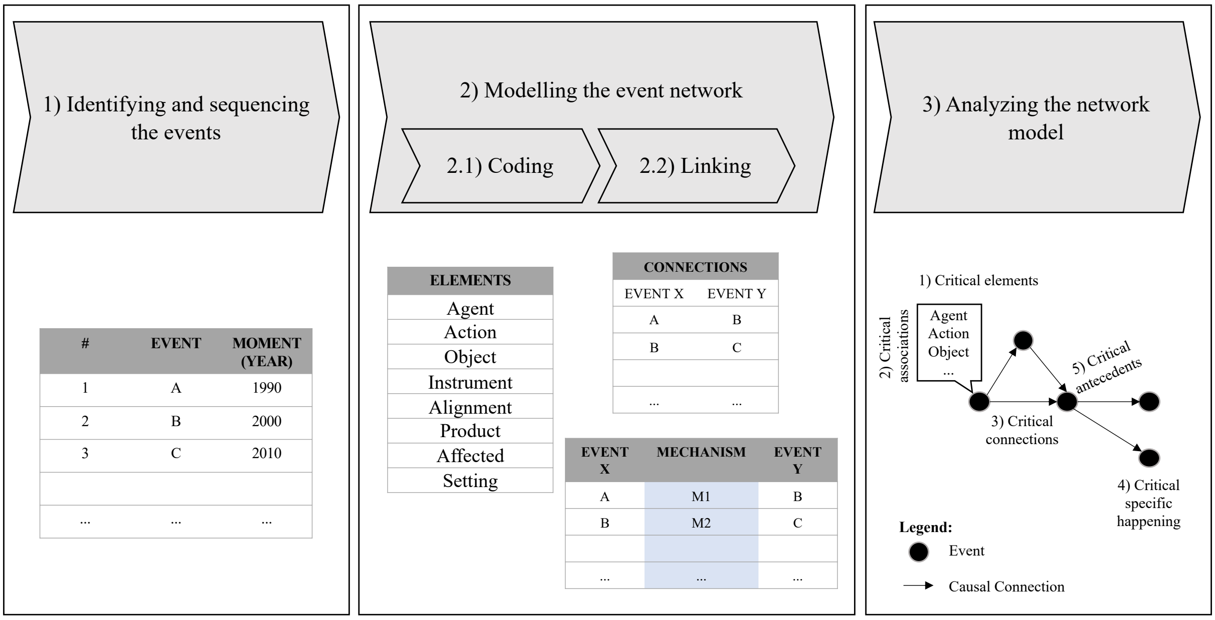
Abstract

This paper presents an innovative application of event structure analysis (ESA). The key improvements incorporated on the method are: (i) a robust system for coding events; (ii) the use of causal process tracing tests for inferring necessary connections; (iii) the combination of ESA with network analyses. Finally, we propose five types of analysis for event network models (i.e.,, critical elements, critical associations, critical connections, critical specific happenings, and critical antecedents) and exemplify some of them in a causal case study about the process of capability construction for open innovation management in an Industrial Electronic Manufacturer.

- ESA can be combined with process-tracing tests to ground counterfactual causal inferences.
- ESA can be combined with network analysis to explore quantitative patterns in event structures.
- ESA is an outstanding method to conduct process research in management and engineering.

Keywords: Event Structure Analysis; ESA; Causal Process Tracing; Emergence; Critical Events.

Figure 27: Graphical Abstract



6.3.1. Context

Event Structure Analysis (ESA) was proposed at the end of the 1980s (Heise, 1989). Supplementing the seminal article, Corsaro, and Heise (1990), Griffin (1993) and Griffin and Korstad (1998) established the foundations of the method. Given its originality and logical rigor, ESA contributed to establishing a new methodological category called "formal qualitative analysis" (Griffin & Ragin, 1994).

Several applications of the ESA procedures were made in the social sciences during the 1990s and 2000s. The release of the ETHNO software (Heise & Lewis, 1988) in parallel with the first publications may have contributed to this diffusion (c.f., Abbott, 1995). The fact is that, in fundamental methodological reviews on the analysis of processes and narratives, Mahoney (2000) and Abell (2004) were unanimous in recognizing ESA as the main analytical approach for intra-case study of events' causal chains.

However, ESA was rarely applied in management-related fields (Stevenson & Greenberg, 1998, 2000; Valorinta, Schildt, & Lamberg, 2011). Also, in general, these applications only replicated the basic procedures of the initial proposal of the method. None of them, for example, adopted the robust system for coding events later proposed by Heise and Durig (1997). Similarly, none of these papers explored the potential of the combination of ESA with network analyses, or with causal process tracing tests - which has been receiving a lot of attention in the field of comparative-historical methodologies in recent years (c.f., Bennett & Checkel, 2012; Blatter & Haverland, 2012; Kittel & Kuehn, 2012; Mahoney, 2012).

6.3.2. Explanation of the methodology

6.3.2.1. Identifying and sequencing the events

Unlike variance research, which provides an explanation from the relationship between the dependent and independent variables, process theories are built from patterns extracted from a sequence of events (Mohr, 1982). Events can be defined as actions of a determined agent on a given object, at a specific moment of time (Heise & Durig, 1997) and may include decisions, meetings, conversations or even a simple, but explanatorily relevant, handshake (Langley, 1999). Thus, the methodological emphasis of process research lies on the historical explanation of an eventually remarkable macro-outcome that emerges over time.

Events can be identified based on semi-structured interviews with key participants of the studied phenomena in order to elicit the narrative of each interviewee. Researchers must interpret these narratives and come to a consensus regarding the set of events that summarizes the story. The discretization of the narrative - i.e.,, of a "continuous discourse" - into distinct events is based on the attempt, by the researchers, to understand (i.e.,, "verstehen") the culture of the "natives" (c.f., Geertz, 1973) - that is, of the selected interviewees. In fact, this understanding is fundamental, not only to distinguish the events adequately but also to describe them using a contextually meaningful language (Corsaro & Heise, 1990; Heise, 1989).

This abstraction from the original description (i.e.,, the description by the interviewees themselves) consists, therefore, in a "theoretical reading" of the meaning of the event in the context of the structuring process under analysis. It involves the interpretation of the causal relevance of the elements of the "concrete" event in order to rephrase it as an "abstract" event (Heise, 1989, 1991).

Once the events have been properly identified and described, the researcher should sequence them in chronological order to be able to assess possible causal connections between them. After all, chronological antecedence is a necessary but insufficient condition for a historical explanation (c.f., Griffin, 1992, 1993, 1995; Griffin & Korstad, 1998; Mahoney et al., 2009). That is, although temporal precedence does not imply causation (i.e., some events may be entirely causally irrelevant to subsequent ones), it is obvious that an event cannot be caused by another event that succeeds it. Hence, sorting them chronologically reduces by half the upper limit of possible causal connections to be assessed (Heise, 1989). Therefore, it is well advised that the events should be firstly sequenced in chronological order to - only then - be then analyzed in terms of causality. In conducting this analysis, researchers can search for accurate references to dates as a starting point for sequencing the events, using temporal conjunctions narrated by the interviewees or collecting support documents which corroborate the occurrence of a given event. Finally, it is also recommended to validate the final results with the interviewees.

6.3.2.2. Modeling the event network

Coding events

In order to code the events and their causal connections, theoretical/conceptual frames can be used, like the theoretical/conceptual table built from the set of eight elements proposed by Heise and Durig (1997) - from now on referred to as “event frame” or “EF” (Table 7). Concerning other theoretical/conceptual frames used for the formal representation of events, EF has been considered a distinctively systematic semantics (c.f., Abell, 2004). These elements were identified from the work of Charles Fillmore on “linguistic cases” (Dirven & Radden, 1987) as the set of basic meaning categories used by people to describe a social event in a whole way, whatever the language.

Table 7: Event Frame (EF)

Element	Definition
Agent	The instigator of a happening.
Action	The fusing of event-frame elements into a happening.
Object	The entity that is moved or changed, such that a repetition of the happening requires replacement. People can be objects.
Instrument	An entity that is used by the agent to causally advance the happening while not being significantly changed by the happening. People, social organizations, and verbalizations can be instruments.
Alignment	The specific place or time at which an instrument is applied to an object or in a setting.
Product	An entity that comes into existence as a result of a happening and that enables or disables subsequent happenings.
Affected[a]	The agent of an event that intentionally is enabled or disabled by the agent in the focal event.
Setting	A convergence of relatable agents, objects, and instruments within a space-time boundary.

[a] Term chosen to make clear that the "beneficiary" (original term in Heise & Durig, 1997) may be disabled by the agent of the focal event; that is, he/she might be, not a beneficiary, but a "victim" of the product of the action under analysis (c.f., Basden & Wood-Harper, 2006; Bergvall-Kåreborn, Mirijamdotter, & Basden, 2004).
Source: Adapted from Heise and Durig (1997).

Linking events (inferring causal connections)

In order to infer causal connections between the events, the next step consists in the causal interpretation of the chronological sequence obtained. That is: for each pair of events, researchers must evaluate the possibility that the older event could be the cause of the more recent event. Based on this assessment, the existence or not of the corresponding causal connection is inferred (c.f., Hodgkinson, Maule, & Bown, 2004).

The theoretical/conceptual frame suggested for coding causal connections between events relies on the notions of causal "necessity" and "sufficiency" (e.g.,, Goertz & Starr, 2003; Mahoney, Kimball, & Koivu, 2009; Ragin, 2000). Specifically, this study focused on necessary connections. After all, the inference of necessary causes has been considered by many the most feasible and desirable means of explanation in the social sciences (Goertz & Starr, 2003). Also, with rare exceptions, the inference of a connection as sufficient is risky, when dealing with historical processes - which means that, in general, this type of causality is reserved to the explanation of technical, and not social, processes (Mahoney, 2012).

In this context, "necessity" was associated with the counterfactual notion that a result would not have occurred if the cause were absent, although the presence of the cause does not guarantee the result. In set-theoretic terms, X is inferred as a necessary cause of Y if Y can be defensibly considered a subset of X (c.f., Mahoney et al., 2009) - that is, if, counterfactually, one could argue that there would not be any plausible historical situation in which an event of type Y (i.e., an event similar to the concrete outcome in analysis) would happen and an event of type X (i.e., an event similar to the potential cause in analysis) would not. To give a trivial but clear example, we may infer that sunlight is a necessary cause of rainbows, because - as far as we know (thus, an inference) - there is no plausible situation in which a rainbow could happen without sunlight. The inference of this type of causality, therefore, is not based on correlations, but on the so-called "explicit" or "set-theoretic" connections (Ragin & Rihoux, 2004) – i.e.,, connections that fit this implicative logic that can also be represented in set-theoretic terms.

This view of causation in terms of necessity and sufficiency has been considered more adequate to qualitative explanation (and to historical-comparative approaches, in particular), than the statistical outlook of "cause as a leverage, on average, of the probability of a result" (Mahoney & Goertz, 2006; Mahoney et al., 2009). To infer the existence (or not) of this type of causality connecting one event to another in a particular case, two types of questions were used (Table 8).

Table 8: Type of question to be answered to infer if event X is a necessary cause of event Y in a case

Type of causality	Implicative question	Counterfactual question
Necessary	Does the occurrence of Y imply the prior occurrence of an event similar[a] to X?	Suppose an event similar to X did not occur. Can Y occur?
	Answer corresponding to the inference of a causal connection: Yes	*Answer corresponding to the inference of a causal connection*: No

[a] i.e., considered, in the culture of the natives, equivalent to the event under discussion - and may even be the event itself.

Source: Adapted from Goertz & Starr (2003) and Heise (2012).

The implicative question requires the evaluation of the necessity of the occurrence of an event, given the occurrence of another. On the other hand, counterfactual questions demand the investigation of the implication of the hypothesis of non-occurrence of an event for the possibility of the occurrence of another. Both are logically equivalent, leading, in principle, to opposite answers - in terms of “yes” and “no” (Heise, 2012). In order to infer that an event is necessary for another, in a particular case, the answer must be affirmative to the implicative question and negative to the counterfactual question (Table 8).

In order to consistently respond to these questionings, however, it is necessary to corroborate the position to be taken (i.e., the answer to the question) in specific and general aspects that apply to the connection being assessed. In other words, researchers must base their answers on specificities of the case and on evidence of comparable cases, relevant theories or other logical or common-sense generalizations (Bennett, 2006, 2008; George & Bennett, 2005; Griffin, 1993; Mahoney, 2012; Freitas et al., 2013). This interaction between the particular and the general in the justification of causal interpretation is considered the essential component for the possibility of an effective historical explanation (Griffin, 1993; Griffin & Korstad, 1998; Mahoney, 2012) and was, therefore, the focus of the authors in the attempt to respond to the implicative and counterfactual questions.

Supplementing these questions, the authors also recommend an adoption of the logic of process tracing tests (Collier, 2010, 2011; George & Bennett, 2005; George & McKeown, 1985; Mahoney, 2012) to analyze the hypothesis of the existence, in a particular case, of a causal connection between any two events. In the case of the logical test that uses a sufficient mechanism for the non-rejection of the hypothesis (Mahoney et al., 2009), it is established that the identification of a mechanism M, that is necessary for Y and requires X, is considered sufficient (but not necessary) to not reject the hypothesis that X is necessary for Y. Thus, all necessity connections in this paper were inferred based on this test. That is, for each assessed pair of events, the authors searched, through thought experiments, for an intermediary event (i.e., mechanism) that would plausibly be connected to both original events by necessity relationships. Of course, such a procedure could be deemed to incur into infinite regression, since these mechanism-related necessity connections themselves would also need to be tested. However, it is considered an acceptable methodological procedure to stop the recursion when the proposed mechanism relationships are intersubjectively obvious enough to be agreed upon as plausible, without further justification (Mahoney et al., 2009; Mahoney, 2012).

Gladly, though, not all pairs of sequential events have to be analyzed. Specifically, when the causal interpretation is carried out in terms of "necessity", certain causal connections can be logically deduced. After all, a necessary cause of a necessary cause of an event is a necessary cause of that event (Heise, 1989; Mahoney et al., 2009) – i.e., if A is a necessary cause of B and B, of C, then A is a necessary cause of C. Thus, these logical simplifications could be applied to some causal connections, making it unnecessary to evaluate them.

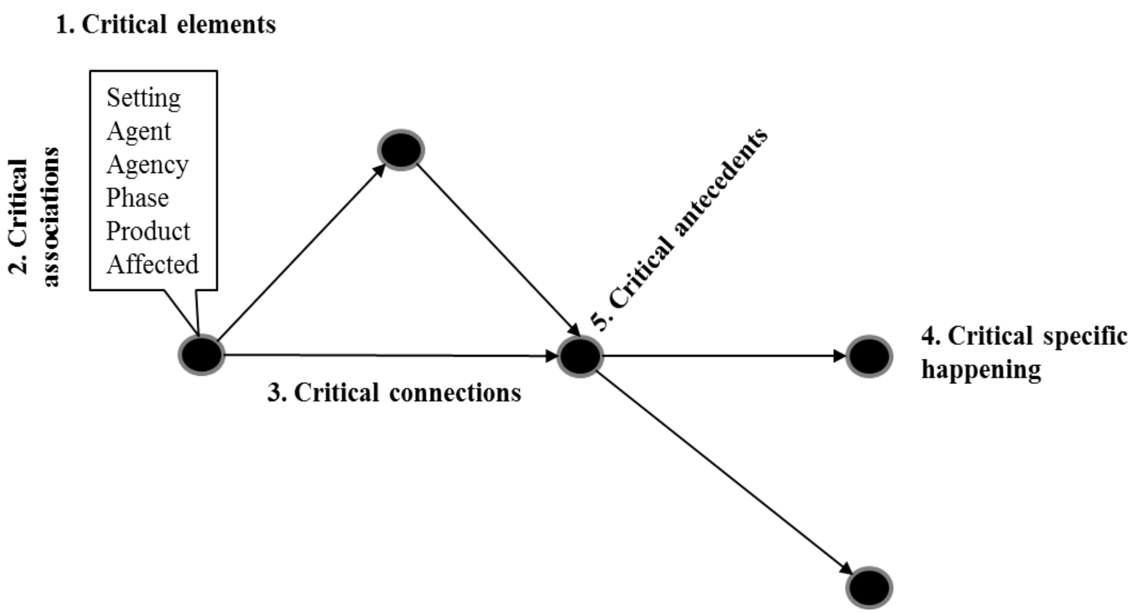
To support this process, the ESA software can be used (Heise, 2012) – c.f., (https://cs.uwaterloo.ca/~jhoey/research/ACTBackup/ESA/ESA.html). This program optimizes the sequencing of evaluations to be carried out by researchers, since it guides the process according to the chronology of events and to the possibility of logical simplification. It sequences the iterations taking into account the inferences made so far, in order to minimize the number of pairs of events to be assessed by researchers.

The ESA software also enables the recording, not only of the inferences made (i.e., if researchers supposed there was - or not - a causal connection), but also of the reasons on which these inferences were based. In this way, it is possible to recover the justifications for the causal structure obtained – which is an essential feature in order to submit the result to rational critiques (Griffin, 1993; Griffin & Korstad, 1998). Therefore, whenever possible, the mechanisms used to infer the necessary connection should also be recorded.

6.3.2.3. Analyzing the network model

Once this essential network model is built, it needs to be analyzed. Five main types of analysis can be carried out: identification of critical (i) elements; (ii) associations; (iii) connections; (iv) specific happenings; (v) and antecedents of these happenings. Figure 28 visually summarizes these types of analysis.

Figure 28: Main types of analysis for an event network.



Source: The authors.

In general, criticality can be initially assessed in terms of frequency of occurrence - e.g.,, how many times a type of event (i.e., how many different concrete events that can be seen as instances of a same class of abstractly described event) happened. For example, each project milestone presentation to a top manager is a historically (i.e., "concretely") unique event, but they are all occurrences of a same conceptual (i.e., "abstract") event (e.g., "presenting results to top management"). However, in several analyses, besides the relative frequency of the event of interest (in relation to the total events), the following measures can be taken into account: the quantity of different components of the other element associated to the code under analysis (e.g., quantity of levels of analysis of "agent" associated to "technological resource"). Thus, for instance, instances of three different analytical levels (e.g.,, individuals, groups, and organizations) may have been identified as agents who produced new technological resources as products of their actions in the historical process under analysis.

Also, four types of structural criticality are defined:

(i) Critical divergences - events whose outdegree (i.e., number of causal connections with subsequent events) is greater than a lower limit established from the outdegree distribution in the corresponding model. Thus, for example, one may consider an event that has an outdegree greater than the outdegrees of, say, 75% of the other events as a critical divergence.

(ii) Critical convergences - events whose indegree (i.e., number of causal connections with precedent events) is greater than a lower limit established from the indegree distribution in the corresponding model. Thus, similarly to the rationale used for inferring critical divergences, one may consider an event that has an indegree greater than the indegrees of 75% of the other events as a critical convergence.

(iii) Critical milestones - events defined both as a critical divergence and a critical convergence – that is, the degree (i.e., sum of indegree and outdegree) of which is greater than the lower limit established from the degree distribution (e.g., greater than, again, the 75-percentile) in the corresponding model; and

(iv) Critical intermediations - events whose betweenness - as defined by Wasserman and Faust (1994) - is greater than the lower limit established from the betweenness distribution in the corresponding model. Betweenness is a network centrality measure that properly captures how central a network node (in our case, an event of the event structure) is in intermediating the flow (in our case, the "causal flow") between all pairs of nodes in the network (Wasserman & Faust, 1994). Thus, one may consider an event that has a centrality betweenness greater than the betweenness level of 75% of the other events as a critical intermediation. This last measure serves as an indicator of the cumulative (i.e., until the focal event) path dependence.

Based on these characterizations, inferences can be made about the types of events that can be more critical for the macro-outcome of the process (i.e., the phenomena of interest).

In all cases, from the evidence obtained, inferences may be proposed on ideal-typical behaviors expected to be observed in similar contexts. This form of “portability” of the results of a unique case is based on the analytical premise of "thin rationality" (Bengtsson & Hertting, 2013), according to which the social mechanisms found in a case can be carried over to other similar contexts, if conceived as ideal-typical expected patterns of action and interaction (Bengtsson & Hertting, 2013) – as in this research. Therefore, it is not assumed that the results are directly generalizable to another particular case, but to an imagined "population" of similar patterns in similar contexts (Bengtsson & Hertting, 2013).

6.3.3. Example of application

We briefly present the basics of the application of Event Structure Analysis (ESA) in a causal case study about the process of capability construction for open innovation management in an Industrial Electronic Manufacturer (“IEM”). Melo et al. (2020) present theoretical discussions about this case study. In order to identify and sequence the events, data was collected through participant observation for three years and refined by semi-structured cross-validating interviews with key stakeholders from IEM. The final event list is presented in Table 9.

For each event, some entities were coded. “AGI”, for instance, is an internal agent that was relevant to the outcome’s historical background. The numbers after the codes (e.g., “AGI-1”, “AGI-2”) differ entities of the same category. Event #3 (“AGI9 dev R&D1”) represents the development of an integrated system for protection and control of power plants (encoded as “R&D-1”) led by an internal employee identified as “AGI-9”. Event descriptions have been shortened in number of characters (“Event - encoded” in Table 9) to serve as an input to the ETHNO Software (https://cs.uwaterloo.ca/~jhoey/research/ACTBackup/ESA/ESA.html). Table 9 also presents two elements per event, categorized using part of Heise and Durig (1997)’s event frame (i.e., Agent and Agency).

Table 9: Event list

#	Event (long name)	Event (encoded)	Agent	Agency
1	IEM associates to a French Engineering Company	EP1 ass GP1	Company	Associate

2	IEM changes its business model to provide turn-key solutions	EP1 cha bus mod	Company	Change business model
3	A Researcher (AGI-9) develops an integrated digital supervision, protection and control system (R&D-1)	AGI9 dev R&D1	Internal individual	Develop
4	IEM acquires a punching machine for the production process of electric panels	EP1 acq punc	Company	Acquire
5	IEM register the integrated digital supervision, protection and control system (R&D-1)'s brand in the National Institute of Industrial Property (INPI)	EP1 reg brand R&D1	Company	Register brand
6	Government sanctions an "Innovation Law"	Gov sanc Inn Law	Government	Sanction
7	Top Management identifies funding opportunities for innovation	TM ide op fund	Top management	Identify opportunity
8	The Automation Department develops "Test Gigas Project"- a device for automatization of panel's final tests (R&D-3)	AD dev R&D3	Department/sector	Develop
9	Top management allocates an Innovation Manager (AGI-3) to lead the Innovation Center initiative (NGI)	TM alo AGI3 to (NGI)	Top management	Allocate
10	The Innovation Manager (AGI-3) present innovation projects to funding agencies	AGI3 pre proj fund	Internal individual	Present project
11	IEM implement "ideation boxes"	EP1 imp idea box	Company	Implement
12	IEM approves the development of a high-performance microprocessor rectifier prototype (R&D-2) with a state-owned energy company	EP1 apr R&D2 PROG1 ENERG1	Company	Approve project
13	Top Management hires a new Innovation Manager (AGI-6) for innovation management (NGI)	TM acq AGI6 p NGI	Top management	Acquire
14	A Science and Technology Institute (ICT-2) makes partnership with IEM for the development of a software to increase the efficiency of hydroelectric generation (R&D-4) with a state-owned energy company	ICT2 mak par EP1 R&D4 PROG1 ENERG1	STI (Science and Technology Institute)	Make partnership

15	The Innovation Manager (AGI-6) perceives opportunity to frame “Test Gigas Project” (R&D-3) in government tax incentives program (PROG-5)	AGI6 ide op R&D3 PROG5	Internal individual	Identify opportunity
16	The Innovation Manager (AGI-6) makes a partnership with a Science and Technology Institute (ICT-3) for the development of a medium voltage panel (36kV) with reduced dimensions (R&D-5)	AGI6 mak par ICT3 des R&D5 PROG6	Internal individual	Make partnership
17	The Innovation Manager (AGI-6) approves new financial grants for the high performance microprocessor rectifier prototype (R&D-2), medium voltage panel (36kV) with reduced dimensions (R&D-5), and incremental improvements in columns of CCMs and panels of low voltage (R&D-10) projects	AGI6 apr FOM4 R&D2,5,10	Internal individual	Approve project
18	NGI approves financing for a platform of instrument transformers for high voltage (72.5 - 550kV) development (R&D-9)	NGI apr FOM1 R&D9	NGI	Approve project
19	NGI approves the development of a computational system for the management of medium and low voltage network assets (R&D-12) in partnership with a Science and Technology Institute (ICT-2)	NGI apr R&D12 ICT2 PROG7	NGI	Approve project
20	IEM presents " solar photovoltaic energy generation" project	EP1 pre proj solar	Company	Present project
21	Project team tests the medium voltage panel (36kV) prototypes abroad	TP test prot R&D5	Project team	Test prototype
22	Top management restructures IEM - creation of an innovation management department	TM ree EP1	Top management	Restructure
23	The Innovation Manager (AGI-6) leaves IEM	AGI6 leaves EP1	Internal individual	Leave company
24	NGI prepares a proposal for the development of a medium voltage panel composed of 2 (two) circuit breakers per column (R&D-45) with a Science and Technology Institute (ICT-3)	NGI pre proj R&D45 ICT3 PROG6	NGI	Present project

25	The Innovation Manager (AGI-19) leaves IEM	AGI19 leaves EP1	Internal individual	Leave company
26	IEM makes partnership with a government agency to develop new innovation management capabilities	EP1 mak par GOV4 PROG12	Company	Make partnership
27	"R&D Department" implements "Visual management"	"R&D" imp Vis Mng	Department/sector	Implement
28	Top management allocates a new Innovation Manager (AGI-23) to lead "R&D Department"	TM acq AGI23 R&D Dep	Top management	Acquire
29	Shareholders sell IEM to a French company	Shareholders sell EP1,4,5 GP7	Shareholders	Sell
30	"R&D Department" implements "Supervision committee"	"R&D" imp Sup Comm	Department/sector	Implement
31	The Vice-President (AGI-1) leaves IEM	AGI1 leaves GP7	Internal individual	Leave company

The relationships (causal linkages between events) were inferred by using the questioning optimization algorithm of the ETHNO Software, choosing the counterfactual question for each pair of events prompted by the program (i.e., “Suppose that a similar event X doesn’t occur. Can Y happen?”). In addition, causal mechanisms that justify the linkage between each pair of events were identified in a process tracing logic (Mahoney, 2012). Exemplifying, the connection #25 (Table 10) shows the causal linkage between event #16 (AGI6 mak par ICT3 des R&D5 PROG6) and event #21 (TP test prot R&D5). Event #16 refers to a specific partnership carried out by an innovation manager (AGI6) with a Science and Technology Institute (ICT-3) for the development of a new electric panel (R&D-5) in the context of a national innovation program (PROG-6) which provided non-refundable financial resources for the winning projects. Event #21 refers to prototype tests performed by the R&D-5 project team to validate technical specifications of the new product. In sum, if the project was not initiated, prototype tests could not be performed. The mechanism “EP1 manufactures R&D5 prototypes” was created to reinforce this linkage (i.e., we assume it to be intersubjectively obvious that, if the project had not been initiated, prototypes could not have been manufactured – and if prototypes had not been manufactured, they could not have been tested).

Table 10: Mechanisms linking the most relevant events

Connection ID	Events Connected	Mechanism

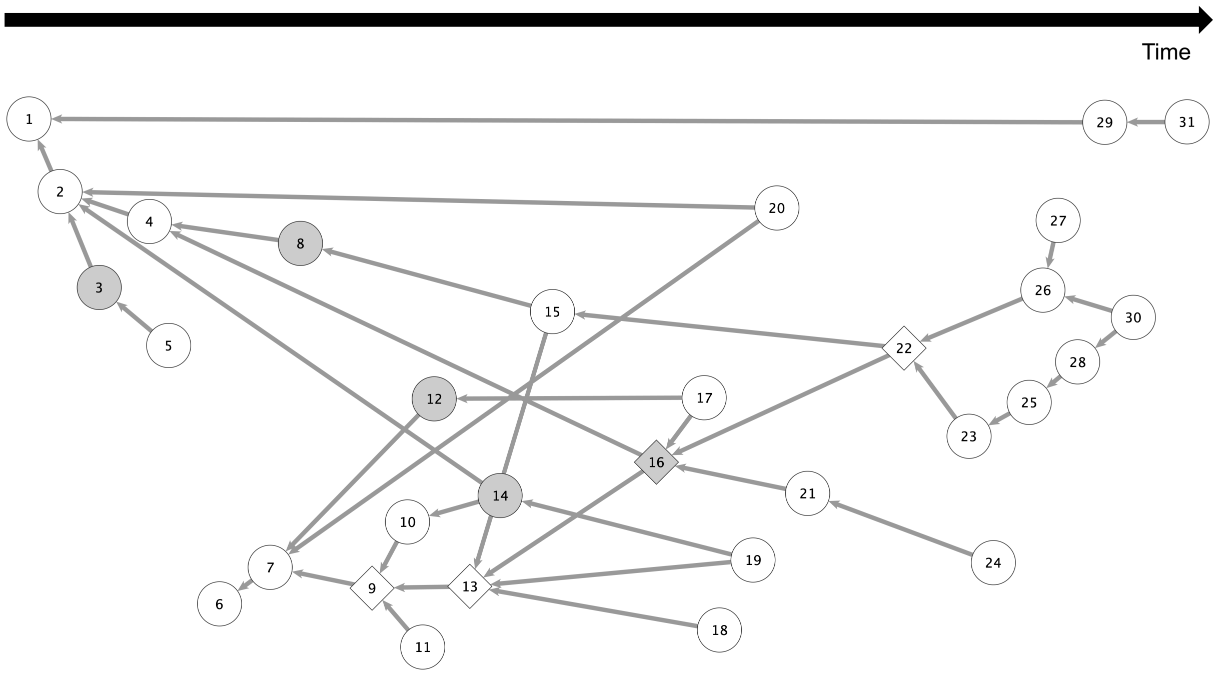
1	1-2	IEM perceives opportunity to provide turn-key solutions
2	2-3	IEM hires a Researcher (AGI-9)
3	2-4	IEM increases solutions sales
4	3-5	IEM presents integrated digital supervision, protection and control system (R&D-1) for the National Institute of Industrial Property (INPI)
5	6-7	The Vice-President (AGI1) takes notice of the "Innovation Law"
6	4-8	IEM increases electric panels production
7	7-9	Top Management realizes the need to allocate a specific employee for innovation management
8	9-10	The Innovation Manager (AGI-3) stimulates innovation idea generation in IEM
9	9-11	IEM realizes the need of a mechanism to collect ideas
10	7-12	Top Management encourages IEM's employees to submit internal projects to funding agencies
11	9-13	The Innovation Manager (AGI-3) leaves IEM
12	10-14	A Science and Technology Institute (ICT-2) approves the development of a software to increase the efficiency of hydroelectric generation (R&D-4) with a state-owned energy company
13	2-14	IEM provides solutions to "Tres Marias" power plant
14	13-15	The Innovation Manager (AGI-6) knows the "Innovation Law" - a government tax incentives program (PROG-5) - in a event
15	8-15	The Innovation Manager (AGI-6) studies "Test Gigas" (R&D-3) financial viability (after project closing)
16	13-16	The Innovation Manager (AGI-6) takes notice SENAI-SESI program (PROG6)
17	4-16	IEM increases electric panels production capacity
18	16-17	The Innovation Manager (AGI-6) presents microprocessor rectifier prototype (R&D-2), medium voltage panel (36kV) with reduced dimensions (R&D-5), and incremental improvements in columns of CCMs and panels of low voltage (R&D-10) projects to funding agencies

19	12-17	The Innovation Manager (AGI-6) presents microprocessor rectifier prototype (R&D-2), medium voltage panel (36kV) with reduced dimensions (R&D-5), and incremental improvements in columns of CCMs and panels of low voltage (R&D-10) projects to funding agencies
20	13-18	The Innovation Manager (AGI-6) realizes the opportunity to frame the platform of instrument transformers for high voltage (72.5 - 550kV) project (R&D-9) in a finance program
21	14-19	NGI invites Science and Technology Institute (ICT2) to participate in the development of a computational system for the management of medium and low voltage network assets (R&D-12) due the advances in the development of a software to increase the efficiency of hydroelectric generation (R&D-4)
22	13-19	The Innovation Manager (AGI-6) takes notice of a new program for innovation project financing (PROG7)
23	7-20	IEM identifies "solar photovoltaic energy generation" as a priority for the Brazilian government (PROG11)
24	2-20	IEM develops solutions for energy generation
25	16-21	IEM manufactures "Panel 36kV" (R&D-5) prototypes
26	16-22	Top Management recognizes "Panel 36kV" (R&D-5) as a case of success
27	15-22	Top Management recognizes benefits of the "Innovation Law" for the businesses
28	22-23	Top Management incorporates NGI as a unit of the IEM's Engineering Department
29	21-24	NGI finishes "Panel 36kV" (R&D-5) with success
30	23-25	A new Innovation Manager (AGI19) assumes NGI
31	22-26	The Innovation Manager (AGI19) realizes availability of internal structure to participate in an "innovation management program" (PROG12)
32	26-27	"R&D Department" knows "Visual management" from the "innovation management program"
33	25-28	Top Management realizes the need to allocate a specific employee for innovation management
34	1-29	Shareholders create a bond with a French company

35	28-30	"R&D Department" knows "Supervision Committee" from the "innovation management program"
36	26-30	"R&D Department" knows "Supervision Committee" from the "innovation management program"
37	29-31	The Vice-President (AGI1) assumes an executive post in the French company

The causal event structure is presented in Figure 29 – the 31 events considered the most important ones for the case are temporarily sequenced. This resulting network was modelled and analyzed using the VISONE Software (www.visone.info). Each event is represented through a circle with its respective codification. The arrows linking the circles are the causal connections between two distinct events.

Figure 29: The causal event structure



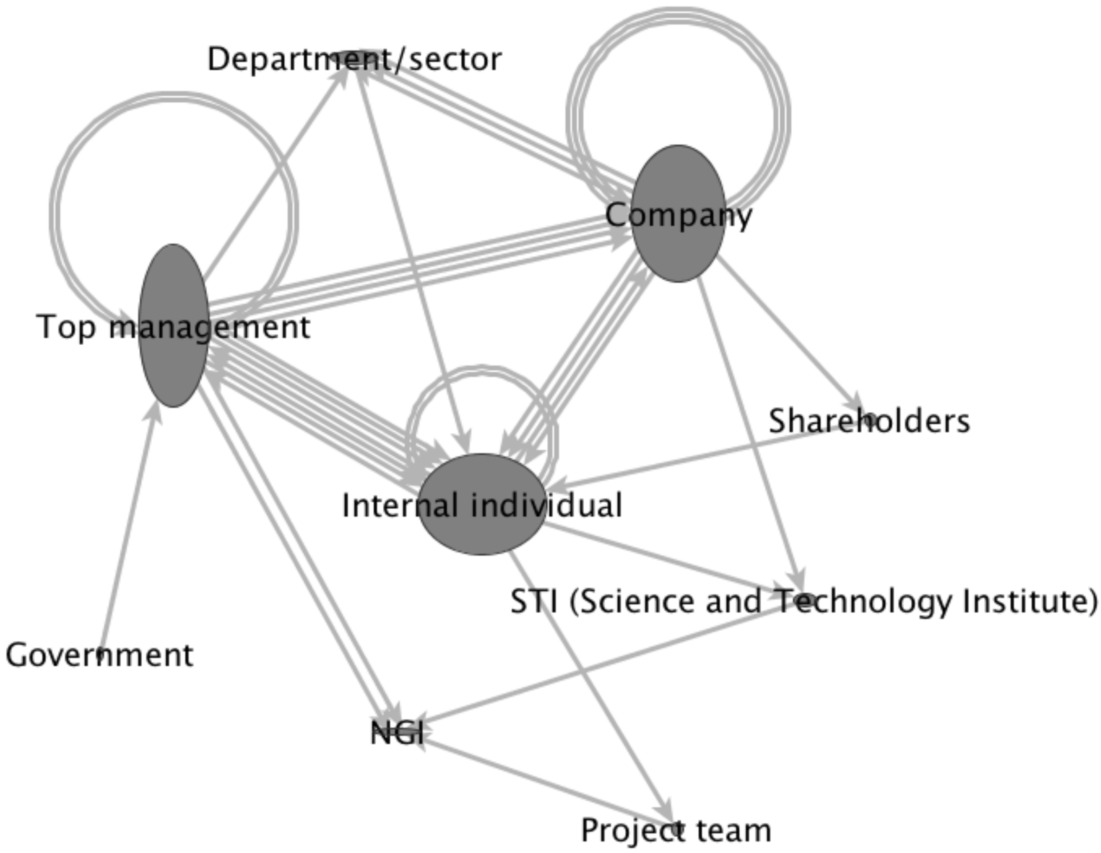
Notes: (i) circles: typical events; (ii) diamonds: turning point events; (iii) grey circles/diamonds: events concerning main innovation projects; (iv) arrows: necessary causal connections between events, read as "the more recent event (i.e., in time) implies (i.e., logically/counterfactually) the older event".

Some visual effects in the network (i.e., diamonds, grey circles/diamonds) represent some results of the analyses that were carried out. Diamonds, for example, are events which were considered "critical specific happenings" for the story, meaning that if they were withdrawn from the network, the historical flux would have been interrupted. Gray symbols represent events in which the element "action" is the execution of an innovation project. This standardization was used in Melo et al. (2020) to theoretically discuss the role of projects to build a new organizational capability. These insights were extracted from a “structural critically” analysis of the network, concerning the events (e.g., #9, #13, #16, #22) with the highest combination of the “degree” and “betweenness centrality” indexes.

Figure 30 presents one illustrative example of “critical associations” representing a preliminary model of relationships between agents during the construction of an open innovation project management capability for the studied case. This model was constructed as follows. Firstly, we identified all the (abstractly defined) types of agents involved in the 31 events of our causal structure shown in Figure 29. Each of the nine types of agents identified (Figure 30) was, then, connected to another type of agent by an arrow if - and only if - there was, in our original causal structure, an event instigated by an instance of the first type of agent that was inferred as causally necessary to another event instigated by an instance of the second type of agent under consideration. If there were more than one pair of connected events instigated by the corresponding pair of types of agents, this number of original causal connections in Figure 29 was represented by the number of arrows connecting the respective pair of agents in Figure 30. Thus, for instance, as shown in Figure 30, there was only one causal connection in our original event structure linking an event instigated by “top management” as a necessary cause of an event instigated by the “department/sector” type of agent. On the other hand, top manager(s) instigated four different events that were - each of them, individually - inferred as causally necessary to one of other four different events instigated by companies, respectively.

Therefore, in Figure 30, the number of arrows between two circles represents the frequency with which the two corresponding nodes were connected as agents of two causally related events. Thus, it visually highlights the most and least frequent causal connections in the historical process in question. In this graphical representation, node width takes this information to represent the number of original events that led to the corresponding node, while node height represents the number of events that were caused by it. Hence, actions led by “Internal Individual” were more caused than causal while actions led by “Top Management” and “Company” were more causal than the opposite. Moreover, the relatively wide loop represented above the “Top Management”, “Company” and “Internal Individuals” nodes indicates that these agents frequently caused events initiated by other similar agents, pointing to some cumulative recursions in their interactions. It can also be noted that, at the core of this structure is the virtuous circle involving "Top Management", "Internal Individual" and "Company" - which can be considered the most influential actors in the story.

Figure 30: The most relevant agents for the story



Notes: (i) circle – type of agent; (ii) circle height – outdegree; (iii) circle width – indegree; (iv) arrows: an event instigated by the type of agent represented in the node at the tail of the arrow was inferred as causally necessary to an event instigated by the other type of agent represented in the head of the arrow.

Analyses such as these may highlight some important processual patterns and exceptions that might not be noticed without such a systematic methodological procedure for modelling and analyzing the event structure. These, in turn, may, of course, help discussing theoretical propositions, their adherence or not to the case in question, and, specially, the possibilities of advancing previous knowledge on the basis of such a detailed micro-processual tracing of a macro-outcome of interest.

6.3.4. Conclusions

Abstaining itself from discussing theoretical backgrounds or implications of its analyses, this paper has focused on presenting a robust method to track the progression of a phenomenon over time in a truly processual approach. As such, it departed from the typical variance-based methodological paradigm, which, with rare exceptions (and at the expense of complicated adaptations), cannot adequately capture temporal flux - but, in general, limits itself to comparisons of static states over points in space or time. Taking temporality seriously, though, requires a shift from variables to events, and from abstract statistical regularities to case-based causal inferences of historical necessity.

However, this departure from conventional mainstream approaches does not degenerate into a purely narrative account, without any analytical potential. On the contrary, as this paper shows, rigorous inferences of dependences between events open up the opportunity to model a temporal sequence of events as a causal structure, which, in turn, may be submitted to various analyses in order to surface relevant abstractions from the causal flow. More specifically, through this inspection of the event network, a robust event coding scheme can be used to assess patterns and exceptions in terms of event elements, associations between these elements and connections between different events.

These historically grounded evidence may illuminate mechanisms intermediating event-related variables previously connected (in statistical terms) in the literature or, even, serve as a basis for new theoretical propositions of behavioral deployments over time that may be observed in similar contexts. Therefore, this innovative proposal on how to apply event structure analysis may contribute to supplement and enrich knowledge sharing practices in disciplines dealing with inherently processual phenomena. Specifically, for the engineering field, this adapted ESA method can support a wide range of organizational problems associated with complex engineering projects which may involve long causality chains within a project and/or high level of path-dependence among projects. The example we discuss in this paper is focused on project/organization levels of analysis, but there is enormous potential for future studies in engineering or other tech-intensive settings where one could apply the method to get insights at other levels of analysis.

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